

[54] HYDRAULIC SYSTEM

[75] Inventors: William D. Wilkerson, Santa Ana; A. P. Henry, Irvine, both of Calif.

[73] Assignee: Berteau Corporation, Irvine, Calif.

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[58] Field of Search 60/52 R, 476; 91/420

[56] References Cited

UNITED STATES PATENTS

1,812,587	6/1931	Ellis	60/52 R
2,524,055	10/1950	Hubert	60/52 R X
2,716,995	9/1955	Baugh et al.	60/52 R
2,768,500	10/1956	Tyler	60/52 R

3,234,957 2/1966 Allen..... 60/52 R X

Primary Examiner—Edgar W. Geoghegan
Attorney—Gordon L. Peterson et al.

[57] ABSTRACT

A hydraulic system comprising an actuator including a housing and a piston movable in the housing, a reversible, variable speed pump, and conduits for connecting the pump to both sides of the piston so that the pump can pump hydraulic fluid from one side of the piston to the other. The pump is driven by a reversible, variable speed drive with the direction of piston movement being a function of the direction in which the pump is driven. The rate of piston movement is a function of the speed at which the pump is driven. The actuator may be an unbalanced actuator, in which event the unbalance can be compensated for by the pump or by suitable piping connections.

14 Claims, 3 Drawing Figures

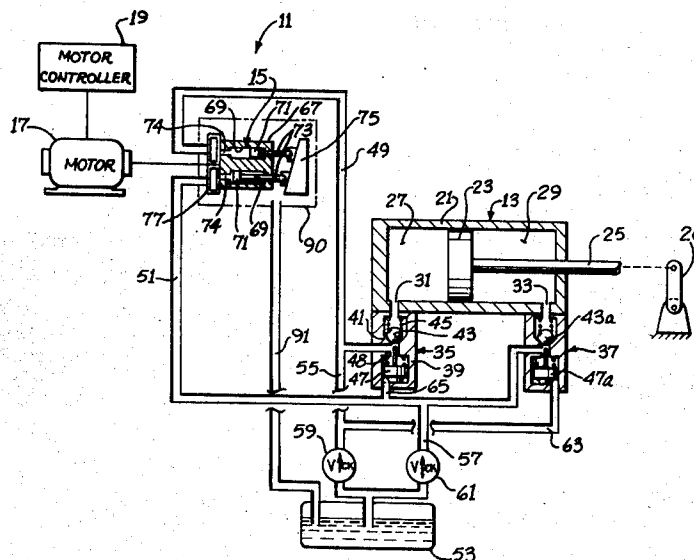


Fig. 1

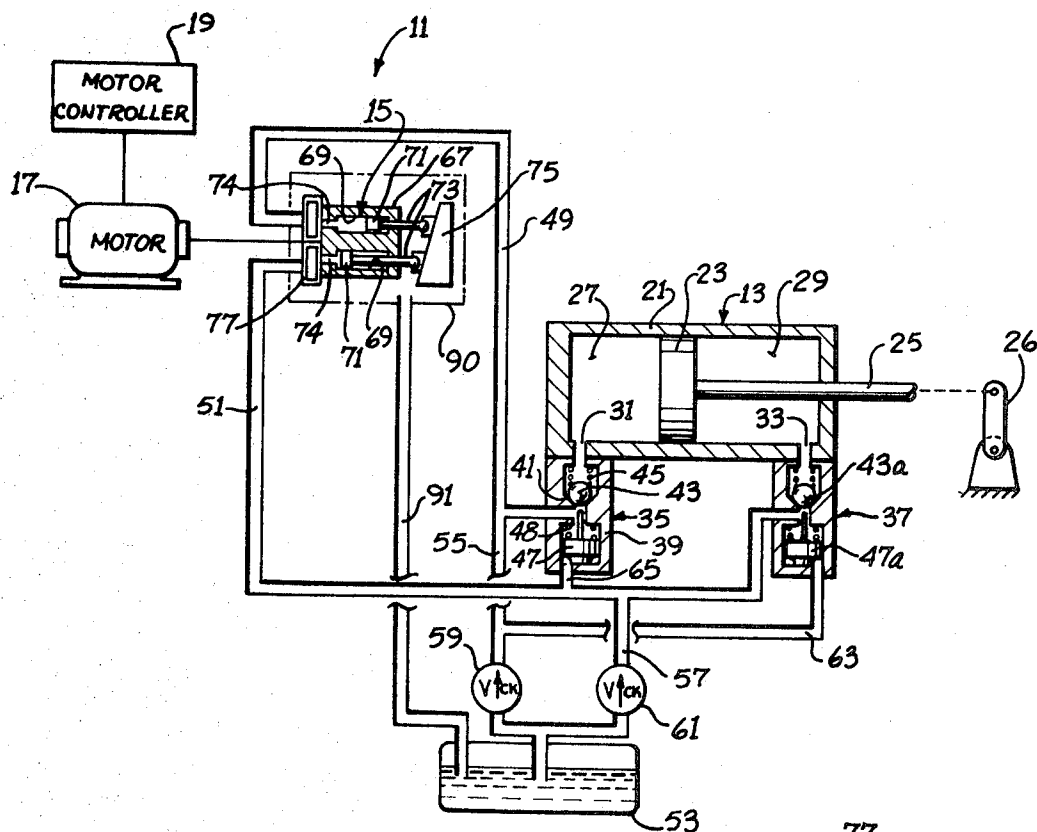
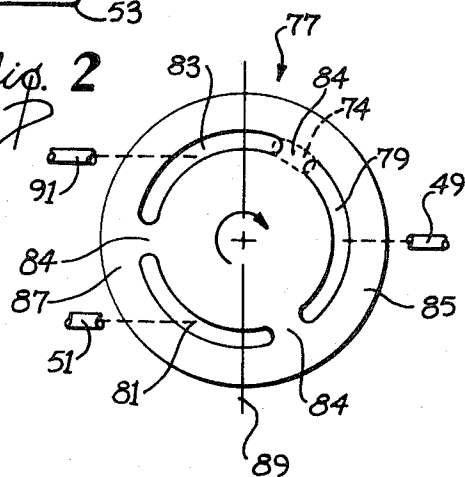
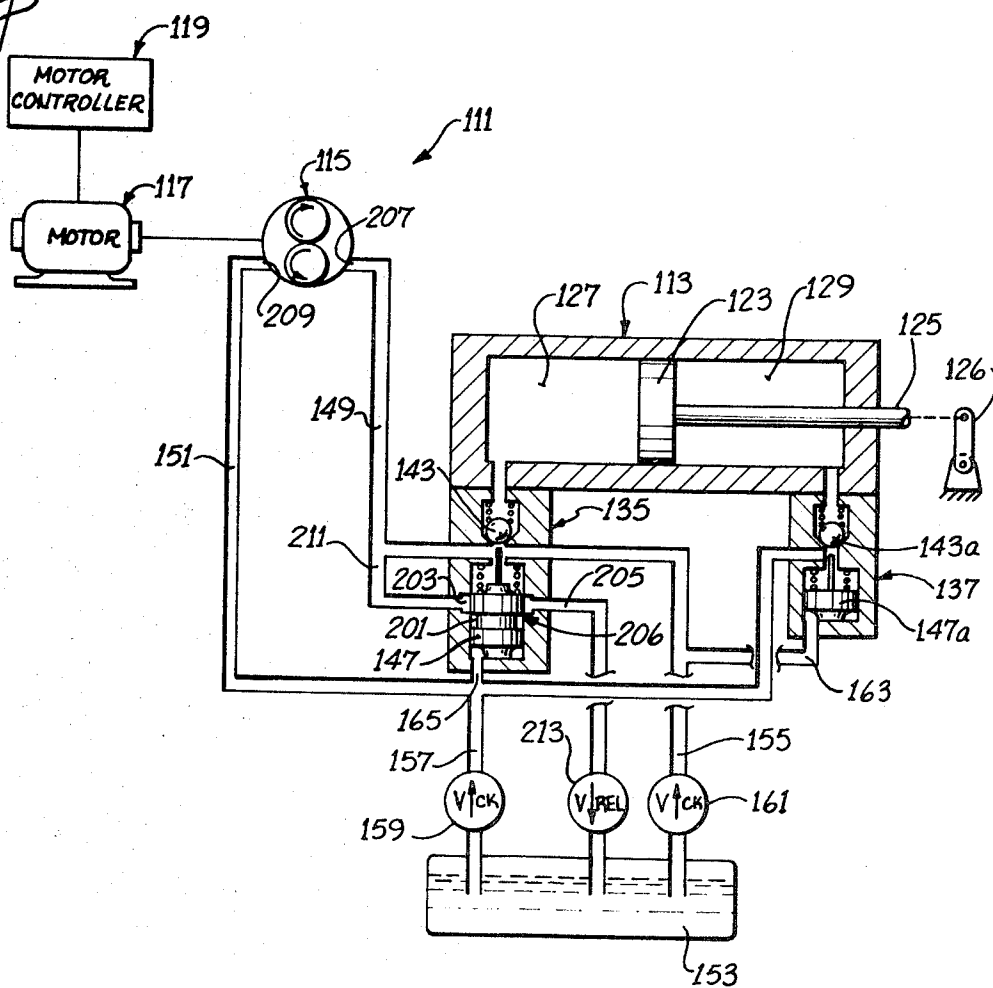


Fig. 2



INVENTORS:
William D. Wilkerson
A. P. Henry
By: Smyth, Poston & Pawitt
ATTORNEYS

Fig. 3



INVENTORS:
 William D. Wilkerson
 A.P. Henry
 By: Smyth, Roston & Pavitt
 ATTORNEYS

HYDRAULIC SYSTEM

BACKGROUND OF THE INVENTION

Hydraulic systems are used to perform many different control functions. One type of hydraulic system includes an actuator and a pump. The actuator includes a cylinder and a piston, and the pump selectively pumps hydraulic fluid from one side of the piston to the other to thereby control movement of the piston.

One problem with systems of this kind is how to provide fine control of piston movement. With prior art devices of this type, it is difficult or impossible to very accurately position the piston.

The problem of accurate piston positioning is compounded when an unbalanced actuator is used. In an unbalanced or differential actuator movement of the piston causes a greater change in volume on one side of the piston than on the other. It then becomes necessary to provide means to compensate for the unbalance. Unbalance is typically caused by the presence of a connecting rod on one side of the piston which effectively reduces the volume of the chamber on that side of the piston.

SUMMARY OF THE INVENTION

The present invention relates generally to a hydraulic system in which a pump moves hydraulic fluid from one side of a pressure-responsive member such as an actuator piston to another to thereby control the position of the pressure-responsive member. The present invention provides several improvements to this kind of system including solutions to the above described problems.

With the present invention, fine control of piston movement is obtained by using a variable speed drive for the pump. This can be used to advantage whether the actuator is balance or unbalanced.

The rate of piston movement is a function of the speed at which the pump is driven. Accordingly, for fine control of piston movement, the pump is driven at a relatively low velocity. This causes pump delivery rate to be relatively low and consequently the piston moves slowly.

Although other drive means could be used for the pump, it is preferred to use a variable speed reversible electric motor. The direction of piston movement is a function of the direction in which the pump is driven.

The present invention also provides two novel ways of compensating for actuator unbalance. According to the first of these, the pump includes means for compensating for the unbalance. More particularly, the pump is of the barrel-type and includes a valve plate having first, second and third ports. The piston divides the cylinder into first and second chambers with the piston being movable to displace more fluid in the first chamber than is taken into the second chamber. First and second conduits provide communication between the first and second ports and the first and second chambers, respectively. A third conduit provides communication between the third port and a source of hydraulic fluid.

When the pump is driven in a first direction, hydraulic fluid is withdrawn from the first chamber. Because a greater volume of fluid is displaced in the first chamber than is taken into the second chamber in response to piston movement, only the fluid required in the second chamber is transmitted thereto by the pump. The

excess fluid is transferred through the third port and the third conduit to the source of hydraulic fluid, thereby compensating for actuator unbalance.

To move the piston in the opposite direction, the pump withdraws fluid from the second chamber and supplies it through the first conduit to the first chamber. However, additional make-up fluid is required in that for any given piston movement, the volume of the first chamber increases more than the volume of the second chamber decreases. This make-up is provided by the pump which draws the additional make-up fluid from the source of the hydraulic fluid through the third conduit and supplies it via the first conduit to the first chamber.

These desirable results are obtained by appropriately sizing and locating the ports in the valve plate. The valve plate may be considered as including first and second segments with a portion of the first port being in the first segment and with portions of the second and third ports being in the second segment. The direction of fluid flow through the first segment is opposite the direction of fluid flow through the second segment. For example, during the intake stroke of the pump, hydraulic fluid may be drawn in from the first chamber through the first port. During the discharge portion of the stroke, the fluid taken in is discharged through the second and third ports, i.e., to the second chamber and to the source of hydraulic fluid to thereby compensate for the unbalance. The pump is preferably housed in a casing filled with hydraulic fluid and this may form a portion of the third conduit or a portion of the source of hydraulic fluid.

According to the second method of compensating for actuator unbalance, the present invention provides first and second conduits providing communication between the first and second chambers and the pump. A third conduit connects the first conduit with a source of hydraulic fluid. The first and second conduits contain first and second valves, respectively, for controlling the flow of hydraulic fluid into and out of their associated chambers. A control valve selectively opens and closes the third conduit.

According to this form of the invention, the first valve means and the control valve are open when fluid is being withdrawn from the first chamber by the pump. This permits excess fluid to flow through the third conduit means to the source of hydraulic fluid.

One feature of this invention is the provision of a restriction in the third conduit to provide back pressure for the pump to prevent starving of the pump. This restriction may be a simple, inexpensive, relief valve which is set at the desired pump back pressure.

Another feature of this form of the invention is that a common valve actuator can be utilized to open both the control valve and the first valve means when the first and third conduits are on the intake side of the pump. The common actuator is preferably responsive to the second conduit being on the discharge side of the pump for opening the control valve and the first valve means. This represents a simplification of the structure and a reduction in the cost of manufacture.

When the piston is moving in a direction to enlarge the first chamber, make-up hydraulic fluid must be provided. This is preferably provided by a fourth conduit which interconnects the second conduit with the source of hydraulic fluid.

Another advantage of the present invention is that the first and second valve means automatically hold the piston in a fixed position in the absence of any command for piston movement. Thus, the pump is not required to hold pressure in a stand-by condition. Another advantage of this construction is that in the event of a hydraulic failure resulting in loss of hydraulic fluid outside of the cylinder, the first and second valve means hold the piston in position.

The invention can best be understood by reference to the following description taken in connection with the accompanying illustrative drawing.

BRIEF DESCRIPTION OF THE DRAWING

FIG. 1 is a diagrammatic view of one form of hydraulic system constructed in accordance with the teachings of this invention.

FIG. 2 is a planned view of one form of valve plate which may be utilized by the pump which forms a portion of the system showing FIG. 1.

FIG. 3 is a diagrammatic view of a second form of hydraulic system constructed in accordance with the teachings of this invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

FIG. 1 shows a hydraulic system 11 constructed in accordance with the teachings of this invention. Generally the hydraulic system 11 includes a hydraulic actuator 13, a pump 15, a motor 17 for driving the pump, and a motor controller 19.

The actuator 13 includes a housing or cylinder 21, a piston 23 slidable in the cylinder, and a connecting rod 25 for joining the piston to a controllable member 26, the position of which is to be controlled. The piston 23 divides the cylinder 21 into chambers 27 and 29. Because of the presence of the rod 25 in the chamber 29, movement of the piston 23 causes displacement of more hydraulic fluid in the chamber 27 than is taken into the chamber 29. Stated differently, the volume of the chamber 27 changes a greater amount than the volume of the chamber 29 in response to predetermined displacement of the piston 23. Actuators of this type are known as unbalanced actuators.

The chambers 27 and 29 communicate with the exterior of the cylinder 21 through ports 31 and 33, respectively. The flow of hydraulic fluid to and from the chambers 27 and 29 is controlled by identical, pilot-operated check valves 35 and 37. Of course, the specific form of the valves 35 and 37 can be varied by those having ordinary skill in the art.

The check valve 35 includes a hollow housing 39 defining a valve seat 41. A valve element in the form of a ball 43 is urged by a spring 45 into fluid tight sealing relationship with the valve seat 41.

The valve element 43 can be moved away from the valve seat 41 to open the valve 35 by an actuator 47 which is slidable in the housing 39 and which is normally biased by a spring 48 out of engagement with the valve element 43. The valve 37 is identical to the valve 35 and parts of the valve 37 corresponding to parts of the valve 35 are designated by corresponding reference numerals followed by the letter a.

Conduits 49 and 51 interconnect the pump 15 and the valves 35 and 37, respectively. The conduits 49 and 51 are placed in communication with a source 53 of hydraulic fluid by conduits 55 and 57, respectively.

Check valves 59 and 61 in the conduits 55 and 57 allow for the flow of hydraulic fluid out of the source 53 and prevent back flow to the source through the conduits 55 and 57. In the embodiment illustrated, the source 53 is closed and pressurized.

The conduit 49 is placed in communication with the actuator 47a by the conduit 55 and another conduit 63. The actuator 47 is placed in communication with the conduit 51 by a conduit 65.

The pump 15 is a reversible, variable speed barrel-type pump. Pumps of this type are known and disclosed, for example, in U.S. Pat. Nos. 2,525,934 and 3,291,067. The pump 15 includes a cylinder barrel 67 suitably mounted for rotation, a plurality of cylinders 69 in the barrel and pistons 71 mounted for reciprocation in the cylinders 69, respectively. The cylinders communicate with ports 74, respectively. The pistons 71 are driven by plungers 73 which rotate with the cylinder 69 and which bear against a fixed cam plate 75. Accordingly, as the barrel 67 rotates, the pistons 71 are reciprocated in their respective cylinders 69. Reciprocation of the pistons 71 causes intake of fluid into the cylinders 69 during one part of each cycle and discharge of such fluid during another part of the cycle. This is standard barrel pump operation.

The pump 15 also includes a valve plate 77 which is stationary during rotation of the barrel 67. As shown in FIG. 2, the valve plate 77 has three arcuate ports 79, 81 and 83 separated by commutating lands 84. The valve plate 77 may be considered as being divided into segments 85 and 87 one of which is for intake and the other of which is for discharge. In the embodiment illustrated, this division is made by an imaginary line 89. The top of the line 89 represents top dead center, and the bottom of the line 89 represents bottom dead center. In the embodiment illustrated, the port 79 and relatively small portions of the ports 81 and 83 are located in the segment 85. Relatively larger portions of the ports 81 and 83 are located in the segment 87.

The ports 79, 81 and 83 are in communication with the conduits 49 and 51 and with the interior of a casing 90 for the pump 15. A conduit 91 provides communication between the interior of the casing 90 and the source 53 of hydraulic fluid under pressure. With the barrel 67 of the pump 15 rotating in a first direction, the slot 79 and the portions of the slots 81 and 83 in the segment 85 are in communication with the cylinders 69 during the intake stroke and the portions of the slots 81 and 83 in the segment 87 are in communication with the cylinders 69 during the discharge stroke.

The pump 15 can be driven in either direction and at different speeds by the motor 17 which is a variable speed, reversible, electrical motor. The discharge rate of the pump 15 is a function of the speed at which the pump is driven with the discharge rate increasing as the rate at which the pump is driven increases.

The motor controller 17 can be any device suitable for varying the speed and direction of rotation of the motor 17. The controller 19 may be operated automatically or manually. By way of example, the motor controller 19 may include the control system shown in common assignee's copending application, Ser. No. 169,345, filed on Aug. 5, 1971, entitled "Acoustic Control System," and naming Curtis E. Stevens as the inventor. Because motor speed is variable the cam plate 75 need not be adjustably mounted.

If it is desired to move the piston 23 to the left, the motor controller 19 causes the motor 17 to rotate in a first direction. This places the conduits 49 and 51 on the intake and discharge, respectively, of the pump 15.

The motor 17 drives the barrel 15 in a direction so that the ports and port portions on the segment 85 of the valve plate 77 are on the intake side of the pump and the port portions on the segment 87 are on the discharge side of the pump. Assuming that the barrel 67 is rotating in the direction of the arrow A in FIG. 2, each piston 71 will draw fluid into its associated cylinder 69 through the port 83 while that piston confronts the portion of the slot 83 on the segment 85. Similarly, fluid is drawn into each of the cylinders 69 through the slot 79 and the portion of the slot 81 on the segment 85 while the cylinders confront these slots in the segment 85. The quantity of fluid drawn into the cylinders from each of the ports 79, 81 and 83 is a function of the lengths and angular orientations of the respective ports on the segment 85. In the embodiment shown in FIG. 2, a relatively large quantity of fluid is drawn in from the conduit 49 through the slot 79 and minor quantities of fluid are drawn in from the case 90 through the slot 83 and from the conduit 51 through the slot 81. Minor quantities are drawn in through the slots 81 and 83 because (1) their lengths on the segment 85 are relatively short, and (2) they are located near bottom and top dead center, respectively, where the rate of pump piston movement is relatively slow. Drawing in fluid through the slot 81 does not cause a loss of pressure in the conduit 51 because the pump 15 includes a sufficient number of pistons, e.g., 7 or 9, so that at any instant more fluid is being discharged into the slot 81 and the conduit 51 than is being withdrawn.

With the pump 15 being driven in the direction of the arrow A in FIG. 2, each of the pistons 71 discharges fluid through the slots 81 and 83 in volumetric amounts which is a function of the lengths and angular orientation of these slots. Because fluid is drawn into the cylinders 69 from the slot 81 and also discharged from the cylinders 69 into the slot 81, the effectiveness of the slot 81 for discharge purposes is reduced. Because the slot 79 is longer than the portion of the slot 81 on the segment 87 and located where pump piston velocity is greater, the pump draws in more fluid from the conduit 49 than it discharges into the conduit 51. This amount can be accurately apportioned so as to precisely compensate for the unbalance of the actuator 13. The fluid which is not discharged into the conduit 51 through the port 81 is discharged through the slot 83, the case 90 and the conduit 91 to the source 53. It should be understood that the valve plate 77 could be constructed in different ways so long as more fluid is drawn in from the conduit 49 than is discharged into the conduit 51.

Each of the ports 74 is sufficiently long so that the associated cylinder 69 is always in communication with at least one of the slots 79, 81 and 83. In FIG. 2 one of the ports 74 is illustrated between the slots 79 and 83 and the remaining ports 74 are not shown. In the position of the port 74 shown in FIG. 2, it communicates with the slots 79 and 83.

When the conduit 51 is on the discharge side of the pump 15, the actuator 47 is urged by the fluid under pressure in the conduit 65 upwardly as viewed in FIG. 1 to move the valve element 43 off of the seat 41 against the biasing force of the spring 45. This permits

the pump to draw fluid from the chamber 27 through the conduit 49.

The hydraulic fluid at discharge pressure in the conduit 51 acts to unseat the valve element 43a so that hydraulic fluid is supplied to the chamber 29 through the valve 37. The pump 15 can also draw fluid from the source 53 through the check valve 59 and the conduit 55. This may be necessary to develop enough pressure in the conduit 51 to unseat the valve element 43. Drawing of fluid from the source 53 may also be necessary to make-up for leakage.

As the piston 23 moves to the left, it displaces a greater volume of fluid in the chamber 27 than is taken into the chamber 29. However, because of the arrangement of the valve plate 77, the pump can be adapted to compensate precisely for this unbalance. Specifically, excess hydraulic fluid discharged from the chamber 27 is delivered through the port 83 to the case 90.

The rate at which the piston 23 moves can be controlled by the speed of the motor 17. Thus, for inching, the motor 17 may be caused by the motor 19 to turn very slowly so that the piston 23 can be accurately positioned. When the desired position of the piston 23 has been reached, the motor 17 is de-energized and thereafter the normally closed check valves 35 and 37 maintain the piston at the preset position. If a failure causes loss of fluid pressure outside of the actuator 13, the normally closed check valves 35 and 37 continue to maintain the piston 23 in the preset position.

To move the piston 23 to the right as viewed in FIG. 1, the motor 17 is energized by the controller 19 in the opposite to the direction A in FIG. 2. This causes the pump 15 to be driven in a direction opposite to the direction in which it was initially driven. The result is that the segment 87 of the valve plate 77 becomes the intake segment and the segment 85 becomes the discharge segment. Accordingly, as the barrel 67 rotates, it draws in fluid through the portions of ports 81 and 83 on the segment 87 and discharges the fluid through the port 79 and the portions of the ports 81 and 83 on the segment 85. Because of the relative lengths and orientations of the slots 79 and 81, the pump discharges more fluid into the conduit 49 through the slot 79 than it draws in from the conduit 51 through the slot 81. The additional fluid is supplied from the source 53 through the conduit 91, the case 90 and the slot 83.

With the conduit 49 on the discharge side of the pump 15, fluid under pressure is transmitted through the conduit 63 to cause the actuator 47a to unseat the valve element 43a. This permits the pump 15 to draw fluid out of the chamber 49 and into the conduit 51.

The hydraulic fluid at discharge pressure in the conduit 49 acts directly against the valve element 43 to unseat the latter to thereby permit hydraulic fluid under pressure to be discharged into the chamber 27 to move the piston 23 to the right as viewed in FIG. 1. If make-up is required for start-up or during operation, it can be obtained from the source 53 through the check valve 61 and the conduit 57.

FIG. 3 shows a hydraulic system 111 constructed in accordance with the teachings of this invention. The hydraulic system 111 is very similar to the hydraulic system 11 except that it provides alternate means for compensating the unbalance of the actuator. The portions of the hydraulic system 111 corresponding to portions of the hydraulic system 11 are designated by cor-

responding referenced characters preceded by the numeral 1.

Generally, the hydraulic system 111 includes an actuator 113, a pump 115, a motor 117, and a motor controller 119. The actuator 113, the motor 117, and the motor controller 119 are identical to the corresponding elements described hereinabove with reference to FIG. 1. The pump 115 is preferably any reversible, variable speed, positive displacement pump and in the embodiment illustrated is a gear pump.

Pilot operated check valves 135 and 137 control the flow of hydraulic fluid into and out of the chambers 127 and 129, respectively. The check valve 137 is identical to the check valve 37 shown in FIG. 1. The check valve 135 is identical to the check valve 35 shown in FIG. 1 except that the actuator 147 includes a pair of lands defining a groove 210 and the body of the valve includes ports 203 and 205. Thus, the actuator 147 and the body of the valve 135 cooperate to form a control valve 206 which is normally biased to the closed position shown in FIG. 3. However, it can be moved to an open position in which the groove 201 provides communication between the ports 203 and 205.

The pump 115 has two ports, 207 and 209, which are connected by conduits 149 and 151, respectively, to the valves 135 and 137. A conduit 211 provides communication between the conduit 149 and the source 153 of hydraulic fluid under pressure. A restriction which, in the embodiment illustrated is in the form of a pressure relief valve 213, is positioned in the conduit 211 intermediate the control valve 206 and the source 153.

As in the embodiment of FIG. 1, conduits 165 and 157 provide communication between the conduit 151 and the actuator 147 and the source 153, respectively. Similarly, a conduit 155 provides communication between the conduit 149 and the source 153 and the conduit 163 provides communication between the conduit 149 and the actuator 147a.

In the operation of the system 111, the motor controller 119 energizes the motor 117 to cause movement of the piston 123 in the desired direction, such as to the left as viewed in FIG. 3. Motor speed 117 is similarly adjusted so that the piston 123 will move at the desired rate. The pump 115 is driven by the motor 117. In order to move the piston 123 to the left, the port 207 is the intake port and the port 209 is the discharge port. With the conduit 151 on the discharge side of the pump 115, the hydraulic fluid under pressure in the conduit 165 moves the actuator 147 upwardly to unseat the valve element 143 and to open the control valve 206 by aligning the groove 201 with the ports 203 and 205. Thus, the control valve 206 and the valve 135 are opened by a single actuator. The unseating of the valve element 143 allows the pump 115 to draw hydraulic fluid from the chamber 127.

The opening of the control valve 206 provides communication between the intake of the pump 115 and the relief valve 213. The conduit 211, the control valve 206 and the pressure relief valve 213 provide means for dumping excess hydraulic fluid from the chamber 127. This is the excess hydraulic fluid which is not required in the chamber 129 due to the unbalance of the actuator 113.

The relief valve 213 is set at a preselected pressure which is preferably relatively low to thereby provide back pressure for the pump. If the relief valve 213 or

some other restriction were not present, the back pressure on the pump may be insufficient and cavitation may result.

The hydraulic fluid discharged by the pump 115 unseats the valve element 143a to permit this hydraulic fluid to be supplied to the chamber 129. This causes the piston 123 to move to the left at a rate which is a function of the velocity at which the pump 115 is being driven. When the desired position of the piston 123 has been reached, the motor 117 is de-energized by the controller 119 and thereafter the check valves 135 and 137 maintain the piston 123 in the preset position. Ordinarily, with the piston 123 being moved to the left as viewed in FIG. 3, there will be an excess of hydraulic fluid which is returned to the source 153 via the conduit 211, the control valve 206, and the pressure relief valve 213. However, if for any reason make-up hydraulic fluid is required, it can be supplied from the source 153 through the check valve 161 and the conduit 155 to the conduit 149.

To move the piston 123 to the right as viewed in FIG. 3, it is only necessary to reverse the direction of the motor 117, thereby reversing the direction in which the pump 115 is driven. This causes the conduit 149 to be on the discharge side of the pump 115 with the result that the actuator 147a is moved upwardly to unseat the valve element 143a. This allows the hydraulic fluid in the chamber 129 to escape into the conduit 151 to feed the pump 115. In addition, the hydraulic fluid under pressure in the conduit 149 unseats the valve element 143 to permit the supply of fluid under pressure to the chamber 127 and consequent movement of the piston 123 to the right. As the conduit 151 is on the intake side of the pump 115, the control valve 206 remains in the closed position shown in FIG. 3.

To move the piston 123 to the right, it is necessary to supply more hydraulic fluid to the chamber 127 than can be drawn from the chamber 129. The additional fluid is supplied from the source 153 through the check valve 159 and the conduit 157 to the conduit 151. Of course, the check valves 159 and 161 prevent reverse flow of hydraulic fluid to the source 153.

Although exemplary embodiments of the invention have been shown and described, many changes, modifications and substitutions may be made by one having ordinary skill in the art without necessarily departing from the spirit and scope of this invention.

We claim:

1. A hydraulic system comprising:

an actuator including a housing and a fluid-responsive member movable in said housing, said member and said housing defining first and second chambers on opposite sides, respectively, of said member;

a reversible, variable speed pump, the output of said pump being a function of the speed at which said pump is driven;

conduit means for connecting said pump to both of said chambers whereby said pump can selectively pump hydraulic fluid from the first chamber to the second chamber and from the second chamber to the first chamber to thereby move the fluid-responsive member;

reversible, variable speed drive means for driving said pump;

means for controlling the direction in which and the speed at which said pump is driven by said drive

means whereby the direction which the pump is driven controls the direction of movement of the fluid-responsive member and the speed at which the pump is driven controls the rate of movement of the fluid-responsive member;

said actuator being an unbalanced actuator whereby the change in volume of the first chamber is greater than the change in volume of the second chamber for a given displacement of the pressure-responsive member;

said conduit means including a first conduit leading from the pump to the first chamber and a second conduit leading from the pump to the second chamber;

a third conduit leading from the pump to a source of hydraulic fluid;

said pump including means for supplying make-up from the third conduit through the first conduit to the first chamber when the volume of the first chamber is being increased and means for dumping excess hydraulic fluid from the first chamber through the first conduit to said source when the volume of the first chamber is being decreased; and said pump including a barrel pump and a valve plate, said valve plate having first, second and third ports therein communicating, respectively, with said first, second and third conduits.

2. A hydraulic system as defined in claim 1 wherein said drive means includes a reversible, variable speed electric motor, said pump including a positive displacement pump.

3. A hydraulic system comprising:

a differential actuator including a housing and a piston movable in said housing, said piston dividing said housing into first and second chambers on opposite sides of said piston, respectively, whereby movement of said piston causes the volumes of said chambers to change;

said actuator including means for causing the volume of said first chamber to undergo a greater change than the volume of said second chamber in response to a predetermined amount of piston displacement;

a reversible pump having first and second ports;

a first conduit interconnecting the first port and said first chamber;

a second conduit connecting said second port and said second chamber whereby the pump can pump hydraulic fluid through said conduits between said chambers to thereby move the piston;

drive means for driving said pump, said drive means being reversible to change the direction in which hydraulic fluid is pumped by said pump to thereby control the direction in which the piston is moved;

first valve means operatively associated with the first conduit and responsive to the first conduit being on the discharge side of the pump to open to permit hydraulic fluid to be supplied to the first chamber through the first conduit;

second valve means operatively associated with the second conduit and responsive to the second conduit being on the discharge side of the pump to open to permit hydraulic fluid to be supplied to the second chamber through the second conduit;

a first valve actuator responsive to the second conduit being on the discharge side of the pump for opening said first valve means to permit hydraulic

fluid to be drawn from the first chamber by said pump;

a third conduit leading from said first conduit for dumping excess hydraulic fluid when said first chamber is being reduced in volume by said movement of the piston;

a control valve for closing said third conduit when said first conduit is on the discharge side of the pump and for opening said third conduit when said second conduit is on the discharge side of the pump;

means defining a restriction in said third conduit to provide back pressure for said pump when said control valve is open; and

means for supplying make-up hydraulic fluid to said first chamber when the volume of said first chamber is being increased.

4. A hydraulic system as defined in claim 3 wherein said restriction is downstream of said control valve.

5. A hydraulic system as defined in claim 3 wherein said first valve actuator also opens said control valve whereby a single valve actuator operates both said first valve means and said control valve.

6. A hydraulic system as defined in claim 3 wherein said reversible drive means is a variable speed reversible drive means, thereby providing for better control of the movement of said piston.

7. A hydraulic system comprising:

a differential actuator including a housing and a piston movable in said housing, said piston dividing said housing into first and second chambers on opposite sides of said piston, respectively, whereby movement of said piston causes the volumes of said chambers to change;

said actuator including means for causing the volume of said first chamber to undergo a greater change than the volume of said second chamber in response to a predetermined amount of piston displacement;

a reversible pump having first and second ports;

a first conduit connecting the first port and said first chamber;

a second conduit connecting said second port and said second chamber whereby the pump can pump hydraulic fluid through said conduits and between said chambers to thereby move the piston, the direction of fluid flow through said conduits being a function of the direction in which said pump is driven;

reversible drive means for driving said pump to thereby control the direction in which the piston is moved;

first valve means operatively associated with the first conduit and responsive to the first conduit being on the discharge side of the pump to open to permit hydraulic fluid to be supplied through the first conduit to the first chamber;

a third conduit leading from said first conduit for dumping excess hydraulic fluid from the first chamber when said first chamber is being reduced in volume by said movement of the piston;

a control valve for opening and closing said third conduit;

a valve actuator for opening said control valve and said first valve means in response to said second conduit being on the discharge side of said pump whereby a single valve actuator opens said first

valve means to allow the pump to draw fluid from the first chamber and opens the control valve to permit dumping of any excess hydraulic fluid through the third conduit; and

means for providing make-up fluid to the first chamber when the volume of the first chamber is being increased.

8. A hydraulic system as defined in claim 7 wherein said reversible drive means includes a reversible variable speed drive means whereby fine control of piston movements can be accomplished.

9. A hydraulic system comprising:

an actuator including a housing and a piston movable in said housing, said actuator being an unbalanced actuator whereby movement of said piston causes a greater change in said piston volume on one side of the piston than on the other side of the piston;

a reversible barrel-type pump, including a valve plate having first, second and third ports;

a first conduit leading from said first port to said one side of piston;

a second conduit leading from the second port to said other side of the piston whereby said pump can pump hydraulic fluid from said one side of the piston to said other side of the piston and from said other side of the piston to said one side of the piston with the direction of fluid flow being a function of the direction in which the pump is driven;

a third conduit leading from the third port to a source of hydraulic fluid;

said valve plate having first and second segments, said first port being at least partially on said first segment and said second and third ports being at least partially on said second segment;

said first and second segments being on the intake and discharge sides, respectively, of said pump when said pump is being driven in one direction and said first and second segments being on the discharge and intake sides, respectively, of said pump when said pump is driven in the opposite direction, said third conduit drawing hydraulic fluid from said source of hydraulic fluid when said pump is being driven in said opposite direction and supplying hydraulic fluid to said source when the pump is driven in said one direction; and

said ports being sized and positioned on said segments to substantially compensate for the unbalance of said actuator whereby said pump supplies more hydraulic fluid to said one side of said piston

than it draws from said other side of said piston and supplies less hydraulic fluid to said other side of said piston than it draws from said one side of said piston.

10. A hydraulic system as defined in claim 9 wherein a region of said second port is on said first segment.

11. A hydraulic system as defined in claim 9 including a casing, said pump and at least a portion of said source being within said casing.

12. A hydraulic system as defined in claim 9 including a reversible, variable speed drive means for driving said pump.

13. A hydraulic system comprising:

an actuator including a housing and a piston movable in said housing, said actuator being an unbalanced actuator whereby movement of the piston causes a greater change in volume on one side of the piston than on the other side of the piston;

a pump including first, second and third ports;

a first conduit for providing communication between said first port and said one side of said piston;

a second conduit leading from the second port to said other side of the piston;

a third conduit for providing communication between said third port and a source of hydraulic fluid;

said pump being drivable in one direction to pump hydraulic fluid from said one side of said piston through said first and second conduits to said other side of said piston and being drivable in the opposite direction to pump hydraulic fluid from said other side of the piston through said second and first conduits to said one side of said piston; and said pump including first means for directing fluid from said first conduit to said second and third conduits when said first conduit is on the intake side of said pump and second means for directing fluid from the second and third conduits to the first conduit when said first conduit is on the discharge side of said pump to thereby at least partially compensate for the unbalance of the actuator.

14. A hydraulic system as defined in claim 13 wherein said pump includes a barrel-type pump and said first and second means include a valve plate having a plurality of ports therein sized and positioned to substantially compensate for the unbalance of the actuator.

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