Sept. 13, 1960 C. C. SANER 2,952,211

PUMP

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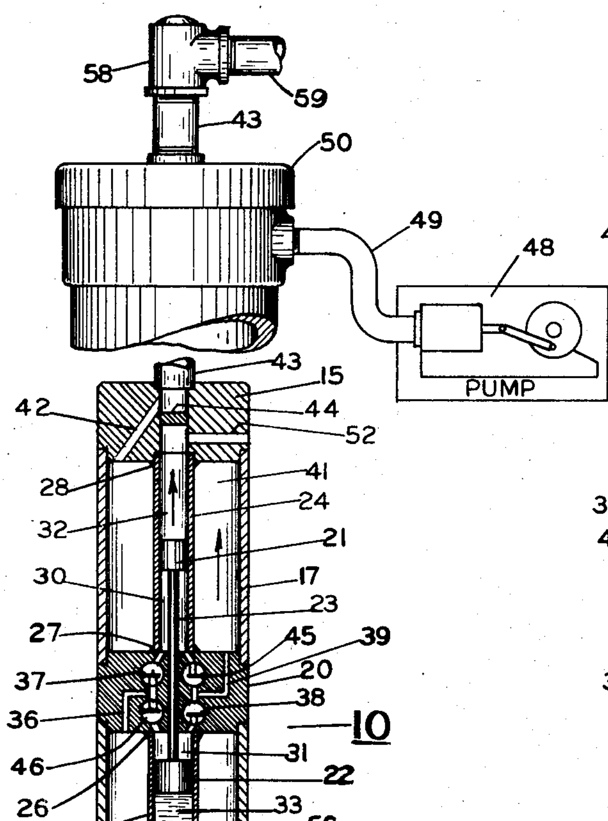

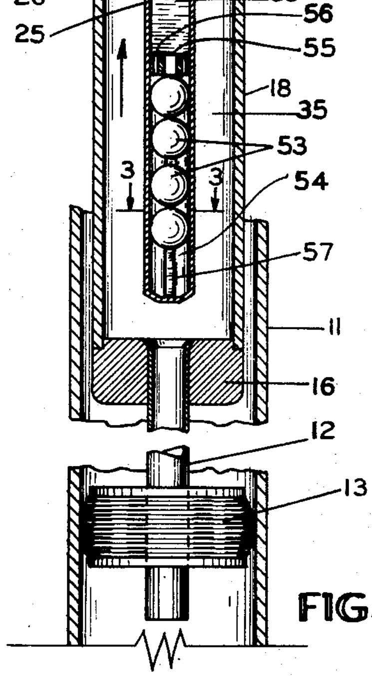

FIG. I.

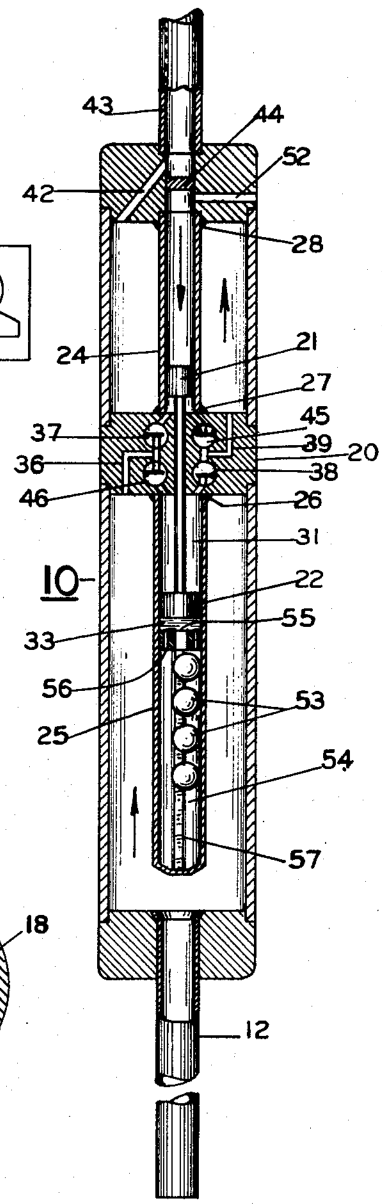

FIG. 2.

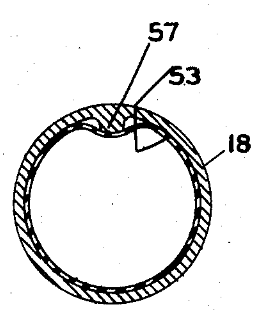

FIG. 3.

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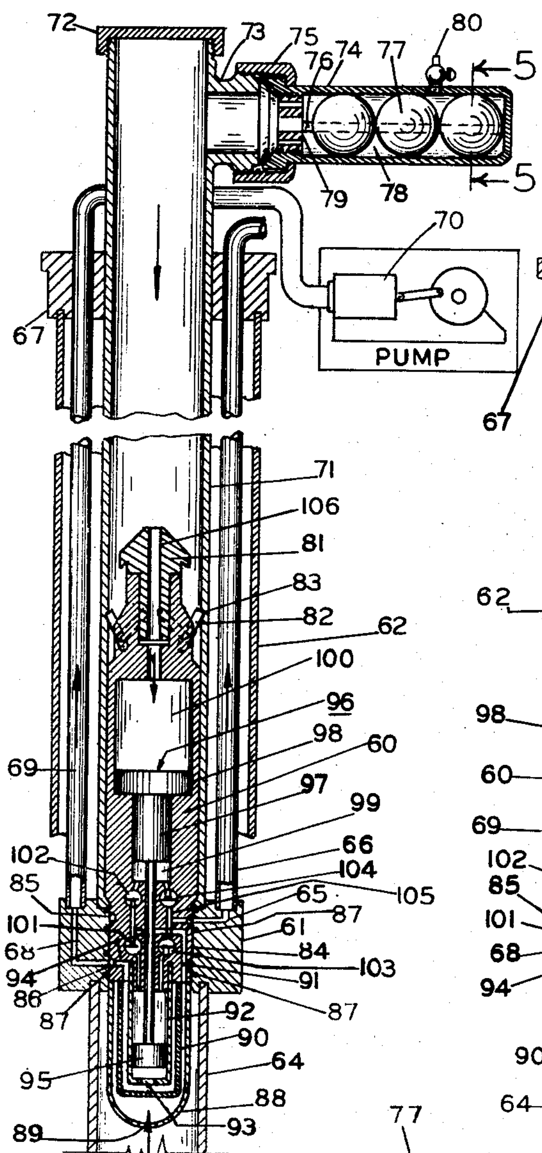

FIG. 4

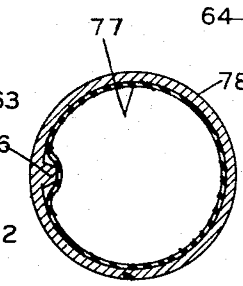

FIG. 5.

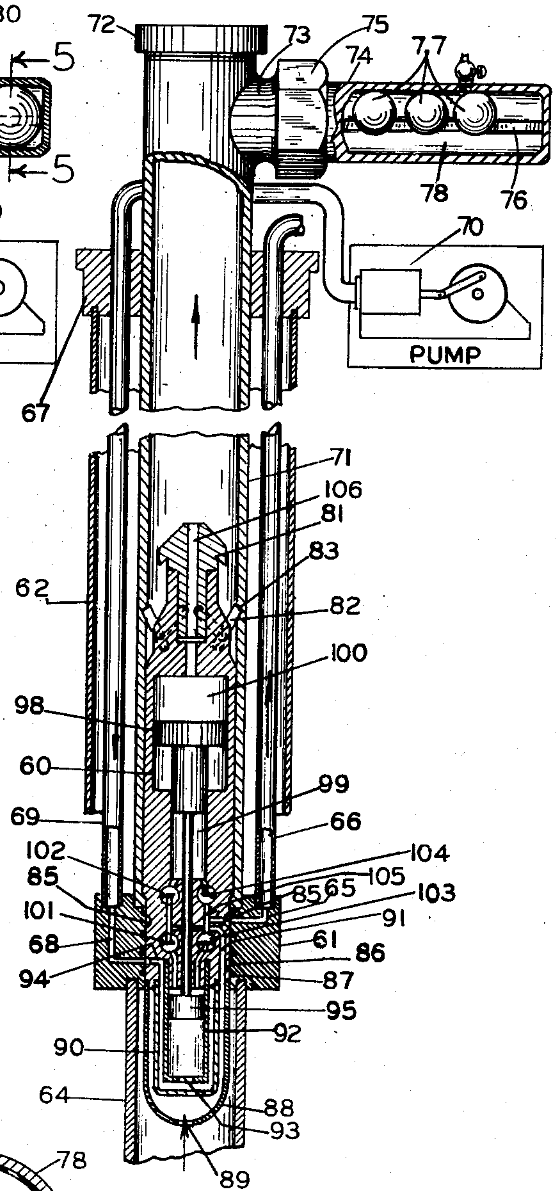

FIG. 6.

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8 Claims. (Cl. 103—44)

This invention relates to pumps and particularly to an improved deep-well pump of the hydraulically actuated type.

The need for deep-well pumping in oil fields has resulted in the development of many types of pumps, and various problems have arisen because of difficulties in servicing and maintaining the operation of the pumps and because of the high power requirements frequently met. One type of deep-well pump employs hydraulic fluid delivered from ground level for operating a fluid motor at the pump location in the well. It is an object of the present invention to provide an improved deep-well pump of the hydraulically actuated type.

It is a further object of this invention to provide a deep-well pump of the hydraulically actuated type including an improved and simplified actuating mechanism.

It is a further object of this invention to provide a deep-well pump of the hydraulically actuated type including an improved arrangement for facilitating servicing and maintenance thereof.

Further objects and advantages of this invention will become apparent as the following description proceeds and the features of novelty which characterize the invention will be pointed out with particularity in the claims annexed to and forming a part of this specification.

Briefly, in carrying out the objects of this invention in one embodiment thereof, a deep-well pump is constructed to comprise a double-acting reciprocating piston type pump driven by two fluid motors, one a forward stroke motor and the other a return stroke motor. The forward stroke motor is a reciprocating piston motor supplied with fluid under pressure from a pump at ground level. The return stroke motor is also of the reciprocating piston type and its energy is derived from the compression of one or more flexible gas-filled containers arranged in a closed chamber in direct communication with the cylinder of the return piston. The closed chamber and cylinder are completely filled with liquid except for the flexible containers. The energy for compressing the flexible containers is supplied by the forward stroke piston which drives the return stroke piston to compress the flexible containers. Upon release of the pressure on the forward stroke piston the flexible containers give up their stored energy to drive the double-acting pump in the opposite direction. The double-acting pump comprises two cylinders the pistons of which are oppositely disposed so that one cylinder is discharging while the other is being charged with liquid from the well. Thus one cylinder is discharging during the forward stroke of the pump and the other during the return stroke.

In another embodiment of the invention the compressible flexible containers are arranged in a chamber at ground level, the chamber and a tubing string connecting the chamber to the return stroke cylinder being completely filled with liquid. This arrangement makes possible the quick servicing or repair of the flexible containers. In this latter embodiment the pump is also con-

structed to comprise a body which may be removed from the well for inspection and servicing and returned to its position in the well for further operation.

For a better understanding of this invention, reference may be had to the accompanying drawings in which:

Fig. 1 is a sectional elevation view of a deep-well pump embodying the invention arranged in position in a well casing;

Fig. 2 is a sectional view of the pump of Fig. 1 showing the pistons in position at the end of their forward stroke;

Fig. 3 is an enlarged sectional view taken along the line 3—3 of Fig. 1;

Fig. 4 is a sectional elevation view similar to that of Fig. 3 illustrating another embodiment of the invention;

Fig. 5 is a sectional view along the line 5—5 of Fig. 4; and

Fig. 6 is a sectional view similar to that of Fig. 4 showing the pump near the end of its forward stroke.

Referring now to the drawing, Fig. 1 illustrates a pump assembly **10** embodying the invention located in a well casing **11** near the bottom of a well and having a supply tube **12** extending through a packer **13** into the production oil; the packer **13** seals off the production oil at the lower end of the casing **11**. The pump assembly **10** comprises upper and lower heads or end pieces **15** and **16**, respectively, connected by a housing formed by upper and lower cylindrical sections **17** and **18**, respectively, joined together and rigidly secured to a central valve block **20**. The pump is thus of elongated cylindrical form and fits concentrically within the casing **11** in spaced relation thereto. The pump is of the double-acting type and comprises an upper piston **21** and a lower piston **22** secured to a longitudinal shaft **23** which is slidably mounted in the block **20**. The piston **21** operates in a cylinder provided within a tube **24** connecting the block **20** and the upper head **15**, and the piston **22** operates within a cylinder formed within a tube **25** secured to the lower side of the block **20**.

The tubes **24** and **25** are secured to the block **20** and to the head **15** by welding as indicated at **26**, **27** and **28** to provide a rigid assembly. Each of the tubes **24** and **25** provides two cylinders, one above and one below each of the pistons **21** and **22**. The lower cylinder within the tube **24** and indicated at **30** and the upper cylinder in tube **25** and indicated at **31** are the cylinders of a double-acting pump formed by the lower side of the piston **21** operating within the cylinder **30** and the upper side of the piston **22** operating within the cylinder **31**. The upper cylinder within the tube **24** indicated at **32** and the lower cylinder within the tube **25** indicated at **33** constitute the forward and return fluid motors, respectively, for actuating the double-acting pump. Thus the upper portion of the piston **21** constitutes the piston of the forward stroke motor and the lower portion of the piston **22** the piston of the return stroke motor.

When the piston assembly is moving upwardly as indicated in Fig. 1, production oil is drawn through the supply tube **12** into a chamber **35** comprising the interior of the casing **18** and thence through an inlet duct **36** and an intake valve **37** to the cylinder **30**. At the same time the piston **22** forces oil from within the cylinder **31** up through a discharge valve **38** and a discharge duct **39** to a chamber **41** comprising the interior of the tube **24** within the casing **17**. This is production oil and is supplied from the chamber **41** through a plurality of discharge ducts in the head **15**, one of which is indicated at **42**, to the production tube or string indicated at **43**. Production tube **43** is sealed from the upper end of the tube **24** within the block **15** by a suitable plug **44**. On the downward stroke of the piston assembly oil is forced from the chamber **30** by the piston **21** and flows through a discharge valve **45** to the discharge duct **39** and thence through the chamber

41 to the production tube 43. Simultaneously, the piston 22 moves downwardly and draws production oil from the inlet duct 36 through an intake valve 46 and thence into the cylinder 31, the valve 38 being held closed by the difference of pressure.

The intake and discharge valves of oil field pumps are commonly of the ball check type; however, for purposes of simplifying the drawings, these valves have been indicated diagrammatically as of the flapper type.

Power for actuating the fluid motors is supplied by a reciprocating pump 48 located at ground level and arranged to discharge oil under pressure through a conduit 49 into the well head indicated at 50. The well head and the entire annular space within the casing 11 about the production tube 43 and the pump assembly 10 are filled with oil and the pressure from the pump 48 is delivered directly to the upper cylinder 32 through one or more supply ducts 52 in the head 15 of the pump.

Energy for both the forward stroke and the return stroke fluid motors is delivered by the pump 48 on its pressure stroke, the pressure transmitted through the oil to the cylinder 32 being sufficient to force the piston 21 downwardly to deliver production oil through the valve 45 and duct 39 and to compress a plurality of flexible containers 53 arranged in a closed chamber 54 constituting the lower portion of the tube 25 which is closed at its bottom end. The chamber 54 and cylinder 32 are filled completely with oil or other liquid surrounding the containers 53. The containers 53 comprise hollow balls of rubber or similar suitable material charged with nitrogen or other suitable inert gas.

The initial gas charge in the containers 53 is dependent upon the pressures under which these containers are required to operate, and the containers, when expanded within the chamber 54 under the lower pressure conditions, may assume an elongated form, they being laterally in engagement with the walls of the chamber as indicated in Fig. 1. When the containers 53 are compressed by the movement of the piston 22 to its lower position as shown in Fig. 2, they may return to their original spherical form as indicated and will tend to rise in the chamber because of their buoyancy. In order to confine the containers within the lower portion of the chamber and to prevent their interference with the piston 22, a suitable barrier or stop 55 is provided on the inner walls of the tube 25. The stop 55 has been illustrated as in the form of an inwardly extending collar having a plurality of passages 56 therethrough to permit the liquid to flow whether or not the top container 53 is in position to close the central opening of the collar 55. In addition, as shown in the sectional view, Fig. 3, the inner wall of the chamber 54 is provided with a land or ridge 57 which prevents the containers 53 from engaging the entire inner wall of the chamber on expansion and assures a bypass for the liquid from the lower portion of the chamber to the top during the expansion of the containers.

The pump 48 is of the reciprocating type and alternately applies and releases the pressure on the column of oil within the casing. When the pressure is released on the suction stroke of the pump 48, the containers 53 immediately expand to drive oil from the chamber 54 back into the cylinder 33 and drive the piston 22 upwardly on its return stroke. Thus the entire energy necessary for the operation of the double-acting pump is delivered on the forward stroke of the pump 48 and no independent or separate driving force is necessary for effecting the return stroke of the pump.

The production oil delivered by the pump through the ducts 42 and tube 43 passes through the well head 50 and into a T-connection 58 to a production oil delivery line 59. The production oil is thus delivered at the well head by the operation of a single pump at the ground level connected to the deep-well pump by a single tube or string, and applicant's invention thus makes it unnecessary to provide a double-acting pump at ground level together with separate strings.

Figs. 4, 5 and 6 illustrate a modified form of this invention wherein the compressible containers are located at ground level and may readily be inspected or replaced and also in which the pump assembly may be retrieved readily for inspection and servicing. The pump assembly as illustrated in Fig. 4 comprises a pump body 60 seated in an annular base 61 which in turn is mounted in a well casing 62 on a packer 63, the base being provided with an intake or production well tube 64 which fits in the packer 63 and extends into the production oil. The base 61 has formed therein a production oil discharge duct 65 which is connected in communication with a production tube or string 66 which extends upwardly through the casing 62 to the well head 67. Also within the base 61 there is provided a duct 68 which is connected to a tube or string 69 which carries the operating fluid for the pump, the tube 69 extending through the head 67 to a pressure fluid supply pump 70 located at ground level.

The body 60 is slidably mounted in a tube 71 the lower end of which is secured to the base 61 and the upper end of which extends through the well head 67 and is closed by a sealed cap 72 at its upper end. Tube 71 above the well head is provided with a T-connection 73 to which a closed cylinder 74 is secured and sealed by a universal coupling 75. A plurality of flexible-wall containers 77 similar to the containers 53 in the embodiment of Fig. 1 are located within the cylinder 74 in the chamber thereof indicated at 78, and a threaded stop or barrier ring 79 is provided at the open end of the chamber 78 to retain the containers within the chamber while permitting the flow of liquid from the chamber regardless of the condition of the expansible containers. As shown in Fig. 5 the cylinder 74 is provided with a rib 76 which prevents the containers from expanding and completely closing the cross section of the chamber 78. The containers 77 may be removed easily for inspection or replacement by disconnecting the coupling 75 and then unscrewing the retainer or stop 79 from its position in the end of the chamber 74.

In order to refill the tube 71 and chamber 78 after replacing the tube 74, liquid is poured in through the top of the tube 71, the cap 72 having been removed; any air present in the chamber 78 may be driven out by opening a petcock 80 and allowing the gas or air to escape until only oil is discharged from the petcock. Thereafter the petcock is closed and the cap 72 replaced with the tube 71 completely filled with oil. The system is then again in condition for operation.

The pump assembly mounted within the body 60 may be removed from its position in the base 61 and drawn to the surface through the tube 71 by an overshot or recovery line secured to an adapter 81 at the top of the body 60. The pump body is held in position in the casing 71 by releasable catches 82 which engage notches 83 in the tube at a position such that the body is in its required position in the base 61. Catches 82 are released when the overshot engages the adapter and remain released while the pump body is being drawn up through the tube 71. The lower end of the body 60 is of reduced cross section, as indicated at 84, and is provided with two annular grooves 85 and 86 which are in communication with the discharge ducts 65 and 68, respectively, and assure communication between the ducts and passages within the pump regardless of the rotation of the pump body about its vertical axis. Resilient gaskets or O-rings 87 are provided on either side of the annular grooves 85 and seal the space between the body 60 and the base 61 against leakage either from the passage outside the base or between the passages therein which are in communication with the grooves 85 and 86.

The lower end of the pump body assembly extends below the base 61 and comprises an outer shield or casing 88 having an opening 89 at its end for admission of production oil through the tube 64. Inside the shield 88 there is provided a cylindrical cap 90 which provides a cylindrical cap 90 which provides a space between it and the shield 88 which is in communication with an inlet duct 91 within the lower end of the body 60. Within the casing 88 there is provided a pump cylinder 92 having an intake opening 93 at its bottom end communicating with the space between the cylinder 92 and the shield 90, which space is in open communication with the duct 68 through the annular groove 86 and a pressure fluid duct 94.

The pump and the fluid driving motors of the embodiment of Fig. 4 are similar to those of the embodiment of Fig. 1 and comprise a lower piston head 95 mounted for reciprocation in the cylinder 92 and an upper head 96 mounted for reciprocation in the upper portion of the body 60; the head 96 comprises a lower portion 97 and an upper portion of greater diameter indicated at 98. The portion 97 is mounted to move within a cylinder 99 and the portion 98 within a cylinder 100. The lower piston 97 and the upper face of the piston 95 operating in the cylinders 99 and 92, respectively, constitute the double-acting pump of the assembly.

A valve assembly similar to that of the pump in Fig. 1 is provided within the body 60 and comprises intake valves 101 and 102 for the cylinders 92 and 99, respectively, which are in communication with the inlet duct 91, and discharge valves 103 and 104 for the cylinders 92 and 99, respectively. The discharge valves are in communication with a discharge duct 105 which communicates with the annular groove 85 and hence with the discharge duct 65 and the production tubing 66.

The upper piston of the head 96 which operates in the cylinder 100 is the return stroke fluid motor and is in open communication with the interior of the tube 71 through a duct 106 which extends centrally of the adapter 81. The power for driving the double-acting pump is supplied by the pump 70 at the surface in the same manner as the power supply for the modification of Fig. 1 under operation of the pump 48.

In Fig. 4 the pump is shown in its position near the end of its down stroke, liquid under pressure having been forced from the chambers 74 down the tube 71 into the cylinder 100 to drive the piston head 96 downwardly and force the discharge production oil from the cylinder 99 through valve 104 and the duct 65; at the same time production oil is being drawn into the upper portion of the cylinder 92 through the inlet valve 101. This downward stroke also forces oil out of the lower portion of the cylinder 92 through the opening 93 on the return stroke of the pump 70. At the end of the down stroke the pump 70 again supplies liquid under pressure to the tubing 69 and forces liquid under pressure into the lower portion of the cylinder 92 to drive the piston 95 upwardly, thereby discharging production oil from the cylinder 92 through the discharge valve 103 and drawing a fresh charge of production oil into the cylinder 99 through the intake valve 102. At the same time, cylinder 98 forces the oil or other liquid back into the tubing 71 and hence to the chamber 78 to compress the containers 77 as indicated in Fig. 6 and store energy for the return stroke. It will thus be seen that the operation of the pump of this embodiment is the same as that of the pump of Fig. 1.

The arrangement of the flexible compression containers 77 at the ground level where they are accessible for servicing, together with the arrangement for retrieving the pump assembly for servicing and repair through the tube 77, provides a simple and effective arrangement for maintaining a deep-well pump in operation over long periods of time and for securing the advtantages of the simplicity whereby the pumping operation is effected through a single reciprocating pump at the ground level.

While the invention has been described in connection with specific constructions and arrangements of deep-well pumps, various other applications and modifications will occur to those skilled in the art. Therefore it is not desired that this invention be limited to the specific details of construction illustrated and described and it is intended by the appended claims to cover all modifications which fall within the spirit and scope of the invention.

I claim:

1. A fluid operated deep well pump comprising a pumping unit constructed and arranged to be positioned in a well, said unit including a double-acting pump and two fluid motors for effecting the forward and return strokes respectively thereof, the return stroke motor comprising a piston and a closed chamber filled with liquid and at least one compressible gas-filled container in the chamber, and the forward stroke motor comprising a piston connected to drive said pump on its forward stroke and to drive the piston of said return stroke motor to compress said container and store energy when fluid under pressure is supplied to the forward motor, said return stroke motor being effective to drive the pump on its return stroke when pressure is released from said forward motor.

2. A fluid operated deep well pump as set forth in claim 1 wherein said container comprises a sealed bag of flexible gas-tight material charged with an inert gas.

3. A fluid operated deep well pump as set forth in claim 1 wherein said double-acting pump and said motors include respective pistons mounted concentrically on a common shaft for reciprocation along the longitudinal axis thereof and means providing cylinders for cooperation with said pistons.

4. A fluid operated deep well pump as set forth in claim 1 including a reciprocating fluid pump for alternately applying and releasing pressure on fluid supplied to said forward motor.

5. A fluid operated deep well pump comprising a pumping unit constructed and arranged to be positioned in a well, said unit including a double-acting pump and two fluid motors for effecting the forward and return strokes respectively thereof, the return stroke motor comprising a piston and a closed chamber filled with liquid and at least one compressible gas-filled container in the chamber, and the forward stroke motor comprising a piston connected to drive said pump on its forward stroke and to drive the piston of said return stroke motor to compress said container and store energy when fluid under pressure is supplied to the forward motor, said return stroke motor being effective to drive the pump on its return stroke when pressure is released from said forward motor, wherein said closed chamber includes a pipe extending upwardly from said pump and wherein said container is located in said chamber near the surface of the ground above the well.

6. A fluid operated deep well pump comprising a pumping unit constructed and arranged to be positioned in a well, said unit including an elongated cylindrical pump body having therein a double-acting pump and two fluid motors for effecting the forward and return strokes respectively thereof, the return stroke motor comprising a piston and a closed chamber filled with liquid and at least one compressible gas-filled container in the chamber, the forward stroke motor comprising a piston connected to drive said pump on its forward stroke and to drive the piston of said return stroke motor to compress said container and store energy when fluid under pressure is supplied to the forward motor, said return stroke motor being effective to drive the pump on its return when pressure is released from said forward motor, means including a packer and an annular base having a seat for receiving said pump for retaining said pump in position in a well, a tube constituting a portion of said closed chamber having an internal diameter

slightly greater than that of said pump body secured to and extending upwardly from said base, fluid connections in said base for communication with said forward stroke motor and with the outlet of said pump, means for connecting strings of tubing with said fluid connections for supplying fluid under pressure to said forward motor and for discharging fluid from said pump, means for opening said tube for access at ground level, and means for drawing said pump from said well through said tube after opening it.

7. A fluid operated deep well pump comprising a pumping unit constructed and arranged to be positioned in a well, said unit including an elongated cyclindrical pump body having therein a double-acting pump and two fluid motors for effecting the forward and return strokes respectively thereof, the return stroke motor comprising a piston and a closed chamber filled with liquid and at least one compressible gas-filled container in the chamber, the forward stroke motor comprising a piston connected to drive said pump on its forward stroke and to drive the piston of said return stroke motor to compress said container and store energy when fluid under pressure is supplied to the forward motor, said return stroke motor being effective to drive the pump on its return when pressure is released from said forward motor, means including a packer and an annular base having a seat for receiving said pump for retaining said pump in position in a well, a tube constituting a portion of said closed chamber having an internal diameter slightly greater than that of said pump body secured to and extending upwardly from said base, fluid connections in said base for communication with said forward stroke motor and with the outlet of said pump, means for connecting strings of tubing with said fluid connections for supplying fluid under pressure to said forward motor and for discharging fluid from said pump, means for opening said tube for access at ground level, and means for drawing said pump from said well through said tube after opening it, wherein said double-acting pump comprises two oppositely acting pistons and a valve block assembly therebetween having intake and discharge ports for said pump and a fluid presure port for said forward stroke motor, said discharge port and said fluid pressure port opening in the side of said pump body, and cooperating ports in said base providing communication between said discharge and pressure ports and respective ones of said strings of tubing, and gasket rings between said body and said base for separating said pressure and discharge ports and for sealing said body in said base.

8. A fluid operated deep well pump as set forth in claim 1 wherein said double-acting pump and said motors include respective pistons mounted concentrically on a common shaft for reciprocation along the longitudinal axis thereof and means providing cylinders for cooperation with said pistons, and wherein said closed chamber comprises an extension of the cylinder of said return stroke motor.

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