Aug. 21, 1962 P. S. BLOUDOFF 3,050,038

VALVE MECHANISM FOR FLUID OPERATED DOWNWELL PUMPS

Filed Feb. 21, 1961 2 Sheets-Sheet 1

Fig. 2.

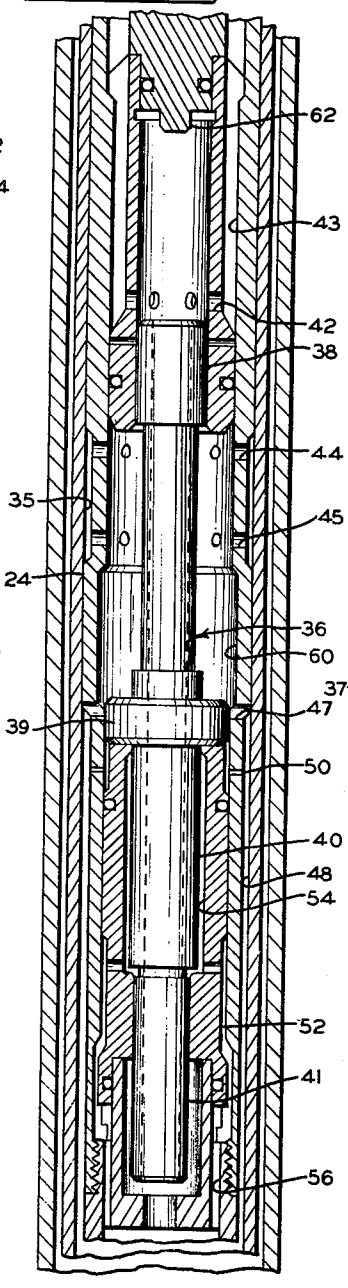


Fig. 3.

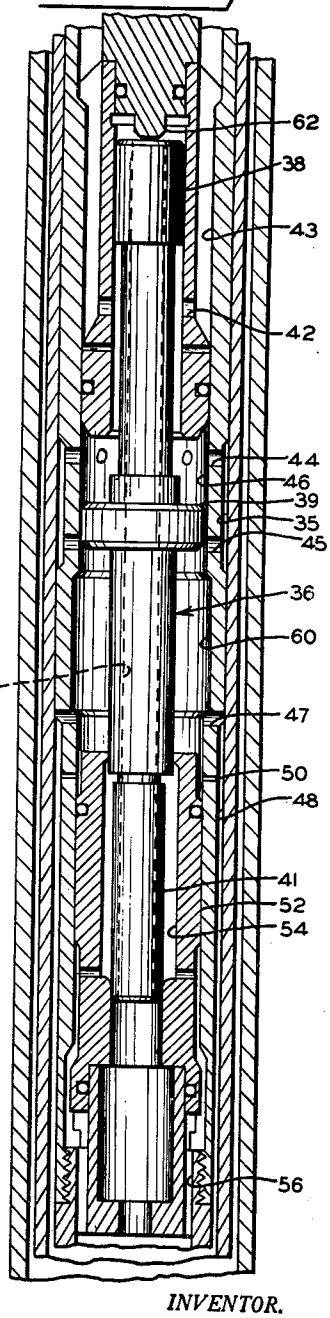
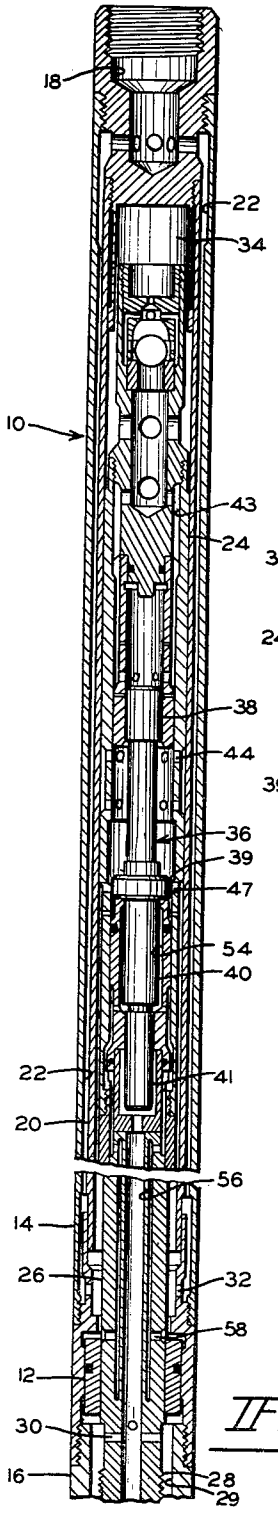


Fig. 1.



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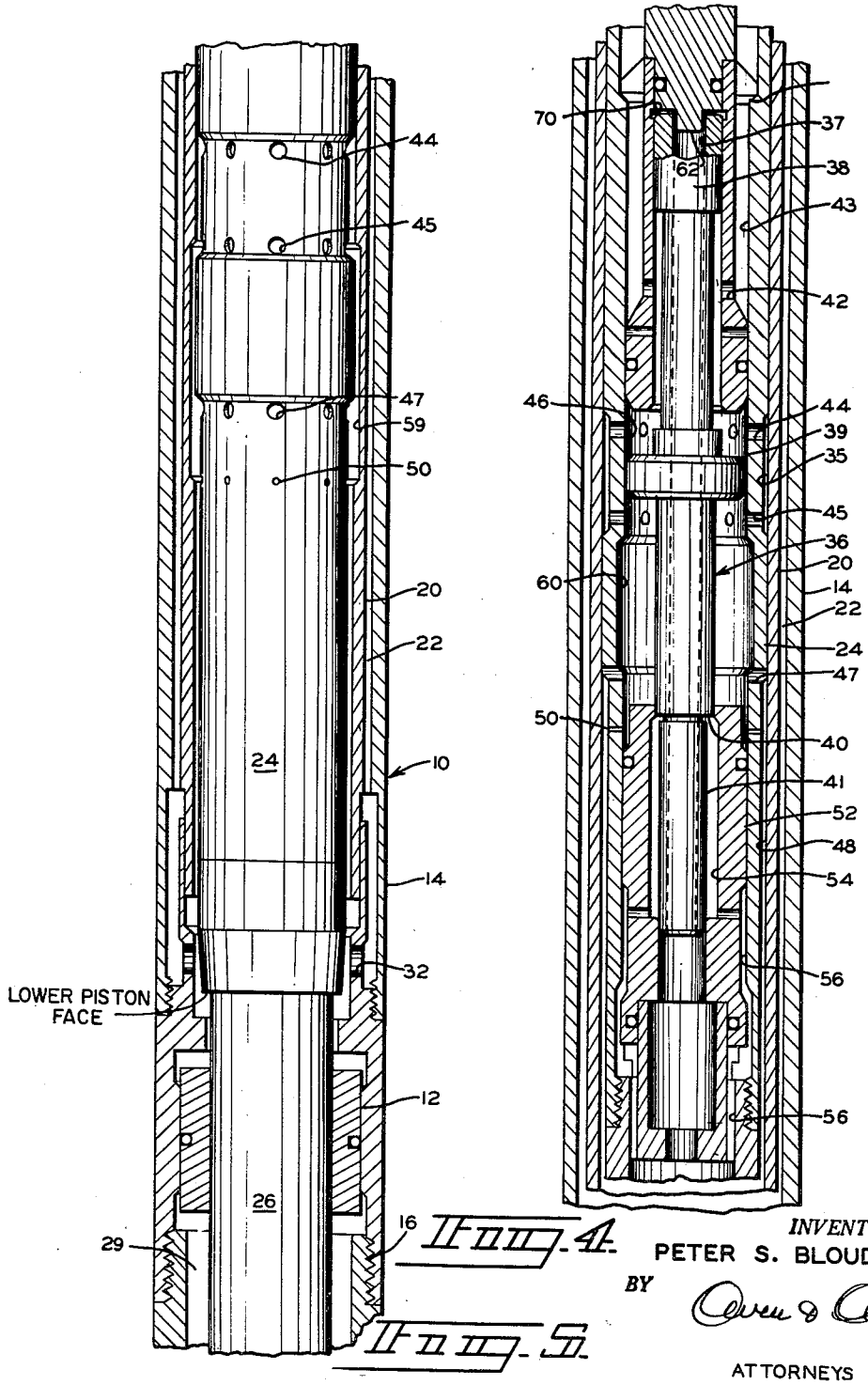


Fig. 4.

Fig. 5.

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3,050,038
VALVE MECHANISM FOR FLUID OPERATED DOWNWELL PUMPS

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This invention relates to fluid operated downwell pumps and is particularly directed to the valve mechanism for the operating engine of such a pump.

In general, a fluid operated downwell pump as used for deep oil wells, for example, includes superimposed but separate engine and pump cylinders and a reciprocating engine piston to which a pump piston is attached, the pump piston operating in its own cylinder either as a double-acting or a single-acting device. The operating fluid for the engine is usually clean crude oil conveyed from the surface under very high pressure either in a separate tubing string or in the suitably packed well tubing in which the pump and engine cylinders are set. The pump can, as is known in the art, be operated as a "free pump" in which case it can be pumped out through the well tubing, or as a fixed pump in which case power oil may be supplied through a separate macaroni string within the well tubing. Production fluid discharged by the pump is taken to the surface through a separate discharge conduit at "exhaust" or discharge pressure. The spent power oil, after being used for actuation of the engine piston, may be intermingled with the pump discharge or may be returned to the surface separately. All of these various combinations of tubings and conduits are well known in the art.

In many of the pumping devices known in the art the engine piston is of the differential area type in which power oil at high pressure appears constantly below the engine piston while valve means are prvided to connect the top portion of the engine cylinder above the piston alternately to a discharge conduit and to the source of power oil. Since the effective area of the top of the engine piston is larger than the effective area of its lower face because of the presence of the connecting rod between the engine and pump pistons, the engine piston will move downwardly if the pressure on its upper face is approximately the full power oil pressure. In the pump of the present invention, the pressure is slightly diminished during the down stroke, but the existing pressure times the area of the top of the piston is still greatly in excess of the product of the power oil pressure and the area of the lower piston face. Thus a large force is available to cause a down stroke of the pump piston. The upstroke of the engine piston is caused by the difference in pressures on the two faces of the engine piston, the lower face being at high pressure and the upper face being at exhaust pressure.

It is also known in the art that the valve which controls the flow of power oil into the top of the engine cylinder and which causes this space to be connected to discharge can be carried within the engine piston itself. There are many advantages derived from this disposition of the parts, all of which have been recognized and fully explained in Patent 2,921,531, issued January 19, 1960, for the invention of John R. Brennan and Peter S. Bloudoff, entitled "Pressure Fluid Operated Pump Structure." Since the valve is disposed within the reciprocating piston, it can test be operated hydraulically. To this end, it has been proposed in the above patent and in the patents to Roy H. Deitrickson Nos. 2,966,893; 2,966,894 and 2,966,-895, to provide the valve body section of the engine piston with passages which will subject a differential area portion of the valve to high pressure at one end of the stroke and in this manner cause reversal of the valve. The opposite reversal can be brought about either by a decided change in pressure on one or more surfaces of the valve or by causing a biasing force which has been acting on the valve body to diminish or disappear.

Valve mechanisms are known in which a pressure differential acting on equal areas of the valve body causes the valve to remain in an attained operative position. The force resulting from the pressure differential acts as a biasing force overcoming a smaller force which tends always to shift the valve body to its opposite position. Thus, if and when the pressure differential disappears, which event usually occurs at the end of the stroke of the engine piston in one direction, the valve will move to its opposite operative position. One of the recognized methods of inducing a usable pressure differential is to cause a flow of engine operating fluid over an enlarged portion of the valve body so that the flowing fluid can expand to a reduced pressure in the space at the "downstream" side of the enlarged valve portion. Another recognized method of inducing such a pressure differential is to cause the high pressure power oil to flow through a restricted port or passage so that the pressure on the "downstream" side of the port or passage is less than the pressure on the "upstream" side thereof.

In the prior patent to Brennan and Bloudoff, abovementioned, the valve or valve spool is maintained in its operative position during the down stroke by reason of the existence of a higher pressure on the lower side of a valve collar than on the upper side, the spool being biased downwardly against this force. In that patent the restriction which causes the drop in pressure above the valve collar is caused by choking off the flow through a port entering a restricted passage for power oil which thus flows through both radial and axial passages drilled in the valve collar itself.

In the present invention the pressure differential needed to act on the valve body is brought about by flowing the hydraulic fluid at high pressure into a chamber defined on one side by a tightly fitting, solid valve collar, flowing the fluid out of the chamber into an annular space formed by a reduced diameter portion of the piston through a peripheral series of ports and reintroducing the fluid into the space on the opposite or upper side of the solid collar. The constantly operating force which is counteracted by the aforementioned biasing pressure differential acts in a direction tending to close the first peripheral series of ports and thereby to choke off the flow of high pressure oil out into the annular space from beneath the collar. As the flow is progressively restricted by movement of the collar over the ports, the pressure above the collar is progressively reduced and the pressure beneath the collar then predominates to the point that the force urging the valve body to reverse is balanced out. When the pressures above and below the collar are equalized, either by reducing the pressure on the lower side or increasing the pressure on the upper side the pressure acting against the biasing force is no longer sufficient to hold the valve body against the reversing force and the valve shifts to its opposite position. In the present invention, means are provided to "short-circuit" the ports into and out of the annular space and thus to increase the pressure above the valve collar at the end of a normal down stroke, but means are also provided by which the valve will shift in the event of an interrupted down stroke caused, for example, by the accumulation of sand in the pump, or for any other reason.

While the operation of the valve spool is very similar to that shown and described in the Brennan and Bloudoff Patent 2,921,531, the spool itself is greatly simplified mechanically and the time required to machine it is greatly

reduced. The cost of the downwell pump can likewise be reduced and its use correspondingly extended.

The solid collar valve spool and the new disposition of the power oil ports employed in the present invention also lead to a faster reversal of the valve in response to the forces tending to switch it from one position to the other. In the valve of the prior patent, it was necessary for the spool to pass over a plurality of axially spaced ports in its traverse from one position to the other. In the present invention, the spool effectively passes over only one peripheral series of ports in moving from its down stroke to its upstroke position.

The port arrangement utilized in the present invention also assures that there is never a quiescent body of oil standing in a chamber on either side of the valve spool collar, and that the entire flow path of the power oil is purged at each down stroke of the engine piston. Thus, any solid particles which might be entrained in the power oil cannot settle out into areas that have no substantial flow to cause sluggish movement and possible seizure of the valve spool.

Since the areas over which the valve spool must be closely fitted in its sleeve are reduced in the present invention, it becomes possible deliberately to open up the space around the spool during shifting and thus greatly increase the speed of switching at the top reversal as will become apparent hereinafter.

The primary object of the present invention is to provide a valving system for a fluid operated downwell pump which is less expensive to manufacture and which has improved operating characteristics as outlined above.

Other objects and advantages of the invention will become apparent from the following detailed description of a preferred embodiment, reference being had to the accompanying drawings, in which:

FIGURE 1 is a central vertical sectional view with parts broken away of a hydraulic motor having a valve mechanism constructed in accordance with the present invention, provision for attachment to the associated pump structure being indicated;

FIG. 2 is a central vertical sectional view, on a somewhat larger scale, of the valve mechanism alone, the valve spool standing in the position that it assumes during the upstroke of the pistons;

FIG. 3 is a view similar to FIG. 2 with the valve spool standing in the position that it assumes during the down stroke of the pistons;

FIG. 4 is a view similar to FIGS. 2 and 3 with the valve spool standing in the position that it assumes immediately after the reversal at the top stroke of the pistons; and

FIG. 5 is a fragmentary sectional view through the engine and pump cylinders with the engine piston shown in elevation and in the position of bottom reversal, or at the extreme lower end of its normal stroke.

The drawings show the outer casing of the downwell pump unit at **10**, this casing being divided by an intermediate packer **12** into an upper engine section **14** and a lower pump section **16** which is broken away except for its extreme upper end. Power oil from the surface is introduced into the engine section from a fitting having a central passage **18** which may be threaded into a conventional swab nose section in the case of a free pump or may receive a macaroni string in the case of a fixed pump as is well known in the art.

An engine cylinder **20** is carried within the engine casing section **14** and the annular space **22** between the cylinder and casing receives power oil from the passage **18** and thus forms a power oil supply passage for the hydraulic engine.

An engine piston **24** is carried for reciprocation within the engine cylinder **20** and is connected by a polish rod **26** to the pump piston (not shown) by a threaded connection **28**, the rod **26** extending through the packer **12** in the usual manner. The space **29** below the packer **12** is constantly at discharge pressure and in communication with the surface through passages that are not shown. This space is used, therefore, to accept spent power oil which flows from the engine in a discharge passage **30** through the hollow rod **26**.

The engine cylinder **20** is formed with a peripheral series of power oil supply ports **32** at its lower end, which open from the power oil annulus **22** into the space beneath the engine piston. The lower piston face is, therefore, constantly subjected to power oil pressure.

The space in the engine cylinder **20** above the engine piston is designated **34** in the drawings and, as is well known in the art, this space is alternately filled with power oil and connected to discharge, and these pressure fluctuations cause the engine piston to reciprocate. When the pressure in space **34** is nearly equal to the full power oil pressure the piston will make a down stroke because the effective area of the top of the piston is greater than the effective area of the bottom due to the presence of the rod **26**, the lower end of which is subject only to discharge or static pressure. The upstroke of the piston takes place when space **34** is connected to discharge pressure, and is caused by the predominance of pressure on the lower face of the piston.

The engine piston **24** fits closely in its cylinder **20** throughout a major portion of its length, but in the present instance is relieved intermediate its ends opposite the valve mechanism to be described so that an annular chamber **35** is formed which is a part of the path of power oil flow.

The valve mechanism of the present invention is carried within the piston and includes a reciprocating spool **36** having a continuous central discharge passage **37** formed therein. The reciprocating spool is formed to provide a land **38** at its upper end to control flow to and from the space **34** over the piston, and below this land a reduced portion followed by an imperforate switching or control collar **39**. Below the control collar **39** the valve spool includes a differential area positive reversing portion comprising a larger diameter **40** and a small diameter lower extension **41**. The valve spool cooperates with valve body members which may be separate elements for ease of machining, or may be portions of the interior of the piston. In either case, the valve body elements are formed with ports **42** at the top which lead to axial passages **43** extending upwardly to communicate with the space **34** over the top of the piston **24**. These ports **42** are opposite the top land **38** of the valve spool and are opened thereby to receive power oil on the down stroke or to discharge oil from space **34** through the central spool discharge passage **37** on the upstroke. Below the top operating land, and opposite the collar **39**, the valve body member (in this case the wall of the piston **24**) is formed with two spaced series of peripheral ports **44** and **45**. The lower series **45** may be considered as ports through which power oil flows out into the annular space or chamber **35**, and the upper series **44** as ports through which power oil reenters the space above the collar **39**. This space is designated **46** in the drawings and constitutes a flow chamber through which power oil passes during the down stroke. As will be more fully described hereinafter, the valve collar **39** operates to pinch off the ports **45** during the down stroke to reduce the pressure of the power oil which appears in the annular chamber **35** and in the flow chamber **46**.

At the lower end of the chamber in which the valve collar **39** reciprocates, the valve body is formed with power oil inlet ports **47** which communicate with the interior of the valve body and also connect to the space below the close fitting portion of the piston **24**. In the drawing this annular space is indicated at **48**. Immediately below this last series of inlet ports, the valve body is formed with dash-pot relief ports **50** the purpose of which will become apparent hereinafter.

The lower stem portion of the spool valve operates in a differential area valve body member **52** formed to accommodate the intermediate land formed by the two

differing spool diameters 40 and 41. The chamber 54 thus formed in the valve body is utilized as a valve reversing means, as in the prior Patent 2,921,531, above mentioned. Normally, the chamber 54 is connected to exhaust pressure through an axial passage 56 in the rod 26 which connects to radial rod ports 58. The rod ports 58 are so located that during reciprocation of the pump they normally communicate with the discharge pressure space 29 or face the interior of the packer 12. At the extreme upper end of the stroke of the engine piston, these ports 58 run out above the packer to the position shown in FIG. 1 and receive power oil from the engine cylinder 20. The power oil pressure thus appears instantly in chamber 54 and causes the valve spool to move upwardly because of the difference in area of the larger and smaller spool diameters 40 and 41 forming the intermediate valve-actuating land. This is a preferred means of reversing the valve at the top of the stroke, but is, of course, not the only means for accomplishing this motion.

The valve stands in its upper working position during the down stroke only because of the reduction in the pressure of the oil above the collar 39 caused by the pinching off of the ports 45. If the flow through ports 45 and 44 were to be reduced to any great extent, the flow-induced drop in pressure would disappear and the pressure above the collar would be equal to the pressure below it, and the valve spool would reverse. Thus, if the engine and pump pistons were to stop before reaching the full lower extent of their intended movement, the flow through ports 45 and 44 would drop to zero and a reversal of motion would take place. This is effective in the event of an accumulation of sand in the pump cylinder, for example, and under these conditions, the pump will short stroke until the sand is washed out or the cylinder cleaned.

Any other device for equalizing the pressures above and below the pump piston will bring about a bottom reversal.

For reversing the valve rapidly at the bottom of the stroke of the piston 24, the engine cylinder 20 is provided with a relieved or undercut section 59, best shown in FIG. 5. When the annular chamber 35 which bridges the upper and lower power oil comes into registry with this undercut section, the pressure reduction effected by the previously pinched-off ports 45 is eliminated and full power oil pressure appears immediately above the collar 39. The valve spool then moves promptly to its lower position, ready for an upstroke.

The reversnig movement of the valve spool is greatly improved in the present invention by relieving the inside of the valve body between ports 45 from which power oil flows beneath the collar on the down stroke and the power oil inlet ports 47, the relieved area being indicated at 60. It is not essential that the collar 39 fit the valve body in which it operates except in the region between the upper and lower power oil flow ports 44 and 45. During the transition of the valve spool from one operative position to the other it is desirable that oil flow freely around the collar 39, because the rapidity of the valve traverse can be greatly increased. However, since the valve travels rapidly in its reversing or switching movement, it is necessary to provide a dash-pot at each end of the valve stroke to slow it down to avoid hammering the valve body against the stationary parts of the system. At the top of the valve chamber, the dash-pot comprises a protuberance 62 which is of a size which closely fits the interior bore of the valve spool which has been designated as the discharge passage 37. Thus the periphery of the valve enters the space between the upper valve body member designated 31 and the protuberance 62 trapping a small body of oil in this space and letting the trapped oil out slowly into the discharge passage. At the lower end, the dash-pot action takes place between the collar 39 and the portion of the valve body immediately below the inlet ports 47. Oil trapped by the collar at this point is forced out through a few restricted dash-pot relief ports 50, thus slowing the motion of the valve spool downwardly at the lower end of its travel.

Operation

Upstroke.—During the upstroke of the pump and engine pistons, the valve spool 39 stands in its lower position. Ports 42 are open to connect the space 34 above the piston to discharge through the central passage 37 in the valve spool, through the hollow polish rod 26 to the space 29 above the pump piston via discharge passage 30. Power oil to force the engine piston upwardly enters from the power oil annulus 22 through the lower series of ports 32. The reversing chamber 54 is at low pressure. This position of the parts is shown in FIG. 2.

Upper reversal.—The upstroke continues until the rod ports 58 pull out of contact with the packer 12. Power oil from the lower end of the engine cylinder then enters the rod passages 56 through these rod ports, and appears in the reversing chamber 54. The high pressure in this chamber then acts on the differential area between the valve spool diameters 40 and 41 and force the valve spool to switch to its upper position. This position of the parts is shown in FIG. 1. The engine and pump pistons are now ready for the next down stroke. This upper reversal is substantially the same as that shown in the prior Patent 2,921,531.

Down stroke.—When the valve spool moves from its lower to its upper position at top reversal, it travels rapidly to a position beyond the desired stable position and the dash-pot formed by protuberance 62 and the hollow interior of the spool is relied upon to slow it down. The extreme upper position of the valve spool is shown in FIG. 4 and the trapped body of oil which slows and ultimately stops the motion of the piston is indicated therein at 70. It will be seen that the collar 39 stands now between the spaced annular series of power oil flow ports 44 and 45 and that the ports 42 are opened to power oil so that the full pressure of this oil appears in space 34 over the engine piston. Therefore, the piston starts downwardly.

Power oil enters from the inlet ports 47, flows through the space beneath the collar 39 and out through ports 45 into the annular space 35 around the reduced piston area and back by way of ports 44 into the flow chamber above the collar 39. From the flow chamber the oil passes to the top of the engine cylinder as above described. Since there is a flow of oil in the spaces above and below the collar 39 the chamber in which the valve spool reciprocates is purged or cleansed at each down stroke and there is little likelihood of solids settling out of the power oil to interfere with the proper action of the valve.

The down stroke begins, of course, with the reversing chamber 54 filled with oil at high pressure. This high pressure persists until the rod ports 58 move out of the lower end of the packer 12, at which time the chamber 54 goes to low pressure. The valve spool, which has been held up by the pressure in the reversing chamber now has a bias downwardly, and would reverse itself. However, when the collar 39 pinches off the lower power oil flow ports 45, the pressure of the oil above the collar is reduced by the amount of the pressure drop in the restricted passage thus formed. Thus the force down on the collar will reach a point of balance with the upward force of power oil beneath the collar. This operating position, which continues throughout the down stroke, is shown in FIG. 3. It will be seen from an inspection of the figure of the drawings that the solid collar 39 fits tightly against its surrounding surfaces and that the oil that is flowing to the top of the engine cylinder to cause the down stroke does not flow past the collar or over any of its contrlling surfaces so that the collar does not tend to become eroded by the rapid passage of oil thereover. The oil also flows into and out of the spaces above and

below the solid collar, so that there are no dead spaces in which foreign matter can accumulate to become later dislodged and which might interfere with the free sliding movement of the valve spool.

It will also be apparent that the solid valve collar, combined with the annular flow chamber **35** is much simpler mechanically than previously known devices accomplishing similar objects. The collar **39** is piloted in its reciprocation by the spool extensions above and below it and offers a simple and effective means to control the flow of operating fluid on the downstroke.

Bottom reversal.—The engine and pump pistons continue downwardly until some event occurs which will act to impose full power oil pressure on the upper surface of collar **39** which creates a definite downward force on the valve spool, and eliminates the biasing force which has been holding it up. This happens when the piston enters the lower dash-pot below inlet port **32** so that its motion is first slowed and then stopped, so that the flow through the restricted port **45** diminishes and ceases. In accordance with the form of the invention disclosed in the drawings, the cylinder relieved area **59** accomplishes a greatly increased speed of reversal by putting the annular chamber **35**, which normally contains power oil at a pressure reduced by the drop resulting from pinching off ports **45**, into direct communication with the full pressure of the oil beneath the piston **24**. The increase in pressure forces the valve to switch quickly to its lower position. As the valve collar **39** closes off the lower ports **45** on its reversing movement, there is no longer any reason to maintain a seal or close fit between the collar **39** and the body in which it operates. Therefore, the body can be relieved to permit oil to pass freely from one side of the collar to the other, which greatly increases the speed of the reversing movement of the valve spool. The relieved area is indicated at **60** in FIGS. 2 and 3. Since the valve spool is moved rapidly downward in its reversal, the motion must be cushioned at the bottom by the dash-pot effect of the oil trapped below the power oil inlet ports **47**. At this point the interior of the valve chamber is again made to have a close-clearance fit with the valve collar **39** and the trapped oil is metered out through the dash-pot relief ports **50**. The size of the ports **50** with relation to the volume of oil trapped beneath the collar will, of course, determine the dash-pot effect.

With the valve in its lower position, the space **34** above the engine piston is again open to exhaust through the communication of ports **42** and the discharge passage **37** through the center of the valve spool. The next succeeding upstroke then occurs and the cycle is repeated.

It will be seen that the present invention provides a simple, imperforate control collar for the valve spool operating in a chamber which is free of obstructions and which contains flowing oil at each reversal of the valve. Further, the present invention provides means to increase the speed at which the reversal can take place in each direction so that the tendency of the engine piston to "dwell" at the ends of its stroke is eliminated or substantially reduced.

While the invention has been disclosed in conjunction with a specific form and disposition of the parts, it should be appreciated that numerous modifications and changes can be made therein without departing from the scope of the appended claims.

What I claim is:

1. In a hydraulically actuated downwell pump of the type comprising a hydraulic engine having a reciprocating differential area piston actuated by power oil placed under pressure at the surface and in constant operative communication with the smaller of the differential areas of the piston, and having valve means controlling ports to apply power oil at substantially full pressure to the larger of the differential areas in a down stroke position and to connect said larger area to a discharge pressure in an upstroke position, the improvement comprising an elongated tubular valve spool member carried by and reciprocable in said piston and including an imperforate collar member, means to place the lower side of said valve collar member under constant power oil pressure, means forming a tubular valve body member in said piston in cooperative valving relationship with said valve spool member and having first and second spaced series of peripheral ports leading to an exterior annular chamber, a flow chamber above said valve collar and receiving power oil from said annular chamber through said second series of ports when said valve spool member stands in its down stroke position, whereby power oil flows into the space below said valve collar, through said first series of ports into said annular chamber, through said second series of ports into said flow chamber and thence through said valve controlled ports into the space above said piston, and means to cause a reversal of said valve spool from its down stroke position to an upstroke position.

2. In a hydraulically actuated downwell pump of the type comprising a hydraulic engine having a reciprocating differential area piston actuated by power oil placed under pressure at the surface and in constant operative communication with the smaller of the differential areas of the piston, and having valve means controlling ports to apply power oil at substantially full pressure to the larger of the differential areas in a down stroke position and to connect said larger area to a discharge pressure in an upstroke position, the improvement comprising an elongated tubular valve spool member carried by and reciprocable in said piston and including an imperforate collar member, means to place the lower side of said valve collar member under constant power oil pressure, means forming a tubular valve body member in said piston in cooperative valving relationship with said valve spool member and having first and second spaced series of peripheral ports leading to an exterior annular chamber, a flow chamber above said valve collar and receiving power oil from said annular chamber through said second series of ports when said valve spool member stands in its down stroke position, whereby power oil flows into the space below said valve collar, through said first series of ports into said annular chamber, through said second series of ports into said flow chamber and thence through said valve controlled ports into the space above said piston, an intermediate land formed on said valve spool having a downwardly acting differential area urging said valve spool in a direction to cut off flow through said first series of ports whereby said reduced flow causes the pressure in said flow chamber to be correspondingly reduced to a point of balance at which said first series of ports is partially closed, and means to equalize the pressure above and below said valve collar to cause a reversal of said valve spool by the force exerted by said differential area intermediate land.

3. In a hydraulically actuated downwell pump of the type comprising a hydraulic engine having a reciprocating differential area piston actuated by power oil placed under pressure at the surface and in constant operative communication with the smaller of the differential areas of the piston, and having valve means controlling ports to apply power oil at substantially full pressure to the larger of the differential areas in a down stroke position and to connect said larger area to a discharge pressure in an upstroke position, the improvement comprising an elongated tubular valve spool member carried by and reciprocable in said piston and including an imperforate collar member, means to place the lower side of said valve collar member under constant power oil pressure, means forming a tubular valve body member in said piston in cooperative valving relationship with said valve collar member and having first and second spaced series of peripheral ports leading to an exterior annular chamber, a flow chamber above said valve collar and receiving power oil from said annular chamber through said second series of ports when said valve spool member

stands in its down stroke position, whereby power oil flows into the space below said valve collar, through said first series of ports into said annular chamber, through said second series of ports into said flow chamber and thence through said valve controlled ports into the space above said piston, an intermediate land formed on said valve spool having a downwardly acting differential area urging said valve spool in a direction to cut off flow through said first series of ports whereby said reduced flow causes the pressure in said flow chamber to be correspondingly reduced to a point of balance at which said first series of ports is partially closed, and means operative at the lower end of the stroke of said piston to supply power oil directly to said annular chamber and said flow chamber at full pressure and thereby move said valve spool to its opposite position.

4. The improvement defined in claim 1, and said valve body having a relieved area, larger in diameter than said valve collar below said first series of annular ports, whereby oil can flow freely around said collar during the excursion of said valve spool from one operative position to another.

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