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Kubik

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[54] **FLUID SYSTEM**

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[63] Continuation-in-part of Ser. No. 50,093, June 26, 1970, Pat. No. 3,653,208.

[52] **U.S. Cl.** ..... **91/411 A,** 92/110

[51] **Int. Cl.** **F01b 31/00,** F15b 11/00

[58] **Field of Search** ..... 92/52, 53, 11 D; 60/52 VS; 91/411 A, 411 R

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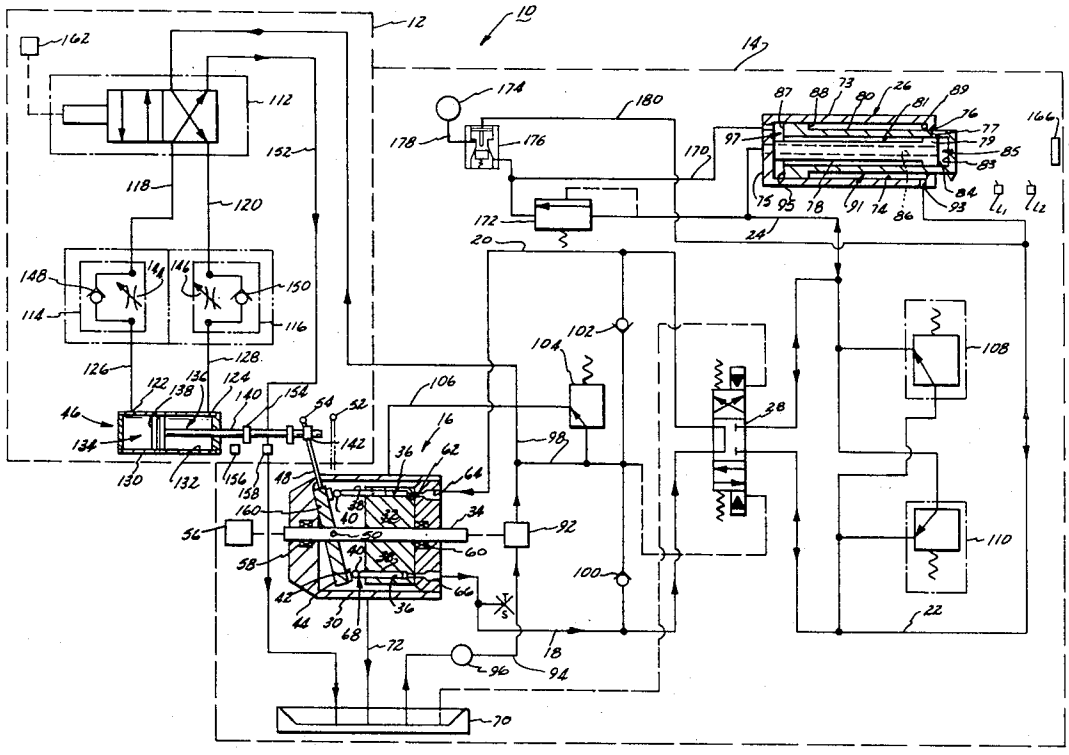
[57] **ABSTRACT**

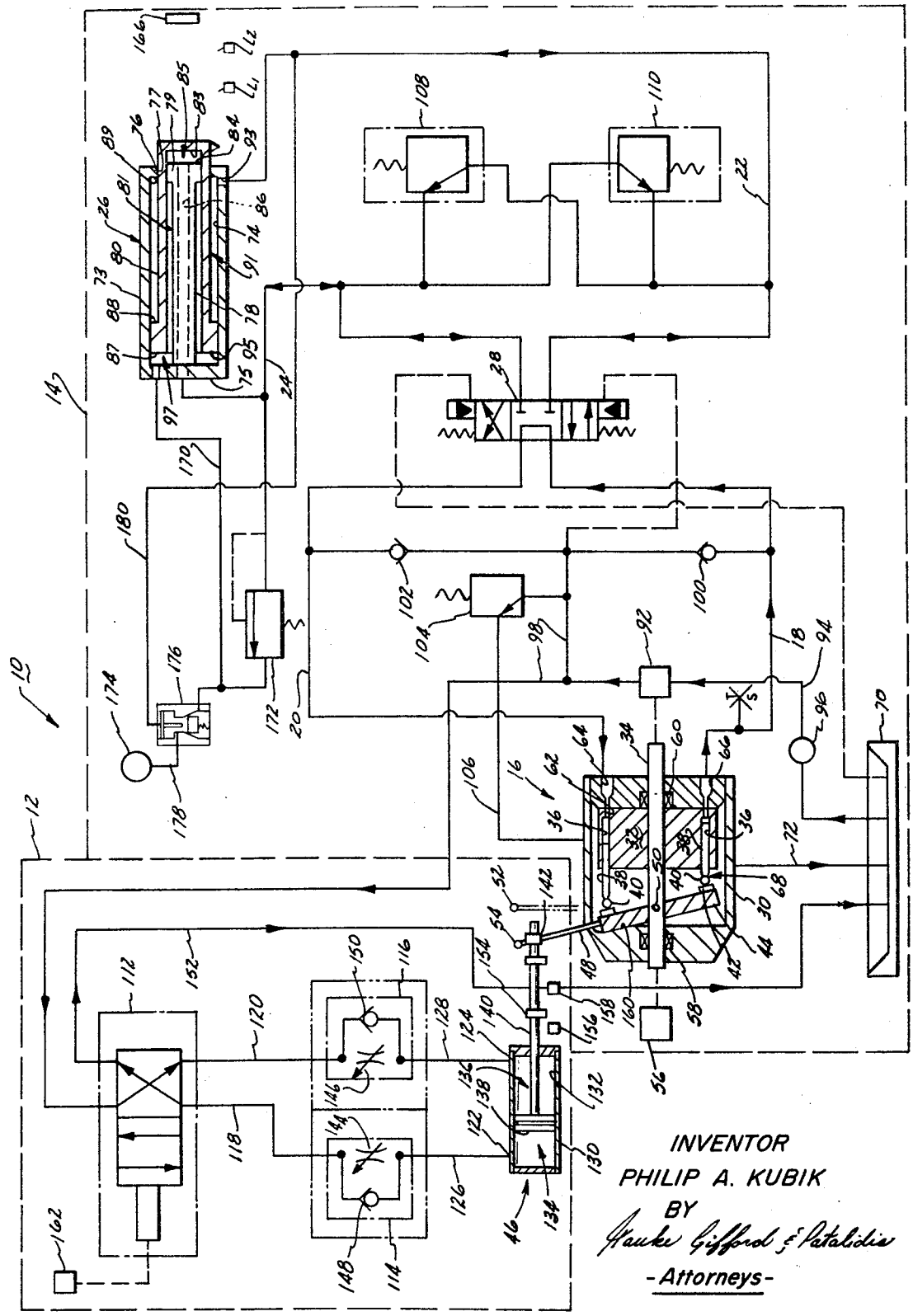
A fluid system having a variable displacement fluid pump connected in a closed loop circuit to a fluid cylinder having a tubular member and a piston reciprocally mounted therein. The piston has a connecting rod extending from one side thereof and externally of the fluid cylinder. A second piston, fixedly attached to the tubular member, is reciprocally mounted within a blind bore in the connecting rod, with the outer face of the second piston and the blind end of the connecting rod defining an expansible pressure chamber. The effective pressure responsive areas of the two pistons are equal, such that when fluid at a selected rate of flow and at a predetermined pressure is communicated to the annular area on the rod side of the first piston, a force of a predetermined magnitude is generated against the piston to cause a contraction of the fluid cylinder at a predetermined rate, and when fluid at the same rate of flow and at the same predetermined pressure is communicated to the expansible chamber, a force of the same predetermined magnitude is generated between the second piston and the blind end of the connecting rod to cause an expansion of the fluid cylinder at the same predetermined rate as when the fluid cylinder is contracted. 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 the rod side of the first piston within the fluid cylinder, while exhausting fluid from the expansible chamber and vice versa, so as to selectively expand and contract the fluid cylinder at the same rate. The rate of movement of expansion and contraction 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 fuid 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 expansion and contraction of the fluid cylinder. When the side of the first piston opposite the rod carrying side thereof is communicated to a fluid under pressure, an additional expansion force may be selectively provided.

11 Claims, 1 Drawing Figure

United States Patent [19] [11] **3,744,375**
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FLUID SYSTEM

CROSS REFERENCE TO RELATED PATENT APPLICATION

The present patent application is a continuation-in-part of U.S. Pat. application Ser. No. 50,093, filed June 26, 1970, for a "Fluid System" now U.S. Pat. No. 3,653,208.

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 a single rod fluid cylinder in which the effective pressure responsive areas for expansion and contraction of the fluid cylinder are equal.

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. In such systems, it is difficult to obtain a controlled movement of the fluid cylinders at equal speeds and forces in opposite directions, while at the same time obtaining an additional hold-down or clamping force at the end of the expansion stroke of a fluid cylinder.

It would therefore be desirable to provide a fluid system having a single rod fluid cylinder 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 single rod type, having equal pressure responsive piston areas for both contraction and expansion of the fluid cylinder, with the single rod extending externally of the main fluid cylinder. The pump has means for varying its displacement between a minimum and maximum and is controlled by a feed 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 expansion and contraction of 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 a primary object of the present invention to provide a single rod fluid cylinder in which the effective pressure responsive areas for contraction and expansion of the fluid cylinder are equal.

Other objects, advantages, and applications of the present invention will become apparent to those skilled in the art of fluid systems and fluid cylinders 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 and a single rod fluid cylinder.

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 a closed loop manner by conduits **18, 20, 22** and **24** to a main fluid cylinder **26**. Incorporated in the main circuit **14** is a conven-

tional directional control valve 28 which is adapted to connect the conduits 18 and 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 reciprocally mounting a piston therewith. Only two of the bores and pistons are shown and are 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 point 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 30 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 via a conduit 94 on inlet and a return conduit 72 on drain, all of which will be described in greater detail hereinafter.

The main fluid cylinder 26 comprises a first outer tubular member 73 provided with an internal bore 74. The tubular member 73 has a closed end 75, while the opposite end 76 is provided with a bore 77 substantially aligned with the longitudinal axis of the internal bore 74. A projecting cylindrical member 78, disposed within the tubular member bore 74 along the longitudinal axis thereof, has one end integrally attached to the closed end 75 of the tubular member 73, while the projecting end of the member 78 has a radially enlarged section forming a piston 79. A piston rod 80, in the form of an inner tubular member radially inwardly spaced from and telescopically received by the outer tubular member 73, has an outer surface of a diameter corresponding to the diameter of the bore 77 in the end 76 and is adapted to be slidably and sealingly mounted therethrough. The inner tubular member or piston rod 80 has an internal bore 81 adapted to slidably and sealingly surround the piston 79 of the projecting cylindrical member 78. The internal bore 81 of the piston rod 80 has a blind end 83 which in conjunction with the outer face 84 of the piston 79 defines an expansible pressure chamber 85 that is in constant fluid communication with the conduit 24 by means of a longitudinal bore 86 extending through the member 78.

The inner end of the piston rod 80 has a radially enlarged portion forming a second piston 87, the outer periphery of which sealingly and slidably engages the internal bore 74 of the outer tubular member 73. The annular space defined by the outer periphery of the piston rod 80, the radially outwardly spaced inner surface of the outer tubular member 73, and the opposing annular areas 88 and 89 on the piston 87 and the tubular member end 76, respectively, form a second expansible pressure chamber 91 which is in constant fluid communication with the conduit 22 through port connection 93.

The effective pressure responsive area of the piston surface 88 exposed to the pressure of the fluid in the expansible chamber 91 is substantially equal to the effective pressure responsive area of the face 84 of the piston 79 exposed to the pressure in the expansible pressure chamber 85. Thus, when fluid is admitted to the expansible pressure chamber 85 from the conduit 24 via longitudinal bore 86 at a predetermined pressure, a force of a predetermined magnitude is generated against the piston 79 and the blind end 83 of the piston rod 80 which causes the fluid cylinder 26 to expand at a certain rate, that is, the piston rod 80 will move outwardly toward the right as viewed in the Figure at a speed which is dependent upon the rate of flow communicated to the expansible pressure chamber 85. When fluid at the same rate of flow and at the same predetermined pressure is supplied to the expansible pressure chamber 91 via conduit 22, a force of the same predetermined magnitude will be generated on the opposing annular surfaces 88 and 89 that will cause the fluid cylinder 26 to be contracted, that is, the piston rod 80 will move leftwardly into the tubular member 73 at the same rate as that obtained during the expansion of the fluid cylinder 26.

The opposite face 95 of the piston 87 and the end wall 75 of tubular member 73 forms a third expansible pressure chamber 97 which is adapted to be connected to the fluid conduit 24 through a conduit 170 and a sequence valve 172. Pressure chamber 97 also communicates with an accumulator 174 through a pilot operated check valve 176 and fluid conduit 178. A pilot line 180 communicates the pilot operated check valve 176 with the conduit 22. The accumulator 174 is adapted to supply fluid to the pressure chamber 97 as the fluid cylinder 26 is being expanded due to pressure fluid entering the pressure chamber 85 via conduit 24. When the fluid cylinder 26 has been fully expanded, pressure fluid from the conduit 24 opens the sequence valve 172 and pressurizes the fluid in pressure chamber 97 to exert an additional clamping force against the piston rod 80 to maintain the same in a fully extended position as will be more fully described hereinafter in the description of the operation of the fluid system 10. When pressure fluid is directed through conduit 22 to the pressure chamber 91 to cause expansion of the pressure chamber 91, and thus contraction of pressure chamber 97, pressure fluid is communicated through pilot line 180 to open the pilot check valve 176 whereupon fluid within pressure chamber 97 is exhausted through conduit 170, through the check valve 176 and back to the accumulator via conduit 178.

The fluid system 10 is further 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 or any other suitable mechanical coupling. 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 through 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 loop main circuit 14 through one of the check valves, while pressure on the high pressure side of the main circuit maintains the other check valve closed.

A conventional spring biased high pressure relief valve 104 is provided for the replenishing pump 92 for relieving excessive fluid pressure in the replenishing delivery conduit 98. The outlet of the relief valve 104 is connected to the reservoir 70 via a fluid conduit 106 connected to the pump case 68 and the return 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, e.g.: 3,000 psi, will exhaust the pressure fluid from one of the conduits to the other conduit so as to prevent damage to the main circuit 14 in the event of over pressurization.

Referring now 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 connect fluid from the replenishing pump 92 to either of a pair of feed control valves 114 and 116 via conduits 118 and 120, respectively. The feed control valves 114 and 116 are in turn respectively connected to the ports 122 and 124 of the secondary cylinder 46 by means of conduits 126 and 128. The secondary fluid cylinder 46 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 that 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 preset 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 only. 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 138 to move the same leftwardly within the cylinder bore 132 to displace the fluid pump 16 towards 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 via directional control valve 112 and a return 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 toward 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 valve 114 and 116. A detailed description of the feed control valves 114 and 116 is not necessary as such feed control valves per se are well known and commercially available.

It can 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, and 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 in the expansion and/or contraction of the fluid cylinder 26.

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 a 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 substantially 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 rod 80 of the main cylinder 26 forwardly (to the right as viewed in the drawing) at a rapid rate, that is, to expand the fluid cylinder 26, the directional control valve 112 of the control circuit 12 is actuated by switching means 162 so as to direct fluid from the fixed pump 92 into the pressure chamber 136 of the fluid cylinder 46 to drive the piston therein leftwardly as viewed in the drawing, 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 chamber 134 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 deliver 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 is actuated, fluid from the variable displacement pump 16 will be directed via conduit 24 and bore 86 to the main fluid cylinder chamber 85 to expand the same and accelerate the piston rod 80 rapidly to the right as viewed in the drawing. After the piston rod 80 is displaced at a rapid rate of

acceleration and a predetermined distance, the rod **80** strikes a first limit switch L_1, whereupon the directional control valve **112** in the control circuit **12** is actuated by switching means **162**, 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 chamber **134** will move the piston **138** rightwardly to stroke swash plate **44** toward the zero or minimum flow position **52** or some intermediate displacement as determined by the adjustable stop **158**. The fluid in the pressure chamber **136** of cylinder **46** will be exhausted through the feed control valve restricted passage **146** of valve **116** 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 chamber **85** is decreased, thereby decelerating the rate of movement of the piston rod **80** of the main fluid cylinder **26**. When the pump **16** is stroked to a minimum, the forward movement of the piston rod **80** of the main cylinder **26** will be brought to a minimum creep speed to seek a final stop position, at which time the valve **28** will be centered, cutting off fluid communication between the pump **16** and the cylinder **26**, whereby further expansion of the cylinder **26** is prevented. A positive stop **166** may be provided to insure that the cylinder piston rod **80** stops at a desired position. The valve **28** may be actuated to a centered position by means of a second limit switch L_2. During the expansion of the main fluid cylinder **26**, fluid flows from the accumulator **174**, through check valve **176** and into the pressure chamber **97**, while the sequence valve **172** is closed so as to prevent communication between the conduit **24** and pressure chamber **97**.

When the piston rod **80** is in its fully extended position, the pressure in conduit **24** will reach a predetermined amount which is sufficient to actuate the sequence valve **172** so as to communicate the pressure fluid in conduit **24** to the pressure chamber **97** whereupon the pressure fluid communicated thereto generates an additional force on the piston rod **80** to hold the same in its extended position. Since the effective pressure responsive area of the piston **87** exposed to the pressure chamber **97** is more than twice that of the pressure responsive area of the piston **79** exposed to the pressure chamber **85**, the holding force acting on piston rod **80** will be more than twice the expansion force generated by the pressure chamber **85** alone. When the sequence valve **172** is open and pressure fluid is communicated from conduit **24** to pressure chamber **97**, the pilot operated valve **176** prevents communication between the pressure chamber **97** and the accumulator **174**.

Acceleration and deceleration of the piston rod **80** in an opposite direction (to the right as viewed in the drawing) that is, a contraction of the fluid cylinder **26** may be had by reversing the flow from the conduits **18** and **20** to the conduits **22** and **24**, respectively, 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 rod **80** in either direction at the same predetermined rate is equal. At the same time the setting of the directional control valve **28** is changed, the pressure drop in conduit **24** will result in the closing of the sequence valve **172**, while the increase pressure in conduit **22** is communicated via pilot line **180** to open the pilot check valve **176** such that the fluid in pressure chamber **97** is communicated to the accumulator **174** as chamber **97** is contracted. When fluid under pressure is communicated from pump **16** to the pressure chamber **91** via conduits **18** and **22**, the piston rod **80** will be shifted leftwardly toward a retracted position.

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 **85** and **91** quickly stopping the movement of the piston rod **80**. 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 to which the piston rod **80** is drivingly connected.

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 rod **80** of the main cylinder **26** may be accelerated or decelerated in opposite directions at any selected rate with the force exerted on the piston rod **80** being equal during both the contraction and expansion of the cylinder **26** as the effective pressure responsive areas of the piston **79** and the annular surfaces **88** and **89** are equal.

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 expansion and contraction of the main fluid cylinder **26**, any desired rate of movement of the piston rod **80** may be obtained.

Since acceleration and deceleration of the main fluid cylinder piston rod **80** 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** during expansion and contraction thereof 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 similar to 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 single rod cylinder has been provided which is much simpler and more compact in its construction than previously used systems and fluid cylinders; and which is more reliable and rapid in its operation.

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 variable displacement pressure energy translating device for providing a source of fluid pressure, said device having a fluid inlet and a fluid outlet;

fluid cylinder means having a first tubular member with at least one end closed;

a piston reciprocably mounted in said first tubular member and forming a first fluid chamber on one side thereof within said first tubular member, said first tubular member being movable in response to an increase in fluid in said first chamber;

a connecting member carried by the other side of said piston and movable therewith;

a second tubular member telescopically received by said first tubular member and radially outwardly spaced therefrom to define a second fluid chamber, said connecting member connecting said piston to said second tubular member, said second tubular member and said fluid actuated member defining a third fluid chamber;

a fluid actuated member in said second fluid chamber connected to said first tubular member and movable in response to an increase in fluid in said second fluid chamber to produce movement of said fluid actuator member relative to said second tubular member;

the effective pressure responsive area of said fluid actuated member exposed to the fluid in said second fluid chamber being equal to the effective pressure responsive area of said one side of said piston exposed to the fluid in said first fluid chamber, said actuated member being operable upon an increase in the fluid in said second fluid chamber to move said first tubular member in a direction toward said piston and contract said first fluid chamber, while said piston is operable upon an increase in fluid in said first fluid chamber to move said first tubular member in a direction away from said piston and expand said first fluid chamber;

valve means connecting the inlet and outlet of said device to said first and second fluid chambers within said fluid cylinder means for selectively directing fluid pressure from said device to and from said first and second fluid chambers; and

second valve means for selectively communicating said third fluid chamber to a source of fluid pressure while said first fluid chamber is in communication with said fluid pressure from said device, said second valve means being operable to communicate said third fluid chamber to said source of fluid pressure when the pressure of the fluid communicated to said first fluid chamber exceeds a predetermined amount, the fluid pressure communicated to said third chamber exerting a force on said fluid actuating member for maintaining said first fluid chamber in an expanded state.

2. The fluid system defined in claim 1 wherein said means for selectively communicating said inlet and outlet of said device to said first chamber comprises a passage extending through said connecting member and said piston and opening into said first chamber.

3. The fluid system defined in claim 1 wherein said fluid pressure energy translating device comprises a fluid pump having means for varying the displacement thereof between a minimum and maximum displacement; and pressure responsive means comprising a second fluid cylinder having a piston with a connecting rod extending from one end thereof, said extending end of said connecting rod being operatively coupled to said pump varying means, a separate source of fluid pressure being selectively communicated to opposite sides of said last-mentioned fluid cylinder; and flow control valve means disposed between said, separate source of fluid pressure and the opposite sides of said second cylinder for controlling the rate of fluid flow to said opposite sides of said second cylinder, whereby the rate of movement of said second cylinder and thus the rate of change in displacement of said fluid pump is selectively controlled.

4. The fluid system defined in claim 3 wherein said fluid system further comprises a fluid feed control valve for controlling the rate of fluid flow from said second source to one side of said second cylinder; a second fluid feed control controlling the rate of fluid flow to the other side of said second cylinder piston; a directional flow control valve for selectively controlling the flow from said second source of pressure to said feed control valve.

5. The fluid system defined in claim 4 wherein each of said feed control valves are selectively adjustable.

6. The fluid system defined in claim 3 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.

7. The fluid system defined in claim 1 wherein said first-mentioned valve means comprises a directional control valve having an inlet and outlet port respectively connected to the outlet and inlet ports of said pressure energy translating device, said directional control valve selectively connecting the outlet of said pressure energy translating device to one of said fluid cylinder chambers, while connecting the other of said fluid cylinder chambers to the inlet of said pressure energy translating device, whereby said fluid cylinder may be selectively expanded and retracted in response to fluid flow selectively communicated to the said fluid cylinder chamber.

8. The fluid system defined in claim 7 wherein said device and said fluid cylinder are fluidly connected in a closed loop circuit.

9. A fluid cylinder comprising:

a first tubular member having at least one closed end;

a piston reciprocably mounted in said first tubular member and forming a first fluid chamber on one side thereof, said first tubular member being movable in response to an increase in fluid in said first fluid chamber;

means for connecting said first fluid chamber to a source of fluid pressure;

a connecting member carried by the other side of said piston and movable therewith;

a second tubular member telescopically received by said first tubular member and radially spaced outwardly therefrom to define a second fluid chamber;

said connecting member connecting said piston to said second tubular member;

a fluid actuated member in said second fluid chamber connected to said first tubular member and movable in response to an increase in fluid in said second fluid chamber;

means for connecting said second fluid chamber to a source of fluid pressure so as to produce movement of said fluid actuated member relative to said second tubular member;

a third fluid chamber defined by said second tubular member and said fluid actuated member; and

means for selectively connecting said third fluid chamber to a source of fluid pressure after the pressure in said first fluid chamber exceeds a predetermined value, the fluid pressure being communicated to said third fluid chamber generating a force against said fluid actuated member for maintaining said first fluid chamber in an expanded state; the effective pressure responsive area of said fluid actuated member exposed to the fluid in said second fluid chamber being equal to the effective pressure responsive area of the side of said piston exposed to the fluid in said first fluid chamber, said fluid actuated member being operable upon increase in fluid in said second fluid chamber to move said first tubular member in a direction toward said piston and contract said first fluid chamber, and said piston being operable upon an increase in the fluid in said first fluid chamber to move said first tubular member in a direction away from said piston and expand said first fluid chamber.

10. The fluid cylinder defined in claim **9** further comprising a passage extending longitudinally through said connecting member and said piston and opening into said first fluid chamber, said source of fluid pressure being communicated to said first fluid chamber through said passage.

11. The fluid cylinder defined in claim **9** wherein said connecting member has a smaller cross sectional area than said piston.

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