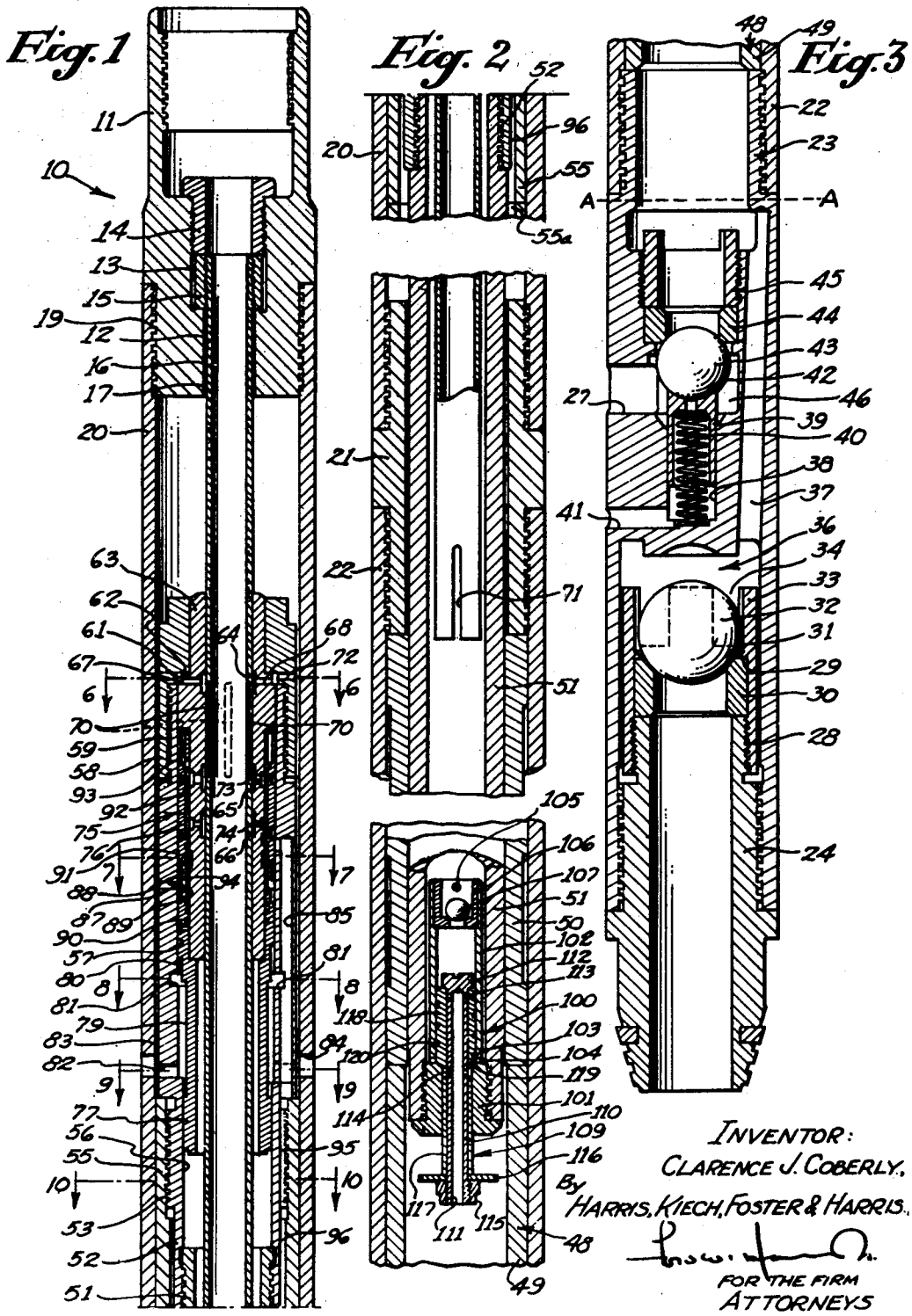
June 21, 1949. C. J. COBERLY 2,473,864

HEAVY OIL AND SAND PUMP

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HEAVY OIL AND SAND PUMP

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Fig. 4

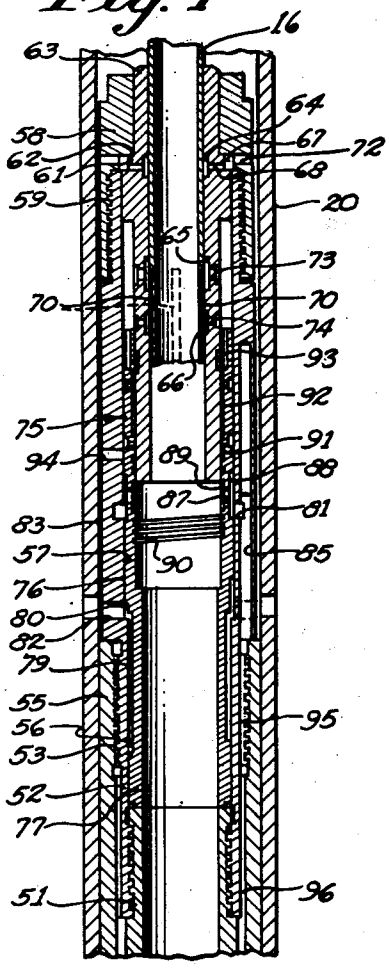
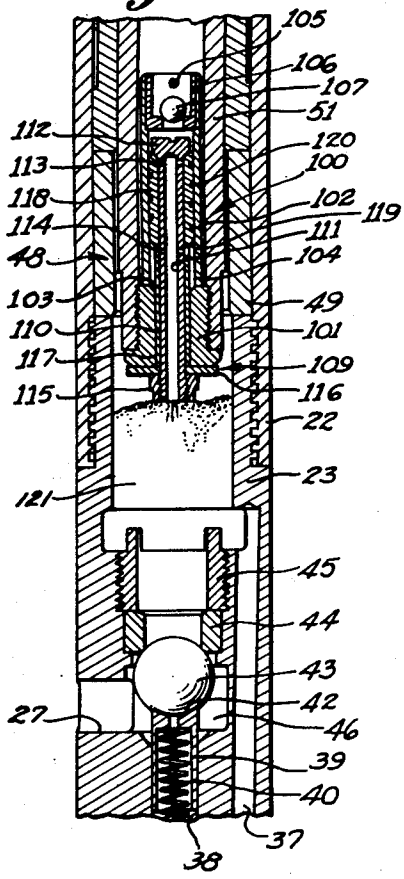


Fig. 5



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Fig. 6

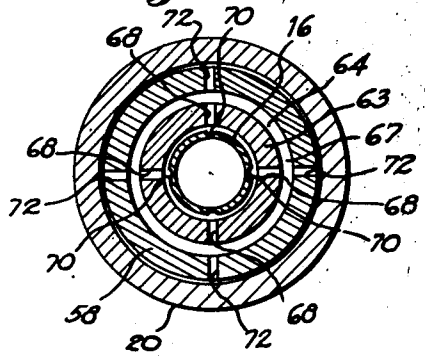


Fig. 7

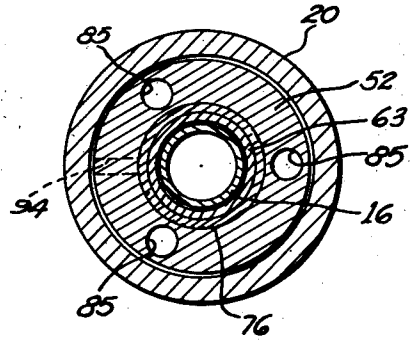


Fig. 8

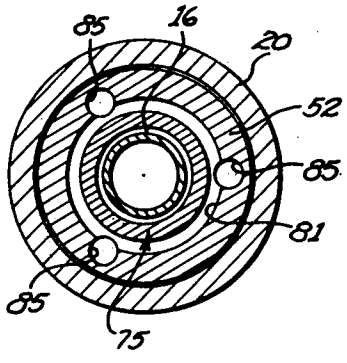


Fig. 9

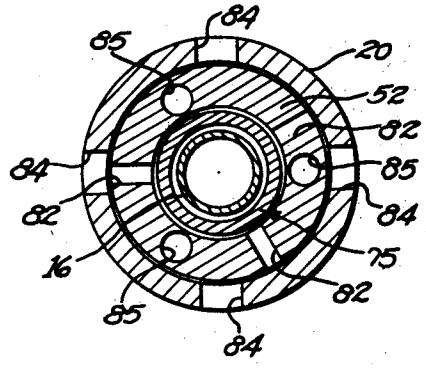
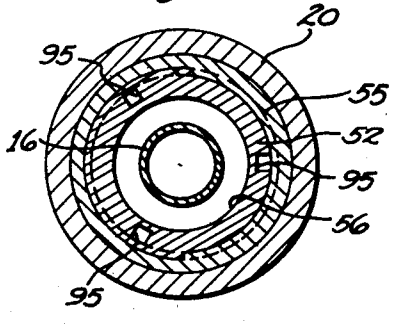


Fig. 10



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2,473,864

HEAVY OIL AND SAND PUMP

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Application May 13, 1946, Serial No. 669,410

26 Claims. (Cl. 103—46)

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This invention relates to hydraulic pumps and, more particularly, to a fluid-operated pump of the displacement type adapted to pump oil from a well.

Conventional fluid-operated pumps of the displacement type, such as illustrated in my Patent No. 2,311,157, issued February 16, 1943, include a motor cylinder having a motor piston therein, a pump cylinder having a pump piston therein and connected by a piston rod with a motor piston, and master valve mechanism for alternatively directing high-pressure operating fluid, such as oil, to opposite ends of the motor cylinder to reciprocate the piston assembly to pump well fluid from the pump cylinder. In such devices the pistons have a substantially fixed stroke length, and reversal of direction of the pump piston cannot take place unless and until it completes its stroke.

Many oil wells produce oil having a high percentage of solids, such as, for example, sand, therein, and when such a conventional type of fluid-operated pump is utilized in pumping such a well it is commonly found that solids, such as sand, in the oil tend to collect in the pump cylinder. When this occurs the conventional pump piston may squeeze the oil through the sand in the pump cylinder, leaving a solid core of sand which stops the travel of the pump piston before it completes its stroke and prevents completion of the stroke. Since such pumps are of the constant displacement type, when the pump piston is prevented from completing its stroke the motor piston likewise stops, and the pump must normally be removed from the well to permit the accumulated sand to be removed from the pump. This requires an expensive pulling job, and complete disassembly of the pump for cleaning, and the well normally lies idle during such an operation, all of which is very undesirable.

It is therefore a primary object of this invention to provide a pump of the fluid-operated type in which the pump piston will reverse its stroke when it contacts a mass of sand or other solid material in the pump cylinder. This prevents stoppage of the pump and permits uninterrupted production from the well, even though perhaps at somewhat reduced capacity.

Another object of this invention is to provide a fluid-operated pump of the character just described, in which means is provided therein for removing, or assisting in the removal of, sand or other solids from the pump cylinder during operation of the pump. I prefer to accomplish this by providing means for jetting a fluid, such as oil, into the pump cylinder or chamber when the

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pump piston contacts solid matter therein, so as to stir up and dislodge such sand so that it may be forced through the pump by the pump piston, and this is still another object of the invention.

A further object of the invention is to provide such a pump which is of the single-acting type, but in which high pressure operating fluid is employed to perform both strokes of the pump piston. I also prefer to provide such a pump in which the downstroke, or return stroke, is at relatively high velocity and in which the upstroke, or working stroke, is at relatively low velocity, so that the suction stroke utilizes about 75% to 90% of the total time of the pump cycle, which is particularly desirable where such a pump is employed to pump heavy oil, and this is another object of the invention. Such a construction has the added advantage that a high-velocity downstroke of the pump piston causes a rapid discharge of oil thereby which causes considerable turbulence tending to keep sand or other solid matter in suspension in the oil so that it can be discharged from the pump with the oil, and this is a further object of the invention. The low velocity of the pump piston on its working or intake stroke also has the added advantage that it does not reduce the intake pressure substantially below the fluid pressure in the well, which is important because if the intake or working stroke is rapid the pressure in the inlet end of the pump cylinder may be reduced to a value at which gas in solution in the oil flashes out thereof to form a froth of free gas in the pump cylinder which greatly reduces the volumetric efficiency of the pump.

Still another object of the invention is to provide such a pump in which high pressure operating fluid at all times bears on a relatively small cross-sectional force area tending to move the pump piston downwardly, and in which such high-pressure fluid is intermittently admitted to a relatively large cross-sectional force area tending to move the pump piston upwardly.

Another object of the invention is to provide a pump as last described above in which such high-pressure operating fluid is admitted to a force area causing the pump piston to move upwardly when the pump piston strikes solid matter in the pump cylinder, regardless at what point this may occur on the downstroke of the pump piston. I prefer to accomplish this by employing such operating fluid to perform the jetting action described above, and to use such jetted fluid to effect upward movement of the pump piston.

Yet a further object of my invention is to provide a fluid-operated pump having a pump piston equipped with a valve mechanism which, when the pump piston strikes solid matter in the pump cylinder, opens the valve to admit high-pressure operating fluid to the bottom of the pump piston, tending to raise the pump piston.

Another object of the invention is to provide such a pump which will operate effectively to handle oil or other fluid containing sand or other solid matter. I accomplish this, in part, by the use of pump intake and discharge valves which are large relative to the pump diameter, which also facilitates the pumping of heavy or viscous crude oil, and is a separate object of the invention.

A further object of my present invention is to provide a fluid-operated pump having a unitary motor piston and main valve, which simplifies the construction and reduces the cost of manufacture.

Still another object of the invention is to provide a fluid-operated pump in which the operating fluid is supplied through a central tubular member on which the motor piston reciprocates, so that the motor and pump cylinders can be simple tubular members. This feature has the added advantage that the fluid pressure of the operating fluid is at all times directed radially outwardly in the motor and pump cylinders.

Another object of the invention is to provide a pumping method for sandy oil wells in which the potential energy of the downwardly moving column of operating fluid is converted and released as kinetic energy to flush out sand collected in the pump chamber, and to use the potential energy of the operating fluid to cause normal operation of the pump at all other times.

Other objects and advantages will appear from the following specification and the drawings, which are for the purpose of illustration only, and in which:

Fig. 1 is a vertical sectional view through the upper portion of my invention;

Fig. 2 is a vertical sectional view of an intermediate portion of the invention, carried downwardly from the lower end of Fig. 1;

Fig. 3 is a vertical sectional view of the lower portion of the invention, carried downwardly from the lower end of Fig. 2;

Fig. 4 is a vertical sectional view of the motor and valve mechanism of my invention, showing the main valve member in its lower, or upstroke, position;

Fig. 5 is a vertical sectional view of the inlet end of the invention, showing the position of the parts when the pump piston strikes an accumulation of sand in the bottom of the pump cylinder;

Fig. 6 is a cross-sectional view taken on the line 6—6 of Fig. 1;

Fig. 7 is a cross-sectional view taken on the line 7—7 of Fig. 1;

Fig. 8 is a cross-sectional view taken on the line 8—8 of Fig. 1;

Fig. 9 is a cross-sectional view taken on the line 9—9 of Fig. 1; and

Fig. 10 is a cross-sectional view taken on the line 10—10 of Fig. 1.

Referring to the drawings, Figs. 1, 2, and 3 show a fluid operated pump 10 having an upper fitting 11 by which the fluid operated pump is secured to the lower end of a conventional fluid supply tubing (not shown), by which operating fluid, such as oil, under relatively high pressure is delivered to the pump. The upper fitting 11 is

provided with a longitudinal bore 12 having a counter-bore 13, the upper end of the counter-bore being internally threaded to receive a tubular nut 14 which rigidly retains in the counter-bore the head 15 of a depending valve tube 16. An annular clearance 17 is provided between the valve tube 16 and the bore 12 of the fitting 11 to permit axial alignment of the valve tube with valve mechanism to be described hereinafter. The tubular nut 14 is tightened against the shoulder in fitting 11 with a slight axial clearance between the nut 14 and the head 15 so that the valve tube can float laterally.

The upper fitting 11 is provided on its lower end with external threads 19 to which is threaded a tubular motor cylinder 20. As shown in Fig. 2, the lower end of the motor cylinder 20 is threaded to a tubular plug member 21, the lower end of which is threaded by external threads to the upper end of a tubular pump cylinder 22. As shown in Fig. 3, the lower end of the tubular pump cylinder 22 is threaded to the upper end of an inlet member 23, the lower end of which is threaded to a tubular seating member 24 provided at its lower end with a conical seating face 25, which is adapted to seat in the conventional pump inlet shoe (not shown) carried by the lower end of a production tubing (not shown) which, as will be understood, extends upwardly around the fluid operated pump 10 to the surface of the ground so as to receive pumped well fluid from a discharge port 27 of the inlet member 23 to convey such discharged well fluid from the fluid operated pump to the surface of the ground, as is generally well known in the art.

The tubular seating member 24 has threaded to its upper end a tubular collar 28 provided with an internal annular shoulder 29 adapted to clamp an annular main valve seat member 30 against the upper end of the tubular seating member. The valve seat member 30 is provided with a semi-spherical valve seat 31 on which is adapted to seat by gravity an inlet ball valve element 32, the valve seat and the ball valve element constituting the main inlet valve of the invention. The upper end of the tubular collar 28 is provided with circumferentially spaced fingers 33 providing spaces 34 therebetween to permit the flow of well fluid from the tubular seating member 24 into the inlet member 23 when the ball valve element 32 is raised off its seat 31. As will be noted, the lower end of the inlet member 23 forms an inlet chamber 36, with which communicates a substantially vertical passage 37 leading upwardly through the inlet member to the upper end thereof to communicate with the interior of the pump cylinder 22.

The central portion of the inlet member 23 is provided with an axial bore 38 in which is disposed a slidable, tubular valve carrier 39 adapted to be retained normally in its uppermost position as shown in Fig. 3 by a compression spring 40 disposed therein. Communicating with the lower end of the axial bore 38 is a radial port 41, which permits fluid to freely enter and discharge from the lower end of the axial bore to permit reciprocation of the valve carrier 39 therein. The valve carrier 39 is provided with a semi-spherical upper face 42 which carries a discharge ball valve member 43 which is normally held in its seated position shown in Fig. 3 by the compression spring 40 against an annular valve seat 44 retained in the inlet member 23 by a threaded tubular nut 45. The ball valve member 43 and its valve seat 44 constitute a discharge valve means of the in-

vention. The discharge ball valve member 43 works in a discharge chamber 46 which communicates with the exterior of the inlet member 23 through the discharge port 27.

Supported on the upper end of the inlet member 23 is a tubular pump cylinder liner 48 having a lower section 49 and an upper section 50, the sections of the cylinder liner being clamped between the inlet member 23 and the tubular plug member 21. Disposed in the cylinder liner 48 is a tubular pump piston member 51 which is reciprocable in the cylinder liner and forms a fluid-tight fit with the upper section 50 thereof. Threadedly connected to the upper end of the pump piston member 51 is a valve body 52, best shown in Fig. 1. The valve body 52 is provided with external threads 53 to which is threaded the upper end of a tubular motor piston 55, which extends downwardly in the tubular motor cylinder 20 and forms a fluid-tight sliding fit therewith, the motor cylinder providing an annular space 55a.

The valve body 52 has a minor bore 56 and a major bore 57 of greater internal diameter than the minor bore, the upper end of the valve body being provided with a tubular head 58 connected thereto by means of threads 59. The tubular head 58 is provided with an annular shoulder 61 which engages a shoulder 62 borne on a valve sleeve 63 which is press-fitted or otherwise secured in the upper end of the major bore 57. The valve sleeve 63 is slidably disposed on the valve tube 16 in fluid-tight engagement therewith and its bore is provided with an upper annular groove 64, a central annular groove 65, and a lower annular groove 66. The annular shoulder 62 is of smaller external diameter than the adjoining part of the tubular head 58 so as to provide an annular space 67 therebetween, which communicates through circumferentially spaced radial ports 68, as best shown in Fig. 6, with the annular groove 64. The valve tube 16 is provided in its external surface with a plurality of circumferentially spaced upper vertical grooves 70, which, in the position of the parts shown in Fig. 1, span the upper annular groove 64 and the central annular groove 65. The lower end of the valve tube 16 is provided with a plurality of circumferentially spaced lower vertical grooves 71, the lower ends of which are open to the interior of the pump piston member 51. Also communicating with the annular space 67 are a plurality of radial ports 72 formed in the tubular head 58. The central annular groove 65 communicates through radial ports 73 formed in the valve sleeve 63 with the exterior thereof, and the lower annular groove 66 similarly communicates through radial ports 74 with the exterior of the valve sleeve.

Disposed in the space provided between the valve sleeve 63 and the valve body 52 is a main valve member 75 of substantially tubular form, having a major portion 76 making fluid-tight slidable engagement with the major bore 57, and a minor portion 77 making fluid-tight slidable engagement with the minor bore 56. The exterior surfaces of the major and minor portions 76 and 77 are separated by an annular channel 79, and the lower exterior surface of the major portion 76 is provided with a plurality of circumferentially spaced vertical throttling grooves 80 of different lengths. With the main valve member 75 in the position shown in Fig. 1, the annular channel 79 spans an annular groove 81 formed in the major bore 57 and a plurality of circumferentially spaced radial ports 82 formed in the valve body 52. The radial ports 82 communicate, through an annular space 83, between the valve body 52 and the motor cylinder 20, with radial exhaust ports 84 formed in the motor cylinder. The annular groove 81 also is intersected by and communicates with vertical passages 85 formed in the valve body.

Also formed in the main valve member 75 are radial ports 87 which communicate with an annular groove 88 formed on the exterior of the valve member and with an annular groove 89 formed on the interior of the valve member. Communicating with the inner annular groove 89 is a lower helical groove 90 and an upper helical groove 91 which communicates at its upper end with an annular channel 92, which in turn communicates at its upper end with vertical passages 93 formed in the upper end of the valve member, and which communicate with the upper end thereof. Also formed in the central portion of the valve body 52 is a radial port 94. Communicating with the lower end of the vertical passages 85 are longitudinal grooves 95 formed in the lower threaded portion of the valve body 52, and which also communicate with the upper end of an annular space 96 provided between the lower end of the valve body and the upper end of the tubular motor piston 55.

As best shown in Fig. 2, the lower end of the tubular pump piston 51 is provided with an auxiliary valve means 100, which also serves as a jetting means as described hereinafter. The auxiliary valve means 100 includes a plug member 101 threaded into the lower end of the tubular pump piston member 51, provided with a tubular neck 102 extending upwardly into the pump piston member, the plug member being provided with a conical valve seat 103 and having radial ports 104 just above the valve seat in the tubular neck. Secured in the upper end of the tubular neck, as by a cross pin 105 is a valve cage 106 having a ball check valve 107 therein. Extending into the plug member 101 is a valve assembly 109 having a central stem 110, the stem being provided with upper radial ports 113 and lower radial ports 114 communicating with an axial passage 111. Threaded on the lower end of the stem 110 is a nut 115 which supports a washer 116. Carried by the stem 110 is a lower sleeve 117 which makes a sliding fit in the plug member 101. Also carried on the stem 110 above the sleeve 117 is an upper-sleeve 118 which makes a sliding fit in the tubular neck 102 and is provided at its lower end with a conical seating face 119 which is adapted to seat on the conical valve seat 103 of the plug member 101, the upper-sleeve being provided in its external surface with a helical groove 120 which provides fluid communication between the upper end of the upper-sleeve and the seating face 119 thereof. As will be noted, the sleeves 117 and 118 are of such length that when the valve assembly 109 is in the position shown in Fig. 2 an annular space is provided between the upper-sleeve 118 and the lower-sleeve 117, which communicates with the lower radial ports 114. The valve sleeve 118 engages an enlarged head 112 formed on the upper end of the stem. The sleeve 117 engages the washer 116. The valve sleeve 118 is provided with a conical seating face 119 which is adapted to seat on the valve seat 103. The sleeve 117 is of such length that radial passages 114 formed in the stem 110 and communicating with the axial passage 111 are open when the head 112 is in contact with the valve sleeve 118. Also formed on the exterior

of the valve sleeve 118, above and communicating with the radial ports 104 is a helical groove 120 which also communicates with the interior of the upper end of the tubular neck 102.

During operation, operating fluid, such as, for example, oil, under relatively high pressure is conveyed down through the well from the surface of the ground through a power tubing (not shown) and into the upper end of the upper fitting 11 of the fluid operated pump 10. As will be understood by those skilled in the art, the main valve member 75 intermittently directs the high-pressure operating fluid from the valve tube 16 to the lower end of the tubular motor piston 55 to raise the piston and assembly connected thereto to cause the upstroke of the motor piston and the pump piston member 51, as will be described more in detail hereinafter. On the upstroke of the pump piston member 51 the suction created thereby in the lower end of the pump cylinder liner 48 is communicated through vertical passages 37 to unseat the inlet ball valve element 32 and to draw well fluid from the well through the tubular seating member 24, the inlet chamber 36, the vertical passage 37, and into the lower end of the pump cylinder liner 48. This is the intake, or suction, stroke of the pump piston member 51. When the pump piston member is moved downwardly on its downstroke, as will be described hereinafter, the inlet ball valve element 32 seats on its valve seat 31, to prevent well fluid from passing from the inlet chamber 36 back into the well, and the increased pressure in the lower end of the pump cylinder liner 48 moves the discharge ball valve member 43 downwardly off its seat on the end of the valve seat 44 to permit the well fluid in the lower end of the pump cylinder liner 48 to be discharged through the discharge chamber 46 and the discharge port 27 into the production tubing (not shown) surrounding the fluid operated pump, through which it is conveyed to the surface of the ground. Due to the relatively large cross-sectional area of the ports and passages in the inlet member 23, the fluid operated pump 10 is well adapted to pump extremely heavy or viscous oil and oil containing large quantities of sand or other solid materials. As will be noted, the construction of the inlet member 23 permits the use of an inlet ball valve element 32 of a diameter which is a high percentage of the diameter of the fluid operated pump 10, and the discharge ball valve member 43 is also of relatively great diameter, which feature facilitates the pumping of heavy or viscous oils. As will also be understood, the discharge ball valve member 43 is normally retained closed on the upstroke of the pump piston member 51 by suction in the lower end of the pump cylinder liner 48 and by the action of the compression spring 40. The radial port 41 communicating with the bottom of the valve carrier 39 merely provides a vent for the lower end of the carrier.

In operation, the high pressure operating fluid is conveyed downwardly from the upper fitting 11 through the valve tube 16 and from the open lower end thereof into the interior of the tubular pump piston member 51, consequently exerting a relatively high force downwardly on the pump piston member, tending to move the pump piston member and the connected motor piston 55 downwardly. As will be understood, such high fluid pressure within the pump piston member 51 normally maintains the auxiliary valve means 100 in its closed position as shown in Fig. 2 in which the seating face 119 of the valve sleeve 118 is seated in sealing relation on the conical valve seat 103, and in which the ball check valve 107 is maintained in its closed position on the seat of the valve cage 106. Consequently, the high pressure operating fluid is prevented during a normal downstroke of the pump piston 51 by the closure of the auxiliary valve means 100 from passing out of the lower end of the tubular pump piston.

With the parts in the positions illustrated in Figs. 1, 2, and 3, the fluid-operated pump is ready to commence the downstroke of the pump piston member 51. In this position, the main valve member 75 is in its uppermost position. In this position, the lower end of the motor piston 55 and the space 55*a* therebelow in the motor cylinder 20 is in open communication with the relatively low fluid pressure in the production tubing, through the annular space 96, the longitudinal grooves 95, the vertical passages 85, the annular groove 81, the annular channel 79 on the minor portion 77 of the main valve member 75, the radial ports 82, the annual space 83, and the radial exhaust ports 84. Consequently, fluid in the space 55*a* may readily exhaust therefrom as the motor piston 55 travels downwardly. Downward travel of the motor piston 55 and the pump piston member 51 is caused by the application of force by the high pressure operating fluid exerted on the interior of the lower end of the pump piston member 51, as pointed out hereinabove. The weight of the piston assembly also assists in this downward movement. The downstroke of the pump piston member 51 is at relatively high velocity, due to the direct application of a large volume of operating fluid thereto.

During the downward movement of the motor and pump piston assembly, when the lower annular groove 66 of the valve sleeve 63 registers with the upper end of the lower vertical grooves 71 operating fluid under high pressure is conveyed thereto through the grooves, and passes outwardly through the radial ports 74 and into and upwardly through the annular channel 92 and the vertical passages 93 to the upper end of the main valve member 75.

The main valve member 75 is of the differential area governing type, generally similar in construction and operation to that shown in my Patent No. 2,311,157, to which reference is hereby made for the details thereof. The major difference is that the main valve member of said Patent No. 2,311,157 is a four-way valve adapted to connect the two ends of a motor piston alternatively with high and low pressures, whereas my present pump is preferably of the single acting type in which the only action of the main valve member 75 is to alternatively open the bottom of the motor piston 55 to high and low pressure. In the position shown in Fig. 1, which is its position during the downstroke of the main piston assembly, the upper end of the main valve member is connected to the relatively low discharge pressure in the annular space 83 through the vertical passages 93, the annular channel 92, the upper helical groove 91, the annular channel 89, the radial ports 87, the annular groove 88, and the radial port 94. As the piston assembly approaches the end of its downstroke, the lower annular groove 66 of the valve sleeve 63 registers with the lower vertical grooves 71 of the valve tube 16, which permits high pressure operating fluid to flow to the upper end of the main valve member 75 through the vertical grooves 71, the lower annular channel 66, the radial ports 74, the annular channel 92, and the vertical passages 93, to cause

the main valve member to move downwardly to the position shown in Fig. 4.

When the main valve member 75 is in its lower position illustrated in Fig. 4 high pressure operating fluid is admitted to the lower end of the motor piston 55 to cause its normal upstroke. Such high pressure operating fluid passes from the lower open end of the valve tube 16 through the radial ports 87, the annular groove 88, the annular groove 81, and downwardly through the vertical passages 85, the longitudinal grooves 95, and the annular space 96 to the lower end of the motor piston 55.

During the upstroke of the motor piston 55, as soon as the radial ports 73 and 74 pass out of registry with the lower vertical grooves 71 in the valve tube 16, high-pressure operating fluid can no longer pass directly therethrough into the space above the main valve member 75 to retain it in its lower position illustrated in Fig. 4. However, high-pressure operating fluid can still pass to the upper end of the main valve member 75 through the upper helical groove 91, so as to maintain the main valve member in its lowermost position during the upstroke.

As the motor piston 55 approaches the end of its upstroke, the central annular groove 65 of the valve sleeve 63 registers with the upper vertical grooves 70 to place the space above the main valve member 75 in communication with low fluid pressure in the annular space 83 through the radial ports 73, the upper vertical grooves 70, the upper annular groove 64, the radial ports 68, the annular space 67, and the radial ports 72, permitting the operating fluid bearing on the lower end of the main valve member 75 to move the same upwardly to the position shown in Fig. 1, in which the fluid-operated pump 10 is ready to perform its downstroke. If the motor piston 55 on its upstroke carries upwardly beyond the position shown in Fig. 1 so as to close or partially close the radial exhaust ports 84, fluid above the piston cannot exhaust through the exhaust ports, and this serves as a dash-pot to bring the motor piston to a stop on its upstroke.

The fluid-operated pump 10 is preferably designed so that the valve member assembly 109 connected to the lower end of the pump piston member 51 moves down into the inlet member 23 to a lowermost point adjacent the discharge ball valve element 43 on the downstroke of the pump piston, the lower end of the valve member assembly 109 approaching the dotted line A—A in Fig. 3 in its normal stroke. In the event that sand or other solid matter accumulates in the upper end of the inlet member 23, as indicated by the numeral 121 of Fig. 5, so that the bottom of the valve member assembly 109 strikes this accumulation of solid matter on the downstroke of the pump piston 51, the valve member assembly will stop its downstroke. The pump piston member 51 will continue to move downwardly, and the upper sleeve 118 will move with it, remaining seated on the conical valve seat 103, until the uper sleeve has moved downwardly away from the head 112 sufficiently to open the upper radial ports 113. As soon as the upper radial ports 113 open slightly, the interior of the neck 102 above the sleeve 118 is open to relatively low discharge pressure through the radial parts 113 and the bore 111, and the fluid pressure in the neck drops to such discharge pressure. The upper sleeve 118 continues to move downwardly with the pump piston member 51 until the lower end of the sleeve closes lower radial ports 114 and then strikes the upper end of the lower sleeve 117, stopping further downward movement of the upper sleeve. Continued downward movement of the pump piston member 51 moves the conical valve seat 103 away from the seating face 119 on the lower end of the upper sleeve 118, permitting access of the high pressure operating fluid from the ports 104 to the seating face 119. Since the fluid pressure in the upper end of the neck 102 is relatively low, an upwardly directed pressure differential is thus impressed on the upper sleeve 118, causing it to move upwardly away from the upper end of the lower sleeve 117, thus opening fluid communication between the ports 104 and the axial bore 111 through the lower radial ports 114, which permits operating fluid under high pressure to flow therethrough and downwardly through the axial passage 111 from the lower end of which it is jetted into the accumulated mass of sand or other solid foreign material. The jetting action of such operating fluid discharged from the lower end of the axial passage 111 tends to stir up and loosen the mass of sand therebelow so that it can be conveyed out of the inlet member through the discharge valve means by continued downward movement of the pump piston. The pump piston member 51 will, of course, continue its downward travel, during which time any excess fluid pressure in the upper portion of the neck 102 will lift the ball 107 off its seat to relieve the same, and such travel will continue until the bottom of the plug 101 strikes the washer 116 and is held from further downward travel (as shown in Fig. 5) or until it finishes its normal downstroke or until the permeability of the sand therebelow is so low, or becomes so low, that the fluid pressure below the pump piston member rises substantially. If, of course, the pump piston member 51 is prevented by sand therebelow from finishing its downstroke, continued jetting may in time clear the discharge valve means to permit the pump piston member to complete its downstroke, which is a common condition of operation. The pump piston member 51 will thus hang up until either the discharge valve means is cleared of sand sufficiently to permit the pump piston to complete its normal downstroke or until the fluid pressure on the lower end of the pump piston rises to a value at which it overbalances the downward pressure of the operating fluid exerted on the interior thereof. If the permeability of the sand pack below the pump piston member 51 is sufficiently low, the fluid pressure will rise to such overbalancing value, either before or after the plug 101 strikes the washer 116. As soon as this condition is reached the fluid pressure of the operating fluid will be applied to the entire cross-sectional area of the bottom of the pump piston member 51, and, since this area is substantially greater than the effective area causing its downward movement, the pump piston will reverse its stroke and move upwardly. The valve member assembly 109 will, of course, start to move upwardly with the pump piston member 51, but, due to relatively high fluid pressure in the upper end of the neck 102 which tends to move the valve member assembly downwardly relative to the piston member, the valve member assembly will also start to move downwardly relative to the pump piston member. Such relative movement of the pump piston member 51 and the valve member assembly 109 continues until the upper sleeve 118 again seats on the conical valve seat 103 to close the radial ports 114,

upon which occurrence the flow of high pressure operating fluid through the ports 114 is stopped and jetting action also stops. The head 112 also seats on the upper end of the upper sleeve 118 to close the upper radial ports 113, and the ports are again in the position shown in Fig. 2 in which the auxiliary valve means 100 is fully closed. Due to the relatively small cross-sectional area of the helical groove 120, the rate of downward movement of the valve member assembly 109 relative to the pump piston member 51, from the position shown in Fig. 5 to the position shown in Fig. 2, is relatively slow, and by the time that the valve member assembly has resumed its closed position shown in Fig. 2 its lower end will be a substantial distance above the sand pack therebelow. When, however, the valve member assembly 109 returns to its seated position illustrated in Fig. 2, the flow of operating fluid therethrough to the axial passage 111 is cut off, and the piston member 51 reverses its stroke and moves downwardly again under the pressure exerted by the operating fluid on the interior thereof. Such renewed downward movement of the pump piston member 51 continues until the valve member assembly 109 again strikes the accumulation of solid materials in the inlet member 23 at which time the jetting action of operating fluid from the axial passage 111 is resumed, and, if the inlet member is still plugged, the piston member 51 again reverses its stroke and moves upwardly. Thus, the pump piston member 51, in such case, reciprocates in short strokes, drilling into and out of the accumulation of sand 121 until the sand is loosened and carried from the inlet member by the downward pumping action of the pump piston. Of course, as soon as the valve member assembly 109 can move downwardly to the end of its normal downstroke, indicated by the line A—A of Fig. 3, a normal upstroke of the pump piston member 51 then occurs and normal pumping is resumed. While the pump piston member 51 is reciprocating in short strokes to attempt to remove the accumulation of sand from the inlet member 23, obviously, the volume of oil pumped from the well will drop materially, and the bottom hole condition can and will be apparent to the operator on the surface. As soon as inlet member 23 is free from accumulated sand, the normal pumping stroke of the pump piston member 51 will be resumed to provide normal pumping capacity, indicating to the operator that the temporary plugged condition has been remedied. If, however, the pump production falls below the normal rated capacity of the pump and remains at a reduced figure over an extended period of time it may be necessary to pull the pump to permit cleaning of the inlet member 23. However, under practically all normal operating conditions the pump 10 will clear itself of such accumulation of sand and other solid materials during operation as described. It is also to be noted that due to the fast, high velocity downstroke of the pump piston member 51 considerable turbulence is caused in the pump inlet member, tending to maintain any sand or other solid material therein in suspension in the oil therein, thus additionally helping to prevent the accumulation and packing thereof in the inlet member.

The velocity of the upstroke of the piston assembly is relatively slow, compared to the velocity of the downstroke, due to the fact that the area of the motor piston 55 is large compared with

the area of the interior of the valve tube 16. The relative upward and downward velocities of the piston assembly will be inversely as such areas without considering the compressibility of the operating fluid. Actually, however, in a deep well installation the operating fluid is substantially compressed, and on the downstroke of the piston assembly its velocity may be higher in actual operation than the above relation would indicate, as the only load on the piston assembly during its downstroke is the mechanical and hydraulic friction, and the operating fluid can expand and impart a greater velocity to the piston assembly. I prefer to design the parts of the fluid operated pump 10 so that the upstroke of the piston assembly occupies between 75% and 90% of the total cycle time, the balance being occupied by the downstroke of the pump piston member. As pointed out above, this has the added advantage of preventing the gas from flashing out of the oil being pumped.

Although I have illustrated and described a preferred embodiment of the invention, it is to be understood that various changes may be incorporated therein without departing from the spirit of the invention, and, consequently, I do not desire to be limited to the specific form shown, but desire to be afforded the full scope of the following claims.

I claim as my invention:

1. In a fluid-operated deep well pump, the combination of: a pump cylinder; a pump piston in said cylinder; inlet and discharge valve means connected to one end of said cylinder; a source of high-pressure operating fluid; means for utilizing said operating fluid to move said piston axially in said cylinder so as to pump well fluid from said one end of said cylinder through said valve means; auxiliary valve means carried by said piston; and passage means communicating between said pressure source and said auxiliary valve means, said auxiliary valve means being adapted to provide fluid communication between said passage means and said one end of said cylinder, said auxiliary valve means being normally maintained in closed position but adapted to be opened in response to said piston striking solid foreign matter in said end of said cylinder to admit operating fluid thereto from said passage means.

2. In a fluid-operated deep well pump, the combination of: cylinder means; a motor piston in said cylinder means; a pump piston in said cylinder means; means connecting said pistons together for unitary movement; a source of high-pressure operating fluid; means for supplying said operating fluid to said pistons so as to reciprocate the same in said cylinder means; valve means carried by said pump piston; and passage means communicating between said source and said valve means, said valve means being operable in response to striking solid foreign material in one end of said cylinder means to admit operating fluid from said pasage means to said end of said cylinder means.

3. In a fluid-operated deep well pump, the combination of: a pump cylinder having a pump piston therein; fluid pressure means for reciprocating said pump piston in said cylinder to pump well fluid from a well, said means being adapted to be actuated by the supply of an operating fluid thereto under relatively high pressure; jetting means carried by said piston; and means for admitting said operating fluid to said jetting means in response to said piston striking solid foreign

material in said cylinder, so as to direct a jet of said operating fluid against said foreign material.

4. In a well pump, the combination of: a pump cylinder; a pump piston in said cylinder; inlet and discharge valves for one end of said cylinder; fluid pressure means for reciprocating said piston in said cylinder so as to pump well fluid from said one end thereof; and valve means carried by said piston and operable to open in response to striking solid foreign material in said one end of said cylinder to convey fluid under pressure into said one end of said cylinder said valve means communicating with said fluid pressure means through passage means

5. In a fluid-operated pump, the combination of: cylinder means; a stationary tubular member extending into said cylinder means, one end of said tubular member being adapted to communicate with a source of high-pressure operating fluid; and a piston assembly reciprocable in said cylinder means on said tubular member, said piston assembly including a tubular motor piston, a tubular pump piston the interior of which is of smaller effective area than the effective area of said motor piston and at all times in open communication with the interior of said tubular member, and tubular valve means adapted to cooperate with said tubular member to intermittently convey operating fluid from said tubular member to one end of said motor piston to move said piston assembly axially in said cylinder means in one direction, the action of said operating fluid on said interior of said pump piston alternately moving said piston assembly in the opposite direction.

6. In a fluid-operated pump, the combination of: a source of operating fluid under relatively high pressure; a motor cylinder having a motor piston therein; a pump cylinder having a pump piston therein, the interior of said pump piston having an effective area substantially less than the effective area of one end of said motor piston and in fluid communication with said source so that said operating fluid tends to move said pump piston axially in one direction; means for operatively connecting said pistons together; and means for intermittently admitting said operating fluid to said end of said motor piston so as to move said motor piston axially in the opposite direction.

7. In a fluid-operated pump, the combination of: a source of operating fluid under relatively high pressure; a motor cylinder having a motor piston therein; a pump cylinder having a pump piston therein, the interior of said pump piston having an effective area substantially less than the effective area of one end of said motor piston and in fluid communication with said source so that said operating fluid tends to move said pump piston axially in one direction at a relatively high velocity; means for operatively connecting said pistons together; and means for intermittently admitting said operating fluid to said end of said motor piston so as to move said motor piston axially in the opposite direction at a relatively low velocity.

8. In a fluid-operated pump, the combination of: cylinder means; a motor piston in said cylinder means; a pump piston in said cylinder means; means operatively connecting said pistons together into a unitary piston assembly; and means for supplying high pressure operating fluid to said piston assembly so as to move it at relatively high velocity in one direction and at relatively low velocity in the opposite direction, both directions of movement of said piston assembly being positively impelled by said operating fluid.

9. In a fluid-operated pump, the combination of: cylinder means; a piston assembly in said cylinder means, including a motor piston and a pump piston operatively connected together; inlet valve means and discharge valve means connected to one end of said cylinder means so that when said piston assembly moves axially in one direction well fluid will be drawn by suction into said cylinder means through said inlet valve means, and so that when said piston assembly moves axially in the other direction such well fluid will be discharged from said cylinder means through said discharge valve means; and means for supplying high-pressure operating fluid to said piston assembly so that it moves axially in said one direction at relatively low velocity and so that it moves axially in said other direction at relatively high velocity, both directions of movement of said piston assembly being positively impelled by said operating fluid.

10. In a fluid-operated pump, the combination of: cylinder means; a reciprocable piston assembly in said cylinder means, including a motor piston and a pump piston; inlet and discharge valve means connected to said cylinder means; a tubular member extending into said cylinder means and into said piston assembly and adapted to convey a high pressure operating fluid to said piston assembly so as to reciprocate the same relative to said tubular member; supporting means for supporting said tubular member relative to said cylinder means so that said tubular member may be initially moved laterally to an adjusted position relative to said cylinder means so as to axially align said tubular member with said piston assembly; and means for securing said tubular member in fluid-tight engagement with said supporting means in said adjusted position.

11. In a fluid operated deep well pump, the combination of: a pump cylinder having a pump piston therein; valve means communicating between a source of fluid under high pressure and one end of said pump cylinder; a pump inlet and a pump discharge communicating with said end of said cylinder; and means for opening said valve means in response to at least a predetermined accumulation of solid foreign material in said end of said pump cylinder, so as to admit a jet of said fluid into said end of said cylinder and directed towards said pump discharge.

12. In a fluid operated deep well pump, the combination of: a pump cylinder having a pump piston therein; valve means communicating between a source of fluid under high pressure and one end of said pump cylinder; and means for opening said valve means in response to at least a predetermined accumulation of solid foreign material in said end of said pump cylinder, said valve means including a nozzle adapted to direct a jet of said fluid towards said accumulation of foreign material when said valve means is so opened.

13. In a fluid operated deep well pump, the combination of: cylinder means; inlet and discharge valve means communicating with one end of said cylinder means; piston means in said cylinder means, said piston means having a first effective force area and a second effective force area, said second area being greater than said first area and in communication with said end

of said cylinder means; means for admitting high pressure operating fluid to said first area so as to exert a force against said first area tending to move said piston means axially in one direction in said cylinder; and auxiliary valve means for admitting high pressure operating fluid to said end of said cylinder means so as to exert a force against said second force area tending to move said piston means axially in the opposite direction.

14. In a fluid operated deep well pump, the combination of: cylinder means; inlet and discharge valve means communicating with one end of said cylinder means; piston means in said cylinder means, said piston means having a first effective force area and a second effective force area, said second area being greater than said first area and in communication with said end of said cylinder means; means for admitting high pressure operating fluid to said first area so as to exert a force against said first area tending to move said piston means axially in one direction in said cylinder; auxiliary valve means for admitting high pressure operating fluid to said end of said cylinder means so as to exert a force against said second force area tending to move said piston means axially in the opposite direction; and means for opening said auxiliary valve means in response to a predetermined accumulation of solid foreign material in said end of said pump cylinder.

15. In a fluid operated deep well pump, the combination of: cylinder means; inlet and discharge valve means communicating with one end of said cylinder means; piston means in said cylinder means, said piston means having a first effective force area and a second effective force area, said second area being greater than said first area and in communication with said end of said cylinder means; means for admitting high pressure operating fluid to said first area so as to exert a force against said first area tending to move said piston means axially in one direction in said cylinder; auxiliary valve means for admitting high pressure operating fluid to said end of said cylinder means so as to exert a force against said second force area tending to move said piston means axially in the opposite direction; means for opening said auxiliary valve means in response to a predetermined accumulation of solid foreign material in said end of said pump cylinder; and means for closing said auxiliary valve means after said piston means has moved in said opposite direction a distance less than the normal stroke of said piston in said opposite direction.

16. In a fluid operated deep well pump, the combination of: cylinder means; piston means in said cylinder means, said piston means including a motor piston having a first effective force area, and a pump piston member having a second effective force area, said first force area being greater than said second force area, said second force area being adapted to be in open communication with a source of high pressure operating fluid capable of exerting a force thereon to move said piston means axially in one direction; and valve means adapted to provide intermittent communication between said source and said first force area so as to move said piston means axially in the opposite direction.

17. In a fluid operated deep well pump, the combination of: cylinder means; piston means in said cylinder means, said piston means including a motor piston having a first effective force area, and a pump piston member having a second effective force area, said first force area being greater than said second force area, said second force area being adapted to be in open communication with a source of high pressure operating fluid capable of exerting a force thereon to move said piston means axially in one direction; and valve means adapted to provide intermittent communication between said source and said first force area so as to move said piston means axially in the opposite direction, said force areas being so related that said piston means moves in said one direction at a relatively high speed and moves in said opposite direction at a relatively low speed.

18. In a fluid operating deep well pump, the combination of: cylinder means; inlet and discharge valve means connected to one end of said cylinder means; piston means in said cylinder means, said piston means including a motor piston having a first effective force area, and a pump piston in said one end of said cylinder means and having a second effective force area, said first force area being greater than said second force area, said second force area being adapted to be in open communication with a source of high pressure operating fluid capable of exerting a force thereon to move said piston means axially toward said one end of said cylinder means to perform the return stroke thereof; and valve means adapted to provide intermittent communication between said source and said first force area so as to move said piston axially in the opposite direction to perform the working stroke thereof, said areas being so related that said piston means moves on said return stroke at relatively high velocity and moves on said working stroke at relatively low velocity.

19. In a fluid operated deep well pump, the combination of: cylinder means; inlet and discharge valve means connected to one end of said cylinder means; piston means in said cylinder means, said piston means including a motor piston having a first effective force area, and a pump piston in said one end of said cylinder means and having a second effective force area, said first force area being greater than said second force area, said second force area being adapted to be in open communication with a source of high pressure operating fluid capable of exerting a force thereon to move said piston means axially toward said one end of said cylinder means to perform the return stroke thereof; and valve means adapted to provide intermittent communication between said source and said first force area so as to move said piston axially in the opposite direction to perform the working stroke thereof, said areas being so related that said working stroke utilizes over 75% of the total time of the pumping cycle.

20. In a fluid-operated deep well pump, the combination of: cylinder means; piston means extending into said cylinder means and reciprocable relative thereto, said piston means having a first relatively large effective force area and a second relatively smaller effective force area, said force areas facing oppositely, said smaller force area being in continuous open communication with a source of high-pressure operating fluid during operation of the pump, said piston means being provided with a valve cylinder; and valve means in said valve cylinder adapted in operation of the pump to provide communication between said larger force area and said source and alternately between said larger force area and a lower-pressure fluid body, the force

exerted by said high-pressure fluid on said smaller force area moving said piston means in one direction when said larger force area is in communication with said body, and the force exerted by said high-pressure fluid on said larger force area moving said piston means in the opposite direction when said larger force area is in communication with said source.

21. In a fluid-operated deep well pump, the combination of: cylinder means; piston means extending into said cylinder means and reciprocable relative thereto, said piston means having a first relatively large effective force area and a second relatively smaller effective force area, said force areas facing oppositely, said smaller force area being in continuous open communication with a source of high-pressure operating fluid during operation of the pump, said piston means being provided with a valve cylinder; differential area main tubular valve means in said valve cylinder adapted in operation of the pump to provide communication between said larger force area and said source and alternately between said larger force area and a lower pressure fluid body, the force exerted by said high-pressure fluid on said smaller force area moving said piston means in one direction when said larger force area is in communication with said body, and the force exerted by said high-pressure fluid on said larger force area moving said piston means in the opposite direction when said larger force area is in communication with said source, said main valve means having a relatively small valve area continuously in communication with said source and having a relatively large valve area adapted to be alternately placed in communication with said source and said body; and pilot valve means extending into said valve means and controlling the operation of said main valve means, said pilot valve means being adapted to open communication between said large valve area and, alternately, said source and said body.

22. In a fluid-operated deep well pump, the combination of: cylinder means providing an engine cylinder and a pump cylinder in axial alignment; piston means in said cylinder means providing an engine piston extending into said engine cylinder and a pump piston extending into said pump cylinder, said engine and pump pistons being connected together, said piston means having a large effective force area and a smaller effective force area, said large force area being greater than said small force area, said small force area being adapted to be in continuous open communication with a source of high-pressure operating fluid, the effect of which on said small force area continuously tends to move said piston means axially in one direction during operation of the pump; means for admitting a fluid to be pumped to said pump cylinder means; main valve means carried by said piston means and adapted to provide communication between said larger force area and, alternately, said source of high-pressure operating fluid and a source of lower-pressure fluid, said main valve means being tubular in form and movable relative to said piston means to provide such communication; and pilot valve means extending into said main valve means and operable in response to movement of said piston means to control the operation of said main valve means.

23. In a fluid-operated deep well pump, the combination of: cylinder means providing an engine cylinder and a pump cylinder in axial alignment; piston means in said cylinder means providing an engine piston extending into said engine cylinder and a pump piston extending into said pump cylinder, said pistons being connected together, said piston means having a relatively small unbalanced area and a relatively large balanced area; means for constantly applying a fluid pressure differential to said small unbalanced area tending to move said piston means in one direction; master valve means carried by said piston means and adapted to be moved to apply a fluid pressure differential to said large balanced area tending to cause said piston means to move in the opposite direction; and pilot valve means extending into said piston means and operable in response to movement of said piston means to control the operation of said master valve means.

24. In a fluid-operated deep well pump, the combination of: cylinder means providing an engine cylinder and a pump cylinder in axial alignment; piston means in said cylinder means providing an engine piston extending into said engine cylinder and a pump piston extending into said pump cylinder, said pistons being connected together, said piston means having a relatively small unbalanced area and a relatively large balanced area, said piston means having a valve chamber therein; means for constantly applying a fluid pressure differential to said small unbalanced area tending to move said piston means in one direction; master valve means carried by said piston means in said valve chamber and slidable in substantially fluid-tight relationship therein and adapted to be moved to apply a fluid pressure differential to said large balanced area tending to cause said piston means to move in the opposite direction, said master valve means having a major diameter on one end thereof and a smaller minor diameter on the other end thereof, said minor diameter being constantly exposed to high-pressure fluid during operation of the pump tending to move said master valve means in one direction; and pilot valve means extending into said piston means and operable in response to movement of said piston means to alternately expose said major diameter to high pressure and relatively low pressure to cause reciprocation of said master valve means.

25. In a fluid-operated deep well pump, the combination of: a double-acting engine including engine piston means having a large area and a relatively small area, said areas being faced in opposite directions, said large area being adapted to have applied thereto pressure differential to move said engine piston means on its power stroke, said small area being adapted to have applied thereto a pressure differential to move said engine piston means on its return stroke; master valve means carried by said engine piston means for controlling the application of pressure differentials to said engine piston means; pilot valve means in said engine piston means and operable when said engine piston means approaches the respective ends of its strokes to control the movement of said master valve means; and a single-acting pump connected to said engine piston means and operable in response to reciprocation of said engine piston means to pump fluid from a well.

26. In a fluid-operated well pump adapted to connected to a column of high-pressure fluid and a column of discharge fluid at lower pressure, the combination of: cylinder means; piston means extending into said cylinder means and reciprocable relative thereto, said piston means having

opposed areas, one of said areas being in open communication with one of said columns at all times during operation of the pump; valve means carried by said piston means and movable to open fluid communication between the other said area of said piston means and said columns alternately during operation of the pump, the fluid pressures on said areas being balanced in one position of said valve means; and piston extension means having a pressure differential applied thereto when said valve means is in said one position.

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