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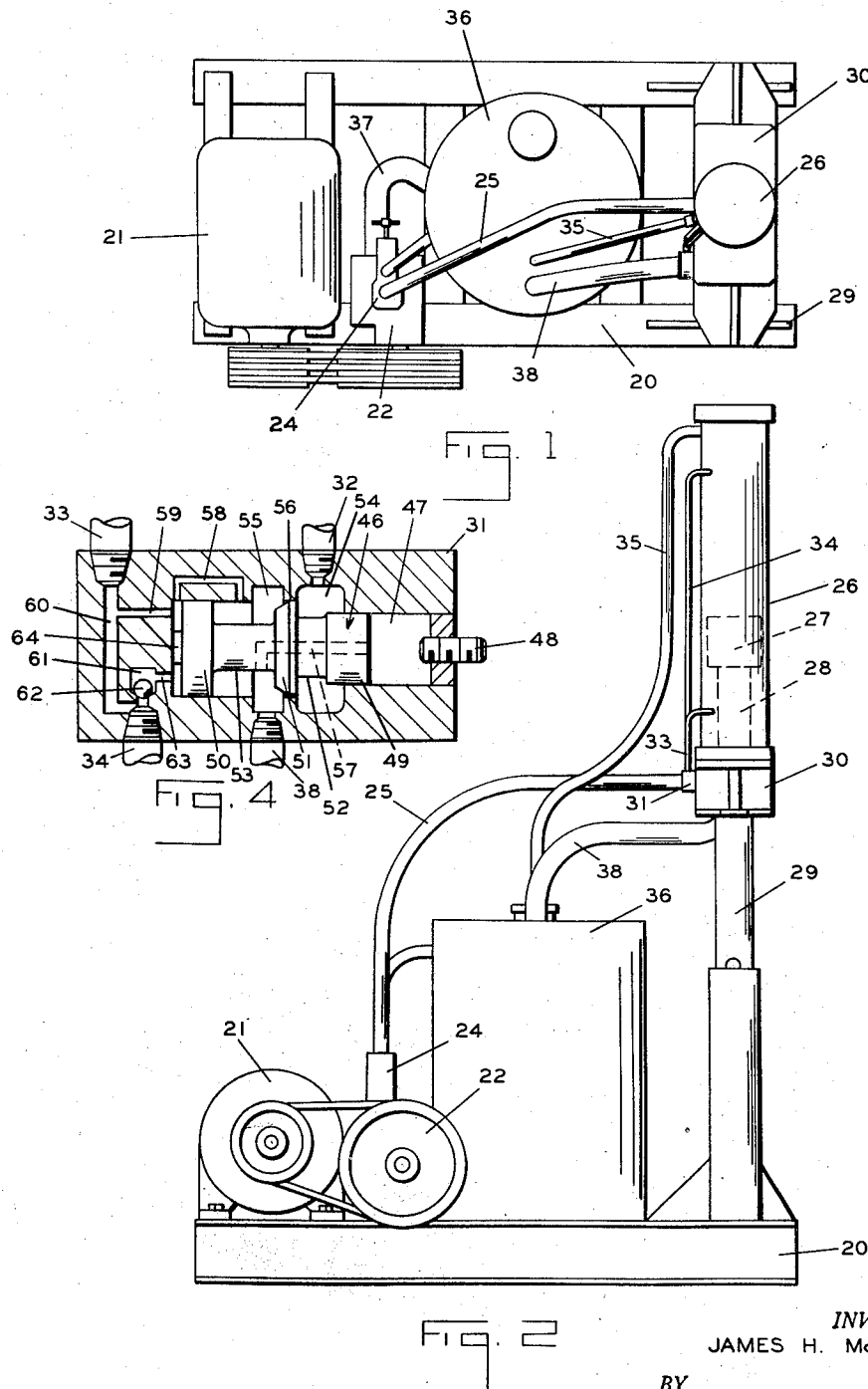
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2,853,057

HYDRAULICALLY OPERATED RECIPROCATING MECHANISM

Filed Aug. 16, 1956

3 Sheets-Sheet 1



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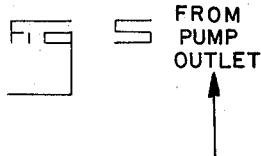
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Fig. 3

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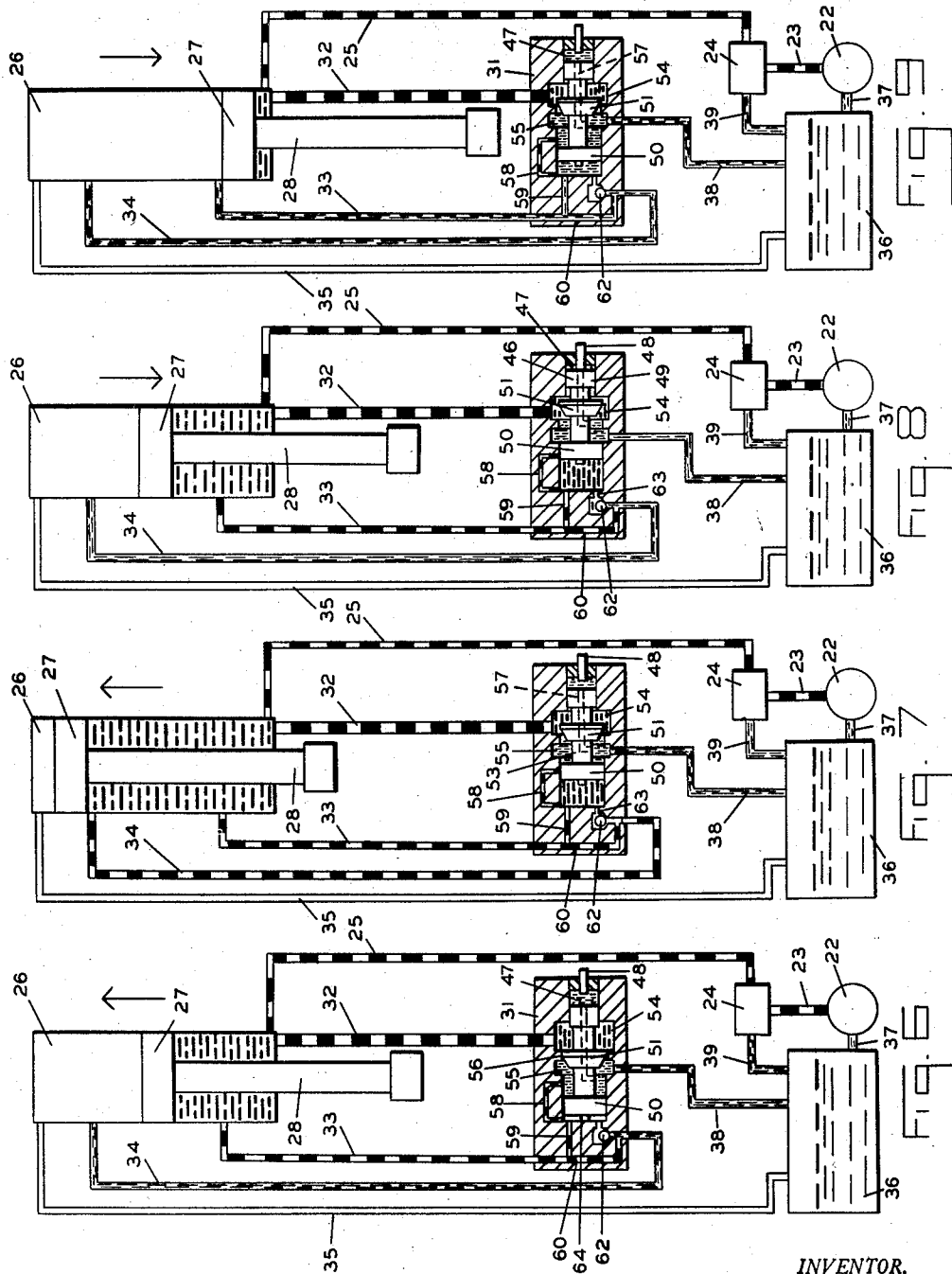
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HYDRAULICALLY OPERATED RECIPROCATING MECHANISM

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Application August 16, 1956, Serial No. 604,508

5 Claims. (Cl. 121—150)

My invention relates to a hydraulically operated reciprocating mechanism. It has to do, more particularly, with a hydraulically actuated reciprocating mechanism which is especially suitable for use in association with pumping mechanism for a well although it could also be used in association with well-drilling mechanism. It is specifically designed to carry heavy loads, such as a string of tools, rods, or cable, in a well, like those used in drilling or pumping deep wells, for example, oil wells.

The main object of my invention is to provide a simple yet practical hydraulically operated mechanism for carrying a heavy load through a fixed reciprocating cycle.

According to my invention I provide a unit which is a closed hydraulic system sealed from the atmosphere. This system includes a single action hydraulic cylinder and piston which is suitably connected to the load to be reciprocated. Connected to the pressure end of the cylinder is a constant flow hydraulic pump. Reciprocation of the piston is automatically controlled by means of an automatic reversing valve which controls only the exhaust of pressure from the cylinder, the pump pressure line being connected to the cylinder at all times, and which is actuated solely by the pressure of the fluid supplied by the pump. Since the pump is continuously connected to the cylinder and since the reversing valve controls the cylinder exhaust only, shock which is ordinarily encountered in reversing the direction of travel of a hydraulic piston connected to a load is reduced to a minimum. The reversing valve is such that a complete stroke of the piston in either direction is insured after the stroke is once started and the reversing movement of the valve itself is positive and complete in either direction. This reversing valve also provides means for controlling the speed of movement of the piston in its reversing direction in the cylinder which is aided by the load. A control and safety valve is connected in the pressure line of the pump between the pump and the cylinder. This latter valve provides an arrangement to cause the piston and its load to gradually start in motion when the hydraulic pump is started abruptly, such as by a time clock, positive clutch, etc. It also provides means for controlling the speed of movement of the piston, during its load lifting stroke. This valve also provides a pressure relief valve to guard against excessive pressures in the system and a check valve to prevent drainage of hydraulic fluid from the system back through the pump in case the pump stops operating. Also, a gauge is associated with this valve for registering hydraulic pressure in the system and for operating a safety switch if the pressure becomes excessive.

In the accompanying drawings I have illustrated one embodiment of my invention.

In these drawings:

Figure 1 is a plan view of a unit embodying my invention and which is designed as an hydraulic pump jack.

Figure 2 is a side elevational view of the unit of Figure 1.

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Figure 3 is an elevational view at right angles to that of Figure 2 and illustrating how the unit is connected to the sucker rod of well-pumping mechanism.

Figure 4 is a longitudinal sectional view taken through the reversing valve which automatically controls my unit.

Figure 5 is a longitudinal sectional view taken through the safety and control valve also used in controlling my unit.

Figures 6 to 9 are diagrammatic views illustrating the sequence of operations through one cycle of my unit.

With reference to the drawings, my invention is illustrated as a hydraulic pumping jack but, as indicated previously, is capable of other applications.

The entire unit is carried by a base frame 20 as shown in Figures 1, 2 and 3. It comprises a driving motor 21 which may be an electric motor or a governor-controlled gasoline or diesel engine. This motor 21 drives a constant volume hydraulic pump 22, these members being associated properly with each other on the frame 20. The pump 22 has its outlet pressure line 23 (Figures 6 to 9) connected to a control and safety valve 24 and then by a pressure line 25 to the lower end of the cylinder 26. The cylinder 26 has a piston 27 reciprocable therein and the piston has a piston rod 28 extending from the lower end thereof. The cylinder 26 is carried in a vertical position on the upper end of an up-standing yoke frame 29 (Figures 2 and 3), which is supported by the base frame 20, by means of a cylinder base 30 which serves as a housing for a reversing valve 31 shown in Figures 4 and 6 to 9, inclusive. The reversing valve 31 controls only the exhaust of fluid from the cylinder 26 and is connected to the pressure or lower end of the cylinder by the exhaust line 32 which is larger than the line 25 and which connects to the valve 31 intermediate its ends. An exhaust and pressure line 33 connects to the left-hand end of the valve 31 and to the pressure end of the cylinder 26 at a point spaced slightly above the lower end thereof. An exhaust and pressure line 34 connects the same end of the valve to the cylinder 26 at a point spaced below the upper end thereof. An exhaust line 35 connects to the cylinder 26 at its upper end and leads to the upper end of a sump tank 36. The tank 36 is connected to the pump 22 by the pump inlet line 37 leading from the lower end thereof. The valve 31 is also connected intermediate its ends to the tank 36 by means of an exhaust line 38. The valve 24 is also connected to the upper end of the tank 36 by an exhaust line 39.

The lower end of the piston rod 28 is suitably connected to the load which the piston is to lift and which, in the example shown, is the sucker rod of a well-pumping mechanism. This sucker rod is suspended from the polish rod 40, shown in Figure 3, which reciprocates in a packing gland 41 on the upper end of the well casing 42. The polish rod 40 is suspended from the piston rod 28 by means of a cable 43 which has its ends clamped by a clamp 44 to the upper end of the polish rod 40 and which passes through an eye 45 on the lower end of the piston rod 28.

The reversing valve 31 is of the spool type and is shown in detail in Figure 4. It comprises the spool 46 which is reciprocably mounted in the valve chamber 47 formed within the housing. A step screw 48 is adjustably mounted at the right-hand end of the chamber 47 for keeping the spool out of contact with the end wall of the chamber and for adjusting the speed of movement of the piston 27 during its return stroke, that is, during its downward movement under influence of the load. The spool 46 is provided with a reduced right-hand piston section 49 which snugly fits in the associated reduced right-hand end of the chamber 47 and an enlarged left-hand piston

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section 50 which fits snugly in the associated enlarged left-hand end of the chamber 47. Intermediate the piston sections 49 and 50 is the valve section 51. Between the section 49 and the section 51 the spool is reduced to provide an annular groove 52 and between the section 51 and the section 50 the spool is reduced to provide an annular groove 53. Where the line 32 connects to the chamber 47 the chamber is provided with an enlarged section 54 and where the drain line 38 connects to the valve chamber a similar enlargement 55 is provided, there being an annular bore 56 therebetween in which the section 51 fits snugly upon sufficient movement to the left. Between the annular groove 53 and the right-hand end of the spool 46 there is a by-pass bore 57. The enlarged left-hand end of the chamber 47 has an inverted U-shape metering passage 58 connected thereto at its extreme end and at a point suitably spaced from its end. A metering passage 59 also extends from the extreme end of the chamber 47 across to the line 33 and is the same cross-sectional area as the passage 58. The lower end of the line 33 also connects by a metering passage 60 to the line 34 which connects to the valve 31 at a check valve seat and chamber 61 which contains a ball-check valve 62, the chamber 61 being connected to the extreme end of the valve chamber 47 by a metering passage 63. A stop boss 64 is provided on the left-hand end of the spool 46 to prevent contact of the end of the spool with the adjacent end of the valve chamber 47. The action of this reversing valve will be described in detail later.

The speed control and safety valve 24 is illustrated in Figure 5. The housing of this valve is provided with a passage 65 leading vertically therethrough at the right-hand side thereof. The inlet end of this passage is connected to the pressure line 23 leading from the pump 22 while the outlet thereof is connected to the pressure line 25 leading to the cylinder 26. A ball-check valve 66 is provided in the passage 65 and will seat on a valve seat 67 if the pump 22 stops, so that the hydraulic fluid in the cylinder 26 will not drain back through the pump and into the sump tank 36.

In communication with the passage 65 is a horizontal tubular bore 68 in which a piston 69 is slidably mounted. This piston 69 carries a stem 70 which projects laterally to the left through a plug 71 and is surrounded by a compression spring 72 which tends to keep the piston in its right-hand position. When the pump 22 is started, hydraulic fluid entering the valve 24 from the line 23 will unseat the ball 66 from the seat 67 and will move the piston 69 along with the stem 70 against the force of the spring 72 to the left. The projecting end of the stem 70 is associated with a pin 73 carried by plug 71 and which may be calibrated to properly indicate pressure. A safety switch 74, connected in circuit with the pump motor 21, may be disposed so that it will be engaged by the outer end of the stem 70 which will occur if excessive pressure is developed by the pump. Thus, a combined pressure-indicating and safety device is provided.

A second safety device is provided by a ball-check valve 75 normally disposed on a valve seat at the right-hand end of a horizontal bore 76 which communicates at its right-hand end with the passage 65. The ball 75 is normally held seated by a compression spring 78. An adjustable screw 80 is provided in a plug 79 by means of which the spring 78 can be adjusted so that the safety valve 75 will unseat at a selected pressure.

The valve 24 is also provided with a speed control arrangement which prevents abrupt starting of the movement of the piston 27 and also controls the speed of movement of the piston in its upward direction. This arrangement is provided in a third horizontal bore 81 which communicates at its right-hand end with the passage 65. This bore 81 has a spool type valve 82 slidably mounted therein. This valve is provided with a right-hand stop 83, which, before starting of the pump 22, contacts the wall of the passage 65, a right-hand piston 84,

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a left-hand piston 85, which is spaced from the piston 84 by an annular groove 86, and a left-hand stop 87. A screw 88 threaded into a plug 89 at the left-hand end of the bore 81 has its inner end positioned in the bore 81 for engagement with the adjacent end of the stop 87 to limit the movement of the spool 82 to the left. A compression spring 90 normally keeps the spool 82 in its right-hand position. To the left of the normal position of the piston 84 is an outlet leading from the bore 81 into the line 39 which leads to the sump tank 36. The piston 84 is provided with a plurality of angularly spaced by-pass notches 91 which are cut into the side surface of the piston, are open at their left-hand ends, and are closed at their right-hand ends. These notches provide by-passes for the fluid flowing through passage 65 to permit part of it to escape from the passage to the drain line 39 when the pump 22 first starts or even during its normal operation provided the screw 88 is set to prevent movement of the piston 84 to the left sufficiently so that the wall of the bore completely covers the by-pass notches 91. In operation, the screw 88 may be set to permit complete covering of the notches 91, which will be the full-speed position for the piston 27 in its upward movement, or to permit only partial covering of the notches so that they will serve as by-passes and permit some of the fluid to return to the tank 36 and thereby the upward speed of the piston will be decreased. However, in any setting of the screw 88, the by-passes 91 will function to cut down the initial amount of fluid reaching the line 25 to the cylinder 26, upon starting of the pump 22, by permitting some of it to go back to the tank 36 through the line 39. The by-pass flow from the passage 65 into the line 39 will gradually diminish as the spool 82 is moved towards the screw 88 by the pressure in the passage 65. This will prevent an abrupt movement of the piston 27 upon starting of the motor 22 by a timing device, clutch, etc.

Operation

The sequence of operation of the single action cylinder 26 and reversing valve 31 through one complete cycle will now be described with reference to Figures 6 to 9, inclusive. The action of the control valve 24 will not be described in this discussion since it has been previously described in detail and normally has no effect on the operation of the system after the pump is once started and the pressure in the system is brought up to normal with the piston 27 moving upwardly at the speed for which the valve 24 is set. In these Figures 6 to 9, the dash lines in the hydraulic system indicate oil without pressure, the block symbols indicate oil under pressure, and the lack of both indicates no oil at all.

With reference to Figure 6, assuming the piston 27 has started on its upstroke in the cylinder 26, the spool 46 will be hydraulically locked in closed position, that is, at its extreme left-hand position in the valve chamber 47 with the valve section 51 disposed within the bore 56. The pump 22 will be supplying a constant volume of oil, through the valve 24 and the pressure line 25, into the lower end of the cylinder 26. The exhaust line 32 leading from the lower end of the cylinder 26 is of somewhat greater capacity than the line 25 but will not exhaust fluid from the cylinder since valve section 51 will prevent flow from valve chamber 54 to the exhaust line 38. A small amount of the oil from the lower end of the cylinder 26 will escape through the line 33, the metering passage 59 into the end of valve chamber 47, from the left side of the piston 50 to the right side thereof through the metering passage 58, through the valve chamber 55 and into the exhaust line 38 back to the tank 36. Since the passage 59 metering oil into the left-hand end of the valve chamber 47 is of the same capacity as the passage 58 metering it out of that end, the spool 46 will be locked in closed position. Some oil will also pass from the lower end of the line 33 through the metering passage 60 into the line 34 to maintain this line free of air, some of the oil spill-

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ing over from its upper end into the upper end of the cylinder 26. However, compared to the volume of oil entering into the cylinder through the line 25, the amount escaping therefrom through the line 33 and metering passages 59 and 60 is small and, therefore, the piston 27 will travel upwardly until it passes beyond the point where the line 34 connects to the cylinder.

This position of the piston 27 is shown in Figure 7. Any fluid which has accumulated above the piston will pass out through the line 35 into the tank 36. Oil under pressure will, at this time, flow from the upper end of the cylinder through the line 34 to unseat the ball-check valve 62 and flow through the metering passage 63 into the left-hand end of the valve chamber 47. Thus, there are two passages 63 and 59 metering oil in and only one passage 58 metering oil out after the piston 27 passes the inlet to the line 34, which will start the valve spool 46 to move to the right, since the pressure-exposed left-hand surface of the piston 50 of the spool is of greater area than that of the exposed right-hand surface of the valve section 51. Any oil at the right-hand end of the valve chamber 47 can drain to the left through the by-pass 57 to the line 38. As the spool moves to the right, the metering passage 58 is closed by the piston 50 and its speed of movement will be increased. Furthermore, the valve section 51 will be moved out of the bore 56 and this will permit oil to exhaust from the line 32, around the annular groove 53 in the valve spool 46, to the line 38 and then to the tank 36, allowing the oil to exhaust from the lower end of the cylinder 26, and the weight of the sucker rod to pull the piston 27 downwardly towards the lower end of the cylinder 26.

The exhaust flow through the line 32 and the valve 31 can be regulated by adjusting the stop screw 48 and thereby regulating the speed of the downstroke of the piston 27. Obviously, the weight of the load would affect this speed and regulation is desirable. As the piston 27 moves downwardly, the upper end of the line 34 is passed as shown in Figure 8 and this eliminates the pressure from this line. Therefore, the ball-check valve 62 will be seated since at this time pressure will have been developed in the left-hand end of the valve chamber 47. This pressure will keep the valve spool 46 locked in its right-hand or open position and the oil will continue to flow from the cylinder 26, through the line 32, annular groove 53 in the valve spool 46, to the line 38 and through it to the tank 36. No oil will be metered out of the left-hand end of the valve chamber 47 at this time and the line 34 will be maintained full of oil and free of air by the metering passage 60.

The piston 27 will continue to move downwardly until it passes the upper end of the line 33 as shown in Figure 9. This will eliminate pressure in this line. It will, therefore, eliminate pressure in the left-hand end of the valve chamber 47. Consequently, this will cause the pressure exerted through the line 32 on the right-hand face of the valve section 51 to start movement of the spool 46 to the left and finally to position the valve section 51 within the bore 56 as in Figure 6. This will now prevent escape of oil from the lower end of the cylinder 26 through the line 32 and will start the piston 27 moving upwardly. When it passes beyond the upper end of the line 33, the conditions illustrated in Figure 6 will be restored and the valve spool 46 will be locked in closed position.

It will be apparent from the above that when the upstroke of the piston 27 in the cylinder 26 is started, the valve spool 46 is moved toward closed position and, after a short interval, is locked in closed position and the upstroke will continue until completed since a constant volume of oil is entering the cylinder 26 below the piston 27 and very little is being exhausted (Figure 6). As soon as the upstroke of the piston 27 is completed (Figure 7), the valve spool 46 is unlocked and is moved towards open position, so that exhaust of the lower end of the cylinder 26 is permitted. The piston 27 will start its downstroke

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and, after a short interval, the valve spool 46 is locked in open position (Figure 8). The piston 27 will continue to move downwardly, since although a constant volume of oil is being applied to the lower end of the cylinder 26, a greater amount is being exhausted from the lower end of the cylinder. The downstroke of the piston 27 will continue until completed (Figure 9).

As previously indicated, the valve 24 may be set to control the speed of the piston 27 in its upstroke by setting the screw 88 and the stop screw 48 of the reversing valve 31 can be set to control the speed of the piston 27 in its downstroke.

It will be apparent from the above that I have provided an extremely simple yet very efficient hydraulic system which will carry a heavy load through a fixed cycle of reciprocation. The system is embodied in a single-action cylinder and piston unit which is controlled by a single hydraulically operated automatic reversing valve which controls the exhaust only of oil from the cylinder, the pump being connected to the cylinder at all times during normal operation of the system. The speed of movement of the piston in both directions is controlled independently. An uninterrupted flow of pressure in the pressure circuit of the system that actuates the piston is maintained and the shock effect caused by reversing the direction of travel of the piston and its load is minimized since only the exhaust of fluid from the cylinder is controlled and the reversing valve is opened and closed gradually due to metering the flow of fluid that causes or allows the valve spool to move. The reversing valve spool will be locked in closed or opened position so that the stroke of the piston in either direction will be complete, when once started. The control valve will not only control the speed of the piston in its upstroke but will cause the piston and its load to gradually start in motion when the hydraulic pump is started abruptly and will provide safety factors.

Various other advantages will be apparent.

Having thus described my invention, what I claim is:

1. A hydraulically-actuated reciprocating unit comprising a single-action cylinder and piston, means for continuously supplying a volume of fluid to the pressure side of said cylinder, and means for controlling the exhaust only of fluid from said pressure side of said cylinder to reverse the direction of movement of said piston, said control means comprising a hydraulically actuated reversing valve connected to said pressure side of said cylinder and means for controlling said valve solely by the pressure of said fluid supplied to said unit and including an exhaust line connecting the pressure side of said cylinder and said reversing valve, an exhaust line leading from said valve, said reversing valve being of the spool type mounted in a housing for reciprocating movement, said two exhaust lines being connected to said housing with a valve chamber therebetween, said spool valve including a valve member in said chamber which controls communication between said two exhaust lines, fluid connections between said valve housing and said cylinder for moving the spool in said housing automatically in opposite directions in accordance with movement of the piston in the cylinder, said fluid-supplying means being connected to the cylinder by a pressure line which connects to the lower end of the cylinder and said exhaust line which connects to the cylinder being connected at the lower end thereof, said fluid connections comprising a first line connected to said cylinder at a point spaced above the lower end thereof at such a level that the piston prevents fluid from reaching it when the piston is at its lowermost position in the cylinder, and a second line connected to the cylinder at a point adjacent the upper end thereof but at a level which will permit the piston to move beyond the point on its upward stroke so as to permit fluid under pressure from the cylinder to enter into said second line.

2. A hydraulically-actuated reciprocating unit accord-

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ing to claim 1 in which the valve housing is provided with an enlarged piston chamber at one end and a reduced piston chamber at the other end with said valve chamber therebetween, said first line being connected to opposite sides of said enlarged piston chamber by a metering passage, said second line being connected to one end only of said enlarged chamber by a metering passage of the same capacity as the first metering passage.

3. A hydraulically-actuated reciprocating unit according to claim 2 including a ball-check valve for controlling said last-named metering passage which is unseated by pressure in said second line and a by-pass through the spool valve between one end of said reduced piston chamber and said valve chamber.

4. A hydraulically-actuated reciprocating unit comprising a single-action cylinder and piston, means for continuously supplying a volume of fluid to the pressure side of said cylinder, and means for controlling the exhaust only of fluid from said pressure side of said cylinder to reverse the direction of movement of said piston, said control means comprising a hydraulically actuated reversing valve connected to said pressure side of said cylinder and means for controlling said valve solely by the pressure of said fluid supplied to said unit and including an exhaust line connecting the pressure side of said cylinder and said reversing valve, an exhaust line leading from said valve, said reversing valve being of the reciprocating type mounted in a housing, said two exhaust lines being connected to said housing with a valve chamber therebetween, said valve including a valve member in said chamber which controls communication between said two exhaust lines, fluid connections between said valve housing and said cylinder for moving said valve member in said housing automatically in opposite directions in accordance with movement of the piston in the cylinder, said fluid-supplying means being connected to the cylinder by a pressure line which connects to one end of the cylinder and said exhaust line which connects to the cylinder being connected at the same end thereof, said fluid connections comprising a first line connected to said cylinder at said end thereof at a point beyond which the piston passes when the piston reaches the extent of its stroke at that end of the cylinder so as to prevent fluid under pressure from the cylinder from reaching said first line, and a second line connected to the cylinder at a point adjacent the opposite end thereof and beyond which the piston will move on its stroke in the opposite direction so as to permit fluid under pressure from the cylinder to enter into said second line.

5. A hydraulically-actuated reciprocating unit com-

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prising a single-action cylinder and piston, means for continuously supplying a volume of fluid to the pressure side of said cylinder, and means for controlling the exhaust only of fluid from said pressure side of said cylinder to reverse the direction of movement of said piston, said control means comprising a hydraulically actuated reversing valve connected to said pressure side of said cylinder and means for controlling said valve by the pressure of said fluid supplied to said unit and including an exhaust line connecting the pressure side of said cylinder and said reversing valve, an exhaust line leading from said valve, said reversing valve being movably mounted in a housing for movement between one position where the two exhaust lines are connected and another position where the two exhaust lines are disconnected, fluid connections between said valve housing and said cylinder for moving said valve member automatically between its reversing positions in accordance with movement of the piston in the cylinder, said fluid-supplying means being connected to the cylinder by a pressure line which connects to the one end of the cylinder and said exhaust line which connects to the cylinder being connected at the same end thereof, said fluid connections comprising a first line connected to said cylinder at the said end thereof at a point beyond which the piston passes when the piston reaches the extent of its stroke at that end of the cylinder so as to prevent fluid under pressure from the cylinder from reaching said first line, and a second line connected to the cylinder at a point adjacent the opposite end thereof and beyond which the piston will move on its stroke in the opposite direction so as to permit fluid under pressure from the cylinder to enter into said second line.

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