

Nov. 7, 1961

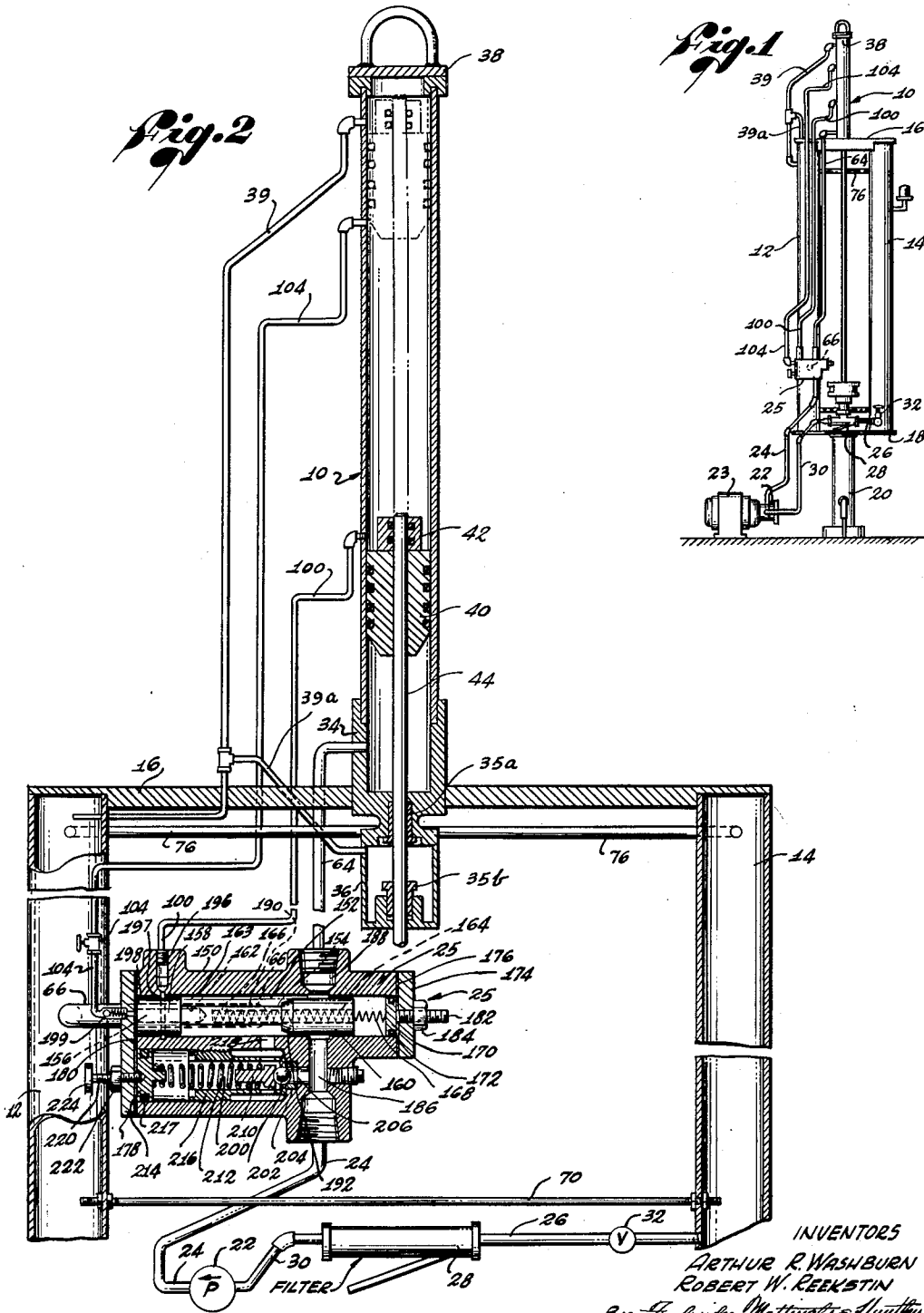
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3,007,451

REVERSING VALVE

Filed May 3, 1960

3 Sheets-Sheet 1



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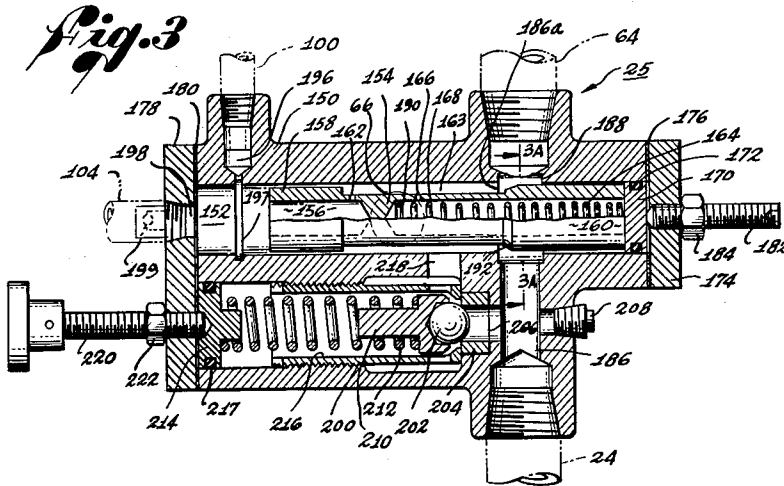
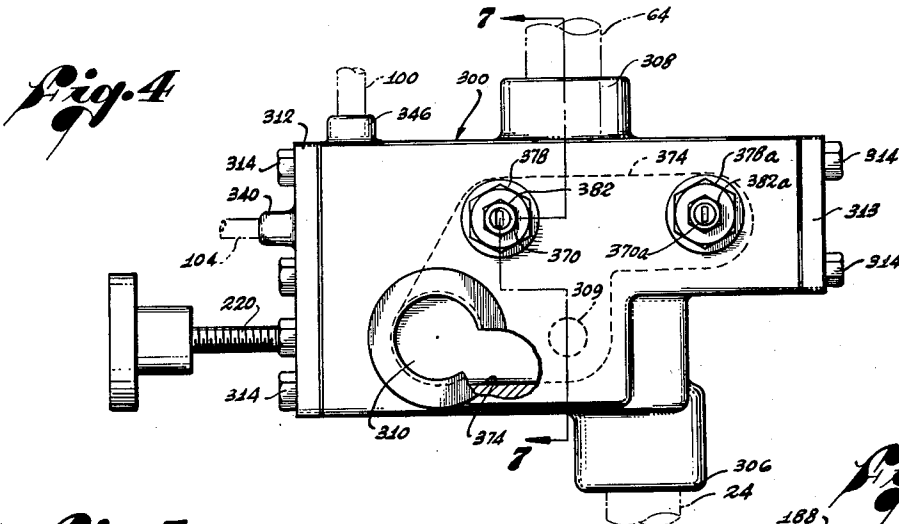
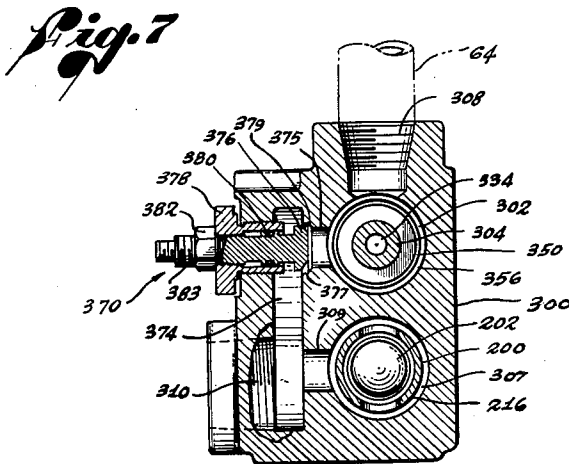
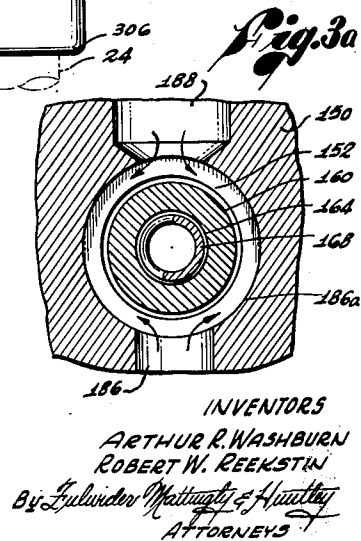
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Fig. 5

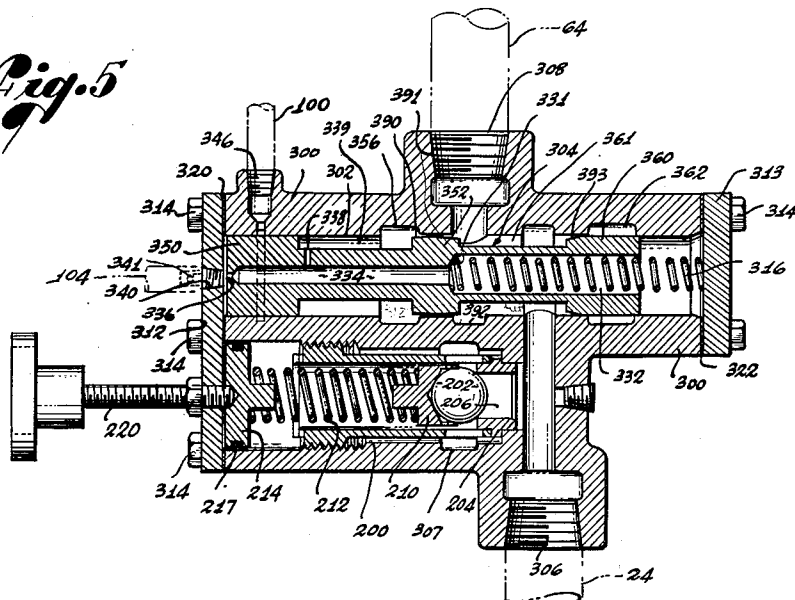
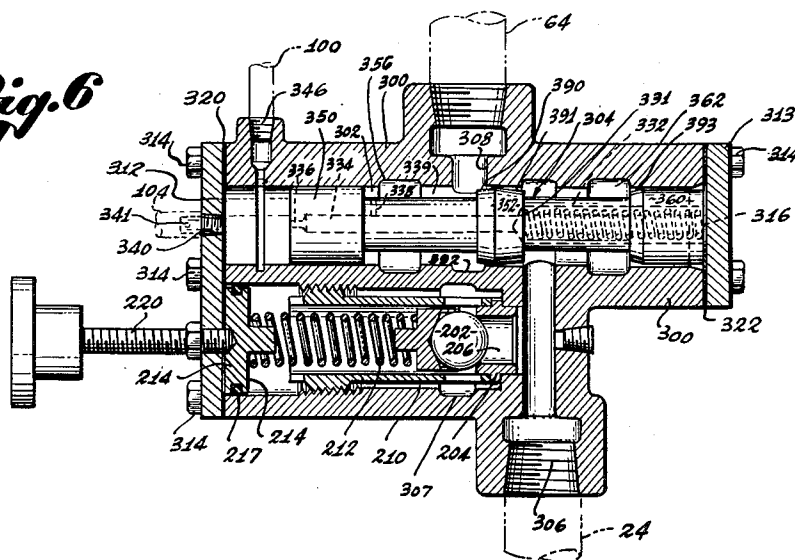


Fig. 6



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REVERSING VALVE

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Filed May 3, 1960, Ser. No. 26,475

14 Claims. (Cl. 121—150)

The present invention relates in general to reversing valves for use in hydraulic pressure systems, and more particularly to a reversing valve adapted for use in connection with hydraulic reciprocating motors in such systems.

The reversing valve of the invention has a particularly useful application with hydraulic pumping jacks of the type used to actuate production pumps in oil wells. Therefore, the invention will be described in that environment. However, it will be understood that there are other useful applications, and that the detailed description of this one is not intended to be limitative.

In the illustrative systems to be described herein, a reciprocating pump is positioned within the production zone of an oil well and arranged to pump oil to the surface through a tubing string. The pump is actuated from the surface by a sucker rod, which in turn is reciprocated by a pumping jack.

The aforementioned pumping jack, embodying a power cylinder and a power piston, is normally connected into a hydraulic pressure system which typically includes a reservoir and a power pump. The power pump introduces fluid to the cylinder to drive the piston upwardly in a power stroke. At the end of the power stroke, hydraulic fluid is released from the cylinder so that the piston may return to its lower position in a return stroke. During the return stroke, fluid from the power pump is bypassed directly to the reservoir. The piston is coupled by suitable means to the string of sucker rods so that reciprocal motion is imparted to actuate the production pump down in the well.

A reversing valve is provided in the above-described hydraulic pressure system to automatically control the operation of the pumping jack. The valve is controlled to have a first operating position wherein it permits hydraulic fluid from the power pump to be introduced to the cylinder to drive the piston in the power stroke. At the end of the power stroke, the valve is moved to a second operating position wherein hydraulic fluid is released from the cylinder and the piston makes the return stroke.

In the past, a pilot valve, actuated in response to the position of the power piston in its cylinder, has been utilized to control the operation of the reversing valve. Thus, in effect, two valves have been required to automatically control the operation of the pumping jack.

It is a primary object of the present invention to provide a reversing valve of the type described which obviates the need for a separate pilot valve.

In accordance with the improved structural concepts of the invention, a single valving member or spool in the reversing valve is itself made to respond to fluid pressure ported from the main power cylinder. In the particular embodiment shown herein, the spool is normally urged to a first operating position, during the power stroke. At the end of the power stroke, a plunger on the spool of the reversing valve is caused to respond directly to the fluid pressure on the pressure side of the power piston acting through an upper pressure-sensing conduit. This fluid pressure moves the spool to its second operating position, wherein fluid is released from the power cylinder so that the power piston moves through its return stroke. At the end of the return stroke, the spool responds to the depressurizing of a second pressure-sensing conduit

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that joins the power cylinder, to move back to its first operating position, wherein fluid is again introduced to the power cylinder to initiate another power stroke.

The elimination of the pilot valve in the improved assembly of the present invention is most advantageous in that it simplifies the construction of the valve itself, and in that it reduces the number of component parts required in the valve assembly to enable it to perform its intended function.

In addition, the improved construction of the present invention reduces the number of conduits or pipelines and joints required to fluid couple the improved valve of the invention into the hydraulic system, as compared with the number of such elements required to couple the prior art type of valves into the hydraulic system. This reduction in the number of conduits and joints is highly desirable, especially for field installations.

It will be appreciated that a tremendous force is exerted on the power piston by the weight of the sucker rods. Because of this force, it is usually necessary that some resistance or throttling effect be provided to control the speed of the return stroke of the power piston.

A somewhat related problem is also encountered during the return stroke. If some throttling or resistance is not provided in the bypass, the power pump will be caused to speed up excessively or "race" and the fluid pressure acting on the vanes and seals of the pump will be greatly reduced. Surges of pressure on the pump are undesirable as they cause excessive wear.

It is, therefore, a further object of the invention to provide an improved reversing valve which incorporates adjustable means for controlling the speed of the return stroke of the power piston and for controlling the load on the power pump during the return stroke.

Another object is to provide a reversing valve embodying means for preventing "dead centering" and "hunting" of the power piston in its cylinder adjacent the ends of the power and return strokes.

Still another object of the invention is to provide a reversing valve of the type described which is sturdy and durable in its construction and which is capable of handling extremely high fluid pressures.

The objects and advantages of this invention discussed above will be better understood, and other objects and advantages will become apparent by a consideration of the following detailed description when taken in conjunction with the accompanying drawings, in which:

FIGURE 1 is a side elevational view of a typical hydraulic pressure system of the type described, which incorporates the reversing valve of the invention;

FIGURE 2 is a fragmentary elevational view of the system of FIGURE 1 on an enlarged scale and partly in section to reveal the internal operating components of the pumping jack and of the reversing valve, the valve being illustrated in a first position for the power stroke;

FIGURE 3 is a sectional view of the reversing valve of FIGURE 2, on an enlarged scale, and illustrating the valve in a second operating position for the return stroke;

FIGURE 3a is a fragmentary section view of the assembly of FIGURE 3 taken along the line 3a—3a of that figure;

FIGURE 4 is an enlarged side elevational view of a modified form of the reversing valve of the invention;

FIGURE 5 is a sectional view of the modified reversing valve of FIGURE 4, illustrating the various operating components which are incorporated in the body of the valve, and showing these components in the first operating position of the valve;

FIGURE 6 is a sectional view similar to the view of FIGURE 5 but showing the operating components of the valve in the second operating position; and

FIGURE 7 is a broken sectional view taken on the line 7—7 of FIGURE 4.

The fluid-actuated pumping jack illustrated in FIGURE 1 includes a power cylinder 10, which is supported in a vertical position by a pair of pedestals 12 and 14. These pedestals, as described and claimed in copending application, Serial No. 10,302, are cylindrically shaped and each defines an inner chamber which is used as a reservoir and cooling chamber for the fluid circulating in the system.

The power cylinder 10 is mounted on a support member 16 which, in turn, is supported by the upper ends of the pedestals 12 and 14. The assembly of FIGURE 1 also includes a lower support member 18, which is attached to the lower ends of the pedestals 12 and 14. The lower support member 18 is mounted on the upper end of a well tubing 20, which extends down into the well and forms an enclosure for the sucker rod string (not shown) and for carrying production fluid from the well.

As shown in FIGURE 2, the vertically extending power cylinder 10 is closed at its lower end by member 34, which incorporates an integral stuffing box 36. The base member 34 is secured to the support member 16 referred to above.

Slidably mounted within the power cylinder 10 is a power piston 40, which is adapted to reciprocate therein between upper and lower limiting positions in a power and a return stroke.

In order to impart reciprocal motion to the production pump down in the well, the power piston 40 is mechanically coupled to the pump. Coupling is effected by securing the piston 40 to a piston rod 44 by means of a clamp 42, and then, in turn, joining the piston rod to the string of sucker rods. The pressure-sealing of the power cylinder 10 is maintained by extending the piston rod out of the cylinder through a pair of packing glands 35a and 35b in the stuffing box 36 and by suitably closing the top of the cylinder as with a cap 38.

The interior of the cap 38 is coupled to the top of the pedestal 12 by scavenging conduit 39. The conduit 39 carries fluid from the power cylinder 10 on the upper side of the piston 40 back to the system. Similarly, an auxiliary scavenging conduit 39a extends from the stuffing box 36 to the conduit 39, so that any fluid leaking through the upper packing gland 35a and accumulating in the stuffing box 36 will also be carried back to the pedestal 12.

Fluid pressure for reciprocating the power piston 40 in its cylinder 10 is supplied through a series of conduits by a power pump 22, preferably driven by an electric motor 23. A reversing valve 25, which incorporates the concepts of the present invention, is installed in the conduits intermediate the pump 22 and the power cylinder 10 to automatically control the operation of the power piston 40 in its cylinder.

In operation, the power pump 22 draws fluid from the lower end of the reservoir-pedestal 14 through conduits 26 and 30. In the illustrated pressure system a valve 32 is installed in the conduit 26 and a filter 28 is installed intermediate conduits 26 and 30. Outlet fluid from the pump 22 passes into the reversing valve 25 of the invention through a conduit 24. The reversing valve 25 is operable to alternately port fluid to the power cylinder 10 through a conduit 64 or to the pedestal 12 through a bypass and return conduit 66.

As will later be described in detail, when the reversing valve 25 is in its first operating position, fluid is introduced through conduit 64 to the power cylinder 10 to move the piston 40 up in a power stroke. When the valve is in its second operating position, fluid is released from the cylinder 10, and the piston 40 will move down in a return stroke. Return fluid from the cylinder flows back to the reversing valve 25 through the conduit 64

and, thence, is ported to the bypass and return conduit 66, which in turn is coupled to the pedestal 12.

With reference to FIGURE 2, the conduit 66 is coupled to the interior of the pedestal 12 at an intermediate point in accordance with the teachings of the aforementioned copending application. During the return stroke of the power piston 40 in its cylinder 10, return hydraulic fluid and the fluid continually being circulated by the pump 22 enter the interior of pedestal 12 through the conduit 66. This fluid is circulated through the interiors of pedestals 12 and 14, which act as reservoirs being intercoupled by an upper conduit 76 and a lower conduit 70. As previously noted, the inlet fluid to the circulating pump 22 is drawn off pedestal 14 near the lower end thereof.

The reversing valve 25 includes a body 150 having an internal cylindrical chamber 152 with a spool 154 slidably mounted therein. Reciprocal movement of the spool 154 in the chamber 152 between the first operating position to the left in the chamber, as illustrated in FIGURE 2, and the second operating position to the right in the chamber, as illustrated in FIGURE 3, controls the flow of hydraulic fluid to and from the power cylinder 10 in the manner previously explained. Such movement of the spool also effects the bypassing of the pressurized fluid from the power pump 22, as will be described.

The spool 154 has a longitudinal bore 156 extending into one end and another longitudinal bore 164 extending into the opposite end. To effect a valving action, the spool 154 is formed with a pair of cylindrical lands or members 158 and 160 on its opposite ends, which lands or members engage the cylindrical wall of chamber 152 in a close sliding fit and thereby act as plungers.

A compression spring 168 positioned in the bore 164 bears against the spool 154 and against a disc-like plug 170 to normally urge the spool to the left to its first operating (power stroke) position in the chamber 152. The plug 170 has an O-ring sealing member 172 in its periphery, which engages the wall of chamber 152 to hermetically close the chamber.

The body 150 is fitted with a first end cap 174, which is secured in the right-hand end of the body by any appropriate means. The assembly also includes a second end cap 178, which is secured to the opposite end of the body. A pair of gaskets 176 and 180 are interposed between end caps 174 and 178, respectively, and the body 150.

Throttling of the return fluid from the power cylinder 10 is accomplished by adjusting the limit position of the spool 154. To this end, a set screw 182 in the right-hand end cap 174 provides means for suitably adjusting the second operating position of the spool 154 in the chamber 152. The set screw 182 is threaded into the end cap 174 and bears against plug 170. Adjustment of the screw 182 varies the relative longitudinal position of plug 170 in chamber 152 and thereby controls the limit position of the spool 154 when it is moved to the right to its second operating position shown in FIGURE 3. A lock nut 184 is threaded on the set screw 182 to serve as locking means for the screw.

An inlet port 186 formed in the body 150 extends radially downward from the chamber 152 to connect with the conduit 24. A cylinder or outlet port 188 extends upward from the chamber 152 in radial alignment with the port 186 to connect with the conduit 64. A return port 190 extends radially from the chamber 152 at right angles to the axis of the ports 186 and 188 and joins with the conduit 66. The return port 190 is longitudinally displaced from ports 186 and 188 to the left in chamber 152. As may be seen in FIGURE 3a, the wall of the chamber 152 is undercut at 186a adjacent the two aligned ports 186 and 188 so that flow between these ports is never blocked, irrespective of the position of the spool 154.

The throttling of the fluid entering the valve during the return stroke of the power piston 40 is effected by a

tapered end 192 at the inner extremity of the land 160. This tapered end 192 extends into a throttling relationship with the edge of the undercut 186a when the spool 154 is in the second operating position shown in FIGURE 3. It will be noted that the fluid entering the valve from both the inlet port 186 and the outlet port will be throttled when the spool is in the second operating position. The extent of such throttling may be suitably controlled by adjusting the longitudinal position of the plug 170 in the chamber 152 with screw 182 as described above.

Pressurized control fluid introduced to one end of chamber 152 through a holding control port or connection 196 and a starting control port or connection 198 is utilized to move the spool 154 against the action of the spring 168 to its second operating position and to hold it there during the return stroke. In effect, an actuator is provided having an expansible chamber with a pressure-responsive, movable wall therein, the wall comprising the left hand end face of the land 158 on the spool. Such control fluid is supplied to the expansible chamber of the actuator by a pair of pressure-sensing conduits 100 and 104 that connect to the ports 196 and 198, respectively, and to the power cylinder 10 at vertically spaced levels.

A novel starting and holding action of the valve is accomplished by locating the two ports 196 and 198 at slightly different points in the chamber 152. The holding control port 196 is located in the body 150 slightly inwardly of the left-hand end thereof and communicates with an annular groove or recess 197 formed in the wall of the chamber 152. The starting control port 198 is formed in the end cap 178 and communicates with the extreme left-hand end of chamber 152. A check valve 199 is provided in the control port 198 to permit fluid to enter the chamber 152 through the port but not to escape through that port.

The lower sensing conduit 100 joins the power cylinder 10 adjacent the lower limit of piston travel and at a level slightly above the junction of the conduit 64 with the cylinder. The vertical spacing between the respective junctions of the conduits 64 and 100 must be at least slightly greater than the length of the power piston 40, so that the piston can slide below the opening to the pressure-sensing conduit 100 without blocking the opening to the conduit 64.

The upper pressure-sensing conduit 104 joins the power cylinder 10 near its upper end. The conduit 104 must be spaced a sufficient distance below the cap 38 to allow the power piston 40 to move above the opening to this conduit.

In describing a cycle of operation of the power piston 40 in the cylinder 10, the cycle will be assumed to commence with the spool 154 of reversing valve 25 in its first operating position, being so urged by the spring 168. Pressurized fluid is pumped by the power pump 22 through the conduit 24 to the inlet port 186 in the reversing valve 25. The land 160 on the spool 154 blocks the flow of fluid to the annular space 163 and, hence, to the return port 190. However, the undercut 186a (FIGURE 3a) provides constant communication between inlet port 186 and valve outlet port 188. Thus, fluid flows to valve outlet port 188 and through the conduit 64 to the lower end of the power cylinder 10.

The pressurized fluid entering the lower end of the power cylinder 10 acts on the underside of the power piston 40, causing it to rise in a power stroke. When the power piston moves from the lowermost position, shown in full lines in FIGURE 2, above the opening to the lower pressure-sensing conduit 100, pressurized fluid enters the conduit and flows to the holding port 196 and the annular groove 197. However, as may be seen in FIGURE 2, the land 158 blocks the opening to the annular groove 197 so that fluid flow to chamber 152 is temporarily prevented. Therefore, the spool 154 remains in the position illustrated in FIGURE 2 and the power piston 40 continues the power stroke in the cylinder 10.

When the power piston 40 moves above the opening to the upper pressure-sensing conduit 104, as shown in phantom lines in FIGURE 2, fluid enters the conduit. This pressurized fluid from the lower side of the power piston is ported to the end of the chamber 152 through the starting port 198 having the check valve 199 therein. The land 158 functions as a plunger and fluid pressure acting on the left-hand end of the spool 154 is sufficient to move the spool to the right in the chamber 152 against the resistance of the spring 168. As the left end of the land 158 moves to the right of the annular groove 197, which communicates with the holding port 196, additional communication between the chamber 152 and the power cylinder 10 is provided through the lower pressure-sensing conduit 100. The spool will then be urged by the pressurized fluid from both sensing conduits 100 and 104 to its second operating position, illustrated in FIGURE 3. As previously described, the position of the spool 154 relative to the chamber 152 in its second operating position will be determined by the longitudinal position of the plug 170 relative to the chamber 152.

In this second operating position, both the inlet port 186 and the outlet port 188 are in communication with the return port 190 through the annular space 163 between the lands 158 and 160. Since fluid pressure in the reservoir-interior of the pedestal 12 is less than that in the power cylinder 10 below the piston 40, fluid flows back through the conduit 64 and the outlet port 188 to the valve 25. This return fluid is ported out through the return port 190 and flows through the conduit 66 back to the pedestal 12.

The resultant release of the hydraulic fluid from the power cylinder 10 beneath the piston 40 permits the weight of the sucker rods and the production fluid to lower the piston, thereby forcing the fluid in the power cylinder back to the pedestal 12 through the aforementioned path. Likewise, during the return stroke, the pressurized fluid continually being introduced by the power pump to the valve 25 through the inlet port 186 also passes to the return port 190 and back to the pedestal 12.

As previously noted, the position of the spool 154 in its second operating condition is controlled by the plug 170, so that the tapered portion 192 on the land 160 provides a throttling effect on the hydraulic fluid passing to the return port 190 from both the inlet port 186 and the outlet port 188. This throttling effect serves two functions. One is to limit the speed with which the power piston 40 moves in the return stroke, and the other is to maintain at least a partial load on the power pump 22 during the return stroke. The latter function is to prevent excessive speeding up or "racing" of the pump 22, and to prevent surges of pressure from acting on the vanes and seals of the pump.

Previous pumping jack systems frequently have the problem of "dead centering" or "hunting" of the power piston in its cylinder. This situation is particularly likely to occur at the end of the power stroke. Using the present system as an example, as the power piston moves just slightly above the opening of the upper pressure-sensing conduit 104, so as to just "crack open" the inlet to the conduit, some pressurized control fluid is delivered to shift the valve to its second operating or open position. In past systems, this fluid is frequently sufficient to just slightly open the valve. Under such conditions, the power piston of previous systems comes to rest or "dead centers" in this position, or begins oscillating or "hunting" about the inlet to the conduit 104. "Dead centering" is caused by fluid being delivered to the cylinder by the power pump at a rate which just balances that escaping through the slightly opened valve.

"Hunting" is caused by a small quantity of fluid being exhausted from the power cylinder 10 through the valve, so that the piston 40 drops to block the opening to the conduit 104. Because of the nature of previous hydraulic valves and pressure actuators therefor, the con-

trol fluid initially delivered to the valve is not sufficient to hold it open. Hence, the valve closes and the piston is driven upwardly to again "crack open" the inlet to the conduit 104.

In order to prevent the above-described "dead centering" and "hunting," the spool 154 of the present invention is so proportioned relative to the spacing of aligned ports 186 and 188, and annular groove 197, that the left end of the land 158 moves to the right of the annular groove before the land 160 unblocks the opening to the ports, i.e., communication with the lower pressure-sensing conduit 100 established before the reversing valve opens.

Pressurized control fluid delivered by the lower pressure-sensing conduit 100 enters the chamber 152 before the valve is opened. Thus, the piston 40 continues to move in the power stroke as control fluid initially enters the chamber 152 through the annular groove 197, and, hence, the possibility of "dead centering" of the power piston at the termination of the power stroke is essentially removed.

Continuing the cycle of operation, as the power piston 40 drops in the cylinder 10, it first blocks the pressurized fluid in the cylinder 10 from the entrance to the upper pressure-sensing conduit 104, so that the supply of pressurized fluid to the chamber 152 through the starting port 198 is removed. Further downward movement of the power piston 40 opens the conduit 104 to the substantially atmospheric pressure in the cylinder 10 above the piston. However, the check valve 199 prevents control fluid from being returned from the chamber 152 through the conduit 104, so that the spool 154 remains essentially in the position of FIGURE 3. Therefore, the power piston 40 continues its return stroke with the cylinder 10 on the lower side of the piston being in constant communication with the chamber 152 through the lower pressure-sensing conduit 100. This last-mentioned communication is necessary in order to hold the spool 154 in its second operating position in the chamber 152.

When the power piston 40 reaches and moves below the entrance to the lower pressure-sensing conduit 100, the pressure source is removed and the fluid pressure urging the spool 154 against the action of the spring is relieved to the essentially atmospheric pressure in the cylinder 10 above the piston 40. The spring 168 then urges the spool 154 back toward its first operating position and a quantity of the control fluid in the chamber 152 is exhausted through the holding port 196 and conduit 100 to the cylinder 10.

Due to the previously described proportioning of the spool 154, relative to the spacing of the ports 186 and 188 and the annular groove 197, slightly before the land 158 moves over the annular groove 197, the other land 160 blocks the communication of the inlet and outlet ports with the return port 199, i.e., closes the reversing valve. Thus, fluid again flows from the inlet port 186 through the undercut 186a to the outlet port 188 and is introduced to the power cylinder 10 on the lower side of the piston 40 to initiate another power stroke.

It will be appreciated that the land 158 must completely block the annular groove 197 before the piston 40 moves above the opening to the lower pressure-sensing conduit 100. If such blocking did not occur, control fluid would enter the chamber 152 and open the reversing valve, and the piston 40 would merely oscillate or "hunt" in short strokes above and below the opening to the conduit 100. To obviate "hunting," a restricted passage 162 communicates with the bore 156 and the annular space 163 to bleed off control fluid trapped in the end of chamber 152. As previously noted, control fluid is exhausted through the annular groove 197 until said groove is nearly blocked by the land 158. The restricted passage 162 must be of a size to bleed off sufficient fluid so that the annular groove is completely blocked before the pis-

ton moves above the opening to the lower circuit 100. The passage 162 continues to bleed off the trapped fluid during the power stroke, allowing the spool 154 to settle back to its first operating position.

Closing of the reversing valve commences the next power stroke and as the power piston 40 moves up the cylinder 10, control fluid which was exhausted to the upper side of the power piston 40 at the termination of previous return strokes will be carried up the cylinder and forced out through the scavenging conduit 39 back to the pedestal 12.

The reversing valve 25 also embodies means for relieving excessive pressure in the hydraulic system. This means includes a valve ball 202 on a seat 204 to normally close an alternate passageway between the inlet port 186 and the return port 190. The alternate passageway is formed by a pair of intersecting ports 206 and 218, the port 206 communicating with the inlet port 186 and the port 218 communicating with the annular space 163 in chamber 152.

A compression spring 212 and abutment 210 are provided to act on, and normally urge the ball 202 to the seated position. A retainer 216 screw threaded into a bore 200 in the body serves to maintain the seat 204 in proper assembly when the ball is moved off the seat by excessive fluid pressure.

The opposite end of the spring 212 bears on a spring anchor 214 which is longitudinally adjustable in the bore 200. Relative adjustment of the anchor 214 in the bore 200 varies the compression of the spring 212 and, hence, the force urging the ball 202 against the seat 204. An O-ring 217 is disposed in a peripheral groove in the anchor 214 for sealing purposes.

The means for adjusting the anchor 214 relative to the bore 200 comprises a set screw 220 threaded into the end cap 178 and bearing against the anchor 214. A lock nut 222 is preferably provided to retain the screw in adjusted position.

When the pressure in the inlet port 186 exceeds a predetermined safe level, the ball will be moved off the seat 204. Fluid will then flow through the ports 206 and 218 to the return port 190. As the pressure subsides to normal, the spring 212 will urge the ball 202 back against the seat 204.

In the embodiment of the invention illustrated in FIGURES 2 and 3, the tapered portion 192 of the land 160 serves to simultaneously throttle both the fluid entering the valve 25 from the power pump 22 and the fluid exhausted through the valve from the cylinder 10 during the return stroke of the piston 40.

Another embodiment of the invention, illustrated in FIGURES 4-7, is similar to the first embodiment except that separate and individually adjustable throttles are provided. One throttle is provided for the fluid entering the valve from the power pump 22, and the other is for the fluid exhausting through the valve 25 from the cylinder 10. The latter arrangement is advantageous in that it provides separate and independent means for adjusting the load on the pump 22 during the return stroke of the piston 40 and for adjusting the rate of the return stroke of the piston.

Referring now to FIGURES 4-7, a main valve body 300 is formed with an internal cylindrical chamber 302. Slidably mounted within the chamber 302 is a spool 304, which is adapted to move between first and second operating positions to control the flow of fluid to and from the power cylinder 10 as in the previously described embodiment. An inlet port 306 is formed in the body and longitudinally offset along chamber 302 is an outlet port 308. As shown in FIGURE 4, a return port 310 is also provided in the body 300. These ports correspond generally to the ports 186, 188 and 190 of the first embodiment of the valve and are adapted to connect to corresponding conduits of the hydraulic pressure system of FIGURE 1. Since there is this similarity, the connec-

tion of this second embodiment of the valve in the hydraulic system will not be discussed again.

The body 300 is sealed at its opposite ends by a pair of end caps 312 and 313 joined to the body 300 as with bolts 314. Suitable gaskets 320 and 322 are interposed between the end caps 312 and 313, respectively, and the body 300.

To prevent "dead centering" and "hunting" and to permit complete return to its first operating position, the spool 304 must provide a bleed passage as in the first embodiment. To this end, the spool 304 has an axial bore 332 extending into the right-hand end, as viewed in FIGURES 5 and 6. Adjacent the central portion of the spool 304, a reduced axial bore 334 joins the bore 332 and extends nearly to the opposite end of the spool 304. A restricted passage 336 extends from the reduced bore 334 to the opposite end of the spool 304. The spool 304 also has a restricted lateral passage 338 extending from the reduced bore 334 to an annular space 339 in the chamber 302. Thus, communication is provided from the end of chamber 302 to the annular space 339 through the passage formed by restricted passage 336, bore 334, and restricted passage 339.

A compression spring 316 normally urges the spool 304 to the first operating position in the chamber as illustrated in FIGURE 5. The spring 316 bears against the end cap 313 and extends into the bore 332 to abut a shoulder 331 formed at the junction of the bores 332 and 334.

The spool 304 is formed with a pair of lands 350 and 360 on the opposite ends thereof. In this embodiment, an additional land 352 is formed at an intermediate point on the spool 304. In order to control the flow of fluid through the valve, the lands 352 and 360 cooperate with a pair of annular recesses 356 and 362 formed in the wall of the chamber 302.

A fluid passage from the annular recesses 356 and 362 to the return port 310 is provided by a common manifold 374, shown in phantom lines in FIGURE 4 and partly in section in FIGURE 7. A pair of independently throttled connecting ports 375 and 375a join the recesses 356 and 362, respectively, to the manifold 374.

When the spool 304 is in the first operating position (power stroke), illustrated in FIGURE 5, the lands 352 and 360 block the flow of fluid from inlet and outlet ports 306 and 308 to the annular recesses 356 and 362, i.e., the reversing valve is closed. However, when the spool 304 is in this position, passage is provided from the inlet port 306 to the outlet port 308 through an annular space 361 in chamber 302 intermediate the lands 352 and 360. Thus, fluid introduced to the inlet port 306 by the power pump 22 flows to the outlet port 308, but is blocked from the return port 310. As previously described, this fluid flows to the power cylinder 10 to drive the power piston 40 in a power stroke.

When the spool 304 is in the second operating position (return stroke), illustrated in FIGURE 6, passage is provided from the inlet port 306 to the annular recess 362, and from the outlet port 308 to the annular recess 356. Thus, in this condition, both the inlet port 306 and the outlet port 308 are in communication with the return port 310. However, such communication is through separate paths to the manifold 374, which in turn connects to the return port 310.

In order to separately throttle the fluid flow from both the power cylinder 10 and the power pump 22 during the return stroke of the power piston 40, identical but independent throttles 370 and 370a are installed in the body 300. These throttles provide adjustable means for controlling the fluid flow between the annular recesses 356 and 362, respectively, and the manifold 374. Since the two throttles are identical, only the unit 370 will be described in detail, it being understood that the same description applies to the unit 370a.

Referring to FIGURE 7, the throttle 370 comprises a valve 376 cooperating with the opening of the connecting port 375 to the manifold 374 to define a restricted passage. The valve 376 is supported by a retaining sleeve 378, which in turn is threaded into the body 300. Sealing between the valve 376 and the sleeve is obtained by installing an O-ring 380 in a circumferential groove in the valve, the O-ring 380 being adapted to sealingly engage the inner periphery of the sleeve 378.

The opening of the port 375 to the manifold 374 is slightly enlarged and beveled to provide a tapered seat 377. The valve 376 is formed with a correspondingly tapered head 379, such that when the valve is adjusted inwardly toward the port 375, the area of the passage between the tapered head 379 and the seat 377 is reduced. Conversely, as the valve 376 is backed away from the port 375, the area of the passage, of course, is increased.

The valve 376 is formed with a threaded extension 383, which extends through a threaded portion of the retainer 378. A lock nut 382 is utilized to maintain the valve in adjusted position.

It is evident that the throttle 370 provides adjustable means for throttling the fluid flow between the annular recess 356 and the manifold 374. Similar adjustable means is provided by the throttle 370a for throttling the fluid flow between the annular recess 362 and the manifold 374.

Thus, as the power piston 40 moves down in a return stroke, the return fluid exhausted from the cylinder 10 is throttled by the throttle 370, the valve 376 being adjustable to control the rate of the return stroke. Fluid introduced by the power pump 22 to the valve during the return stroke is independently throttled by the throttle 370a to control the load on the pump.

In the second embodiment, the ball 202 of a pressure-relieving means, similar to that in the first embodiment, is adapted to seat on the seat 204 to close an alternate passage from the inlet port 306 to the manifold 374. The alternate passage in this embodiment includes the port 206, which joins an annular recess 307. Referring to FIGURE 7, the annular recess 307 is coupled to the manifold 374 by a connecting port 309. As previously explained, the manifold 374 connects to the return port 310.

In operation, excessive fluid pressure in the inlet port 306 forces the ball 202 off the seat 204. Fluid then flows through the aforementioned path to the return port 310. When the pressure subsides, the spring 212 will urge the ball 202 back to the seated position. It will be noted that the pressure-relieving means is operable in the system during both the power stroke and the return stroke of the power piston 40. During the power stroke, the inlet port 306 is in communication with the outlet port 308 through the chamber 302. During the return stroke, the inlet port 306 and the outlet port 308 remain in communication, but such communication is through the manifold 374 and the ports 375 and 375a and the respective annular recesses 356 and 362 in the chamber 302.

To recapitulate the operation of the second embodiment, at the end of the power stroke fluid pressure is introduced to the chamber 302 from the cylinder 10 through a starting control port 340 having a check valve 341 therein and a holding control port 346. Such fluid moves the spool 304 to its second operating position, the movement being yieldingly opposed by the spring 316, which normally urges the spool 304 to the first operating position. The control ports 340 and 346 correspond to the control ports 196 and 198 of the first embodiment, and further, shifting the spool 304 between operating positions is accomplished in the same manner as previously described. Therefore, the description of a cycle of operation is not repeated with respect to the second embodiment.

As spool 304 moves from its second toward its first operating position, control fluid trapped in the end of the chamber 302 bleeds out through the restricted passage 336 to the bore 334 and thence through the lateral restricted passage 338 to the annular space 339. Referring to the drawings, it will be noted that annular space 336 is in constant communication with the return port 310. Thus, the control fluid will be bled back to the system.

In connection with the shifting of the spool 304 between operating positions, it is desirable to have the reversing of the valve be somewhat gradual in order that the system is not subjected to violent surges of pressure. To preclude such surges of pressure, the lands 352 and 356 are formed with tapered surfaces.

The land 352 has reversely tapered surfaces 390 and 391, which alternately move into longitudinal alignment with an annular recess 392 as the spool is moved between first and second operating positions. It is noted that the recess 392 is an extension of the outlet port 308, its function being to insure uniform distribution of fluid about the spool 304. As the land 352 moves into and out of alignment with the recess 392, the passage of fluid between the chamber 302 and the outlet port 308 will be gradually blocked or unblocked.

Similarly, the land 360 is provided with a tapered surface 393. As the land 360 is moved into and out of alignment with the annular recess 362, the passage of fluid between the chamber 302 and the recess is gradually blocked and unblocked.

Although certain embodiments of the invention have been shown and described in considerable detail, it will be understood that various changes in the details of construction and arrangement may be made without departing from the spirit and scope of the invention as defined in the appended claims.

We claim:

1. In a fluid pressure responsive system of the type wherein a control element is selectively moved between alternate positions in response to fluid pressure from at least two separate pressure-sensing sources, an actuator for said element comprising: an expansible chamber having a wall movable therein between a first operating position wherein said chamber is in a contracted condition and a second operating position wherein said chamber is in an expanded condition, said wall being operatively connected to said element and movable therewith at least to the extent that the first and second operating positions of said wall correspond to the alternate positions of said element; starting and holding fluid connections in said chamber adapted to connect respectively, to said pressure-sensing sources; and means operatively associated with the movable wall to block said holding connection when the movable wall is in said first operating position and to unblock said holding connection responsive to movement of said wall toward said second operating position, whereby control fluid initially admitted to said chamber through said starting connection moves said wall toward said second operating position to expand said chamber and unblock said holding connection.

2. In a fluid pressure responsive system of the type wherein a control element is selectively moved between alternate positions in response to the fluid pressure at pressure-sensing sources, an actuator for said element comprising: an expansible chamber having a movable wall therein, said wall being movable in said chamber between a first operating position wherein said chamber is in a contracted condition and a second operating position wherein said chamber is in an expanded condition; means operatively connecting said wall and said element whereby movement of said wall between said first and second operating positions effects movement of said element between its alternate positions; starting and holding fluid connections adapted to connect respectively, to said pressure-sensing sources; means connected to said

movable wall to block said holding connection when the wall is in said first operating position and to unblock said holding connection when the wall is moved toward said second operating position, whereby control fluid admitted to said chamber through said starting connection moves said wall toward said second operating position to expand said chamber and unblock said holding connection and fluid admitted through said holding connection holds said wall in said second operating position; and means responsive to the exhaustion of control fluid from said chamber for returning said wall to said first operating position.

3. In a fluid pressure responsive system of the type wherein a control element is selectively moved between alternate positions in response to the fluid pressures at pressure-sensing sources, an actuator for said element comprising: an expansible chamber having a wall movable therein between a contracted and an expanded position, said wall being operatively connected to said element to move the same as aforesaid; a starting fluid connection adapted to connect one of said pressure-sensing sources to said chamber for admitting control fluid thereto for moving said wall from said contracted position toward said expanded position; a holding fluid connection adapted to connect another of said pressure-sensing sources to said chamber at a point spaced from said starting connection for admitting fluid to said chamber to hold said wall in said expanded position; means operatively associated with said wall to block said holding connection when the wall is in said contracted position and to unblock said holding connection upon movement of the wall toward said expanded position; means forming a bleed passage from said chamber for exhausting control fluid therefrom, thereby allowing said wall to move from said expanded to said contracted position so as to block said holding connection; and means yieldingly urging said wall toward said contracted position.

4. A fluid pressure actuated valve system comprising, in combination: a two-position valving member; an actuator having a pressure responsive element movable between first and second limit positions and operatively connected to said member to move said member alternately between its two positions; pressure-sensing sources for supplying fluid for moving said element as aforesaid; a starting connection adapted to connect one of said pressure-sensing sources to said actuator for admitting fluid to said actuator to move said element toward said second limit position; a holding connection adapted to connect another of said pressure-sensing sources to said actuator at a point spaced from said starting connection for admitting fluid to said actuator upon movement of said element from said first toward said second limit position; means operatively associated with said element to block said holding connection when said element is in said first limit position and to unblock said last-mentioned connection upon movement from said first toward said second limit position; unidirectional flow control means between said starting connection and its respective pressure-sensing source for preventing the exhausting of fluid from said actuator through said starting connection, whereby fluid admitted to said actuator through said holding connection holds said element in said second limit position irrespective of the pressure in said one of said pressure-sensing sources; means forming a bleed passage from said actuator for exhausting fluid therefrom; and means responsive to the exhaustion of fluid from said chamber for moving said element to said first position.

5. A fluid pressure actuated valve system comprising, in combination: a valving member movable between an open and a closed position; an actuator having a pressure responsive element operatively connected to said member and movable between a first operating position, wherein said member is in its closed position, and a second operating position, wherein said member is in its open position; at least two separate sources of fluid pressure, each being

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independently sufficient to move said element as afore-said; respective starting and holding connections adapted to connect said pressure sources respectively, to separate points in said actuator; and means operatively associated with said element to block said holding connection when said element is in said first operating position and to unblock said holding connection upon movement toward said second operating position, said means being arranged relative to said valve member whereby the unblocking of said holding connection occurs prior to said member reaching its open position.

6. A reversing valve comprising, in combination: a body having an internal chamber with an inlet port, an outlet port, and a return port all communicating with said chamber, and an alternate passage between said inlet port and said return port; a valving member mounted in said chamber and movable therein between first and second operating positions, said valving member being operable in said first position to block flow through said return port, there being constant communication between said inlet and outlet ports during said blocking, and in the second position to permit flow through said return port; valve means in said alternate passage normally closing said passage, said valve means being responsive to a pressure of a predetermined level to open said passage; and means yieldingly urging said valve means to close said alternate passage.

7. A hydraulic reciprocating motor comprising, in combination: a cylinder; a slidable piston in said cylinder adapted to reciprocate over a predetermined path therein in a power stroke and in a return stroke; a power conduit connected to said cylinder adjacent a first end of said path for admitting pressurized fluid to said cylinder to move said piston in the power stroke and for exhausting hydraulic fluid from said cylinder to allow the piston to move in the return stroke; a valve body having formed therein a chamber, connector means at a given point in said chamber in constant communication with said cylinder and power conduit, and a return port longitudinally displaced in said chamber from said connector means, said return port being adapted to communicate through said chamber with said connector means; a valve element slidably disposed in said chamber for movement between first and second operating positions, said valve element being operable in said first operating position to block said return port, and in said second operating position to open said return port to permit fluid from said connector means to flow through said return port; an actuating plunger in said chamber adjacent one end thereof and operatively associated with said valve element and movable therewith, at least to the extent that the first and second operating positions of said valve element correspond to first and second limit positions respectively, of said plunger; a starting conduit connected at one end to said cylinder adjacent a second end of said path, and at the other end to the end of said chamber adjacent said plunger, whereby pressurized fluid from said cylinder enters said chamber substantially coincidentally with the termination of the power stroke to move said spool from its first toward its second operating position; and a holding conduit connected at one end to said cylinder adjacent the lower end thereof, and at the other end to said chamber at a point therein, spaced from said end of the chamber, said connection of said holding conduit to said chamber being blocked by said plunger when in its first limit position and being unblocked as said plunger moves from said first toward said second limit position, said unblocking occurring prior to the opening of the return port, whereby fluid admitted to said chamber through said holding conduit urges said plunger to its second limit position and maintains it therein during the return stroke.

8. A hydraulic reciprocating motor comprising, in combination: a cylinder; a slidable piston in said cylinder adapted to reciprocate over a predetermined path therein in a power stroke and in a return stroke; a power conduit connected to said cylinder adjacent a first end of said path

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for admitting pressurized fluid to said cylinder to move said piston in the power stroke and for exhausting hydraulic fluid from said cylinder to allow the piston to move in the return stroke; a valve body having formed therein a chamber, connector means at a given point in said chamber in constant communication with said cylinder and power conduit, and a return port longitudinally displaced in said chamber from said connector means, said return port being adapted to communicate through said chamber with said connector means; a valve element slidably disposed in said chamber for movement between first and second operating positions, said valve element being operable in said first operating position to block said return port, and in said second operating position to open said return port to permit fluid from said connector means to flow through said return port; an actuating plunger in said chamber adjacent one end thereof and operatively associated with said valve element to move the same as aforesaid between corresponding first and second positions; a starting conduit connected at one end to said cylinder adjacent a second end of said path, and at the other end to the end of said chamber adjacent said plunger, whereby pressurized fluid from said cylinder enters said chamber through said starting conduit and acts on said plunger substantially coincidentally with the termination of the power stroke to move said plunger toward its second position; a holding conduit connected at one end to said cylinder adjacent the first end of said path, and at the other end to said chamber at a point therein, spaced from said end of the chamber, said connection of said holding conduit to said chamber being blocked by said plunger in its first position and unblocked upon movement of said plunger toward its second position, whereby fluid initially admitted to said chamber through said starting conduit moves said plunger to unblock said holding connection and fluid admitted to said chamber through said holding conduit holds said plunger in its second position during the return stroke; and means for exhausting fluid from said chamber substantially coincidentally with the termination of the return stroke to permit said plunger to move from its second toward its first position.

9. A hydraulic reciprocating motor comprising, in combination: a vertical cylinder; a slidable piston in said cylinder adapted to reciprocate therein in a power and a return stroke; a power conduit connected to said cylinder adjacent the lower end thereof for admitting pressurized fluid to said cylinder to move said piston in the power stroke and for exhausting hydraulic fluid from said cylinder to allow the piston to move in the return stroke; a valve body having formed therein a chamber, connector means at a given point in said chamber in constant communication with said cylinder and power conduit, and a return port longitudinally displaced in said chamber from said connector means, said return port being adapted to communicate through said chamber with said connector means; a valve element slidably disposed in said chamber for movement between first and second operating positions, said valve element being operable in said first operating position to block said return port, and in said second operating position to open said return port to permit fluid from said connector means to flow through said return port; an actuating plunger in said chamber adjacent one end thereof and operatively associated with said valve element and movable therewith, at least to the extent that the first and second operating positions of said valve element correspond to first and second limit positions respectively, of said plunger; a starting conduit connected at one end to said cylinder adjacent the upper end thereof, and at the other end to the end of said chamber adjacent said plunger, whereby pressurized fluid from said cylinder enters said chamber through said starting conduit substantially coincidentally with the termination of the power stroke to move said plunger from its first toward its second limit position; and a holding conduit connected at one end to said cylinder adjacent the lower end

thereof, and at the other end to said chamber at a point therein, spaced from said end of the chamber, said connection of said holding conduit to said chamber being blocked by said plunger when in its first limit position and being unblocked as said plunger moves from said first toward said second limit position, whereby fluid admitted to said chamber through said holding conduit holds said plunger in said second limit position during the return stroke.

10. A hydraulic reciprocating motor comprising, in combination: a vertical cylinder; a slidable piston in said cylinder adapted to reciprocate therein in a power and a return stroke; a power conduit connected to said cylinder adjacent the lower end thereof for admitting pressurized fluid to said cylinder to move said piston in the power stroke and for exhausting hydraulic fluid from said cylinder to allow the piston to move in the return stroke; a valve body having formed therein a chamber, connector means at a given point in said chamber in constant communication with said cylinder and power conduit, and a return port longitudinally displaced in said chamber from said connector means, said return port being adapted to communicate through said chamber with said connector means; a valve element slidably disposed in said chamber for movement between first and second operating positions, said valve element being operable in said first operating position to block said return port, and in said second operating position to open said return port to permit fluid from said connector means to flow through said return port; an actuating plunger in said chamber adjacent one end thereof and operatively connected to said valve element and movable therewith, at least to the extent that the first and second operating positions of said valve element correspond to first and second limit positions respectively, of said plunger; a starting conduit connected at one end to said cylinder adjacent the upper end thereof, and at the other end to the end of said chamber adjacent said plunger, said connection to said cylinder being sufficiently spaced from the top thereof to allow said piston to move above said last-mentioned connection at the end of the power stroke, whereby pressurized fluid from said cylinder below said conduit acts on said plunger to move it toward said second limit position; a holding conduit connected at one end to said cylinder adjacent the lower end thereof, and at the other end to said chamber at a point therein, longitudinally spaced from said end of the chamber, said connection of the holding conduit to said cylinder being spaced above said connection to said power conduit by a distance greater than the length of said piston, said connection of said holding conduit to said chamber being blocked by said plunger when in its first limit position and being unblocked upon movement of the plunger toward its second limit position, whereby fluid admitted to said chamber through said holding conduit moves said plunger to its second limit position irrespective of fluid admitted through said starting conduit and maintains said plunger therein during the return stroke of the power piston; unidirectional flow control means in said starting conduit preventing the exhaustion of fluid from said chamber through said starting conduit; means for exhausting fluid from said chamber substantially coincidentally with the termination of said return stroke to permit said plunger to move from its second to its first limit position; and means yieldingly urging said plunger toward said first limit position.

11. A hydraulic reciprocating motor comprising, in combination: a vertical cylinder; a slidable piston in said cylinder adapted to reciprocate therein in a power and a return stroke; a power conduit connected to said cylinder adjacent the lower end thereof for admitting pressurized fluid to said cylinder to move said piston in the power stroke and for exhausting hydraulic fluid from said cylinder to allow the piston to move in the return stroke; a valve body having formed therein, a cylindrical chamber, connector means at a given point in said chamber

in constant communication with said cylinder and power conduit, and a return port longitudinally displaced in said chamber from said connector means, said return port being adapted to communicate through said chamber with said connector means; a spool slidably disposed in said chamber for movement between first and second operating positions, said spool having a land formed thereon which is operable in said first operating position to block said return port, and in said second operating position to open said return port to permit fluid from said connector means to flow through said return port; an actuating plunger formed on said spool and slidable in said chamber adjacent one end thereof in response to fluid pressure therein to move said spool as aforesaid; a starting conduit connected at one end to said cylinder adjacent the upper end thereof, and at the other end to the end of said chamber adjacent said plunger, said connection to said cylinder being sufficiently spaced from the top of said cylinder to allow said piston to move above said last-mentioned connection at the end of the power stroke, whereby pressurized fluid from said cylinder below said piston enters said chamber through said starting conduit and acts on said plunger to move said spool toward its second operating position; a holding conduit connected at one end to said cylinder adjacent the lower end thereof, and at the other end to said chamber at a point therein, longitudinally spaced from said end of the chamber, said connection of the holding conduit to said cylinder being spaced above said connection to said power conduit by a distance greater than the length of said piston, said connection of said holding conduit to said chamber being in the cylindrical wall of said chamber and being blocked by said plunger when said spool is in its first operating position and being unblocked as said spool moves from its first toward its second operating position, said unblocking occurring prior to opening of said return port, whereby fluid admitted to said chamber through said holding conduit urges said spool to its second operating position and maintains it therein during the return stroke of said piston; a check valve in said starting conduit preventing the exhaustion of fluid from said chamber through said starting conduit; a bleed passage formed in said plunger for exhausting fluid from said chamber at the end of the return stroke to permit said spool to move from its second to its first operating position, said bleed passage being of sufficient size to permit movement of said plunger to block the connection to said holding conduit prior to movement of said piston in said cylinder above the connection to said holding conduit during the power stroke; and a compression spring yieldingly urging said spool to its first operating position.

12. A reversing valve comprising, in combination: a valve body having an internal operating chamber with an inlet port, an outlet port, and a return port, all communicating with said chamber, and an internal actuating chamber; a valving member slidably mounted in said operating chamber for movement between first and second operating positions, said member being operable in said first operating position to block said return port, there being constant communication between said inlet and outlet ports during said blocking, and in said second operating position to open said return port to permit fluid flow from said inlet and outlet ports through said return port; a pressure responsive element in said actuating chamber and movable therein between first and second limit positions, said element being operatively associated with said valving member and movable therewith, at least to the extent that the first and second limit positions of said element correspond to the first and second operating positions, respectively, of said valving member; means forming a starting port in said body in constant communication with said actuating chamber, said starting port being adapted to admit pressurized control flow to said actuating chamber to move said element toward its second limit position; means forming a holding port in

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said body communicable with said actuating chamber at a point spaced from said starting port, said holding port being adapted to admit pressurized control fluid to said actuating chamber upon movement of said element from its first to its second limit position; and means on said element blocking said holding port when said element is in its first limit position and unblocking said holding port upon movement from its first to its second limit position, said unblocking occurring prior to the opening of said return port.

13. A reversing valve comprising, in combination: a body having formed therein, an internal chamber with the inlet port, an outlet port, and a return port, there being provided a first fluid passage between said inlet port and said return port through said chamber and a second fluid passage between said outlet port and said return port through said chamber; a valving member slidably mounted in said chamber and movable therein between first and second operating positions, said member being operable in said first operating position to block flow through said first and second passages, there being constant communication between said inlet and outlet ports through said chamber during said blocking, and in said second operating position to open said passages for fluid flow therethrough; and first and second adjustable throttles mounted in said body and operable in said

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first and second passages, respectively, to throttle the fluid flow.

14. A fluid pressure actuated valve system comprising, in combination: a two-position valving member; an actuator having a fluid pressure responsive element movable from a first to a second operating position and operatively associated with said member to move it from one to the other of its two positions; two separate sources of fluid pressure, each being independently sufficient to move said element as aforesaid; a pair of connections adapted to connect said pressure sources, respectively, to separate points in said actuator; and means on said element operable in the first operating position in said element to block one of said connections and during movement of said element from said first to said second operating position to unblock said one of said connections, said unblocking occurring prior to said valving member moving to the other of its positions.

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