United States Patent

[11] 3,582,238

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[54] **DOWN HOLE HYDRAULIC PUMP**
13 Claims, 5 Drawing Figs.

[52] **U.S. Cl.** **417/397, 91/411**
[51] **Int. Cl.** **F04b 17/00, F15b 11/00**
[50] **Field of Search** 103/44, 45, 46, 50, 51; 91/344, 411; 417/377, 397

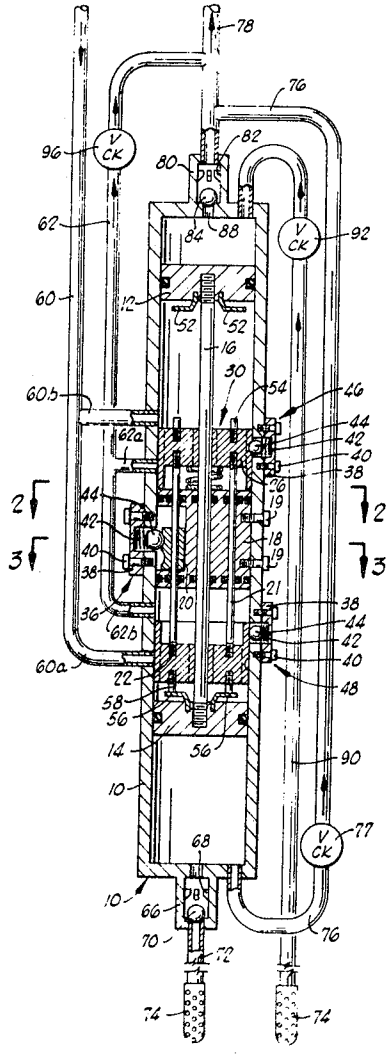
[56] **References Cited**

UNITED STATES PATENTS

1,714,425	5/1929	Knab	103/51X
2,057,364	10/1936	Bystricky	103/50X
2,346,026	4/1944	Hendricks	103/46X
2,645,208	7/1953	Hardesty	103/46X
3,276,381	10/1966	Harklau et al.	103/51X

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ABSTRACT: A down hole pump adapted to be driven by a power fluid circulated into the hole from the surface and including at least one main power piston, a working barrel surrounding the power pistons, a pair of power fluid charging ports in the working barrel, a pair of power fluid discharge ports in the working barrel, fluid passageways connecting the ports to the surface, and a double slide valve assembly positioned in the working barrel and cooperating with the power pistons during portions of the stroke thereof for alternately opening one of the charging ports and closing one of the discharge ports while concurrently closing the second charging port and opening the other discharge port, then, at a different time, reversing the status of the four ports. The slide valve assembly is actuated to open and close the ports at critical times by contact of at least one power piston with this assembly, coupled with the resilient bias of a spring and ball assembly cooperating with a cam surface on a portion of the slide valve assembly.



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SHEET 1 OF 2

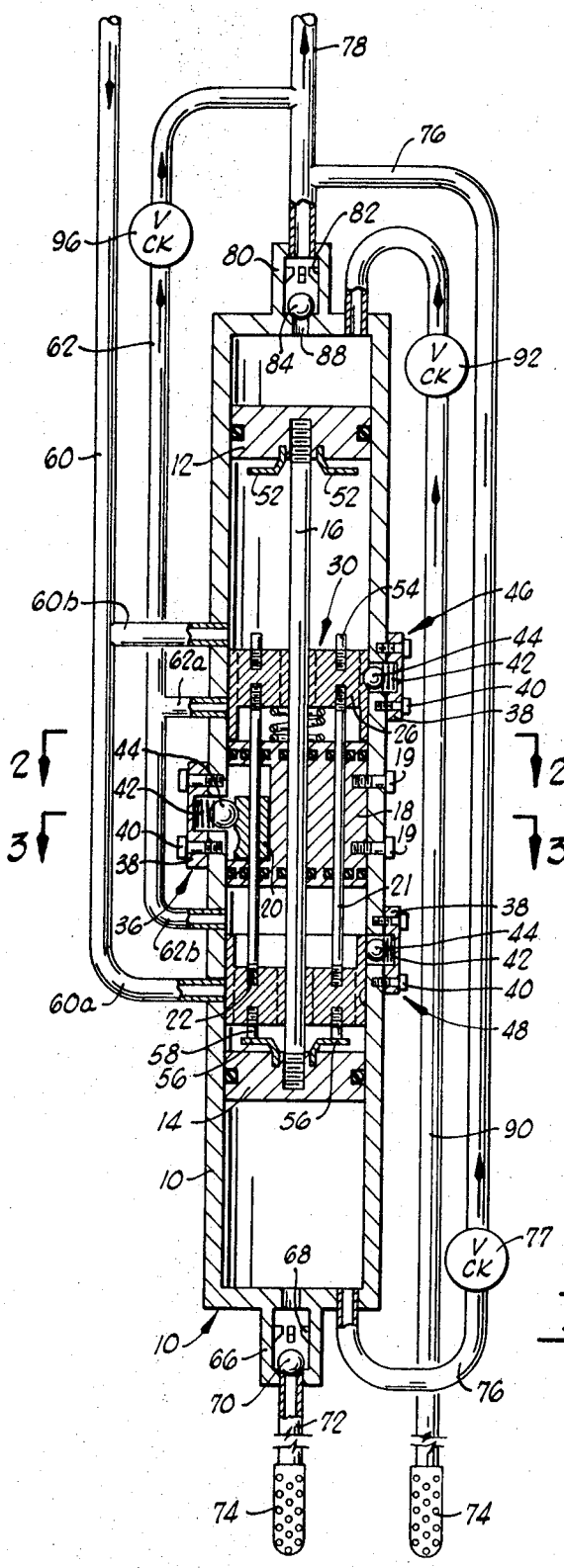


Fig. 1

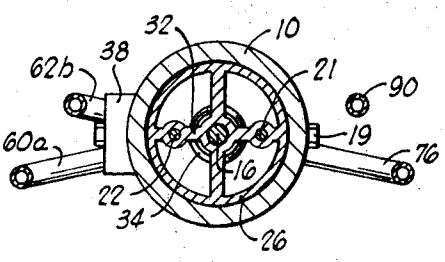


Fig. 2

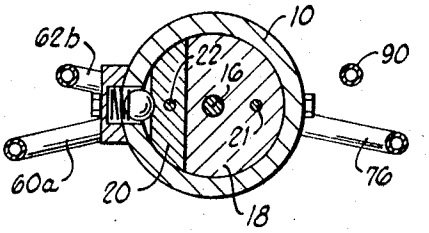


Fig. 3

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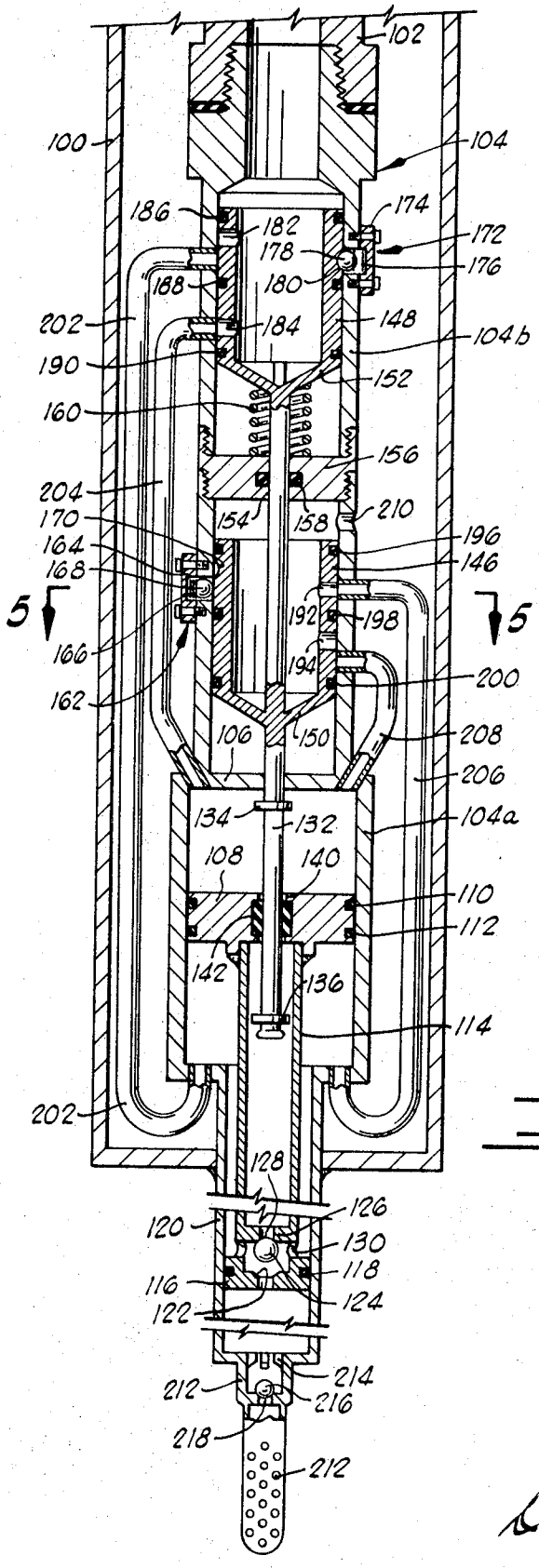


Fig. 4

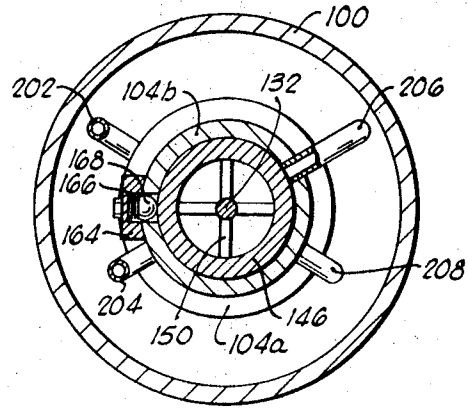


Fig. 5

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DOWN HOLE HYDRAULIC PUMP

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention relates to down hole hydraulically actuated pumps, and particularly, to such pumps having slide valves functioning to open and close porting used to effect stroke reversal of such pumps.

2. Brief Description of the Prior Art

Many types of both single-acting and double-acting down hole hydraulic pumps have been heretofore used for producing hydrocarbons from petroliferous subterranean formations. Pumps of this type generally involve some type of working barrel in which a working piston is driven in a reciprocating movement by a hydraulic power fluid delivered to the pump from the surface. In some instances, the hydraulic power fluid is maintained in an isolated system, both for circulation into the hole to the working barrel of the pump, and for return to the surface. In other arrangements, the hydraulic power fluid is mixed with the production fluid being produced from the subterranean formation prior to its return to the surface. In either eventuality, it is necessary to provide reliable valving of some type in the pump in order to transfer the flow of power fluid from one side of the power piston to the other side of the power piston in order to effect stroke reversal. The types of valving heretofore provided have worked on various principles, and have functioned with varying degrees of effectiveness. In some instances, the valving is susceptible to sticking or malfunction over extended periods of use, rendering the hydraulic pumps in which it is employed of marginal advantage over other types of pumps, such as sucker rod pumps or other types of hydraulically actuated pumps.

BRIEF DESCRIPTION OF THE PRESENT INVENTION

The present invention provides a hydraulically actuated down hole pump which can be used over an extended period of time for producing oil from relatively deep subterranean formations. Broadly described, the hydraulically actuated down hole pump of this invention includes a working barrel which has reciprocably positioned therein, either a single power piston or a pair of power pistons which are interconnected to each other and which stroke together. Suitable piping or conduits are provided for delivering a hydraulic power fluid to the working barrel from the surface, and the working barrel is ported so as to receive and discharge the power fluid at different times during the stroke of the power pistons.

As is well understood in the art, it is necessary to provide multiple porting above and below each of the power pistons which are provided in the pump in order that during one directional reciprocation of each of such power pistons, power fluid may be delivered to one side of one or both the power pistons from the surface, and discharged to the surface from the other side of the power pistons toward which the pistons are moving. It then follows that in order for the conduits conveying power fluid to and from the working barrel to be used interchangeably, dependent upon the particular portion of the stroke cycle in which the piston is moving, suitable valving must be utilized for redirecting the flow of the power fluid.

In the present invention, the valving employed in the down hole hydraulic pump takes the form of a pair of interconnected slide valves which are concurrently actuated by dual forces provided, in the first instance, by contact of a portion of the valve assembly with one of the main power pistons and, in the second instance, by a carry-through snap action imparted to the valve assembly by a spring-biased camming mechanism. The spring-biased camming mechanism assures that the slide valve assembly will be positively moved in the proper sequence to the desired positions in which the working barrel is ported for causing the power pistons to reciprocate in the desired directions to deliver the necessary pumping action.

From the foregoing broad description of the invention, it will be perceived that it is an object of the present invention to provide an improved down hole hydraulically actuated pump.

Another object of the invention is to provide a down hole hydraulically driven pump which has a pair of positively actuated slide valves which are characterized in having a long and trouble-free service life.

Additional objects and advantages of the invention will become apparent as the following detailed description of the invention is read in conjunction with the accompanying drawings which illustrate the invention.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a partially sectional and partially elevational view of a double-acting, hydraulically actuated down hole pump constructed in accordance with the present invention.

FIG. 2 is a sectional view taken along line 2–2 of FIG. 1.

FIG. 3 is a sectional view taken along 3–3 of FIG. 1.

FIG. 4 is a partially sectional, partially elevational view of a single-acting, hydraulically actuated down hole pump constructed in accordance with the invention.

FIG. 5 is a sectional view taken along 5–5 of FIG. 4.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS OF THE INVENTION

Referring now to the drawings, and initially to FIG. 1, shown therein is a down hole hydraulic pump constructed in accordance with the invention. The embodiment of the invention illustrated in FIGS. 1—3 is a double-acting pump and includes a working barrel **10** in which are located an upper power piston **12** and a lower power piston **14**. The power pistons **12** and **14** are interconnected by an elongated connecting rod **16** which extends between the pistons and centrally in the pump barrel **10**. The connecting rod **16** passes through a central divider block **18** positioned intermediate the ends of the working barrel **12**.

The divider block **18** sealingly engages the internal walls of the working barrel **10**, and is retained in position by means of suitable screws **19** extended through the working barrel into the divider block **18**. As will be noted in referring to FIGS. **1** and **3**, the divider block **18** has a portion cut away from one side thereof to accommodate a cam block **20** in the recess **21** thus formed in the divider block **18**. The connector elements **22** and **24** are secured at their opposite ends to slide valve members **26** and **28**, and with the slide valve members, for a portion of a slide valve assembly designated generally by reference numeral **30**. The slide valve members **26** and **28** each constitute annular sleeves which slidingly engage the internal walls of the working barrel **10** for sliding movement therealong. Connection of each of the connector members **22** and **24** to the slide valves **26** and **28** is through a spider **32** secured inside each of the slide valves in the manner best illustrated in FIG. **2**. Each spider **32** also slidingly accommodates the push rod **16** through a bore formed axially therethrough.

Resting upon the central divider block **18** and extending upwardly around the elongated connecting rod **16** is a helical spring **34**. The upper end of the helical spring **34** bears against the underside of the spider **32** and is a fairly weak spring which is merely sufficient to oppose and balance the weight of the slide valve assembly **30**. Secured to the working barrel **10** at a location which is opposite the recess **21** in the cam block **20** is a first spring and ball assembly, designated generally by reference numeral **36**.

The first spring and ball assembly **36** includes a cap plate **38** which is secured by screws **40** or other suitable means over an aperture formed in the side of the working barrel **10**. The cap plate **38** is recessed at its central portion, with the recess therein aligned with the aperture in the working barrel **10**. A spring **42** is seated in the recess in the cap plate **38** and bears against a ball **44** and forces such ball **44** against the cam block **20**. As will appear in referring to FIG. **1**, the cam block **20** has a pair of adjacent semispherical recesses formed in the outer surface thereof, and the ball **44** is biased by the spring **42** into one of these recesses. As the cam block **20** is shifted by the shifting of the slide valve assembly **36** as hereinafter

described, the ball **44** moves from one of the recesses in the cam block to the other, and in doing so, biases the slide valve assembly upwardly or downwardly within the working barrel with a snap action to assure positive seating of the slide valve members **26** and **28** as more specifically hereinafter described.

Mounted on the working barrel **10** at locations opposite the slide valve member **26** and the slide valve member **28** are second and third spring and ball assemblies, **46** and **48**, respectively. Each of these assemblies is constructed substantially identically to the spring and ball assembly **36**, and is aligned with an aperture or recess formed in the working barrel. In the case of the second spring and ball assembly **46**, the ball **44** thereof projects into contact with a portion of the slide valve member **26** which carries a cam depression, and the ball moves alternately into and out of this cam depression to further aid in producing the snap action which moves the slide valve assembly from one operative position to another. The third spring and ball assembly **48** functions substantially the same as the spring and ball assembly **46**. It should be pointed out that, in some instances, the spring and ball assembly **36** may alone provide the snap action which is desired, and the spring and ball assemblies **46** and **48** can be eliminated from the pump structure. In other cases, economy of manufacture is effected and satisfactory performance is obtained by including in the structure only the spring and ball assemblies **46** and **48**, with the concurrent elimination of the spring and ball assembly **36**.

Projecting downwardly from the lower side of the upper power piston **12** are a pair of resilient metal fingers **52** which function to contact rods **54** projecting upwardly from the spider **32** in the slide valve member **26**. Similarly, a pair of spring metal fingers **56** extend upwardly from the upper side of the lower power piston **14** and are positioned for contacting the rods **58** which project downwardly from the spider **32** secured in the lower slide valve member **28**.

For the purpose of conveying power fluid from the surface to the down hole hydraulic pump, a hydraulic power fluid charging conduit or passageway **60** is provided. The passageway **60** has a first branch **60*a*** which is connected through a suitable fitting or port to the interior of the working barrel **10** at the location which is below the central divider block **18**. A second branch **60*b*** of the conduit **60** is connected through a suitable port to the interior of the working barrel **10** at a location which is above the central divider block **18**.

For the purpose of permitting power fluid to be exhausted from the pump, a power fluid discharge conduit **62** is provided which includes a branch **62*a*** which communicates with the interior of the working barrel **10** at a location between the upper side of the central divider block **18** and the location at which the branch conduit **60*b*** of the power fluid charging conduit **60** enters the working barrel. A second branch **62*b*** of the power fluid discharge conduit **62** enters the working barrel **10** through a fitting or port which is located between the point of connection of the branch **60*a*** of the conduit **60** to the working barrel and the lower side of the central divider block **18**.

Extending from the lower end of the working barrel **10** is a standing valve housing **66** which includes a movement limiting cage **68** and a standing valve ball **70**. The standing valve ball **70** seats upon a seat formed on the upper end of a tubing **72** which has a perforated sandpipe **74** secured to the lower end thereof. A production fluid discharge conduit **76** extends from a lower end of the working barrel **10** and contains a check valve **77** which prevents retrograde flow of production fluid from this conduit back into the working barrel **10**. The upper end of the production fluid discharge conduit **76** is connected to a fluid return conduit **78** which communicates with a standing valve housing **80** formed on the upper end of the working barrel **10**. The standing valve housing **80** contains a cage **82** and a standing valve ball **84** which is shown resting upon a seat formed at the upper end of an opening **88** formed through the closed upper end of the working barrel **10**.

Communicating with the interior of the upper end of the working barrel **10** through the closed upper end of the working barrel is a production fluid conduit **90** which contains a check valve **92** preventing retrograde flow of production fluid from the interior of the working barrel **10** downwardly through the production fluid conduit to a sandpipe **94** located on the lower end thereof. It will be understood that the sandpipes **74** and **94** secured to the lower ends of the conduits **76** and **90**, respectively, are disposed in the lower end of the well bore, and are adapted to receive production fluid from the producing formation. It will also be noted that the upper end of the conduit **62**, after passing through a check valve **96**, is also connected to the fluid return conduit **78** and charges power fluid thereto after such power fluid is exhausted or discharged from the working barrel **10**.

Operation of the Embodiment Illustrated in FIG. **1**

In the use of the down hole hydraulic pump illustrated in FIG. **1**, hydraulic power fluid is charged to the pump from the surface through the conduit **60**. Hydraulic power fluid can enter the working barrel **10** through either the branch **60*a*** or the branch **60*b***, depending upon the status of the slide valve members **26** and **28** at that time. In the status illustrated in FIG. **1** of the drawings, the branch **60*a*** of the conduit **60** cannot charge hydraulic power fluid to the interior of the working barrel **10** because it is closed by the slide valve member **28**. Hydraulic power fluid can, however, be charged to the interior of the working barrel **10** above the central divider block **18** since, in the illustrated status of the pump, the upper slide valve member **26** does not extend across and close the branch conduit **60*b***. Thus, at this time, hydraulic power fluid is introduced to the interior of the working barrel **10** at a location above the central divider block **18**, and the upper power piston **12** is driven upwardly within the working barrel **10**.

As the upper power piston **12** moves upwardly in the working barrel **10**, it carries with it the lower power piston **14** as a result of the interconnection formed by the elongated connecting rod **16**. With the movement of both the upper power piston **12** and the lower power piston **14** upwardly within the working barrel **10**, any liquid which may be located above the upper power piston **12** is forced upwardly through the standing valve housing **80** and into the fluid return conduit **78**. This liquid is returned to the surface through this conduit. The liquid forced out of the top of the working barrel **10** by upward movement of the power piston **12** is prevented from flowing downwardly through the conduits **76** and **90** by the check valves **77** and **92**, respectively, located in these conduits.

At the time that the upper power piston is forcing any liquid thereabove upwardly through the standing valve housing **80** and into the fluid return conduit **78**, the upward movement of the lower piston **14** forces the hydraulic power fluid which has been previously introduced above this piston out through the branch **62*b*** of the conduit **62**, through the check valve **96** and into the fluid return conduit **78**. Thus, the fluid passed upwardly to the surface via the conduit **78** is any fluid located above the upper power piston **12** (which, as will be hereinafter explained, is production fluid) and the exhausted hydraulic power fluid which enters the conduit **78** from the conduit **62**.

Upward movement of the lower power piston **14** also effectively draws production fluid upwardly through the standing valve housing **66** from the sandpipe **74** which the production fluid enters from the surrounding subterranean formation. The reduced pressure created in the lower end of the working barrel **10**, coupled with the movement of the production fluid upwardly into the standing valve housing **66**, effectively lifts the standing valve **70** off of its seat and permits the upward flow of production fluid into the working barrel to occur. Thus, the space between the lower power piston **14** and the lower end of the working barrel **10** is filled with this production fluid during the upstroke of the lower power piston **14**. When the power pistons **12** and **14** reach the upper end of their strokes, the spring fingers **56** on the upper side of the lower power piston **14** will strike the rods **58** projecting down from the spider **32** mounted in the lower slide valve member **28**.

As a result of this contact, which is cushioned by the springs **56**, the slide valve assembly **30** will be shifted upwardly. The shifting of the slide valve assembly **30** results in an upward shifting or movement of the slide valve member **26** and the slide valve member **28** so that the branch conduit **60***b* becomes covered by the upper slide valve member **26**, and the branch conduit **62***b* simultaneously becomes covered or closed by the lower slide valve member **28**. Simultaneously, the branch conduit **60***a* of the hydraulic power fluid conduit **60** is opened by upward movement of the lower slide valve member **28**, and the branch conduit **62***a* is opened by upward movement of the upper slide valve member **26**. It is important to point out here that after the initial upward increment of movement of the slide valve assembly **30** has been commenced as a result of contact of spring fingers **56** with the rods **58**, the completion of the shifting of the slide valve assembly is effected by the snap action developed by the spring and ball assemblies **36**, **46** and **48**. These assemblies function so that the contact of the spring fingers **56** with the rods **58** move the slide valve assembly, and specifically, the upper slide valve member **26**, the lower slide valve member **28** and the cam block **20**, upwardly with respect to the balls **44**. The balls thus move onto the high spot adjacent depressions on the several cam surfaces, and then the balls snap into the depressions under the resilient bias of their respective springs **42**. This snap action drives the slide valve assembly **30** to the completion of its upward shifting movement, and thus positively seats the upper and lower slide valve members **26** and **28**, respectively, at the locations in which they cover the branch conduits **60***b* and **62***b* respectively.

After the slide valve assembly **30** has been shifted in the manner described, the branch conduit **60***a* of the hydraulic power fluid charging conduit **60** has been placed in communication with the interior of the working barrel **10** at a location above the lower power piston **14**. Thus, hydraulic power fluid can flow into the working barrel **10** and act against the upper side of the lower power piston **14**. At the same time, the introduction of power fluid to the upper end of the working barrel **10** from the branch conduit **60***b* has been terminated by the closing of this branch conduit by the slide valve member **26**. Thus, power fluid ceases to push upwardly against the lower side of the upper power piston **12**. Under these conditions, the power pistons **12** and **14** commence to move downwardly in the working barrel **10**. As the lower power piston **14** moves downwardly in the working barrel **10**, the production fluid which has been previously drawn upwardly into the lower portion of the working barrel through the standing valve housing **66** is forced outwardly into the production fluid discharge conduit **76** as the standing valve **70** is forced downwardly against its seat located at the upper end of the conduit **72**. The seating of the standing valve **70** prevents any of the production fluid from flowing back through the conduit **72** and through the sandpipe **74**. The production fluid forced into the conduit **76** passes through the check valve **77** and into the conduit **78** to which the production fluid conduit **76** is connected at its upper end.

As the upper power piston **12** moves downwardly in the working barrel **10**, production fluid is drawn through the sandpipe **94** and into conduit **90** due to the reduced pressure created in the upper end of the working barrel above the upper power piston **12**. This production fluid flows through the check valve **92** and into the space above the power piston **12** so as to at least partially fill this space.

Downward movement of the power pistons **12** and **14** continues until the spring fingers **52** contact the upper ends of the rods **54** secured to the upper side of the spider **32** which is located in the upper slide valve member **26**. At this time, the first commencement of the snap action of the slide valve assembly **30** is commenced, with the slide valve assembly being moved downwardly in the working barrel **10**. The snap action is carried through by the spring and ball assemblies **36**, **46** and **48** heretofore described, so that the status of the branch conduits **60***a*, **60***b*, **62***a* and **62***b* is reversed. The reversal of the status (that is, whether they are open or closed) of these branches of the conduits **60** and **62** effects a stroke reversal of the power pistons **26** and **28** in the manner hereinbefore described. In this manner, the cycle of the pump is completed.

A single-acting embodiment of the down hole hydraulic pump of the invention is depicted in FIGS. **4** and **5**. As shown in these FIGS., the pump includes an outer tubing **100**, an inner tubing **102** and a working barrel **104** which is connected to the lower end of the inner tubing **102**. The working barrel **104** may be of substantially uniform diameter over its length, or it may, as in the illustrated embodiment, include an enlarged diameter portion **104***a* which is secured to the lower end of a relatively smaller diameter portion **104***b*. A fluidtight partition **106** extends transversely across the working barrel **104** at the intersection of the relatively larger diameter portion **104***a* with the relatively smaller diameter portion **104***b*. Slidingly disposed in the relatively larger diameter portion **104***a* of the working barrel **104** is a power piston **108**. The power piston **108** is provided with suitable sealing rings **110** and **112** around its outer periphery to sealingly engage the internal walls of the large diameter portion **104***a* of the working barrel **104**. Secured to the bottom side of the power piston **108** is an elongated tubular member **114** which carries a pump piston **116** at its lower end. Pump piston **116** carries a sealing ring **118** around its outer periphery for sealing engagement with the internal wall of a pump barrel **120** which is secured to, and communicates with, the lower end of the working barrel **104**. The pump piston **116** contains a valve seat **122** upon which is seated, during one portion of the operating stroke of the pump, a traveling ball valve **124**. The traveling ball valve **124** can move upwardly a limited distance within the tubular member **114** until it strikes an upper seat **126** which has an orifice **128** therethrough which is closed upon seating of the ball valve **124** in the manner depicted in FIG. **4**. Between the seat **126** and the seat **122** are a plurality of radial orifices **130** formed in the side of the tubular member **114**.

Projecting downwardly into the relatively large diameter lower portion **104***a* of the working barrel **104** is the lower end portion of an actuator rod **132**. The actuator rod **132** has an upper collar **134** and a lower collar **136** spaced axially therealong and secured to the actuator rod for movement therewith. The power piston **108** slidingly surrounds the actuator rod **132** at a location between the upper collar **134** and the lower collar **136**.

It will be noted that the actuator rod **132** extends through a bore **140** formed through the center of the power piston **108** and that fluid leakage along the actuator rod **132** through this bore is prevented by an annular sealing element **142** disposed around the rod **132** and within the bore **140**. The actuator rod **132** extends upwardly and centrally within the relatively small diameter portion **104***b* of the working barrel **104**. It will be noted that the actuator rod **132** extends through the center of a hollow sleeve forming a lower slide valve member **146** and into proximity to the lower end of a hollow sleeve forming an upper slide valve member **148**. The actuator rod **132** is secured to the lower slide valve member **146** by a suitable spider **150** and is likewise secured by a suitable spider **152** to the lower end of the upper slide valve member **148**.

Between the lower slide valve member **146** and the upper slide valve member **148**, the actuator rod **132** extends through a central bore **154** which is centrally formed in a central divider block **156** secured transversely across the relatively small diameter upper portion **104***b* of the working barrel **104**. The central divider block **156** carries an annular sealing element **158** around the bore **154**, which sealing element sealingly engages the actuator rod **132** as the actuator rod reciprocates through the central divider block. A weight counterbalancing spring **160** is positioned between the upper side of the central divider block **156** and the spider **152** to carry or balance the weight of the slide valve assembly constituted by the lower and upper slide valve members **146** and **148**, respectively, and the actuator rod **132**.

Mounted on the wall of the relatively small diameter portion **104***b* of the working barrel **104** at the location which is aligned with the lower slide valve member **146** is a spring and ball assembly **162**. The spring and ball assembly **162** is constructed similarly to the spring and ball assemblies **46** and **48** which have been hereinbefore described in referring to the double-acting embodiment of the invention depicted in FIGS. **1—3**. Thus, the spring and ball assembly **162** includes a cap plate **164** which has a recess formed therein to accommodate a spring **166** which biases a ball **168** radially inwardly through an aperture or opening formed in the side of the working barrel. The outer peripheral wall of the lower slide valve member **146** has a semispherical recess **170** formed therein adjacent the ball **168** so that the snap action to which reference has hereinbefore been made can be obtained as the lower slide valve member **146** is shifted.

In similar fashion, a spring and ball assembly **172** is secured to the relatively small diameter portion **104***b* of the working barrel **104** adjacent the upper slide valve member **148**. The spring and ball assembly **172** is constructed identically to the spring and ball assembly **162** and thus includes a cap plate **174** which is recessed to receive a spring **176** which biases a ball **178** inwardly against the wall of the upper slide valve member **148**. As illustrated in FIG. **4**, the ball **178** is positioned in an accommodating recess **180** formed in the outer peripheral wall of the upper slide valve member **148**. As will be hereinafter explained, when the slide valve assembly which includes the upper and lower slide valve members, **148** and **146**, respectively, is shifted, the ball **178** will be caused to move out of the recess **180** and onto the adjacent relatively smooth peripheral surface of the upper slide valve member.

It will be noted in referring to the upper slide valve member **148** that this slide valve member is ported and thus contains a pair of radial ports **182** and **184**. It will also be noted that the radial ports **182** and **184** are located between a series of annular sealing rings, these being designated by reference numerals **186, 188** and **190**. The lower slide valve member **146** also is provided with a pair of radial ports **192** and **194** extending through the wall thereof. Located on the opposite sides of the radial ports **192** and **194** are a series of annular sealing rings **196, 198** and **200**. The sealing rings **196, 198** and **200** extend around the outer periphery of the lower slide valve member **146** and sealingly engage the internal wall of the small diameter portion **104***b* of the working barrel **104**.

Extending from the upper end portion of the relatively small diameter portion **104***b* of the working barrel **104** is a first power fluid charging conduit **202**. It will be noted that the upper end of the first power fluid charging conduit **202** communicates with the interior of the working barrel **104** through a suitable fitting or port at a location which is immediately below the radial port **182** formed in the upper slide member **148**. At its other end, the first power fluid charging conduit **202** communicates with the lower end of the relatively large diameter portion **104***a* of the working barrel **104** through a suitable port or fitting.

A second power fluid charging conduit **204** is connected at its upper end to the interior of the working barrel **104** through a suitable port or fitting which, as illustrated in FIG. **4**, is aligned in one operative position of the pump with the radial port **184** in the upper slide valve member **148**. The lower end of the second power fluid charging conduit **204** is connected through a suitable port or fitting to the upper end of the relatively large diameter portion **104***a* of the working barrel **104** so that power fluid is charged from the second power fluid charging conduit **204** to a portion of the working barrel **104** which is above the power piston **108**.

A power fluid discharge conduit **206** extends from the bottom of the relatively large diameter portion **104***a* of the working barrel **104** and is communicated with the interior of the working barrel through a suitable port or fitting located opposite the lower slide valve member **146**. As illustrated in FIG. **4**, in one operative position of the pump, the upper end of the power fluid discharge conduit **206** registers with the radial port **192** formed through the lower slide valve member **146** so that power fluid discharged from the working barrel during one portion of the stroke of the power piston **108** is forced through the conduit **206** and through the radial port **192** to the interior of the hollow sleeve constituting the lower slide valve member **146**.

A second power fluid discharge conduit **208** extends from the upper portion of the relatively large diameter portion **104***a* of the working barrel **104** and is connected at its upper end to the relatively small diameter portion **104***b* of the working barrel at a location which is opposite the lower slide valve member **146**. At this location, the upper end of the power fluid discharge conduit **208** can be communicated with the hollow interior of the lower slide valve member **146** through the radial port **194** at a time when the slide valve assembly is shifted as hereinafter described. Positioned immediately below the central divider block **156** and above the lower slide valve member **146** is a radial port **210** which opens through the relatively small diameter portion **104***b* of the working barrel **104** so as to place the interior of the working barrel in communication with the annulus between the outer tubing **100** and the working barrel **104**. This annulus is continuous, and in communication, with an annulus formed between the inner tubing **102** and the outer tubing **100**, and this annulus extends all the way to the surface for the purpose of returning power fluid and production fluid to the surface as hereinafter explained.

Secured to the lower end of the pump barrel **120** is a standing valve housing **212**. The standing valve housing **212** contains a movement limiting spider **214** which limits the upward movement in the standing valve housing of a standing valve ball **216**. The standing valve ball **216** is shown seated upon a seat formed at the upper end of a port or orifice **218** which permits the interior of the standing valve housing **212** to communicate with a sandpipe **220** when the standing valve ball **216** is unseated as hereinafter explained.

Operation of the Embodiment of the Invention Depicted in Figure 4

Upon commencement of the operation of the single-acting pump embodiment of the invention depicted in FIG. **4**, power fluid is delivered from the surface of the ground down the hole to the pump via the inner tubing **102**. The power fluid thus delivered to the pump passes into the interior of the upper slide valve member **148**. This fluid, however, cannot pass the central divider block **156** so as to enter the lower portion of the working barrel **104**. The power fluid, in the illustrated status of the pump, passes through the radial port **184** and enters the second power fluid charging conduit **204**. From this conduit, power fluid is charged to the upper end of the relatively large diameter portion **104***a* of the working barrel **104**. As the power fluid enters this portion of the working barrel, it forces the power piston **108** downwardly in the relatively large diameter portion **104***a* of the working barrel **104**.

Downward movement of the power piston **108** forces any liquid which may be located therebelow out through the power fluid discharge conduit **206** which, as illustrated, is at this time communicated with the interior of the working barrel through the radial port **192** formed in the lower slide valve member **146**. The fluid which is forced through the power fluid discharge conduit **206** will actually be a mixture of power fluid and production fluid, as production fluid has previously been drawn into the lower end of the relatively large diameter portion **104***a* of the working barrel **104** in a manner hereinafter to be described. As the mixture of power fluid and production fluid passes into the hollow interior of the working barrel **104** through the radial port **192** formed in the lower slide valve member **146**, this fluid accumulates above the partition **106**, and ultimately will flow through the radial port **210** into the annulus between the working barrel **104** and the outer tubing **100**. From this point, the fluid can be forced to the surface by the further downward movement of the power piston **108**.

It should be pointed out that the fluid which is forced from the space beneath the power piston **108** by the downward movement of the power piston cannot flow upwardly through the first power fluid charging conduit **202** due to the interruption of the communication of the upper end of this conduit with the interior of the working barrel **104** by the upper slide valve member **148**. In other words, at this time during the operation of the pump shown in FIG. **4**, the upper slide valve member **148** is in a blocking position which closes the entrance to the first power fluid charging conduit **202** and prevents power fluid from entering this conduit, and likewise prevents any fluid from being forced by the power piston **108** upwardly through this conduit and into the interior of the working barrel **104**.

As power piston **108** continues to move downwardly in the relatively large diameter portion **104***a* of the working barrel **104**, the elongated tubular member **114** and the pump piston **116** carried on the lower end thereof are also forced downwardly within the pump barrel **120**. If it be assumed that, at this time, production fluid has previously entered the pump barrel **120** via the sandpipe **212**, it will be seen that the effect of this downward movement of the elongated tubular member **114** and pump piston **116** is to force the standing valve ball **216** against its seat, and thus close the port **218** and prevent retrograde flow of production fluid out through the sandpipe **212**. The traveling valve ball **124**, on the other hand, is lifted off its seat **122** and production fluid can flow upwardly into the space beneath the traveling valve ball **124** and out through the radial orifices **130**. Thus, production fluid can fill the annular space between the elongated tubular member **114** and the pump barrel **120** during the downstroke of the power piston **108**.

As the power piston **108** moves downwardly to approach the lower end of the enlarged diameter portion **104***a* of the working barrel **104**, the power piston strikes the lower collar **136** secured to the lower end of the actuator rod **132** with the result that the actuator rod is forced downwardly. The downward movement of the actuator rod **132** necessarily carries with it in a corresponding downward movement the lower slide valve member **146** and the upper slide valve member **148** which are secured to the actuator rod through the spiders **150** and **152**, respectively. The shifting of the lower and upper slide valve members **146** and **148**, respectively, in this manner, initiates the throw or stroke of the slide valve assembly. This throw or shifting of the slide valve assembly is then carried through by the snap action which is developed by the ball and spring assembly **162**. In other words, as the ball **168** reaches the edge of the semispherical recess **170** formed in the outer periphery of the lower slide valve member **146**, the spring **166** biases the ball into this recess, and the slide valve assembly is snapped downwardly to complete its downward shift to the second alternate position which is to effect stroke reversal as hereinafter described. At the same time, the initial contact of the power piston **108** with the collar **136** formed on the lower end of the actuator rod **132** moves the upper slide valve member **148** to a position such that the ball **178** rides on the outer peripheral surface of the upper slide valve member and leaves the recess **180**.

As the slide valve assembly is shifted in the manner described, the effect of the shift is to interrupt communication of the interior of the working barrel **104** with the second power fluid charging conduit **204** by moving the radial port **184** downwardly out of registry with the entrance to this conduit. Simultaneously, the radial port **182** in the upper slide valve member **148** is moved downwardly into registration with the opening into the first power fluid charging conduit **202**. Thus, at this time, power fluid is able to pass from the upper end of the working barrel **104** into the first power fluid charging conduit **202** and downwardly in this conduit to enter the lower end of the relatively large diameter portion **104***a* of the working barrel **104**. Power fluid is thus now being delivered to the underside of the power piston **108**. Simultaneously with the shifts of the upper slide valve member **148** in the manner described to change the status of the radial ports **182** and **184**, the lower slide valve member **146** shifts downwardly so that the radial port **192** moves out of registry with the opening in the upper end of the power fluid discharge conduit **206** and the radial port **194** is moved into registry with the upper end of the power fluid discharge conduit **208**.

As power fluid commences to act against the lower side of the power piston **108**, the downward movement of the power piston **108** is completely arrested and stroke reversal occurs. The power piston **108** thus commences to move upwardly in the relatively large diameter portion **104***a* of the working barrel **104**. This movement of the power piston **108** forces liquid located above the power piston out through the power fluid discharge conduit **208** and through the radial port **194** into the hollow interior of the lower slide valve member **146**. This discharge power fluid is then free to flow through the radial port **210** in the working barrel **104** into the annulus between the working barrel and the outer tubing **100**. The upward movement of the power piston **108** also creates a reduced pressure in the lower end of the relatively large diameter portion **104***a* of the working barrel **104** with the result that production fluid which has been moved into the annulus between the pump barrel **120** and the elongated tubular member **114** in the manner hereinbefore described is drawn upwardly into the space beneath the power piston **108** where it is mixed with the incoming power fluid. The upward movement of the production fluid is also caused by the pumping action developed by the pump piston **116**. At this time, the traveling valve member **124** is seated on the seat **122** so that retrograde flow of this production fluid cannot occur. At the same time, the upward movement of the pump piston **116** results in additional production fluid being drawn upwardly through the sandpipe **212** and through the port **218** which is then opened by the unseating of the standing valve **216**. Production fluid thus moves upwardly through the standing valve housing **212** and fills the lower end of the pump barrel **120**.

As the power piston **108** approaches the upper end of the enlarged diameter portion **104***a* of the working barrel **104**, it strikes the upper collar **134** on the actuator rod **132** to commence the upward shifting movement of the slide valve assembly which includes the upper slide vale member **148** and the lower slide valve member **146**. This upward shifting of the slide valve assembly is carried through by the snap action effected by the spring and ball assembly **162**. Thus, the pump is, at this time, returned to the status depicted in FIG. **4**, and the stroke of the pump is completed. It will be noted that, in this embodiment of the invention, both the power fluid and the production fluid produced by the pump are returned to the surface by circulation of the fluid mixture through the radial port **210** and into the annulus between the working barrel **104** and the outer tubing **100**.

From the foregoing description of the invention, it will have become apparent that it is an important object of the invention to provide an improved down hole hydraulic pump which employs a unique slide valve action by which the dual slide valves are positively snapped to one of two alternate positions to effect stroke reversal of the pump.

Although certain preferred embodiments of the invention have been illustrated in the drawings and hereinbefore described, it is to be understood that various changes and modifications of these embodiments can be effected without departure from the basic principles of the invention. Changes and innovations of this type are therefore deemed to be circumscribed by the spirit and scope of the invention.

What I claim is:

1. A hydraulic pump comprising:
   - a working barrel having an upper portion and a lower portion;
   - an upper power piston disposed in the upper portion of said working barrel;
   - a lower power piston disposed in the lower portion of said working barrel;

connecting rod means interconnecting said upper power piston and said lower power piston;

a central divider block extending transversely across the central portion of said working barrel and sealingly separating the upper portion of said working barrel from the lower portion of said working barrel, said central divider block sealingly surrounding said connecting rod means, said connecting rod means extending slidingly through said central divider block;

power fluid charging conduit means connected to, and communicating with, the interior of said working barrel at two locations spaced therealong for alternately driving said power piston means, first in one direction in said working barrel, then in the opposite direction in said working barrel;

power fluid discharge conduit means connected to, and communicating with, the interior of said working barrel at two locations spaced therealong, and spaced from said first-mentioned two locations for receiving power fluid discharged from said working barrel at different times during the reciprocation of said power piston means therein;

a slide valve assembly slidably positioned in said working barrel and including

a first slide valve positioned in said working barrel on one side of said central divider block over one of said first-mentioned two locations to close one point of communication of the interior of said working barrel with said power fluid charging conduit means, said first slide valve being movable to a second position to open said one point of communication of the interior of the working barrel with said power fluid charging conduit means;

a second slide valve positioned in said working barrel on the opposite side of said central divider block and over one of said second-mentioned two locations to close one point of communication of the interior of said working barrel with said power fluid discharge conduit means, said second slide valve being movable to a second position to open said one point of communication of the interior of said working barrel with said power fluid discharge conduit means;

means interconnecting said first and second slide valves for concurrent movement, said interconnecting means extending slidingly through said central divider block; and

a cam surface positioned adjacent said working barrel and movable with said first and second slide valves and interconnecting means;

means cooperating with said power pistons for transferring motion from said power pistons to said slide valve assembly; and

a spring-biased cam follower device resiliently bearing against said cam surface, and substantially immovable in an axial direction in said working barrel, said cam follower device cooperating with said cam surface to alternately snap said slide valve assembly between two operating positions in said working barrel in a reciprocating movement.

2. A hydraulic pump as defined in claim 1 wherein said pump includes one of said cam surfaces located on a portion of each of said slide valves;

and wherein said pump further includes one of said cam follower devices bearing against each of said cam surfaces, each of said cam follower devices comprising:

a rolling member contacting the respective cam surface and at least partially seated in an opening in the wall of said working barrel; and

a spring mounted on the wall of the working barrel and biasing the rolling member against the cam surface.

3. A hydraulic pump as defined in claim 1 wherein said pump further includes

a cam block mounted on said interconnecting means and carrying said cam surface; and

wherein said cam follower device comprises a spring and ball assembly mounted in the wall of said working barrel and cooperating with said cam surface.

4. A hydraulic pump comprising:

a working barrel having an upper portion and a lower portion;

a power piston means slidably disposed in the lower portion of said working barrel for reciprocation therein;

power fluid charging conduit means connected to, and communicating with, the interior of said working barrel at two locations spaced therealong for alternately driving said power piston means, first in one direction in said working barrel, then in the opposite direction in said working barrel;

power fluid discharge conduit means connected to, and communicating with, the interior of said working barrel at two locations spaced therealong, and spaced from said first mentioned two locations for receiving power fluid discharged from said working barrel at different times during the reciprocation of said power piston means therein;

a slide valve assembly slidably positioned in said working barrel and including

a first slide valve positioned over one of said first-mentioned two locations to close one point of communication of the interior of said working barrel with said power fluid charging conduit means, said first slide valve being movable to a second position to open said one point of communication of the interior of the working barrel with said power fluid charging conduit means;

a second slide valve positioned over one of said second-mentioned two locations to close one point of communication of the interior of said working barrel with said power fluid discharge conduit means, sad second slide valve being movable to a second position to open said one point of communication of the interior of said working barrel with said power fluid discharge conduit means;

an actuator rod secured to said first slide valve and said second slide valve and extending axially in said working barrel; and

a cam surface positioned adjacent said working barrel and movable with said first and second slide valves and with the actuator rod interconnecting said first slide valve and second slide valve;

a first collar secured around said actuator rod and positioned above said power piston;

a second collar secured around said actuator rod and positioned below said power piston;

a spring-biased cam follower device resiliently bearing against said cam surface, and substantially immovable in an axial direction in said working barrel, said cam follower device cooperating with said cam surface to alternately snap said slide valve assembly between two operating positions in said working barrel in a reciprocating movement;

a partition extending transversely across said working barrel between said slide valve assembly and said power piston and sealingly separating the portion of the working barrel containing said power piston from the portion of said working barrel containing said slide valve assembly, said partition slidingly receiving said actuator rod therethrough; and

a divider block positioned between said first slide valve and said second slide valve and extending sealingly across said working barrel, and slidingly receiving said actuator rod therethrough.

5. A hydraulic pump comprising:

a working barrel having an upper portion and a lower portion;

an upper power piston slidably positioned in the upper portion of said working barrel for reciprocation therein;

a lower power piston slidably disposed in the lower portion of said working barrel for reciprocation therein;

connecting rod means interconnecting said upper power piston and said lower power piston;

power fluid charging conduit means connected to, and communicating with, the interior of said working barrel at two locations spaced therealong for alternately driving said power pistons, first in one direction in said working barrel, then in the opposite direction in said working barrel;

power fluid discharge conduit means connected to, and communicating with, the interior of said working barrel at two locations spaced therealong, and spaced from said first-mentioned two locations for receiving power at different times during the reciprocation of said power pistons therein;

a slide valve assembly slidably positioned in said working barrel in axial alignment with said power pistons and including

a first slide valve positioned in said working barrel in axial alignment with said power pistons and over one of said first-mentioned two locations to close one point of communication of the interior of said working barrel with said power fluid charging conduit means, said first slide valve being movable axially in said working barrel to a second position to open said one point of communication of the interior of the working barrel with said power fluid charging conduit means;

a second slide valve positioned in said working barrel in axial alignment with said power pistons and over one of said second-mentioned two locations to close one point of communication of the interior of said working barrel with said power fluid discharge conduit means, said second slide valve being movable to a second position to open said one point of communication of the interior of said working barrel with said power fluid discharge conduit means;

means extending axially in said working barrel and interconnecting said first and second slide valves for concurrent axial movement in said working barrel; and

a cam surface positioned adjacent said working barrel and movable with said first and second slide valves and interconnecting means;

means cooperating with said power piston means for transferring motion from said power piston means to said slide valve assembly;

a spring-biased cm follower device resiliently bearing against said cam surface, and substantially immovable in an axial direction in said working barrel, said cam follower device cooperating with said cam surface to alternately snap said slide valve assembly between two operating positions in said working barrel in a reciprocating movement;

a standing valve housing secured to the lower end of said working barrel;

a standing valve in said standing valve housing;

means for conveying fluid from a fluid-producing formation around said pump to said standing valve housing;

conduit means connected to said working barrel below said lower power piston for receiving production fluid from said working barrel;

a second standing valve housing secured to the upper end of said working barrel;

a second standing valve in said second standing valve housing;

second conduit means connected to said second standing valve housing for receiving production fluid discharged through said second standing valve housing from said working barrel; and

third conduit means connected to said working barrel above said upper power piston for conveying fluid from a fluid-producing formation around said pump to the upper portion of said working barrel.

6. A hydraulic pump comprising:

a working barrel having an upper portion and a lower portion;

a power piston disposed in the lower portion of said working barrel;

power fluid charging conduit means connected to, and communicating with, the interior of said working barrel at two locations spaced therealong for alternately driving said power piston, first in one direction in said working barrel, then in the opposite direction in said working barrel;

power fluid discharge conduit means connected to, and communicating with, the interior of said working barrel at two locations spaced therealong, and spaced from said first-mentioned two locations for receiving power fluid discharged from said working barrel at different times during the reciprocation of said power piston therein;

a slide valve assembly slidably positioned in said working barrel and including

a first slide valve positioned over one of said first-mentioned two locations to close one point of communication of the interior of said working barrel with said power fluid charging conduit means, said first slide valve being movable to a second position to open said one point of communication of the interior of the working barrel with said power fluid charging conduit means;

a second slide valve positioned over one of said second-mentioned two locations to close one point of communication of the interior of said working barrel with said power fluid discharge conduit means, said second slide valve being movable to a second position to open said one point of communication of the interior of said working barrel with said power fluid discharge conduit means;

means interconnecting said first and second slide valves for concurrent movement; and

a cam surface positioned adjacent said working barrel and movable with said first and second slide valves and interconnecting means;

means cooperating with said power piston for transferring motion from said power piston to said slide valve assembly;

a spring-biased cam follower device resiliently bearing against said cam surface and substantially immovable in an axial direction in said working barrel, said cam follower device cooperating with said cam surface to alternately snap said slide valve assembly between two operating positions in said working barrel in a reciprocating movement;

a partition extending transversely across said working barrel between said slide valve assembly and said power piston and sealingly separating the portion of the working barrel containing said power piston from the portion of said working barrel containing said slide valve assembly;

a divider block positioned between said first slide valve and said second slide valve and extending sealingly across said working barrel;

a pump barrel connected to the lower end of said working barrel;

a pump piston slidably and reciprocably mounted in said pump barrel;

means connecting said pump piston to said power piston for movement therewith; and

traveling valve means in said pump piston for passing fluid from below to above said pump piston during the downward stroke thereof.

7. A hydraulic pump as defined in claim **6** wherein said power fluid charging conduit means comprises:

a first charging conduit connected at one end to the upper portion of said working barrel at a location aligned with said first slide valve, and connected at a second end to the lower portion of said working barrel at a location above said power piston; and

a second charging conduit connected at one end to the upper portion of said working barrel at a location aligned with said first slide valve, and connected at a second end to the lower portion of said working barrel at a location below said power piston.

8. A hydraulic pump as defined in claim 7 wherein said power fluid discharge conduit means comprises:

a first discharge conduit having one end connected to the lower portion of said working barrel below said power piston, and having a second end connected to the upper portion of said working barrel at a location aligned with said second slide valve; and

a second discharge conduit having one end connected to the lower portion of said working barrel above said power piston, and having a second end connected to the upper portion of said working barrel at a location aligned with said second slide valve.

9. A hydraulic pump as defined in claim 8 and further characterized to include fluid passageway means for conveying fluid from a location within said working barrel above said partition to the surface.

10. A hydraulic pump as defined in claim 9 wherein said cam surface is formed on at least one of said slide valves.

11. A hydraulic pump as defined in claim 10 wherein said interconnecting means comprises an actuator rod secured to said first slide valve and said second slide valve and extending axially in said working barrel and slidingly through said divider block, partition and power piston; and

wherein said means cooperating with said power piston means comprises:

a first collar secured around said actuator rod and positioned about said power piston; and

a second collar secured around said actuator rod and positioned below said power piston.

12. A hydraulic pump as defined in claim 11 wherein said fluid passageway means comprises:

annulus-defining tubular means surrounding said working barrel; and

a port through said working barrel between said slide valves communicating with the annulus between said working barrel and tubular means.

13. A hydraulic pump comprising:

a working barrel having an upper portion and a lower portion;

a power piston slidably positioned in the lower portion of said working barrel for reciprocation therein;

power fluid charging conduit means connected to, and communicating with, the interior of said working barrel at two locations spaced therealong for alternately driving said power piston, first in one direction in said working barrel, then in the opposite direction in said working barrel;

power fluid discharge conduit means connected to, and communicating with, the interior of said working barrel at two locations spaced therealong, and spaced from said first-mentioned two locations for receiving power fluid discharged from said working barrel at different times during the reciprocation of said power piston means therein;

a slide valve assembly positioned in said working barrel in axial alignment with said power piston and slidably movable in said working barrel, said slide valve assembly including

a first slide valve positioned in said working barrel in axial alignment with said power piston and over one of said first-mentioned two locations to close one point of communication of the interior of said working barrel with said power fluid charging conduit means, said first slide valve being movable to a second position to open said one point of communication of the interior of the working barrel with said power fluid charging conduit means;

a second slide valve positioned over one of said second-mentioned two locations to close one point of communication of the interior of said working barrel with said power fluid discharge conduit means, said second slide valve being movable to a second position to open said one point of communication of the interior of said working barrel with said power fluid discharge conduit means;

an actuator rod interconnecting said first and second slide valves and extending axially in said working barrel, said actuator rod being secured to said first and second slide valves;

a cam surface positioned adjacent said working barrel and movable with said first and second slide valves, and with said actuator rod;

a divider block positioned between said first slide valve and said second slide valve and extending transversely and sealingly across said working barrel;

means cooperating with said power piston for transferring motion from said power piston to said slide valve assembly; and

a spring-biased cam follower device resiliently bearing against said cam surface, and substantially immovable in an axial direction in said working barrel, said cam follower device cooperating with said cam surface to alternately snap said slide valve assembly between two operating positions in said working barrel in a reciprocating movement.