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(54) VARIABLE DISPLACEMENT PUMP HAVING PRESSURE COMPENSATOR CONTROL MEANS

(71) We, CATERPILLAR TRACTOR CO., a corporation organised and existing under the laws of the State of California, United States of America, of 100 N.E. Adams Street, Peoria, State of Illinois 61602, United States of America, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention is directed to a variable displacement pump of the type having a plurality of rotatable, axially-aligned pistons guided by a nonrotatable, tiltable swash plate which enables adjustment of pump displacement by the operation of pressure compensator control means.

Currently, constant displacement, as opposed to variable displacement, pumps are widely used as a source of fluid pressure to power hydraulic circuits in many applications. For example, constant displacement pumps are used to power hydraulic implement circuits on heavy construction equipment such as tractors. In this application there is no provision for returning pump flow to tank when the implement control valves are in a neutral position unless an open-center system is used. However, with this type of system, an additional amount of engine horsepower is needed to drive the constant delivery pump at maximum-relief valve pressure even when no actuating fluid is demanded by the system. This, in turn, results in an undesirable, excessive amount of heat generation in the hydraulic system.

Also, separate and apart from the problem of wasted engine horsepower and undesirable heat generation resulting from operation of the pump at the neutral or no-load condition, there is the problem of cooling system overloading caused by continued operation of the pump at the maximum displacement position even after a predetermined maximum pressure is reached. This requires corrective action in the form of re-

turning the pump to its minimum displacement position upon attaining the predetermined maximum pressure.

It is to a solution of these and other problems that the invention of this disclosure is directed.

According to the invention we provide a variable displacement axial piston pump of the type having a housing containing an inlet port and a discharge port, a plurality of pistons and an angularly-adjustable swash plate for determining piston displacement and thereby the amount of fluid discharged from the pump, resilient means in a first cartridge assembly biasing the swash plate to its maximum discharge position whereby a maximum of fluid is displaced by the pump and pressure responsive means in a second cartridge assembly for suddenly shifting said swash plate to its maximum discharge position in response to a pressure such as from a hydraulic system whereby sharp cut-off of pump flow occurs thereby curtailing heat generation and horsepower loss, and further including reversing means whereby interchanging said first cartridge assembly with said second cartridge assembly causes the pump flow direction to be reversed.

Advantages of the present invention will become apparent from the following description and claims as illustrated in the accompanying drawings which, by way of illustration only, show a preferred embodiment of the present invention and the principles of operation thereof. In the drawings:—

Fig. 1 is a top plan view of a hydraulic, variable displacement pump having hydraulic pressure compensator control means installed therein;

Fig. 2 is a vertical, cross-sectional view of the variable displacement pump taken along line II—II of Fig. 1, and illustrating in detail the mechanism for changing the displacement of the pump;

Fig. 3 is a graphical illustration of the pump flow/pressure characteristics of the

variable flow displacement pump of the subject invention.

Referring now to Fig. 1, there is shown generally at 10 a top view of a variable displacement pump containing two vertical bores 12, 14 which are offset from the pump center line. These bores contain the mechanisms for changing the pump displacement, as will be hereinafter described. The pump body consists of a head 16 seated upon a housing 18. Contained within the head is an inlet passage 20 and an outlet passage 22.

Referring now to Fig. 2, there is shown a vertical, cross-sectional view of variable displacement pump 10 taken along line II—II in Fig. 1. A pump cylinder barrel 24, having a plurality of axially-oriented bores 26 and a plurality of reciprocally-mounted pistons therein, is located within the pump housing. The pistons are guided by a slipper pad 28 rotatably, slidably mounted on support means in the form of a nonrotatable but tiltable swash plate 30. The swash plate is pivotable about a transverse axis by means of transverse pivot pins (not shown) retained in transverse bores (not shown) in the sides of housing 18.

The angle of tilt of the swash plate 30 with respect to the axial direction of the bores 26 determines the amount of stroke or displacement of the piston 32 within their respective bores 26 in the conventional manner. Since slipper pad 28 is ball-and-socket joint connected to pistons 32 and rides on surface 34 of the swash plate, it can be seen that if the swash plate were rotated clockwise about its pivot point from the position shown, the reciprocating action of the pistons in their respective bores would be minimized. Thus, a minimum displacement of fluid would occur through outlet passage 22 by way of kidney port 36.

The operation of the invention is as follows. When all of the implement control valves on a machine (not shown) utilizing the invention are in a neutral condition, a pilot line 38 will be open to tank. Prior to pump cylinder barrel rotation, the swash plate 30 is swivelled as shown against maximum displacement stop 40 by means of a piston 42 which is biased by a spring 44 which, in turn, reacts against a housing 46 of cartridge assembly 48. A flange 50 on cartridge assembly 48 securely locates the assembly between the pump head 16 and pump housing 18. The entire assembly is secured in place within the pump body by means of a nut 52 which abuts against the top surface of head 16.

When the pump cylinder barrel 24 starts to rotate by means of shaft 54 connected to the engine or other power means (not shown), an output fluid flow will be generated along with an output fluid pressure. This output flow and pressure will be com-

municated from axial bores 26 through kidney port 36 and into passage 56. From this passage the pressure will be intercommunicated with chamber 58 formed on the end of a spool 60, by way of an annulus 62 and a passage 64. Fluid will then flow through axial passage 66 and orifice 68 of spool 60 and into chamber 70 and then to tank by way of passage 72, annulus 74 and pilot line 38.

This will cause spool 60 to shift upwardly from the position shown due to the differential pressure created by fluid flowing through orifice 68. The upward movement of spool 60 will compress spring 76 until the spool communicates annular groove 78 thereon with an annulus 80. This will vent chamber 82, wherein piston 42 is reciprocally located, to tank by way of passage 84, annulus 80, annular groove 78, and line 86 by way of passage 88. At the same time, pump pressure in passage 56, annulus 62 and kidney port 36 will be communicated to an annulus 90 via a passage 92. Pressure will be then communicated into passage 94 contained in cartridge 96 of the cartridge or capsule assembly generally shown at 98. A flange 100 on the cartridge securely locates the assembly between the pump head 16 and the pump housing 18.

Fluid under pressure in passage 94 is directed to a chamber 102 where it works against a piston 104. The force of the pressure acting on piston 104 will cause the piston to move downwardly. Since the piston is in contact with an arm extension 106 of swash plate 30, the swash plate will be swivelled in a clockwise direction toward its minimum displacement position. This minimum displacement position would be achieved when the extension 106 contacts adjustable minimum displacement stop 108. This clockwise rotation of the swash plate 30 will occur against the biasing force of spring, piston combination 44, 42 which is acting upon the opposite arm extension 110 of the swash plate. The position of the extension 106 against adjustable stop 108 corresponds to point A in the graph of Fig. 3. At this minimum displacement position, pump flow and pressure will be at a minimum, which will result in less horsepower loss and less heat generation in the system.

When one or more of the control valves on the machine are activated, line 38 will be blocked from tank by means (not shown) such that the pressures in chambers 58 and 70 will equalize and spool 60 will be moved downwardly by the influence of biasing spring 76 to the position shown in Fig. 2. In this position, system pressure is directed to passage 66, a passage 112 transversely intersecting passage 66, annulus 80, passage 84, and then into chamber 82. Since the area of piston 42 in chamber 82 is greater than

the area of piston 104 in chamber 102, piston 42 will push downwardly on the swash plate extension 110 until it is stopped at the maximum displacement position by stop 40.

5 When this occurs, pump flow and pressure will correspond to point B on the graph of Fig. 3. The pressure within the circuit will then rise in proportion to the load placed on the circuit, while pump flow is held constant as represented by the line B—C on the graph. When the system pressure reaches a predetermined maximum, as shown by point C on the curve of Fig. 3, a poppet valve 114 (as seen in Fig. 2) will open against the biasing force of a spring 116, thus venting chamber 70 to tank by way of passage 118 and line 120.

This operation also allows fluid to flow through orifice 68, which will result in a differential pressure to move spool 60 upwardly to vent chamber 82, as previously described. This action will allow the operating pressure in chamber 102 to overcome the pressure in chamber 82 and will swivel the pump back to the minimum displacement position corresponding to point D on the graph of Fig. 3. This swiveling of the swash plate will cause the sharp cutoff of pump flow along the almost vertical line C—D. As is well known in the art, very low flow and high pressure (D) will result in much less heat generation and horsepower loss than will high flow at high pressure (C).

35 Turning to Fig. 2, pump rotation will be in one direction due to the fact that the swash plate can be swivelled only in a clockwise direction. Therefore, when pump flow direction is to be changed, the capsule or cartridge assemblies 98 and 122 must also be interchanged along with stops 40 and 108, and the functions of the inlet and outlet ports will be interchanged. This interchanging may be easily accomplished with the device of the instant invention, since cartridge assemblies 98 and 122 have the same exterior circumferential dimension as well as being generally cylindrical.

In addition, and to facilitate this interchanging, the locations and dimensions of the leftmost annuli 62, 74, duplicate those of the rightmost annuli 90, 124, respectively. More particularly, annulus 74 is located at the same vertical level in the head as annulus 124 whereby interchanging of assemblies 98 and 122 results in passage 72 in cartridge assembly 48 being in fluid communication with tank line 38 by way of the annuli and passages 126, 128 and chamber 130. Access to chamber 130 may be conveniently had by means of plug 132 which is threadably secured in the top surface of head 16.

Similarly, annuli 62 and 90 are located at the same vertical level in the head. Passage 134 and line 136 leading to tank are provided so as to correspond with their counterparts numbered 88, 86. Obviously, when the assemblies are located as shown in Fig. 2, cartridge 96 obturates passage 134 and annulus 124 whereby these elements are unused.

70 To interchange the assemblies, head 16 is removed from housing 18 by detaching fastening means (not shown). Threaded plug 138 is unscrewed from its mating opening in the end of cartridge 96 and nut 52 is similarly unscrewed from the threaded end of assembly 48. The respective cartridges are interchanged, plug 138 and nut 52 resecured, and the head 16 resecured to housing 18. As aforementioned, an intermediate step of exchanging stops 40 and 108 would also be accomplished.

75 It will be seen that there is provided a variable displacement pump having pressure compensator control means operable to control pump displacement in response to system pressure. The pressure compensator control means serves to automatically change the pump displacement from maximum to minimum when the system pressure reaches a predetermined maximum value, thereby limiting horsepower loss and preventing excessive heat generation, and can utilize pilot operation for controlling pump displacement whereby more stability and less hunting and overshoot are encountered when a change in displacement is required.

WHAT WE CLAIM IS:—

100 1. A variable displacement axial piston pump of the type having a housing containing an inlet port and a discharge port, a plurality of pistons and an angularly-adjustable swash plate for determining piston displacement and thereby the amount of fluid discharged from the pump, resilient means in a first cartridge assembly biasing the swash plate to its maximum discharge position whereby a maximum of fluid is displaced by the pump and pressure responsive means in a second cartridge assembly for suddenly shifting said swash plate to its minimum discharge position in response to a pressure such as from a hydraulic system whereby sharp cutoff of pump flow occurs thereby curtailing heat generation and horsepower loss, and further including reversing means whereby interchanging said first cartridge assembly with said second cartridge assembly causes the pump flow direction to be reversed.

125 2. A pump as claimed in claim 1 wherein said reversing means comprises a pair of stop means, one of which is associated with the swash plate adjacent said first cartridge assembly and the other of which is associated with the other of said cartridge assemblies, said stop means being interchangeable, one with the other.

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the area of piston 104 in chamber 102, piston 42 will push downwardly on the swash plate extension 110 until it is stopped at the maximum displacement position by stop 40.

When this occurs, pump flow and pressure will correspond to point B on the graph of Fig. 3. The pressure within the circuit will then rise in proportion to the load placed on the circuit, while pump flow is held constant as represented by the line B—C on the graph. When the system pressure reaches a predetermined maximum, as shown by point C on the curve of Fig. 3, a poppet valve 114 (as seen in Fig. 2) will open against the biasing force of a spring 116, thus venting chamber 70 to tank by way of passage 118 and line 120.

This operation also allows fluid to flow through orifice 68, which will result in a differential pressure to move spool 60 upwardly to vent chamber 82, as previously described. This action will allow the operating pressure in chamber 102 to overcome the pressure in chamber 82 and will swivel the pump back to the minimum displacement position corresponding to point D on the graph of Fig. 3. This swiveling of the swash plate will cause the sharp cutoff of pump flow along the almost vertical line C—D. As is well known in the art, very low flow and high pressure (D) will result in much less heat generation and horsepower loss than will high flow at high pressure (C).

Turning to Fig. 2, pump rotation will be in one direction due to the fact that the swash plate can be swivelled only in a clockwise direction. Therefore, when pump flow direction is to be changed, the capsule or cartridge assemblies 98 and 122 must also be interchanged along with stops 40 and 108, and the functions of the inlet and outlet ports will be interchanged. This interchanging may be easily accomplished with the device of the instant invention, since cartridge assemblies 98 and 122 have the same exterior circumferential dimension as well as being generally cylindrical.

In addition, and to facilitate this interchanging, the locations and dimensions of the leftmost annuli 62, 74, duplicate those of the rightmost annuli 90, 124, respectively. More particularly, annulus 74 is located at the same vertical level in the head as annulus 124 whereby interchanging of assemblies 98 and 122 results in passage 72 in cartridge assembly 48 being in fluid communication with tank line 38 by way of the annuli and passages 126, 128 and chamber 130. Access to chamber 130 may be conveniently had by means of plug 132 which is threadably secured in the top surface of head 16.

Similarly, annuli 62 and 90 are located at the same vertical level in the head. Passage 134 and line 136 leading to tank are pro-

vided so as to correspond with their counterparts numbered 88, 86. Obviously, when the assemblies are located as shown in Fig. 2, cartridge 96 obturates passage 134 and annulus 124 whereby these elements are unused.

To interchange the assemblies, head 16 is removed from housing 18 by detaching fastening means (not shown). Threaded plug 138 is unscrewed from its mating opening in the end of cartridge 96 and nut 52 is similarly unscrewed from the threaded end of assembly 48. The respective cartridges are interchanged, plug 138 and nut 52 resecured, and the head 16 resecured to housing 18. As aforementioned, an intermediate step of exchanging stops 40 and 108 would also be accomplished.

It will be seen that there is provided a variable displacement pump having pressure compensator control means operable to control pump displacement in response to system pressure. The pressure compensator control means serves to automatically change the pump displacement from maximum to minimum when the system pressure reaches a predetermined maximum value, thereby limiting horsepower loss and preventing excessive heat generation, and can utilize pilot operation for controlling pump displacement whereby more stability and less hunting and overshoot are encountered when a change in displacement is required.

WHAT WE CLAIM IS:—

1. A variable displacement axial piston pump of the type having a housing containing an inlet port and a discharge port, a plurality of pistons and an angularly-adjustable swash plate for determining piston displacement and thereby the amount of fluid discharged from the pump, resilient means in a first cartridge assembly biasing the swash plate to its maximum discharge position whereby a maximum of fluid is displaced by the pump and pressure responsive means in a second cartridge assembly for suddenly shifting said swash plate to its minimum discharge position in response to a pressure such as from a hydraulic system whereby sharp cutoff of pump flow occurs thereby curtailing heat generation and horsepower loss, and further including reversing means whereby interchanging said first cartridge assembly with said second cartridge assembly causes the pump flow direction to be reversed.

2. A pump as claimed in claim 1 wherein said reversing means comprises a pair of stop means, one of which is associated with the swash plate adjacent said first cartridge assembly and the other of which is associated with the other of said cartridge assemblies, said stop means being interchangeable, one with the other.



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3. A pump as claimed in claim 1 or 2 wherein said first cartridge assembly comprises a first generally cylindrical cartridge member in closely-fitted relation within a first bore in said housing, said second cartridge assembly comprises a second generally cylindrical cartridge member in closely-fitted relation in a second bore in said housing, and wherein the respective diameters of said first and second cartridge members are substantially identical to facilitate interchanging of said cartridge members in said bores.

4. A pump as claimed in claim 3 wherein said housing includes a head mounted thereon and wherein said cartridge members further comprise means for removably securing said cartridge members to said head.

5. A pump as claimed in claim 3 or 4 wherein said second cartridge member comprises a generally elongate member and said pressure responsive means comprises a first reciprocable piston extending from a bore in one end of said cartridge member and thereby defining a first chamber therein.

6. A pump as claimed in claim 5 wherein said first cartridge member is a generally elongate member and wherein said resilient means in said first cartridge member comprises a second reciprocable piston extending from a bore in one end of said cartridge member and thereby defining a second chamber therein, and further including spring means in said second chamber biasing said piston outwardly from said bore.

7. A pump as claimed in claim 6 including a pilot line in said housing adapted to sense pressure from a hydraulic system and wherein said means for suddenly shifting said swash plate to its minimum discharge position comprises a spool responsive to line

pressure for directing pressure fluid to said first chamber so as to cause said first reciprocable piston to tilt said swash plate means to the minimum discharge position.

8. A pump as claimed in any one of claims 3 to 7, further including a plurality of spaced annuli in said first bore and a plurality of spaced annuli in said second bore and wherein each annulus in said first bore has a counterpart annulus in said second bore at the same vertical level in said head.

9. A pump as claimed in claim 8 wherein the plurality of spaced annuli comprises two in each of said bores and further including passage means intercommunicating one annulus in said first bore with its counterpart in said second bore.

10. A pump as claimed in claim 7 wherein said spool is contained in a bore and defining a third chamber at one end of said bore, and further including a poppet valve for relieving excessive pressure occurring in said third chamber.

11. A pump as claimed in claim 4 wherein said means for removably securing said cartridge members to said head comprise a flange on each cartridge located intermediate the ends of each cartridge and adapted to be contained between said head and said housing.

12. A variable displacement axial piston pump substantially as described with reference to the accompanying drawings.

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