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[54] FLUID SYSTEM

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[58] **Field of Search** ..... 60/52 VS

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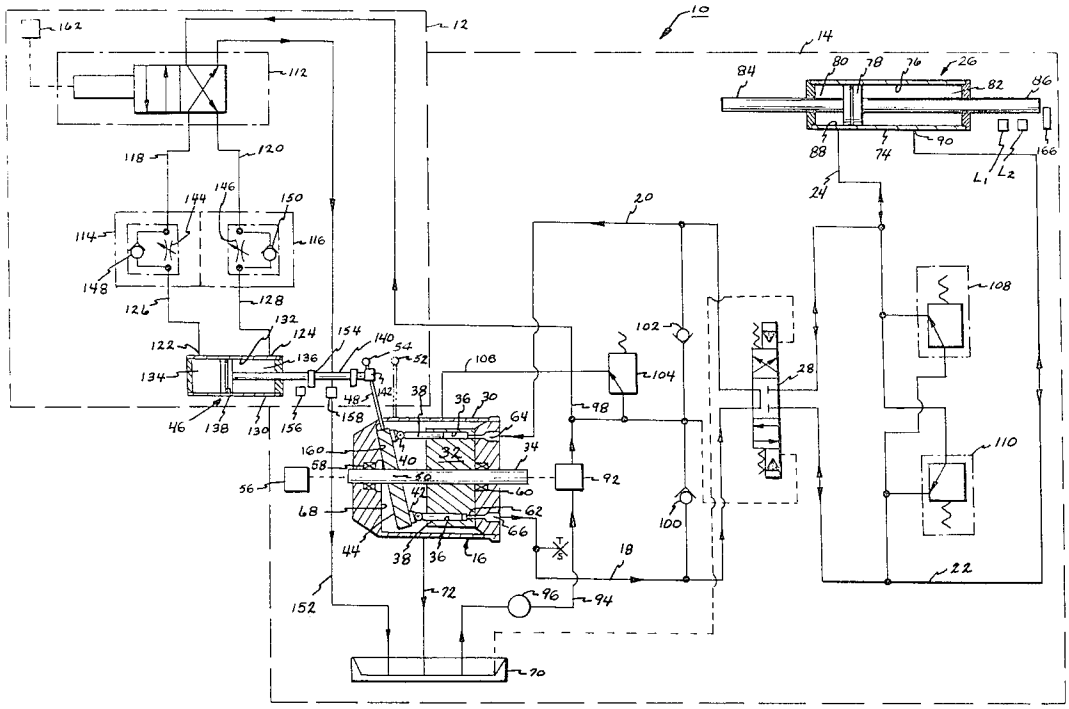
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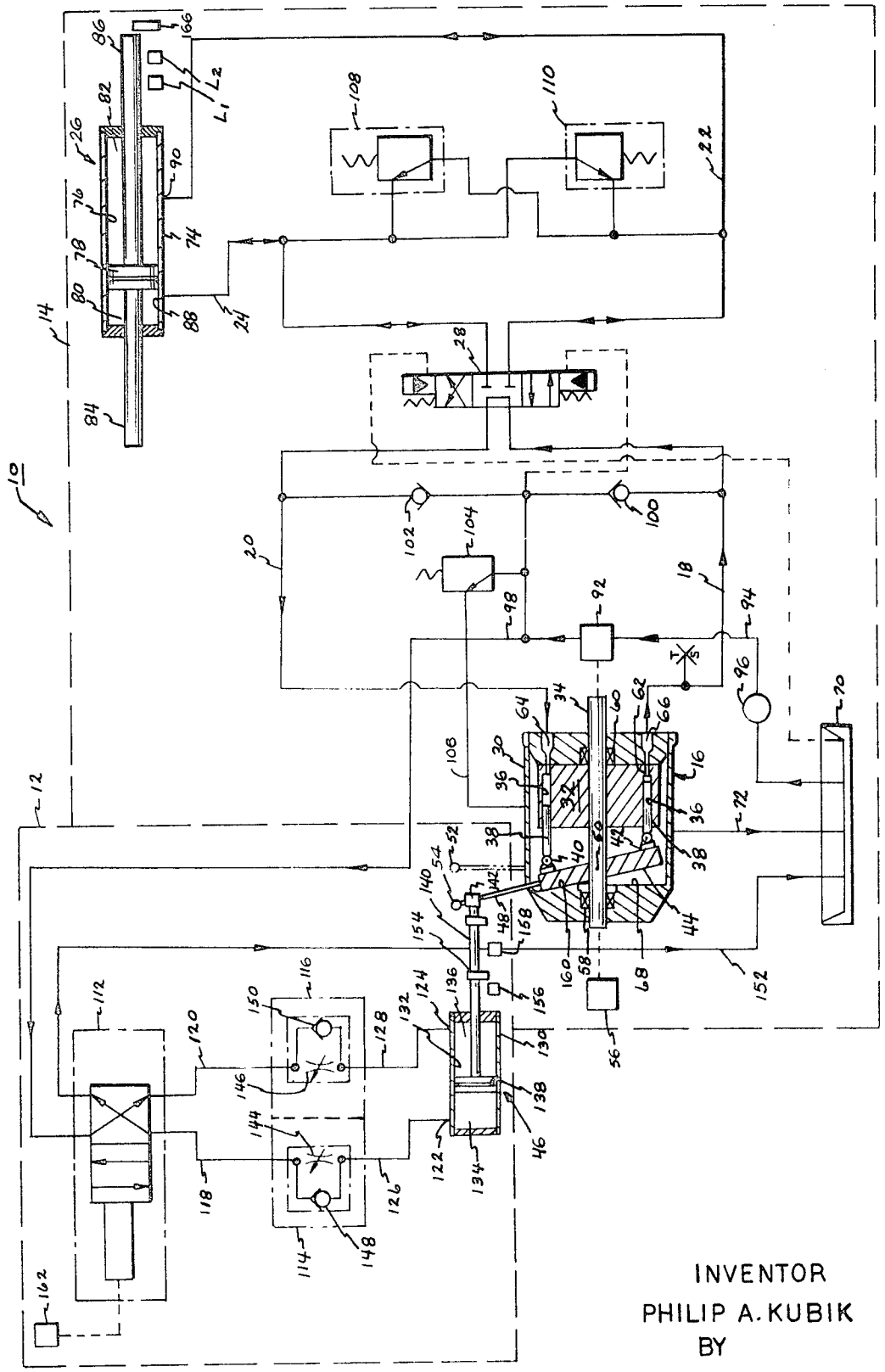
[57] **ABSTRACT**

A fluid system having a variable displacement fluid pump connected in a closed loop circuit to a fluid cylinder having a piston and a pair of connecting rods extending from opposite sides of the piston externally of the fluid cylinder. A directional control valve disposed in the closed circuit between the inlet and outlet of the fluid pump is adapted to selectively direct fluid to one side of the piston within the fluid cylinder, while exhausting fluid from the other side of the piston, so as to selectively move the piston within the fluid cylinder. The rate of movement of the piston in either direction of movement is controlled by the amount of fluid displaced by the fluid pump.

A second directional control valve is adapted to direct fluid from a second source of fluid to a pressure responsive displacement control mechanism to selectively vary the displacement of the fluid pump. The rate of fluid flow to the pressure responsive displacement control mechanism is selectively varied to control the rate of displacement of the fluid pump and to thereby selectively control the rate of movement of the cylinder piston.

4 Claims, 1 Drawing Figure





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FLUID SYSTEM

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to a fluid system for controlling the movement of a fluid cylinder and, in particular, the present invention relates to a closed-loop hydrostatic system in which the output of a variable displacement pump is selectively directed at various rates to the opposite sides of a piston within a fluid cylinder.

2. Description of the Prior Art

Heretofore, numerous fluid systems have been employed for controlling the rate of movement of a hydraulic motor and, particularly, such fluid systems have found extensive use in hydraulic machine tool drive transfer systems and the like. Such fluid systems are used to accelerate and decelerate a fluid cylinder respectively at the beginning and the end of its stroke prior to a feed movement. Such previously used fluid systems have normally consisted of a reservoir and a fluid pump for drawing fluid from the reservoir to supply the fluid cylinder and drive the same at some selected rate of movement. Suitable valving means are employed between the pump and the fluid cylinder to control the rate of movement of the fluid cylinder. The rate of movement of the fluid cylinder is a significant factor which must be considered in all but the simplest of circuits. When a variable rate control of the fluid cylinder is desired, it is customary to employ either a meter-in, meter-out, or a bleed-off system. Such systems generally include a deceleration valve connected in series with the pump and which is actuated by the movement of the fluid cylinder to variably restrict or stop the fluid flow between the outlet of the pump and the inlet of the fluid cylinder. When a finer rate control is desired, a feed control valve connected in parallel with the deceleration valve is utilized. The feed control valve, which may be of the meter-in or meter-out type, controls the rate of flow to or from the fluid cylinder and may either be a fine or coarse feed, depending on the desired application. If the feed control is of the meter-in type, the rate of fluid flow supplied to the fluid cylinder is controlled. If the fluid flow from the device is controlled, the circuit is known as a meter-out circuit. When a portion of the fluid supply is diverted to a reservoir, the circuit is known as a bleed-off circuit.

Thus, in the previously used systems, fluid flows directly from the pump through a deceleration valve, a feed control valve and to the fluid cylinder. In such systems, if the load greatly varies, the feed control valves require pressure compensation.

Such systems, although commonly used, are difficult to adjust and control and, because of the pressure compensation required for variable loads, they have a lower efficiency than is desirable. Since acceleration and deceleration of the fluid cylinder is accomplished by means of a deceleration valve, such acceleration and deceleration is not smooth as the deceleration valves tend to generate pulsations in the fluid system which can damage the fluid cylinder and/or the fluid pump. Further, braking of the fluid cylinder is not obtainable as such previously used fluid systems are not a closed-loop system.

It would therefore be desirable to provide a fluid system which has all the advantages of the heretofore previously used systems without any of the disadvantages.

SUMMARY OF THE INVENTION

The present invention, which will be described subsequently in greater detail, comprises a fluid system having a closed-loop fluid circuit for selectively connecting the inlet and outlet of a main fluid cylinder to the inlet and outlet of a fluid pump. The main fluid cylinder is of the type having a piston with connecting rods extending from the opposite sides thereof and externally of the main fluid cylinder, whereby the effective pressure responsive areas on the opposite sides of the main cylinder piston are equal. The pump has means for varying its displacement between a minimum and maximum and is controlled by

a fluid circuit having a secondary fluid cylinder which is operatively connected to the displacement varying means of the pump. The piston in the secondary fluid cylinder has its opposite sides selectively connected to a source of fluid through a pair of feed control valves and a conventional directional control valve. The acceleration and deceleration of the piston in the main fluid cylinder is controlled by varying the displacement of the fluid pump, which, in turn, is controlled by the feed circuit.

It is therefore an object of the present invention to provide a fluid system for controlling the rate of movement of a fluid cylinder which is easily adjustable and controlled more efficiently than previously used control circuits.

It is also an object of the present invention to provide a fluid system for controlling the rate of movement of a fluid cylinder control circuit in which the acceleration and deceleration forces exerted on the fluid cylinder are smooth.

It is also an object of the present invention to provide a fluid system for controlling the rate of movement of a fluid cylinder in which the fluid cylinder may be braked.

Other objects, advantages, and applications of the present invention will become apparent to those skilled in the art of fluid systems when the accompanying description of one example of the best mode contemplated for practicing the invention is read in conjunction with the accompanying drawing.

BRIEF DESCRIPTION OF THE DRAWING

The description herein makes reference to the accompanying drawing in which the sole FIGURE represents a schematic illustration of the present invention in the form of a fluid system.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring to the drawing there is illustrated a fluid system **10** comprising a control circuit **12** and a main circuit **14**. The main circuit **14** comprises a variable displacement pump **16** connected in closed-loop manner by conduits **18**, **20**, **22** and **24** to a main fluid cylinder **26**. Incorporated in the main circuit **14** is a conventional directional control valve **28** which is adapted to connect the conduits **18-20** selectively to the conduits **22** and **24** or be positioned tandem-center so as to allow communication between conduits **18** and **20** but prevent fluid communication between conduits **22** and **24**.

The pump **16** may be of the well known axial piston type, comprising a housing **30** having a cylindrical barrel **32** rotatably mounted therein and suitably connected to a drive shaft **34**. The cylinder barrel **32** is formed with a plurality of axial cylinder bores each housing a piston reciprocal therein; only two of the bores and pistons being shown and respectively indicated by the numerals **36** and **38**. Each piston **38** has a spherical outer end portion **40** carrying a bearing shoe **42** that engages a swash plate **44** which is operatively coupled to a secondary fluid cylinder **46** by a connecting arm **48** for movement about a pivot **50** from a neutral, minimum displacement position **52** to a maximum or full flow position **54**. A prime mover, such as an electric motor schematically illustrated at **56**, is mechanically connected through a suitable coupling to the drive shaft **34** which, in turn, is supported within the pump housing by bearings **58** and **60**.

As is conventional in pumps of the type illustrated, each cylinder bore **36** in the cylinder barrel **32** is provided with a cylinder port **62** adapted to alternately register with the inlet and outlet ports **64** and **66** respectively as the cylinder barrel **32** rotates. The inlet and outlet ports **64** and **66** respectively communicate with the conduits **20** and **18**.

The cylinder barrel **32**, pistons **38**, swash plate **44**, and the input shaft **34** are immersed in fluid in a filled cavity normally referred to as a pump case **68**. The pump **16** communicates with a reservoir **70** through a charge pump **92** and valving **100** or **102** and a conduit **94** on inlet and a conduit **72** on drain, all of which will be described hereinafter.

The main fluid cylinder 26 has a cylindrical housing 74 with an internal bore 76 in which a cylindrical piston 78 is reciprocally mounted, dividing the internal bore 76 into two pressure chambers 80 and 82 respectively on the opposite sides of the piston 78. The opposite sides of the piston 78 have cylinder rods 84 and 86 which extend through the opposite end walls and externally of the main fluid cylinder 26. The pressure chambers 80 and 82 of the cylinder 26 respectively have fluid parts 88 and 90 which, in turn, are respectively connected to the fluid conduits 24 and 22. Since the connecting rods 84 and 86 are of an equal diameter, the effective pressure responsive areas on the opposite sides of the piston 78 are also equal. The cylinder 26 operates in a well known manner to move the piston 78 in opposite directions within the cylinder bore 76 when one of the pressure chambers 80 or 82 is pressurized, while the other pressure chamber is exhausted.

The fluid system 10 is provided with a positive fixed displacement replenishing pump 92, such as a gear pump, which is also driven by the prime mover 56 through the drive shaft 34. The replenishing pump 92 is in communication with the reservoir 70 through a supply conduit 94 and a filter 96 for supplying the replenishing fluid to the main circuit 14 by means of a delivery conduit 98. Spring biased check valves 100 and 102 are in communication with the delivery conduit 98 and the closed-loop main circuit conduits 18 and 20, respectively, for supplying replenishing fluid to whichever of the conduits 18 and 20 is the low pressure side of the closed main circuit through one of the check valves, while pressure on the high pressure side of the main circuit maintains the other check valve closed.

A spring biased relief valve 104 is provided for the replenishing pump 92 for relieving excessive fluid pressure in the replenishing delivery conduit 98 and for exhausting fluid to the reservoir 70 by means of a fluid conduit 106 connected to the pump case 68 and the conduit 72.

Downstream of the directional control valve 28, the conduits 22 and 24 are respectively connected to the inlets of high pressure relief valves 108 and 110 which at a predetermined pressure, eg: 3,000 p.s.i., will exhaust the fluid pressure from one of the conduits to the other conduit so as to prevent damage to the main circuit in the event of over pressurization.

Referring to the control circuit 12 for a description of the method of controlling the displacement of the fluid pump 16, there is illustrated a directional control valve 112 adapted to selectively connected fluid from the replenishing pump 92 to either of a pair of feed control valves 114 and 116 by conduits 118 and 120 respectively. The feed valves 114 and 116 are respectively connected to the ports 122 and 124 of the secondary cylinder 46 by means of conduits 126 and 128 respectively. The fluid cylinder 46 is similar in construction to the main cylinder 26 and comprises a tubular housing 130 having an interior bore 132 divided into two pressure chambers 134 and 136 by means of a reciprocally mounted piston 138, which in turn carries a connecting rod 140. Connecting rod 140 extends externally of the housing 130 and is operatively coupled at 142 to the swash plate connecting arm 48 of pump 16. The pressure chambers 134 and 136 are respectively connected to the conduits 126 and 128.

The feed control valves 114 and 116 may be of the conventional type and have restricted passages 144 and 146 which are adjustable such that each of the feed control valves may be pre-set to vary the flow rate therethrough over a wide range. Each of the feed control valves 114 and 116 includes a check valve 148 and 150, respectively, which permits fluid to bypass the restricted passages 144 and 146 in one direction. Thus, when the directional control valve 112 is in the position indicated, fluid flow is directed from the fixed displacement pump 92 through the conduit 120 to the feed control valve 116, bypassing the restricted passage 146 while flowing through check valve 150 and is then directed to the pressure chamber 136 on one side of the cylinder piston 140 to move the same leftwardly within the cylinder bore 132 to displace the fluid pump 16 toward its full flow position 54. Fluid on the opposite side of the piston cylinder 138 within the pressure chamber 124 will be exhausted through the cylinder port 122 and directed through conduit 126 to the feed control valve 114 at a rate of flow which is determined by the setting of the restricted passage 144. Fluid returns to the reservoir 70 through the directional control valve 112 and a conduit 152. When the directional control valve 112 is reversed so as to direct fluid flow through the check valve 148 of the feed control valve 114 to the pressure chamber 134 to move the piston 138 rightwardly, fluid is exhausted through the restricted passage 146 of the feed control valve 116 which, in turn, controls the rate of movement of the piston 138. As the piston 138 moves rightwardly, the swash plate connecting arm 48 is moved to the minimum displacement position 52.

The type of feed control illustrated is known as a meter-out control, that is, the rate of movement of the piston 138 within the secondary cylinder 46 is determined by the rate of the fluid being exhausted from the pressure chamber 134 or 136, which, in turn, is controlled by the feed control valves 114 and 116. A detailed description of the feed control valves 114 and 116 is not necessary as such feed control valves are well known and commercially available.

It can thus be seen that the rate of change in the displacement of the fluid pump 16 is controlled by the feed control valves 114 and 116, thus, if the restricted passages 144 and 146 of the feed control valves are set to permit a high rate of flow to pass therethrough, the cylinder piston 138 will be displaced rapidly causing a rapid change in the displacement of the fluid pump 16 which, in turn, when communicated to the main fluid cylinder 26 will generate a rapid acceleration and/or deceleration of the cylinder piston 78 therein.

The cylinder rod 140 carries a stop member 154 which is adapted to abut axially adjustable limit stops 156 and 158 so as to permit a variation in the displacement of the fluid pump 16 at predetermined intermediate displacements respectively below the maximum displacement of the fluid pump 16 and above the minimum displacement of the pump 16. The maximum displacement of the pump 16 occurs when the swash plate 44 abuts the wall 160 of the pump housing, while the minimum displacement of the pump 16 occurs when the swash plate 44 is disposed in a plane which is perpendicular to the longitudinal axis of the drive shaft 34.

In operation, when it is desired to direct fluid from the fluid pump 16 through the conduit 18, the directional control valve 28 and the conduit 24 so as to accelerate the piston 78 in the main cylinder 26 forwardly (to the right as viewed in the drawing) at a rapid rate, the directional control valve 112 of the control circuit 12 is actuated by switching means 162 so as to direct fluid from the fixed displacement pump 92 into the pressure chamber 136 of the fluid cylinder 46 to drive the piston therein leftwardly, as viewed in FIG. 1 so as to stroke the swash plate 44 of the fluid pump 16 to the maximum displacement 54 or some other intermediate displacement as determined by the setting of the adjustable stop 156. Fluid from the secondary cylinder 46 is exhausted through the adjustable restricted passage 144 of the feed control valve 114 which is set to permit a high rate of fluid flow therethrough, thus permitting a rapid stroking of the pump 16 which, in turn, will displace a maximum amount of fluid into the conduit 18. The directional control valves 112 and 28 in the control and main circuits, respectively, are simultaneously actuated so that as the secondary cylinder 46 is actuated, fluid from the variable displacement pump 16 will be directed to the main fluid cylinder 26 to accelerate the piston 78 therein rapidly to the right as viewed in the drawing. After the piston is displaced at a rapid rate of acceleration and strikes a limit switch L1, the directional control valve 112 in the control circuit 12 is actuated, so as to direct fluid to the pressure chamber 134 on the opposite side of the piston 138 in the secondary fluid cylinder 46. Fluid entering the secondary cylinder 46 will move the piston 138 rightwardly to stroke swash plate 44 toward the zero flow position 52 or some intermediate displacement as determined by the adjustable stop 158. The fluid in the pres-

sure chamber 136 of cylinder 46 will be exhausted through the feed control valve restricted passage 146 at some predetermined rate which will control the rate at which the piston 138 of the fluid cylinder 46 strokes the pump 16 back towards a lower displacement. As the pump 16 is stroked toward a lower displacement, the rate at which fluid is directed to the main cylinder 26 is decreased, thereby decelerating the movement of the piston 78 within the main fluid cylinder 26. When the pump 16 is stroked to a minimum the forward movement of the piston 78 of the main cylinder 26 will be brought to a minimum creep speed to seek a final stop position at which time valve 28 will be centered and the piston will stop. A positive stop 166 may be provided to insure that the cylinder piston 78 stops at a desired position. The valve 28 may be actuated to a centered position by means of limit switch L2.

Acceleration and deceleration of the piston 78 within the main cylinder 26 in an opposite direction (to the right as viewed in the drawing) may be had by reversing the flow from the conduits 18 and 20 to the conduits 22 and 24 by means of the directional control valve 28 without requiring any change in the setting of the feed control valves 114 and 116 as the volume of fluid required to move the piston in either direction at some predetermined rate is equal.

Moving the directional control valve 28 to a tandem center or no flow condition will prevent fluid flow either to or from the cylinder chambers 80 and 82 quickly stopping the piston 78. Such a quick stop may be utilized in the event of an emergency when it is necessary to prevent damage to the machine tool or transfer mechanism which the connecting rod 86 and/or 84 is driving.

It can thus be seen by proper utilization of the directional control valves 28 and 112 and the feed control valves 114 and 116, the piston 78 within the main cylinder 26 may be accelerated or decelerated in opposite directions at any selected rate.

It should be noted that by using a feed control valve to vary the displacement of the pump 16 which, in turn, controls the amount of displacement and the rate of displacement of the main fluid cylinder piston 78, any desired rate of movement of the piston 78 may be obtained.

Since acceleration and deceleration of the main fluid cylinder piston 78 is controlled by the control circuit 12 by varying the displacement of the pump 16 and not by means of a deceleration valve connected in series with the main cylinder 26 as in the previously used systems, the acceleration and deceleration of the main cylinder 26 is substantially smoother.

It can also be seen that the fluid system 10 provides a means for braking and/or positively stopping the main fluid cylinder 26 when necessary.

It should also be noted that since the feed control valves 114 and 116 are operated in a circuit, which is separate from the main fluid circuit 14 there is no need for the feed control valves 114 and 116 to be pressure compensated as would normally be required when heavy loads are encountered. Thus the system is simplified and less expensive to construct and maintain.

It can thus be seen that a fluid system has been provided in which the movement of a fluid cylinder with respect to its rate of acceleration and/or deceleration, and rate of travel in opposite directions is determined by the volume of fluid supplied to the cylinder by a variable displacement pump and the rate of change in the displacement of the variable displacement pump; all of which is accomplished in a simple manner by means of the control circuit 12.

While a system has been described which includes an axial piston pump 16, it should be apparent that any other variable displacement pump could be used as well. Also, it should be noted that in some applications it has been found desirable to utilize a second fluid cylinder like the cylinder 46 but connected to the opposite side of the swash plate 44. In such an arrangement, one cylinder is used to stroke the swash plate toward a maximum position, while the other cylinder is used to stroke the swash plate to a minimum displacement.

The fluid system of the present invention has been found to be especially suitable for inline shuttle, lift and transfer systems wherein rapid movement combined with smooth acceleration and deceleration, and positive braking are important. It is apparent though that the system has much wider application than this.

It can thus be seen that a new and improved closed loop hydrostatic drive for a double connecting rod cylinder has been provided which is much simpler in its construction than previously used systems; and which is more reliable and rapid in its operation.

It should be noted that two equal volume fluid cylinders in a back to back relation may be used in lieu of the single main fluid cylinder 26. One of the cylinders is pressurized to stroke in one direction while the other cylinder is pressurized to stroke in an opposite direction.

While the form of the embodiment of the present invention, as disclosed herein, constitutes a preferred form, it is to be understood that other forms might be adopted all coming within the spirit of the invention and the scope of the appended claims which follow.

What is claimed is as follows:

1. A fluid system comprising a unidirectional fluid pump having a displacement control means such that the fluid displacement of said fluid pump is adapted to be varied between a minimum and a maximum fluid flow displacement position, said pump having a high pressure fluid outlet and a low pressure fluid inlet;

a main fluid cylinder having a main piston reciprocably mounted therein and movable in response to fluid pressure acting on the opposite sides of said piston, said main fluid cylinder piston having connecting rods extending from the opposite sides thereof externally of said main fluid cylinder, said rods being so sized that the opposite pressure responsive areas of said main cylinder piston on which fluid pressure acts to move said piston in opposite directions are equal;

a first directional flow control means having a first pair of ports, one of which is in fluid communication with said pump inlet port while the other valve port is in communication with said pump outlet port, said first directional flow control means having a second pair of valve ports which respectively communicate with the opposite sides of said main piston within said main fluid cylinder, said first directional flow control means being selectively movable to one position for forming a closed loop circuit between said fluid pump and said main fluid cylinder to connect the pump outlet port pump to one side of said main piston and direct fluid pressure thereagainst, while connecting the other side of said main piston to said pump inlet port to exhaust fluid pressure from said main fluid cylinder associated with the other side of said main piston, whereby, said main piston may be selectively reciprocated within said main fluid cylinder in response to fluid flows selectively communicated by said first directional control means to the opposite sides of said main piston from said fluid pump, said first directional control means being movable to another position wherein communication between said main fluid cylinder and said fluid pump is closed and said pump inlet port and said pump outlet port are fluidly connected in a closed loop fashion, said main piston being movable in one direction when fluid pressure is directed against one side of said main piston and at a rate of movement which is a function of the amount of displacement of said fluid pump, said main cylinder piston being movable in an opposite direction when fluid pressure is directed against the other side of said main piston and a rate of movement which is a function of the amount of displacement of said fluid pump;

a second fluid cylinder having a second piston reciprocably movable therein in response to pressure fluid acting thereon, said second piston having a connecting rod extending from one end thereof, said extending end of said

connecting rod being operatively coupled to said pump displacement control means, said pump displacement control means being moved between said fluid flow displacement positions as said second piston is reciprocated within said second fluid cylinder;

a second source of fluid pressure;

means for selectively communicating said second source of fluid pressure to the opposite sides of said second piston, said last mentioned means comprising: first and second fluid feed control means for respectively controlling the rate of fluid flow from said second source to the opposite sides of said second piston to act against said second piston and move the same in opposite directions at a rate which is a function of the rate of fluid flow through said first and second fluid feed control means; second directional flow control means for selectively controlling the flow of fluid from said second source of fluid pressure to said first and second fluid feed control means whereby the rate of change in the displacement of said fluid pump between said minimum and maximum flow displacement positions is selectively controlled and thus the rate of movement of said main piston in opposite directions is selectively controlled.

2. The fluid system defined in claim 1 wherein each of said feed control valves is selectively adjustable.

3. The fluid system defined in claim 1 wherein said fluid system further comprises means for adjustably varying the minimum and maximum displacement of said fluid pump at some selected displacement less than the maximum displacement of said pump and at some displacement greater than the minimum displacement of said pump, respectively.

4. The fluid device defined in claim 3 wherein said variable displacement pump is of the axial piston displacement type having a swash plate and means for positioning said swash plate to vary the stroke of said piston pump thereby changing the displacement of said pump, said pump being adapted to be stroked between a full flow and no flow position.

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