Dec. 15, 1959 R. L. SWITZER 2,917,029

HYDRAULIC SYSTEM CONTROL

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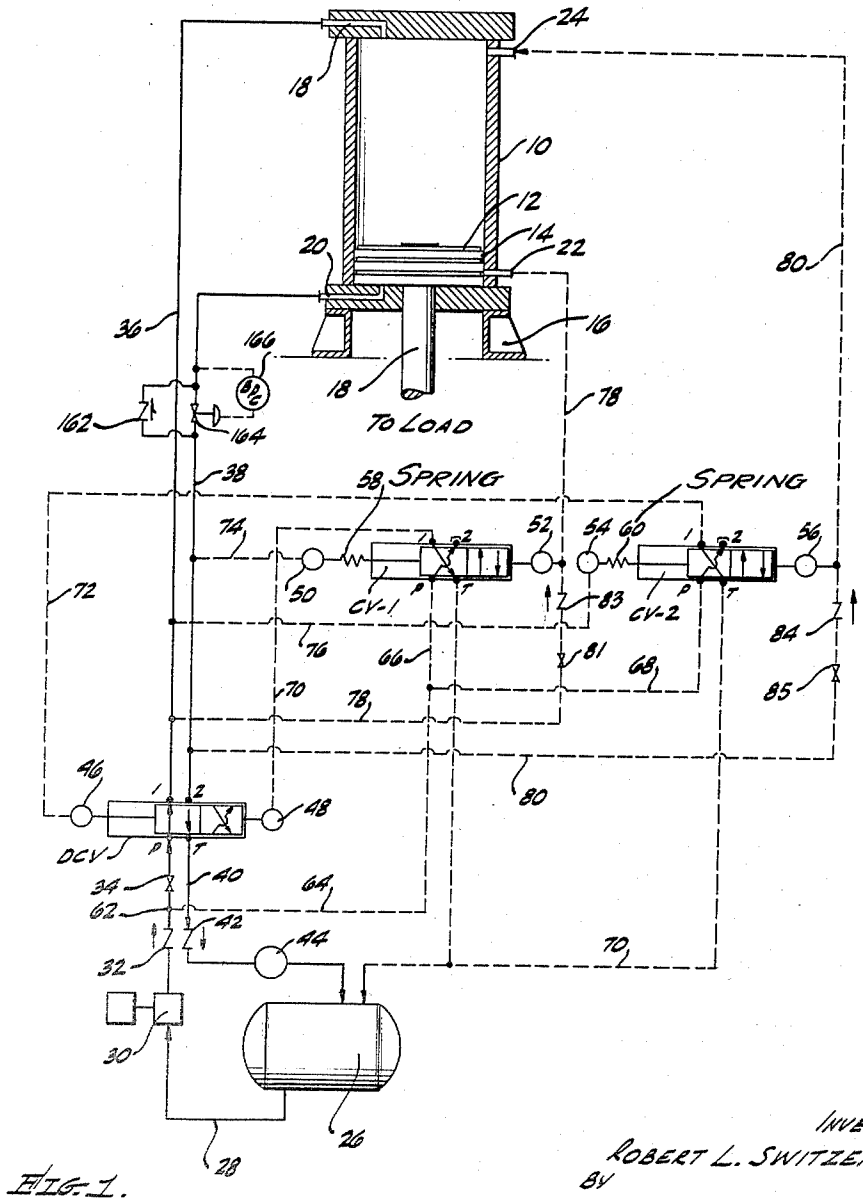


FIG. 1.

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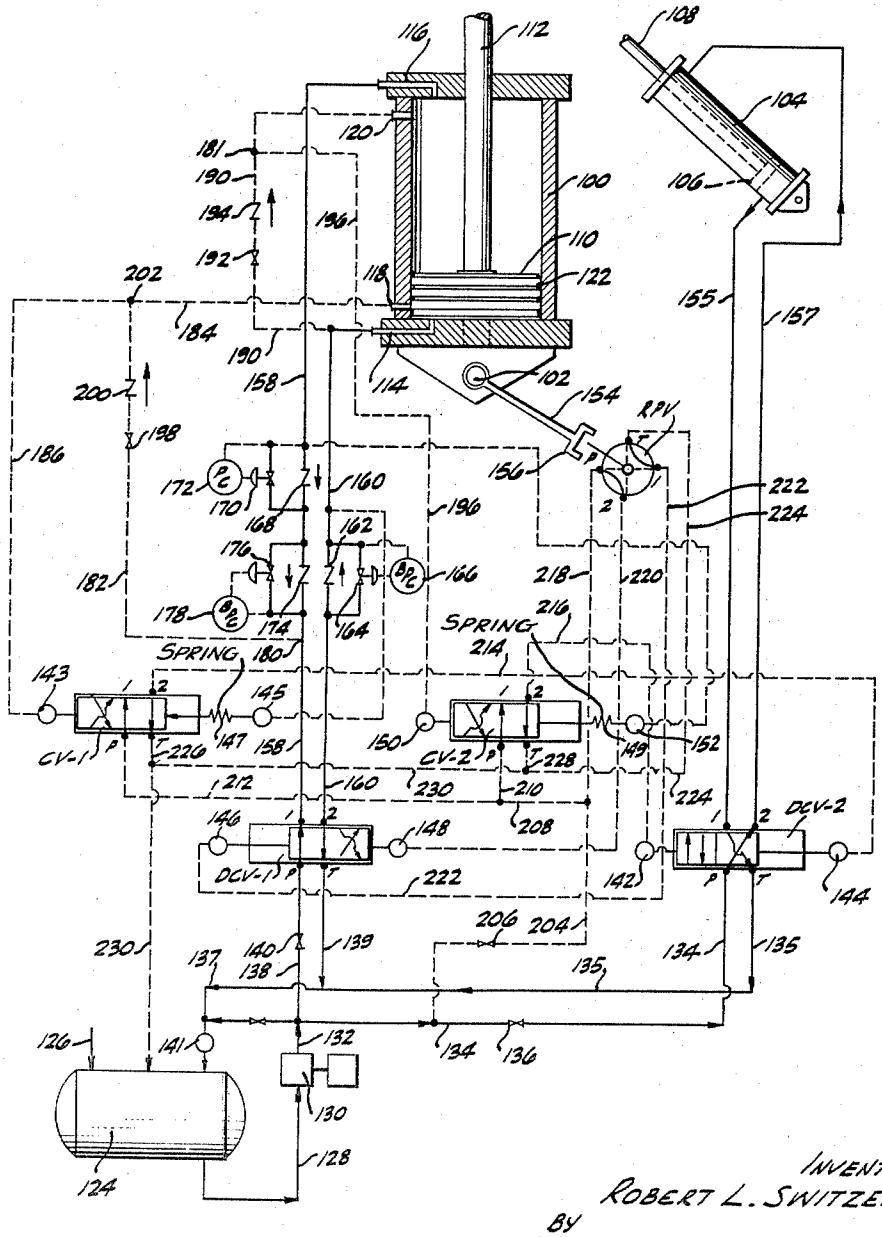


FIG. 2.

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2,917,029

HYDRAULIC SYSTEM CONTROL

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7 Claims. (Cl. 121—158)

This invention relates to the automatic control of hydraulic systems for the delivery of power by means of hydraulic cylinders and particularly relates to improvements in the control of such systems whereby the mechanically actuated pilot valves normally associated with the hydraulic cylinder in such systems have been eliminated.

Reciprocal motion of mechanical elements is widely used in mechanical devices of all kinds, some of which deliver power in appreciable quantities and others of which are merely used to actuate other elements at low force levels. Hydraulic cylinders containing a piston and piston rod are frequently used to generate such reciprocating motion, but heretofore they have required some means for detecting and signalling the time when the piston reached the end of its stroke in the cylinder. Ordinarily this detection and signalling is by means of a mechanically actuated pilot valve placed near the piston rod and tripped by means of kickers attached to it. The movement of the pilot valve alters the flow of hydraulic fluid through the valve and ultimately permits the reversal of the fluid flow to and from the cylinder so as to either retract or extend it depending upon which extreme has caused the signal generation.

Although such pilot valves are generally reliable, they are frequently difficult to maintain in some locations, particularly if they are submerged in a liquid medium, or located within a closed vessel, or in any other elements inaccessibly located.

One specific example of such inaccessibility lies in the feeder case enclosing the oscillating-reciprocating feeder mechanism employed in the upflow oil shale retort. Herein the reciprocating feeder is operated by a hydraulic cylinder which is contained within the feeder case and completely submerged therein in a body of shale oil. It is in general of advantage to eliminate the customary mechanical pilot valves in any situation since it constitutes a moving part of the mechanism which can be a source of trouble.

The present invention is therefore directed to an improved hydraulic system in which some or all such pilot valves are eliminated. The invention further relates to an improved hydraulic cylinder modified to provide self-signalling when the piston reaches either extreme of its stroke.

It is therefore a primary object of this invention to provide an improved hydraulic system for the generation of a reciprocating motion at any desired power level without the requirement of hydraulic pilot valves associated with the mechanism.

It is a more specific object of this invention to provide an improved hydraulic means for operating reciprocating pumps without the use of pilot valves.

One specific object of this invention is to provide an improved automatic hydraulic system for operating a single reciprocating load, such as an oil well pump, hydraulically without the use of pilot valves.

Another specific object of this invention is to provide an improved hydraulic system for operating the oscillating and reciprocating solids feeder in the upflow shale retorting process.

It is another object of this invention to provide an improved hydraulic cylinder modified to provide self-signalling when the piston reaches either extreme of the stroke.

Other objects and advantages of the present invention will become apparent to those skilled in the art as the description and illustration thereof proceed.

Briefly the present invention comprises an improved hydraulic system having for its essential element a modified hydraulic cylinder containing a piston and piston rod, provided with the conventional fluid inlets and outlets adjacent each end of the cylinder, and modified to provide pilot fluid inlets in the cylinder wall adjacent each end of the piston stroke. These pilot fluid inlets are located a distance away from the end of the cylinder which is less than the thickness of the piston contained therein, or less than the span occupied by piston rings on the piston side, so that when the piston has moved to either extreme of the cylinder, the pilot fluid inlet at that end is sealed either by the piston or by or between the piston rings, or both, so that no pilot fluid may enter or leave the cylinder through the pilot inlet.

In operation this modified hydraulic cylinder is supplied with hydraulic fluid through the usual inlets and outlets to move the piston in either direction in the conventional way. A pilot fluid obtained from the hydraulic pump supplying fluid to the cylinder is introduced at a relatively low rate into each of the pilot inlets through separate lines and preferably each of these lines is provided with a check valve permitting flow into the cylinder only. When the piston is moving from one extreme to the other, pilot fluid will not ordinarily flow into the pilot fluid inlet adjacent the high pressure end of the cylinder because the pilot fluid pressure will not ordinarily exceed the pressure of the main hydraulic fluid stream. The other end of the cylinder is venting displaced fluid to the hydraulic reservoir at a low pressure and therefore pilot fluid will flow into the pilot inlet near the low pressure or venting end of the cylinder and flow directly out again through the main fluid connection as it is displaced by the moving piston. At the end of the stroke however the pilot inlet at that end is sealed by the piston or its rings and accordingly the pilot fluid pressure in this inlet rapidly rises signalling the end of the piston stroke. This pressure increase is the pilot signal obtained from the modified hydraulic cylinder of this invention so that no mechanically operated pilot valve is needed. The signal so obtained can be used to operate the main direction reversing hydraulic valve controlling flow of hydraulic fluid to and from the cylinder through the principal or main connections so as to reverse the principal fluid flow and cause the piston to move in the reverse direction. At the end of this reverse stroke, the other pilot inlet is sealed in the same manner, and a pressure rise is generated in that pilot fluid inlet. This signal indicates the other end of the stroke and causes the direction reversing hydraulic valve to be moved back into the original position completing the hydraulic cycle.

The present invention is most readily understood by reference to the accompanying drawings in which:

Figure 1 shows a schematic piping and instrumentation diagram of a hydraulic system using a single hydraulic cylinder operated in a two-step sequence, and

Figure 2 shows a schematic piping and instrumentation diagram of hydraulic system utilizing two hydraulic cylinders operated in a four-step sequence to oscillate and reciprocate one of the cylinders.

System, Fig. 1 modification

Referring now particularly to Figure 1, hydraulic cylinder **10** provided with piston **12** and having piston rings **14**

is mounted by means of supports 16 and connected to a suitable reciprocating load, not shown but which may be a load such as a bottom hole oil well pump, by means of piston rod 18. Cylinder 10 is provided with the conventional main connections 18 and 20 for hydraulic fluid. Also provided according to this invention are pilot fluid connections or inlets 22 and 24 opening through the wall of hydraulic cylinder 10 a distance from each end thereof which is less than the thickness of piston 12, or the span of piston rings 14. This distance is determined so that with piston 12 in the position shown, pilot inlet 22 is sealed against fluid introduction by the piston or its rings. Similarly pilot fluid inlet 24 is sealed when piston 12 is at the top of the stroke in Figure 1. Hydraulic fluid from oil reservoir 26 flows through outlet line 28 into oil pump 30. Oil is pumped therefrom through check valve 32 and on through rate control valve 34 into a four-way directional control valve DCV having ports P, T, 1 and 2. The high pressure oil opens thereinto through port P. Directional control valve DCV is connected from port 1 by means of line 36 to upper main hydraulic oil connection 18 and lower main connection 20 communicates through line 38 to port 2 of DCV. The vented hydraulic oil displaced from cylinder 10, is removed from port T of DCV, flows through line 40 provided with check valve 42, and continues back to reservoir 26 through filter and cooler 44. With directional control valve DCV in the position shown, high pressure oil is supplied through line 36 to the top of cylinder 10 moving piston 12 downwardly therein, while displaced oil is vented through lines 38 and 40 back to reservoir 26. With DCV moved to the left, the hydraulic oil passes through DCV between ports P and 2, is introduced to the bottom connection of cylinder 10 causing piston 12 to rise, and the displaced hydraulic oil passes through line 36 and through DCV between ports 1 and T back to reservoir 26.

Directional control valve DCV thus selects the main hydraulic oil connection of cylinder 10 to which the high pressure oil is supplied and thus determines the direction of movement of piston 12. DCV is actuated and moved from left to right between the two extreme positions by means of hydraulic operators 46 and 48. These operators are in turn actuated by a pilot pressure impulse from either of control valves CV–1 or CV–2. Control valve CV–1 in turn is actuated by hydraulic operators 50 and 52 while control valve CV–2 is actuated by hydraulic operators 54 and 56. Control valves CV–1 and CV–2 are spring loaded by means of springs 58 and 60 biasing them into the positions shown whereby DCV operators 46 and 48 are vented into reservoir 26. Each of control valves CV–1 and CV–2 controls the flow of pilot fluid to the hydraulic operators 46 and 48 to actuate directional control valve DCV in response to the signal pressure increase in the pilot fluid connections. The signal pressure rise actuates control valves CV–1 and CV–2 through their hydraulic operators against loading springs 58 and 60. Ports 2 of each of CV–1 and CV–2 are blocked so that these valves are in reality three-way control valves. Port 1 of CV–1 is connected through line 70 to hydraulic operator 48 and port 1 of CV–2 is connected through line 72 to hydraulic operator 46, both of which operators actuate directional control valve DCV. A supply of pilot fluid is taken from point 62 on the main high pressure hydraulic oil line, and is connected by means of pilot oil manifold 64 and line 66 to port P of CV–1 and line 68 to port P of CV–2. These ports are normally closed because of loading springs 58 and 60. Ports T of each of CV–1 and CV–2 are connected through pilot oil vent manifold 70 to reservoir 26.

Hydraulic operator 50 of CV–1 is connected through line 74 and line 38 to lower main hydraulic connection 20 of cylinder 10. Hydraulic operator 54 of CV–2 is connected through line 76 and line 36 to upper main hydraulic connection 18 of cylinder 10. Thus when a high pressure exists in either of the main connections 18 or 20, as when the high pressure oil is applied therethrough to move piston 12 in one direction or the other, it is reflected through lines 36 and 76 or lines 38 and 74 so that hydraulic operators 54 and 50 respectively, in conjunction with loading springs 58 and 60, force control valves CV–1 or CV–2 to the right into the positions shown. The loading springs are required to prevent the main high pressure fluid from backing up through pilot lines 78 and 80 and actuating operators 52 and 56 thereby moving CV–1 and CV–2 in the reverse direction.

The supply of pilot fluid injected directly at pilot inlets 22 and 24 near the ends of cylinder 10 is obtained from the main hydraulic lines 36 and 38 referred to previously. Lower inlet 22 receives pilot fluid through line 78 provided with control valve 81 and check valve 83 and it also connects to and actuates hydraulic operator 52. Upper pilot fluid inlet 24 receives oil from main hydraulic line 38 through line 80 provided with control valve 85 and check valve 84 and is also connected with hydraulic operator 56. With this connection a high pressure at lower pilot inlet 22 signalling the arrival of piston 12 at the bottom of hydraulic cylinder 10 actuates hydraulic operator 52 moving CV–1 to the left against loading spring 58 and thereby supplies pilot hydraulic fluid to hydraulic operator 48 moving DCV to the left. Similarly the arrival of piston 12 at the top of the stroke seals pilot inlet 24, causes the pressure in line 80 to rise, actuates hydraulic operator 56 moving CV–2 to the left against loading spring 60, and thereby supplies pilot fluid pressure through line 72 to actuate hydraulic operator 46 moving DCV back to the right in the position shown. In this way the movements of piston 12 in hydraulic cylinder 10 signal the arrival of the piston at the extremes of piston travel and causes a reversal of the main flow of hydraulic fluid so as to return the piston toward the opposite extreme. The system continues in this reciprocating motion indefinitely at a rate controlled by valve 34 and pump 30 which regulate the rate at which high pressure hydraulic fluid is supplied to cylinder 10 to move piston 12.

Operation, Fig. 1 modilcation

A complete description of the movement sequence of each of the three valves DCV, CV–1, and CV–2, and the reciprocation of piston 12 in hydraulic cylinder 10 is given immediately below to provide a concise and clear description of the operation of this modification of the apparatus of this invention. In Figure 1 piston 12 is shown arriving at the bottom of its downstroke. During the downstroke the weight of the load, if any, plus the weight of piston rod 18 and piston 12, plus the supply of high pressure fluid through line 36 to upper inlet 18 of the cylinder causes piston 12 to move downwardly through cylinder 10. During this time a small flow of pilot fluid into the lower pilot fluid inlet 22 is maintained from line 36 through pilot line 78. Meanwhile displaced fluid flows through lower main hydraulic connection 20 together with the pilot fluid which is introduced through inlet 22 and flows through line 38 and DCV back to reservoir 26.

When piston 12 arrives at the lowest position, pilot inlet 22 is sealed and the pressure there and in line 78 rises sufficiently to actuate operator 52 and move CV–1 to the left against spring 58. This places pilot fluid pressure through ports P and 1 of CV–1 onto operator 48 moving DCV to the left. This connection vents hydraulic fluid from the top of cylinder 10 while supplying high pressure fluid through lower main connection 20 to raise piston 12. Since connection 18 is now vented, this relieves pressure at pilot inlet 24 permitting CV–2 to return to its right-hand position shown through the action of spring 60.

The piston now moves upwardly connected to the load through connecting rod 18. When the piston arrives at the top of the stroke, upper pilot inlet 24 is sealed against further pilot fluid flow from line 38 through line 80. The pressure rises and this pressure impulse is transmitted

through line 80 to operator 56 moving CV–2 to the left against spring 60 thereby placing pilot fluid pressure therethrough between ports P and 1 and through line 72 to operator 46 moving DCV to the right thereby reversing the main flow of hydraulic fluid. The bottom of cylinder 10 is now vented through line 38 and high pressure fluid is supplied through line 36 to return the piston toward the bottom position. This relieves the high pressure formerly below piston 12 and also at the lower pilot inlet 22 lowering the pressure at operator 52 and permitting CV–1 to return to the right-hand position shown by means of loading spring 58.

Piston 12 is now moving downwardly toward the lower position to begin the cycle all over again. The cycle continues indefinitely at a rate determined by the rate of supply and the pressure of the main stream of hydraulic fluid. The end of each of the two steps is signalled by the pilot pressure increase, and this begins the next step. The weight of the piston 12, shaft 18, and the load is prevented from causing the piston downstroke by check valve 162, valve 164, and back pressure controller 166 which maintain during the downstroke a pressure below piston 12 which is sufficient to support the weight. A slightly greater pressure above piston 12 will cause the downward movement.

As stated briefly above, the modification shown in Figure 1 is particularly adaptable to the hydraulic pumping of oil wells by means of a hydraulic cylinder having a diameter of from 2 to 12 inches or more and a stroke of from 2 to 40 feet located at the surface of the earth and connected through a string of sucker rods to a bottom hole pump in the well. Obviously the apparatus is adapted to any other use in which a reciprocal motion in power application is required. This reciprocal movement can be vertical as described, horizontal, or at any other angle. These other applications of course will occur to those skilled in the art from a reading of the present description.

System, Fig. 2 modification

Referring now more particularly to Figure 2, a more complex four-step modification of the present invention is shown using one mechanically actuated pilot valve employing two hydraulic cylinders and is adapted for use in operating the solids feeding mechanism of the upflow shale retorting apparatus shown, for example, in U.S. Patent No. 2,640,019. In this modification, a first or main feed cylinder 100, which drives the piston in a solids feeder, is oscillated between the vertical position shown and an inclined position, not shown, around trunnion 102. This oscillation is imparted by means of a second or oscillating cylinder 104 provided with piston 106 and piston rod 108 which is integrally connected by any means not shown to cylinder 100. Feed cylinder 100 is provided with piston 110, piston rod 112, and the solids feeder not shown at the upper end of the piston rod. Cylinder 100 is inclined from the vertical by extending cylinder 104 at a time when piston 110 is extended. Crushed oil shale is supplied to the top of the solids feeder piston and cylinder system, piston 110 is retracted accepting a charge of shale, feeder cylinder 100 is returned from this charging position to the vertical feeding position by retracting oscillating piston 106, and then the charge of shale is introduced upwardly into the retort by extending feeder piston 110 upwardly to the upper limit of its travel, thereby completing the cycle. The end of each step in the sequence signals the start of the next step. This four-step sequence cycle is continued to force periodic charges of oil shale upwardly into the retort.

In Figure 2 the piping and instrumentation connections by means of which the foregoing sequence of operations is effected are shown schematically. The main hydraulic conduits are shown as solid lines while the pilot fluid connections are shown as broken lines. Feeder cylinder 100 is provided with upper and lower ends with the usual main hydraulic fluid connections 114 and 116, hydraulic fluid being introduced through 114 and vented through 116 to extend piston 110 and piston rod 112, and subsequently being introduced through inlet 116 and vented through 114 to retract piston 110 and piston rod 112. Also provided adjacent each end of feeder cylinder 100 are lower and upper pilot fluid connections 118 and 120. These pilot fluid connections are disposed a distance from the end of the cylinder which is less than the thickness of piston 110. Piston 110 is provided with piston rings 122 which seal, as shown in the drawing, pilot fluid connection 118. Pilot fluid connection 120 is similarly sealed when piston 110 is in its upper or extended position. The function of these connections so placed has been referred to above in connection with Figure 1 to provide a pressure signal indicating the arrival of the piston at the ends of its stroke. This signal is utilized to change the flow of hydraulic fluid in the system so as to continue automatically the sequential operation of feeder cylinder 100 and oscillating cylinder 104.

The present system is provided with hydraulic fluid reservoir 124 having filling line 126. Outlet line 128 opens into fluid pump 130 which delivers high pressure hydraulic fluid into manifold 132. This fluid is divided into two principal streams, one flowing through line 134 at a rate controlled by valve 136 through four-way direction reversing valve DCV–2 to oscillating cylinder 104, and the other through line 138 at a rate controlled by valve 140 through four-way direction reversing valve DCV–1 to feeder cylinder 100. Displaced hydraulic fluid is vented from oscillating cylinder 104 through line 157, back through valve DCV–2 and through line 135 into low pressure manifold 137. Displaced low pressure hydraulic fluid passes from feeder cylinder 100 through valve DCV–1 through line 139 through low pressure manifold 137. The returning hydraulic fluid is passed through a cooler and a filter indicated generally at 141 and returned to reservoir 124. The rate of movement of piston 106 in oscillating cylinder 104 is controlled by the setting of valve 136. Similarly the rate of movement of piston 110 in feeder cylinder 100 is controlled by the setting of valve 140.

Direction reversing valve DCV–2 is actuated by means of hydraulic operators 142 and 144 and serves to provide high pressure hydraulic fluid to and vent low pressure hydraulic fluid from the fluid connections at the end of oscillating cylinder 104. Similarly, direction reversing valve DCV–1 is actuated by hydraulic operators 146 and 148 and provides hydraulic fluid to and vents fluid from connections 114 and 116 at the ends of feeder cylinder 100.

Operators 142 and 144 which actuate directional control valve DCV–2 are themselves actuated by pilot fluid through control valves CV–1 and CV–2.

Control valve CV–1 is actuated by hydraulic operators 143 and 145, and control valve CV–2 is actuated by operators 150 and 152 by means of signal pressures obtained in part from the pilot fluid lines and in part from rotary pilot valve RPV. As noted on the drawing, control valves CV–1 and CV–2 are spring loaded by means of loading springs 147 and 149 which tend to bias them to the left into the positions shown in which both operators 142 and 144 of DCV–2 are vented to reservoir 124. Thus the impulse generated by operators 143 and 150 must overcome the compression force of these loading springs in order to move valves CV–1 and CV–2 to the right. Once the signal pressure is removed from operators 143 and 150, the loading springs return then to the positions shown in the drawing. In the present invention where feeder cylinder 100 oscillates about trunnion 102, it is simple to bring an extension rod through the feeder case from trunnion 102 provided with arm 154 and kicker 156 which actuates rotary pilot

valve RPV at the extremes of the oscillation. The extremes of reciprocation of piston 110 however are difficult to sense because of the location of this cylinder within a sealed oil filled case. Accordingly the pilot hydraulic inlets 120 and 118 are respectively used according to the present invention to provide the signal pressures to actuate operator 150 when piston 110 reaches the top of its stroke and hydraulic operator 143 when piston 110 is in the position shown at the bottom of its stroke.

Briefly, then, rotary pilot valve RPV signals the extremes in the oscillation of feeder cylinder 100, which actually is the same as signalling the extremes of reciprocation of oscillating cylinder 104, so as to actuate directional control valve DCV–1 through hydraulic operators 146 and 148. Pressure increases in connections 118 and 120 signal the arrival of piston 110 at the extremes of travel in feeder cylinder 100 so as to operate control valves CV–1 and CV–2 which in turn operate direction reversing valve DCV–2 for the purposes discussed above.

Direction reversing valve DCV–2 is connected at ports 1 and 2 by means of lines 155 and 157 to oscillating cylinder 104. Direction reversing valve DCV–1 is connected at ports 1 and 2 respectively with main fluid connections 116 and 114 of feeder cylinder 100 by means of lines 158 and 160. As will be noted, these latter two lines are provided with several check valves and back pressure controllers for the specific purposes discussed below.

Line 160 is provided with check valve 162, permitting fluid flow only therethrough into connection 114, and control valve 164 actuated by back pressure controller 166 connected in parallel therewith. The purpose of this back pressure controller is to maintain during the downstroke of piston 110 a predetermined minimum hydraulic pressure below piston 110 which prevents the piston from moving downwardly, because of its own weight and the weight of the piston rod and he load attached thereto, at an undesirably high rate.

Line 158 is provided with check valve 168, permitting outflow of hydraulic fluid from connection 116 only, and control valve 170 connected in parallel therewith and actuated by pressure reducer 172. The purpose of this pressure reducer is to limit the maximum hydraulic pressure which can be placed in cylinder 100 at port 116 above piston 110 during the retraction stroke. This pressure need only be as great as the pressure applied to lift piston 110 since the weight of the load, the piston rod 112, and piston 110 act in a direction which aids the retraction of the piston.

Line 158 is further provided with check valve 174, permitting outflow of fluid only from cylinder 100 above piston 110, and control valve 176 connected in parallel therewith and actuated by back pressure controller 178. The purpose of this back pressure controller is to generate a back pressure in the line 158 at point 180 during the retraction stroke of piston 110 so as to generate a signal pressure through control lines 182 and 184 at pilot fluid inlet 118 when piston 110 reaches its retracted position, which pressure signal is sufficiently high so that it will actuate through line 186 hydraulic operator 143 against the loading spring 149 in control valve CV–1.

Hydraulic pilot fluid flow into connections 118 and 120 is derived from the high presure fluid flow directed through direction reversing valve DCV–1 and through lines 158 and 160 into main connections 116 and 114. Thus when high pressure fluid is being introduced through connection 114 during the extension stroke of piston 110, a minor portion of the fluid flows through line 190 provided with control valve 192 and check valve 194 through the upper pilot hydraulic connection 120. The pressure rise in this line from the vent pressure to the supply value generated by the arrival of piston 110 at the extension end of the stroke is transmitted through line 196 to operator 150 which moves control valve CV–2 to the right against loading spring 149. When high pressure hydraulic fluid is being introduced through line 158 to the upper main connection 116 in feeder cylinder 100 during the retraction stroke, a minor flow is taken from line 158 at point 180, is passed through line 182 provided with control valve 198 and check valve 200, then through line 184 into lower pilot hydraulic inlet 118. The pressure rise from the vent pressure to the supply value signalling the arrival of piston 110 at the retracted extreme, as shown in the drawing, is detected at point 202 and is transmitted through line 186 thereby actuating hydraulic operator 143 and moves control valve CV–1 to the right against loading spring 147.

As stated above, these aforementioned movements to the right of control valves CV–1 and CV–2 permit the flow of pilot hydraulic fluid from high pressure manifold 134 through pilot fluid manifold 204 provided with valve 206 and, respectively, through lines 208 and 212 through control valve CV–1 at ports P and 2 through line 214 to actuate operator 144 and move DCV–2 to the left, and through line 210 through control valve CV–2 at ports P and 2 through line 216 to actuate operator 142 to move DCV–2 to the right. The flow of hydraulic fluid to and from oscillating cylinder 104 is thus controlled.

High pressure pilot manifold 204 is also connected through line 218 to port P of rotary pilot valve RPV. As stated above, this pilot valve is mechanically actuated by the oscillation of feeder cylinder 100. When the feeder cylinder reaches the vertical or feeding position shown in the drawing, a position in which the piston 110 is also in its lower or retracted position, rotary pilot valve RPV is internally connected between ports P and 2 thereby permitting the high pressure hydraulic pilot fluid to flow through line 220 to hydraulic operator 148 moving direction reversing DCV–1 to the left. This permits the flow of high presure hydraulic fluid through the main line 138 through DCV–1, ports P and 2, on through line 160 to the bottom connection 114 of cylinder 100 thereby raising piston 110. At the top of this stroke and as previously described, feeder cylinder 100 is oscillated into an inclined position which again actuates rotary pilot valve RPV by means of kicker 156 so as to connect ports P and 1. This permits high pressure pilot fluid to flow through RPV, through line 222 to hydraulic operator 146 which moves DCV–1 into the position shown. This supplies a main high pressure stream of hydraulic fluid through lines 138 and 158 to open connection 116 to retract piston 110 in feeder cylinder 100.

Ports T on each of rotary pilot valve RPV and control valves CV–1 and CV–2 are connected respectively by means of lines 224, 226, and 228 to low pressure pilot fluid manifold 230 through which it is returned to fluid reservoir 124.

The foregoing discussion briefly describes the functions and the interconnections between each of the essential elements of the system described in Figure 2. The operation will be perhaps most readily understood by following the motions of each element through a complete cycle of operation. Such a cycle is described immediately below.

Operation, Fig. 2 modification

Figure 2 shows the feeder cylinder 100 in its fully retracted position and also shows the oscillating cylinder 104 in its fully retracted position. The setting of RPV shown, resulting from the movement of cylinder 100 into the vertical position, supplies high pressure pilot fluid through ports P and 2 to hydraulic operator 148 while venting hydraulic operator 146 through ports T and 1 thereby shifting directional control valve DCV–1 to the left. This connects ports P and 2 and connects ports 1 and T in DCV–1 thereby directing high pressure fluid through line 160 to the bottom of cylinder 100 causing piston 110 to rise delivering shale into the kiln.

The fluid lying above piston 110 is vented through connection 116 and through line 158, through ports 1 and T of DCV–1, and lines 139 and 137 to reservoir 124.

At the same time as high pressure fluid is introduced through inlet 114, a small pilot fluid stream passes into upper pilot fluid inlet 120 through line 190. When piston 110 reaches the fully extended position, this pilot fluid flow at inlet 120 is cut off causing the pressure at 181 in line 190 to rise signalling the end of the feeder cylinder 100 extension stroke. This places a high signal pressure through line 196 on hydraulic operator 150 sufficient to actuate it against loading spring 149 thereby moving control valve CV–2 to the right. This connects ports P and 2 and ports 1 and T of CV–2. High pressure pilot fluid is thereby passed through ports P and 2 through line 216 on to hydraulic operator 142 moving direction reversing valve DCV–2 to the right. This places high pressure hydraulic fluid through line 134, connected ports P and 1 in DCV–2, through line 155 to the lower port of oscillating cylinder 104 causing piston 106 to move into the extended position thereby oscillating feeder cylinder 100 into the inclined charging position while piston rod 112 is extended.

Upon reaching the fully inclined position, kicker 156 again actuates RPV thereby connecting ports P and 1 and connecting ports T and 2. High pressure pilot fluid flows from line 218 through connected ports P and 1 in RPV, through line 222 to actuate hydraulic operator 146 moving DCV–1 to the right connecting ports 1 and P and connecting ports 2 and T thereof. This places high pressure hydraulic fluid from pump 130 through line 158 into upper inlet 116 while venting displaced hydraulic fluid from cylinder 100 through lower connection 114, line 160, connected ports 2 and T in DCV–1, back to reservoir 124. While high pressure fluid thus flows through line 158 into upper connection 116, a small high pressure pilot stream flows through lines 182 and 184 into lower pilot fluid inlet 118 only so long as piston 110 does not seal this inlet. When piston 110 is fully retracted, in accepting a fresh charge of oil shale, pilot fluid inlet 118 is sealed causing pressure to rise at point 202. This actuates through line 186 hydraulic operator 143 moving CV–1 to the right against loading spring 147 thereby connecting ports P with 2 and ports 1 with T in CV–1. Pilot hydraulic fluid flows from lines 132, 204, 208 and 212 through ports P and 1 of CV–1, through line 214 actuating hydraulic operator 144, moving direction reversing valve DCV–2 to the left thereby connecting ports P and 2 and ports T and 1 in DCV–2. High pressure hydraulic fluid then flows through DCV–2 through connected ports P and 2, through line 156 to the upper connection on oscillating cylinder 104. This causes the piston 106 to retract. Hydraulic fluid is vented from the lower connection in cylinder 104 through line 155 and connected ports 1 and T in DCV–2, through lines 135 and 137 to reservoir 124. This brings oscillating cylinder 104 back into the position shown in Figure 2 thereby oscillating feeder cylinder 100 into the vertical or feeding position also shown in the drawing. This causes kicker 156 again to trip rotary pilot valve RPV thereby interconnecting ports P and 2 and ports T and 1. This begins the cycle all over again. Pilot fluid flows through line 218 and connected ports P and 2 and RPV, then through line 220 actuating hydraulic operator 148 moving direction reversing valve DCV–1 to the right thereby connecting port P with 2 and port T with 1. This supplies high pressure hydraulic fluid to lower connection 114 in feeder cylinder 100 forcing piston 110 upwardly to deliver the charge of oil shale into the kiln.

The cycle automatically repeats in the aforementioned steps causing a continuous alternate extension and retraction of each of cylinders 100 and 104 in the sequence described.

It is obvious from the foregoing description the manner in which the pilot valves formerly used have been eliminated from the mechanism associated with piston rod 112 in cylinder 100 and have been substituted with lower and upper hydraulic fluid inlets 118 and 120. Rotary pilot valve RPV was only used because trunnion 102 was readily fitted with a sealed shaft which could be brought through a seal in the feeder case enclosing feeder cylinder 100 and oscillating cylinder 104. It should be understood that in other situations it may be inconvenient to use rotary pilot valve RPV and it may be eliminated together with its mechanical actuation means and oscillating cylinder 104 may be provided with the two hydraulic fluid inlets at each end in a manner entirely analogous to that shown in connection with feeder cylinder 100. In this situation all pilot valves are eliminated and the moving cylinders may be completely enclosed in inaccessible positions and the signals indicating the end of each piston stroke obtained by pressure increases in the hydraulic fluid inlet lines as described in connection with cylinder 100 in Figure 2.

The system shown in Figure 1 was employed in actuating a bottom hole pump in an oil well located in southern California. The well was 7,800 feet deep, the actuating cylinder was 30 feet long, and 8 inches in diameter. Hydraulic fluid was applied thereto at a pressure of 500 to 800 p.s.i. to move the sucker rod upwardly so as to actuate the pump. The cycle was continued at a rate of approximately 6 strokes per minute while pumping at a rate of 400 barrels per day. The system was entirely successful, operated for extended periods without maintenance, and made substantially no noise while in operation.

The system of Figure 2 was employed in actuating the so-called rock pump in the upflow shale retorting process. In this modification crushed shale rock was fed to the retort at a rate of about 350 tons per day in a retort which was 17 feet in diameter and about 35 feet high. The shale feeder cylinder was 66 inches in diameter, had a stroke of 24 inches, and was operated at a rate of 10 strokes per hour by means of the hydraulic system indicated in Figure 2. The oscillating cylinder had a stroke of 4 feet and was 16 inches in diameter. The feeder cylinder, which actuated the shale piston feeder, had a stroke of 2 feet and was 32 inches in diameter. The hydraulic fluid was supplied in the system at a maximum of 2,000 p.s.i.g., the pilot hydraulic fluid was used in the system at a maximum pressure of about 200 p.s.i.g. by means of valve 206 shown in Figure 2, the lower feeder cylinder pressure was maintained by means of back pressure controller 164 to a value of about 200 p.s.i.g. during the downstroke, the pressure in the top of feeder cylinder 100 was limited by means of pressure controller 172 during the downstroke to a maximum of about 1,000 p.s.i.g., and back pressure controller 178 during this same downstroke maintained a pressure differential of about 200 p.s.i.g. across valve 176 so as to supply at point 180 a source of pilot hydraulic fluid of a sufficient pressure during the downstroke to generate at point 202 when piston 110 is in its fully retracted position a hydraulic pressure sufficiently high to actuate hydraulic operator 143 in control valve CV–1.

The present invention has been described above by way of illustration in connection with two processes in which it has been used. The apparatus of Figure 1 and Example 1 is relatively simple employing a single hydraulic cylinder which has been provided at its end with two oscillating pilot hydraulic fluid inlets for the purposes described. The system of Figure 2 and of Example 2 is more complicated because of its simultaneous reciprocating and oscillating movements. The principles employed are the same however and from the foregoing description those skilled in the art will readily understand how the invention may be applied to other and more complex systems as well as to other uses in which power at any level is to be delivered through reciprocat-

ing motion to a load. The system of Figure 2 is claimed in my divisional application Serial Number 750,684, filed July 24, 1958.

A particular embodiment of the present invention has been hereinabove described in considerable detail by way of illustration. It should be understood that various other modifications and adaptations thereof may be made by those skilled in this particular art without departing from the spirit and scope of this invention as set forth in the appended claims.

I claim:

1. An apparatus comprising an hydraulic cylinder having a piston reciprocable therein, an hydraulic fluid pressure line, and hydraulic fluid exhaust line, a four-way direction reversing valve connected by conduits to the ends of said cylinder and to said pressure line and said exhaust line, hydraulic operators for said reversing valve, a pair of spring loaded hydraulically operated pilot fluid control valves connected between said pressure line and said operators, a first and a second pilot fluid line communicating with each end of said cylinder and opening into the other end thereof, separate means connecting each of said pilot fluid lines with one of the operators of said spring loaded pilot fluid control valves so that fluid pressure acts against the spring loading and so that said piston reciprocates continuously and automatically in a two-step sequence so long as fluid pressure is maintained in said pressure line.

2. An apparatus according to claim 1 wherein said hydraulic cylinder is positioned vertically and the piston therein is connected by a connecting rod extending through at least one end of said cylinder to a vertically reciprocating load.

3. An apparatus according to claim 2 in combination with a pressure controller and valve connected in that conduit which connects said reversing valve to the lower end of said cylinder to maintain below said piston during the downstroke a pressure above a minimum so that the weight of said piston and the connecting rod and said load will not alone cause said piston to move downward.

4. An apparatus according to claim 1 in combination with a valve in said pressure line to control the rate of reciprocation of said piston.

5. An apparatus according to claim 1 wherein said pilot fluid inlet lines open into the side of said hydraulic cylinder near each end thereof so that the piston seals and prevents pilot fluid flow through said inlet when said piston moves to that end of said cylinder.

6. An apparatus comprising a closed hollow cylinder having first and second ports adjacent the opposite ends thereof; a piston adapted to reciprocate within said cylinder; a connecting rod attached to said piston and extending through at least one of the closed ends of said cylinder; a first main fluid line communicating with the interior of said cylinder adjacent one of the closed ends thereof; a second main fluid line communicating with the interior of said cylinder adjacent the other closed end thereof; a fluid pressure line; a fluid exhaust line; a reversing valve which, in a first position, simultaneously connects said first main fluid line to said pressure line and said second main fluid line to said exhaust line, and, in a second position, simultaneously connects said first main fluid line to said exhaust line and said second main fluid line to said pressure line; a first fluid-actuated reversing valve operator for moving said reversing valve into said first position; a second fluid-actuated reversing valve operator for moving said reversing valve into said second position; a first control valve which, in a first position, connects said first reversing valve operator to said exhaust line, and, in a second position, connects said second reversing valve operator to said pressure line; means for biasing each of said control valves into its said first position; a fluid-actuated first control valve operator for moving said first control valve into its said second position; a fluid-actuated second control valve operator for moving said second control valve into its said second position; a first pilot fluid line communicating between said first port and the interior of said cylinder at a point on the opposite side of said piston; a first fluid line connecting said first pilot fluid line to said first control valve operator; a second pilot fluid line communicating between said second port and the interior of said cylinder at a point on the opposite side of said piston; and a second fluid line connecting said second pilot fluid line to said second control valve operator; said ports being so positioned as to be sealed off by said piston when it reaches the limit of its travel to the corresponding end of said cylinder.

7. An apparatus as defined by claim 6 in combination with a third fluid-actuated control valve operator for moving the said first control valve into its said first position; a fluid line connecting said third control valve operator to said first main fluid line; a fourth fluid-actuated control valve operator for moving the said second control valve into its said first position; and a fluid line connecting said third control valve operator to said second main fluid line.

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