Feb. 26, 1963 A. F. ANDERSON 3,078,674

HYDRAULIC CONTROL SYSTEM FOR VARIABLE DISPLACEMENT PUMP

Filed Feb. 18, 1960 9 Sheets-Sheet 1

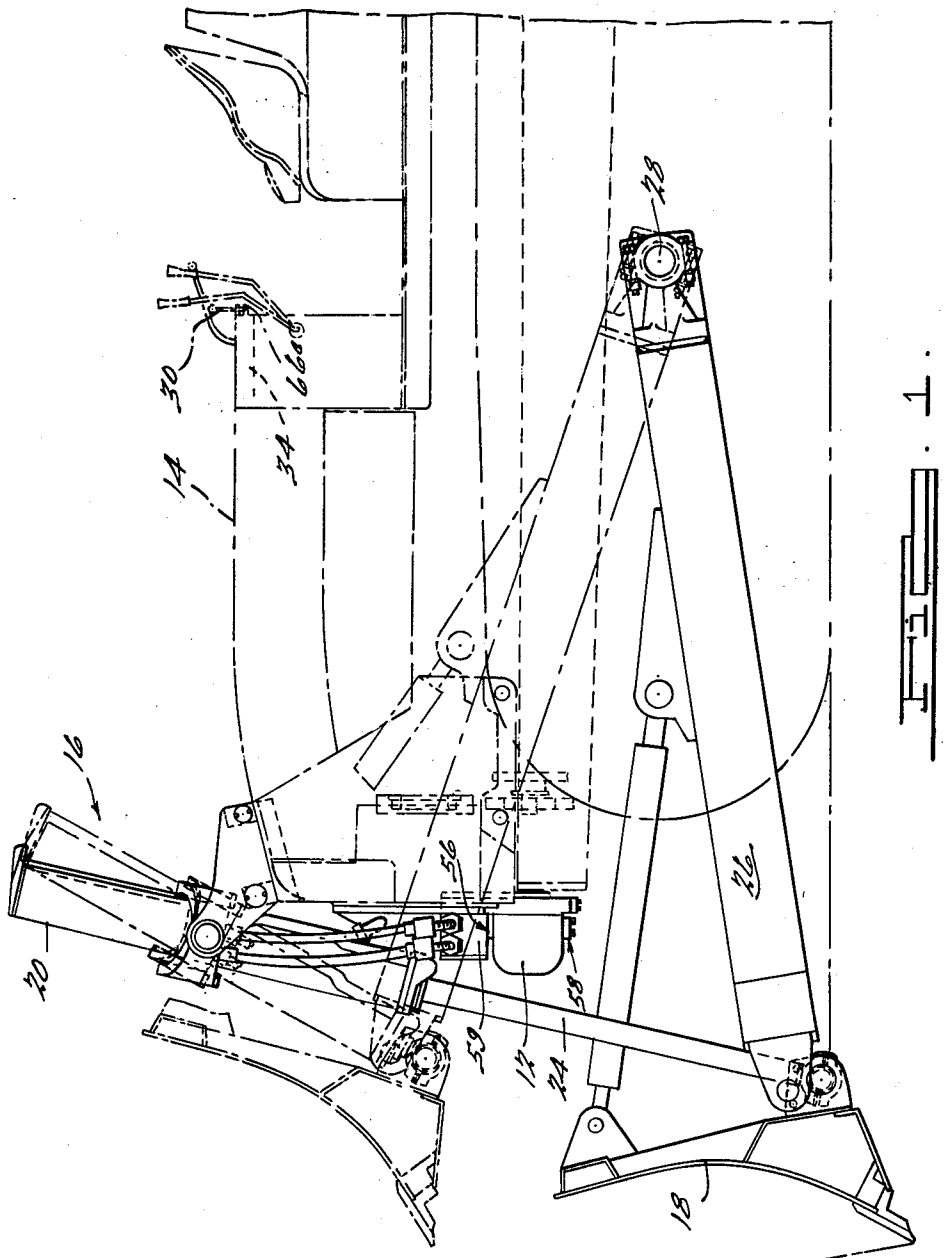



Fig. 1.

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Filed Feb. 18, 1960 9 Sheets-Sheet 2

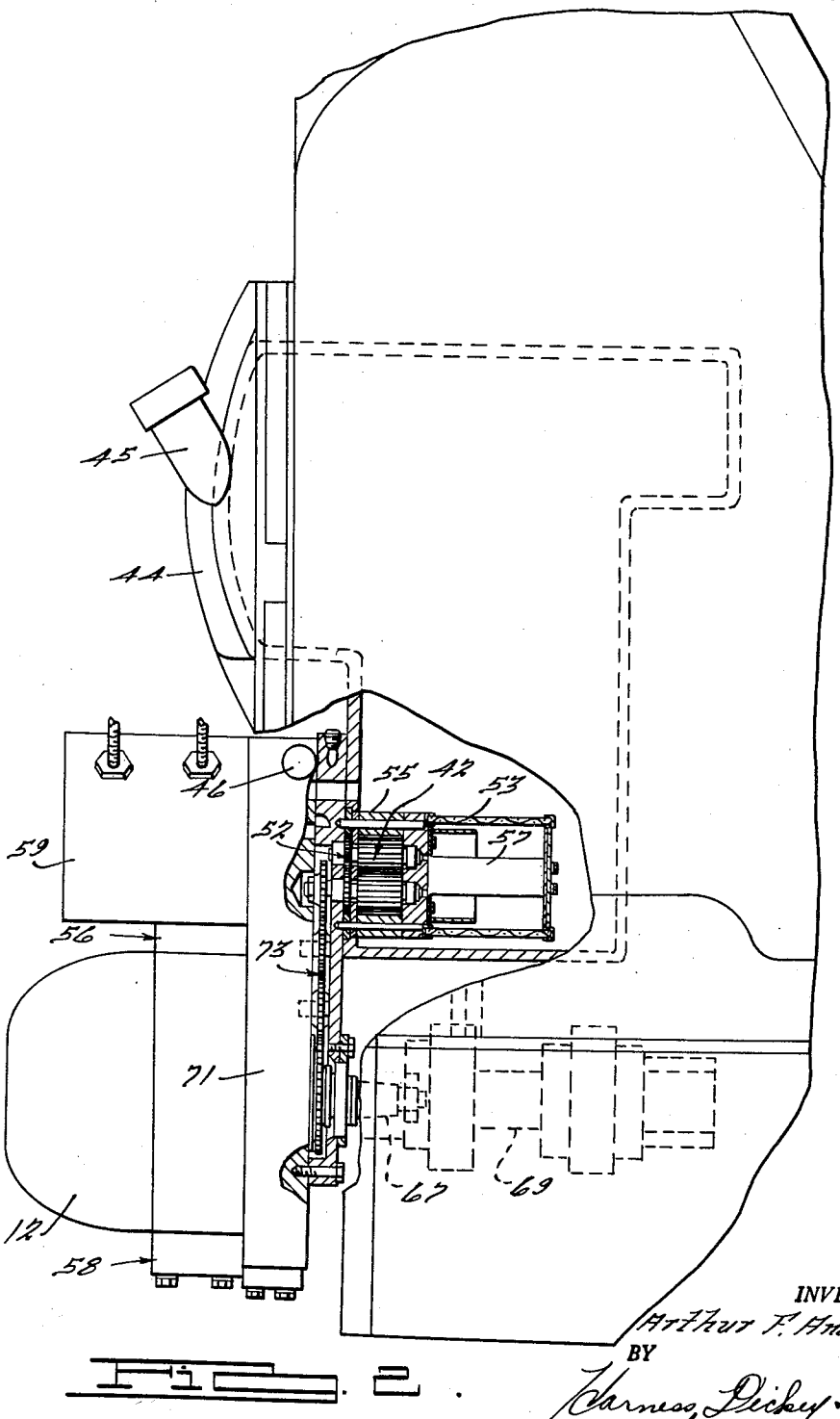



Fig. 2.

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HYDRAULIC CONTROL SYSTEM FOR VARIABLE DISPLACEMENT PUMP

Filed Feb. 18, 1960 9 Sheets-Sheet 3

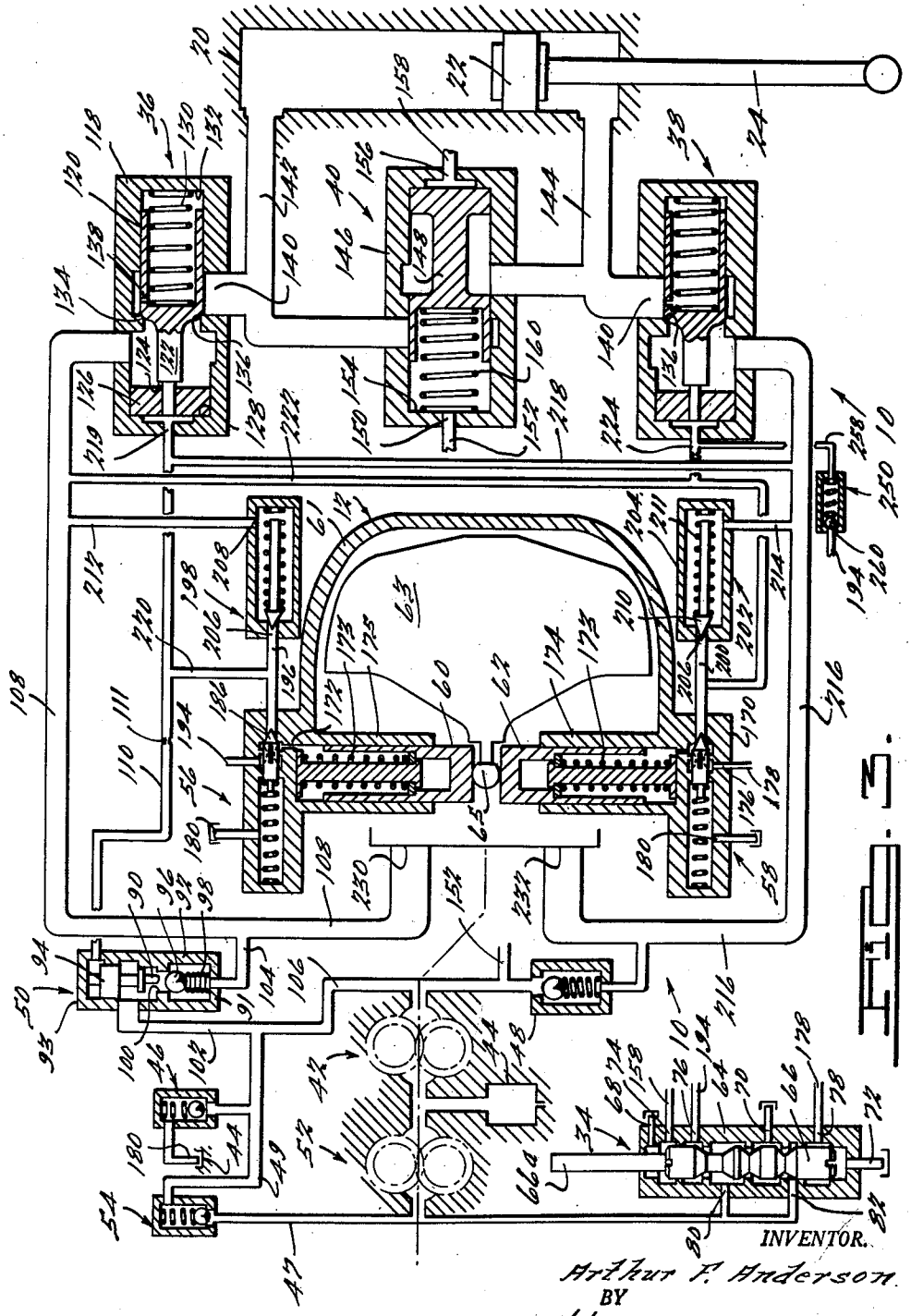


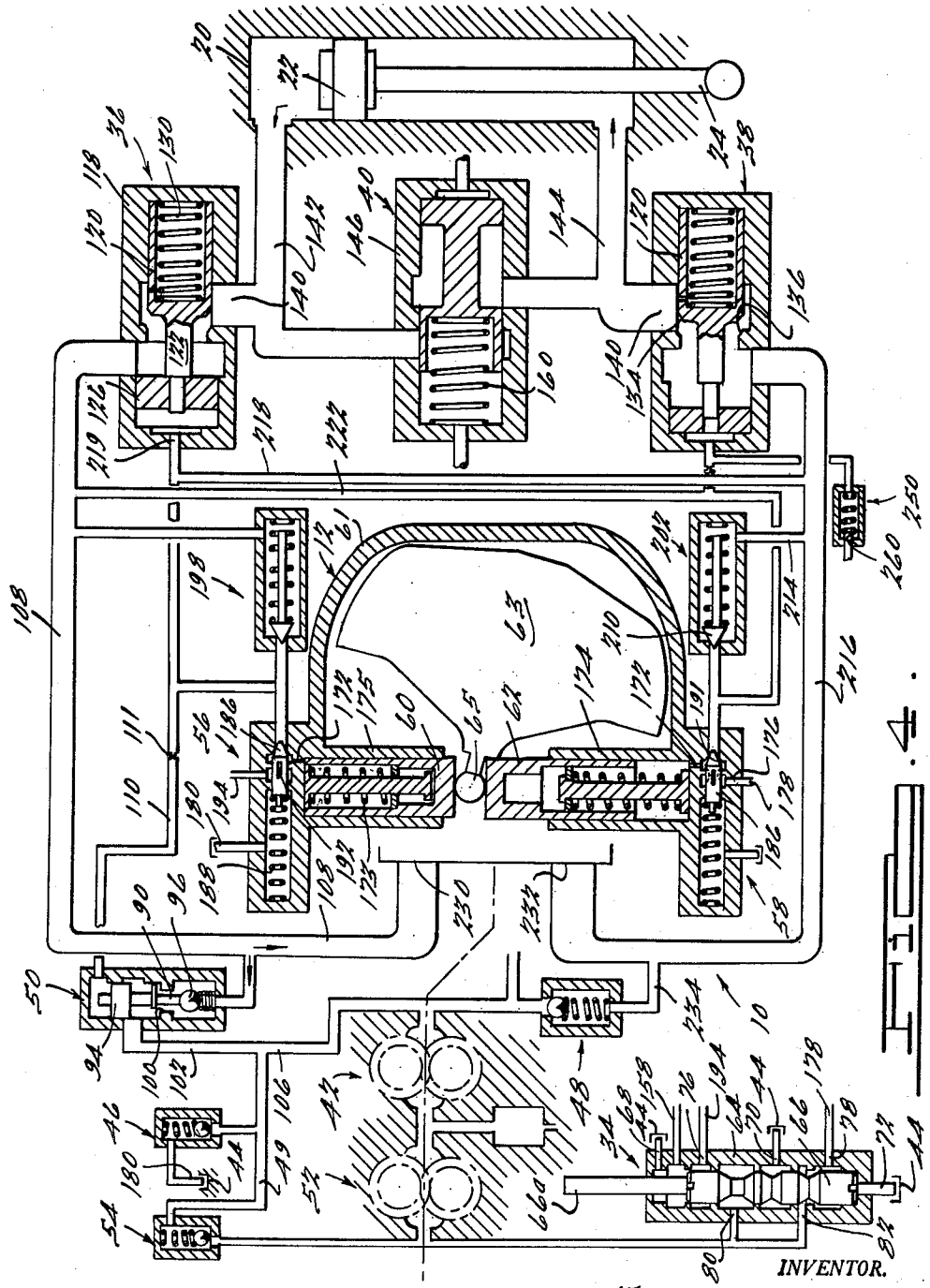
FIG. 3.

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HYDRAULIC CONTROL SYSTEM FOR VARIABLE DISPLACEMENT PUMP

Filed Feb. 18, 1960 9 Sheets-Sheet 4



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Feb. 26, 1963 A. F. ANDERSON 3,078,674

HYDRAULIC CONTROL SYSTEM FOR VARIABLE DISPLACEMENT PUMP

Filed Feb. 18, 1960 9 Sheets-Sheet 5

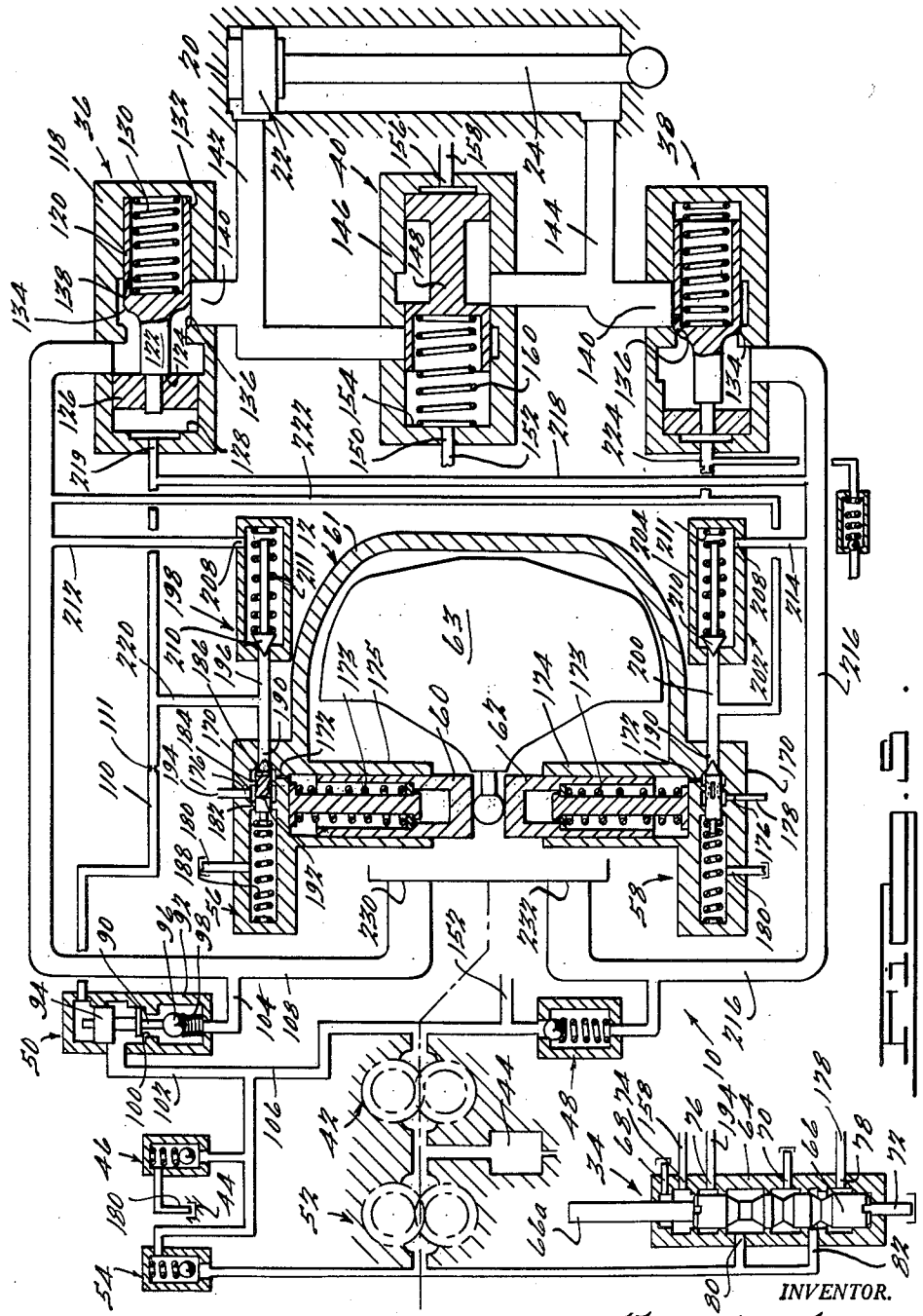


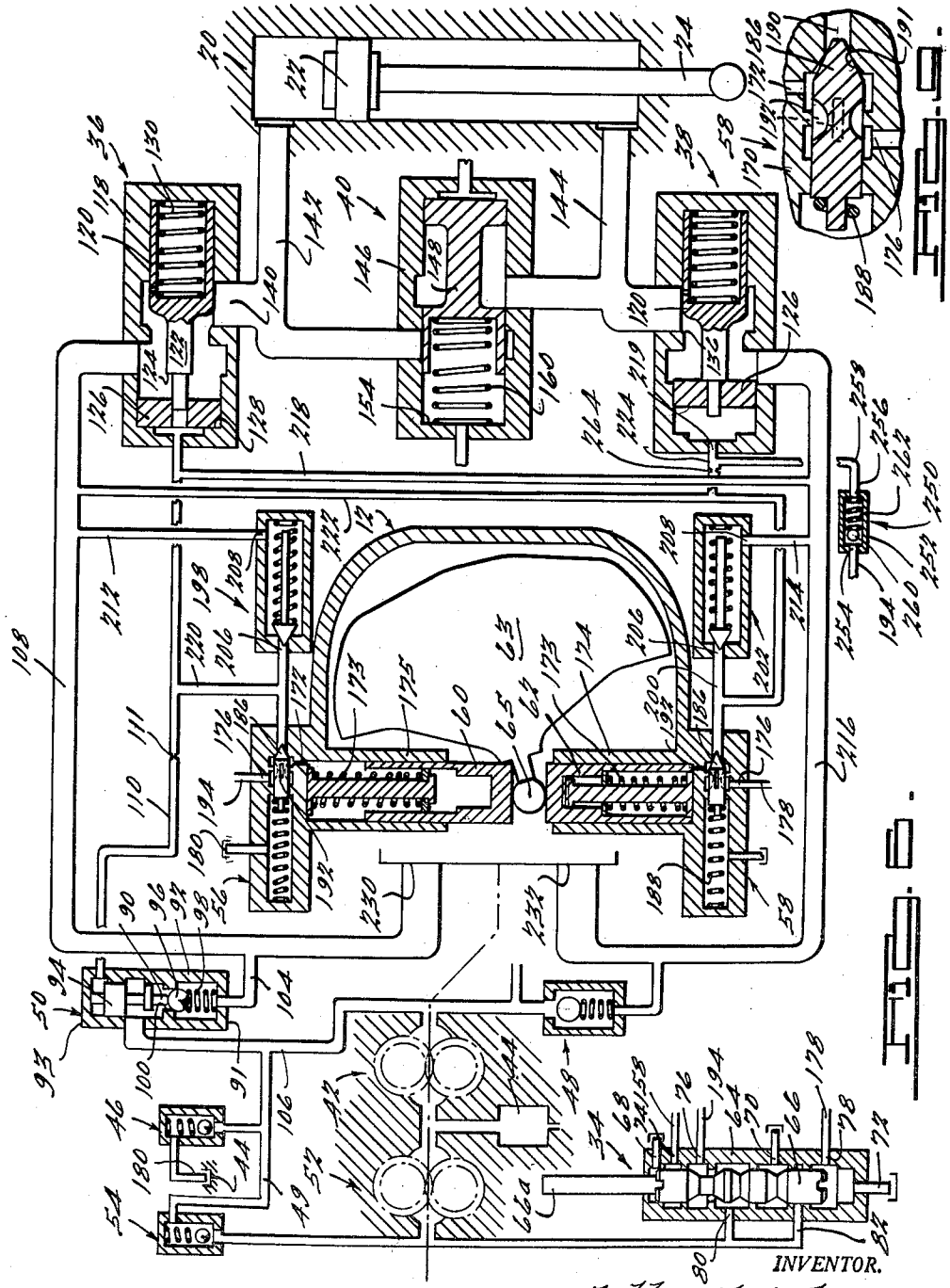
Fig. 5.

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HYDRAULIC CONTROL SYSTEM FOR VARIABLE DISPLACEMENT PUMP

Filed Feb. 18, 1960 9 Sheets-Sheet 6



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Feb. 26, 1963 A. F. ANDERSON 3,078,674

HYDRAULIC CONTROL SYSTEM FOR VARIABLE DISPLACEMENT PUMP

Filed Feb. 18, 1960 9 Sheets-Sheet 7

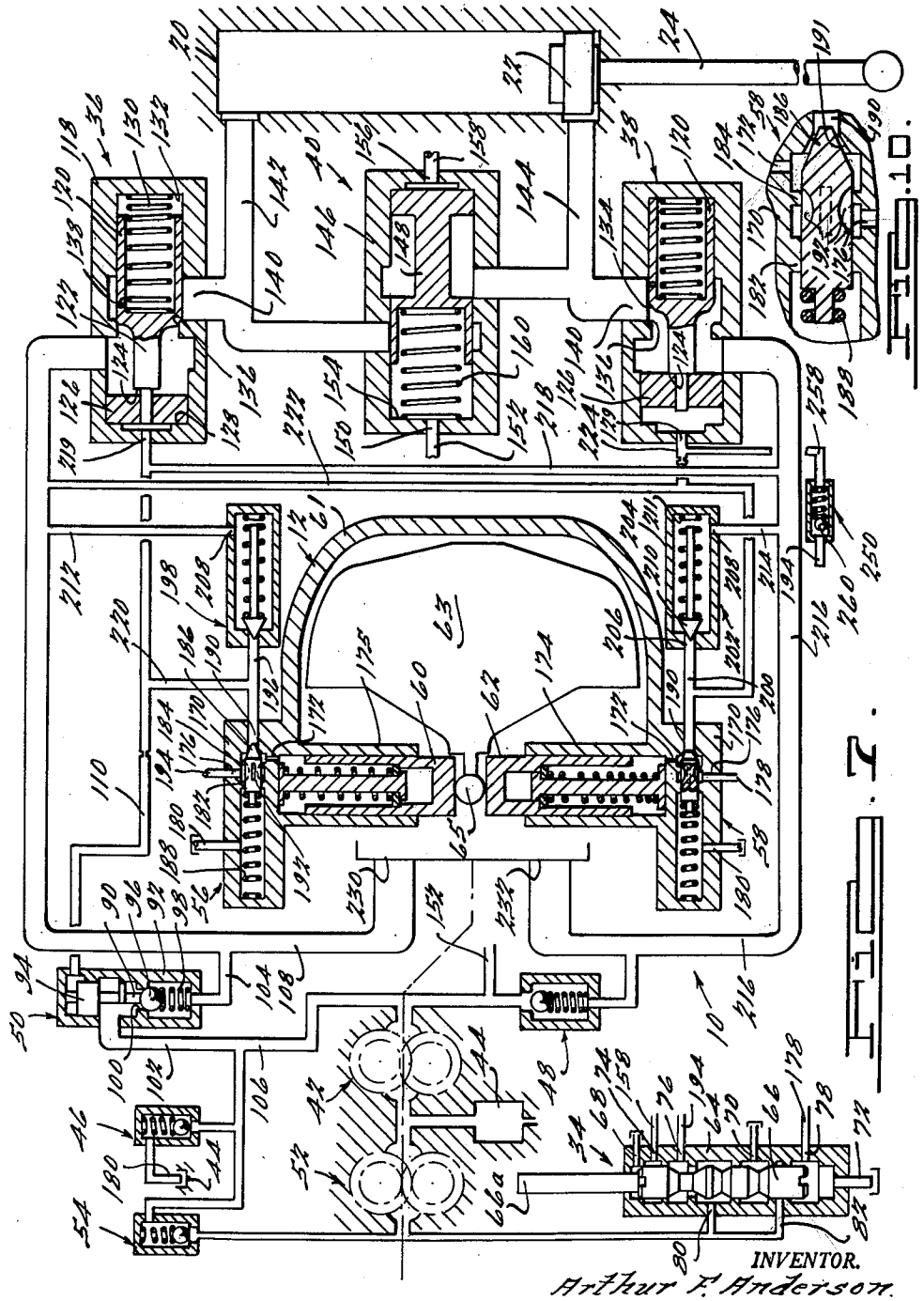


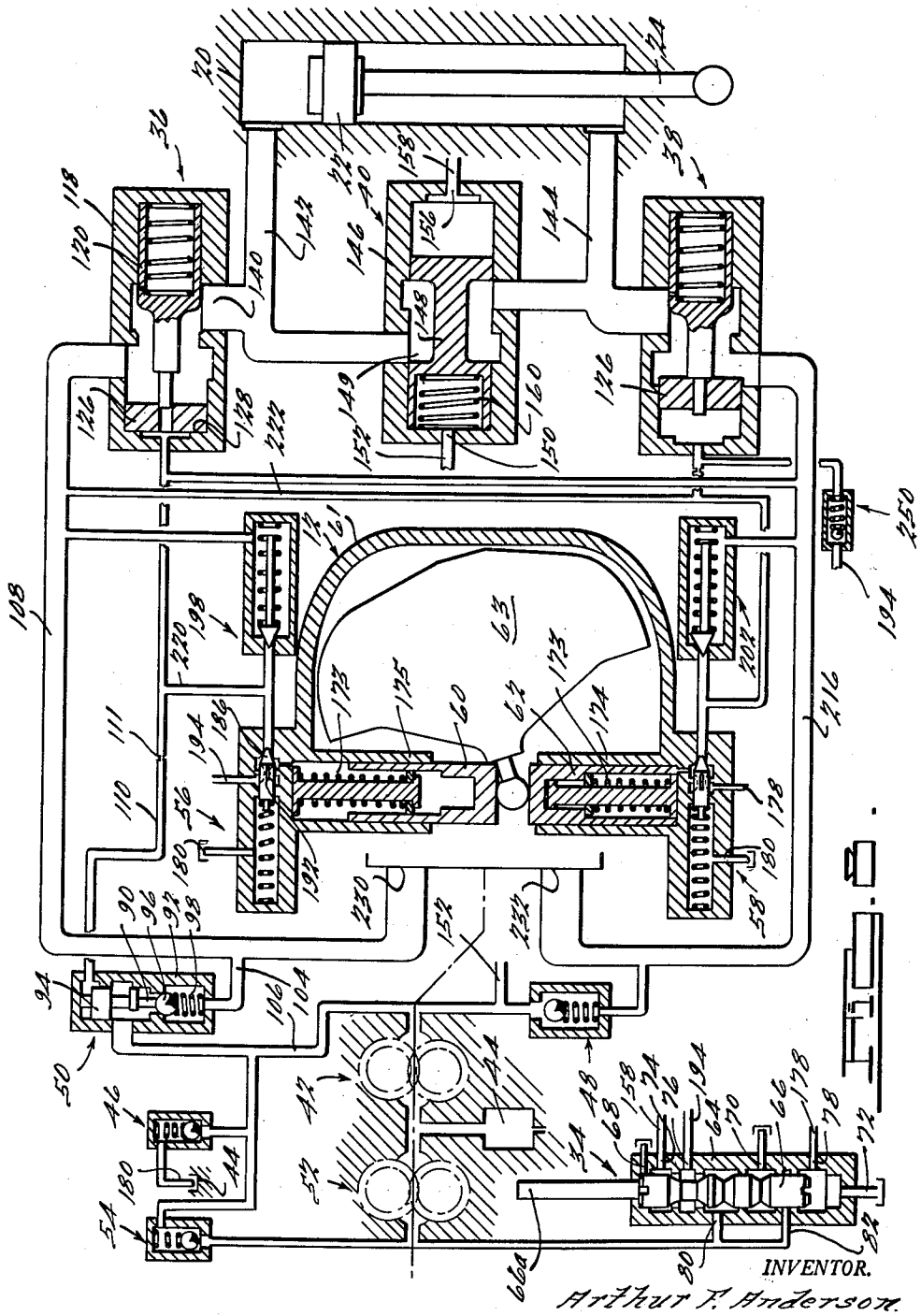
FIG. 7.

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HYDRAULIC CONTROL SYSTEM FOR VARIABLE DISPLACEMENT PUMP

Filed Feb. 18, 1960 9 Sheets-Sheet 8



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HYDRAULIC CONTROL SYSTEM FOR VARIABLE DISPLACEMENT PUMP

Filed Feb. 18, 1960 9 Sheets-Sheet 9

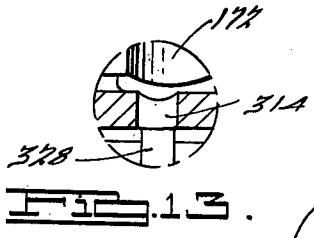



Fig. 13.




Fig. 11.

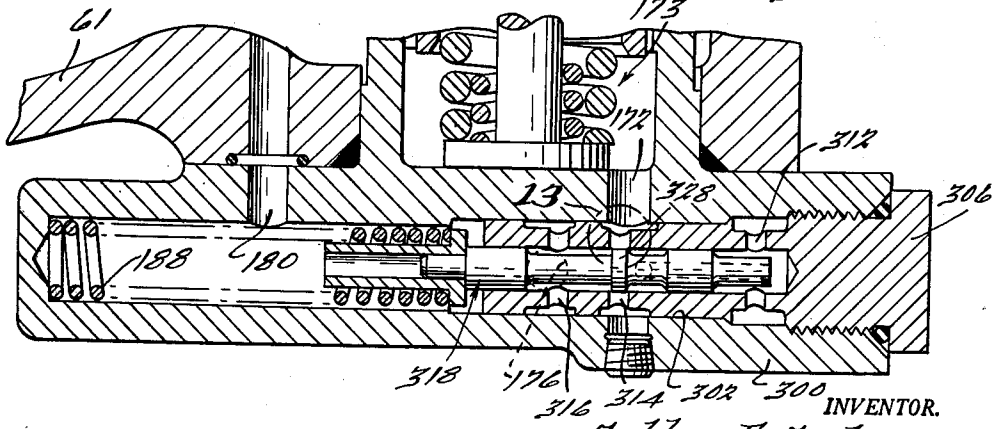



Fig. 12.

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United States Patent Office

3,078,674

Patented Feb. 26, 1963



# 3,078,674
# HYDRAULIC CONTROL SYSTEM FOR VARIABLE DISPLACEMENT PUMP

Arthur F. Anderson, Livonia, Mich., assignor to Gar Wood Industries, Inc., Wayne, Mich., a corporation of Michigan

Filed Feb. 18, 1960, Ser. No. 9,461
29 Claims. (Cl. 60—52)

This invention relates generally to pump control systems and more particularly to a hydraulic control system for a variable displacement pump.

In a system in which a variable displacement pump is used to operate a hydraulic device, a provision for actuating the pump to substantially "zero" displacement in the limit positions of the hydraulic device is desirable, because this eliminates unnecessary heating of the system due to circulation of the hydraulic fluid, and makes it possible to use the power required for operating the pump for other useful purposes. By "limit position" is meant a position in which the hydraulic device cannot be moved in a direction in which fluid from the pump tends to move it, either because of the structure of the hydraulic device or some external force applied to it. The invention is best understood by referring to a system in which a variable displacement pump of reciprocating piston type operates a hydraulic cylinder assembly that raises and lowers a dozer blade mounted on the front end of a tractor. In a pump of this type, which is described in detail in my prior application Serial No. 835,002, filed August 20, 1959, and now abandoned, a movable tilt box is angularly adjustable relative to the axis of rotation of the cylinder barrel to control the displacement of the pistons. When the tilt box is perpendicular to the axis of cylinder barrel rotation, the pistons have no stroke and no fluid is pumped. This is called the "zero" displacement or "neutral" position of the tilt box which is hereinafter sometimes generally referred to as the pump displacement control member. When the tilt box is moved in either direction from the perpendicular position fluid is pumped by the pump in one or the other directions depending on the direction of movement of the tilt box. The greater the extent of movement of the tilt box from the perpendicular position, the greater the stroke of the pistons and, consequently, the greater the output of the pump. When the pump is driven by the tractor engine, any diversion of engine power for unnecessary pump operation is to be avoided if possible. Consequently, in limit positions of the hydraulic cylinder assembly it is desirable to have the tilt box moved from a full to substantially a "zero" displacement position so that substantially the full power of the engine is available for purposes other than operating the pump at full pressure and unnecessarily heating the control system. It is also desirable in systems of this type to provide for a flow of replenishing fluid to the main pump circuit to replace the piston rod when it is moving out of the cylinder assembly and to compensate for leakage at the pump, which is a necessary characteristic of pumps of this type since a lubricating layer of fluid must be provided between the rotating cylinder barrel and the adjacent stationary valve face through which fluid is supplied to the pump and discharged from the pump. When the cylinder is maintained substantially full of fluid at all times, an immediate response of the cylinder assembly to operation of the control valve therefor is insured.

It is an object of this invention, therefore, to provide an improved hydraulic control system for a variable displacement pump which provides for an automatic actuation of the pump displacement control member to substantially a "zero" displacement position when the pump output pressure exceeds a predetermined maximum pressure.



This is accomplished in the system of this invention by communicating the high pressure fluid on the output side of the pump with the control apparatus which actuates the pump displacement control member so as to overpower the control apparatus which is maintaining the displacement control member in a positive displacement position.

Another object of this invention is to provide a control system for a variable displacement pump which includes a separate hydraulic control circuit operable to actuate the pump so that it will pump fluid in either of two directions to the hydraulic device which is being controlled.

A further object of this invention is to provide a hydraulic control system for a variable displacement pump and a hydraulic device operated thereby which includes a supercharge circuit that replenishes the operating circuit to maintain the operating circuit substantially full at all times.

Another object of this invention is to provide in a hydraulic control system for a variable displacement pump, means for automatically relieving the pressure in the operating circuit during the time the pump displacement control member is being moved toward a "zero" displacement or "neutral" position so that the pressure in the system does not exceed a predetermined maximum pressure, thereby requiring conditioning of the system for withstanding only this predetermined maximum pressure.

Still another object of this invention is to provide a control system for a variable displacement pump which provides for movement of the pump displacement control member to substantially a "neutral" position from a positive displacement position in either direction from the "neutral" position without any "hunting" of the member for the "neutral" position.

Further objects, features and advantages of this invention will become apparent from a consideration of the following description, the appended claims and the accompanying drawing in which:

FIGURE 1 is a fragmentary side elevational view of a tractor having a dozer blade which is raised and lowered by a hydraulic cylinder assembly which is actuated by the control system of this invention;

FIGURE 2 is an enlarged fragmentary elevational view of a portion of the tractor and pump mounting shown in FIG. 1, with some parts broken away for the purpose of clarity;

FIGURE 3 is a diagrammatic view of the control system of this invention, shown associated with a variable displacement pump of reciprocating piston type and the hydraulic cylinder assembly shown in Fig. 1, and illustrating the system is a "hold" condition, namely, a condition for holding the piston in the cylinder assembly, and consequently the dozer blade, in a fixed position with respect to the front end of the tractor.

FIGURE 4 is a diagrammatic view of the system of this invention, illustrated similarly to FIG. 3, showing the system in a "raise" condition, in which the dozer blade will be moved upwardly;

FIGURE 5 is a diagrammatic view, illustrated similarly to FIG. 4, showing the system in a "raise-overload" condition, namely, a condition in which the dozer blade has been raised to a limit position and further effort by the pump to raise the blade has raised the pressure on the output side of the pump to a predetermined safety limit at which the system has operated to move the pump displacement control member to a substantially "neutral" position;

FIGURE 6 is a diagrammatic view illustrated similarly to FIG. 3 showing the system in a "lower" condition, namely, a condition providing for downward movement of the dozer blade;

FIGURE 7 is a diagrammatic view illustrated similarly to FIG. 6, showing the system in a "lower-overload" condition;

FIGURE 8 is a diagrammatic view illustrated similarly to FIG. 3, showing the system in a "float" condition;

FIGURES 9 and 10 are enlarged sectional views of one of the valves in the control system of this invention, showing two positions of the valve;

FIGURE 11 is a fragmentary sectional view of a modified form of the control valve shown in FIGS. 9 and 10, showing the valve in assembly relation with the housing for the variable displacement pump and illustrating the valve in one position;

FIGURE 12 is a fragmentary sectional view of the modified valve shown in FIG. 11 illustrating the valve in another position; and

FIGURE 13 is an enlarged view of the encircled portion of FIG. 12 indicated by the numeral 13.

With reference to the drawing, the hydraulic control system of this invention is illustrated in connection with a variable displacement pump 12, of reciprocating piston type and described in detail in my prior application Serial No. 835,002, filed August 20, 1959, mounted on a tractor 14 for operating a hydraulic cylinder assembly 16 to raise and lower a dozer blade 18. However, it is to be understood that while the control system of this invention has particular utility in the illustrated installation, the system has general utility in systems which include variable displacement pumps. As used herein, "variable displacement pump" means a positive displacement pump which can be adjusted at a given speed of operation to vary the volumetric displacement.

The cylinder assembly 16 includes a cylinder member 20 which is pivotally mounted on the front end of the tractor, a piston 22 (FIG. 3), and a piston rod 24 which extends through the lower end of the cylinder and is connected at its lower end to the dozer blade 18. A dozer blade supporting frame 26 which is pivotally supported at its rear end on shafts 28 carried by the tractor 14 has the dozer blade 18 mounted on the front end thereof so that the blade is forwardly of the front end of the tractor 14. The pump 12 is hydraulically connected to the cylinder assembly 16 for moving the dozer blade 18 between its upper position shown in broken lines and its lower position shown in full lines. A handle 30 mounted on the tractor 14 at a position for convenient operation by the operator is connected to a control valve 34 which controls the operation of the pump 12.

The control system, which is indicated generally by the numeral 10 and is illustrated diagrammatically in FIGS. 3–8, inclusive, is made up of three related circuits, namely, a main or cylinder operating circuit which includes the pump 12 and the cylinder assembly 16, a supercharge or makeup circuit which replenishes fluid in the main circuit to compensate for pump leakage and movement of the piston rod 24 into and out of the cylinder 20, and a control circuit which includes the valve 34 and is provided for hydraulically actuating the pump 12 to achieve the desired movement of the dozer blade 18.

The main circuit includes, in addition to the pump 12 and the cylinder assembly 16, a pair of substantially identical cylinder holding check valves 36 and 38 connected to the upper and lower ends, respectively, of the cylinder 20 and a cylinder float control valve 40 disposed between the valves 36 and 38 and closed except in the "float" condition of the system 10. Each of the valves 36, 38 and 40 is constructed for pilot operation, as will more clearly appear hereinafter. The pressure in the main circuit, in the illustrated embodiment of the invention in which the cylinder assembly 16 raises and lowers a dozer blade 18, may be as high as 1500 p.s.i. on the output side of the pump 12, which is capable of pumping 150 gallons or more of fluid per minute.

The supercharge circuit includes a gear pump 42 connected to a tank or reservoir 44 for the system 10, a check valve 46 over which the pump 42 pumps to tank, a check valve 48 which communicates with one side of the pump 12 and a pilot-operated check valve 50 which communicates with the opposite side of the pump 12. In the illustrated embodiment of the invention the check valve 46 is set to provide a pressure of about 50 p.s.i. in this circuit and the pump 42 is capable of pumping about 28 gallons per minute.



The control circuit includes a gear pump 52 which is connected through a line 47 to one side of a check valve 54 that is connected on the opposite side by a line 49 to the supercharge circuit. In addition, the control circuit includes the control valve 34 and a pair of substantially identical control valves 56 and 58 which control a pair of tilt box actuating pistons 60 and 62, respectively, which are axially aligned and disposed on opposite sides of the pump 12 for moving the tilt box. In other words, control fluid can be directed through either one of the pilot valves 56 and 58 to extend either one of the pistons 60 and 62 to move the pump tilt box in a desired direction to obtain the desired flow of fluid from the pump 12. In the illustrated embodiment of the invention, the pressure in the control circuit is about 400 p.s.i. and the pump 52 is capable of pumping about 8 gallons per minute.

The pump 12, which is described in detail in my prior application referred to above and is only shown diagrammatically, includes a casing 61 having a tilt box 63 mounted therein for rotatable movement in opposite directions about an axis perpendicular to the plane of the paper in FIGS. 4 and 6 between the limit positions illustrated therein in which the actuating pistons 62 and 60 bottom in their respective cylinder supports. The tilt box 63 is provided with an actuating arm 65 disposed between the control pistons 60 and 62. A pair of spring assemblies 173 are associated with the pistons 60 and 62 and are initially accurately adjusted so that they constitute yieldable abutments which exert no force on the pistons 60 and 62 in the zero displacement position of the tilt box 63. Each spring assembly 173 will compress and yield so as to permit retraction of its piston 60 or 62 when a retracting force is applied to the piston. The details of assembly of the spring assemblies 173 with the pump 12 are included in my copending application referred to above.

As shown in FIG. 2, the drive shaft 67 for the pump 12 is driven by a tractor engine-driven shaft 69 disposed below the tank 44 which is mounted on the front end of the tractor 14 and provided with a fill neck 45. The gear pumps 42 and 52 are driven from a common shaft and are mounted in a casing 55 located within the tank 44 and communicating with fluid in the tank 44 through a filter 53. The pump 12 is mounted on a valve block 71 at the front end of the tractor and a gear train 73 is provided on the block 71 for transmitting driving power from the shaft 67 to the pumps 42 and 52. The check valve 54 is mounted in a casing 57 disposed within the filter 53, the check valve 46 is mounted on one side of the valve block 71, and a housing 59 which projects forwardly from the valve block 71 at a position above the pump 12 encloses the valves 36, 38, 40, 48 and 50 which communicate through passages in the valve block 71 and the housing 59 with the pump 12 and the tank 44 in a manner hereinafter described. The valves 56 and 58 are mounted on the pump casing 61.

While the pump 12 is normally controlled by the control circuit, under overload conditions the pump 12 is controlled by fluid on the output side of the pump 12. Under such conditions when the pressure on the output side of the pump rises to a predetermined high pressure, fluid under pressure from the pump 12 is applied to one of the control pistons 60 and 62 so as to immediately stroke the pump 12 toward a zero displacement position. As used herein, "stroking of the pump" refers to rotation of the tilt box 63 in either direction so as to vary the stroke of the pistons in the pump.

The operation of the system 10 can be better understood

if the valves in the system are first described in detail. The control valve **34** includes a casing **64** in which a spool **66** is mounted for reciprocal movement and which is connected through ports **68**, **70** and **72** to the tank **44**. The spool **66** has a stem **66***a* which is connected to the handle **30** so that the handle **30** is operable to reciprocate the spool **66**. The casing **64** has three outlets **74**, **76** and **78** for fluid under pressure and a pair of inlets **80** and **82**. The spool **66** is shiftable longitudinally of the casing **44** between "hold," "raise," "lower" and "float" positions, shown in FIGS. 3, 4, 6 and 8, respectively, which are hereinafter described in detail in connection with a detailed description of the operation of the system.

The pilot-operated check valve **50** includes a valve stem **90** which is guidably mounted in a casing **92** and is provided adjacent one end with a valve member **94**. The opposite end of the stem engages a ball **96** which is urged by a spring **98** into a position closing a valve passage **100** in the casing **92**. The casing **92** has one end **91** provided with an opening that communicates with a line **104** and the opposite end **93** of the casing **92** is closed.

As used herein, the term "line" refers to a passage, conduit, tube or the like, through which fluid can flow from one point to another. When the passage **100** is closed, communication of a fluid line **102** on one side of passage **100** with the line **104** on the opposite side is blocked. The line **102** connects to a line **106** extending between pump **42** and relief valve **46** and line **104** connects to a line **108** which extends between pump **12** and check valve **36**. The portion of the casing **92** between the closed end **93** and the valve member **94** communicates with one end of a line **110** connected at its opposite end to the valve **36**. When the pressure in the line **110** is above the pressure in line **104**, the fluid under pressure from line **110** acting on valve member **94** will move the valve stem **90** so as to move the ball **96** out of a position closing the valve passage **100**, against the pressure of spring **98**, which is small.

Since the cylinder holding check valves **36** and **38** are substantially identical, only the valve **36** will be hereinafter described in detail, with like numerals on the two valves indicating like parts. The valve **36** consists of a casing **118** in which a hollow elongated plunger member **120**, provided at one end with a stem **122**, is mounted for reciprocal movement. The stem **122** is formed intermediate its ends with a shoulder **124**, and a disk **126** is slidably supported on the valve stem **122** for movement in one direction to a position engaged with one end **128** of the casing **118** and in the opposite direction to a position engaged with the shoulder **124**. A spring **130** positioned within the hollow plunger **120** and engaged with the opposite end **132** of the casing **118** urges the plunger **120** in a direction to seat an inclined surface **134** on the plunger member **120** against a correspondingly inclined surface **136** formed in the casing **118**. An opening **138** in the plunger **120** provides for a constant communication of the spring urged side of the plunger **120** with a port **140** in the casing **118**. The port **140** communicates with a line **142** extending between the valve **40** and the closed end of the cylinder **20**. The corresponding port **140** in the valve **38** communicates with a line **144** which extends between the valve **40** and the piston rod end of the cylinder **20**.

The cylinder float control valve **40** thus communicates on one side through the line **142** with the cylinder **20** on the top side of the piston **22** and on the opposite side through the line **144** with the cylinder **20** on the bottom side of the piston **22**. The control valve **40** consists of a casing **146** having a valve member **148** disposed therein and provided at one end **154** with a port **150** which communicates through a line **152** with the line **106** which is connected to the output side of the supercharge pump **42**. A port **156** at the opposite end of the casing **146** communicates through a line **158** with the outlet port **74** in the control valve **34**. A spring **160** extends between the casing end **154** and the valve member **148** for urging the valve member toward the opposite end of the casing against the pressure of fluid at the port **156**. Whenever the pressure at the port **156** is sufficient to move the valve member **148** in the opposite direction, the valve member **148** is moved to the position shown in FIG. 8 in which the lines **142** and **144** are fluid connected through the valve **40**.

Since the tilt box control valves **56** and **58** are substantially identical only the valve **58**, enlarged views of which are shown in FIGS. 9 and 10, will be described in detail with like numerals indicating like parts on the valves. The valve **58** includes a casing **170** that has a port **172** which communicates with a cylinder support **174** for the control piston **62**. A port **176** in the casing **170** communicates through a line **178** with the outlet port **78** in the control valve **34**. A port **180** in the casing **170** communicates with tank **44**. A pair of spaced annular walls **182** and **184** in the casing **170** separate the ports **172**, **176** and **180**. A piston **186** is slidably supported on the walls **182** and **184** and is urged by a spring **188** toward a position engaged with an annular seat **191** which surrounds a port **190** at one end of the casing. A plurality of keyway-shaped grooves **192** in the piston **186** are located so that they extend across the wall **184** (FIG. 9) when the piston is engaged with the seat **191**.

The port **172** for the valve **56** communicates with a supporting cylinder **175** for the control piston **60** and the port **176** communicates through a line **194** with the outlet port **76** in the control valve **34**.

The ports **190**, which under circuit overload conditions hereinafter described constitute inlet ports for the valves **56** and **58**, are connected to the ends of lines **196** and **200**, respectively. The opposite end of the line **196** is connected to the inlet port for a peaking relief valve **198** and the opposite end of the line **200** is connected to the inlet port for a peaking relief valve **202**. The peaking relief valves **198** and **202** are identical, each including a casing **204** having an inlet port **206** and an outlet port **208** and a valve member **210** urged by a spring **211** toward a seated position closing the inlet port **206**. In the valve **198** the port **206** communicates with the line **196** and the outlet port **208** communicates with a line **212** which connects to the line **108**. In the valve **202** the inlet port **206** communicates with the line **200** and the port **208** communicates with a line **214** which is connected to a line **216** that extends between the pump **12** and the valve **38**. A line **218** extends between the line **216** and the line **110** which is in turn connected to the line **196** by a line **220** for a purpose to appear presently. A line **222** connects the line **200** and the line **108** and a line **224** connects the line **222** and the valve **38** also for a purpose to appear presently.

*Operation*

The operation of the control system **10** can now be understood by explaining how the various elements of the system react to movement of the control valve **34** to the "hold," "raise," "lower" and "float" positions illustrated in FIGS. 3–8, inclusive.

First assume that the valve **34** is moved to its "hold" position illustrated in FIG. 3 for the purpose of maintaining the blade **18** in a fixed vertical position with respect to the front end of the tractor **14**. In this position of the valve **34**, the control pump **52** is supplying fluid to the valve inlet ports **80** and **82** both of which communicate through the valve casing **64** with the tank port **70** so that no pressure is being developed by the control pump **52** and the relief valve **54** is closed. Consequently, since no pressure is being applied to the control pistons **60** and **62** the tilt box **63** is in a "zero" displacement position and no oil is being pumped by the pump **12**. The supercharge pump **42** is pumping over the relief valve **46** to tank **44** so the pressure required to open the valve **46** determines the pressure developed by the pump **42**. The valves **48** and **50** are set to open at a pressure below this pressure and the volume output of pump **42** is such that the full volume of fluid from pump **42** is greater than

will flow through valves 48 and 50 at a pressure below the pressure at which relief vale 46 opens. At this pressure sufficient fluid will flow through relief valve 46 under all conditions to prevent a pressure rise in the supercharge circuit above the pressure at which valve 46 opens, which is hereinafter referred to as "supercharge pressure."

Fluid under a supercharge pressure is supplied to both the cylinder holding check valves 36 and 38, and in the illustrated embodiment of the invention this pressure on the valve members 120 is not sufficient to overcome the force of the springs 130. This is because the springs 130 are strong to insure quick and positive closing of the check valves 36 and 38. In the illustrated embodiment of the invention, a spring 130 exerts a force of about one hundred pounds on its valve member 120. However, even if the springs 130 were weak enough to permit opening of a valve 36 or 38 under supercharge pressure, the system 10 would work satisfactorily so long as the weight of the dozer blade 18 is sufficient to maintain the pressure on the spring side of valve member 120 in valve 38 closed against supercharge pressure on the opposite side. If the valve 36 opens under supercharge pressure, there will only be enough flow therethrough to fill the cylinder 20 on the top side of piston 22, following which the valve member 120 will seat because the pressures on opposite sides thereof will be equal.

Normally, the cylinder 20 is full and the cylinder holding check valves 36 and 38 are closed and prevent movement of the piston 22 in either direction in the cylinder, and the shut-off valve 40 blocks communication of opposite ends of the cylinder 20.

Since the piston 22 is unbalanced in the system of this invention, meaning that the areas on opposite sides thereof are unequal, it must be weighted sufficiently to raise the pressure on the small area side enough to maintain the valve 38 closed against supercharge pressure, in the event the spring 130 will not accomplish this purpose, to prevent the piston 22 from moving downwardly when valve 34 is in a hold position. In the use of the system of this invention with a piston 22 which is not weighted, and with a spring 130 which will not hold the valve 38 closed against supercharge pressure, the piston 22 must be balanced, as by extending the piston rod 24 completely through the cylinder 20, if the piston 22 is to be maintained in a fixed position in cylinder 20 in the "hold" position of the control valve 34. The valves 48 and 50 are shown open but of course as soon as the lines 108 and 216 are filled with fluid from the pump 42, the valves 48 and 50 will close since the fluid pressures on both sides of each valve will be the same, and the full output of fluid from pump 42 will flow through the relief valve 46 to tank.

It can thus be seen that in the "hold" position of the valve 34, the dozer blade 18 is held in a fixed position relative to the front end of the tractor 14.

When it is desired to raise the dozer blade 18, the control valve 34 is moved to its "raise" position shown in FIG. 4 in which fluid from the pump 52 supplied to the inlet port 80 is blocked by the spool 66 against travel out of the casing 64 and fluid supplied to the inlet port 82 flows through the casing 64 to the outlet port 78. Line 194 is now in communication with tank port 68 since in this position of the control valve fluid may pass around the upper end of the spool 66, as well as through the grooves thereat, as can be seen in FIGURE 4. Fluid from the outlet port 78 flows through the line 178 to the inlet port 176 in the valve 58. Since the piston 186 is seated, fluid from the port 176 flows through the piston grooves 192 to the valve outlet 172 and into the support cylinder 174 for the pump control piston 62. The control piston 62 is extended by this fluid to thereby tilt the tilt box 63 in a clockwise direction to the limit position shown in FIG. 4. Excess fluid from pump 52, over and above that required to extend piston 62, flows through the check valve 54 and the line 49 into the line 106 in the supercharge circuit.

The pump 12 has two ports or openings, shown diagrammatically at 230 and 232, either one of which can function as the pump inlet or outlet depending on the direction of tilt of the tilt box 63, as described in my copending application hereinbefore referred to, and in the position of the tilt box 63 shown in FIG. 4 the valve port 230 communicates with the cylinder bores (not shown) in the pump 12 when the pistons in these bores are on their suction stroke. Consequently, the port 230 functions as the inlet port for the pump 12 and the other pump port 232, which communicates with the cylinder bores during the time the cylinders in these bores are on their discharge stroke, functions as the pump outlet. Fluid under pressure from the pump port 232 flows through the line 216 to the valve 38 and moves the plunger 120 off its seat 136 so that fluid flows through the valve 38 and line 144 into the lower end of the cylinder 20 so as to raise the piston 22. Fluid from line 216 flows through a line 234 to the relief valve 48 and keeps the valve closed.

Fluid in the cylinder 20 above the piston 22 is exhausted through the line 142 and is returned to the pump 12 through the open valve 36 and the line 108. The valve 36 is maintained open by fluid under pressure from the pump 12 supplied through the line 218 to a pilot port 219 in valve 36 so as to move the disk 126 toward the right as viewed in FIG. 4 to unseat the valve plunger 120.

The volume of fluid exhausted from the closed end of the cylinder 20, during upward travel of the piston 22, exceeds the volume of fluid being supplied to the piston rod end of the cylinder 20 because of the space in the cylinder 20 occupied by the piston rod 24. Consequently, the volume of fluid flowing toward the inlet port 230 exceeds the volume of fluid being pumped out of the pump 12 through the outlet port 232. The excess fluid flowing to the pump inlet 230 flows back to the tank 44 through the pilot operated check valve 50 which is maintained in an open position, illustrated in FIG. 4, by fluid under main pump outlet pressure supplied to the valve 50 through the line 110 so as to move the valve member 94 in a direction to unseat the ball 96. A restriction 111 is provided in the line 110 to prevent a surge of fluid to the valve 50 tending to move the valve parts so rapidly as to decrease the wear life thereof.

The spring 188 in the pump control valve 56 is adjusted to prevent unseating of the piston 186 when the pressure of fluid on the outlet side of pump 12 is at or below the predetermined maximum pump operating pressure, which in the illustrated embodiment is about 1500 p.s.i. This pressure is determined by the capabilities of the pump 12 and the other components of the system 10 and is adequate for moving the blade 18 to accomplish the usual work operations for which the tractor and dozer assembly is intended.

However, in the event the blade 18 encounters an obstruction which prevents raising movement of the blade 18 or, as more often happens, in the event the piston 22 engages the closed end of the cylinder 20, continued operation of the pump 12 causes an immediate rise of the pump pressure to a pressure above the predetermined maximum pressure which is high enough to unseat the piston 186 in the valve 56 as shown in FIG. 5. Fluid then flows into valve 56 through port 190 and from valve 56 into the cylinder support 175 for piston 60 through port 172 so as to extend the depressed pump operating piston 60 and move the tilt box 63 toward its "zero" displacement position. Since some time is involved in moving the tilt box 63 to substantially its "zero" displacement position, and since the pressure in the system 10 on the output side of the pump 12 is continually rising during this time, the peaking relief valve 198 is provided to limit the pressure. In the illustrated embodiment of this invention, the spring 211 in valve 198 is adjusted so that the valve member 210 moves off its seat at a peak pressure of about 1700 p.s.i. Consequently, the valve 198 will open to dump enough fluid from the pump outlet line 216 to the inlet line 108 to

lower the pump output pressure to below 1700 p.s.i. To accomplish this it is not necessary that the relief valve 198 be of a large size sufficient to carry the entire pump output. It is only necessary that the valve 198 be capable of carrying about 30 to 40 gallons per minute of fluid.

Since no relief has been provided for the fluid on the output side of the pump 12, other than to prevent the pressure from rising above 1700 p.s.i., a pump output pressure of about 1500 p.s.i. is maintained. Since there is no flow through valve 38, it closes tightly to trap fluid in cylinder 20 which is on the underside of the piston 22 and which is at about the 1500 p.s.i. pressure so that the blade 18 does not fall.

When the piston 186 is unseated (FIG. 10) some of the fluid supplied through port 190 to valve 56 flows through the grooves 192 to the port 176 and into line 194 which communicates with the tank port 68 in control valve 34. The grooves 192 are located relative to the wall 184 and are of a size such that they constitute a restriction to flow through the valve 56 from port 190 to tank when the pump 12 is pumping at full volume capacity. Consequently, some fluid entering valve 56 through port 190 flows out through port 172 into cylinder 175 and causes a rise in the pressure in cylinder 175 until the combined force of the fluid and spring assembly 173 tending to extend piston 60 exceeds the oppositely directed force on piston 62, so that the piston 60 is extended. During extension of piston 60, the tilt box 63 is rotated toward its neutral position.

This causes a corresponding reduction in the volume of fluid being pumped by the pump 12 through the port 190 for valve 56, until at some position of piston 60 short of a centered position of tilt box 63, the volume of fluid being pumped into valve 56 through port 190 equals the volume of fluid flowing through the grooves 192. In this equilibrium position of the piston 186 in valve 56, the force exerted on the piston by the compressed spring 188 is balanced by an equal and oppositely directed force exerted on the piston 186 by the fluid entering through port 190. The flow through port 190 in this equiblibrium position of piston 186 at a pressure drop of from about 1500 p.s.i. to the lower pressure existing at port 172 and in cylinder 175 equals the flow through the grooves 192 at the pressure drop existing between ports 172 and 176. By forming the valve 56 so that a flow through grooves 192 is insured when the valve member 186 is unseated, a movement of the pump tilt box 63 to a substantially zero displacement position without any "hunting" is insured.

All of the above described action of valve 56 during movement of tilt box 63 toward a substantially zero displacement position takes place very quickly. In the event the piston 186 should momentarily move against the spring 188 to a position in which the grooves 192 are closed by the wall 184, as in the case of a sudden pressure above 1700 p.s.i., the quick response of the tilt box 63 to provide for a reduced pump output and the action of the peaking relief valve 198 provide for a reduced pressure at port 190 so that the spring 188 again moves the piston 186 to its equilibrium position. The spring 188 is of a strength such that at pressures at port 190 between the equilibrium pressure and the peaking relief pressure fluid can flow through grooves 192 to tank.

In the equilibrium position of piston 186 in valve 56, the pump 12 will pump sufficient fluid to take care of flow through grooves 192, leakage at the pump 12 and all other leakage in the system parts communicating with the pump outlet. The supercharge pump 42 supplies this amount of fluid to the pump 12. Thus the pump 12 is not stroked to an absolute zero displacement condition, only a substantially zero displacement condition.

It can thus be seen that if raising movement of the blade 18 is prevented and the control valve 34 is in the "raise" position, the tilt box 63 is automatically moved to a substantially "zero" displacement position, by the action of valve 56, so that very little power is required from the tractor engine to operate the pump 12, and the blade 18 is maintained in the position at which raising movement was stopped.

In the event downward movement of the blade 18 is desired, the control valve 34 is moved to its "down" position shown in FIG. 6, in which the valve spool 66 is in a position in which the inlet port 82 is blocked and the inlet port 80 communicates with the outlet port 76. The outlet port 74 communicates with the tank port 68 and the outlet port 78 communicates with the tank port 72. Fluid under pressure from the port 76 flows through line 194 to the inlet port 176 in valve 56 for flow out the port 172 into the cylinder 175 so as to extend the control piston 60 and rotate the tilt box 63 in a counterclockwise direction, as viewed in FIG. 6. Some of the fluid in the cylinder 174 is exhausted, during retraction of piston 62, through the valve 58, the line 178 and the control valve tank port 72. Assume that the blade 18 is encountering an obstacle, such as the ground surface which resists its downward movement so that the piston rod 24 is under compression.

The pump 12 now operates so that the port 230 functions as the outlet port and the port 232 functions as the inlet port. Fluid is pumped out of the port 230 and travels through the line 108 to the check valve 36, where it unseats the valve plunger 120 and travels out the port 140 and through the line 142 to the closed end of the cylinder 20 so as to exert a pressure on the top side of piston 22 which moves the piston downwardly, to in turn move the dozer blade 18 downwardly. Since the float control shut-off valve 40 is closed no fluid under pressure is supplied to the piston rod end of the cylinder 20.

As the piston 22 moves downwardly, fluid is exhausted from the cylinder 20 through the line 144, the open valve 38 and the line 216 to the pump inlet 232. The valve 38 is maintained open by fluid under pump outlet pressure supplied to the pilot inlet 219 for the valve 38 through the lines 222 and 224. This fluid moves the disk 126 on the stem 122 into engagement with the shoulder 124 so as to move the plunger 120 to an unseated position.

The area of the disk 126 subjected to pressure by fluid entering port 219 is sufficiently greater than the area on the spring-urged side plunger 120 to provide for opening of valve 38 at a pressure considerably below the limit pressure of 1500 p.s.i. when the pressure of fluid trapped in cylinder 20 on the underside of piston 22 is 1500 p.s.i. The ratio of this area of disk 126 to the area of the spring-urged side of plunger 120 is greater than the ratio of the areas on the top and bottom sides of piston 22 to prevent a buildup of the force on the plunger 120 resisting opening faster than the buildup of the force on the disk 126 in the condition of the system 10 shown in FIG. 6 following a condition such as shown in FIG. 5 in which fluid is trapped in cylinder 20 on the underside of the piston 22. In the illustrated embodiment of the invention, the ratio of the area of disk 126 to the area of the spring-urged side of the plunger 120 is about 2 to 1 and the ratio of the area of the top side of the piston 22 to the area of the bottom side of piston 22 is less than this.

In a free fall condition of the dozer blade 18, namely, a condition in which there is no external force resisting downward travel of the blade 18 so that the piston rod 24 is in tension, the pressure in the cylinder 20 below the piston 22 will rise and the pressure above the piston 22 will fall. Consequently, the plunger 120 in the valve 38 will be moved by the pressure on the underside of the piston 22 toward a seated position against the pressure applied to the disk 126, which latter pressure is the same pressure that exists on the top side of the piston 22, by virtue of the connection of line 108 with valve 38 by means of lines 222 and 224. As soon as the plunger 120 seats against the seat 136, the pressure on the top side of the piston 22 will rise, because of the resistance to downward movement of the piston 22 created by the fluid trapped in cylinder 20 below the piston 22. This will cause the disk 126 to be moved in a direction to open the valve 38. The result of this type of operation is that the

dozer blade 18 tends to "hunt" during its downward movement. In other words, the downward movement of the blade 18 is a start and stop type of movement.

In order to overcome this tendency of the system 10 to operate so that the dozer blade 18 moves downwardly in this manner when the piston rod 24 is under tension, the line 194 which is connected to the port 176 in the control valve 56 is also connected to the inlet port 254 in a one-way check valve 250 that includes a casing 252 having an outlet port 256 which is connected by a line 258 to the line 224 communicating with the pilot port 219 in the valve 38. The check valve 250 has a ball member 260 therein which is urged by a spring 262 toward a seated position closing the inlet port 254. There is a restriction 264 in the line 224 at a position between the line 222 and the connection of the line 258 to the line 224 for a purpose to appear presently.

When fluid under control pressure is supplied through the line 194 to the check valve 250, in response to movement of valve 34 to a "down" position (FIGS. 6 and 7), the ball member 260 is unseated so that fluid under control pressure is supplied through the line 258 to the pilot port 219 in the valve 38 so as to move the disk member 126 against the valve stem shoulder 124 and unseat the plunger 120. The restriction 264 prevents free flow of this valve actuating fluid into the main pump operating circuit. When the pressure in the line 108 exceeds the pressure in line 258, the check valve 250 is closed. The valve opens again only if the pressure in line 108 drops below the pressure in the control circuit. At such time valve 250 opens to prevent hunting of the piston 22 during downward movement.

The area of the disk 126 in valve 38 is proportioned with respect to the area on the underside of the piston 22 and the weight of the blade 18 so that the total force exerted on the disk 126 by the fluid under control pressure is sufficient to maintain the plunger 120 in an unseated position against the combined forces in the opposite direction exerted by the fluid communicating with the underside of the plunger 120 and the spring 130.

It is seen, therefore, that the fluid from the control circuit is used to insure an open position of the valve 38 when the pressure in line 108 is not high enough to keep the valve 38 open during a powered movement of the dozer blade 18 downwardly.

When the pump 12 is operating to pump fluid into the upper end of the cylinder 20, to move the dozer blade 18 downwardly, fluid under operating pressure from the pump 12 is supplied from the line 108 through the line 104 to the pilot operated check valve 50 so as to maintain the ball member 96 in a seated position. Fluid under operating pressure is supplied from the line 222 to the line 200 which communicates with the control valve 58 and the peaking relief valve 202, and so long as the pressure of this fluid does not exceed the maximum normal operating pressure, about 1500 p.s.i. in the illustrated embodiment of the invention, the valve members 58 and 202 remain closed as shown in FIG. 6. The volume of fluid being supplied to the pump inlet 232 through the line 216 is less than the volume of fluid which must be supplied to the cylinder 20 on the top side of the piston 22 to keep the cylinder 20 full because the piston rod 24 is moving out of the cylinder 20. The necessary additional volume of fluid is supplied to the inlet port 232 from the supercharge pump 42 which pumps through the open check valve 48 to the line 216. So long as replenishing fluid is required at the pump inlet 232, the pressure in the line 216 will be below supercharge pressure so that the valve 48 will be open. The communication of the relief valve 54 in the control circuit with the line 106 provides for a dumping of control circuit fluid into the supercharge circuit as a precaution against the creation of voids in the cylinder 20 above the piston 22. The valve 54 can be connected to tank, instead of to the supercharge circuit, but it is advantageous to utilize the control circuit fluid to increase the volume of fluid available in the supercharge circuit.

In the event the downward movement of the piston 22 is stopped, because it engages the lower end of the cylinder 20 (FIG. 7), the pump operating pressure immediately rises above the predetermined maximum pressure for which the valve 58 is set, 1500 p.s.i. in the example, resulting in unseating of the piston member 186, so that fluid flowing to port 190 in valve 58 is supplied to the cylinder 174 so as to extend the control piston 60 and stroke the tilt box 63 toward its neutral position. The valve 58 operates like the valve 56 previously described to insure stroking of the pump to a substantially zero displacement position without any hunting.

The peaking relief valve 202 bleeds off enough fluid in the line 200 to prevent the pressure from exceeding a predetermined maximum pressure. In the illustrated embodiment of the invention this pressure is about 1700 p.s.i., and as previously explained, the peaking relief valve 202 functions to prevent undue pressure rise in the system 10 during the time involved in moving the tilt box 63 to a substantially zero displacement position. Since there is no flow through the valve 36 the piston 120 is moved by the spring 130 to a position engaged with the seat 136 to thereby hold the pressure on the top side of piston 22. In this position of the tilt box, the pump 12 pumps enough fluid to take care of leakage at the pump, flow through the valve 58, and any other leakage in the system on the output side of the pump. In the event the pressure falls below the pressure necessary to maintain the piston member 186 in valve 58 in an unseated position, for any reason, the piston member 186 moves to the seated position shown in FIG. 9 in which the cylinder 174 communicates with the tank port 176 in the valve 58, and the control pressure in the cylinder 175 again extends the piston 60 to provide for tilting of the tilt box 63 to a position in which the pumping of an increased volume of fluid out the pump outlet 230 is resumed to again raise the pressure at the port 190 to the predetermined maximum.

In FIGS. 11–13, a valve 58*a* is illustrated which may be substituted for the valves 56 and 58, and is shown associated with the cylinder 174 only for purposes of illustration, it being understood that an identical valve may be mounted on the opposite side of the tilt box 63 and associated with the cylinder 175 if desired. The valve 58*a* includes an elongated casing 300 which is provided with a longitudinally extending bore 302 and is integrally formed with the cylinder 174 which is at substantially right angles to the bore 302. The valve 58*a* is assembled with the pump 12, only fragmentary portions of which are shown in FIG. 11, by inserting the cylinder 174 in an opening 304 in the pump casing 61. The cylinder 175 is similarly inserted on the diametrically opposite side of the casing 61 so that it is in substantial alignment with the cylinder 174, as shown in FIGS. 3–8, and as described in detail in my copending application Serial No. 835,002. The spring assembly 173 is positioned in the cylinder 174 and engaged with the piston 62 so that the spring assembly constitutes a yieldable abutment which exerts no force on the piston 62 in the neutral position of the tilt box 63 in which the actuating arm 65 is centered between the pistons 60 and 62. The spring assembly 173 will compress and yield so as to permit retraction of its piston 62 when a retracting force is applied to the piston and of course the more the spring assembly 173 is compressed the greater the force it exerts on the piston 62.

The valve casing 300 is secured, such as by bolts (not shown) to the pump casing 61 so as to maintain the cylinder 174 in the position shown in FIGS. 11 and 12.

A spool sleeve 306 is threaded into the bore 302 in the casing 300 and is provided with an axial bore 308 which extends inwardly from the inner end 309 of the

sleeve 306 and has its inner end 310 located intermediate the ends of the sleeve 306. Three sets of radially extending openings 312, 314 and 316, are formed at longitudinally spaced positions in the sleeve 306 and intersect the bore 308. A spool 318 is slidably supported in the bore 308 so that the inner end 320 thereof is spaced from the bore end 310. An axial passage 322 in the spool 318 at the end 320 thereof is in constant fluid communication with the sleeve opening 312 through the space between the spool end 320 and the bore end 310. The spool 318 is formed with three longitudinally spaced lands 326 328 and 330 and the passage 322 has a transversely extending portion 332 at its inner end which intersects the outer surface of the spool 318 between the lands 326 and 328.

The opposite end of the spool 318 has a reduced diameter extension 334 which supports a guide 336 for the spring 188 that extends between the inner end of the bore 302 and the guide 336. The spring 188 urges the spool 318 toward the right as viewed in FIGS. 11 and 12 to the position shown in FIG. 11 in which an end flange 337 on the guide 336 engages the inner end of the sleeve 306.

In use, the valve 58*a* is connected in the control system 10 so that the sleeve openings 312 communicate with the end of line 200 opposite the peaking relief valve 202, the sleeve openings 314 communicate with the connecting port 172 between the cylinder 174 and the bore 308, and the openings 316 communicate through the port 176 in the casing 300 with the line 178 which is connected to the port 78 in the control valve 34.

In the operation of the valve 58*a*, when the tilt box 63 is to be rotated to the position shown in FIG. 4 to raise the dozer blade 18, fluid under control pressure from the valve 34 is supplied through the line 178 to the bore 302, through the openings 316, around the spool 318 and through the ports 314 and 172 into the cylinder 174 so as to extend the piston 62, spool 318 being in the position shown in FIG. 11. When the components of the system 10 are in the position shown in FIG. 6 and the dozer blade 18 is being moved downwardly, the valve 58*a* is still in the position shown in FIG. 11, however the line 178 which communicates with the sleeve openings 316 connects through the control valve 34 with the tank 44, the sleeve openings 312 communicate with the output side of the pump 12, and the tilt box operating piston 62 is depressed by the action of piston 60.

When the piston 22 engages the bottom end of the cylinder 20 (FIG. 7) so that continued operation of the pump 12 causes an immediate rise of the pump pressure to a pressure above the predetermined maximum operating pressure, which in the illustrated embodiment of the invention is about 1500 p.s.i., the force of the fluid at the openings 312 is sufficient to move the spool 318 against the force of the spring 188 to a position in which the land 328 is positioned relative to the sleeve openings 314 such that fluid supplied through the passage 322 to the space between the lands 326 and 328 can flow out the openings 314 to the cylinder port 172 and around the land 328 to the openings 316 which communicate with the tank. Fluid supplied through the port 172 to the cylinder 174 extends the depressed pump operating piston 62 and moves the tilt box 63 toward a position centered between the pistons 60 and 62. The peaking relief valve 202 will open to prevent the pressure on the output side of the pump 12 from rising above the 1700 p.s.i. pressure during the time involved in moving the tilt box 63 toward a neutral position.

This arrangement provides for a continual flow of fluid through the valve 58*a* to tank, during the time the valve 58*a* is in a position providing for a flow of fluid to extend the piston 62. During extension of the piston 62, the volume of fluid being pumped by the pump 12 is continually being reduced and at some position of piston 62 short of a fully extended position in which the tilt box 63 is centered, the volume of fluid being pumped into the valve 58*a* through the openings 312 equals the volume of fluid flowing out the valve 58*a* through tank port 176.

In an equilibrium position of the spool 318, shown in FIGS. 12 and 13, the amount of fluid flowing past land 328 to the openings 314 for cylinder 174 equals the amount of fluid flowing from the openings 314 past land 328 to tank port 176. As shown in FIG. 13, the land 328 is slightly to the right of a centered position relative to the openings 314, in the equilibrium position of spool 318, because the pressure drop, in the illustrated embodiment of the invention, is greater between the fluid on the right-hand side of land 328 and the fluid in openings 314 and cylinder 174 than the drop between the fluid in openings 314 and the fluid on the left-hand side of land 328, which communicates with tank port 176. In this position of the tilt box 63, the volume of fluid being pumped by the pump 12 is sufficient to take care of the flow through the valve 58*a* and leakage at the pump 12, as well as any other leakage in the portion of the system 10 communicating with the output side of the pump 12. At a pressure of the fluid at the openings 312 above the equilibrium pressure and below the peaking pressure of 1700 p.s.i., the spool 318 is moved slightly to the left of the position shown in FIGS. 12 and 13 to a position in which fluid leaks past the land 328 to tank and around the land 328 to the port 172 and into the cylinder 174 so as to extend the piston 62 to rotate the tilt box 63 to a position in which the amount of fluid pumped is insufficient to maintain the pressure above the equilibrium pressure. Consequently, the pressure at the openings 312 quickly falls to the equilibrium pressure and the spring 188 moves the spool 318 to the equilibrium position.

In the equilibrium position of the spool 318 shown in FIGS. 12 and 13, the force exerted on the spool by the compressed spring 188 is balanced by an equal and oppositely directed force exerted on the spool 318 by the fluid supplied through the openings 312. The construction of the valve 58*a* to provide for a continual flow around the land 328, insures stroking of the pump 12 to a substantially zero displacement position without any "hunting."

The above described action of the valve 58*a* to provide for movement of the tilt box 63 to a substantially centered position takes place very quickly and the pump 12 responds very quickly to reduce the volume of fluid being pumped since the distance the actuating arm 65 must be moved to center the tilt box 63 is small. In the event the pump output pressure at the openings 312 should momentarily be high enough to move the spool 318 to a position in which the land 328 blocks flow of fluid to the tank openings 316, the quick response of the tilt box 63 to extension of the piston 62 to provide for a reduced volume of fluid being pumped by the pump 12 and the operation of the peaking relief valve provide for an immediate reduction of the pressure of the fluid at the openings 312.

The valve 58*a* thus operates in conjunction with the peaking relief valve 202 to provide for movement of the tilt box 63 to a substantially neutral position in response to a rise in the pressure on the output side of the pump 12 above a predetermined limit pressure. In the illustrated embodiment of the invention, this pressure is about 1500 p.s.i., and is determined by the strength of the spring 188. If the spring 188 is of a slightly reduced strength, this pressure will be slightly lower and if the spring is of a slightly greater strength, this pressure will be slightly higher. The size of the openings 314 relative to the land 328 determines the volume of fluid which will leak past the land 328 to tank and the smaller this volume is the less work that is required from the pump 12 in the substantially zero displacement position of the tilt box 63. In the illustrated embodiment of the invention about one quarter gallon per minute leaks past the land 328.

In the event it is desired to have the dozer blade 18

move freely up and down with respect to the front end of the tractor 12, the valve member 34 is moved to the float position illustrated in FIG. 8 in which the valve spool 66 is in a position blocking the inlet port 82 and providing for communication of the inlet port 80 with the outlet ports 74 and 76 which are blocked by the spool 66 against communication with the tank port 68. The outlet port 78 communicates with the tank port 72.

Fluid from the outlet port 74 flows through the line 158 to the inlet port 156 in the float control shut-off valve 40 and operates to move the valve member 148 against the pressure of spring 160 to a position in which the lines 142 and 144 on opposite sides of valve 40 are communicated, by a groove 149 in the valve member 148 as shown in FIG. 8, to provide for a fluid communication of opposite ends of the cylinder 20. The piston 22 is thus free to float up and down in the cylinder 20 as the dozer blade 18 moves over the ground surface, since the fluid is free to flow from one side to the other of the piston 22, complicated only by the fact that during movement of the piston rod 24 into the cylinder 20 some of the fluid being forced out of the upper end of the cylinder 20 must be bled off because it is more than enough to fill the opposite end and during movement of the piston rod out of one end of the cylinder, additional fluid must be supplied to the opposite end of the cylinder if it is to be kept full of fluid.

Fluid from the control valve outlet 76 is supplied through line 194 to the valve 56, and through the valve 56 into the cylinder 175 so as to extend the control piston 60 and rotate the tilt box 63 in a counterclockwise direction as shown in FIG. 8. The pump 12 thus pumps its full volume of fluid out the port 230 and through line 108 to holding valve 36. However, since the piston 22 is floating in the cylinder 20, the only pressure developed in line 108 is that required to overcome line loss and open valves 36 and 38, as shown in FIG. 8, and provide a complete circuit for the fluid from the pump outlet port 230 through the line 108, valves 36, 40 and 38 and the line 216 to the inlet port 232. Fluid under pressure from the control circuit supplied through the open check valve 250 to the valve 38 maintains the valve 38 open at all times in the "float" position of control valve 34 so that the piston 22 can move downwardly without "hunting."

During downward floating movement of the piston 22 in the cylinder 20, the pressure in line 216 falls because there is insufficient fluid flowing out of the lower end of cylinder 20 to supply the pump 12 with enough fluid to fill the upper end thereof since the piston rod 24 is moving out of the cylinder 20. Consequently, the fluid under supercharge pressure in line 106 opens the check valve 48 and enough of this fluid flows into the pump inlet 232 to insure filling of the upper end of the cylinder 20. During upward movement of the piston 22 a greater volume of fluid is forced out of the top end of cylinder 20 than is required to fill the cylinder 20 on the underside of piston 22 because the piston rod 24 is moving into cylinder 20. This additional fluid in the main circuit causes a rise in the pressure in line 216 sufficient to close valve 48 and move the valve member 94 to open the pilot valve 50 so that a volume of fluid equal to the volume of the fluid displaced in the cylinder 20 by the piston rod 24 can flow through the valve 50 to tank. For this reason the area of the surface of valve member 94 exposed to pressure fluid from line 110 is proportioned to the area of ball 96 to insure unseating of ball 96 when the fluid pressures applied to the ball from line 104 and to the valve member 94 from the line 110 are substantially equal.

It can thus be seen that the check valves 48 and 50 function to continuously maintain the cylinder 20 full of fluid. As a result, if downward movement of the blade 18 is desired, when the control valve 34 is in the float position, it is only necessary to move the control valve 34 to the "down" position shown in FIGS. 6 and 7 and the piston 22 will be immediately moved downwardly without any time delay. As soon as the valve 34 is moved from the "float" position (FIG. 8) to any other position, the port 74, which is connected by the line 158 to the valve 40 is connected to tank, so that the fluid under supercharge pressure supplied through the line 152 to the port 150 in the valve 40 is operative to close the valve 40.

From the above description, it is seen that this invention provides a hydraulic system in which the piston 22, which constitutes a work member, can be raised, lowered, held, or floated, without requiring unnecessary operation of the pump 12 while still providing for quick response of the piston 22 to manipulation of the control valve 34. As a result, the power required for operation of the pump 12 is then made available for other useful purposes required in the particular installation of the pump. The supercharge pump 42 provides the fluid necessary to maintain the main circuit full at all times with the check valves 48 and 50 separating the supercharge and main circuits when no fluid is to be added to or taken from the main circuit. The use of control circuit fluid to open the valve 38 prevents "hunting" of the piston 22 during the time the piston 22 is being powered down, and if desired control circuit fluid may be similarly utilized to open the valve 36 if there is any tendency for the piston 22 to hunt in the opposite direction. In the illustrated system this is not a problem and in a system where hunting of the piston 22 is not objectionable, use of control fluid to open either or both of the valves 36 and 38 is not necessary.

It will be understood that the specific construction of the improved control system for variable displacement pumps and similar devices which is herein disclosed and described is presented for purposes of explanation and illustration and is not intended to indicate limits of the invention, the scope of which is defined by the following claims.

What is claimed is:

1. In a hydraulic control system for a variable displacement pump having an actuating member for varying displacement, and a hydraulically actuable device operable by fluid from said pump: actuating means movable in response to a supply of fluid under pressure thereto for moving said actuating member to and from a first position in which the displacement of said pump is zero and a second position in which said displacement is maximum; fluid supply and return lines connecting said pump and said device; means independent of said pump for supplying fluid at a control pressure; valve means for communicating said fluid at control pressure to said actuating means to move said member to increase the displacement and hence output of said pump, and means responsive to the pressure of the output fluid from said pump in said supply line to communicate said output fluid to said actuating means to move said member in the opposite direction to decrease the displacement of said pump to a substantially zero-flow equilibrium position when said output pressure reaches a predetermined high pressure.

2. In a hydraulic control system for a variable displacement pump having an actuating member for varying displacement, and a hydraulically actuable device operable by fluid from said pump: actuating means movable in response to a supply of fluid under pressure thereto for moving said actuating member to and from a first at-rest position in which the displacement of said pump is zero and a second position in which said displacement is maximum; spring means for resisting movement of said member by said actuating means away from said first position, said spring means being restrained and prestressed so as to allow movement of said member away from said first position only when a substantial force is applied thereto by said actuating means; fluid supply and return lines connecting said pump and said device; means independent of said pump for supplying fluid at a control pressure; valve means for communicating said fluid at control pressure to said actuating means to move said member to increase the displacement and hence output of said pump, and means responsive to the pressure of the output fluid from said pump in said supply line to com-

municate said output fluid to said actuating means to move said member in the opposite direction to decrease the displacement of said pump to a substantially zero-flow equilibrium position when said output pressure reaches a predetermined high pressure.

3. In a hydraulic control system for a variable displacement pump having an actuating member for varying displacement, and a hydraulically actuable device operable by fluid from said pump: actuating means including a double-acting piston unit movable in response to a supply of fluid under pressure thereto for moving said actuating member to and from a position in which the displacement of said pump is zero and a position in which said displacement is maximum; fluid supply and return lines connecting said pump and said device; a fluid reservoir; means independent of said pump for supplying fluid from said reservoir at a control pressure; and valve means operable in a first position to communicate said fluid at control pressure to one side of said double-acting piston unit to move said member to increase the displacement and hence output of said pump, said valve means being responsive to the pressure of the output fluid from said pump in said supply line and operable in a second position to communicate said output fluid to the opposite side of said double-acting piston unit to move said member in the opposite direction to decrease the displacement of said pump to a substantially zero-flow equilibrium position when said output pressure reaches a predetermined high pressure.

4. A system as claimed in claim 3, wherein said valve means is operable in said first position to communicate said opposite side of said double-acting piston unit with said reservoir, and in said second position to substantially block communication between said opposite side and said reservoir.

5. A system as claimed in claim 3, wherein said valve means comprises a housing having a bore therein, a passageway connecting said bore to the side of said double-acting piston unit not subject to control pressure, a spool having a land slidable in said bore relative to said passageway, said bore adapted to communicate on one side of said land with said supply line and on the other side of said land with said reservoir, said spool land normally blocking communication between said passageway and said supply line and being movable from said normal position to progressively restrict communication between said passageway and said reservoir and progressively admit fluid from said supply line to said passageway in response to a predetermined high pressure in said supply line, whereby said spool assumes an equilibrium position in which the amount of fluid flowing into said passageway from said supply line substantially equals the amount of fluid flowing from said passageway to said reservoir and the total forces exerted on said unit are substantially balanced to maintain said pump in an equilibrium positive displacement position in which said predetermined high pressure is maintained and a limited flow is provided through said valve for said unit.

6. In a hydraulic control system for a reversible variable displacement pump having an actuating member for varying displacement, and a hydraulically actuable device operable by fluid from said pump; actuating means including a double-acting piston unit movable in response to a supply of fluid under pressure thereto for moving said actuating member through an at-rest zero displacement position to and from a position in which the displacement of said pump is maximum for one direction of flow and a position in which said displacement is maximum for the opposite direction of flow; fluid supply and return lines connecting said pump and said device; a fluid reservoir; means independent of said pump for supplying fluid from said reservoir at a control pressure; valve means for selectively communicating said fluid at control pressure to one side or the other side of said piston unit to move said member to increase the displacement and hence output of said pump in either said one or said opposite directions respectively, and means responsive to the pressure of the output fluid from said pump in said supply line to communicate said output fluid to the side of said piston unit not subject to control pressure to move said member to decrease the displacement of said pump to a substantially zero-flow equilibrium position when said output pressure reaches a predetermined high pressure.

7. In a hydraulic control system for a reversible variable displacement pump having an actuating member for varying displacement, and a hydraulically actuable device operable by fluid from said pump: actuating means including a double-acting piston unit movable in response to a supply of fluid under pressure thereto for moving said actuating member through an at-rest zero displacement position to and from a position in which the displacement of said pump is maximum for one direction of flow and a position in which said displacement is maximum for the opposite direction of flow; spring means for resisting movement of said member by said double-acting piston unit in either direction away from said at-rest zero-displacement position, said spring means being restrained and prestressed so as to allow movement of said member away from said zero displacement position in either direction only when a substantial force is applied thereto by said actuating means, fluid supply and return lines connecting said pump and said device; a fluid reservoir; means independent of said pump for supplying fluid from said reservoir at a control pressure; and valve means for selectively communicating said fluid at control pressure to one side or the other side of said piston unit to move said member to increase the displacement and hence output of said pump in either said one or said opposite directions respectively, said valve means being responsive to the pressure of the output fluid from said pump in said supply line to communicate said output fluid to the side of said piston unit not subject to control pressure to move said member to decrease the displacement of said pump to a substantially zero-flow equilibrium position when said output pressure reaches a predetermined high pressure.

8. In a hydraulic control system for a reversible variable displacement pump having an actuating member for varying displacement, and a hydraulically actuable device operable by fluid from said pump: actuating means including a double-acting piston unit movable in response to a supply of fluid under pressure thereto for moving said actuating member through an at-rest zero displacement position to and from a position in which the displacement of said pump is maximum for one direction of flow and a position in which said displacement is maximum for the opposite direction of flow; fluid supply and return lines connecting said pump and said device; a fluid reservoir; means independent of said pump for supplying fluid from said reservoir at a control pressure; and valve means for selectively communicating said fluid at control pressure to one side or the other side of said piston unit and said reservoir with the opposite side thereof to move said member to increase the displacement and hence output of said pump in either said one or said opposite directions respectively, said valve means being responsive to the pressure of the output fluid from said pump in said supply line to substantially block said communication between said reservoir and the side of said piston unit not subject to control pressure and to communicate said output fluid thereto to move said member to decrease the displacement of said pump to a substantially zero-flow equilibrium position when said output pressure reaches a predetermined high pressure.

9. A system as claimed in claim 7, wherein said valve means comprises a housing having a bore therein, a passageway connecting said bore to the side of said double-acting piston unit not subject to control pressure, a spool having a land slidable in said bore relative to said passageway, said bore adapted to communicate on one side of

said land with said supply line and on the other side of said land with said reservoir, said spool land normally blocking communication between said passageway and said supply line and being movable from said normal position to progressively restrict communication between said passageway and said reservoir and progressively admit fluid from said supply line to said passageway in response to a predetermined high pressure in said supply line, whereby said spool assumes an equilibrium position in which the amount of fluid flowing into said passageway from said supply line substantially equals the amount of fluid flowing from said passageway to said reservoir and the total forces exerted on said unit are substantially balanced to maintain said pump in an equilibrium positive displacement position in which said predetermined high pressure is maintained and a limited flow is provided through said valve for said unit.

10. In a hydraulic control system for a reversible variable displacement pump and a reversible hydraulically actuatable device operable by fluid from said pump: a member that is movable in opposite directions to control the direction and magnitude of the pump displacement; hydraulically operable means for moving said member in opposite directions between a zero pump displacement position and a maximum pump displacement position for each direction of flow; spring means arranged to resist movement of said member by said hydraulically operable means in either direction away from said zero pump displacement position, said spring means being restrained and prestressed so as to allow movement of said member away from said zero displacement position in either direction only when a substantial force is applied thereto by said hydraulically operable means; and means including a control valve operable in one position to supply fluid to said hydraulically operable means to move said member in one direction against said spring means to increase the displacement of said pump in one direction and in a second position to supply fluid to said hydraulically operable means to move said member in an opposite direction against said spring means to increase the displacement of said pump in the opposite direction.

11. In a hydraulic control system for a variable displacement pump having inlet and outlet ports and a hydraulically actuatable cylinder assembly consisting of a cylinder, a piston, and a piston rod projecting through one end of the cylinder, first passage means communicating the inlet and outlet ports on said pump with opposite ends of said cylinder, a supercharge circuit including a second pump, second passage means connecting said second pump and said first passage means, check valve means in said second passage means movable to an open position when the pressure in said second passage means is above the pressure in said first passage means to provide for flow of fluid from said second pump into said first passage means when said piston rod is moving out of said cylinder, tank means communicating with said second passage means, second check valve means in said second passage means, and means responsive to fluid pressure in the rod end of said cylinder for moving said second check valve means to an open position to provide for flow of fluid therethrough to said tank when said piston rod is moving into said cylinder.

12. In a hydraulic control system for a variable displacement pump having a pair of ports operable to pump fluid in either of two directions so that when the pump is pumping in one direction one port functions as an inlet port and the other port functions as an outlet port and when the pump is pumping in the opposite direction said other port functions as an inlet port and said one port functions as an outlet port, and wherein said pump is connected to a hydraulic cylinder assembly including a cylinder having a working piston slidably mounted therein, said system comprising first passage means extending between one of said ports and one end of said cylinder, second passage means extending between said other one of said ports and the opposite end of said cylinder, a first pilot-operated check valve in said first passage means operable in response to the pressure of fluid from said pump in said first passage means to admit said fluid to said cylinder to move said piston in one direction, a pilot line connecting said first check valve and said second passage means for opening said first check valve in response to a predetermined high pressure in said second passage means, a second pilot-operated check valve in said second passage means operable in response to the pressure of fluid from said pump in said second passage means to admit fluid to said cylinder to move said piston in the opposite direction, means for opening said second check valve when a predetermined high pressure exists in said first passage means, a pilot-operated float-control valve connected to opposite ends of said cylinder, a pilot line communicating with said float-control valve, and means for selectively supplying fluid under pressure to said float-control pilot line to open said float-control valve, whereby when all of said valves are closed said piston is fluid-locked against movement in either direction in said cylinder, when said float-control valve is open said piston is freely movable in said cylinder, and when said float-control valve is closed and said pump is pumping fluid under pressure through said first passage means said piston is moved in said one direction and when said pump is pumping fluid under pressure through said second passage means said piston is moved in said opposite direction.

13. In a hydraulic control system for a variable displacement pump having a pair of ports operable to pump fluid in either of two directions so that when the pump is pumping in one direction one port functions as an inlet port and the other port functions as an outlet port and when the pump is pumping in the opposite direction said other port functions as an inlet port and said one port functions as an outlet port, and wherein said pump is connected to a hydraulic cylinder assembly including a cylinder having a working piston slidably mounted therein: first passage means extending between one of said ports and one end of said cylinder, second passage means extending between said other one of said ports and the opposite end of said cylinder, a first pilot-operated check valve in said first passage means operable in response to the pressure of fluid from said pump in said first passage means to admit said fluid to said cylinder to move said piston in one direction, a first pilot line connecting said first check valve to said second passage means for opening said first check valve in response to a predetermined high pressure in said second passage means, a second pilot-operated check valve in said second passage means operable in response to the pressure of fluid from said pump in said second passage means to admit fluid to said cylinder to move said piston in the opposite direction, a second pilot line communicating with said second check valve, a hydraulic control circuit operatively associated with said pump for controlling the direction in which said pump pumps, means connecting said control circuit with said second pilot line to communicate fluid thereto to open said second check valve when said pump is pumping into said first passage means to move said piston in said one direction, a pilot-operated float-control valve connected to opposite ends of said cylinder, a pilot line communicating with said float-control valve, and means for selectively supplying fluid under pressure to said float-control pilot line to open said float-control valve, whereby when all of said valves are closed said piston is fluid-locked against movement in either direction in said cylinder, when said float-control valve is open said piston is freely movable in said cylinder, and when said float-control valve is closed and said pump is pumping fluid under pressure through said first passage means said piston is moved in said one direction and when said pump is pumping fluid under pressure through said second passage means said piston is moved in said opposite direction.

14. In a hydraulic control system for a variable displacement pump having a pair of ports and operable to pump fluid in either of two directions so that when the pump is pumping in one direction one port functions as an inlet port and the other port functions as an outlet port and when the pump is pumping in an opposite direction said other port functions as an inlet port and said one port functions as an outlet port, and wherein said pump is connected to a hydraulic cylinder assembly which includes a cylinder having a piston mounted therein and a load carrying piston rod attached to the piston and extending through one end of the cylinder, said system comprising first passage means extending between said one of said ports and said one end of said cylinder, second passage means extending between said other one of said ports and the opposite end of said cylinder, a first pilot-operated check valve in said first passage means operable in response to the pressure of fluid from said pump to admit said fluid to said cylinder, a first pilot line extending between said first check valve and said second passage means providing for opening of said check valve in response to a predetermined high pressure in said second passage means, a second pilot-operated check valve in said second passage means operable in response to the pressure of fluid from said pump to admit fluid to said cylinder, a second pilot line extending between said second check valve and said first passage means providing for opening of said second check valve in response to a predetermined high pressure in said first passage means, a pilot-operated float control valve connected to opposite ends of said cylinder, a third pilot line connected to said float control valve for supplying fluid under pressure to the float control valve so as to open the valve, and means for selectively supplying fluid under pressure to said third pilot line, whereby when all of said valves are open said piston is freely movable in said cylinder, when all of said valves are closed the piston is fluid-locked against movement in either direction in said cylinder, when said float control valve is closed and said pump is pumping fluid under pressure out of said first port and through said first passage means to said one end of the cylinder the piston is moved toward the opposite end of the cylinder, and when said pump is pumping fluid under pressure out said second port and through said second passage means to said other end of the cylinder the piston is moved toward said one end of the cylinder.

15. In a hydraulic control system for a variable displacement pump wherein said pump is connected to a hydraulic cylinder assembly which includes a cylinder having a piston mounted therein and a load-carrying piston rod attached to the piston and extending through one end of the cylinder, said system comprising first passage means extending between said pump and said one end of said cylinder, second passage means extending between said pump and the opposite end of said cylinder, said pump being operable to pump fluid in a first direction such that it travels out said first passage means for return through said second passage means and in a second direction such that it travels out said second passage means for return through said first passage means, a first pilot-operated check valve in said first passage means operable in response to the pressure of fluid from said pump to admit said fluid to said cylinder, a first pilot line extending between said first check valve and said second passage means providing for opening of said check valve in response to a predetermined high pressure in said second passage means, a second pilot-operated check valve in said second passage means operable in response to the pressure of fluid from said pump to admit fluid to said cylinder, a second pilot line extending between said second check valve and said first passage means providing for opening of said second check valve in response to a predetermined high pressure in said first passage means, a pilot-operated float control valve connected to opposite ends of said cylinder, a pilot line connected to said float control valve for supplying fluid under pressure to the float control valve so as to open the valve, and means for selectively supplying fluid under pressure to said pilot line, whereby when all of said valves are open said piston is freely movable in said cylinder, when all of said valves are closed the piston is fluid-locked against movement in either direction in said cylinder, when said float control valve is closed and said pump is pumping fluid under pressure through said first passage means to said one end of the cylinder the piston is moved toward the opposite end of the cylinder, and when said pump is pumping fluid under pressure through said second passage means to said other end of the cylinder the piston is moved toward said one end of the cylinder, a hydraulic control circuit operatively associated with said pump for actuating the pump to determine the direction of flow in said first and second passage means and means connecting said control circuit and said first pilot line to provide for a flow of fluid into said first pilot line so as to open said first check valve when said variable displacement pump is pumping fluid in said second direction.

16. In a hydraulic control system for a variable displacement pump connected by a main circuit to opposite ends of a hydraulic cylinder having a piston therein and a piston rod connected thereto and extending through one end of the cylinder, and wherein said main circuit includes a first line extending between one pump port and the closed end of said cylinder and a second line extending between another pump port and the rod end of said cylinder, a fluid reservoir, a supercharge circuit connected to said reservoir and said second line in said main circuit for supplying fluid from the reservoir to the main circuit when said piston rod is moving out of said cylinder, means providing a path from said first line to said reservoir for fluid displaced by the piston rod during movement of the rod into the cylinder, said supercharge circuit including a pump connected to said reservoir, a first check valve communicating on one side with said supercharge pump and on the opposite side with said second main circuit line and movable to an open position by a high pressure on said one side, a normally closed pilot-operated check valve in said path and communicating on one side with said reservoir and on the opposite side with said first line, a pilot line communicating said pilot-operated check valve with said cylinder on the piston rod side of said piston so that when fluid under pressure is supplied to said cylinder so as to move the piston in a direction moving the piston rod into the cylinder the pressure in the pilot line maintains said pilot-operated check valve in an open position so that excess fluid in the main circuit can flow through the pilot-operated check valve to the reservoir.

17. In a hydraulic control system for a variable displacement pump having a pair of inlet and outlet ports and a hydraulically acuatable device operable by fluid from said pump, a member that is movable from a zero displacement position to control the pump displacement, means engaged with one side of said movable member for urging the member in one direction to a position corresponding to a first positive displacement condition of said pump in which fluid is pumped out one of said ports, a piston and cylinder unit engaged with the opposite side of said movable member, means associated with said unit for resisting retraction thereof on movement of said movable member in said one direction, said unit being extendible by fluid under pressure supplied thereto to thereby move said movable pump member in an opposite direction to a position corresponding to a second positive displacement condition of said pump in which fluid is pumped out another one of said ports, a reservoir for fluid, a valve for said unit controlling communication between said unit and the outlet port for said pump and communication between said unit and said reservoir when said pump is in said first positive displacement condition, said valve including a member formed with a bore and an opening communicating with said bore and said unit, a spool member having a land slidable in said bore rela-

tive to said opening, said bore communicating on one side of said land with said outlet port and on the other side of said land with said reservoir, said spool land normally closing communication between said opening and said outlet port and being movable from said normal position to progressively restrict communication between said opening and said reservoir and progressively admit fluid from said outlet port to said opening in response to pressure at said outlet port whereby the spool assumes an equilibrium position in which the amount of fluid flowing into said opening from said outlet port substantially equals the amount of fluid flowing from said outlet port to said reservoir and the total force exerted on said unit by the fluid therein and said resisting means will substantially balance the force exerted on said movable member by said urging means and will maintain said pump in a positive displacement condition maintaining a limited flow through said pump.

18. In a hydraulic control system for a variable displacement pump which is connected by a main circuit to opposite ends of a hydraulic cylinder having a piston therein which has a piston rod extending through one end of the cylinder, a fluid reservoir, a supercharge circuit connected to said reservoir and said main circuit for supplying fluid to the main circuit when said piston rod is moving out of said cylinder and for providing a path to said reservoir for fluid displaced by the piston rod during movement of the rod into the cylinder, said pump including an actuating member movable in one direction to operate said pump so that fluid under pressure is pumped to one end of said cylinder and movable in an opposite direction to operate said pump so that fluid under pressure is pumped to the opposite end of said cylinder, fluid operable means operatively associated with said actuating member, said fluid operable means being arranged so that when fluid under pressure is supplied to one side thereof said actuating member is moved in said one direction and when fluid under pressure is supplied to the opposite side thereof said actuating member is moved in said opposite direction, control valve means, pump means connected to said control valve means and communicating with said fluid reservoir, and fluid passage means connecting the control valve means to said fluid operable means, said control valve means being movable to a plurality of positions to provide for a selective flow of fluid from said pump means to either side of said fluid operable means or to said reservoir, a pilot-operated float control valve connected to opposite ends of said cylinder, a pilot line connecting said control valve means and said float control valve and operable in one position of said control valve means to supply fluid to said float control valve so as to open the float control valve.

19. In a hydraulic control system for a variable displacement pump having a pair of ports and operable to pump fluid in either of two directions so that when the pump is pumping in one direction one port functions as an inlet port and the other port functions as an outlet port and when the pump is pumping in an opposite direction said other port functions as an inlet port and said one port functions as an outlet port, and wherein said pump is connected to a hydraulic cylinder assembly which includes a cylinder having a piston mounted therein and a piston rod attached to the piston and extending through one end of the cylinder, said system comprising first passage means extending between said one of said ports and said one end of said cylinder, second passage means extending between said other one of said ports and the opposite end of said cylinder, a first pilot operated check valve in said first passage means operable in response to the pressure of fluid from said pump to admit said fluid to said cylinder, a first pilot line extending between said first check valve and said second passage means providing for opening of said check valve in response to a predetermined high pressure in said second passage means, a second pilot operated check valve in said second passage means operable in response to the pressure of fluid from said pump to admit fluid to said cylinder, a second pilot line extending between said second check valve and said first passage means providing for opening of said check valve in response to a predetermined high pressure in said first passage means, each of said check valves including a casing having a pair of spaced main ports and a valve seat disposed generally between said ports, a valve member movable in said casing into engagement with said seat, means in said casing on one side of said seat engaged with said valve member urging the valve member toward said seat, said one side of said valve member being in fluid communication with one of said main ports in all moved positions of said valve member, said casing having a pilot port on the opposite side of said valve member, means in said casing on said opposite side of said valve member responsive to fluid pressure at said pilot port for moving said valve member off the seat therefor, and said pair of main ports being connectible in the passage means for said check valve so that fluid from said pump flows into said casing on said opposite side of said seat.

20. In a hydraulic control system for a variable displacement pump including a member that is movable in opposite directions from a zero displacement position to control the pump displacement and a hydraulically actuatable device connected by a main hydraulic circuit with said pump for operation thereby, a pair of pistons engaged with opposite sides of said movable member, cylinders telescopically supporting said pistons, each of said pistons being extendible in a direction out of its telescopic support by fluid under pressure supplied to said support to thereby move said movable pump member in one direction, control pump means, a reservoir for fluid, means including a control valve connecting said control pump means and said cylinder supports so that in one position of the control valve fluid is supplied to one of said cylinder supports and the other cylinder support is communicated with said reservoir so that said member is moved in one direction and in a second position fluid is supplied to said other cylinder support and said one support is communicated with said reservoir so that the member is moved in an opposite direction, passage means communicating said main circuit and said cylinder supports, normally closed valve means preventing flow of fluid from said passage means into said cylinder supports, said valve means being movable to a position providing for flow of fluid into the one of said cylinder supports which when extended moves said movable pump member toward a zero displacement position in response to a predetermined high pressure in said main circuit.

21. In a hydraulic control system for a variable displacement pump having a pair of inlet and outlet ports and a hydraulically actuatable device operable by fluid from said pump, a member that is movable from a zero displacement position to control the pump displacement, means engaged with one side of said movable member for urging the member in one direction to a position corresponding to a first positive displacement condition of said pump in which fluid is pumped out one of said ports, a piston and cylinder unit engaged with the opposite side of said movable member, means associated with said unit for resisting retraction thereof on movement of said movable member in said one direction, said unit being extendible by fluid under pressure supplied thereto to thereby move said movable pump member in an opposite direction to a position corresponding to a second positive displacement condition of said pump in which fluid is pumped out another one of said ports, a reservoir for fluid, a valve for said unit controlling communication between said unit and the outlet port for said pump and communication between said unit and said reservoir when said pump is in said first positive displacement condition, said valve normally closing com-

munication between said unit and said outlet port and being movable from said normal position to progressively restrict communication between said unit and said reservoir and progressively admit fluid from said outlet port to said valve unit in response to pressure at said outlet port whereby the valve assumes an equilibrium position in which the amount of fluid flowing into said valve from said outlet port substantially equals the amount of fluid flowing from said valve to said reservoir and the total force exerted on said unit by the fluid therein and said resisting means will substantially balance the force exerted on said movable member by said urging means and will maintain said pump in a positive displacement condition maintaining a limited flow through said pump.

22. In a hydraulic control system for a variable displacement pump having an inlet and an outlet and a hydraulically actuatable device operable by fluid from said pump, a member that is movable from a zero displacement position to control the pump displacement, a pair of piston and cylinder units engaged with opposite sides of said movable member, each of said units being extendible by fluid under pressure supplied thereto to thereby move said movable pump member in one direction to a position corresponding to a positive displacement condition of said pump, spring means associated with each of said units resisting extension of the other unit, means including a hydraulic control circuit for supplying fluid to said units to control the output of the pump, a reservoir for fluid, means including a control valve in said control circuit movable to a position in which fluid from said control circuit is supplied to one of said units so that said member is moved and the pump operates to pump fluid through said outlet, a valve for the other one of said units controlling communication between said other unit and the outlet and controlling communication between said other unit and said reservoir when said pump is in a positive displacement condition caused by extension of said one unit, said valve normally closing communication between said other unit and said outlet and being movable from said normal position to progressively restrict communication between said other unit and said reservoir and progressively admit fluid from said outlet to said other unit in response to pressure at said outlet whereby the valve assumes an equilibrium position in which the amount of fluid flowing into said valve from said outlet substantially equals the amount of fluid flowing out of said valve to said reservoir and the total force exerted on said other unit by the fluid therein and the spring therefor will substantially balance the fluid pressure force on said one unit and which will maintain said pump in a positive displacement condition maintaining a limited flow through said pump.

23. In a hydraulic control system for a variable displacement pump having a pair of ports operable to pump fluid in either of two directions so that when the pump is pumping in one direction one port functions as an inlet port and the other port functions as an outlet port and when the pump is pumping in the opposite direction said other port functions as an inlet port and said one port functions as an outlet port, and wherein said pump is connected to a hydraulic cylinder assembly including a cylinder having a working piston slidably mounted therein, said system comprising first passage means extending between one of said ports and one end of said cylinder, second passage means extending between said other one of said ports and the opposite end of said cylinder, a first pilot-operated check valve in said first passage means operable in response to the pressure of fluid from said pump in said first passage means to admit said fluid to said cylinder to move said piston in one direction, means for opening said first check valve when a predetermined high pressure exists in said second passage means, a second pilot-operated check valve in said second passage means operable in response to the pressure of fluid from said pump in said second passage means to admit fluid to said cylinder to move said piston in the opopsite direction, and means for opening said second check valve when a predetermined high pressure exists in said first passage means.

24. In a hydraulic control system for a variable displacement pump having a pair of ports operable to pump fluid in either of two directions so that when the pump is pumping in one direction one port functions as an inlet port and the other port functions as an outlet port and when the pump is pumping in the opposite direction said other port functions as an inlet port and said one port functions as an outlet port, and wherein said pump is connected to a hydraulic cylinder assembly including a cylinder having a working piston slidably mounted therein, said system comprising first passage means extending between one of said ports and one end of said cylinder, second passage means extending between said other one of said ports and the opposite end of said cylinder, a first pilot-operated check valve in said first passage means operable in response to the pressure of fluid from said pump in said first passage means to admit said fluid to said cylinder to move said piston in one direction, means for opening said first check valve in response to a predetermined high pressure in said second passage means, a second pilot-operated check valve in said second passage means operable in response to the pressure of fluid from said pump in said second passage means to admit fluid to said cylinder to move said piston in the opposite direction, and means for opening said second check valve when a predetermined high pressure exists in said first passage means.

25. In a hydraulic control system for a variable displacement pump having a pair of ports operable to pump fluid in either of two directions so that when the pump is pumping in one direction one port functions as an inlet port and the other port functions as an outlet port and when the pump is pumping in the opposite direction said other port functions as an inlet port and said one port functions as an outlet port, and wherein said pump is connected to a hydraulic cylinder assembly including a cylinder having a working piston slidably mounted therein, said system comprising first passage means extending between one of said ports and one end of said cylinder, second passage means extending between said other one of said ports and the opposite end of said cylinder, a first pilot-operated check valve in said first passage means operable in response to the pressure of fluid from said pump in said first passage means to admit said fluid to said cylinder to move said piston in one direction, a pilot line connecting said first check valve and said second passage means for opening said first check valve in response to a predetermined high pressure in said second passage means, a second pilot-operated check valve in said second passage means operable in response to the pressure of fluid from said pump in said second passage means to admit fluid to said cylinder to move said piston in the opposite direction, and means for opening said second check valve when a predetermined high pressure exists in said first passage means.

26. In a hydraulic control system for a variable displacement pump having a pair of ports operable to pump fluid in either of two directions so that when the pump is pumping in one direction one port functions as an inlet port and the other port functions as an outlet port and when the pump is pumping in the opposite direction said other port functions as an inlet port and said one port functions as an outlet port, and wherein said pump is connected to a hydraulic cylinder assembly including a cylinder having a working piston slidably mounted therein, said system comprising first passage means extending between one of said ports and one end of said cylinder, second passage means extending between said other one of said ports and the opposite end of said cylinder, a

first pilot-operated check valve in said first passage means operable in response to the pressure of fluid from said pump in said first passage means to admit said fluid to said cylinder to move said piston in one direction, means for opening said first check valve in response to a predetermined high pressure in said second passage means, a second pilot-operated check valve in said second passage means operable in response to the pressure of fluid from said pump in said second passage means to admit fluid to said cylinder to move said piston in the opposite direction, and means for opening said second check valve in response to a predetermined high pressure in said first passage means.

27. In a hydraulic control system for a variable displacement pump having a pair of ports operable to pump fluid in either of two directions so that when the pump is pumping in one direction one port functions as an inlet port and the other port functions as an outlet port and when the pump is pumping in the opposite direction said other port functions as an inlet port and said one port functions as an outlet port, and wherein said pump is connected to a hydraulic cylinder assembly including a cylinder having a working piston slidably mounted therein: first passage means extending between one of said ports and one end of said cylinder, second passage means extending between said other one of said ports and the opposite end of said cylinder, a first pilot-operated check valve in said first passage means operable in response to the pressure of fluid from said pump in said first passage means to admit said fluid to said cylinder to move said piston in one direction, a first pilot line connecting said first check valve to said second passage means for opening said first check valve in response to a predetermined high pressure in said second passage means, a second pilot-operated check valve in said second passage means operable in response to the pressure of fluid from said pump in said second passage means to admit fluid to said cylinder to move said piston in the opposite direction, a second pilot line communicating with said second check valve, a hydraulic control circuit operatively associated with said pump for controlling the direction in which said pump pumps, and means connecting said control circuit with said second pilot line to communicate fluid thereto to open said second check valve when said pump is pumping into said first passage means to move said piston in said one direction.

28. In a hydraulic control system for a variable displacement pump having a pair of ports and operable to pump fluid in either of two directions so that when the pump is pumping in one direction one port functions as an inlet port and the other port functions as an outlet port and when the pump is pumping in an opposite direction said other port functions as an inlet port and said one port functions as an outlet port, and wherein said pump is connected to a hydraulic cylinder assembly which includes a cylinder having a piston mounted therein and a piston rod attached to the piston and extending through one end of the cylinder, said system comprising first passage means extending between said one of said ports and said one end of said cylinder, second passage means extending between said other one of said ports and the opposite end of said cylinder, a first pilot operated check valve in said first passage means operable in response to the pressure of fluid from said pump to admit said fluid to said cylinder, a first pilot line extending between said first check valve and said second passage means providing for opening of said check valve in response to a predetermined high pressure in said second passage means, a second pilot operated check valve in said second passage means operable in response to the pressure of fluid from said pump to admit fluid to said cylinder, and a second pilot line extending between said second check valve and said first passage means providing for opening of said second check valve in response to a predetermined high pressure in said first passage means.

29. In a hydraulic control system for a variable displacement pump having an inlet and an outlet and a hydraulically actuatable device operable by fluid from said pump, a member that is movable in opposite directions from a zero displacement position to control the pump displacement, a pair of piston and cylinder units engaged with opposite sides of said movable member, each of said units being extendible by fluid under pressure supplied thereto to thereby move said movable pump member in one direction, spring means associated with each of said units resisting extension of the other unit, means including a hydraulic control circuit for supplying fluid to said units to control the output of the pump, a reservoir for fluid, means including a control valve in said control circuit movable to a position in which fluid from said control circuit is supplied to one of said units so that said member is moved in one direction and the pump operates to pump fluid through said outlet, a valve for each of said units controlling communication between its unit and the outlet and controlling communication between its unit and the reservoir in a position of said movable member caused by extension of the other unit, each of said valves normally closing communication between its unit and the outlet and being movable from said normal position in response to a predetermined high pressure at said outlet to progressively restrict communication between its unit and said reservoir and progressively admit fluid from said outlet to its unit whereby the valve assumes an equilibrium position in which the amount of fluid flowing into said valve from said outlet is substantially equal to the amount of fluid flowing from the valve to the reservoir and the total force exerted on said unit by the fluid therein and the spring therefor will substantially balance the force exerted on said movable pump member by said other unit and will maintain said pump in a positive displacement condition maintaining a limited flow through said pump.

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