

July 5, 1960

C. L. ENGLISH

2,943,576

OIL WELL PUMP

Filed Oct. 9, 1959

7 Sheets-Sheet 1

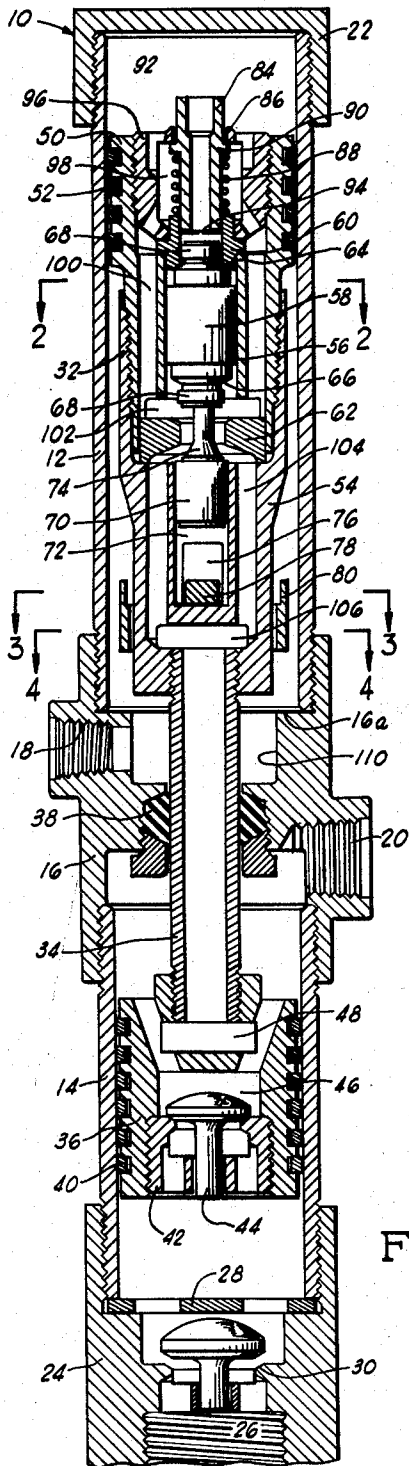


Fig 1

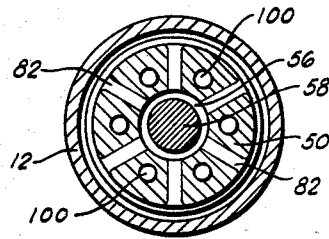


Fig 2

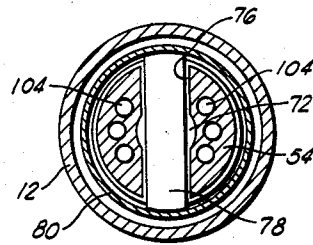


Fig 3

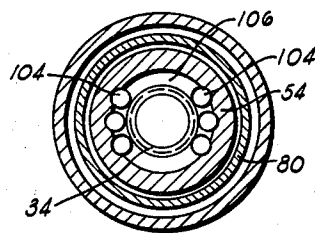


Fig 4

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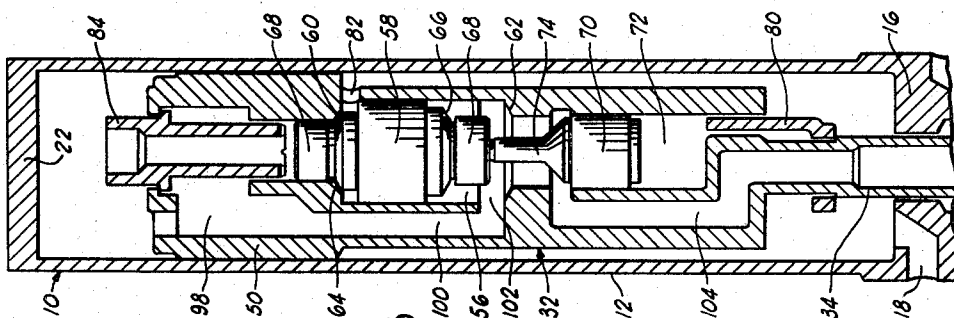
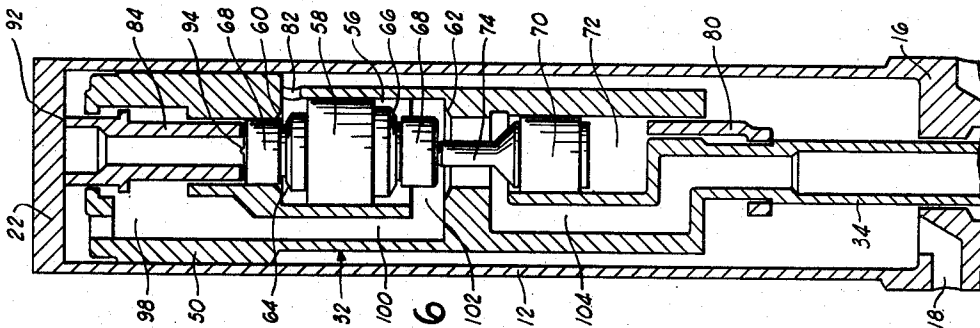
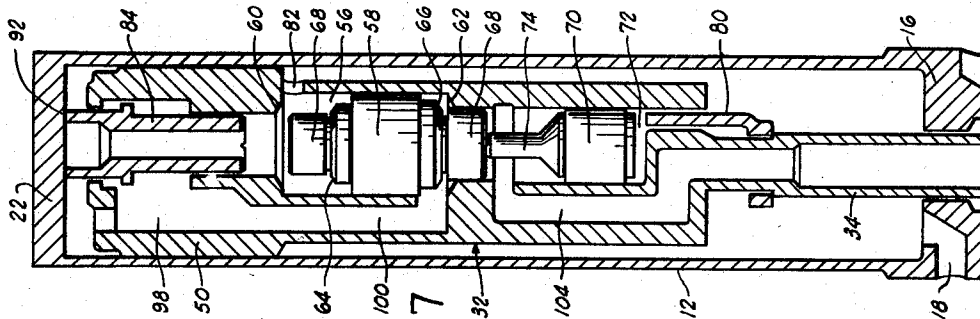
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7 Sheets-Sheet 2



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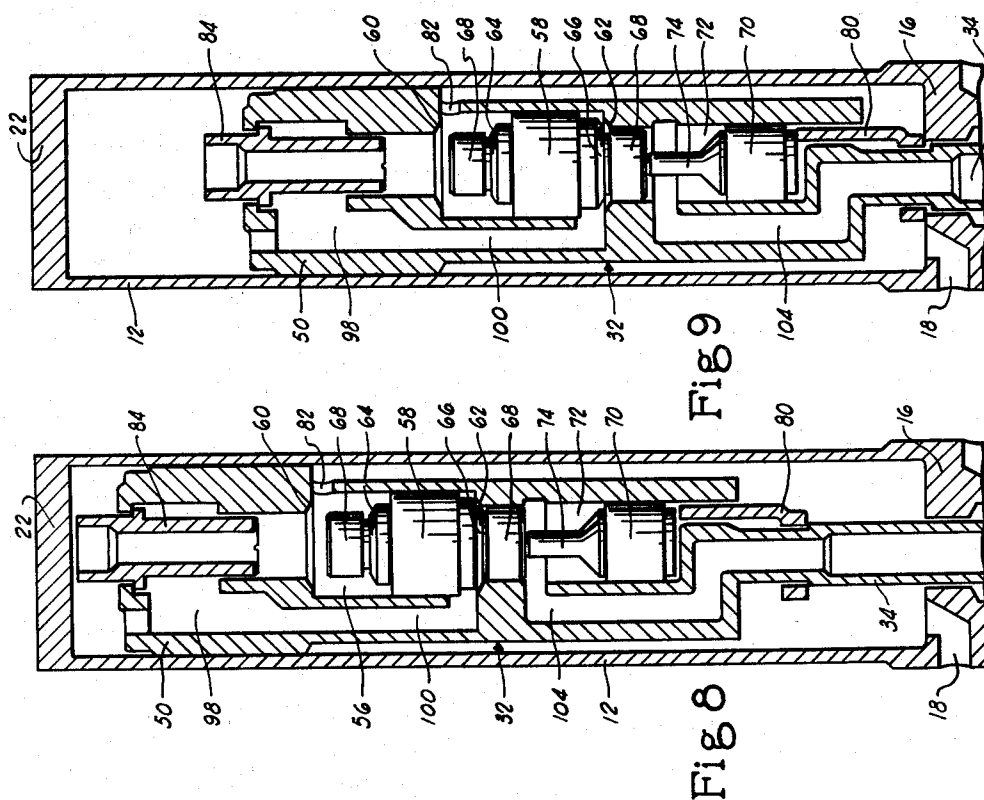
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7 Sheets-Sheet 3



July 5, 1960

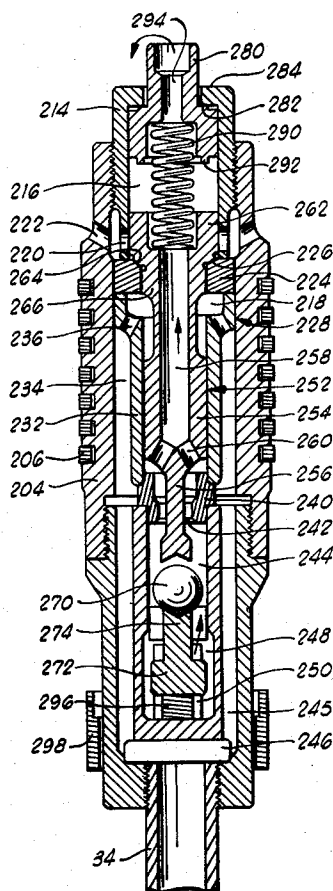
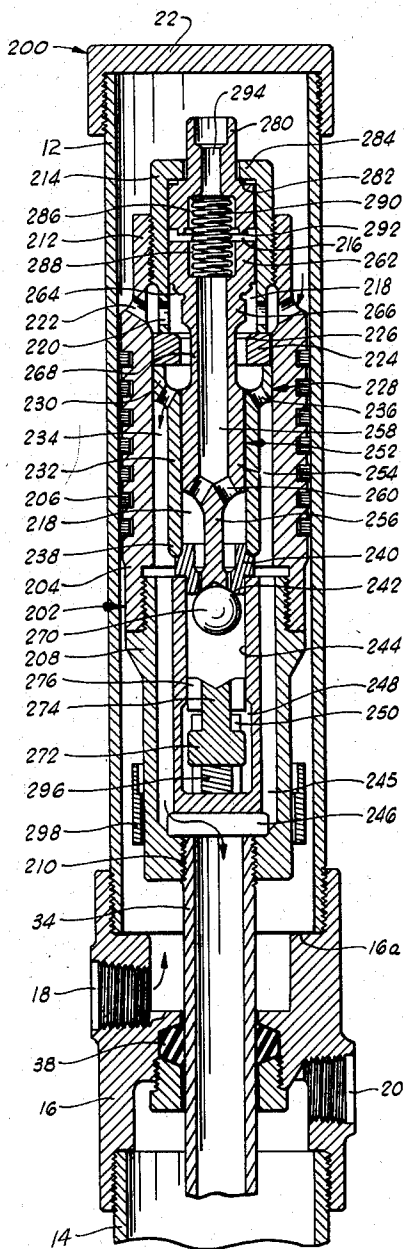
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7 Sheets-Sheet 5

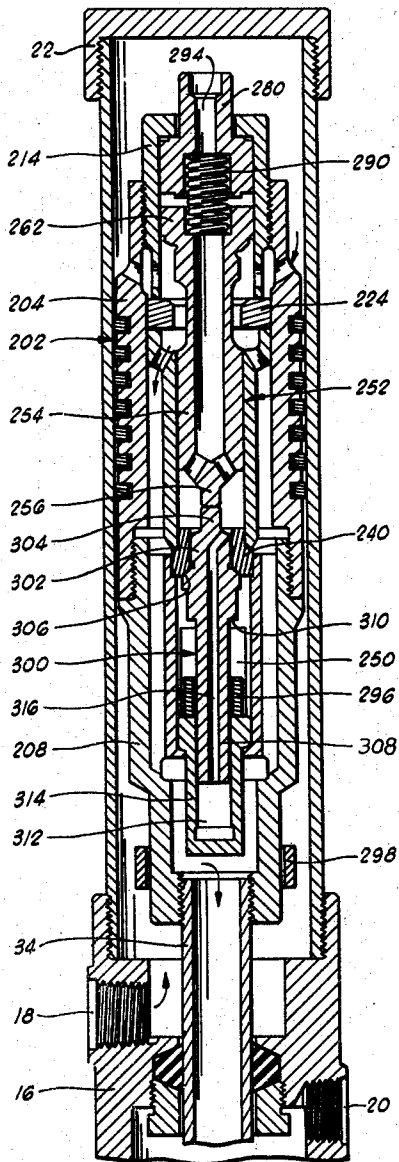


FIG-12

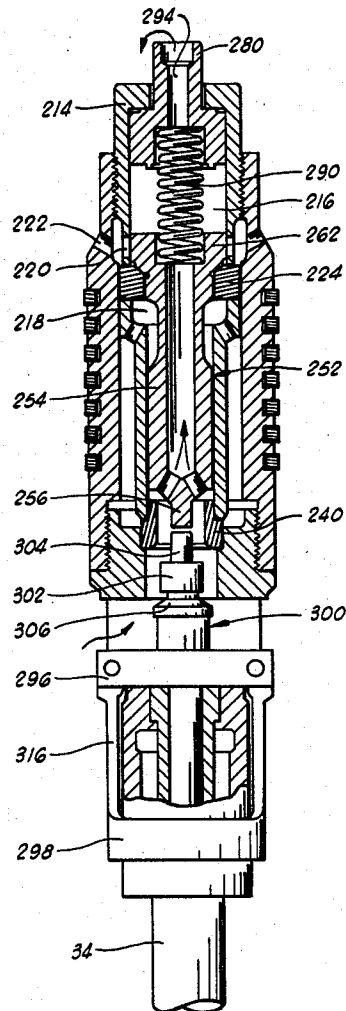


FIG-13

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OIL WELL PUMP

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7 Sheets-Sheet 6

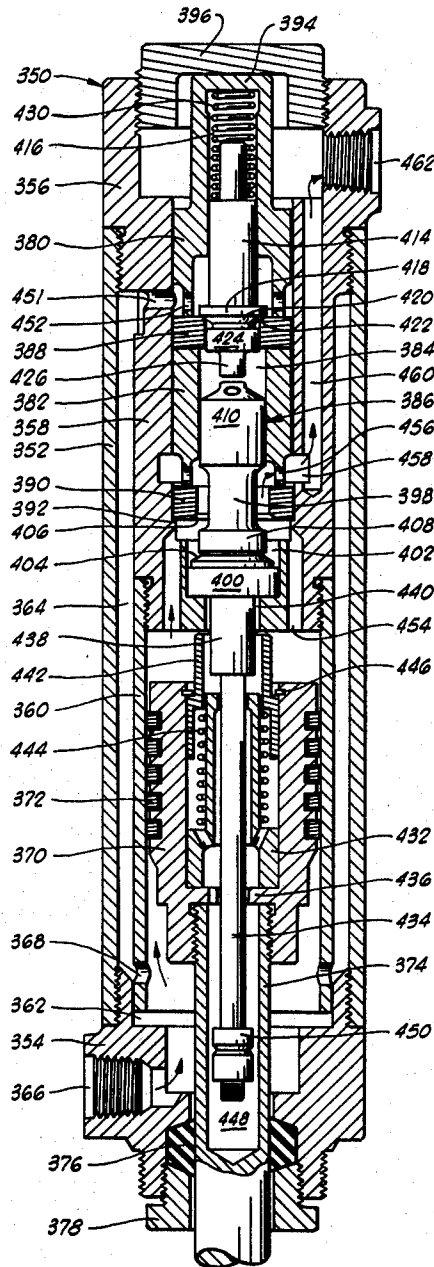


FIG. 14

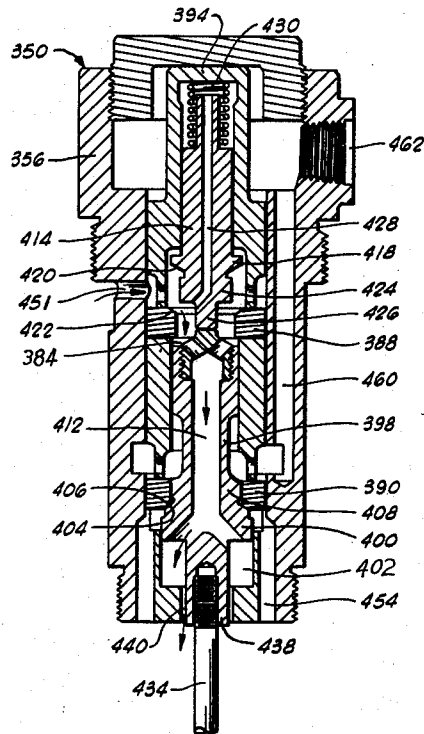


FIG. 15

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7 Sheets-Sheet 7

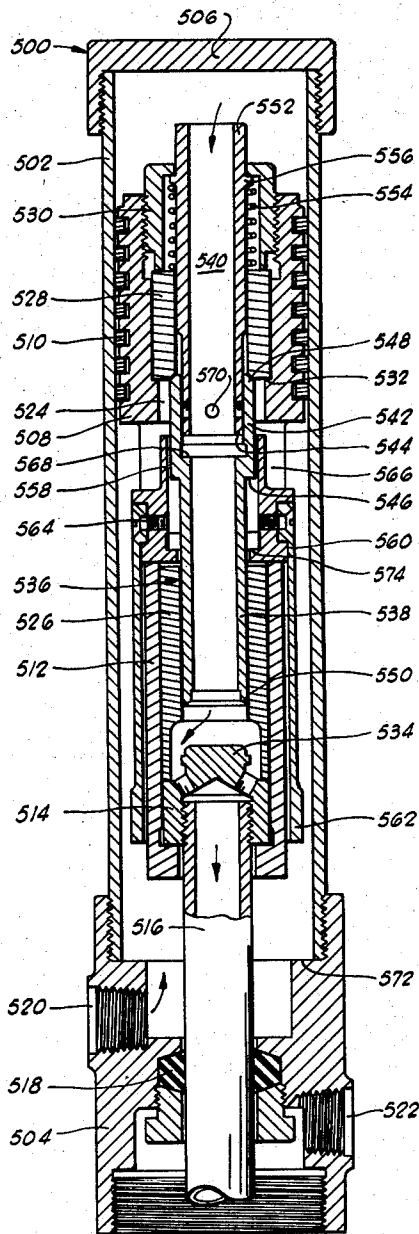


Fig. 16

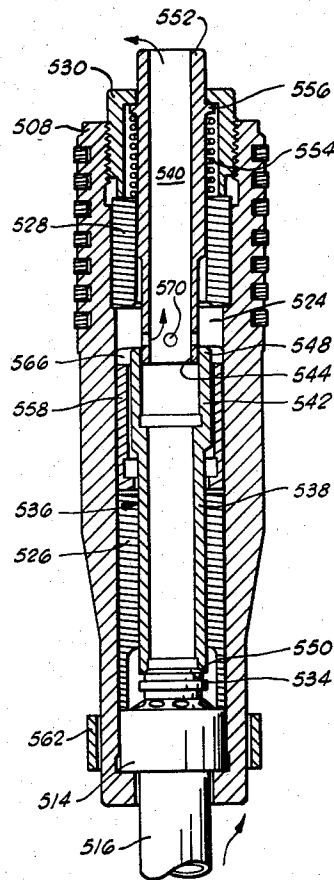


Fig. 17

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Filed Oct. 9, 1959, Ser. No. 845,571

32 Claims. (Cl. 103—46)

This invention relates to improvements in fluid operated pumping units of the type used below the surface in pumping oil wells. This is a continuation-in-part of applicant's co-pending application entitled Oil Well Pump, filed October 9, 1957, Ser. No. 689,181, now abandoned.

As it is well known in the oil producing industry, more and more wells are being pumped by subsurface hydraulic or fluid actuated pumping units. The most popular present day subsurface hydraulic pump unit comprises a substantially single acting pump powered by a hydraulic motor, with the hydraulic motor receiving its motive force from high pressure oil pumped down the well to the motor. In general, the hydraulic motor comprises a differential area piston having its smaller end continuously exposed to high pressure power fluid, and a main valve in the piston for controlling the flow of power fluid to the larger end of the piston, whereby the piston is reciprocated to operate the pumping unit. The main valve is in turn controlled by a pilot valve, with the pilot valve usually being carried by the piston and mechanically shifted by the piston to open one or more ports and hydraulically shift the main valve. The pilot valve must be moved a substantial distance to control the flow of high pressure fluid to and from the main valve for the hydraulic operation of the main valve. As a result, the pilot and/or main valves will be moved "off center" in the event the piston does not complete its stroke for some reason or other, or the valves partially shift by gravity when the unit is shunt down; whereupon the main valve will be stuck in an inoperative position and can not be shifted until the unit is removed from the well. Present day pumps also experience difficulty in operating at a desirably slow rate of speed on the working stroke, as well as over an extended speed range and still not be torn apart when the pump encounters gas in the fluid being produced. Generally speaking, when gas is encountered, the resistance to the return stroke of the pumping unit is greatly reduced and the hydraulic motor is moved on a return stroke with an excessive speed to literally tear the pumping unit apart.

The present invention contemplates a subsurface fluid operated pumping unit having a control for the power fluid introduced into the motor of the unit for the return stroke, whereby the return stroke will be accomplished at an acceptable speed at substantially any operating condition encountered. The present invention also contemplates the use of a single valve in such a pumping unit which will be operated through the major portion of its movement by hydraulic forces and will be mechanically unseated by a minute movement of the motor piston. The valve is so constructed and arranged as to automatically move to one of its seats, such as the seat associated with a power stroke of the pumping unit, unless the valve is either completely on its opposite seat or is just completing a power stroke, whereby the motor will not become stuck or inoperative when the motor has been shut down for a period of time, or when the motor piston does not complete a particular stroke.

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An important object of this invention is to provide a fluid operated pumping unit which may be operated as slow as desired, and yet may be operated through a substantial speed range.

5 Another object of this invention is to provide a fluid motor having a valve which is thrown hydraulically upon being unseated mechanically, and, further, to minimize the mechanical movement required for operating the valve.

10 A further object of this invention is to provide a fluid operated pumping unit which may be operated effectively in gaseous wells.

Another object of this invention is to provide a fluid operated pumping unit wherein the control valve for the motor is shifted into a position for a particular stroke of the unit, unless the valve is on its opposite seat or the unit is just completing the particular stroke.

20 Another object of this invention is to provide a fluid operated pumping unit wherein the power fluid is directed through the motor piston and the velocity of the power fluid is controlled for a controlled return stroke of the unit.

25 A still further object of this invention is to provide a fluid operated pumping unit which will produce a minimum fluctuation of power fluid pressure during throwing of the valve.

Other objects and advantages of the invention will be evident from the following detailed description, when read in conjunction with the accompanying drawings which illustrate my invention.

In the drawings:

Figure 1 is a vertical sectional view through a complete pumping unit constructed in accordance with this invention.

35 Figure 2 is a sectional view as taken along lines 2—2 of Fig. 1.

Figure 3 is a sectional view as taken along lines 3—3 of Fig. 1.

40 Figure 4 is another sectional view as taken along lines 4—4 of Fig. 1.

Figure 5 is a schematic sectional view of the motor illustrating the seated position of the valve for a power stroke of the pumping unit.

45 Figure 6 is another schematic sectional view of the motor illustrating the operation of the motor at the end of the power stroke.

Figure 7 is a view similar to Fig. 6, illustrating a further shifting of the valve.

50 Figure 8 is another schematic sectional view of the motor illustrating the seating of the valve for a return stroke of the pumping unit.

Figure 9 is still another schematic sectional view of the motor illustrating the unseating of the valve at the lower end or completion of the return stroke.

55 Figure 10 is a vertical sectional view through the upper end portion of a modified pumping unit constructed in accordance with this invention illustrating a tubular type of valve, and with the valve in position for a power or upstroke of the unit.

60 Figure 11 is a vertical sectional view of the piston and valve shown in Fig. 10, with the valve shown in position for a return or down stroke of the unit.

65 Figure 12 is a vertical sectional view through a modified pumping unit similar to the unit shown in Figs. 10 and 11 but illustrating a construction for controlling the force required to unseat the valve from the high pressure seat.

70 Figure 13 is a vertical sectional view of the valve and piston shown in Fig. 12 and taken at right angles to Fig. 12.

Figure 14 is a vertical sectional view through the upper portion of another modified pumping unit illustrating the

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installation of the valve in the cylinder head, rather than in the piston as in the previous embodiments, and with the valve shown in elevation.

Figure 15 is a vertical sectional view through the valve and cylinder head shown in Fig. 14 and illustrating an opposite position of the valve.

Figure 16 is a vertical sectional view through still another modified embodiment of this invention.

Figure 17 is a vertical sectional view of the piston and valve shown in Fig. 16, illustrating the valve in an opposite position.

Referring to the drawings in detail, and particularly Figs. 1 through 4, reference character 10 generally designates the pumping unit which includes a motor cylinder 12 and a pump cylinder 14 threadedly secured in the opposite ends of a middle plug 16. It will be observed that the cylinders 12 and 14 are arranged in tandem relation for positioning of the pump 10 in a well bore (not shown) in the usual manner. The middle plug 12 has a fluid inlet 18 in one side thereof for continuously directing high pressure power fluid to the lower end of the motor cylinder 12, and a fluid outlet 20 in the opposite side for the discharge of fluid from the pump cylinder 14. It will be understood that the inlet 18 and outlet 20 will be connected through suitable passageways and conduits (not shown) to the top of the well in the usual manner, whereby high pressure power fluid may be supplied to the inlet 18 and the pumped fluid recovered from the outlet 20.

A suitable head 22 is secured on the upper end of the motor cylinder 12, and a suitable shoe 24 is secured to the lower end of the pump cylinder 14. The shoe 24 contains a standing valve 26 of any desired type, and a spider or stop 28 is secured between the valve 26 and the lower end of the cylinder 14 to limit the upward movement of the valve 26. The standing valve 26 operates in the usual manner to open in an upward direction when a suction is induced in the lower end of the cylinder 14 and to seat against the seat 30 when the pressure in the lower end of the pump cylinder 14 is greater than the pressure below the valve, that is, well pressure.

A fluid operated motor piston assembly 32 is reciprocally disposed in the motor cylinder 12 and is connected through a hollow middle or connecting rod 34 to a pump piston 36 in the pump cylinder 14. The connecting rod 34 extends through a suitable packing gland 38 in the middle plug 16, whereby fluid in the cylinders 12 and 14 will be separated, and the middle plug 16 will form the adjacent heads for the cylinders 12 and 14. The pump piston 36 has a series of suitable piston rings 40 on the outer periphery thereof in sliding and sealing engagement with the inner periphery of the cylinder 14, and a combination valve seat and guide 42 for a traveling valve 44. The valve 44 may be of any suitable type to control the flow of fluid through the bore 46 extending vertically through the piston 36. The bore 46 communicates with the interior of the hollow connecting rod 34 through a chamber 48, whereby fluid flowing downwardly through the connecting rod 34 will be directed into the pump cylinder 14 above the pump piston 36, as will be more fully hereinafter set forth.

The motor piston assembly 32 comprises a piston member 50 having a series of suitable piston rings 52 on the outer periphery thereof in sliding and sealing engagement with the inner periphery of the motor cylinder 12. A tubular extension 54 is threadedly secured to the lower end of the piston member 50 and is in turn threadedly connected to the upper end of the hollow connecting rod 34. An elongated valve chamber 56 is provided in the central portion of the piston member 50 and extends in a direction parallel to the reciprocal movement of the piston member 50 to slidably receive a valve member 58. High and low pressure valve seats 60 and 62, respectively, are secured in the piston member 50 at the

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opposite ends of the valve chamber 56 to receive the seating areas 64 and 66, respectively, of the valve 58, as will be more fully hereinafter set forth. It will also be observed that the valve 58 has a cylindrical extension or choke 68 on each end thereof of reduced diameter and of a size to enter the respective valve seats 60 and 62 when the valve 58 is seated on the respective seat. Although it will be explained more in detail below in connection with the operation of the unit, it may also be noted here that the valve 58 is of such a size, and the valve seats 60 and 62 are so spaced, that the upper extension 68 will still be within the upper valve seat 60 when the lower extension 68 enters the lower valve seat 62, and vice versa, during reciprocation of the valve 58. The valve 58 also has a head portion 70 slidably disposed in a secondary valve chamber 72 below and in line with the main valve chamber 56. A neck 74 extends upwardly from the head portion 70 to the lower extension 68 of the valve 58. For convenience in manufacture, I prefer to form the head portion 70 and neck 74 separately from the remaining portion of the valve 58. It will be understood however, that these members may be formed as an integral unit, since they operate as a unit in controlling the movement of the piston assembly 32. The neck 74 is of a size to extend through the lower valve seat 62 with substantial clearance around the neck 74 when the valve 58 is in its upper position as illustrated in Fig. 1.

Opposed slots 76 (Figs. 1 and 3) are provided in the walls of the secondary valve chamber 72 at the lower end of the chamber to loosely receive a cross-member 78 of a valve actuating harness 80. The harness 80 loosely surrounds the piston extension 54 and may thus move up and down over the extension 54; however, the harness 80 will normally be retained in its lower position, as shown, by gravity. It will also be observed that the slots 76 are of a size to provide constant communication between the lower end portion of the motor cylinder 12 and the lower end of the secondary valve chamber 72, whereby high pressure power fluid is constantly exposed to the lower end face of the valve head portion 70.

As illustrated in Fig. 2, a series of circumferentially spaced transverse ports 82 extend through the piston member 50 slightly below the lower piston ring 52 to provide communication between the motor cylinder 12 below the piston member 50 and the valve chamber 56 slightly below the upper, high pressure valve seat 60. The ports 82 are thus utilized to provide a constant supply of high pressure power fluid to the upper end of the valve chamber 56, as will be more fully hereinafter set forth.

A valve actuating sleeve 84 extends through a bushing 86 in the upper end of the piston member 50 in line with the valve member 58. The lower end of the sleeve 84 extends into the valve seat 60 to provide a passageway from the upper end of the valve chamber 56 to the upper portion of the motor cylinder 12 above the piston member 50. A helical compression spring 88 is anchored to the valve seat 60 and a flange 90 on the sleeve 84 to urge the sleeve 84 upwardly and in a direction out of the piston member 50. It will be observed that the flange 90 also serves as a stop against the bushing 86 to limit the outward movement of the sleeve 84. The outer end 92 of the sleeve 84 is squared off with respect to the bottom face of the head 22; that is, the upper end 92 of the sleeve 84 is formed on the same plane as the bottom face of the head 22, whereby the sleeve 84 will closely contact the bottom face of the head 22 around the entire periphery of the sleeve when the sleeve is moved upwardly against the head. The inner diameter of the sleeve 84 is substantially less than the inner diameter of the seat 60 and the combined diameters of the ports 82, whereby the sleeve 84 will form an orifice for controlling the high pressure fluid directed through the ports 82 and valve seat 60 to

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ward the upper end of the piston member 50. It should be further noted that the clearance around the lower end of the sleeve 84 (between the sleeve 84 and the inner periphery of the valve seat 60) is less than the clearance between the upper valve extension 68 and the inner periphery of the valve seat 60, whereby fluid introduced to the valve seat 60 will flow around the upper extension 68 with less resistance than it will flow around the sleeve 84. It is further preferred that notches 94 be cut in the lower end of the sleeve 84 to provide passageways for fluid escaping around the upper valve extension 68 when the sleeve 84 is in contact with the valve, as will be more fully hereinafter set forth.

A tubular insert 96 is threaded into the upper end of the piston member 50 to form a plurality of exhaust passageways 98 from the upper face of the piston member 50 to a point approximately even with the upper valve seat 60. It will be observed that the bushing 86 receiving the sleeve 84 is formed by an inner portion of the insert 96. A plurality of vertical bores 100 are formed lengthwise in the piston member 50 outwardly of the valve chambers 56 (see also Fig. 2) to form continuations of the exhaust passageways 98. The lower ends of the bores 100 communicate with a chamber 102 which is formed between the lower end of the valve chamber 56 and the lower ends of the bores 100. The chamber 102 is located directly above the lower, low pressure seat 62, whereby exhaust fluid may flow from the bores 100 through the chamber 102 and the lower valve seat 62 when the valve 58 is in its upper position as illustrated. Additional bores 104 are formed vertically in the piston extension 54 on opposite sides of the secondary valve chamber 72 to direct the exhausting fluid downwardly from the seat 62 to a chamber 106 formed in the lower end portion of the piston extension 54 directly above the upper end of the hollow connecting rod 34. Thus, when the valve 58 is off of the seat 62, communication is established from the top of the piston member 50 through the passageways 98, bores 100, chamber 102, seat 62, bores 104 and chamber 106 to the interior of the hollow connecting rod 34.

Operation

As previously indicated, high pressure power fluid is constantly directed through the inlet 18 into the lower end of the motor cylinder 12 for operation of the pumping unit 10. The power fluid in the lower end of the motor cylinder 12 acts on all of the exposed areas of the piston extension 54 and the lower exposed face of the piston member 50 to constantly urge the piston assembly 32 in an upward direction. Simultaneously, high pressure fluid is directed through the slots 76 into the lower end of the secondary valve chamber 72 to act in an upward direction on the lower end of the valve head portion 70, and through the ports 82 to act on some portion of the upper end of the valve 58.

In general, the operation of the pumping unit 10 is such that when the valve 58 is in its upper position as illustrated in Fig. 1, the upper end of the piston member 50 is exposed to a pressure lower than the power fluid pressure through the various exhaust passageways and bores described above and the hollow connecting rod 34 through the upper end of the pump cylinder 14. In this position of the valve 58, the net force imposed on the piston assembly 32 will be in an upward direction to raise the motor piston assembly 32 and the pump piston 36. As the pump piston 36 is raised, the traveling valve 44 is closed by fluid in the upper portion of the pump cylinder 14 to provide a suction in the lower end of the cylinder 14. Well fluid surrounding the pump unit 10 is then drawn upwardly through the standing valve seat 30 into the lower end of the cylinder 14. Simultaneously, of course, fluid in the upper end of the cylinder 14 is forced through the outlet 20 and upwardly through the well to the surface where it may be recovered. The fluid being raised and

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directed through the outlet 20 will therefore be a combination of well fluid drawn into the cylinder 14 on a previous up stroke, and power fluid exhausting from above the motor piston member 50 downwardly through the connecting rod 34 and into the upper portion of the pump cylinder 14.

At the end of the up or power stroke, the sleeve 84 contacts the head 22 to mechanically unseat the valve 58, and the valve 58 is then shifted hydraulically onto the lower seat 62, as will be explained in more detail below. It will then be observed that communication is established from the ports 82 to the interior of the seat 60, whereby power fluid is directed through the ports 82, seat 60 and sleeve 84 into the upper end of the motor cylinder 12 to act in a downward direction on the upper end of the piston member 50. Simultaneously, the lower seating portion 66 of the valve 58, in combination with the valve seat 62, prevents communication between the exhaust bores 100 and the exhaust bores 104. In this condition, power fluid will be acting on the piston extension 54 and the lower face of the piston member 50, as well as the upper end of the piston member 50. It will be observed, however, that the area of the upper face of the piston member 50 is greater than the exposed area of the lower face of the piston member 50 and the extension 54 by an area equal to the cross-sectional area of the hollow connecting rod 34. Therefore, the piston assembly 32 is what is commonly known in the art as a differential piston, and, assuming the pressure of the fluid in the upper end of the motor cylinder 12 is substantially equal to the pressure of the fluid in the lower portion of the motor cylinder 12, the net force on the piston assembly 32 will be in a downward direction to move the pump unit 10 on a down stroke.

As the pump piston 36 is moved downwardly, the standing valve 26 is closed by an increase in pressure in the lower end of the pump cylinder 14 compared with the pressure of fluid below the shoe 24, and the traveling valve 44 is opened by reason of a greater pressure in the lower end of the pump cylinder 14 than the pressure in the upper portion of the cylinder 14. Thus, fluid in the lower portion of the cylinder 14 will be moved through the valve seat 42 and passageways 46 into the upper portion of the cylinder above the pump piston 36. It may also be noted that a volume of fluid equal to the volume occupied by the connecting rod 34 will be displaced through the outlet 20 and upwardly through the well. However, this displaced fluid is small compared to the volume of fluid displaced on the up stroke, hence the down stroke may be considered as a return or non-working stroke and the pump unit may be considered as single acting.

At the end of the down stroke, the harness 80 contacts shoulders 16a in the middle plug 16 to raise the harness 80 (with respect to the piston assembly 32) into contact with the head portion 70 of the valve 58. This operation mechanically unseats the valve 58 from the lower seat 62, and the valve 58 is then thrown hydraulically back to the upper seat 60, as will be explained in more detail below. The up stroke of the pumping unit is then effected in the same manner as previously described.

The detailed operation of the valve 58 and the various positions of the valve are best illustrated in Figs. 5 through 9. The position of the valve 58 for an up stroke of the pumping unit is shown in Fig. 5. It will be observed that the upper seating area 64 of the valve is in contact with the upper, high pressure seat 60 to prevent the flow of high pressure power fluid to the upper end of the motor cylinder 12. Also, the lower seating area 66 of the valve is above the low pressure seat 62, and the lower valve extension 68 is withdrawn from the interior of the seat 62 to open the exhaust passageway from the upper end of the motor cylinder 12 to the hollow connecting rod 34. It may be further noted that the neck 74

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of the valve head portion 70 is substantially smaller in diameter than the inner diameter of the lower seat 62 to provide substantially unrestricted flow of the exhaust fluid through the valve seat 62.

The valve 58 is held on its upper seat by a combination of hydraulic forces which result in a net upward force. In detail, the hydraulic force exerted by the high pressure power fluid on the lower end of the head portion 70, plus the force exerted by the exhaust fluid pressure on the lower face of the main body portion of the valve 58 is greater than the force exerted by the exhaust fluid pressure on the upper end of the upper extension 68 and approximately $\frac{1}{2}$ of the area of the seat 64, plus the high pressure fluid exerted downwardly on the exposed area of the valve 58 between the middle of the valve seating area 64 and the outer periphery of the valve, plus the lower pressure fluid exerted downwardly on the cross-sectional area of the head portion 70.

Near the end of the up stroke, the upper end 92 of the sleeve 84 contacts the lower face of the upper motor cylinder head 22 to provide an upward movement of the piston member 50 over the sleeve 84. As soon as the upper extension 68 of the valve 58 contacts the lower end of the sleeve 84 (see Fig. 6), the valve 58 is unseated from the upper seat 60, by virtue of the continued upward movement of the piston member 50. Upon unseating of the valve 58 from the valve seat 60, high pressure fluid leaks around the upper extension 68 and through the notches 94 to exert an increased pressure on the upper end of the upper extension 68. As previously indicated, the clearance around the upper extension 68 is greater than the clearance around the lower end of the sleeve 84. Also, the mating faces of the upper end 92 of the sleeve 84 and the lower face of the head 22 restricts the flow of fluid upwardly around the upper end of the sleeve 84 to such an extent that high pressure fluid leaking around the upper extension 68 will be substantially confined within the sleeve 84 to provide a higher pressure on the upper end of the upper extension 68 than exists in the lower end of the valve chamber 56, which last-mentioned pressure acts upwardly on the lower end of the valve 58. It should also be noted that the high pressure fluid which does leak past the sleeve 84 is exhausted through the lower seat 62, even after the lower extension 68 enters the lower seat 62, since the clearance between the lower extension and lower valve seat is greater than the clearance between the upper extension and upper valve seat. This increase in pressure above the upper extension 68 is sufficient to overcome the previously described upwardly acting hydraulic forces and provide a downward movement of the valve member 58. It will be further observed that the upper extension 68 remains in the valve seat 60 until after the lower extension 68 enters the lower valve seat 62 to seriously restrict the flow of high pressure fluid to the sleeve 84. In addition, the sleeve 84 remains in contact with the upper head 22 until after the valve 58 is completely shifted to the lower seat (Figs. 7 and 8). Therefore, the sleeve 84 prevents a substantial supply of high pressure fluid being directed to the upper end of the motor cylinder 12 until the exhaust from the upper end of the motor cylinder is stopped by reason of the valve 58 being on the valve seat 62.

The leakage around the upper valve extension 68 compared with the leakage around the lower end of the sleeve 84 and through the upper end of the sleeve 84 during the unseating operation may be so adjusted that the valve 58 will be thrown hydraulically immediately upon being unseated mechanically by the sleeve 84. With this arrangement, the upward movement of the motor piston assembly 32 will be slowly reversed to prevent damage by the piston assembly 32 contacting the upper head 22 and to allow sufficient time for the standing valve 26 of the pump unit to become seated for the subsequent down stroke.

With the valve 58 in its lower position as shown in Fig.

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8, the ports 82 will be in communication with the sleeve 84 to direct high pressure power fluid against the upper cylinder head 22 which leaks around the upper end of the sleeve and tends to move the piston assembly 32 down. As soon as the sleeve 84 is removed from the head 22, high pressure fluid is supplied to the upper end of the motor cylinder at increased velocity to increase the speed of the down stroke.

In its lower position, the valve 58 is urged downwardly by the action of high pressure power fluid contacting the entire upper area of the valve, including the upper extension 68, as well as the pressure of the exhausting fluid acting on the upper end of the head portion 70. These downwardly acting forces are greater than the force obtained by the action of the high pressure power fluid on the lower end of the head portion 70 and the high pressure power fluid acting on the area of the valve 58 between approximately the center of the lower seating area 66 and the outer periphery of the valve, plus the lower pressure exhaust fluid acting upwardly on the remainder of the lower end of the valve 58. It may also be observed that the valve 58 will stay on this lower seat during the down stroke, regardless of the loss of load on the pump end of the unit. The exhaust pressure acts on the upper end of the head portion 70 and the lower extension 68 out to approximately the center of the lower seating area 66 and these forces substantially cancel out, regardless of the exhaust pressure.

Near the end of the down or return stroke of the pumping unit 10, the harness 80 contacts the middle plug 16 and the lower end of the head portion 70 to unseat the valve 58 from the lower seat 62 as shown in Fig. 9. Immediately upon this unseating movement, the entire lower seating area 66 of the valve is exposed to the high pressure power fluid. This addition to the upwardly acting hydraulic forces is sufficient to overcome the downwardly acting hydraulic forces and move the valve 58 upwardly through the valve chamber 56 and seat the valve on the upper seat 60. It will thus be apparent that the upward movement of the valve 58 is initiated by a minute downward movement of the motor piston assembly 32 when the harness 80 contacts the middle plug 16. Although the motor piston assembly 32 will continue moving downwardly by its own momentum upon shifting of the valve 58, the high pressure fluid in the lower end of the motor cylinder 12 will be prevented from further leakage through the upper valve seat 60 to provide a cushioning effect and tend to prevent the lower end of the piston assembly 32 from contacting the middle plug. In addition, I prefer to provide a dash pot action in the lower end of the motor cylinder 14 to bring the motor piston assembly 32 to a rather slow stop at the end of a downward movement and to retard the initial portion of the up stroke of the unit. This dash pot may take any suitable form, such as a cylindrical cavity 110 (Fig. 1) formed in the upper end of the middle plug 16 of a size to loosely receive the lower end of the motor piston extension 54. The side walls of the cavity 110 and the lower end of the piston extension 54 may be tapered as desired to provide the necessary dash pot action. With this delay in reversal of the pumping unit 10, the traveling valve 44 will have sufficient time to seat itself on the seat 42 prior to the oncoming up stroke to prevent damage to the traveling valve and associated parts.

When the valve 58 has been moved upwardly to such a position that the upper valve extension 68 enters the upper seat, as illustrated in Fig. 6, the flow of high pressure power fluid into the exhaust passageways 98 etc. is restricted, thereby reducing the upward force on the lower end face of the valve. Therefore, to assure a final seating on the upper seat 60, the cross-sectional area of the head portion 70 (being urged up by high pressure power fluid) must be greater than the cross-sectional area of the main body portion of the valve 58 less the

cross-sectional area of the upper extension 68, which last-mentioned area is being forced down by the high pressure power fluid.

One of the important features of the present invention is the provision of an orifice in the power fluid passage-way leading to the upper, larger end of the motor piston assembly 32 to control the down, return stroke of the pumping unit. The inner diameter of the sleeve 84 is made of such a size, as compared to the size of the seat 60 and ports 82, to provide an orifice downstream of the valve 58. The cross-sectional area of this orifice should be no more than fifty percent as large as the cross-sectional area of either the seat 60 or the ports 82, and is preferably only twelve to fifteen percent as large as either of the last-mentioned areas. By positioning the orifice downstream of the valve, the orifice will tend to retain a pressure on the upper end of the valve 58, particularly on the down stroke to retain the valve in its lower position. Also, the orifice will control the amount of high pressure power fluid introduced into the upper end of the motor cylinder 12, whereby the speed of the down or return stroke of the pumping unit may be subject to control. As it is well known in the art, the changes in velocity of a liquid flowing through the sleeve 84 will be substantially equal to only the square root of the changes in pressure of the high pressure power fluid upstream of the sleeve. Therefore, when the pressure of the power fluid is increased to increase the speed of operation of the pumping unit 10, the speed of the down stroke of the unit will be increased a substantially lesser extent than that of the up stroke. This feature increases in importance when the most desired operation of the pumping unit 10 is analyzed. The cross-sectional areas of the piston assembly 32 and the connecting rod 34 are such to provide a relatively slow up stroke for the unit as compared to the down stroke, since the up stroke is the working stroke and the down stroke is a non-working stroke. This relative movement is also desirable to minimize the velocity of well fluid sucked into the lower end of the pump cylinder 14. Thus, at a normal operating speed, the down stroke will be accomplished substantially faster than the up stroke. And, if the speed of the down stroke is increased substantially the same amount as the speed of the up stroke upon an increase in pressure of the power fluid, as occurs when no orifice is present, the operating range of the pumping unit is seriously limited.

Another feature of note in the present invention is the capability of the unit for operation at a speed as slow as desired. This advantage is made possible principally by the minimum loss of power fluid in shifting the valve 58, and the minute piston movement required to unseat the valve at the opposite ends of the piston movement to subject the valve 58 to hydraulic forces for a complete shifting of the valve. Since only a minute mechanical movement is required to initiate shifting of the valve 58, it is a practical impossibility to stick the valve 58 in an inoperative position by only a partial mechanical movement, as in present day pumps utilizing a pilot and main valve as described previously. As to loss of power fluid in shifting the valve 58, it will be observed that as the valve is shifted in either direction, the leading extension 68 enters the respective seat 60 or 62 at an early point in the valve movement and restricts the amount of leakage through the seat until the valve is seated.

Still another feature of note in the present invention is the tendency of the valve 58 to move to one of the valve seats under certain conditions. In the preferred form, the valve 58 moves to its upper seat, unless the valve is either on its lower seat or the pumping unit is just completing an up stroke. The movement of the valve 58 is, of course, controlled by the relative areas of the valve and the porting through the motor piston assembly 32 which exposes the various areas to high and low pressures. These factors are so controlled to pro-

vide a net upward force on the valve, unless the valve is in either of the two positions previously described. It will be observed in Figs. 5 through 9 that in every position of the valve 58, except when the valve is on the lower seat or the pumping unit is completing an up stroke, the entire top of the valve is exposed to high pressure power fluid tending to force the valve down, and the lower end of the head portion 70 and the area between the outer periphery of the valve and the lower extension 68, or only the lower end of the head portion 70 and the upper end of the valve less the upper extension 68 are exposed to high pressure fluid tending to force the valve up. Therefore, the cross-sectional area of the head portion 70 should be greater than the cross-sectional area of the upper extension 68, as well as greater than the cross-sectional area of the main body portion of the valve less the cross-sectional area of the upper extension 68 to assure that the valve will be moved up when, for example, the pumping unit is first run in a well or is started after a period of idleness. However, the cross-sectional area of the head portion 70 should be less than the cross-sectional area of the valve 58 in order that the valve will move to the lower seat under the conditions shown in Figs. 6 and 7 and will remain on the lower seat during the down stroke.

In constructing a valve in accordance with this invention, the various areas exposed to power and exhaust fluid may be easily proportioned to maintain the valve on either seat with an extremely small force, compared to present day valves. In practice, the hydraulic force holding the valve on either seat should be no greater than ten percent of the difference between the power and exhaust fluid pressures, and preferably less than five percent. This arrangement minimizes damage to the valve seats, and, of course, the force required to shift the valve, which in turn minimizes fluctuations in power fluid pressure when shifting the valve.

Embodiment of Figs. 10 and 11

A modified embodiment of this invention is illustrated in Figs. 10 and 11 and comprises a pumping unit 200 constructed, in many respects, similar to the pumping unit 10 previously described. The pumping unit 200 may be easily constructed to utilize the motor cylinder 12 and pumping cylinder 14 interconnected in tandem relation by the middle plug 16 in the same manner as in the pumping unit 10. In this embodiment, a modified motor piston assembly, generally designated by reference character 202, is reciprocally disposed in the motor cylinder 12 for movement in response to power fluid introduced into the motor cylinder through the inlet 18 in the middle plug 16. The lower end of the motor piston assembly 202 is connected to the hollow connecting rod 34 which extends through packing 38 in the middle plug 16 into connection with a suitable pump plunger (not shown) disposed within the pump cylinder 14 in substantially the same manner as in the pumping unit 10, previously described.

The modified motor piston assembly 202 comprises a main tubular piston member 204 of a size to slidably fit in the motor cylinder 12 and having suitable piston rings 206 around the outer periphery thereof to slidably seal the main piston member 204 in the motor cylinder 12. A tubular extension 208 is threadedly secured on the lower end of the piston member 204 and extends downwardly from the piston 204 into connection with the upper end of the hollow connecting rod 34 in any suitable manner, such as by the use of threads 210. It will also be noted that the piston extension 208 is reduced in diameter to provide substantial clearance between the outer periphery of the extension 208 and the inner periphery of the motor cylinder 12.

The upper end 212 of the piston member 204 is reduced in diameter and internally threaded to receive a tubular insert 214 which forms one end portion 216

of a valve chamber 218 in the motor piston assembly 202. The lower end portion of the insert 214 is provided with ports 220 which correspond with ports 222 in the piston member 204 to provide communication between the upper end portion of the motor cylinder 12 and the valve chamber 218. A low pressure annular valve seat 224, having an upwardly facing annular seating area 226, is secured in the bore of the piston member 204 between the lower end of the insert 214 and the upper end of another insert 228 positioned in the medial portion of the piston member 204. It will therefore be observed that the insert 228 forms the major portion of the valve chamber 218 and communicates with the valve chamber portion 216 through the low pressure valve seat 224. It may also be noted that the upper end portion 230 of the tubular insert 228 is of a size to fit tightly within the bore of the piston member 204, while the main body portion 232 of the insert 228 is reduced in diameter to provide an annular passageway 234 between the outer periphery of the valve body portion 232 and the inner periphery of the piston member 204. The passageway 234 communicates with the low pressure valve seat 224 through ports 236 extending at an angle through the upper end portion 230 of the insert 228.

The lower end 238 of the insert 228 is in contact with a high pressure valve seat 240 having a downwardly facing annular seating area 242. The valve seat 240 is held between the lower end 238 of the insert 228 and the upper end of the piston extension 208 and extends into the upper end of a bore 244 in the extension 208. Passageways 245 extend through the extension 208 around the bore 244 and communicate with the passageway 234 in the piston member 204. A counterbore 246 is formed in the lower end of the piston extension 208 to provide communication between the passageways 245 and the upper end of the hollow connecting rod 34. Also, it will be observed that the bore 244 provides an extension of the valve chamber 218 and has its inner diameter increased in downwardly spaced relation from the seat 240 to provide a slightly enlarged portion 248 at the lower end of the valve chamber 218. A slot 250 is extended transversely through the piston extension 208 to provide constant communication between the lower end portion 248 of the valve chamber 218 and the lower end of the motor cylinder 12, whereby the high pressure power fluid in the lower end portion of the motor cylinder 12 will be in constant communication with the lower end portion of the valve chamber 218 below the high pressure valve seat 240.

The valve mechanism is generally designated by reference character 252 and is reciprocally disposed in the valve chamber 218 for controlling the flow of fluid to and from the upper end portion of the motor cylinder 12. The valve mechanism 252 comprises a tubular main valve body 254 having an extension 256 on the lower end thereof of a size to extend through the high pressure valve seat 240 with substantial clearance between the extension 256 and the inner periphery of the valve seat 240. The bore 258 extending longitudinally through the valve body 254 communicates with the valve chamber 218 immediately above the valve seat 240, through ports 260, and is open at the upper end of the valve body 254 to provide a flow of high pressure power fluid through the valve chamber 218 upon opening of the valve seat 240, as will be described.

The medial portion of the valve body 254 is of a size to slidably fit in the valve chamber 218, and the upper end or head portion 262 of the valve body 254 is increased in diameter to slidably fit in the enlarged upper end portion 216 of the valve chamber. The lower face 264 of the head portion 262 is tapered downwardly and inwardly to mate with the sealing area 226 of the valve seat 224 in the lower position of the valve body 254, as illustrated in Fig. 11. Immediately below the seating area 264, the valve body 254 is provided with a cylindrical portion 266 of a size to provide a loose sliding fit

thereof in the low pressure valve seat 224 to form a choke member and control flow of fluid through the valve seat 224 in intermediate positions of the valve body 254, as will be described. That portion 268 of the valve body 254 between the choke portion 266 and the main body portion of the valve is reduced in diameter to provide substantial clearance between the valve body and the valve seat 224 when the valve is in its upper position as illustrated in Fig. 10.

A ball member 270 is positioned in the valve chamber 218 below the high pressure valve seat 240 and is of a size to engage the seating area 242 of the valve seat 240 as illustrated in Fig. 10. It will be apparent that the ball 270 forms the lower valve head for the valve mechanism 252 to alternately open and close the valve seat 240. The ball 270 may be formed as an integral part of the valve body 254, although I prefer to form the ball 270 separately from the valve body for economy of manufacture. In either of these constructions, the ball 270 will operate efficiently to open and close the valve seat 240 in the alternate positions of the valve mechanism.

Another choke member 272 is positioned in the lower end portion 248 of the valve chamber and is of a size to substantially restrict the flow of high pressure fluid from the inlet 250 into the valve chamber 218 when in an upper position (not shown in the drawings). An extension 274 is formed on the upper end of the choke member 272 and is provided with circumferentially spaced ears 276 which slidably engage the walls of the valve chamber 218 above the enlarged portion 248 for guiding the choke member 272 in its upward and downward movements. It will be noted that the diameter of the extension 274 is substantially less than the diameter of the valve chamber 218 above the enlarged portion 248, such that the extension will provide no appreciable restriction to flow of power fluid from the inlet 250 into the valve chamber 218 when the choke member 272 is in its lowermost position, as shown in both Figs. 10 and 11.

In the pumping unit 200, the actuating means for mechanically moving the valve mechanism 252 off of the valve seats 224 and 240 comprises a sleeve 280 at the upper end of the motor piston assembly 202 slidably extending into the upper end portion 216 of the valve chamber 218. The sleeve 280 is decreased in diameter at 282, and the upper end of the insert 214 is provided with an inwardly extending flange portion 284 to engage the sleeve 280 in the upper position of the sleeve and prevent the sleeve from moving out of the valve chamber. Counterbores 286 and 288 are provided in the lower end of the sleeve 280 and the upper end of the valve body head portion 262, respectively, to receive the opposite ends of a helical spring 290 which constantly urges the sleeve 280 upwardly away from the valve body 254, as will be described. Also, a partial flange or shoulder 292 is formed on the lower face of the sleeve 280 around the counterbore 286 to contact the upper face of the valve body head portion 262 when the sleeve 280 is moved against the valve body to permit the application of fluid pressure against the upper end of the valve head 262, as will be described. Finally, it may be noted that the inner bore 294 through the sleeve 280 is substantially smaller in cross-sectional area than the bore 258 through the valve body 254 to provide an orifice for the high pressure fluid being directed to the upper end portion of the motor cylinder 12, as will be described.

The valve actuating means at the lower end of the piston assembly 202 comprises a cross bar 296 extending through the slot 250 in the piston extension 208. The cross bar 296 is suitably connected (not shown) at its opposite ends to a ring 298 which forms a harness assembly for engaging the choke member 272 when the piston assembly approaches the end of the down stroke in substantially the same manner as the operation of the har-

ness 80 previously described in connection with the pumping unit 10.

In operation of the pumping unit 200, the valve mechanism 252 will be in the position shown in Fig. 10 on the up stroke or power stroke of the pumping unit, and the valve mechanism will be in the position shown in Fig. 11 on the down stroke or return stroke of the pumping unit. Referring first to Fig. 10, it will be noted that the high pressure power fluid is constantly available at the inlet 18 and is discharged into the lower end portion of the motor cylinder 12 to react on the lower, smaller end portion of the piston assembly 202. This high pressure power fluid is also constantly available in the lower end portion of the valve chamber 218 through the inlet 250. On the up stroke of the unit, this power fluid is directed through the lower portion of the valve chamber 218 against the ball member 270 to hold the ball member 270 on the seat 240, such that the high pressure power fluid cannot flow on upwardly through the valve chamber 218 to the upper end of the motor cylinder 12.

Fluid in the upper end portion of the motor cylinder 12 is exhausted through the ports 222 and 220 into the upper end portion of the valve chamber 218. Since the valve seating area 264 is spaced upwardly above the low pressure seat 224, this exhausting fluid may flow on downwardly through the seat 224 around the valve body portion 268 and then through the annular exhaust passageway 234 and passageways 245 to the upper end of the hollow connecting rod 34. As described in connection with the preferred embodiment illustrated in Figs. 1 through 9, this exhausting power fluid is combined with well fluid in the pump cylinder 14 and is discharged through the outlet 20.

Near the end of the up stroke of the pumping unit 200, the upper end of the sleeve 280 contacts the lower face of the motor cylinder head 22; whereupon the insert 214 is telescoped upwardly over the sleeve 280. Upon continued upward movement of the piston assembly 202, the valve body head 262 is brought into contact with the flange 292 on the lower end of the sleeve 280. The sleeve 280 will therefore move the valve body 254 relatively downward in the valve chamber 218 through physical contact and remove the ball member 270 off the high pressure seat 240. The high pressure power fluid present in the lower end of the valve chamber 218 will therefore flow upwardly through the seat 240 and through the valve body 254 toward the upper end of the motor cylinder 12. However, since the upper end of the sleeve 280 is in contact with the motor cylinder head 22, this upwardly flowing high pressure fluid is prevented from escaping into the upper end of the motor cylinder 12 and reacting on the entire piston assembly 202. When the ball member 270 is removed from the seat 240, the high pressure fluid in the valve body 254 flows outwardly between the mating faces of the sleeve member 280 and the upper head portion 262 of the valve body to provide a downwardly acting force on the valve body 254 which moves the seating area 264 toward the low pressure seat 224. It will also be noted that during the early stages of the downward movement of the valve body 254, the choke portion 266 of the valve enters the low pressure valve seat 224 and restricts flow of fluid from above the piston assembly 202 downwardly through the valve seat 224. Therefore, a cushioning of the upward movement of the piston assembly is obtained and the minimum of fluid will be lost through the valve chamber during shifting of the valve. The seating area 264 will be fully seated on the valve seat 224 even though the piston assembly 202 may start on the down stroke and remove the sleeve 280 from the cylinder head 22, since the inner diameter of the seat 224 is larger than the outer diameter of the portion 254 of the valve mechanism. When the valve 254 is seated on the seat 224, all flow through the valve seat

224 is stopped and the valve will be held on this seat by hydraulic forces.

As previously indicated, the down stroke position of the valve mechanism is illustrated in Fig. 11. It will be observed that in this position of the valve mechanism, the high pressure valve seat 240 is opened, such that the high pressure power fluid will flow upwardly through the valve body 254 and through the sleeve member 280 into the upper end portion of the motor cylinder 12 to react on the upper, larger end of the piston assembly 202. Since the upper end of the piston assembly 202 is larger than the lower end of the piston assembly (by reason of the connecting rod 34) the net force reacting on the piston assembly 202 will force the piston assembly 202 on a down stroke. It has already been noted that the valve mechanism is in a closed position with respect to the low pressure seat 224 to prevent a discharge of fluid from the upper end of the motor cylinder 12 and into the connecting rod 34.

As the piston assembly 202 approaches the end of the down stroke, the harness ring 298 contacts the shoulder 16a of the middle plug 16 to move the choke member 272 upwardly with respect to the valve chamber 218. The ball member 270 resting on the upper end of the choke member 272 is therefore also moved upwardly and into contact with the extension 256 of the valve body 254 to move the seating area 264 of the valve head portion 262 off the low pressure seat. As the valve 252 is unseated from the low pressure seat 224, the choke member 272 is moved into the reduced diameter portion 244 of the valve chamber 218 immediately above the high pressure fluid inlet 250 to seriously restrict further flow of high pressure fluid upwardly through the valve body 254. Simultaneously, the fluid in the upper end of the motor cylinder 12 may leak downwardly around the upper choke member 266 through the low pressure seat 224. Therefore, the action of the high pressure power fluid across the lower face of the choke member 272 will overcome all downwardly acting forces on the valve 252 and force the valve 252 upwardly to the position shown in Fig. 10 where the ball member 270 is seated on the high pressure seat 242. When the ball member 270 becomes seated on the high pressure seat 240, the leakage of high pressure fluid will equalize the pressure above and below the choke member 272 in a very short period of time and the choke member 272 will fall by gravity back downwardly to the position shown in Fig. 10. It will be understood, of course, that the harness ring 298 and cross bar 296 also fall by gravity back to the position shown in Fig. 10 as soon as the piston assembly 202 starts on the up stroke.

Embodiment of Figs. 12 and 13

The modification illustrated in Figs. 12 and 13 is the same as the modification illustrated in Figs. 10 and 11, except in the construction of the lower end portion of the valve mechanism 252, and in the construction of the lower end portion of the valve chamber to accommodate the modified valve construction. Instead of a ball-type valve member cooperating with the high pressure valve seat 240, I may utilize an elongated valve element 300 having a choke portion 302 on the upper end thereof of a size to fit rather loosely in the valve seat 240. The upper end portion 304 of the element 300 above the choke portion 302 is reduced in diameter to contact the extension 256 on the lower end of the main valve body 254. Also, an annular seating area 306 is provided on the valve element 300 immediately below the choke portion 302 to seat on the high pressure valve seat 240.

The lower end portion 308 of the valve element 300 is reduced in diameter in downwardly spaced relation from the seating area 306 to provide a downwardly facing shoulder 310 and to provide a sliding fit of the lower end of the valve element in a secondary valve chamber 312 formed by a suitable insert 314 in the

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extreme lower end of the valve chamber 218. In this embodiment, the cross bar 296 is formed in two parts to straddle the reduced diameter portion 308 of the valve element 300 and (see Fig. 13) is connected at its opposite ends by means of bars 316 to the harness ring 298. The split cross bar 296 is provided to contact the downwardly facing shoulder 310 at the end of the down stroke of the pumping unit to unseat the valve means 252 from the low pressure seat 224 and move the choke portion 302 of the valve element 300 into the high pressure seat 240; whereupon the high pressure fluid present at the inlet 250 will react on the downwardly facing portion of the valve element 300 (which is equal to the area of the portion 302 minus the cross-sectional area of the reduced portion 308 of the valve element 300) and seat the valve element 300 on the high pressure seat 240.

A bore 316 extends through the length of the valve element 300 and provides communication between the valve chamber 218 above the high pressure seat 240 and the secondary valve chamber 312 to equalize the forces acting on that portion of the cross-sectional area of the valve element 300 represented by the cross-sectional area of the reduced portion 308. Therefore, the force required to knock the valve 252 off the high pressure seat 240 at the upper end of the up stroke may be controlled as desired by controlling the diameters of the valve element 300. The embodiment illustrated in Figs. 12 and 13 provides a reversal of the valve 252 at the end of the up stroke in the same manner as the embodiment illustrated in Figs. 10 and 11 and previously described.

Embodiment of Figs. 14 and 15

As previously indicated, the pump unit construction illustrated in Figs. 14 and 15 shows the use of a valve mechanism in the cylinder head rather than in the motor piston as in the previous embodiments. This construction, which has been generally designated by reference character 350, comprises an outer jacket 352 threadedly connected at its lower end to a middle plug 354 and threadedly connected at its upper end to the upper end portion of the motor cylinder head 356. The motor cylinder head 356 has a tubular extension 358 extending downwardly therefrom into the jacket 352 to connect with the upper end of the motor cylinder 360, which in turn extends downwardly into a counterbore 362 of the middle plug 354. It will be apparent that the head extension 358 and the motor cylinder 360 have outer diameters less than the inner diameter of the jacket 352 to provide an annular passageway 364 extending throughout substantially the entire length of the jacket 352. The middle plug 354 has a high pressure power fluid inlet 366 in one side thereof which communicates with the counterbore 362 to continuously expose the lower end portion of the motor cylinder 360 to high pressure power fluid. It will further be observed that a plurality of ports 368 are provided in the lower end portion of the motor cylinder 360 to also direct this high pressure power fluid into the annular passageway 364. The pump cylinder (not shown) is suitably connected to the middle plug 354 in a direction to extend vertically downward from the motor cylinder 360 and provide a complete pumping unit suitable for use in oil wells, as previously described in connection with the other embodiments.

The motor piston 370 is tubular in form and is of a size to reciprocate in the motor cylinder 360. Suitable piston rings 372 are provided around the outer periphery of the motor piston 370 to provide a sliding, sealing fit of the piston 370 in the cylinder 360. A connecting rod 374 is threadedly secured to the lower end of the piston 370 and extends downwardly through the middle plug 354 into connection with a suitable single acting pump piston (not shown) disposed in the pump cylinder which is located below the middle plug 354. Suitable packing 376 is provided in the middle plug 354 around the connecting rod 374 to prevent leakage of the high pressure

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power fluid through the middle plug into the pump cylinder. The packing 376 is suitably held in position by a follower 378 in a substantially conventional manner.

Tubular inserts 380 and 382 are secured in the tubular cylinder head 356 to form an elongated valve chamber 384 which extends along the axis of movement of the motor piston 370 to slidably receive the valve mechanism, generally designated by reference character 386. A high pressure valve seat 388 is secured in the cylinder head extension 358 between the inserts 380 and 382, and a low pressure valve seat 390 is secured in the extension 358 below the insert 382 against a shoulder 392 in the extension 358. It will also be observed that the upper end 394 of the upper insert 380 is closed, and both of the inserts and the valve seats are held in the desired positions in the cylinder head 356 by a cap member 396 threadedly secured in the upper end of the cylinder head 356.

The valve mechanism 386 comprises a main body portion 398 extending through the low pressure valve seat 390 and having a head portion 400 on the lower end thereof slidably fitting in a bore 402 in the lower end portion of the cylinder head extension 358 in alignment with the valve chamber 384 and forming a portion of the valve chamber. An upwardly facing annular seating area 404 is provided on the valve head portion 400 and is of a size to engage the annular seating area 406 of the low pressure valve seat 390 when the valve mechanism is in its uppermost position as illustrated in Fig. 15. A choke portion 408 is formed on the main body portion 398 of the valve mechanism immediately above the seating area 404 and is of a size to extend rather loosely through the low pressure valve seat 390 in intermediate positions of the valve mechanism for controlling the application of fluid pressure on the valve mechanism and hydraulically shifting the valve mechanism, as will be described. Immediately above the choke portion 408, the valve body 398 is reduced in diameter to provide substantial clearance between the valve seat 390 and the valve body when the valve mechanism is in its lowermost position as illustrated in Fig. 14. The upper end portion 410 of the valve body 398 is of a size to slidably fit in the valve chamber 384 between the valve seats 388 and 390. As shown in Fig. 15, a passageway 412 is provided through the valve body 398 to provide communication between the counterbore 402 of the cylinder extension 358 and the valve chamber 384 immediately below the high pressure seat 388 when the valve mechanism is in its uppermost position, for purposes which will be described.

The valve mechanism 386 also includes a valve body 414 above the high pressure valve seat 388 and being of a size to slidably fit in the reduced inner diameter portion 416 of the upper insert 380 for reciprocation simultaneously with the valve body 398. A head portion 418 is formed around the lower end portion of the valve body 414 and is provided with a downwardly facing annular seating area 420 of a size to mate with the seating area 422 of the high pressure valve seat 388 when the valve mechanism is in its lowermost position as illustrated in Fig. 14. Also, a choke portion 424 is formed immediately below the head portion 418 and is of a size to fit rather loosely in the high pressure valve seat 388 in intermediate positions of the valve mechanism for hydraulically shifting the valve mechanism, as will be described.

An extension 426 is formed below the choke portion 424 to contact the upper end of the valve body 398 and provide simultaneous movements of the valve body 414 when the valve body 398 is forced longitudinally, as will be described. It will also be observed that the extension 426 is of a size to provide substantial clearance through the high pressure valve seat 388 when the valve mechanism is in its uppermost position as illustrated in Fig. 15. A bore 428 is extended through the valve body 414 to provide constant communication between the valve chamber 384 and the upper portion 416 of the insert 380 to

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reduce the pressure differential across the valve body 414 in substantially the same manner as previously described in connection with the valve body 300 of the valve mechanism illustrated in Figs. 12 and 13. The valve body 414 is constantly urged in a downward direction by a suitable spring 430 to overcome any possibility of the valve body 414 becoming stuck in an upper and inoperative position. It will be apparent that the spring 430 retains the valve body 414 in contact with the valve body 398 when the valve mechanism is in its uppermost position, as illustrated in Fig. 15, and aids in retaining the head 418 seated on the high pressure seat 388 in the lowermost position of the valve mechanism, as illustrated in Fig. 14.

The valve mechanism 386 is alternately mechanically moved off of the high and low pressure seats 388 and 390 at the upper and lower ends of the movement of the motor piston 370 by an insert 432 carried in the piston 370, and by a trip rod 434 extending downwardly through the piston 370 from the lower end of the lower valve body 398. The insert 432 extends from a spider 436 in the motor piston 370 upwardly around the trip rod 434 into proximity with the upper end of the motor piston 370. The insert 432 operates to contact an extension 438 formed on the lower end of the valve body 398 near the end of the up stroke of the motor piston 370. It will be observed that the extension 438 of the valve body 398 extends through a bore 440 in the lower end of the cylinder head extension 358 immediately below the counterbore 402 when the valve mechanism 386 is in its lowermost position as illustrated in Fig. 14. It may also be noted that the extension 438 fits loosely in the bore 440 to provide a restriction in the flow of high pressure fluid in its movement toward the upper end of the motor cylinder 360, as will be described.

As shown in Fig. 14, a sleeve 442 is slidably carried in the upper end of the motor piston 370 and has its upper end formed parallel with the lower end face of the cylinder head extension 358 to contact the extension 358 near the end of the up stroke of the motor piston 370 and restrict flow of fluid through the bore 440, as also will more fully be described. The sleeve 442 is urged in an upward direction by a suitable coil spring 444 and is prevented from moving out of the upper end of the piston 370 by a suitable snap ring 446.

The trip rod 434 is threadably secured in the valve body extension 438 and extends downwardly through the insert 432 into a counterbore 448 formed in the upper end portion of the connecting rod 374. A shoulder 450 is suitably formed or secured on the lower end of the trip rod 434 in a position to be contacted by the spider 436 near the end of the down stroke of the motor piston 370 to mechanically move the lower valve body 398 in a downward direction. It may be noted here that in this embodiment the connecting rod 374 may be formed solid, in contrast with the hollow connecting rod described in connection with the embodiment shown in Fig. 1.

As previously indicated, high pressure power fluid is constantly present in the lower end portion of the motor cylinder 360 and in the annular passageway 364 formed by the jacket 352. This high pressure power fluid is also constantly fed into the upper end portion of the valve chamber 384 through ports 451 in the cylinder head extension 358 and through ports 452 in the upper insert 380 for control by the valve mechanism 386 which alternately directs this high pressure fluid into the upper end of the motor cylinder 360 and closes the high pressure valve seat 388, as will be described.

On the upstroke of the pumping unit 350, as illustrated in Fig. 14, the fluid present in the upper end portion of the motor cylinder 360 is exhausted through ports or passageways 454 formed vertically in the lower end portion of the cylinder head extension 358 into the valve chamber 384 immediately above the valve head portion 400. This fluid is then directed through the low pressure seat 390 and out through ports 456 and 458 formed in

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the insert 382 and in the cylinder head extension 358, respectively, into a vertical passageway 460 extending through the cylinder head extension 358 and the cylinder head 356. The upper end of the passageway 460 communicates with an outlet 462 which is suitably connected (not shown) with the discharge from the pump end of the present embodiment for conduction of the exhausted power fluid to the surface of the well, along with the well fluid being produced.

Near the end of the up stroke of the pumping unit 350, the sleeve 442 carried by the piston 370 first contacts the lower face of the cylinder head extension 358 and effectively closes off the bore 440 around the valve extension 438. The insert 432 then contacts the lower end of the valve extension 438 to mechanically unseat the valve head 418 from the high pressure valve seat 388. As soon as the valve head 418 is removed from the seat 388, a portion of the high pressure power fluid leaks around the upper choke member 424 and downwardly through the bore 412 of the valve body 398 into the counterbore 402 at the lower end of the valve chamber. However, this high pressure power fluid is prevented from flowing into the upper end of the motor cylinder 360 by the sleeve 442. Therefore, this high pressure fluid reacts on the lower face of the valve head 400 to hydraulically shift the entire valve mechanism 386 upwardly to the position shown in Fig. 15 where the lower valve head 400 is seated on the low pressure valve seat 390.

During upward movement of the valve mechanism 386, the choke 408 will enter the low pressure valve seat 390 prior to the time the movement of the piston member 370 is reversed to remove the sleeve 442 from the lower end face of the cylinder head extension 358, such that the valve head 400 will be completely seated on the low pressure valve seat by the action of the high pressure fluid reacting on the valve and assure that the valve 386 will not be stuck in an intermediate and inoperative position. It may also be noted that the bore 428 through the upper valve body 414 provides a balancing of forces across the major portion of the area of the upper valve body when the upper valve head 418 is seated on the high pressure valve seat 388 to minimize the force required to knock the valve head 418 off of the valve seat 388.

During the down stroke of the pumping unit 350 (see Fig. 15), the high pressure power fluid is directed from the upper end portion of the valve chamber 384 downwardly through the high pressure valve seat 388 around the valve extension 426 and then through the bore or passageway 412 through the valve body 398 into the counterbore 402 in the lower end of cylinder head extension 358. This high pressure fluid then flows through the bore 440 in the lower end of the cylinder head extension 358 into the upper end portion of the motor cylinder 360 to react on the larger, upper end of the motor piston 370 and overcome the upwardly acting power fluid in the lower end portion of the motor cylinder 360. The clearance in the bore 440 around the valve extension 438 is less than one-half the cross-sectional size of any other portion of the flow path of the high pressure fluid during the down stroke of the pumping unit to minimize the velocity of the high pressure fluid being injected into the upper end of the motor cylinder 360, without affecting the action of this high pressure fluid on the valve mechanism 398. As previously described, this action minimizes the speed of the down stroke or return stroke of the pumping unit and minimizes possible damage of the pumping unit in gassy wells. It may also be noted that the valve mechanism 398 will be held in its uppermost position by the action of the high pressure fluid in the counterbore 402 to hydraulically hold the valve mechanism on the low pressure valve seat 390 during the complete down stroke.

From the foregoing it will be apparent that the pump construction illustrated in Figs. 14 and 15 utilizes sub-

stantially the same valve mechanism as in the pump construction illustrated in Figs. 12 and 13, except that the valve mechanism is inverted and placed in the cylinder head, rather than in the motor piston as illustrated in Figs. 12 and 13. In each of these embodiments the valve mechanism will be hydraulically held on its respective seats but may be removed from the seats with a minimum of force. After the valve mechanism is mechanically removed from the respective valve seat, it will be automatically moved by hydraulic forces to the opposite valve seat, without fear of the valve sticking in an intermediate and inoperative position. It may also be noted that when a spring is used above the valve mechanism, as in either the embodiment shown in Figs. 12 and 13, or the embodiment shown in Figs. 14 and 15, the valve will be shifted to its lowermost position upon stopping of the pumping unit to assure that the valve mechanism will be operative when high pressure power fluid is again fed to the pumping unit.

Embodiment of Figs. 16 and 17

Still another embodiment of the present invention is illustrated in Figs. 16 and 17 wherein reference character 500 generally designates a complete pumping unit comprising a motor cylinder 502 connected in tandem relation to a pump cylinder (not shown) by a middle plug 504 in substantially the same manner as illustrated in Fig. 1. It will therefore be apparent that the middle plug 504 forms a lower head for the motor cylinder 502 and a suitable head 506 may be threadedly secured on the upper end of the cylinder 502 to form the opposite head portion of the motor cylinder. In this embodiment, the tubular motor piston 508 is provided with suitable piston rings 510 in the usual manner to provide a sealing, sliding fit of the motor piston in the cylinder 502. Also, a tubular extension 512 extends downwardly from the motor piston 508 and is threadedly secured by means of a spider 514 to the upper end of a hollow connecting rod 516. The hollow connecting rod 516 extends through suitable packing 518 in the middle plug 504 into connection with a single acting pump piston (not shown) which may be in the form of the pump piston 36 illustrated in Fig. 1. A power fluid inlet 520 is provided in one side of the middle plug 504 to continuously inject high pressure power fluid into the lower portion of the motor cylinder 502, and a fluid outlet 522 is provided in the opposite side of the middle plug 504 to discharge the exhausting power fluid and pumped well fluid from the pumping mechanism in substantially the same manner as in the embodiment illustrated in Fig. 1.

The valve chamber 524 of the pumping unit 500 extends through the lower portion of the piston 508 and through an insert 526 suitably secured in the piston extension 512 against the outer portion of the spider 514. A high pressure valve seat 528 is secured in the piston 508 by a suitable tubular insert 530 threadedly secured in the upper end of the piston 508. It will be apparent that the insert 530 holds the high pressure valve seat 528 against a shoulder 532 formed in the lower end portion of the piston 508. A low pressure valve seat 534 is formed on the upper end of the spider 514, with substantial clearance being provided between the valve seat 534 and the inner periphery of the adjacent portion of the insert 526.

The valve mechanism, generally designated by reference character 536, comprises a tubular valve body 538 reciprocally disposed in the valve chamber 524, and a valve sleeve 540 extending through the high pressure valve seat 528. The upper end portion 542 of the valve body 538 is increased in diameter to telescope over the lower end portion 544 of the valve sleeve 540 and to provide a downwardly facing shoulder 546 on the outer periphery of the valve body. The extreme upper end 548 of the valve body 538 is shaped to seat on the high pressure seat 528 when the valve mechanism is in its uppermost position, as illustrated in Fig. 16. The ex-

treme lower end portion 550 of the valve body 538 is shaped to seat on the low pressure seat 534 when the valve mechanism is in its lower position, as illustrated in Fig. 17.

As previously indicated, the valve sleeve 540 extends through the high pressure valve seat 528 into the upper end of the valve body 538. It may also be noted here that the sleeve 540 is of a length and is held in the piston member 508 in such a position that it constantly extends into the upper end of the valve body 538 in all positions of the valve mechanism. The upper end 552 of the sleeve 540 is formed parallel with the lower face of the upper cylinder head 506 to contact the cylinder head 506 at the end of the up stroke of the piston 508 and restrict the flow through the sleeve 540, as will be described. The sleeve 540 is urged in an upward direction by a suitable spring 554 positioned around the sleeve in the insert 530 and anchored between the valve seat 528 and a suitable flange 556 formed around the sleeve 540. Also, the flange 556 contacts the upper end portion of the insert 530 in the upper position of the sleeve 540 and prevents the sleeve 540 from being removed from the upper end of the piston 508.

The valve mechanism 536 also includes a tubular choke member 558 telescoped over the valve body 538 and being of a size to fit loosely in the valve chamber 524 below the high pressure valve seat 528 for controlling the flow of high pressure fluid to the valve mechanism, as will be described. The choke member 558 is actuated by a harness assembly 560 extending downwardly around the piston extension 512 and terminating in a harness ring 562 positioned adjacent the lower end of the piston extension 512. It will be apparent that the upper end of the harness 560 is threadedly secured to the choke member 558 by suitable screws 564 to mechanically move the choke member 558 upon movement of the harness 560.

As previously indicated, high pressure power fluid is constantly present at the inlet 520 in the middle plug 504 and is constantly fed into the lower end portion of the motor cylinder 502 for reaction on the lower, smaller end of the piston 508 and piston extension 512. High pressure power fluid is also constantly fed to the medial portion of the valve chamber 524 through ports 566 in the piston extension 512 immediately below the piston member 508. During the up stroke of the pumping unit 500, the valve mechanism 536 is in its uppermost position with the upper end 548 of the valve body 538 in engagement with the high pressure seat 528 to prevent the flow of high pressure fluid into the upper end portion of the motor cylinder 502. The fluid present in the upper end portion of the cylinder 502 is exhausted downwardly through the valve sleeve 540 and the valve body 538 into the lower end portion of the insert 526 around the low pressure valve seat 534. At this point the fluid flows on downwardly around the valve seat 534 and through the hollow connecting rod 516 into the pump cylinder for discharge with the pumped well fluid in the same manner as in the embodiment illustrated in Fig. 1. It may also be noted that during the up stroke of the pumping unit 500 the high pressure power fluid present in the medial portion of the valve chamber 524 reacts on the downwardly facing shoulder 546 to hold the valve body 538 in its uppermost position, and the spring 554 holds the valve sleeve 540 in its uppermost position with the flange 556 in contact with the upper end of the insert 530.

Near the end of the up stroke, the upper end 552 of the valve sleeve 540 contacts the lower face of the cylinder head 506; whereupon the piston 508 moves upwardly over the valve sleeve 540 and provides a relatively downward movement of the sleeve 540 in the piston member 508. The lower end 544 of the sleeve 540 is therefore brought into contact with an internal shoulder 568 formed in the valve member 538 to unseat the valve head portion 548 from the high pressure valve seat

528. As soon as high pressure power fluid may flow around the upper end 548 of the valve member 538, the hydraulic forces imposed on the valve member 538 are reversed to hydraulically move the valve member 538 downwardly through the valve chamber 524 onto the low pressure valve seat 534. As the valve member 538 is seated on the low pressure seat 534, the upper end 548 of the valve member is positioned to slightly open the small ports 570, such that high pressure fluid leaks into the valve sleeve 540 to react on the cylinder head 506 and start urging the piston assembly down. However, the valve sleeve 540 will be removed from the cylinder head 506 when the upper end of the insert 530 contacts the flange 556 and the ports 570 will then be completely open, as shown in Fig. 17. Also, when the valve body 538 is seated on the low pressure valve seat 534, approximately one-half of the seating area of the lower end 550 of the valve body will be exposed only to the lower pressure in the hollow connecting rod 516 and the net hydraulic forces on the valve body 538 will be in a downward direction to hold the valve body on the low pressure seat during the down stroke.

During the down stroke of the pumping unit 500, the high pressure fluid flows through the inlet ports 566 and through the reduced diameter ports 570, and then upwardly through the valve sleeve 540 into the upper end portion of the motor cylinder 502. This power fluid therefore reacts on the upper, larger end of the piston 508 and creates a net hydraulic force in a downward direction for the down stroke. It may also be noted that the apertures 570 are substantially smaller in total cross-sectional area than the inlet ports 566 to limit the velocity of high pressure fluid flowing into the upper end portion of the motor cylinder 502, without affecting the pressure forces on the valve mechanism.

Near the end of the down stroke of the pumping unit 500, the harness ring 562 contacts an upwardly facing shoulder 572 in the middle plug 504 to provide a relatively upward movement of the choke member 558 with respect to the valve body 538 and the piston member 508. Therefore, the upper end of the choke member 558 is moved into the valve chamber 524 immediately below the high pressure valve seat 528 and materially restricts the flow of high pressure fluid through the ports 570. Immediately following this restriction of flow through the ports 570, a shoulder 574 formed on the inner periphery of the choke member 558 contacts the downwardly facing shoulder 546 of the valve body 538 to mechanically unseat the valve body 538 from the low pressure seat 534. Immediately upon unseating of the valve body 538 from the low pressure seat 534 the pressure of the fluid in the valve body 538 and in the valve sleeve 540 will drop to an intermediate pressure. This intermediate pressure is also present above the upper end of the valve body 538 by reason of the ports 570, and high pressure fluid reacts on the shoulder 546 of the valve body 538 to produce a net hydraulic force on the valve body 538 in an upward direction to shift the valve body 538 upwardly against the high pressure seat 548.

When the valve body 538 is in engagement with high pressure seat 528, the piston member 508 will be urged upwardly and the choke member 558 and harness 560 will move back downwardly to a lower position, as illustrated in Fig. 16, by the action of gravity. As previously described, the fluid present in the upper end of the motor cylinder 502 is exhausted downwardly through the valve sleeve 540, valve member 538, and hollow connecting rod 516 into the pump cylinder to provide a net hydraulic force on the piston member 508 in an upward direction.

The pumping unit 500 illustrated in Figs. 16 and 17 provides a valve mechanism which directs the flow of the high pressure fluid to and from the larger end of the motor piston through the valve mechanism to minimize the required size of the piston assembly and valve mechanism, such that the maximum capacity of the motor end

of the unit may be realized. It may be noted, however, that the valve mechanism 536 is mechanically unseated from the high and low pressure seats and is then hydraulically shifted to an opposite seat by action of choking members, along the same lines as the embodiment shown in Fig. 1. In this regard it may be observed that the lower end portion 544 of the valve sleeve 540 acts as a choking member in shifting the valve mechanism to the low pressure seat after the valve mechanism has been mechanically unseated from the high pressure seat.

From the foregoing it will be apparent that the present invention provides a novel fluid operated pumping unit which may be operated as slow as desired and yet may be operated through a substantial speed range. The unit utilizes a single valve mechanism which will be thrown at the opposite ends of the piston movement by a minute physical movement of the piston to minimize a possibility of the valve becoming locked in an inoperative position. The present invention also provides a means for controlling the speed of the return stroke of the unit in the form of an orifice in the passageway leading to the larger end of the differential area motor piston assembly, whereby increases in operating fluid pressure will have a minimum effect on the speed of the return stroke. It will be further apparent that the valve will be moved to one of the seats of the motor unit, such as the high pressure seat which provides a power stroke of the pump, unless the valve is on an opposite seat or is just completing a power stroke, thereby minimizing the possibility of the valve assuming an inoperative position when the pumping unit is shut down for any period of time.

Changes may be made in the combination and arrangement of parts as heretofore set forth in the specification and shown in the drawings, it being understood that changes may be made in the precise embodiments shown without departing from the spirit and scope of the invention as defined in the following claims.

I claim:

1. In a fluid operated pump unit including a single acting pump operated by a reciprocating fluid motor having a motor piston and a motor cylinder and a fluid passageway through the motor piston having a valve means therein for directing high pressure fluid to one end of the motor piston for the return stroke of the pump, the improvement which comprises a sleeve slidably secured in said passageway downstream of the valve means providing an effective cross-sectional area for the passageway downstream of the valve substantially less than the effective cross-sectional area of the passageway upstream of the valve means, and means supporting said sleeve for movement to contact and unseat the valve means at the end of the power stroke of the pumping unit.

2. In a fluid operated pumping unit as defined in claim 1 characterized further in that said sleeve movement is arranged to contact the end of the motor cylinder at the end of the power stroke and momentarily restrict the flow of high pressure fluid downstream of the valve.

3. A fluid operated pumping unit, comprising a fluid motor, a single acting pump connected to and operated by the motor, said motor comprising a motor cylinder, a differential area piston reciprocally disposed in the cylinder and having the smaller end thereof continuously exposed to high pressure power fluid, a piston type valve having opposed seating areas and reciprocally disposed in a valve chamber in the piston on an axis parallel with the axis of the piston, a first passageway in the piston intersecting one end portion of the valve chamber and arranged to direct high pressure fluid to the larger end of the piston for a return stroke of the pumping unit, a second passageway in the piston intersecting the opposite end portion of the valve chamber and arranged to exhaust fluid from the larger end of the piston for a

power stroke of the pumping unit, opposed seats in the valve chamber around the first and second passageways to alternately receive the valve and close the passageways, a sleeve slidably secured in the first passageway between the valve chamber and the larger end of the piston to form an orifice in the first passageway and control the velocity of high pressure fluid flow through the first passageway, said sleeve being of a length to contact the respective end of the motor cylinder near the end of the power stroke and unseat the valve from the seat associated with the first passageway for exposing the respective end of the valve to high pressure power fluid which moves the valve to the opposite seat, and means for moving the valve in the opposite direction at the end of the return stroke of the unit.

4. A fluid operated pumping unit as defined in claim 3 characterized further in that the valve has an extension on the end thereof associated with the first passageway of a size to extend through the respective seat when the valve is adjacent to the seat, the clearance between the extension and the respective seat being greater than the clearance between the outer periphery of the sleeve and the inner periphery of the respective portion of the first passageway in which the sleeve is positioned, and the outer end of the sleeve being formed parallel with the respective end of the motor cylinder, whereby high pressure power fluid escapes past said extension faster than past the end of the sleeve and around the sleeve, when the sleeve contacts the respective end of the motor cylinder and unseats the valve, for hydraulically shifting the valve to the opposite seat immediately upon unseating the valve from the seat around the first passageway.

5. A fluid operated pumping unit as defined in claim 3 characterized further in that the valve is extended through the seat associated with the second passageway to form a head portion slidably disposed in a secondary valve chamber in the motor piston, the end of the secondary valve chamber remote from the seat around the second passageway being in communication with the smaller end of the motor piston to continually expose the respective end of said head portion to high pressure power fluid and urge the valve toward the seat around the first passageway, the respective pressure areas of the valve and head portion being distributed to provide a net hydraulic force on the valve to move the valve to the seat around the first passageway when the valve is off the seat around the second passageway, and means for unseating the valve from the seat around the second passageway at the end of the return stroke of the pumping unit.

6. A fluid operated pumping unit, comprising a fluid motor, a single acting pump connected to and operated by the motor, said motor comprising a motor cylinder, a differential area piston reciprocally disposed in the cylinder and having the smaller end thereof continuously exposed to high pressure power fluid, a piston type valve having opposed seating areas and reciprocally disposed in a valve chamber in the piston on an axis parallel with the axis of the piston, a first passageway in the piston intersecting one end portion of the valve chamber and arranged to direct high pressure fluid to the larger end of the piston for a return stroke of the pumping unit, a second passageway in the piston intersecting the opposite end portion of the valve chamber and arranged to exhaust fluid from the larger end of the piston for a power stroke of the pumping unit, opposed seats in the valve chamber around the first and second passageways to alternately receive the valve and close the passageways, an extension on each end of the valve of a size to extend into the respective seat in intermediate positions of the valve, yet the valve is of a size such that each extension will be removed from its respective seat when the valve is seated on the opposite seat, a head portion extending outwardly from the valve extension associated with the seat around the second passageway and slidably dis-

posed in a secondary valve chamber in the piston, the end of the secondary valve chamber opposite the seat around the second passageway being in communication with the smaller end of the motor piston to continuously expose the respective end of said head portion to high pressure power fluid and continuously urge the valve toward the seat around the first passageway, and means for unseating the valve at the ends of the power and return strokes of the pumping unit.

7. A pumping unit as defined in claim 6 characterized further in that the cross-sectional area of said head portion is greater than the cross-sectional area of the main body portion of the valve less the cross-sectional area of the valve extension associated with the seat around the first passageway to provide a net hydraulic force on the valve tending to move the valve to the seat around the first passageway when the valve is unseated from the seat around the second passageway.

8. A pumping unit as defined in claim 6 characterized further in that said means comprises a sleeve slidably disposed in the first passageway downstream of the respective valve seat and being of a length to extend beyond the larger end of the motor piston to contact the respective end of the motor cylinder at the end of the power stroke, whereby the sleeve moves into the motor piston and unseats the valve from the seat around the first passageway, and a harness slidably secured to the smaller end of the motor piston and extending into the secondary valve chamber for contacting the respective end of the motor cylinder and the head portion at the end of the return stroke for unseating the valve from the seat around the second passageway.

9. A pumping unit as defined in claim 8 characterized further in that said sleeve is of a size to provide an orifice in the first passageway for controlling the velocity of high pressure fluid flow to the larger end of the motor piston.

10. A fluid operated motor comprising a cylinder, a differential area piston reciprocally disposed in the cylinder and having the smaller end thereof continuously exposed to high pressure power fluid, a piston type valve having opposed seating areas and reciprocally disposed in a valve chamber in the piston on an axis parallel with the axis of the piston, a first passageway in the piston intersecting one end portion of the valve chamber and arranged to direct high pressure fluid to the larger end of the piston, a second passageway in the piston intersecting the opposite end portion of the valve chamber and arranged to exhaust fluid from the larger end of the piston, opposed seats in the valve chamber around the first and second passageways to alternately receive the valve and close the passageways, a sleeve slidably secured in the first passageway between the valve chamber and the larger end of the piston to form an orifice in the first passageway and control the velocity of high pressure fluid flow through the first passageway, said sleeve being of a length to contact the respective end of the motor cylinder near the end of one stroke of the motor and unseat the valve from the seat associated with the first passageway for exposing the respective end of the valve to high pressure power fluid which moves the valve to the opposite seat, and means for moving the valve in the opposite direction at the end of the opposite stroke of the motor.

11. A fluid operated motor as defined in claim 10 characterized further in that the valve has an extension on the end thereof associated with the first passageway of a size to extend through the respective seat when the valve is adjacent to the seat, the clearance between the extension and the respective seat being greater than the clearance between the outer periphery of the sleeve and the inner periphery of the respective portion of the first passageway in which the sleeve is positioned, and the outer end of the sleeve being formed parallel with the respective end of the motor cylinder, whereby high pres-

sure power fluid escapes past said extension faster than past the end of the sleeve and around the sleeve, when the sleeve contacts the respective end of the motor cylinder and unseats the valve, for hydraulically shifting the valve to the opposite seat immediately upon unseating the valve from the seat around the first passageway.

12. A fluid operated motor as defined in claim 10 characterized further in that the valve is extended through the seat associated with the second passageway to form a head portion slidably disposed in a secondary valve chamber in the motor piston, the end of the secondary valve chamber remote from the seat around the second passageway being in communication with the smaller end of the motor piston to continually expose the respective end of said head portion to high pressure power fluid and urge the valve toward the seat around the first passageway, the respective pressure areas of the valve and head portion being distributed to provide a net hydraulic force on the valve to move the valve to the seat around the first passageway when the valve is off the seat around the second passageway, and means for unseating the valve from the seat around the second passageway at the end of said opposite stroke of the motor.

13. A fluid operated motor comprising a cylinder, a differential area piston reciprocally disposed in a cylinder and having the smaller end thereof continuously exposed to high pressure power fluid, a piston type valve having opposed seating areas and reciprocally disposed in a valve chamber in the piston on an axis parallel with the axis of the piston, a first passageway in the piston intersecting one end portion of the valve chamber and arranged to direct high pressure fluid to the larger end of the piston, a second passageway in the piston intersecting the opposite end portion of the valve chamber and arranged to exhaust fluid from the larger end of the piston, opposed seats in the valve chamber around the first and second passageways to alternately receive the valve and close the passageways, an extension on each end of the valve of a size to extend into the respective seat in intermediate positions of the valve, yet the valve is of a size such that each extension will be removed from its respective seat when the valve is seated on the opposite seat, a head portion extending outwardly from the valve extension associated with the seat around the second passageway and slidably disposed in a secondary valve chamber in the piston, the end of the secondary valve chamber opposite the seat around the second passageway being in communication with the smaller end of the motor piston to continuously expose the respective end of said head portion to high pressure power fluid and continuously urge the valve toward the seat around the first passageway, and means for unseating the valve at the ends of the power and return strokes of the pumping unit.

14. A motor as defined in claim 13 characterized further in that the cross-sectional area of said head portion is greater than the cross-sectional area of the main body portion of the valve less the cross-sectional area of the valve extension associated with the seat around the first passageway to provide a net hydraulic force on the valve tending to move the valve to the seat around the first passageway when the valve is unseated from the seat around the second passageway.

15. A motor as defined in claim 13 characterized further in that said means comprises a sleeve slidably disposed in the first passageway downstream of the respective valve seat and being of a length to extend beyond the larger end of the motor piston to contact the respective end of the motor cylinder at the end of one stroke of the motor, whereby the sleeve moves into the motor piston and unseats the valve from the seat around the first passageway, and a harness slidably secured to the smaller end of the motor piston and extending into the secondary valve chamber for contacting the respective end of the motor cylinder and the head portion at the end of the

opposite stroke of the motor for unseating the valve from the seat around the second passageway.

16. A motor as defined in claim 15 characterized further in that said sleeve is of a size to provide an orifice in the first passageway for controlling the velocity of high pressure fluid flow to the larger end of the motor piston.

17. A reciprocating type fluid motor, comprising: a cylinder member; a piston member reciprocally disposed in the cylinder member and having a large end and a small end; a supply of high pressure power fluid; means providing constant communication between said supply and the small end of the piston member to constantly apply power fluid against said small end and urge the piston member in one direction in the cylinder member, a valve chamber in one of said members; a first passageway intersecting the valve chamber providing communication between said supply and the large end of the piston member to direct power fluid against the large end of the piston member and urge the piston member in an opposite direction; an exhaust passageway intersecting the valve chamber and communicating with the large end of the piston member for exhausting power fluid from the end portion of the cylinder member associated with the large end of the piston member and provide movement of the piston member in said one direction; a valve seat in the valve chamber associated with each of the first and exhaust passageways, said valve seats being positioned in spaced relation; valve means reciprocally disposed in the valve chamber for alternately closing said valve seats and controlling the flow of power fluid to and from the large end of the piston member; and valve actuating means carried by the piston member physically engaging the valve means near the end of the movement of the piston member in either direction, to unseat the valve means from the valve seat associated with the respective passageway closed by the valve means during movement of the piston member in the respective direction; said valve means including choke means controlling the flow of fluid through the valve chamber in intermediate positions of the valve means for hydraulically shifting the valve means into a closed position with respect to either seat when the valve means has been unseated from the other seat by the valve actuating means.

18. A motor as defined in claim 17 wherein said valve means includes an elongated body portion having a bore extending longitudinally therethrough, said body portion being arranged to position said bore in communication with one of said passageways when the seat associated with the respective passageway is opened.

19. A motor as defined in claim 17 wherein one of said valve actuating means includes a sleeve slidably carried by the piston member and protruding from the large end of the piston member arranged to contact the respective end of the cylinder member and restrict flow through said first passageway.

20. A motor as defined in claim 17 wherein the cross-sectional area of said first passageway downstream of said valve means is less than one half the cross-sectional area thereof upstream of said valve means.

21. A motor as defined in claim 17 wherein said valve chamber and said first and exhaust passageways are in the piston member.

22. A motor as defined in claim 17 wherein said valve chamber and said first and exhaust passageways are in the cylinder member.

23. A reciprocating type fluid motor, comprising: a cylinder member; a piston member reciprocally disposed in the cylinder member and having a large end and a small end; a supply of high pressure power fluid; means providing constant communication between said supply and the small end of the piston member to constantly apply power fluid against said small end and urge the piston member in one direction in the cylinder member; a valve chamber in one of said members; a first passageway intersecting the valve chamber providing communication between said supply and the large end of the piston

member to direct power fluid against the large end of the piston member and urge the piston member in an opposite direction; an exhaust passageway intersecting the valve chamber and communicating with the large end of the piston member for exhausting power fluid from the end portion of the cylinder member associated with the large end of the piston member and provide movement of the piston member in said one direction; a valve seat in the valve chamber associated with each of the first and exhaust passageways, said valve seats being positioned in spaced relation; a piston type main valve reciprocally disposed in the valve chamber for alternately closing said valve seats and controlling the flow of power fluid to and from the large end of the piston member; and valve actuating means carried by the piston member physically engaging said valve near the end of the movement of the piston member in either direction, to unseat said valve from the valve seat associated with the respective passageway closed by said valve during movement of the piston member in the respective direction; said valve having variable diameter portions cooperating with said valve seats in intermediate positions of the valve to control the application of the power fluid to the valve in intermediate positions of the valve and hydraulically shift the valve after the valve has been unseated by the valve actuating means.

24. A reciprocating type fluid motor, comprising: a cylinder member; a piston member reciprocally disposed in the cylinder member and having a large end and a small end; a supply of high pressure power fluid; means providing constant communication between said supply and the end portion of the cylinder member associated with the small end of the piston member to constantly apply power fluid against said small end and urge the piston member in one direction in the cylinder member; an elongated valve chamber in one of said members; a first passageway intersecting the opposite end portions of the valve chamber providing communication between said supply and the large end of the piston member through a portion of the valve chamber to direct power fluid against the large end of the piston member and urge the piston member in an opposite direction; an exhaust passageway intersecting intermediate portions of the valve chamber and communicating with the large end of the piston member for exhausting power fluid from the end portion of the cylinder member associated with the large end of the piston member and provide movement of the piston member in said one direction; a low pressure annular valve seat in the valve chamber positioned between the intersections of the exhaust passageway; a high pressure annular valve seat in the valve chamber positioned between the low pressure seat and that portion of the first passageway leading from the high pressure power fluid supply; valve means reciprocally disposed in the valve chamber for alternately opening and closing said passageways and having a first annular seating area positioned to engage the lower pressure valve seat in one position of the valve means, said valve means having a second annular seating area positioned to engage the high pressure valve seat in a second position of the valve means, said valve means also having a bore through a portion thereof arranged to communicate with the first passageway when said valve means is in said first position, and valve actuating means carried by the piston member in positions to physically engage said valve means at the end of the movement of the piston member in either direction to unseat the valve means from the valve seat associated with the respective passageway closed by the valve means during movement of the piston member in the respective direction, said valve means including choke means controlling the flow of fluid through the valve chamber in intermediate positions of the valve means for hydraulically shifting the valve means into a closed position with respect to either seat when the valve means has been unseated from the other seat by the valve actuating means.

25. A fluid motor as defined in claim 24 wherein the cross-sectional area of that portion of the first passageway between the valve means and the large end of the piston member is less than one half the cross-sectional area of that portion of the first passageway between the valve means and the power fluid supply.

26. A fluid motor as defined in claim 24 wherein the valve chamber is positioned in the piston member, and one of said valve actuating means comprises a sleeve slidably secured in the piston member in a position to protrude from the large end of the piston member, said sleeve forming a portion of said first passageway and the cross-sectional area of the bore therethrough being less than one half the cross-sectional area of that portion of said passageway between the valve means and the power fluid supply.

27. A fluid motor as defined in claim 24 wherein that portion of the first passageway leading from the power fluid supply intersects the valve chamber between the high pressure seat and the respective end of the valve chamber, said respective end of the valve chamber being reduced in diameter, and said valve means being shaped to slidably extend into said reduced diameter portion of the valve chamber, whereby the area of said valve means exposed to the power fluid when said valve means is in engagement with the high pressure seat is less than the cross-sectional area of the high pressure seat and the force required to move the valve means off the high pressure seat is reduced.

28. A fluid motor as defined in claim 27 wherein said valve means has a pressure equalizing bore therethrough extending from the end thereof in said reduced diameter portion of the valve chamber to that portion of the valve chamber between the high pressure seat and low pressure seat when the valve means is seated on the high pressure seat.

29. A fluid motor as defined in claim 24 wherein the valve chamber is located in the end of the cylinder member associated with the large end of the piston member in alignment with the movement of the piston member.

30. A reciprocating type fluid motor, comprising a cylinder member, a piston member reciprocally disposed in the cylinder member having a large end and a small end, a high pressure power fluid supply, means providing constant communication between the power fluid supply and the end of the cylinder member associated with the small end of the piston member to urge the piston member in one direction in the cylinder member, an elongated valve chamber in the piston member extending along the axis of the piston member and communicating at one end thereof with the large end of the piston member, means forming an exhaust passageway communicating with the opposite end of the valve chamber, a power fluid inlet in the piston member intersecting the valve chamber at a point spaced from the opposite ends of the valve chamber to provide communication between the valve chamber and the end of the cylinder member associated with the small end of the piston member, a high pressure valve seat in the valve chamber between the power fluid inlet and the large end of the piston member, a low pressure seat in the end portion of the valve chamber adjacent the exhaust passageway, a tubular valve body reciprocally disposed in the valve chamber between the valve seats and having seating areas on the opposite ends thereof for alternately engaging the valve seats and controlling the flow of power fluid to and from the large end of the piston member, a valve sleeve slidably secured in the valve chamber in a position to protrude from the large end of the piston member for contacting the respective end of the cylinder member and unseating the tubular valve from the high pressure seat at the end of the movement of the piston member in said one direction, said valve sleeve being extended into the respective end of the tubular valve and having transverse ports therein arranged to be exposed when

the tubular valve is on the low pressure seat to pass the power fluid to the large end of the piston member, said ports having a cross-sectional area less than one half the cross-sectional area of said power fluid inlet, a harness ring telescoped over the piston member and arranged to contact the end of the cylinder member associated with the small end of the piston member near the end of the movement of the piston member in a direction opposite to the first-mentioned direction, and a tubular choke member telescoped over the end of the tubular valve adjacent the high pressure seat connected to said harness ring and having a projection thereon arranged to engage the tubular valve and unseat the tubular valve from the low pressure seat at the end of said opposite movement of the piston member, said valve chamber being increased in diameter adjacent the high pressure seat to receive said choke member upon actuation of said choke member by the harness ring to control the application of fluid pressure to the tubular valve and to shift the tubular valve hydraulically after the tubular valve is unseated from the low pressure seat by action of the harness ring.

31. In a fluid operated pump unit, comprising: a motor cylinder member; a motor piston member reciprocally disposed in the cylinder member and having a large end and a small end; a supply of high pressure power fluid; means providing constant communication between said supply and the small end of the piston member to constantly apply power fluid against said small end and urge the piston member in one direction in the cylinder member, a valve chamber in one of said members; a first passageway intersecting the valve chamber providing communication between said supply and the large end of the piston member to direct power fluid against the large end of the piston member and urge the piston member in an opposite direction; an exhaust passageway intersecting the valve chamber and communicating with the large end of the piston member for exhausting power fluid from the end portion of the cylinder member associated with the large end of the piston member and provide movement of the piston member in said one direction; a valve seat in the valve chamber associated with each of the first and exhaust passageways, said valve seats being positioned in spaced relation; valve means reciprocally disposed in the valve chamber for alternately closing said valve seats and controlling the flow of power fluid to and from the large end of the piston member; valve actuating means carried by the piston member physically engaging the valve means near the end of the movement of the piston member in either direction to unseat the valve means from the valve seat associated with the respective passageway closed by the valve means during movement of the piston member in the respective direction; said valve means including choke means controlling the flow of fluid through the valve chamber in intermediate positions of the valve means for hydraulically shifting the valve means into a closed position with respect to either seat when the valve means has been unseated from the other

seat by the valve actuating means; a pump cylinder connected in tandem relation to the motor cylinder member; a pump piston reciprocally disposed in the pump cylinder, and a rod connecting the pump piston to the small end of the motor piston member for reciprocating the pump piston upon reciprocation of the motor piston member.

32. In a fluid operated pump unit, comprising: a motor cylinder member; a motor piston member reciprocally disposed in the cylinder member and having a large end and a small end; a supply of high pressure power fluid; means providing constant communication between said supply and the small end of the piston member to constantly apply power fluid against said small end and urge the piston member in one direction in the cylinder member; a valve chamber in one of said members; a first passageway intersecting the valve chamber providing communication between said supply and the large end of the piston member to direct power fluid against the large end of the piston member and urge the piston member in an opposite direction; an exhaust passageway intersecting the valve chamber and communicating with the large end of the piston member for exhausting power fluid from the end portion of the cylinder member associated with the large end of the piston member and provide movement of the piston member in said one direction; a valve seat in the valve chamber associated with each of the first and exhaust passageways, said valve seats being positioned in spaced relation; a piston type main valve reciprocally disposed in the valve chamber for alternately closing said valve seats and controlling the flow of power fluid to and from the large end of the piston member; valve actuating means carried by the piston member physically engaging said valve near the end of the movement of the piston member in either direction to unseat said valve from the valve seat associated with the respective passageway closed by said valve during movement of the piston member in the respective direction; said valve having variable diameter portions co-operating with said valve seats in intermediate positions of the valve to control the application of the power fluid to the valve in intermediate positions of the valve and hydraulically shift the valve after the valve has been unseated by the valve actuating means; a pump cylinder connected in tandem relation to the motor cylinder member; a pump piston reciprocally disposed in the pump cylinder, and a rod connecting the pump piston to the small end of the motor piston member for reciprocating the pump piston upon reciprocation of the motor piston member.

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