United States Patent

McMillen et al.

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[54] HYDRAULIC SYSTEM

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[52] **U.S. Cl.** ....**60/52 US**, 417/213, 417/222
[51] **Int. Cl.** **F15b 1/00**, F04b 49/00, F04b 1/26
[58] **Field of Search**..................60/52 US; 417/218, 222, 213

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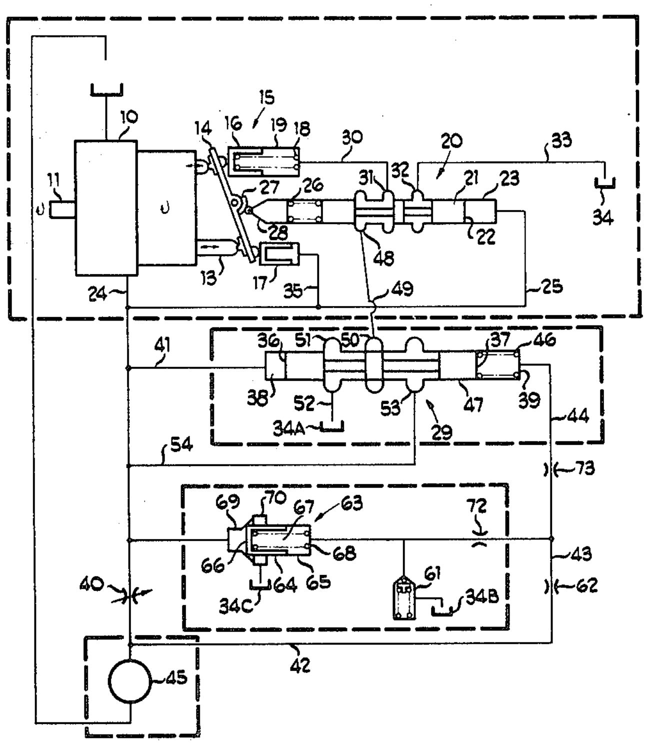
[57] **ABSTRACT**

Pump controls having a sensor valve that operates between two positions to control the displacement of a pump in response to pressure differentials caused by flow through a variable orifice. Override of the sensor valve is provided by a pressure and displacement sensitive valve thereby limiting the input torque of the pump.

33 Claims, 7 Drawing Figures



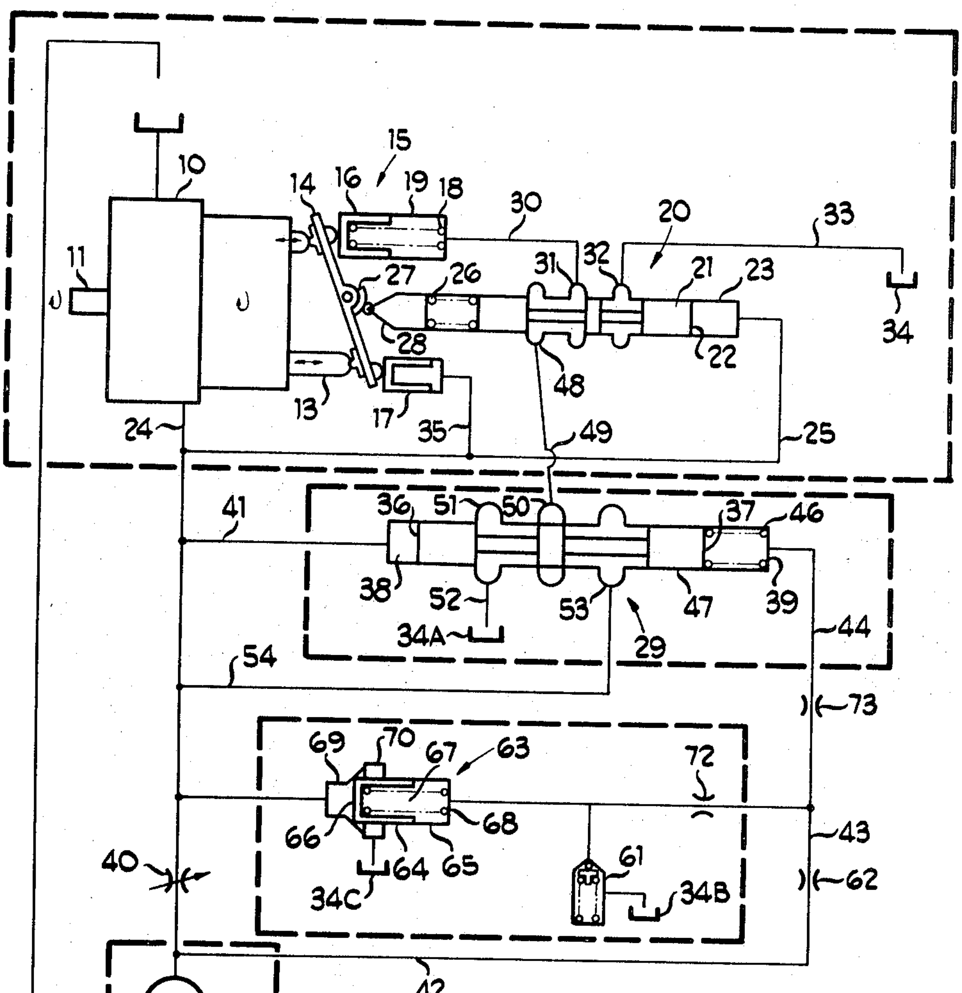


Fig 1

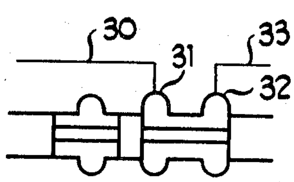


Fig 1A

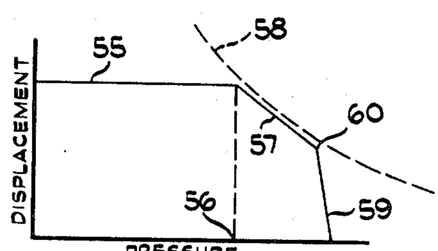


Fig 1B

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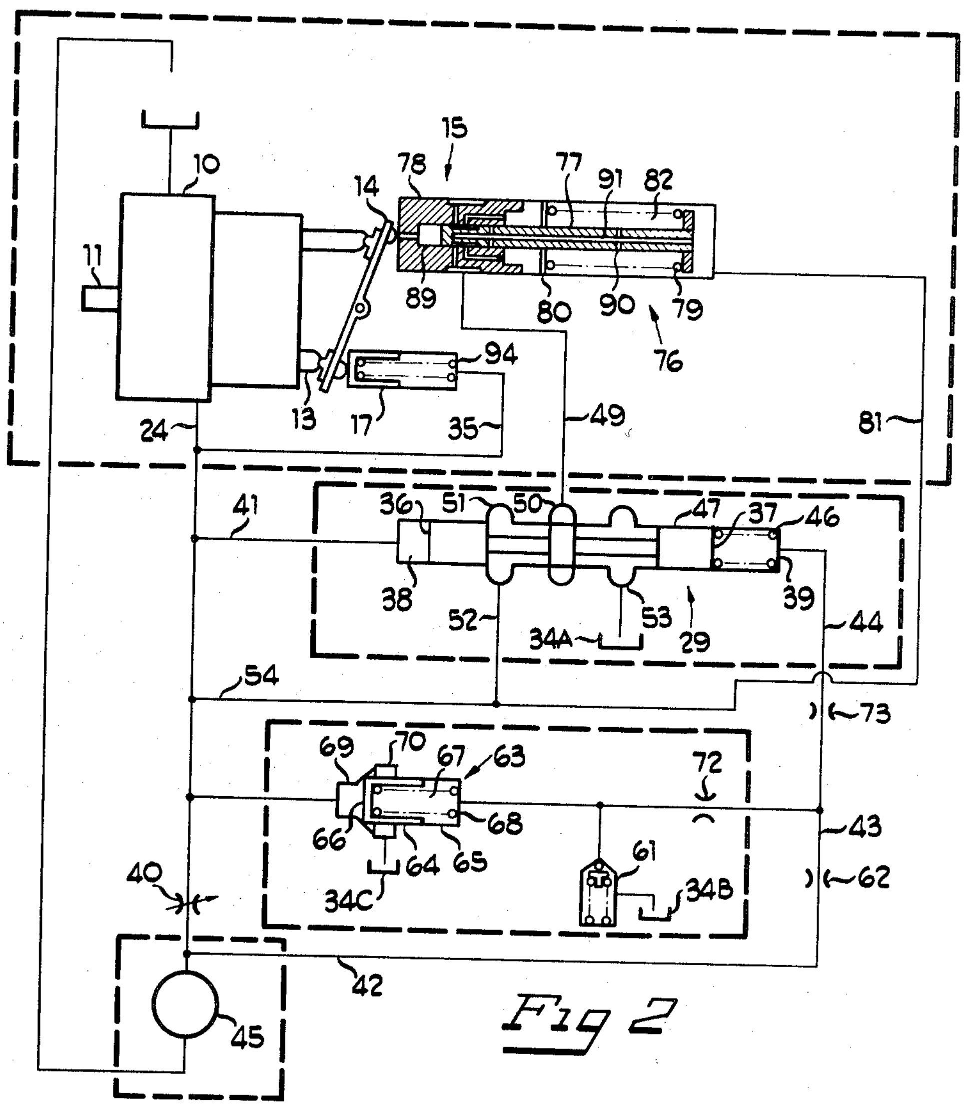

Fig 2

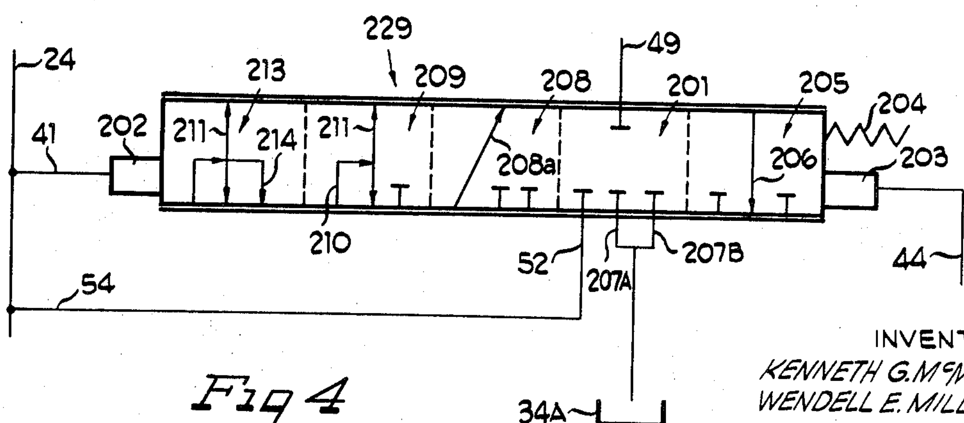

Fig 4

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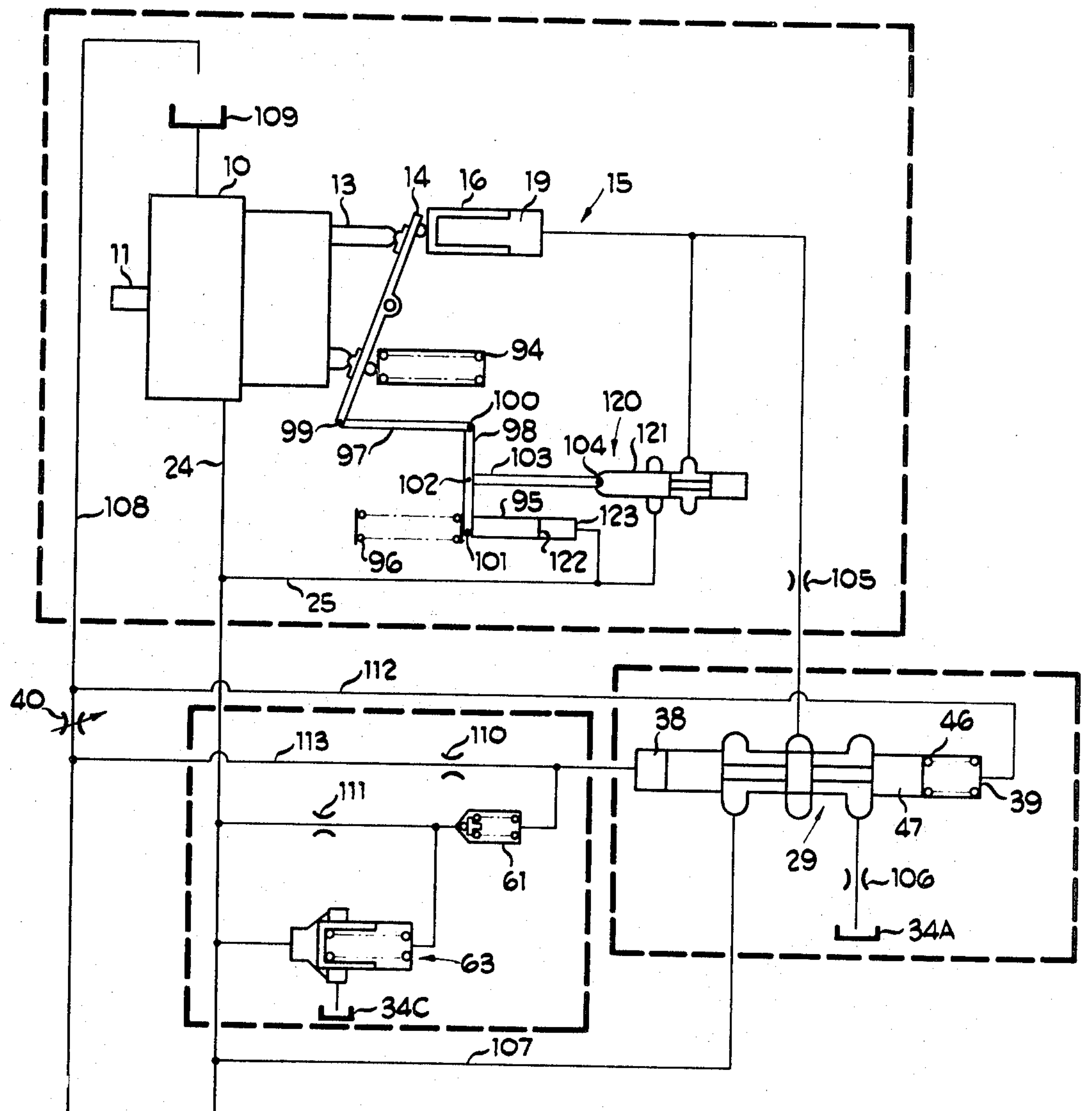

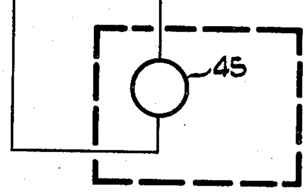

Fig 3

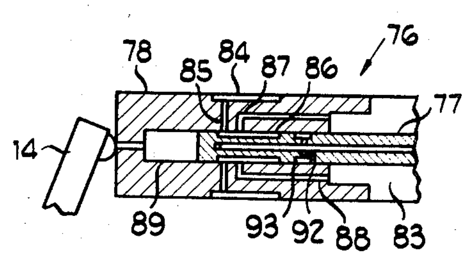

Fig 2A

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HYDRAULIC SYSTEM

SUMMARY OF THE INVENTION

The invention herein disclosed includes in combination, a variable displacement pump, as for example, a swash plate pump constructed so that the inclination of its swash plate can be varied. Varying the inclination of the swash plate varies the stroke of the pump pistons and thus the displacement of the pump.

A sensor valve is provided that operates between two positions to control the displacement of the pump in response to pressure differentials caused by flow through a variable orifice. The sensor valve is thus a control based upon demand in that the flow through the variable orifice is the driving means for a fluid motor.

Override of flow sensing control of the pump's displacement is achieved by the use of a torque compensator. This torque compensator is a pressure-and-displacement-sensitive valve that is effective to reduce the displacement of the pump whenever the pump pressure and displacement exceed predetermined combinations.

The sensor valve is made to be pressure-sensitive, as well as being flow-sensitive through the use of a pilot relief valve. The pump is now controlled by pressure, flow, and torque.

Means is also provided to bypass excess fluid. This means may consist of a separate bypass valve or of a third operating position and cooperating ports and passages in the sensor valve. Either way, excess fluid is bypassed as a function of signals indicating either excess flow, excess pressure, or both.

THE DRAWINGS

FIG. 1 is a schematic of a pump system incorporating the invention showing the sensor valve piston in one position;

FIG. 1A is a partial schematic showing the sensor valve piston in the second position;

FIG. 1B is a graph showing a constant torque curve (displacement plotted against pressure) and further illustrating a cam surface with two slopes allowing pump displacement to be decreased as two different functions of pressure and displacement;

FIG. 2 is a schematic illustrating another embodiment of the system of FIG. 1 in which the torque compensator is replaced with a different valve;

FIG. 2A is an enlarged view of the pressure-and-displacement-sensitive valve of FIG. 2;

FIG. 3 is a schematic illustrating a third embodiment in which a third type of torque compensator is shown; and

FIG. 4 is a symbolic illustration of a modified form of sensor valve.

FIGS. 1 and 1A illustrate in schematic form a first embodiment of the invention which includes a piston pump 10 driven through the shaft 11 from a prime mover (not shown). The shaft 11 rotates a cylinder barrel causing reciprocation of pistons 13 as they engage a swash plate 14. The inclination of the swash plate 14 is variable to vary the displacement of the pump. This is a conventional variable displacement pump and requires no further explanation, it being understood that other variable displacement pumps can be used in the system being described.

The swash plate 14 is a part of a displacement control mechanism, generally identified as 15 which includes, in addition to the swash plate 14, a first or large control piston 16, a second or small control piston 17, and a bias spring 18 biasing the control piston 16 toward the swash plate 14.

The inclination of the swash plate 14 and thus the displacement of the pump 10 is dependent upon the amount of fluid in the first or large control cylinder 19 which acts upon the control piston 16. The pressure fluid in the control cylinder 19 is controlled by a pressure-and-displacement-sensitive valve (PDV) 20. PDV 20 is effective to control the pump displacement relative to predetermined discharge pressures, thereby providing a control of pump input torque.

PDV 20 is sensitive to pressure because the projected end of its valve spool or plunger 21 has a fluid response surface 22 which is subjected to the pump outlet pressure in valve chamber 23 via conduits 24 and 25, conduits 24 being in communication with the outlet of the pump 10. The force of pump outlet pressure on the spool surface 22 is resisted and measured by the action of a spring 26 opposing movement of the spool 21. The spring 26 and the surfaces 22 combine to form a fluid pressure-to-position mechanism, and PDV 20 is made pressure-sensitive.

PDV 20 is also displacement sensitive through the action of a cam 27 on the swash plate 14 and a cam follower 28 associated with the valve 20. A change in inclination of the swash plate 14 rotates the cam 27 and actuates the cam follower 28, the latter providing a displacement sensitive locating position for the spring 26. Thus it is apparent that the PDV 20 is positioned by fluid pressure (pump output) as it acts on the surface 22 and if sufficiently high will shift the spool to compress the spring 26. Likewise, the spool is positioned by the positioning of the spring 26 as a function of pump displacement. The entire valve mechanism, which includes the spool of the valve 20, the spring 26, the cam 27 and the cam follower 28, is a pressure and displacement sensitive valve having as its output variable fluid resistances and communications.

In operation, PDV 20 measures pump pressure and pump displacement. On the basis of the combination, PDV 20 either reduces the displacement of the pump 10 or it turns the control of the displacement over to a differential pressure sensor valve 29 which will later be described. When the combination of pressure in the chamber 23 (from the pump outlet) and the position of the cam follower 28 permits the spool of PDV 20 to be moved to the position shown in FIG. 1A, fluid is discharged from the large control cylinder 19 through a conduit 30, port 31, port 32 and a conduit 33 to a sump 34. The small control piston 17 meanwhile provides a force to reduce the inclination of the swash plate 14 because the small control piston 17 continually is in fluid communication with the pump outlet pressure through conduits 24, 25 and 35.

PDV 20 is thus effective to (1) reduce the pump displacement as described, or (2) to turn control of the pump displacement over to the sensor valve 29. In FIG. 1 the position of PDV 20 is shown when the combination of pressure and displacement is not excessive, and PDV 20 has connected the large control piston 16 to the sensor valve 29 for control of the piston 16 and control of the pump displacement by the sensor valve 29.

The sensor valve 29 is sensitive to a differential pressure signal due to its fluid-responsive areas 36 and 37 at the opposite ends of its spool and the fluid pressure chambers 38 and 39 which are connected to opposite ends of a variable orifice or flow responsive means 40 on the pump outlet conduit 24 through control conduits 41, 42, 43 and 44. The variable orifice 40 is responsive to flow and effective to produce a signal comprising a pressure drop proportional to flow. The variable orifice 40 may be incorporated in the return line of a system having return flow, or it may be a part of a valve as that described in the copending application Ser. No. 725,766 filed May 1, 1968 of common assignee.

Flow through conduit 24 to a fluid motor 45 causes a differential pressure across the variable orifice 40, which differential pressure is applied to the fluid-responsive areas 36 and 37 of the sensor valve 29. A flow across the variable orifice 40 which is above the desired flow as determined by the restriction of the variable orifice 40 results in a lowering of fluid pressure in the conduits 42, 43 and 44 as opposed to that in the conduits 24 and 41. Thus a valve spring biasing the spool of the sensor valve to the left, as viewed in the drawings, will be compressed such that the spool will move to the right, again as viewed in the drawings, to a second operating position, establishing fluid communication between the control cylinder 19 and the sump 34A through the conduit 30, the port 31, a port 48, a conduit 49, a port 50, a port 51 and a conduit 52.

A flow that is less than the desired flow as determined by the variable orifice **40** will allow the spring **46** to shift the spool of the valve **29** to the left to a first operating position, thereby establishing a fluid pressure connection to the control cylinder **19** via conduit **30**, port **31**, port **48**, conduit **49**, port **50**, port **53** and a conduit **54** which is connected to the outlet pressure conduit **24**.

The sensor valve **29** as is illustrated in FIG. **1** has equal fluid-responsive areas **36** and **37** and a spring **46** biases the spool to the left (as viewed in the drawings) when the fluid pressures applied to the areas **36** and **37** are such as to create the following relationship: fluid pressure times area **36** minus fluid pressure times area **37** is less than the force of spring **46**.

As an alternative, one fluid-pressure-responsive area may be larger than the other to provide the bias force. The spring may or may not be retained to obtain the desired control of pump displacement vs. the differential pressure signal.

The system which has been described may be enhanced by replacing the cam **27** with a cam having a profile with two rates of rise vs. an angular rotation. The first rate of rise on the cam permits the displacement of the pump to be decreased at a predetermined constant rate with respect to pressure increases until reaching a point of angular rotation of the cam at which the cam follower **28** engages a portion having a second rate of rise. The second rate of rise permits displacement of the pump to be decreased at a predetermined constant rate significantly different from the first slope. As illustrated in FIG. **1B**, the pump **10** operates at its maximum displacement noted by the curve **55**, to a given pressure, noted by curve **56**. From the intersection of these curves, the displacement is reduced according to curve **57** which approximates the torque limitation of the source of mechanical power, as shown by the constant torque curve **58**. Further reduction in displacement is effected along curve **59** by the use of a second rate of rise on the cam **27**, thus providing pressure compensation with relatively sharp cutoff, that is, displacement is reduced from the point **60**, the intersection of curves **57** and **59** to substantially zero without a pressure rise as great as if displacement reduction followed curve **57**.

An arrangement is provided for obtaining sharp cutoff pressure compensation through the function of a pilot relief valve **61** and an orifice or restrictor **62**. The relief valve **61** opens at a predetermined pressure, permitting fluid to flow into sump **34B** thereby causing a pressure drop across the restrictor **62** which results in the spool of the sensor valve being moved to the right, as viewed in the drawings, because of the reduction in fluid pressure in the conduit **43**, the conduit **44** and the chamber **39**. The movement of the sensor valve makes fluid connections to reduce the displacement of the pump, as previously described.

An optional bypass valve **63** may be provided which includes a poppet **64** movable in a bore **65** and constructed to provide first and second substantially equal fluid-pressure-responsive areas **66** and **67**, respectively. A spring **68** holds the poppet **64** to the left, as viewed in the drawings, blocking communication between the pump outlet pressure in a chamber **69** and a port **70** in communication with a sump **34C**. The bypass valve **63** is set as determined by the force of spring **68** to open at differential pressures slightly greater than those required to actuate sensor valve **29** to a displacement decreasing position. Thus bypass valve **63** cooperates with the displacement control mechanism in controlling the effective output of the pump **10** by the bypassing of transient excesses of flow, if such occur, and system stability is enhanced.

The bypass valve **63** can also function as a pilot operated relief valve. The pressure drop across the orifice or restrictor **62** by flow across the relief valve **61** will also reduce the pressure applied to the fluid responsive area **67** of the bypass valve **63**, permitting the poppet **64** to move and connect chamber **69** with the sump **34C**. Thus the relief valve **61** is effective to control both the sensor valve **29** and the bypass valve **63**.

The location of a restrictor, such as **62**, can be changed and the system will operate differently. If an alternate restrictor **72** is used in the location illustrated in FIG. **1**, the relief valve will be effective only to limit the system pressure through interaction with the bypass valve **63**.

A second embodiment of the invention is illustrated schematically in FIGS. **2** and **2A**. The major difference between this embodiment and that illustrated in FIG. **1** is that a pressure-and-displacement-sensitive valve (PDV **76**) **76**) replaces PDV **20** and control piston **16** previously described. Also, a bias spring **94** assists the small control piston **17** in increasing the pump displacement.

The PDV **76** (see both FIGS. **2** and **2A**) includes a valve spool **77**, cooperating portions of a coaxial control piston **78**, a spring **79**, and a control bore partition **80**. The valve spool **77** provides a fluid-pressure-responsive surface equal to the area of the valve spool **77** as it moves through the partition **80**. Pump pressure from conduits **24** and **54** and a conduit **81** is applied to a spring cavity **82** and the pressure-responsive surface of the valve spool **77**. The force of the pressure is converted into a position signal through the resistance of the spring **79**.

PDV **76** has been shown to be pressure sensitive by the action of the spring **79** biasing the spool **77** and the pressure-responsive surface of the spool **77**. PDV **76** is also displacement-sensitive (in that the axial position of control piston **78** is dependent upon the position of the swash plate **14**). The control piston **78** being in contact with the swash plate is movable for the purpose of varying the displacement of the pump.

In operation, as explained with reference to the first embodiment, the sensor valve **29** increases and decreases the displacement of the pump **10** in accordance with the differential pressure as established by the variable orifice **40**. In this embodiment, the flow path from the conduit **49** is to a control piston chamber **83**. The sensor valve is able to control the position of the piston **78** through a passage formed by the conduit **49**, a piston relief groove **84**, a cross-drilled servo port **85**, a valve spool relief **86**, a servo port **87** and a longitudinal passage **88** to the chamber **83**.

The passage from the sensor valve **29** to the chamber **83** can be blocked by the valve **76** as a function of the relative position of the valve spool **77** and the cooperating portion of the control piston **78**. The passage from sensor valve **29** to chamber **83** is blocked when an increase in pump pressure overcomes the resistance of spring **79** to move into bore **89** and block communication between ports **85** and **87**.

Additional movement of the valve spool **77** into the bore **89**, as caused by an increase in pump pressure, results in a flow path being established from the spring cavity **82** to the chamber **83** via the cross holes **90**, a longitudinal hole **91** and an annular groove cross hole **92** to the port **87** and to the longitudinal passage **88**. This communication provides pump pressure from the conduit **81** and the spring cavity **82** into the chamber **83**, thus providing pressurized fluid to reduce the pump displacement by moving the piston **78** toward the swash plate **14**. This action continues until the combination of pressure and pump displacement is within acceptable limits.

FIG. **3** shows a modified form of pump control still within the scope of this invention. Like elements of FIG. **3** have the same reference numerals as used in FIGS. **1** and **2**. One of the principal differences of FIG. **3** as compared to FIGS. **1** and **2** is in the construction of the pressure and displacement sensitive valve (PDV) **120** and its feedback mechanism. Fluid responsive surface **122** is the projected end of plunger **95** rather than being a part of valve spool **21** of FIG. **1**. Surface **122** of plunger **95** cooperates with a spring **96** to form a fluid pressure to position transducer that is responsive to the fluid pressure in chamber **123**. The resultant positional output as reflected by the position of plunger **95** is combined with the feedback signal indicating the pump displacement through the action of links **97** and **98** and pivots **99**, **100**, **101** and **102** for activation of valve spool **121** through a link **103** and a pivot **104**.

A second difference of the FIG. **3** construction is in the connection of the PDV **120** to sensor valve **29**. PDV **120** of FIG. **3** is a two-way torque or pressure-and-displacement-sensitive valve connected in a parallel relationship with sensor valve 29. PDV 120 can be effective to reduce the displacement of pump 10 even though sensor valve 29 is actuated to the left by bias spring 46. The ability of sensor valve 29 to increase the displacement of pump 10 is limited by valve 29 having a limited conductance or by a fluid restrictor. The use of either a fluid restrictor 105 or a fluid restrictor 106 will be sufficiently restrictive to the fluid being discharged from piston 16, through sensor valve 29 such that PDV 120 is effective to reduce the displacement of pump 10 by directing pressure fluid into control cylinder 19. This type of valving connection will also function with the swash plate inclination of FIG. 1. In this case PDV 120 would control flow from cylinder 19 to sump and the restrictor limiting the conductance of sensor valve 29 would be located either as shown by restrictor 105 or by a restrictor in conduit 107.

A third difference in the FIG. 3 construction is seen in the location of flow responsive means 40. Flow responsive means 40 is shown located in return line 108 between fluid motor 45 and sump 109. This construction requires that pilot relief valve 61 be located to supply fluid to chamber 38 of sensor valve 29 rather than relieving pressure from chamber 39 as shown in the constructions of FIGS. 1 and 2. Fluid restrictor 110 cooperates with pilot relief valve 61 to limit the flow from chamber 38 to sump 109 through return line !08 so that the flow from pilot relief valve 61 is sufficient to build pressure in chamber 38 that will overcome the force exerted by spring 46. Resistor 111 cooperates with pilot relief valve 61 to cause a pressure drop for actuating bypass valve 63.

It should be noticed that chamber 39 of sensor valve 29 is connected to sump 109 through conduits 112 and 108. It is apparent that the operation of FIG. 3 construction would be the same if chamber 39 were vented to the atmosphere. Sensor valve 29 would still be operated by a differential pressure, that is, the difference between the pressure signal transmitted by the flow responsive means or variable orifice and atmospheric pressure. It should also be noticed that orifice 40 produces only a single pressure signal in the FIG. 3 configuration if we consider the pressure signal in the conduit 108 to be zero between orifice 40 and sump 109. Thus it is apparent that orifice 40 provides a pressure signal proportional to flow. Even when differential pressures are used from flow-responsive means 40 to actuate sensor valve 29 it is apparent that the pressure signal is the difference in pressures in control conduits 112 and 113, and that this pressure signal acts upon sensor valve 29 to move it from a first operating position to a second operating position.

In FIG. 4 a bypass-type sensor valve 229 is shown which comprises a modification of sensor valve 29 of FIG. 2 to add a third operating position to bypass excess fluid.

Referring to FIG. 4, bypass-type sensor valve 229 is shown in a neutral position, as represented by box 201, in which fluid communication is blocked between conduit 49 and the conduits 52, 207A, and 207B thereby blocking fluid in the control piston chamber 83 which is connected to conduit 49 (FIGS. 2 and 2A).

Sensor valve 229 is actuated to its operating positions by operator 202, operator 203, and bias spring 204. Operators 202 and 203 correspond respectively to areas 36 and 37 and to chambers 38 and 39 of FIG. 2.

Sensor valve 229 is moved to its first operating position by bias spring 204 when the fluid pressure in operators 202 and 203 approach a predetermined differential. This first operating position is shown by box 205. Pressure fluid trapped in piston chamber 83 (FIGS. 2 and 2A) then is released via conduit 49, valve communication path 206 and exhaust port 207 to sump 34A. The releasing of fluid from chamber 83 allows an increase in pump displacement (FIG. 2) which results in an increase in flow and an increase in pressure drop across orifice 40 thereby moving sensor valve 229 back to its neutral position.

In like manner, sensor valve 229 is actuated to second or pump displacement decreasing position 208 when fluid pressure in operator 202 is sufficient to overcome the combined force produced by operator 203 and spring 204. In position 208 passage 208A connects the pressure conduit 52 and conduit 49 to decrease pump displacement.

A third operating position, not previously described is shown by box 209. An excess of pressure differential between conduits 41 and 44 beyond that necessary to force sensor valve 229 to its second operating position, will be effective to move sensor valve 229 to third operating position 209.

In the third operating position, pressure from conduit 52 is applied to valve passage 210 and is then applied to chamber 83 of FIG. 2 via passage 211 and conduit 49 to decrease the displacement of the pump and to passage 212 and exhaust port 207A to bypass excess fluid.

A fourth operating position represented by box 213 may be utilized to obtain a more nearly idealized combination of large flow area. The value of the fourth operating position is that an additional bypass flow path is achieved since bypass flow also takes place through passage 214 and exhaust port 207B as well as through passage 211 and exhaust port 207A as in position 209.

It is apparent that the bypass type sensor valve 229 provides the same function as does bypass valve 63 of FIG. 2 and that it is responsive to the same signals, that is, excess pressure and excess flow. Therefore bypass valve 63 of FIG. 2 can be eliminated from the circuit of FIG. 2 if bypass sensor valve 229 is used.

Various features of the invention have been particularly shown and described. However, it should be obvious to one skilled in the art that modifications may be made therein without departing from the scope of the invention.

We claim:

1. In a hydraulic system including a variable displacement pump and a fluid actuated displacement control mechanism connected thereto, the improvement which comprises: flow-responsive means connected in said system to measure the flow in a part of said system and to produce a signal proportional to said flow, a fluid-actuated sensor valve connected to said flow-responsive means and to said displacement control mechanism adapted to control the displacement of said pump in response to said signal by controlling the volume of fluid in said displacement control mechanism, bypass means connected to said flow-responsive means and responsive to said signal to bypass excess fluid, and a pressure-and-displacement-sensitive valve operatively associated with said sensor valve and connected to said displacement control mechanism and adapted to control the displacement of said pump whenever the pressure and displacement of said pump varies beyond predetermined lines.

2. A hydraulic system as claimed in claim 1 which includes a pressure-sensitive valve means producing a second signal, and said bypass means being responsive to said second signal to bypass excess fluid.

3. A hydraulic system as claimed in claim 1 in which said sensor valve is fluid actuated to first and second operating positions to control the displacement of said pump, and said bypass means comprises a third operating position of said sensor valve, whereby said sensor valve is responsive to said signal to move to said third operating position to bypass excess fluid.

4. A hydraulic system as claimed in claim 1 wherein said sensor valve has a fluid-responsive area and bias means for actuation to first and second operating positions and wherein said pressure-and-displacement-sensitive valve is effective to control the displacement of said pump irrespective of the operating position of said sensor valve.

5. A hydraulic system as claimed in claim 4 including a source of pressure and a fluid sump, said sensor valve being operative to establish fluid communication between said displacement control mechanism and said source and block fluid communication between said displacement control mechanism and said sump as it moves to one of said operating positions.

6. A hydraulic system as claimed in claim **5** in which said sensor valve and said pressure-and-displacement-sensitive valve are connected in series to said displacement control mechanism.

7. A hydraulic system as claimed in claim **5** in which said sensor valve and said pressure-and-displacement valve are connected in parallel with said displacement control mechanism.

8. A hydraulic system as claimed in claim **6** wherein said pressure-and-displacement-sensitive valve comprises means responsive to fluid pressure and a mechanical connection to said displacement control mechanism said mechanical connection being operative to vary the response of said valve to said fluid pressure.

9. A hydraulic system as claimed in claim **8** wherein said means responsive to fluid pressure comprises a spring-loaded valve plunger with one end thereof subjected to pressure from said pump and said mechanical connection to said displacement control mechanism comprises said spring that loads said valve plunger.

10. A hydraulic system as claimed in claim **9** further including a cam operatively associated with said displacement control mechanism, said cam being a portion of said mechanical connection.

11. A hydraulic system as claimed in claim **10** wherein said cam has a profile such that said pressure-and-displacement-sensitive valve has a greater sensitivity to an incremental change of displacement at one displacement than at another displacement.

12. In a hydraulic system including a variable displacement pump and a fluid-actuated displacement control mechanism connected thereto, said displacement control mechanism including a control piston for actuation thereof, flow-responsive means connected in said system to measure the flow in a part of said system and to produce a signal proportional to said flow, a sensor valve connected to said flow-responsive means and to said displacement control mechanism having a fluid-responsive area and bias means for actuation to first and second operating positions to control the displacement of said pump in response to said signal, and a pressure-and-displacement-sensitive valve operatively associated with said sensor valve, said pressure-and-displacement-sensitive valve being coaxial to and including cooperating portions of said control piston, said sensor valve controlling the displacement of said pump and said pressure-and-displacement-sensitive valve being effective to control the displacement of said pump whenever the pressure and displacement vary beyond predetermined limits.

13. A hydraulic system as claimed in claim **12** including a source of pressure and a fluid sump, said sensor valve being operative to establish fluid communication between said displacement control mechanism and said source and block fluid communication between said displacement control mechanism and said sump as it moves to one of said operating positions.

14. A hydraulic system comprising a variable displacement pump for operating a fluid motor, a fluid-actuated displacement control mechanism connected to said pump, a differential pressure sensor valve connected to said displacement control mechanism and adapted to actuate same having first and second fluid responsive areas for fluid pressure actuation from a first operating position to a second operating position, bias means urging said sensor valve toward said first operating position when both said areas are subjected to equal pressures, a differential pressure means located in one of said conduits and adapted to produce a differential pressure signal proportional to the fluid flow in said one conduit, first and second control conduits operatively connecting said first and second areas to said one conduit on opposite sides of said differential pressure means to actuate said sensor valve to said first and to said second operating positions by said differential pressure signal and by said bias means and thereby control the displacement of said pump, and a pressure-and-displacement-sensitive valve connected to said displacement control mechanism and operative to reduce the displacement of said pump whenever the pressure and displacement of said pump exceed predetermined limits.

15. A hydraulic system as claimed in claim **14** which includes a bypass means connected to said differential pressure means and responsive to said signal whereby fluid is bypassed when flow in said one conduit is excessive.

16. A hydraulic system as claimed in claim **15** which includes a pressure-responsive pilot valve connected to said bypass means and adapted to actuate same, whereby said pilot valve and said bypass valve means cooperate with said variable displacement control mechanism in the controlling of the effective output of said variable displacement pump by bypassing excessive pump flow.

17. A hydraulic system as claimed in claim **15** in which said bypass means comprises a third operating position of said sensor valve and said sensor valve being responsive to said differential pressure signal to move to said third operating position to bypass excess fluid.

18 A hydraulic system as claimed in claim **17** including a pressure sensitive valve connected to said sensor valve and producing a second signal, whereby said sensor valve is responsive to said second signal to bypass excess fluid.

19. A hydraulic system comprising a variable displacement pump, for driving a fluid motor and including a fluid supply conduit conducting pressure fluid from said pump to said motor, a fluid-actuated displacement control mechanism connected to said pump, a differential pressure sensor valve connected to said displacement control mechanism and adapted to actuate same having first and second fluid-responsive areas for fluid pressure actuation from a first operating position to a second operating position, bias means urging said sensor valve toward said first operating position when both said areas are subjected to equal pressures, flow responsive means located in said supply conduit and adapted to produce a differential pressure signal proportional to the fluid flow in said supply conduit, first and second control conduits operatively connecting said first and second areas to said supply conduit on opposite sides of said flow-responsive means to actuate said sensor valve to said first and to said second operating positions by said differential pressure signal and by said bias means and thereby control the displacement of said pump, and a pressure and displacement sensitive valve connected to said displacement control mechanism and operative to reduce the displacement of said pump whenever the pressure and displacement of said pump exceed predetermined limits.

20. A hydraulic system as claimed in claim **19** which includes a bypass means connected to said flow-responsive means and responsive to said signal whereby fluid is bypassed when flow in said supply conduit is excessive.

21. In a hydraulic system including a variable displacement pump and a fluid actuated displacement control mechanism connected thereto, the improvement which comprises: flow responsive means connected in said system to measure the flow in a part of said system and to produce a first signal proportional to said flow, a fluid-actuated sensor valve connected to said flow-responsive means and to said displacement control mechanism adapted to control the displacement of said pump in response to said signal by controlling the volume of fluid in said displacement control mechanism, fluid-responsive bypass means connected to said flow-responsive means and adapted to bypass excess fluid in response to said signal, means in said hydraulic system adapted to produce a second signal and said means being operatively connected to said sensor valve and said bypass means whereby said displacement control mechanism, by means of said sensor valve, and said bypass means cooperate to control the effective output of said pump in response to both said signals.

22. A hydraulic system as claimed in claim **21** wherein said second signal is produced by a pressure-sensitive valve means and said bypass means being responsive to said second signal to bypass excess fluid.

23. A hydraulic system as claimed in claim 21 wherein said sensor valve responds to said first signal at a signal level less than that required to actuate said bypass means.

24. A hydraulic system as claimed in claim 21 in which said sensor valve is fluid actuated to first and second operating positions to control the displacement of said pump and said bypass means comprises a third operating position of said sensor valve, whereby said sensor valve is responsive to said first or second signal to move to said third operating position to bypass excess fluid.

25. A hydraulic system as claimed in claim 24 wherein said sensor valve is responsive to said first signal to move to said third position at higher signal level than that required to move the sensor valve between its first and second positions.

26. A hydraulic system as claimed in claim 24 wherein said means producing a second signal comprising a pressure-sensitive relief valve.

27. In a hydraulic system including a variable displacement pump and a fluid-actuated displacement control mechanism connected thereto, the improvement which comprises: flow-responsive means connected in said system to measure the flow in a part of said system and to produce a signal proportional to said flow, a sensor valve connected to said flow-responsive means and to said displacement control mechanism having a fluid responsive area and bias means for actuation to first and second operating positions to control the displacement of said pump in response to said signal, bypass means operatively associated with said flow-responsive means adapted to bypass excess fluid in response to said signal, means adapted to produce a second signal being operatively connected to said sensor valve and said bypass means whereby said displacement control mechanism, by means of said sensor valve, and said bypass means cooperate to control the effective output of said pump in response to both said signals.

28. A hydraulic system as claimed in claim 27 wherein said second signal is produced by a pressure-sensitive valve means and said bypass means being responsive to said second signal to bypass excess fluid.

29. A hydraulic system as claimed in claim 27 wherein said sensor valve responds to said first signal at a signal level less than that required to actuate said bypass means.

30. A hydraulic system as claimed in claim 27 in which said sensor valve is fluid actuated to first and second operating positions to control the displacement of said pump and said bypass means comprises a third operating position of said sensor valve, whereby said sensor valve is responsive to said first or second signal to move to said third operating position to bypass excess fluid.

31. A hydraulic system as claimed in claim 30 wherein said sensor valve is responsive to said first signal to move to said third position at higher signal level than that required to move the sensor valve between its first and second positions.

32. A hydraulic system as claimed in claim 30 wherein said means producing a second signal comprises a pressure-sensitive relief valve.

33. A hydraulic system comprising a variable displacement pump for driving a fluid motor, a fluid-actuated displacement control mechanism connected to said pump, a differential pressure sensor valve connected to said displacement control mechanism and adapted to actuate same having first and second fluid responsive areas for fluid pressure actuation from a first operating position to a second operating position, bias means urging said sensor valve toward said first operating position when both said areas are subjected to equal pressures, a differential pressure means located in one of said conduits and adapted to produce a differential pressure signal proportional to the fluid flow in said one conduit, fluid-responsive bypass means connected to said differential pressure means and responsive to said signal to bypass excess fluid, first and second control conduits operatively connecting said first and second areas to said one conduit on opposite sides of said differential pressure means to actuate said sensor valve to said first and to said second operating positions by said differential pressure signal and by said bias means, means in said hydraulic system adapted to produce a second signal and said means being connected to said sensor valve and said bypass means whereby said displacement control mechanism, by means of said sensor valve, and said bypass means cooperate to control the effective output of said pump in response to both said signals.

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