United States Patent

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[73] Assignee Borg-Warner Corporation
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[54] **SUBMERSIBLE MULTIPLE-ACTING FLOATING PISTON DEEP WELL PUMP**
10 Claims, 16 Drawing Figs.

[52] U.S. Cl. 417/339, 417/390, 417/393
[51] Int. Cl. F04b 17/00
[50] Field of Search 417/339, 390, 392, 393

[56] **References Cited**
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2,220,334 11/1940 Holmberg 417/390
2,489,505 11/1949 Schmidt 417/339

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Attorneys—Donald W. Banner, William S. McCurry and John W. Butcher

ABSTRACT: A deep well piston pump system in which pistons, in two or more cylinders, are reciprocated by high-pressure hydraulic oil from a hydraulic pump which is driven by an electric motor. Reversal of flow to any one of the cylinders is achieved by a rotating valve driven from the motor shaft through a gear reduction.

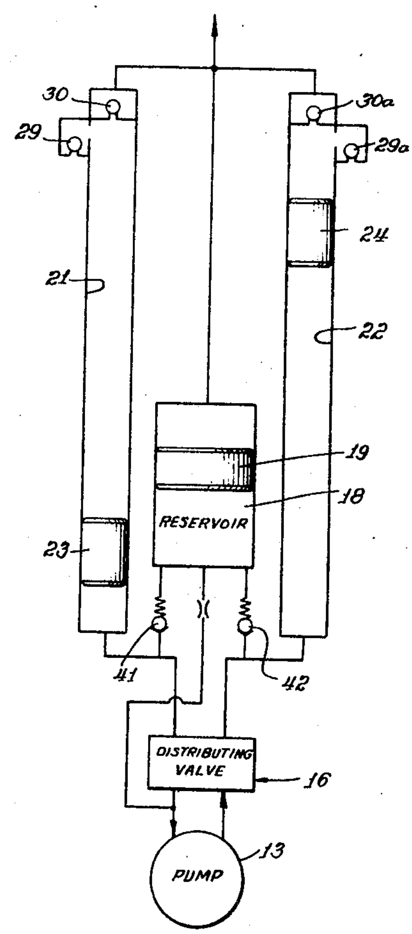

Fig. 1

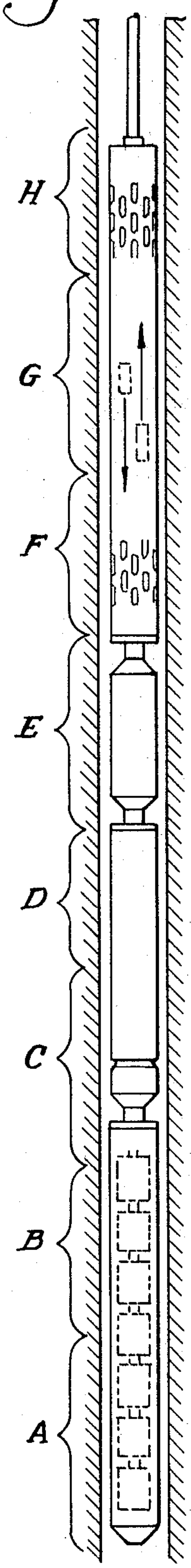

Fig. 2

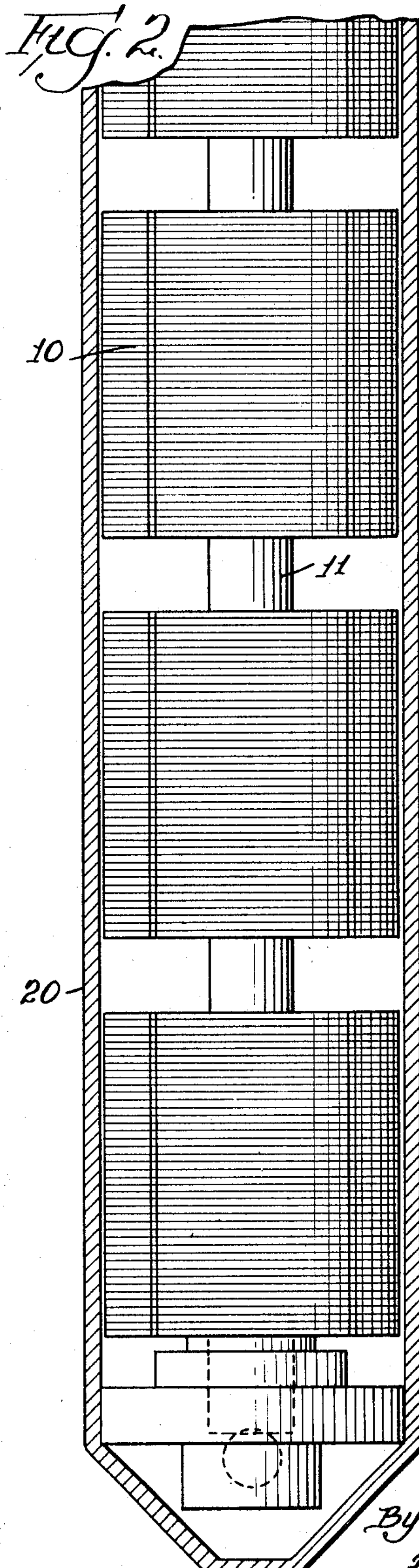

Fig. 3

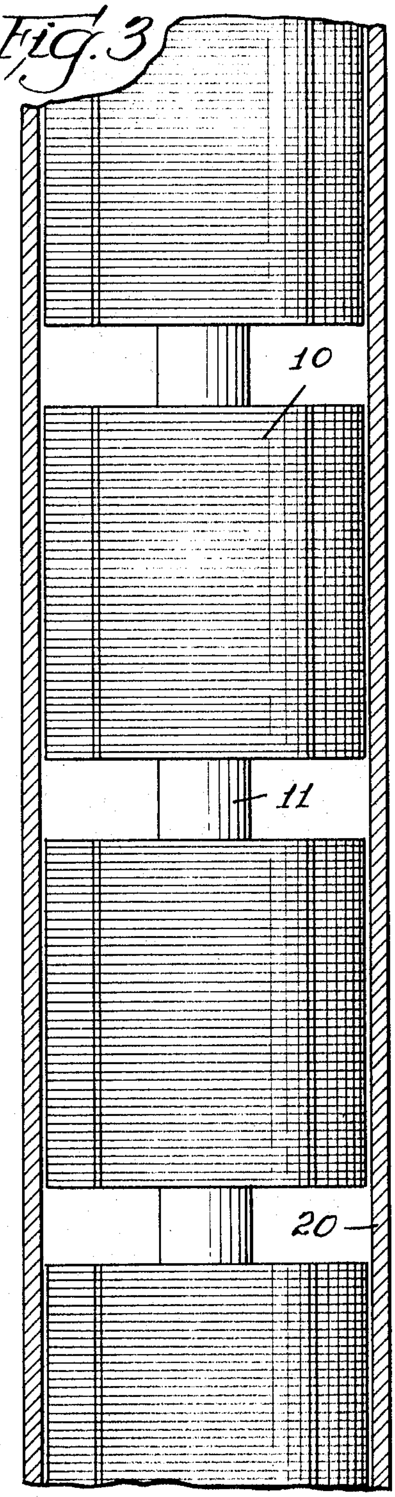

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Fig. 4

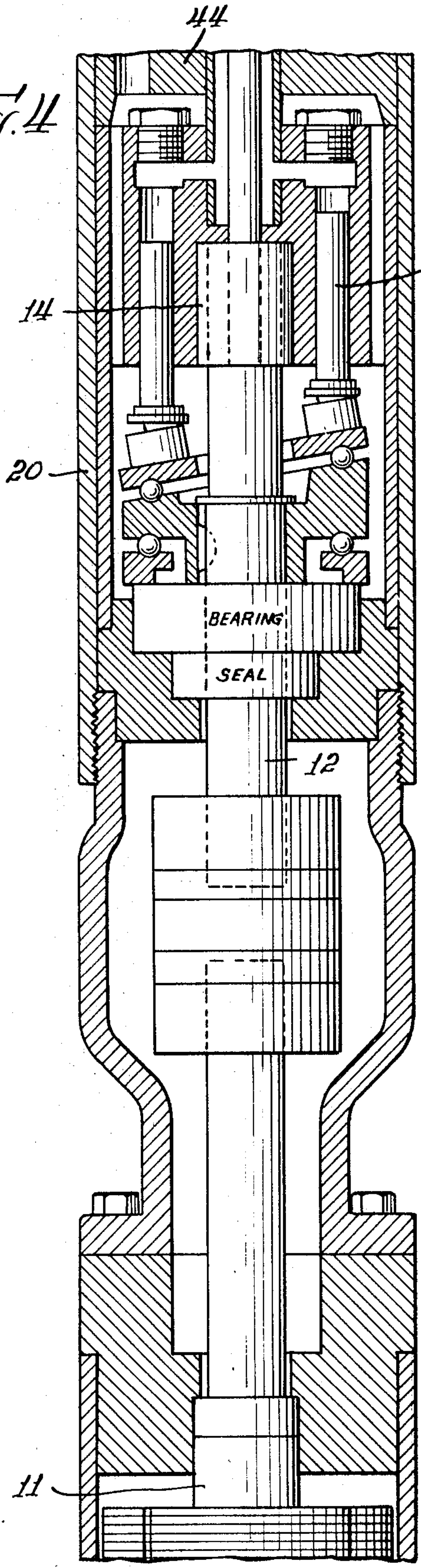


Fig. 5

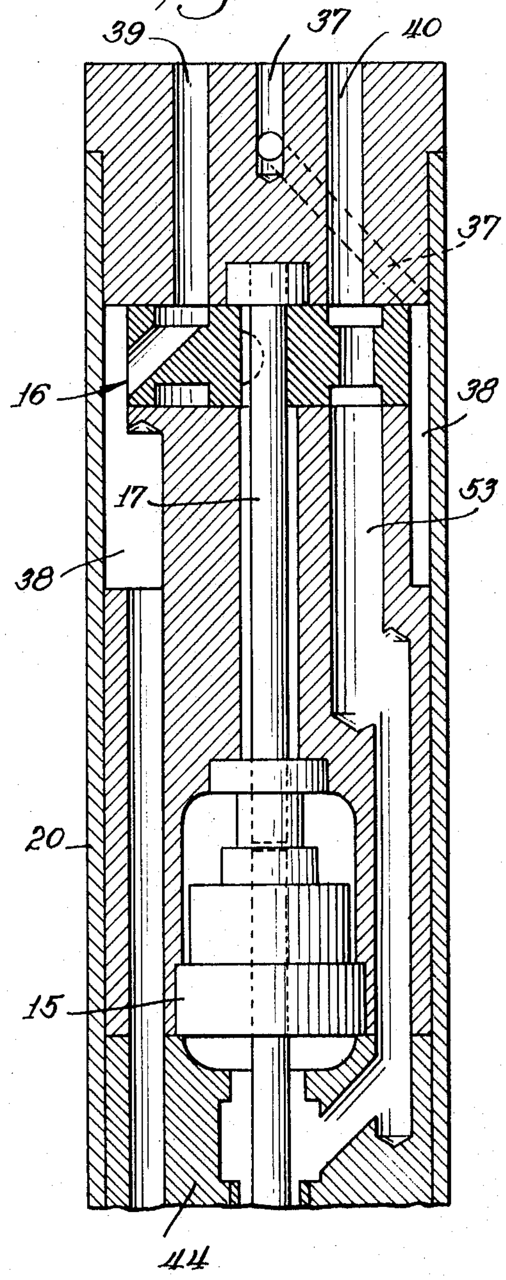


Fig. 6.

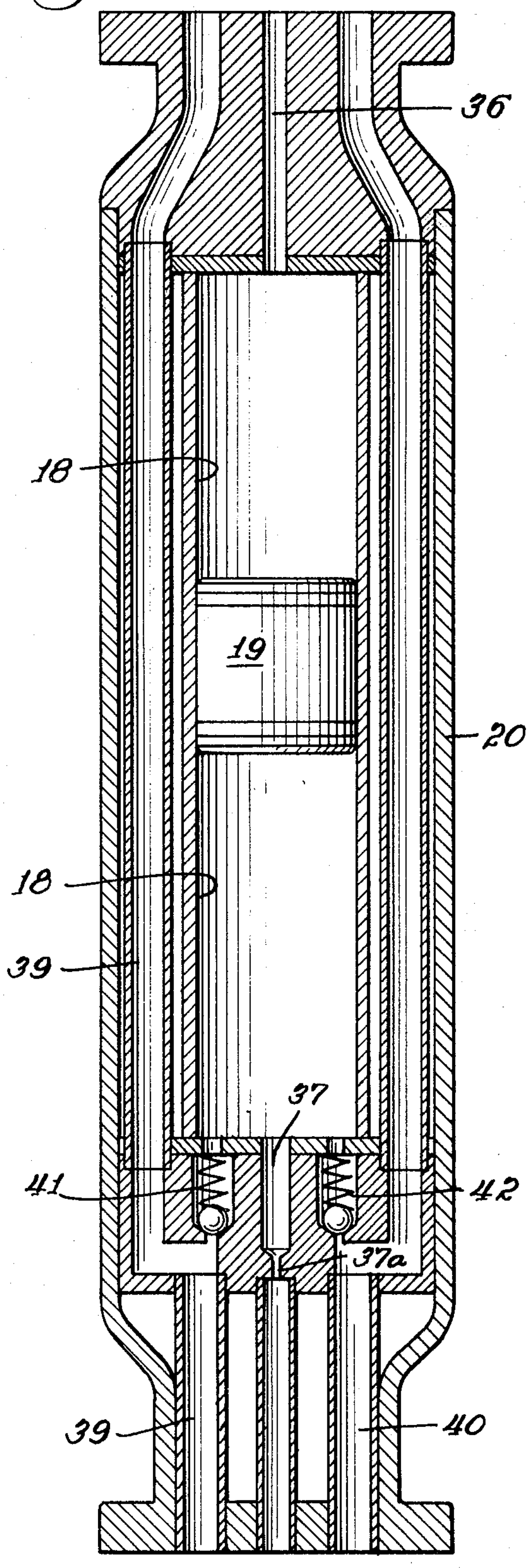


Fig. 7

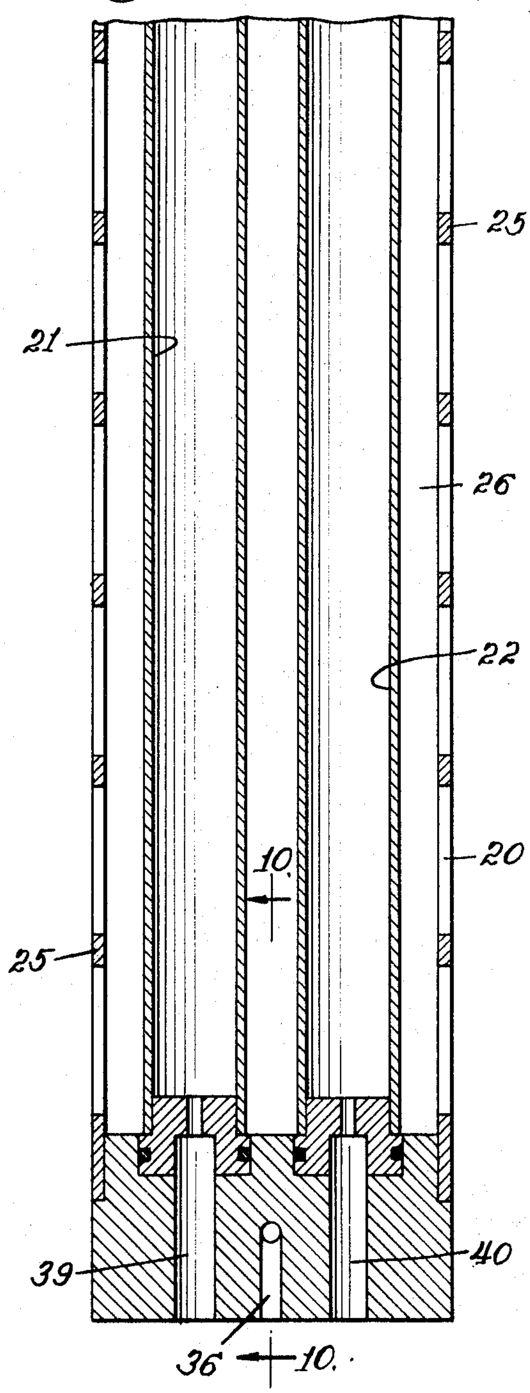


Fig. 8.

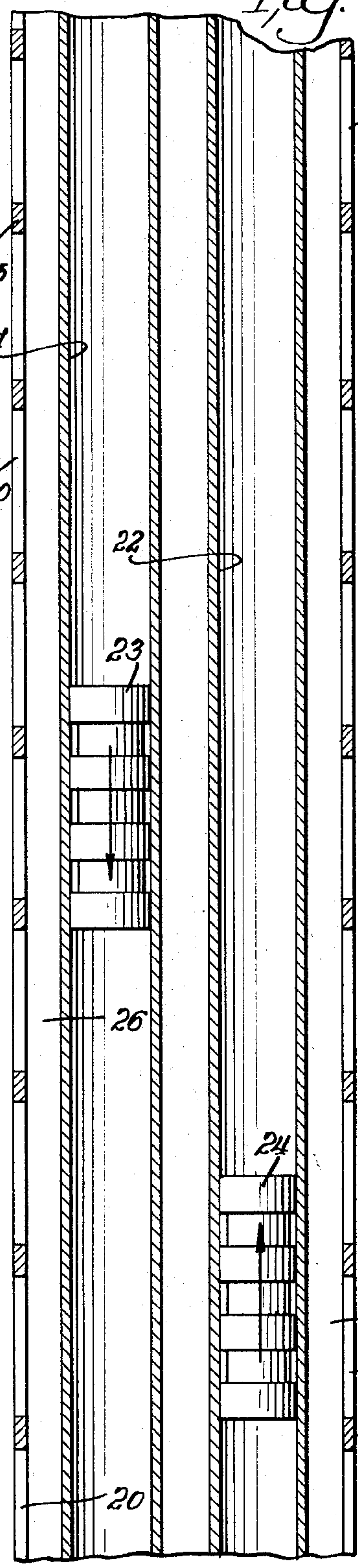


Fig. 9.

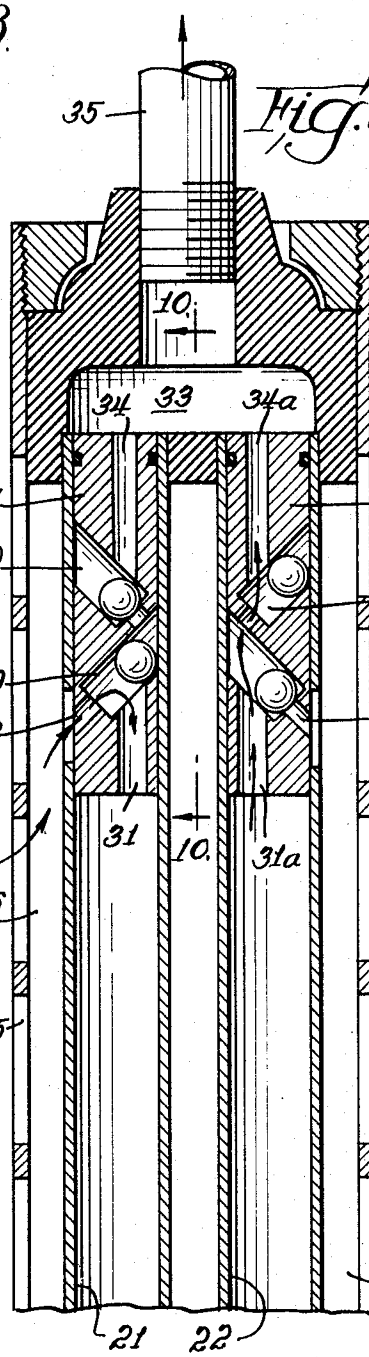


Fig. 10.

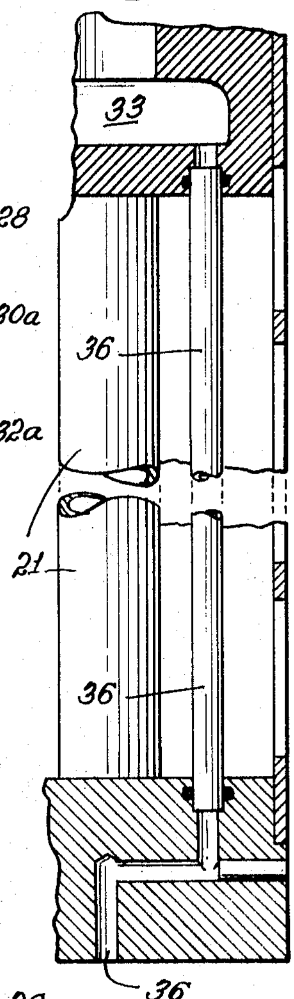


Fig. 11.

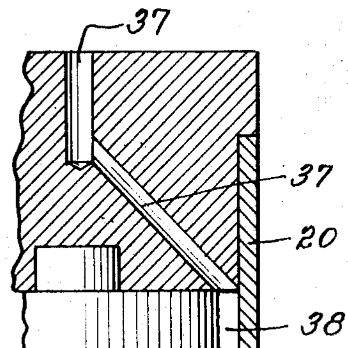


Fig. 12.

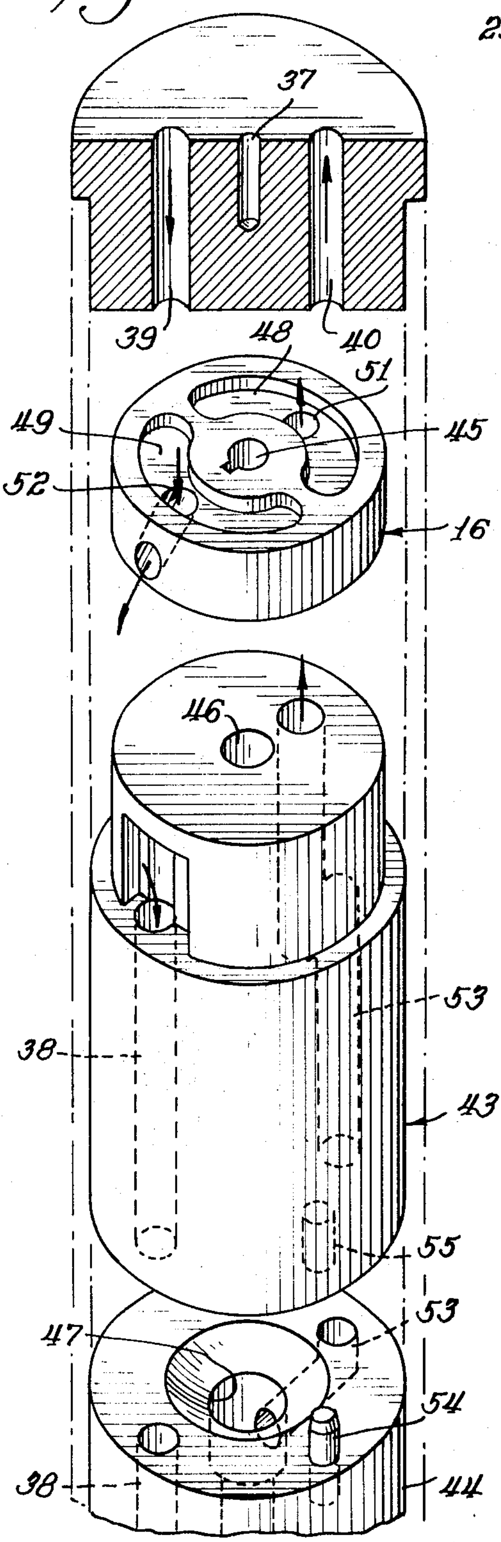
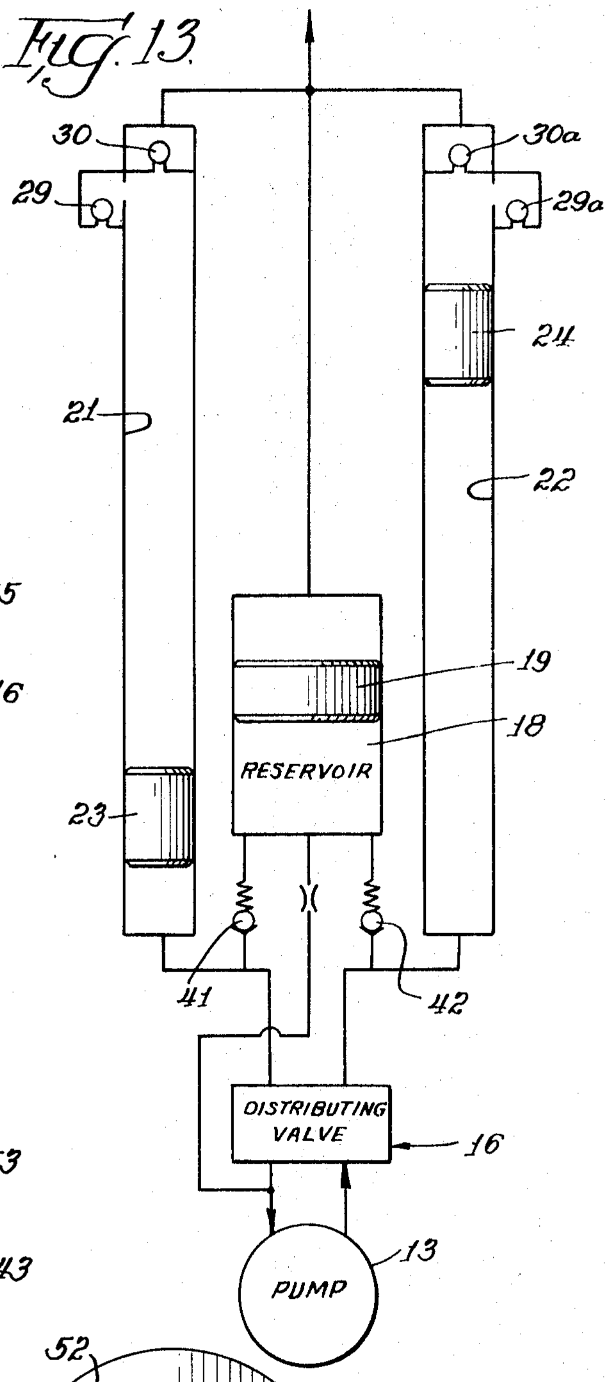


Fig. 13.



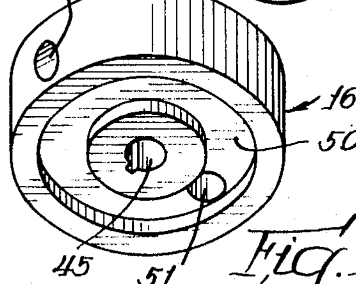


Fig. 14.

Fig. 15

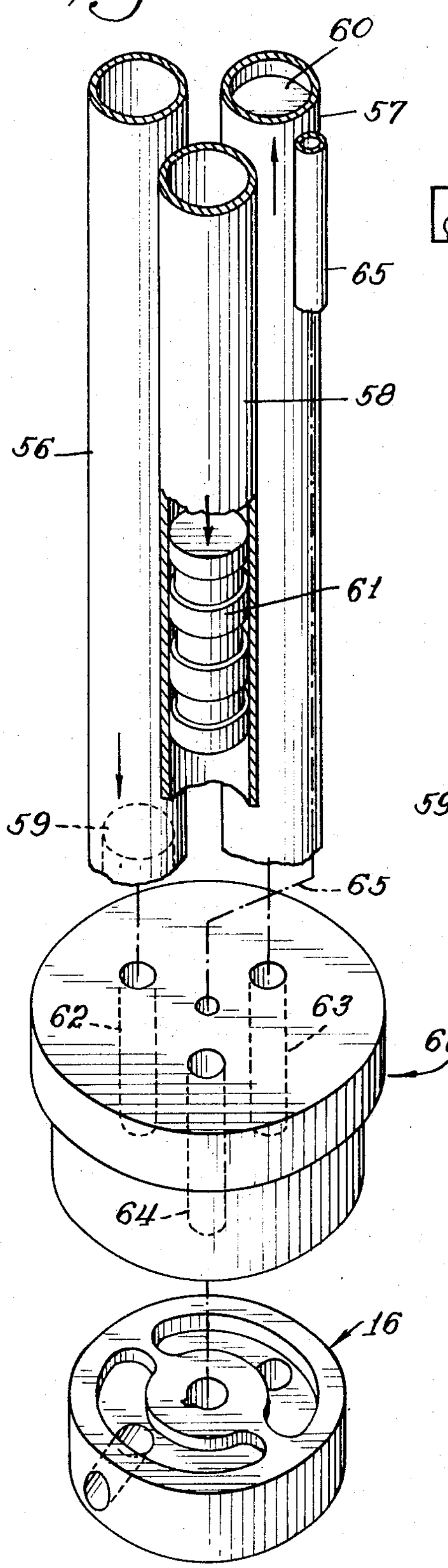

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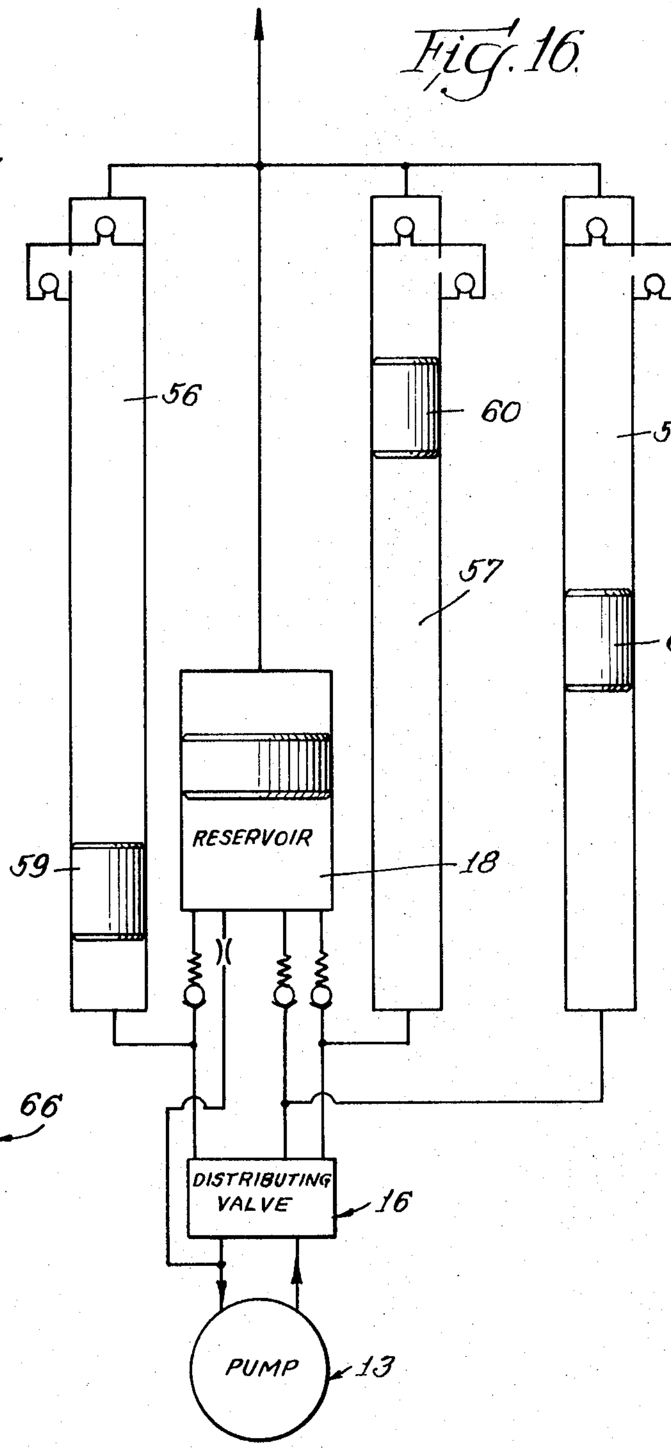
Fig. 16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RESERVOIR
18
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DISTRIBUTING VALVE
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PUMP
13

SUBMERSIBLE MULTIPLE-ACTING FLOATING PISTON DEEP WELL PUMP

BACKGROUND OF THE INVENTION

The present invention relates to a well pump and particularly with respect to oil well pumps. The majority of piston pumps presently in this field are the rod type and the master drive mechanism is above ground.

U.S. Pat. No. 2,630,071 is of the free piston type which, generally speaking, is the approach used in the present invention, however, it distinguishes patentably therefrom in many respects, for example, the tubing is provided with two cylinders in which free pistons are operable as compared with the patent referred to above which has but one cylinder within which floating pistons operate on a shaft. The term floating pistons is synonymous with free pistons, either of which may be used in the specifications.

BRIEF DESCRIPTION OF THE INVENTION

The present invention comprises a submersible electric motor which drives a hydraulic power unit comprising a hydraulic pump and a speed reducer which drives a reversing valve. Free pistons operating in pumping cylinders separate hydraulic oil from the crude oil. At the ends of the stroke the reversing valve causes reverse action of one or more free pistons thereby pumping crude oil from the well. The crude oil is admitted to and exhausted from the pumping cylinders through ball check valves.

A deep well piston pump according to the present invention, being self-contained, will permit operation at great depth. Application of sucker rod type pumps is limited by depth.

The present invention will be further described and illustrated by reference to the drawings in which:

FIG. 1 is a schematic view of the central portions of the Floating Piston Pump divided into bracketed portions A, B, C, D, E, F, G, and H.

FIGS. 2 and 3 are enlarged block forms of the electric motor and components of the present invention located in bracketed portions A and B respectively.

FIG. 4 is an enlarged side elevational view in section showing a pump of the present invention located in bracketed portion C, FIG. 1.

FIG. 5 is an enlarged side elevational view in section showing a pump speed reducer and distributing valve of the present invention located in bracketed portion E, FIG. 1.

FIG. 6 is an enlarged side elevational view in section showing an oil reservoir and pressure equalizer piston of the present invention located in bracketed portion E, FIG. 1

FIG. 7 is an enlarged side elevational view in section showing portions of pumping cylinders of the present invention located in bracketed portion F, FIG. 1.

FIG. 8 is an enlarged side elevational view in section showing additional portions of pumping cylinders shown in FIG. 7, including free pistons, of the present invention located in bracketed portion H, FIG. 1.

FIG. 9 is an enlarged side elevational view in section showing additional portions of pumping cylinders shown in FIGS. 7 and 8 including the check valves of the present invention located in bracketed portion H, FIG. 1.

FIG. 10 is a fragmentary sectional view of the upper portion and lower portion of FIGS. 9 and 7 respectively in a direction shown by arrows 10–10.

FIG. 11 is a fragmentary sectional view of FIG. 5 in the direction shown by arrow 11.

FIG. 12 is a perspective view of the distributing valve as shown in block form in FIG. 13, and other components.

FIG. 13 is a schematic view of the pump, distributing valve, reservoir and cylinders having free pistons operable therein in the present invention.

FIG. 14 is a bottom view of the upper portion of the distributing valve shown in FIG. 12 of the present invention.

FIG. 15 is a perspective view of modified components pertaining to those components shown in previous Figures, comprising three cylinders having floating pistons operable therein including as additional pump passage to those shown in lower portion, FIG. 7.

FIG. 16 is a schematic view of a modified form of the present invention incorporating the components shown in FIG. 15 including a reservoir and pump.

Referring in greater detail to the drawings in which FIGS. 2 and 3 show a view of an electric 18, 10, in block form, and other components including a drive shaft 11 which is connected to a pump shaft 12 that drives a hydraulic pump 12 shown in FIG. 4.

The electric motor 10 is positioned at the lower end of the free piston pumping system of the present invention which is lowered in the well casing, not shown, and submerged in the oil to a desired depth position.

An output shaft 14 of the hydraulic pump 13 drives a speed reducer 15 shown, in block form, in FIG. 5, which drives a distributing valve shaft 17.

In FIG. 6 hydraulic oil reservoir 18 is shown which carries a pressure equalizer piston 19.

FIGS. 7, 8 and 9 are sections which, as a unit, comprise a pump casing 20 having pump cylinders 21 and 22 provided with floating pump pistons 23 and 24 respectively. The pump casing 20 has vents 20 therein which admit fluid into an area 26 between the pump casing 20 and the cylinders 21 and 22. It should be noted that the vents 25 are confined to the above sections as a unit. The pump cylinders 21 and 22 are fitted with closures 27 and 28 respectively. The closure 27 is equipped with a pair of ball check valves 29 and 30. The ball check valve 29 is communicable with the cylinder 21 and the area 26 by fluid passages 31 and 32 respectively, and the ball check valve 30 is communicable with the pump cylinder 21 by means of the fluid passage 31 and is also communicable with a chamber 33 by a fluid passage 34. The closure 28 is equipped with ball check valves 29*a* and 30*a* which are identical to the ball check valves 29 and 30 in the closure 27 but are operable with respect to the cylinder 22 and the chamber 33. Fluid passages 31*a*, 32*a* and 34*a* are counterparts of the fluid passages 31, 32 and 34 and serve the same purpose. A discharge pipe 35 connected to the chamber 33 serves to deliver well fluid to the surface.

A well fluid passage 36, FIG. 10, the extension of which is shown in FIGS. 7 and 6, provides communication with the hydraulic oil reservoir 18 which serves to supply well fluid pressure against the pressure equalizer piston 19.

A hydraulic fluid passage 37, provides with a hydraulic fluid passage constriction 37*a*, interconnects hydraulic oil reservoir 18 FIG. 6, with a hydraulic pump return passage 38 and the pump casing 20, FIG. 11. The hydraulic pump 13 delivers hydraulic fluid to the pump cylinders 21 and 22 by way of hydraulic pump passages 39 and 40, respectively, FIGS. 4, 5, 6 and 7.

Reservoir relief valves 41 and 42 are operably interconnected between the hydraulic pump passages 39 and 40 and the hydraulic oil reservoir 18.

Referring now to FIG. 12; a perspective view of the distributing valve 16, including a pair of casings 43 and 44 affixed within the pump casing 20, is shown.

The distributing valve 16 and the casings 43 and 44 have bores 45, 46 and 47 passing therethrough, respectively, for receiving the distributing valve shaft 17 which is anchored to the distributing valve 16.

The distributing valve 16 is equipped with a high-pressure kidney-shaped cavity 48 and a low-pressure kidney-shaped cavity 49 in its upper face and an annular cavity 50 in the bottom face. The kidney-shaped cavities 48 and 49 are provided with ports 51 and 52, respectively, one each of which terminates in the annular cavity 50 and the outer periphery of the distributing valve 16, respectively.

The distributing valve 16 rotates on the upper face of casing 43 and serves to alternately connect passages 39 and 40 to the hydraulic pump output passage 53 and hydraulic pump return passage 38.

The casing 44 is provided with an aligning pin 54 that is anchored in a bore 55 in the bottom face of the casing 43.

OPERATION

The electric motor 10 drives the hydraulic pump 13, which aspirates clean transmission oil from the hydraulic pump return passage 38 and delivers high-pressure transmission oil through the hydraulic pump output passage 53 to the distributing valve 16 which in turn alternatively delivers the high-pressure transmission oil to one of the pump cylinders while the oil from the other returns to the pump and this causes reciprocation of the floating pump piston 23, thereby separating the transmission oil from the well fluid. On the down stroke of the floating pump piston 23, well fluid is admitted into the top part of the pump cylinder 21 through the ball check valve 29. On the up stroke of the floating pump piston 23, the well fluid is delivered to the surface by way of the chamber 33 and the discharge pipe 35.

More specifically, the pressure of the hydraulic fluid closes the check valve *29a* and opens the check valve *30a* thereby opening the passages *31a* and *34a* and closing the fluid passages *32a* thereby sealing off communication between the cylinder 22 and the well. While this operation is completed, the pickup of well fluid by one of the floating pump pistons and delivery of the well fluid to the surface is reversed as is apparent from the drawings.

Reversal of transmission oil flow in the hydraulic pump passages 39 and 40 leading to the lower part of cylinders 21 and 22 is accomplished by the distributing valve 16 by connecting the hydraulic pump output passage 53 and the hydraulic pump return passage 38 alternatively to one or the other of the hydraulic pump passages 39 and 40.

More specifically, the hydraulic pump output passage 53, the annular cavity 50, port 51 and the kidney-shaped cavity 48 remain in communication regardless of the rotational position of the distributing valve 16 thereby establishing, at all times, high transmission oil pressure in the kidney-shaped cavity 48. The hydraulic pump return passage 38, port 52 and the kidney-shaped cavity 49 also remain in communication regardless of the rotational portion of valve 16 to thereby establishing at all times low transmission oil pressure in the kidney-shaped cavity 49. Because of the relative motion of the distributing valve 16 and the fixed positions of the hydraulic pump passages 39 and 40, either of these passages will be connected with the high-pressure kidney-shaped cavity 48 during one-half of the revolution of the distributing valve 16 and will be connected with the low-pressure kidney-shaped cavity 49 during the other half of the revolution of the valve. When the high-pressure kidney-shaped cavity 48 is connected to the hydraulic pump passage 40, transmission oil will flow to the lower part of pump cylinder 22 and floating pump piston 24 will ascend. When the low-pressure kidney-shaped cavity 49 is connected to hydraulic pump passage 40 transmission oil will return from the lower part of the pump cylinder 22 and the floating pump piston 23 will descend. It is preferable to locate hydraulic pump passages 39 and 40 in such a manner that reversal of flow in these passages should occur simultaneously in order to maintain, at all times, one or the other of the two pump cylinders in connection with the hydraulic pump output passage 53, and therefore assure an even load on the hydraulic pump 13.

More specifically, passages 39 and 40 are located diametrically opposite at 180°rotation of the distributing valve 16. Therefore, at the moment when the connection between hydraulic pump passage 40 and the high-pressure kidney-shaped cavity 48 is interrupted and the connection with low-pressure kidney-shaped cavity 49 is established simultaneously, the connection between hydraulic pump passage 39 and the low-pressure kidney-shaped cavity 49 is interrupted and connection with the high-pressure kidney-shaped cavity 48 is established.

In order to assure satisfactory pump operation, provision has to be made to compensate for leakage losses of the clean transmission oil and to maintain the floating pump pistons in their proper positions in the cylinders. If the floating pump pistons do not move all the way up the cylinder, then gases can accumulate in the top of the cylinders and can vapor-lock the pump.

The schematic flow diagram shown in FIG. 13 will illustrate the principle of operation of this compensating system.

The upper part of the oil reservoir 18, shown in FIG. 6, communicates through the well fluid passage 36 with chamber 33 and is therefore subjected to the high pressure of the well fluid exhaust. In the lower part of the oil reservoir 18, which is separated from the upper part by pressure equalizer piston 19, clean transmission oil therein is at substantially the same pressure. This transmission oil will bleed through passage 38 to more than compensate for any leakage loss to the well casing. The result of an enlarged transmission oil supply will be that one of the floating pump pistons will gradually move up to the end of its cylinder, before the distributing valve 16 reverses the flow to the other cylinder and therefore, will, for a brief moment, stall against the top of the cylinder. The stalling of the floating pump piston 24 for example, will block the transmission oil flow from the pump and raise the pressure in hydraulic pump passage 40 to a point where the reservoir relief valve 42 opens thereby permitting the excess transmission oil to return to the oil reservoir 18.

Advantage of the system here described is that the excess pressure required to open the reservoir relief valves 41 and 42, is relatively small and therefore will not produce a significant disturbance to the hydraulic pump 13.

A modified form of the present invention is provided with three pump cylinders 56, 57 and 58 having operably therein floating pump pistons 59, 60 and 61 respectively. The use of three or possibly more cylinders eliminates a slight disturbance of pump flow which is present when two pump cylinders are used for the reason that during the crossover from one kidney-shaped cavity to the other the flow passages are temporarily restricted.

In this modified form of the present invention, fluid passages 62, 63 and 64 leading to the pump cylinders 56, 57 and 58, respectively, are located at intervals of 120°rotation of the distributing valve 16. All parts of the distributing valve 16 remain the same. Each of the passages still remains connected with one of the kidney-shaped cavities for one half-revolution of the distributing valve 16 and with the other kidney-shaped cavity for the other half of the revolution. However, reversal of flow in the three passages does not take place simultaneously but is staggered, one after the other. Therefore, in order to describe performance with respect to these three passages 62, 63 and 64, they are referred to abstractly as first, second and third passages but not necessarily in the order in which they are identified numerically. Throughout the time when the connection between the first passage and the high-pressure kidney-shaped cavity 48 is interrupted and the connection with the low-pressure kidney-shaped cavity 49 is established, the second passage remains connected to the low-pressure kidney-shaped cavity 49 and third passage remains connected to the high-pressure kidney-shaped cavity 48. Unrestricted flow from the pump to at least one of the pump cylinders is maintained at all times and assures disturbance-free operation of the pump.

With reference to the operation of the modified form of the present invention explained above, attention is called to the components in FIGS. 15 and 16 which were not referred to.

A well fluid passage 65, FIG. 15, is a duplicate of the well fluid passage 36 partly shown in FIGS. 7 and 10. A portion of the passage 65 is shown in a segment 66 which is a duplicate of the upper portion of FIG. 6 but is shown perspective and is provided with an additional fluid passage. It appears that FIG. 16 is self-explanatory because of its similarity to FIG. 13, the difference residing in the addition of another piston and cylinder, the addition of another reservoir relief valve and the addition of another pair of ball check valves carried in another closure in the additional cylinder.

While preferred and alternate embodiments of the present invention have been shown and described, it is to be understood that variations thereof are included within the spirit of the invention and the scope of the following claims.

I claim:

1. A deep well floating pump comprising:

A. an electric motor at the bottom end thereof serving as a source of power;

B. a hydraulic pump driven by said electric motor;

C. a hydraulic oil reservoir having a pressure equalizer means therein;

D. pump cylinders each having a floating pump piston therein, the said pump cylinders provided with hydraulic pump passages communicable with the said hydraulic pump and the said hydraulic oil reservoir;

E. a distributing valve operably connected to the said hydraulic pump passages for regulating the flow of fluid between the said hydraulic pump and the said pump cylinders;

F. a pump casing encompassing the said cylinders thereby providing an area between the said pump casing and the said cylinders;

a. vents in the said pump casing thereby providing admission for well fluid; and

G. closures at the upper end of said pump cylinders each provided with a pair of ball check valves communicable with the said area and a discharge pipe.

2. A deep well floating piston pump comprising:

A. an electric motor at the bottom end thereof serving as a source of power;

B. a hydraulic pump driven by said electric motor,

C. a hydraulic oil reservoir having a pressure equalizer means therein;

D. three pump cylinders having floating pump pistons therein, the said three pump cylinders provided with fluid passages communicable with the said hydraulic pump and the said hydraulic reservoir;

E. a distributing valve operably connected to the said fluid passages for regulating the flow of fluid between the said hydraulic pump and the said three pump cylinders;

F. a pump casing encompassing the said three pump cylinders thereby providing an area between the said pump casing and the said three pump cylinders;

a. vents in the said pump casing thereby providing admission for well fluid; and

G. closures at the upper end of said three pump cylinders each provided with a pair of ball check valves communicable with the said area and a discharge pipe.

3. In a deep well floating piston pump according to claim 1, wherein a chamber is provide interposed between the said discharge pipe and the said closures.

4. In a deep well floating piston pump according to claim 1, wherein a well fluid passage is provided which is communicable between the said hydraulic oil reservoir and the said discharge pipe.

5. In a deep well floating piston pump according to claim 1, wherein the said hydraulic pump is provided with a shaft means for driving the said distributing valve.

6. In a deep well floating piston pump according to claim 5, wherein the said shaft means is provided with a speed reducer.

7. In a deep well floating piston pump according to claim 1, wherein a hydraulic fluid passage is provided which is communicable between the other end of the said hydraulic oil reservoir and a hydraulic pump return passage.

8. In a deep well floating piston pump according to claim 7, wherein the said hydraulic fluid passage is provided with a constriction.

9. In a deep well floating piston pump according to claim 1, wherein the said hydraulic oil reservoir is provided with a pair of reservoir relief valve communicable between the said hydraulic oil reservoir and the said hydraulic pump passages.

10. In a deep well floating piston pump according to claim 1, wherein the said distributing valve is provided with an annular cavity on the lower face communicable with the said hydraulic pump passages, the said distributing valve having two kidney-shaped cavities on the upper face, one of the said kidney-shaped cavities communicable with the said annular cavity whereby communication is established with the said hydraulic pump output passage, and the other kidney-shaped cavity communicable with the said hydraulic pump return passage and the said hydraulic pump output passage.