

May 16, 1961

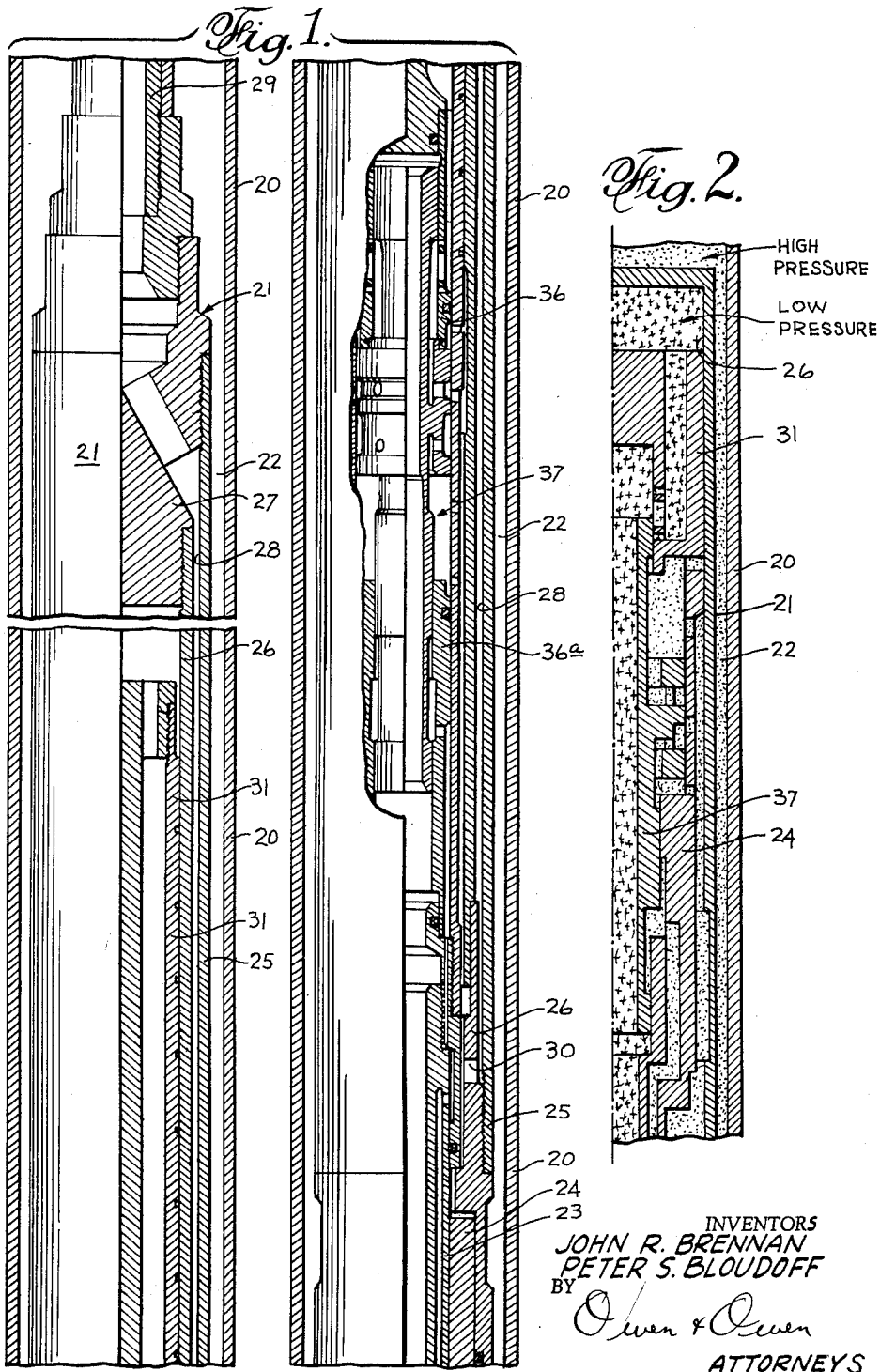
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2,984,224

REVERSING VALVES FOR FLUID OPERATED PUMPS

Filed Oct. 22, 1959

2 Sheets-Sheet 1



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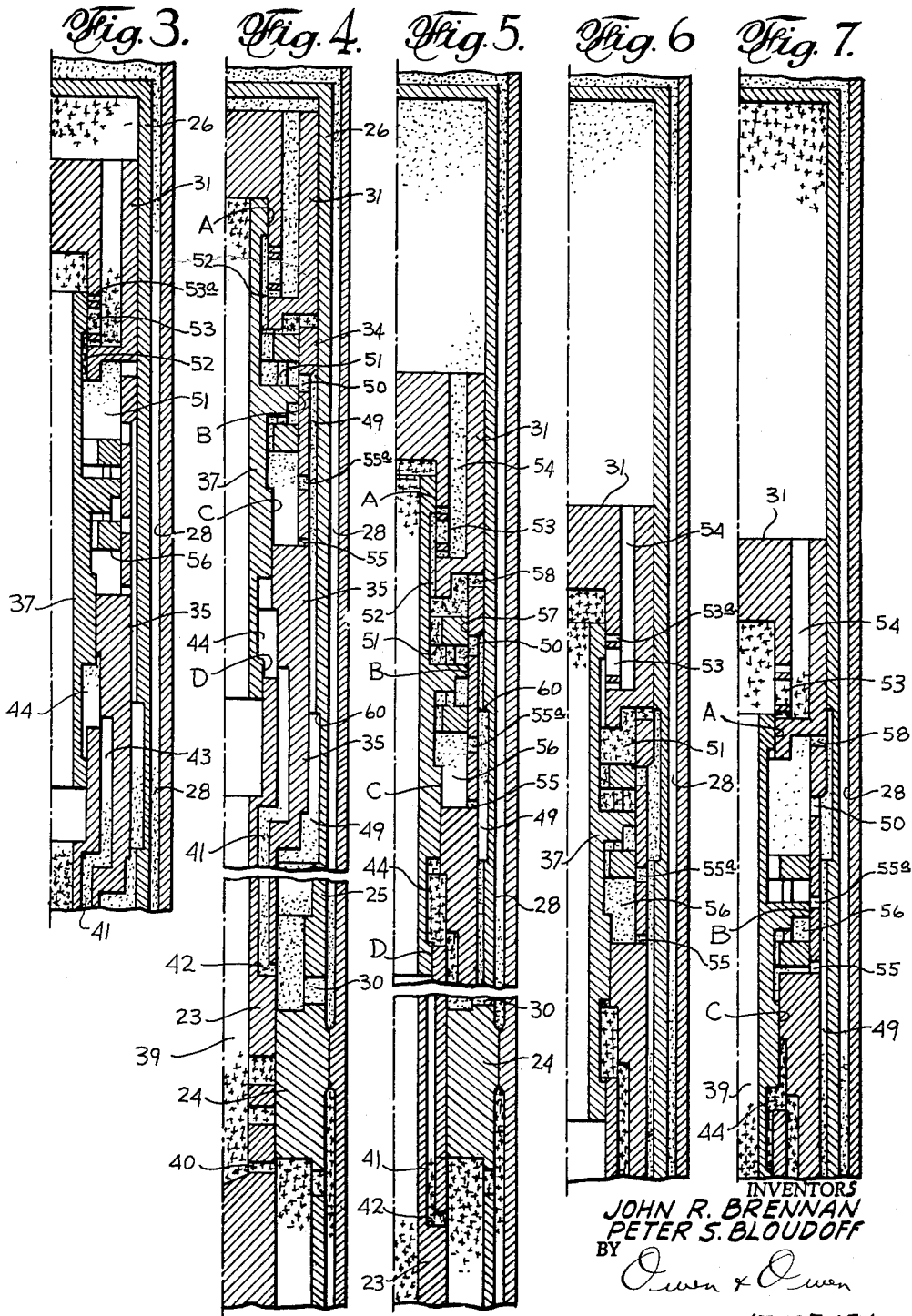
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REVERSING VALVES FOR FLUID OPERATED PUMPS

John R. Brennan, Long Beach, and Peter S. Bloudoff, Whittier, Calif., assignors, by mesne assignments, to Armco Steel Corporation, Middletown, Ohio, a corporation of Ohio

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4 Claims. (Cl. 121—150)

This invention relates to control valves for fluid operated downwell pumps and is particularly directed to a construction in which the control valve for directing fluid to the space above the engine piston, and for discharging fluid from such space, is carried within the piston.

The control valve of the present invention is utilized in a fluid actuated engine of the type having differential area upper and lower faces so that if the smaller face of the engine piston is exposed to high pressure fluid at all times, and the other and larger face of the piston is alternately exposed to high pressure and low pressure fluid, reversal of movement of the piston will occur.

The primary object of the invention is to provide a control valve for a fluid operated engine for a downwell pump in which a high reversing force for the valve is available at one end of the stroke of the engine piston, and in which reversal of the valve position at the opposite end of the stroke of the piston is caused normally by a change in a pressure condition on one or more of the valve surfaces.

Still another object of the invention is to provide a reversing valve of the character described in the preceding paragraph which includes provision for reversal of valve movement during a down stroke in the event that the stroke of the engine piston is stopped for any reason.

Another object of the invention is to provide a control valve for a fluid operated engine for a downwell pump in which a reversal at the bottom of the stroke is caused by the reduction in a holding force derived from a flow of fluid into and around the valve body, the valve body being normally biased to a reverse position by the fluid pressures acting on its surfaces.

Other objects and advantages of the invention will become apparent from the following specification, reference being had to the accompanying drawings, in which—

Fig. 1, in two sections, one of which is broken, is a longitudinal quarter-sectional view of a fluid operated engine for a downwell pump embodying the present invention;

Fig. 2 is a diagrammatic quarter-sectional view of the engine shown in Fig. 1, with the parts in the position occupied immediately prior to the top reversal of the engine piston;

Fig. 3 is a view similar to Fig. 2 showing the parts in the position occupied at the mid-point of the top reversal of the engine piston;

Fig. 4 is a view similar to Fig. 3 with the parts shown in the position occupied at the beginning of the down stroke of the piston, the valve having been shifted to its fully open position for admitting fluid to the top of the engine cylinder;

Fig. 5 is a similar view showing the parts in the position occupied during the down stroke;

Fig. 6 is a similar view showing the parts in the position occupied at the end of the down stroke and at the start of the lower reversal of the engine piston; and

Fig. 7 is a view similar to Fig. 6 showing the parts in the position occupied at the end of the lower reversal

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and the beginning of an upstroke of the engine piston.

The invention consists of a pressure actuated valve carried within the piston of a fluid operated engine, and reversing its position at the top and bottom of the stroke of the piston. At the position of top reversal, the actuation of the valve is caused by an application of high pressure fluid in a chamber around the valve body having differential area walls which pressure fluid acts to establish a temporary shifting force on the valve body, while at the bottom reversal position, the actuation of the valve is caused by a change in flow conditions of power oil passing into and around the valve body. When in one position, the valve serves to connect the engine cylinder above the piston with a source of high pressure operating fluid, while in its second position the valve serves to connect this same cylinder space with a lower, or discharge pressure. The engine cylinder contains oil at constant high pressure in the space below the engine piston.

As used in the following specification and in the claims, the term "hydraulic force" covers the summation of hydraulic forces acting at any given time in any one direction. The hydraulic force can be created in either of two ways: First, by exposing equal areas to different and oppositely acting pressures; secondly, by exposing different and opposed areas (or differential areas) to the same pressure. It should also be noted that, as used in the following specification, the terms "up" and "down" and other forms thereof such as "upwardly," "downwardly," "upstroke" and "downstroke" relate to the orientation of the embodiments described and are not limitations either upon the position of the parts in other embodiments of the invention or to be interpreted as limiting the invention to such positions or directions.

Reference numerals have not been carried to all of the figures of the drawings except to the extent necessary to explain fully the operative relationship of the parts and the hydraulic forces involved in each of the several positions of the valve occupied during reciprocation of the engine piston.

A control valve embodying the invention is intended to be employed with a fluid actuated engine for a downwell pump of the general type that is located at or near the bottom of a well and is shown as being received in and spaced from a string of tubing 20. The downwell pump comprising an engine section and a pump section is generally designated 21, and the annulus between the outside of the engine and pump and the inside of the tubing 20 is designated 22. This annulus may, if desired, be used to convey production fluid to the surface, or a separate pipe or conduit may be utilized for this purpose in a manner well known in the art. It will be assumed that the pump section itself is of a conventional construction, and that the pump piston is reciprocated by the engine piston through a rod 23. The rod 23 passes through a stuffing box 24 which separates the engine and pump sections. A jacket 25 extending above and below the stuffing box 24 forms the outer casing of the downwell pump, and the engine for the device is contained within the upper portion of the jacket above the stuffing box and the pump is contained in the lower section, below such stuffing box.

The engine for the downwell pump comprises a cylinder 26 which is carried by a fitting 27 at the top of the jacket 25 and which is spaced radially inward from the jacket to form an annulus 28. The annulus 28 is connected by the fitting 27 to a string of power oil tubing 29 which extends to the surface of the well so that the downwell pump in the form shown is of the "fixed" type, as distinguished from the "free" type in which power oil fills the well tubing and suitable packers are used

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around the downwell pump to confine the power oil to the desired space. Both types are well known in the art, and the present invention is equally applicable to both.

The power fluid annulus 28 is thus filled constantly with oil at high pressure from the tubing 29, and this annulus is connected by one or more radial ports 30 to the interior of the engine cylinder near the lower end thereof beneath the engine piston which is designated 31 in the drawings. This is most clearly shown in Fig. 4. Thus the lower portion of the engine cylinder is filled at all times with power oil at high pressure acting constantly upwardly against the lower surface of the engine piston 31.

The engine piston comprises a close fitting section 34 and a portion of smaller diameter therebelow which is designated 35 in the drawings. In general, the valve parts hereinafter described are contained within the smaller diameter portion of the piston.

Within the piston, a valve jacket designated 36, 36a is provided which is formed to cooperate with a spool-type valve the body of which is designated 37. The jacket itself is preferably made in upper and lower parts for ease of assembly and each part is drilled with the various supply and exhaust passages hereinafter described.

The spool valve 37 is a hollow cylindrical member guided by its various lands for reciprocation within the jacket 36, 36a. During the down stroke, the valve stands in an upper position, and during the upstroke of the piston 31 the valve stands in a lower position. The periphery of the valve is stepped to provide close fitting lands A, B, C and D which serve to separate fluids at various pressures from each other, and which also serve to provide differential areas shoulders against which pressures can act to move the valve body from one position to the other. A differential area shoulder occurs between lands of the valve and represents a step in diameter. Thus, a chamber formed by such lands or shoulders may have, for example, an area greater by .040 square inch on one side than on the other. If such a chamber is filled with oil at 2000 p.s.i. a force of 80 lbs. will be set up tending to move the valve in the direction of the larger area land or shoulder.

The engine piston 31 is, as above stated, connected to the pump piston by the piston rod 23 which is hollow and thus provides a central discharge passage. This discharge passage is designated 39 in the drawings and is connected to a series of discharge ports 40 which are at all times below the stuffing box 24 as is best indicated in Fig. 4 of the drawings.

The piston rod 23 is provided with an additional, separate longitudinal passage 41 which terminates in a lower lateral rod port 42 and at its upper end communicates with a passage 43 in the jacket 36a which, in turn, supplies or exhausts fluid to or from an annular space or chamber 44 between differential area lands C and D on the valve body. Since land D is made smaller in diameter than land C, the pressure of a fluid introduced into chamber 44 will tend to move the valve body upwardly. Such action will be described in connection with the "top reversal" of the valve hereinafter. As will also be more fully described hereinafter, the lateral rod port 42 moves temporarily above the stuffing box 24 at the end of the upward stroke of the engine piston with the result that the pressure conditions in passages 41 and 43 and in chamber 44 change abruptly at this point in the stroke of the engine piston.

In the drawings, spaces at low or discharge pressure are designated by small "x" marks or crosses while spaces at high pressure are shown by stippling. The pressures in certain passages or chambers such as the power oil annulus which is always at high pressure, and the central discharge passage 39 do not change. Other chambers and passages are at high and low pressure alternately as the valve body 7 is shifted from one position to another.

The valve body 37 has two positions of operation.

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It stands in an upper position during a down stroke of the engine piston and in a lower position during the upstroke of the engine piston. When the valve is in its lower position the engine cylinder space above the piston is connected to discharge through ports and passages which will be hereinafter described. When the valve is in its upper position, the ports and passages hereinafter described connect the power oil annulus 28 to the cylinder space above the engine piston 31. Since the area of the upper face of the engine piston is greater than the area of the lower face which is constantly subjected to power oil pressure, equal pressures in the cylinder space above and below the piston will cause a down stroke to occur.

Downstroke

Figure 5 of the drawings shows the valve body 37 in the position occupied while the engine piston is making a down stroke. Fluid is supplied from the power fluid annulus 28 through the main supply ports 30 below the engine piston. As above noted these ports are never cut off during operation, and the lower end of the power cylinder is constantly filled with high pressure power oil. Power oil is taken around the lower piston section 35 via the longitudinal annular space 49 to a supply port 50 in the side wall of the piston to a chamber 51 in the valve jacket 36, through an annular passage 52 formed between lands A and B on the valve body, through a radial port 53 in the valve jacket to an upwardly extending passage 54 which communicates with the cylinder space above the engine piston. Power oil is thus supplied to the upper cylinder volume and since, as above noted, the upper face of the engine piston has a greater effective area than the lower side thereof, due to the presence of the piston rod 23, the piston will move downwardly since the pressure times the area of the upper face is greater than the pressure times the area of the lower face.

During the downstroke of the piston the lateral rod port 41 in the wall of the piston rod 23 is below the stuffing box 24 and is thus exposed to oil at discharge pressure. The chamber 44 is thus at low pressure.

The supply passage 49 around the lower piston section 35 is formed, below the intermediate shoulder or land B with one or more serially related and spaced radial ports 55, 55a, leading into a chamber 56 between shoulders B and C.

The land B acts as a control collar for the valve body during the down stroke. Because land C is larger in area than land A, and because the shifting chamber 44 is at low pressure, there is biasing force acting down on the valve body which would move it to its lower reversed position unless it were counteracted in some way.

The biasing force is counteracted by the control collar or land B. It will be seen that chamber 56 below the land or collar contains oil at high pressure since it is in direct communication with the power oil through radial port 55. The force acts upwardly on the collar or land B and downwardly on land C. If the spool valve starts to move down, a port-restricting extension 57 of the valve starts to move across the supply port 50 and tends to reduce or restrict the flow. This causes a drop in pressure in the chamber 51 above the land B. The pressure above the land or collar is thus less than the pressure below it, and the valve body is held by this flow-induced pressure difference against the shifting or biasing force resulting from the high pressure on land C in chamber 56.

So long as the piston continues to move down by reason of a continued flow of power oil into and out of chamber 51 this state of equilibrium will continue with the valve in its upper position. However, should the piston stop its downward travel the pressure in chamber 51 above the collar or land B will quickly equal the pressure below the collar or land in chamber 56 and the valve body will reverse downwardly.

The down stroke continues under normal conditions

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until a positive movement of the piston opens chamber 51 to full pressure. To this end, the close fitting portion of the piston is provided with a radial port 58 which enters chamber 51 from above. Normally this port rides against and is closed by the wall of the engine cylinder. Near its lower end, however, the cylinder is provided with a stepped enlargement or shoulder 60 and when the radial port 58 opens into the space below the shoulder as shown in Fig. 6, the pressure in chamber 51 above the control collar or land B, and the pressure in chamber 56 below the land are equalized. The flow-induced force that previously held the valve up thus disappears and the valve will shift to its lower position, shown in Fig. 7, by reason of the biasing force on the top of land C.

It will thus be apparent that the shifting of the valve from its upper to lower position can be accomplished in either of two ways: First, by stopping the motion of the piston which will permit the pressure drop across the supply port 50 to become equalized, and secondly, by exposing the radial port 58 to high pressure. The first expedient for shifting the valve is utilized in the event that the normal down stroke of the pump cannot be completed for any reason such as the accumulation of sand in the pump cylinder. The second expedient for shifting the valve is that which is normally used and assumes that the engine piston has made a complete downward stroke.

When the valve has shifted to its lower position, the parts are ready to make an upstroke. The shifted position is shown in Fig. 7.

Upstroke

It will be seen from Fig. 7, that land A of the valve body 37 has opened port 53 and passage 54 to discharge through the central passage 39. The pressure on the lower face of the engine piston 31 has not changed, and hence this high pressure is available to cause the piston to move on an upstroke.

Chambers 51 and 56 are still connected by ports 50 and 55 to the power fluid passage 49 and hence contain oil at high pressure. Because land C is larger than land A, and because the pressure on each side of land B is balanced, the valve body is held in its lower position by a force equal to the difference in areas of lands A and C times the difference between the values of high and exhaust pressures. This is a positive and constant force and is unaffected by any flow conditions of the power oil passing into or around the valve body.

The upstroke continues until the piston 31 reaches the point where top reversal occurs, and the transition of the valve body from the lower position occupied during the upstroke to its reversed position is shown in Figs. 2, 3 and 4. In Fig. 2 the top reversal has just commenced, and in Fig. 3 the parts are shown in the mid-position and in Fig. 4 the parts are shown in the position when the reversal is complete.

The reversal of the valve at the end of the upstroke is caused by the lateral rod port 42 moving above the stuffing box 24 so that power oil can flow readily from the supply port 30 around the reduced lower section of the piston 31 and into the longitudinal passages 41 and 43 to chamber 44. Chamber 44 is between lands D and C, land D being the smaller in area. A high force upwardly is thus quickly imposed on the valve body 37 which is equal to the difference in areas between lands C and D times the pressure. The parts must be so designed that this force is greater than the force which held the valve in its lower position during the upstroke, which latter force resulted from the differential areas between lands A and C.

When the valve has moved partially upwardly as shown in Fig. 3, there is a temporary reduction in pressure in chamber 51 since this chamber is connected by its longitudinal passage 52 to the upper cylinder port 53, and the upper cylinder volume has been at discharge pressure. This temporary reduction in pressure is quite small, but

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it is sufficient to so reduce the downward force on the valve body by reducing the pressure in chamber 51 that completion of the reversal under the influence of the high pressure in chamber 44 is assured. The completely shifted position of the valve body 37 is shown in Fig. 4, wherein the parts are shown ready for the down stroke previously described.

Since, in hydraulic systems of the type exemplified by the present invention, it is desirable to avoid hydraulic hammer or shock, the present apparatus provides for means obviating a too rapid build up of pressure in any chamber. In the form shown, serially related spaced ports are used for this purpose. For example, at the top reversal position of the valve body 37, the valve changes the pressure above the piston 31 from low to high. It will be seen that, if any portion of the upper chamber supply port 53 remains open after the valve 37 starts up, there will be some upward movement of the piston. When the spool valve 37 starts to make its upward reversal, land A first covers the largest of the serially related ports 53, leaving open a smaller port 53a above it for a brief instant to cause a dissipation of any hydraulic shock that would be generated upon a complete closing of all ports at the same time. The same expedient is used in providing spaced serially related ports 55 and 55a for the power oil entering chamber 56. Port 55 can be made very small and used as a metering port while port 55a is made larger. Thus wherever a pressure condition changes in a chamber, provision is made for a relatively slower change in pressure rather than a rapid one such as would occur by the full uncovering of a large port.

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

This application is a continuation-in-part of our co-pending application Serial No. 721,178, filed March 13, 1958, now Patent No. 2,921,531.

What we claim is:

1. In a hydraulic engine having a cylinder, a source of power fluid, a discharge, and a piston slidable in said cylinder, a reversing valve comprising in combination, a slidable cylindrical valve body, a first passageway controlled by said valve body and open when said valve body is in a first position for connecting one end of said cylinder to said source, said valve body when in a second position closing said passageway and opening said one end of said cylinder to discharge, a first chamber around said valve body having differential area walls, means operable only near one end of the stroke of said piston to connect said first chamber to said source of fluid pressure and thereby impose a pressure on said differential area walls to establish a force to move said valve from its second position to its first position, said last means being operable to reduce the pressure in said first chamber after said valve has reversed, whereby said valve stands ready to reverse from its first position to its second position.

2. The combination of elements defined in claim 1 and a second chamber around said valve body having differential area walls, and a passageway connecting said second chamber to said source to establish a biasing force on said valve body opposite to and smaller than the force established by pressure in said first chamber, said smaller biasing force acting to hold said valve in its second position.

3. The combination of elements defined in claim 2, and means forming a flow restriction in said first passageway to establish a flow-induced force acting on said valve body to hold said valve body in said first position and against movement to said second position.

4. In a hydraulic engine having a cylinder, a source of power fluid, a discharge, and a piston slidable in said cylinder, a reversing valve comprising in combination, a slidable cylindrical valve body, a first passageway con-

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 trolled by said valve body and open when said valve body is in a first position for connecting one end of said cylinder to said source, said valve body when in a second position closing said passageway and opening said one end of said cylinder to discharge, means in said first passageway between said source and end of said cylinder forming a flow restriction therein, means responsive to a flow-induced pressure drop across said restriction for holding said valve body in said first position, a chamber around said valve body having differential area walls, and means operable at the upper end of the stroke of

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 said piston to connect said chamber to said source and thereby impose a pressure on said differential area walls to establish a force to move said valve from its second position to its first position, said last means being operable to reduce the pressure in said chamber after said valve has reversed.

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