United States Patent

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[73] Assignee **Sunstrand Corporation**

[54] **HYDRAULIC PUMP**
10 Claims, 6 Drawing Figs.

[52] **U.S. Cl.** **417/202,** 417/206, 417/281, 417/270
[51] **Int. Cl.** **F04b 23/12,** F04b 49/00, F04b 23/14
[50] **Field of Search** ..... 103/162, 5, (Comp), 38, 42, 202; 230/178, 45, 207, 209; 417/202, 222, 206, 281, 270

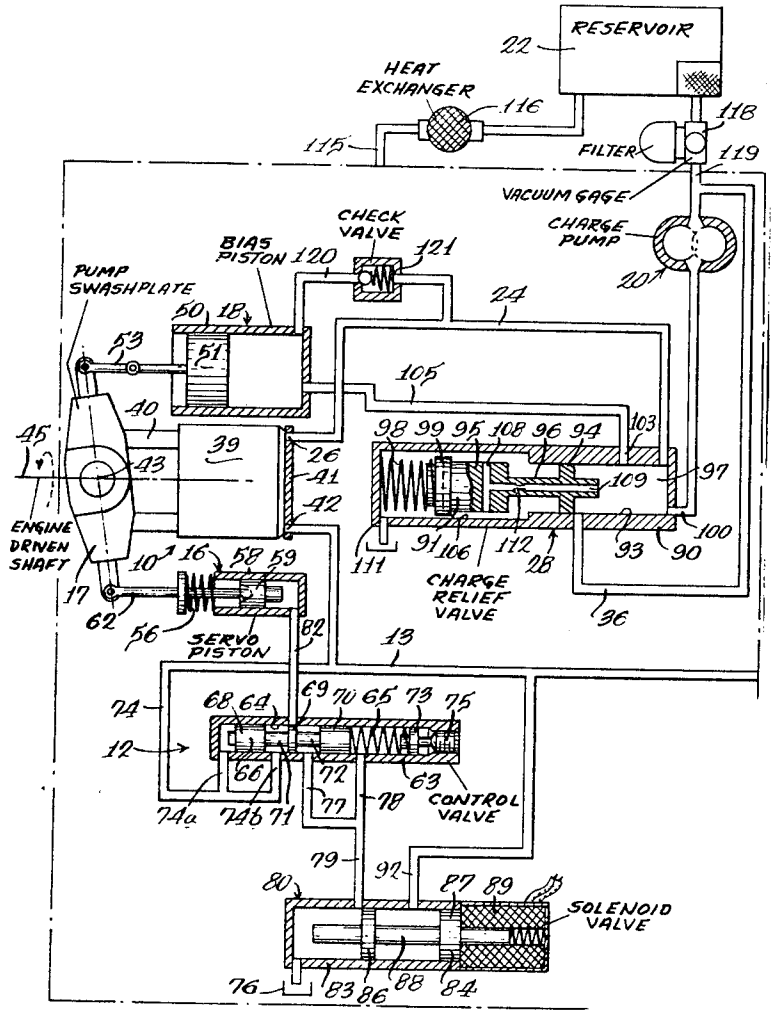
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ABSTRACT: A variable displacement hydraulic pump of the multiple piston type having a fluid operable biasing piston for biasing the pump toward maximum displacement, a control valve for controlling the fluid pressure in a displacement control motor opposing the biasing piston, and a charge relief valve that operates on a priority basis in the low pressure side of the hydraulic circuit in conjunction with a charge pump to sequentially (1) supply fluid to the low pressure side of the main pump in open circuit, (2) supply hydraulic fluid to the biasing piston, (3) supply cooling oil for the rotating components of the pump, and (4) provide a bypass relief directly to the inlet of the charge pump.

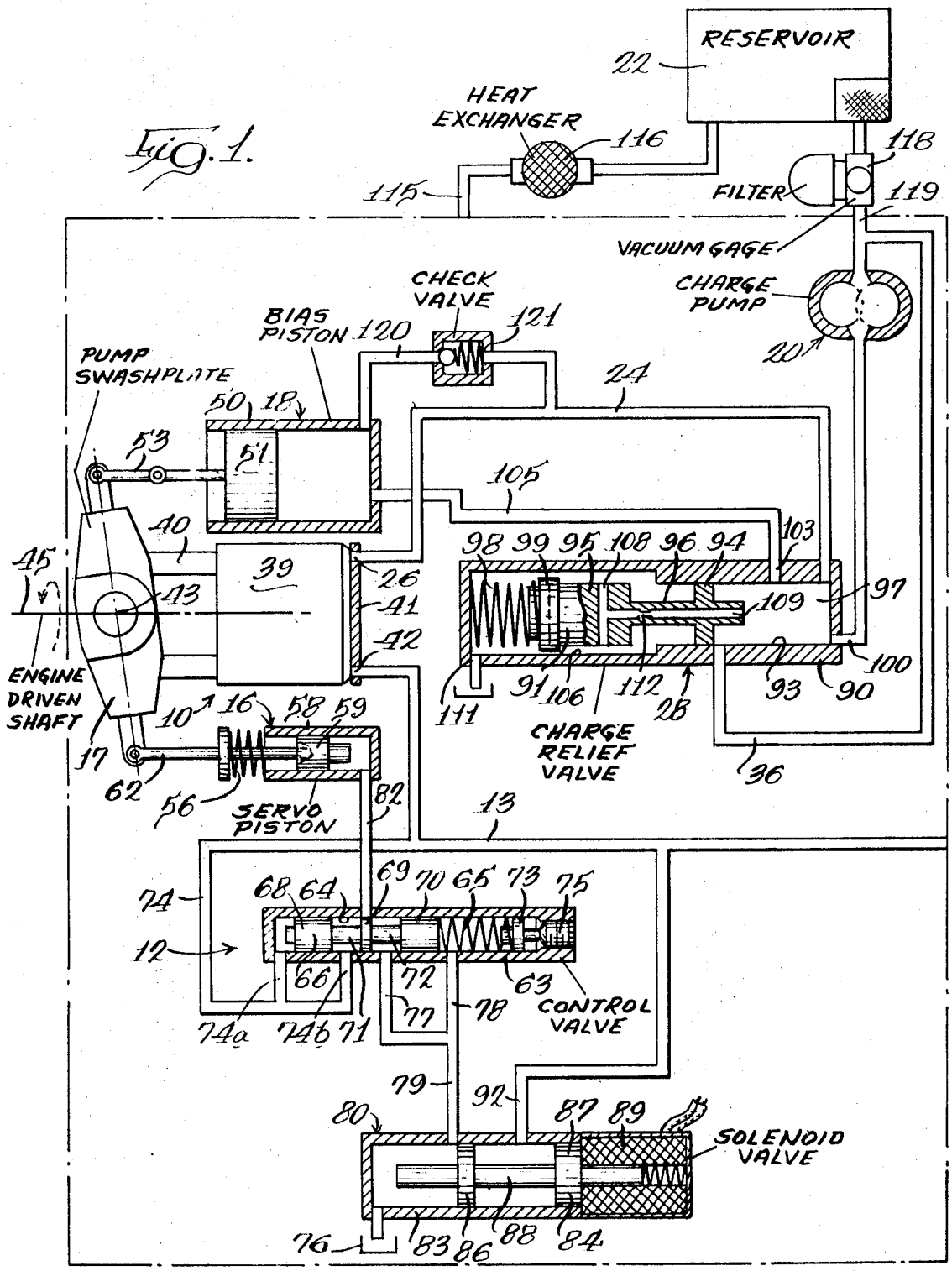


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SHEET 1 OF 2

Fig. 1.



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Fig. 2.

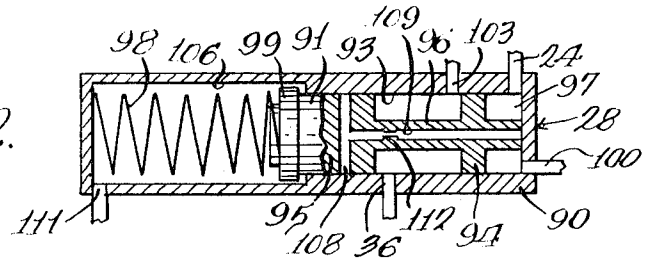


Fig. 3.

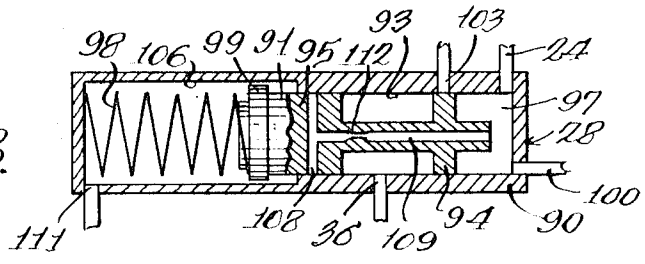


Fig. 4.

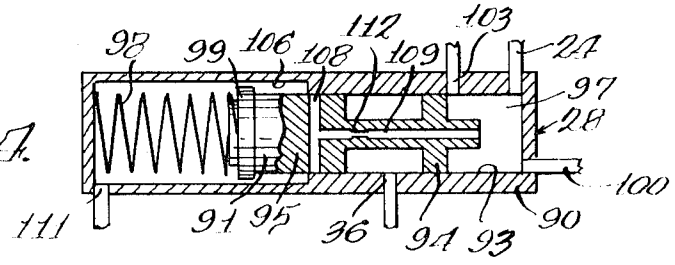


Fig. 5.

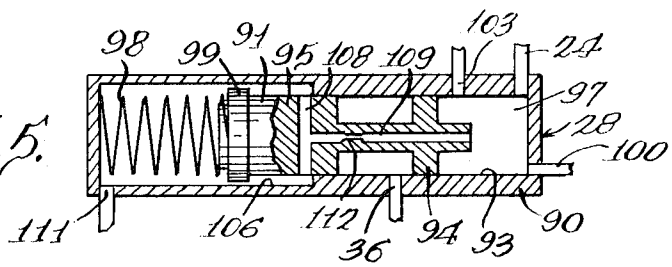
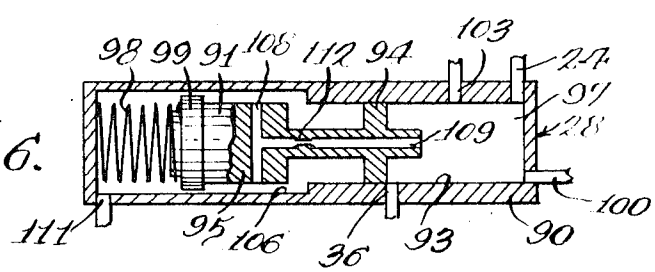


Fig. 6.



HYDRAULIC PUMP

BACKGROUND OF THE INVENTION

High speed pumps of the multiple piston type have in the past had the disadvantage of insufficient pump filling creating a severe inlet vacuum and cavitation, particularly in open circuit pumps where fluid is drawn from a reservoir to the pump inlet through a charge pump.

SUMMARY OF THE PRESENT INVENTION

According to the present invention a charge pressure relief valve is provided that permits the pump to operate at higher speeds with sufficient pump filling and elimination of cavitation particularly where the pump is in open circuit with closed center valving. To accomplish this the charge pressure relief valve communicates with the pump inlet passage which is supplied fluid from a charge pump normally withdrawing fluid from a reservoir and delivering it to the main pump inlet. The charge relief valve operates on a priority basis so that it delivers fluid to a stroke producing biasing piston only when the demand of the pump has been fully satisfied, and so long as the demand of the pump is not satisfied, the biasing piston permits the pump cam to move toward neutral thereby reducing the demand of the pump. Such a situation can occur when a line breaks in the charge pump circuit or when the charge fluid filter becomes clogged. A further importance of this feature is that in cold weather when the hydraulic oil flows very slowly the stroke of the cam will only be increased to the degree that the pump can remain completely filled and thus prevent damage to the pump.

A further function of the charge relief valve is that after the pump is adequately filled and the biasing piston has been supplied charge fluid, it supplies hydraulic cooling oil for the rotating components of the pump. A still further function that is effected sequentially with the above functions of the relief valve is to finally bypass excess fluid from the charge pump directly to the inlet of the charge pump to maintain the predetermined desired inlet fluid pressure to the main pump as well as to reduce the inlet vacuum at the charge pump.

A further feature of the present invention is the provision of a separate relief passage associated with the biasing piston and cylinder device which permits the cam to move toward neutral even when the charge relief valve would otherwise block fluid flow from the biasing piston and cylinder device.

BRIEF DESCRIPTION OF THE DRAWINGS

Further objects and advantages will become apparent from the following detailed description taken in connection with the accompanying drawings, in which:

FIG. **1** is a diagrammatic illustration of the present fluid pump and the hydraulic circuitry associated therewith;

FIG. **2** is a subassembly view of a charge relief valve in a first position porting fluid only to the low pressure side of the main pump;

FIG. **3** is a fragmentary view of the charge relief valve in a position blocking flow from the biasing piston;

FIG. **4** is a fragmentary view of the charge relief valve in a position supplying fluid to the biasing piston;

FIG. **5** is a fragmentary view of the charge relief valve in a position supplying fluid to the cooling circuit; and

FIG. **6** is a fragmentary view of the charge relief valve additionally bypassing fluid to the charge pump inlet.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring to the drawings and particularly FIG. **1** an axial piston hydraulic pump **10** is illustrated with a pressure compensating valve **12** adapted to control the displacement of the pump **10** to maintain a substantially constant pressure in the high pressure pump outlet passage **13**. The control valve **12** effects this control by porting fluid to a displacement control motor **16** which acts on cam **17** against the biasing force of a biasing piston and cylinder device **18**.

To maintain the pump **10** filled with hydraulic fluid and to provide a hydraulic piston return device, as well as other functions, a charge pump **20** is provided which withdraws fluid from a reservoir **22** and delivers it through inlet passage **24** to inlet port **26** of the main pump **10**.

A charge relief valve **28** operates on a priority basis to (1) permit the supply of fluid to the pump inlet, (2) supply fluid to the bias piston **18** after the demand of the pump **10** has been satisfied, (3) supply cooling fluid for the rotating components of the pump, and (4) supply bypass fluid from the charge pump back to the charge pump inlet through passage **36**, all of these events occurring in sequential fashion to maintain a substantially predetermined pressure in the main pump inlet passage **24** and port **26**.

Turning to a description of the above elements in more detail the pump **10** is seen to be of the axial piston type shown only diagrammatically in FIG. **1** and includes a rotary cylinder block **39** having a plurality of axially disposed pistons **40** slidably received in cylinders in the block **39**. The cylinder block **39** rotates against a normally stationary valve plate **41** having inlet port **26** and outlet port **42** therein serially communicable with the cylinders in the block **39** as the block rotates.

For reciprocating the pistons and varying the displacement of the hydraulic unit, swashplate or cam assembly **17** is provided pivotally mounted in a housing (not shown) for rotation about an axis **43** generally transverse and perpendicular to axis **45** about which the cylinder block **39** rotates. The cylinder block is driven by a suitable prime mover through a shaft rotating on axis **45**.

For the purpose of biasing the cam **17** toward a maximum displacement position on one side of neutral the biasing piston and cylinder device **18** is provided and is seen to include a stationary cylinder **50** with an enlarged piston **51** therein connected to the cam assembly **17** through an articulated link arrangement **53**. The piston **51** is sized such that the hydraulic fluid under pressure acting on the piston from the charge pump **20** produces a force on the cam member **17** about axis **43** in excess of that required to overpower spring **56** and also the inherent fluid pressure moment acting on the swashplate assembly **17** through the pistons **40**. This fluid pressure moment is well known to act in a stroke reducing direction and is caused by the delay in pressure change after each piston crosses the sealing portion of valve member **41** between the ports **26** and **42**. This fluid pressure moment is described in more detail in the Hann U.S. Pat. Ser. No. 3,230,893 entitled "Swashplate Pump," assigned to the assignee of the present invention, and reference should be made thereto for a better understanding thereof.

The control motor **16** urges the cam selectively in a clockwise direction against the biasing force of piston and cylinder device **18**. The control motor **16** is seen to include a cylinder **58** with a piston **59** slidable therein and engaging a separate linkage assembly **62** connected at one end to the cam assembly **17**. In addition to the biasing force of the piston **59** the link assembly **62** is biased in a stroke reducing direction by spring **56**. This spring is sized with an appropriate spring rate to bias the swashplate **17** to a zero stroke stop (not shown) against the inertia moments acting on the swashplate **17** caused by the reciprocation of the pistons **40**. This moment is described in more detail in the Moon U.S. Pat. Ser. No. 3,282,225 entitled "Industrial Hydrostatic Transmission," assigned to the assignee of the present invention. The piston inertia moment is proportional to pump stroke or displacement at any fixed speed, and spring **56** is sized to overpower this moment and return the swashplate to a zero stroke position in the absence of other forces influencing movement of the cam assembly.

With the cam **17** biased toward a maximum displacement position by piston and cylinder device **18**, the pressure compensator control valve **12** selectively ports fluid to control motor **16** to reduce the displacement of the hydraulic unit **10** to maintain a constant pressure in the outlet passage **13**. Control valve **12** consists of a valve housing **63** having a valve bore **64** slidably receiving a valve member **66** having lands **68**, **69**

and 70 separated by reduced stem portions 71 and 72. The valve member 66 is biased to the left by a spring 54, the tension of which is adjustable through a spring seat 73 by adjusting screw 75 threadedly received in the right end of valve housing 63. Valve bore 64 communicates with the high pressure passage 13 through passage 74 and branch passages 74*a* and 74*b*. Portions of the valve bore 64 normally communicate with a tank 76 or the interior of the pump casing (not shown) through passages 77 and 78 which connect and communicate with a passage 79 which in turn communicates with a depressurization valve 80. Discharge fluid pressure from line 13 is selectively supplied across valve member 66 to the control motor 16 and outlet passage 82 (which is blocked by land 69 in the position of the valve member 66 shown in FIG. 1).

The adjustment of spring 65 sets the predetermined pressure level in the discharge passage 13. The movable valve member 66 balances the high pressure acting on the left end thereof through passage 74*a* against the spring 65 to control the pressure level in the outlet passage 82 and the control motor 16.

Spring 65 biases the valve member 66 to the left causing the control motor 16 to drain through passage 82, reduced stem portion 72, passage 77, passage 79 and tank 76, allowing the bias piston 18 to move the swashplate 17 into stroke. If the pressure in the high pressure passage 13 rises above the predetermined desired pressure value, the hydraulic force acting on the left end of valve member 66 will move the valve member to the right compressing spring 65 to a position where land 69 blocks communication between outlet passage 82 and drain passage 77, and providing communication between high pressure passage 74*b* and outlet passage 82 across reduced stem 71 thereby porting fluid to the control motor 16. This causes a biasing force on the cam member 17 sufficient to overpower the biasing piston and cylinder device 18 and the inertia moments so that the displacement of the swashplate 17 is reduced and the pressure in outlet passage 13 returns to its predetermined desired value.

It should be understood that the piston 59 in the control motor 16 is sized such that the forces provided by the bias piston 51, spring 56, and the inertia and pressure moments will just balance to maintain the predetermined pressure in the high pressure passage 13 by hydraulic fluid being ported to or from the control motor 16 by the valve 12.

The depressurization valve 80 is provided to selectively lower the pressure level of the pump 10 when the predetermined high pressure level is no longer desired. Valve 80 includes a valve housing 83 with a valve member 84 having spaced lands 86 and 87 separated by reduced stem portion 88. The valve member 84 is shiftable from its disabled position shown to a left hand depressurizing position by a solenoid 89. In the position shown the valve member 84 connects the cavity associated with spring 65 with tank through passages 78, 79 and the left side of the valve member 84. When the solenoid 89 is activated shifting spool valve member 84 to the left, land 86 blocks the tank 76 and connects a passage 92 communicating with main passage 13 with the normally low pressure passage 79, pressurizing the normally low pressure passages associated with the pressure compensator valve 12. This equalizes the pressure on both ends of the valve member 66 and the spring 65 unbalances the forces acting on that valve member shifting it to the left and allowing high pressure fluid in passage 77 to communicate and flow to the control motor 16 through passage 82 across reduced stem portion 72. This moves the swashplate assembly 17 in a clockwise direction toward the zero stop lowering the pressure in the high pressure passage 13.

As described briefly above, the charge relief valve 28 is a multipurpose valve between the charge pump 20 and the inlet port 26 of the hydraulic unit 10. Valve 28 includes a valve housing 90 with a valve member 91 slidable in valve bore 93. Valve member 91 has lands 94 and 95 separated by a reduced stem portion 96. The valve member 91 is biased to the right against fluid pressure in chamber 97 by a spring 98 and spring seat 99 engaging the left end of valve member 91. Chamber 97 communicates with the outlet of charge pump 20 through passage 100. The charge pressure in chamber 97 balances the spool valve member 91 against the spring 98 to maintain the pressure in pump inlet passage 24 and port 26 at a predetermined desired inlet value. Note that inlet passage 24 communicates with chamber 97 at the extreme right end thereof and in no position of the valve member 91 does the latter block communication between the charge pump outlet and inlet passage 24.

The charge relief valve 28 performs all of its functions on a priority basis. As the demands of the pump 10 are satisfied by the delivery of sufficient fluid from the charge pump through inlet passage 24, the charge relief valve 28 shifts to the left in response to further increased fluid under pressure from the charge pump to successively relieve pressure in the inlet 24 while performing in sequential fashion other functions in the hydraulic circuit as will appear hereinbelow.

The charge pump 20 is sized such that under normal operation it displaces a volume of hydraulic oil sufficient to supply the demands of the cylinder block 39 and the bias piston 18 during the transient condition when the swashplate moves from its minimum displacement to maximum displacement positions without loosing hydraulic oil pressure in the low pressure passage 24.

When the charge pump 20 is operating below its normal capacity the valve member 91 will assume a position shown in FIG. 2 where it permits all of the hydraulic fluid from the charge pump 20 to flow into the low pressure passage 24 to the cylinder block 39. The same condition can occur on start up as the cylinder block is being filled even though the charge pump is delivering fluid at its design capacity noted above. After the oil supplied is sufficient or the charge pump begins delivering fluid at its design capacity, the pressure in chamber 97 will rise urging valve member 91 to the left to the position shown in FIG. 4 where valve land 94 opens port 103 providing communication between the chamber 97 and the servo cylinder 50 through passage 105. The charge relief valve thus is on priority "2" which is to supply hydraulic fluid to the bias piston 51 causing the bias piston to move the cam assembly toward full stroke against the opposing force of spring 56 and the fluid pressure moments acting on the swashplate. This second function is very important in that if the oil flow to the low pressure passage 24 is insufficient to fill the cylinder block 39 the valve member 91 will not move to the position shown in FIG. 4 and will remain in the FIG. 2 position where fluid is not supplied to the biasing piston and the cam will remain against the zero stroke stop. A secondary importance of this feature is that in cold weather when the hydraulic oil flows very slowly the stroke of the swashplate assembly will only be increased to the degree that the cylinder block can remain completely filled and thus prevent damage to the pump.

As flow from the charge pump 20 increases further the pressure acting on the valve member 91 will shift it further to the left to the position shown in FIG. 5 where land 95 moves sufficiently into the enlarged portion 106 of bore 92 to provide communication between bore portion 106 and chamber 97 through transverse slot 108 and axial slot 109, both in the valve member 91. A throttle 112 in passage 109 permits only limited cooling flow through this passage. The purpose of fluid flowing into the enlarged bore 106 is that it passes out port 111 and is sprayed over the rotating components of the pump by suitable means (not shown) for the purpose of cooling these parts. This provides a means of carrying off the heat generated by the rotating components. The cooling oil is then passed out through a case drain line 115, through a heat exchanger 116 and then to the reservoir 22. From the reservoir hydraulic fluid is returned to the charge pump through a suction filter 118 in passage 119 leading to the charge pump inlet.

The fourth function and priority of the charge relief valve 28 is to allow for a relief directly to the suction of the charge pump 20. Assuming the delivery from the pump 20 increases

further, valve member **91** will assume the position shown in FIG. **6** wherein valve land **94** opens passage **36** to chamber **97** permitting a portion of the fluid flow from the charge pump to be returned directly to the inlet of the charge pump through passage **36**. This is to allow the charge pump **20** to operate under conditions of low inlet vacuum in passage **119**.

In the event that pressure in passage **24** should fall below the predetermined desired value, spring **98** will move to the right progressively cutting off the priority functions in the reverse order of that described above. When the spool valve moves back toward the position shown in FIG. **2** blocking the port **103** as shown in FIG. **3**, the biasing piston **18** is unable to drain across the valve member **91**. To permit the biasing piston **51** to move to the right allowing a rapid reduction in displacement under these conditions of excessive pump demand (in excess of the fluid supplied in passage **24**), the fluid in the piston and cylinder device **18**, or more specifically in cylinder **50**, may be expelled therefrom through passage **120** which communicates with the low pressure passage **24**. A check valve **121** is provided in passage **120** to prevent the flow of fluid from passage **24** to the biasing piston prior to the time valve land **94** opens port **103**, thus preserving the priority integrity of the charge relief valve **28**.

As the valve member moves further to the right to the position shown in FIG. **2** in response to a further decrease in pressure in passage **24** the bias piston and cylinder device **18** can then drain through passage **105** across reduced stem portion **96** and passage **36**, permitting the swashplate **17** to destroke thus protecting the main pump **10** from damage. As explained above, the reduction in pressure in passage **24** could be due to a variety of causes including the breakage of an inlet line, the filter **118** becoming clogged, etc.

It is thus seen that the charge relief valve **28** controls the stroking of the swashplate **17** in a manner to protect the main pump during cold weather starting or low hydraulic pressure in the main inlet passage **24** to the pump. Moreover, the check valve **121** and passage **120** permit the rapid destroking of the cam **17** when the relief valve is in its blocking position shown in FIG. **3**. Thus, the pump has the ability to operate at speeds much higher than previously obtained without severe inlet vacuum or cavitation as well as the ability to operate in open circuit applications with or without closed center valves using a suction filter at the charge pump inlet.

I claim:

1. In a hydraulic pump unit, the combination, comprising: a cylinder block having a plurality of cylinders therein, pistons slidable in said cylinders, cam means for reciprocating the pistons upon rotation of the cylinder block relative to the cam means, valve means having inlet and outlet ports serially communicable with said cylinders, displacement varying means for said unit including fluid operable means for controlling movement of said cam means, a charge pump for supplying at least a portion of the charge fluid to said inlet port and to said fluid operable means, and valve means responsive to a predetermined reduction in flow or pressure from said charge pump for controlling the fluid operable means to permit a reduction in pump displacement while maintaining flow to said inlet port upon a predetermined reduction in flow or pressure from the charge pump to minimize the possibility of pump inlet starvation.

2. In a hydraulic pump unit, the combination, comprising: a cylinder block having a plurality of cylinders therein, pistons slidable in said cylinders, cam means for reciprocating the pistons upon rotation of the cylinder block relative to the cam means, valve means having inlet and outlet ports serially communicable with said cylinders, displacement varying means for said unit including fluid operable means for said unit including fluid operable means for controlling movement of said cam means, a charge pump for supplying at least a portion of the fluid to said fluid operable means and at least a portion of the fluid to said inlet port means, and valve means for supplying said charge fluid to said fluid operable means only after the demand of the pump has been satisfied.

3. A hydraulic pump unit as defined in claim **2**, wherein said valve means is a sequentially operable charge relief valve for controlling pressure at a predetermined value in said inlet port means, passage means connecting the outlet of said charge pump and said inlet port means, said charge relief valve means communicating with said passage means, means for supplying cooling oil to said pumping unit, said charge relief valve porting charge fluid to said cooling oil means after the demands of the pump and the fluid operable means have been satisfied.

4. A hydraulic pump unit as defined in claim **2**, wherein said valve means is a sequentially operable charge relief valve for controlling pressure at a predetermined value in said inlet port means, passage means connecting the outlet of said charge pump and said inlet port means, said charge relief valve means communicating with said passage means, a bypass passage for returning charge fluid from the charge pump outlet directly to the charge pump inlet to reduce the vacuum at the charge pump inlet, said charge relief valve opening said bypass passage only after the demands of the pump unit and the fluid operable means have been satisfied.

5. A hydraulic pump unit as defined in claim **2**, wherein said valve means is a sequentially operable charge relief valve for controlling pressure at a predetermined valve in said inlet port means, passage means connecting the outlet of said charge pump and said inlet port means, said charge relief valve means communicating with said passage means, means for supplying cooling oil to said pumping unit, said charge relief valve porting charge fluid to said cooling oil means after the demands of the pump and the fluid operable means have been satisfied, a bypass passage for returning charge fluid from the charge pump outlet directly to the charge pump inlet to reduce the vacuum at the charge pump inlet, said charge relief valve opening said bypass passage only after the demands of the pump unit and the fluid operable means have been satisfied.

6. A hydraulic pump unit as defined in claim **2**, including passage means communicating the outlet of the charge pump with the inlet port means, said valve means including a movable valve member, spring means biasing said valve member in a first direction, said valve means communicating with said passage means so that fluid pressure from said charge pump urges said valve member in a second direction, first port means associated with said valve means, passage means connecting said first port means and said fluid operable means, said valve member opening said first port means to fluid pressure from said charge pump.

7. A hydraulic pump unit as defined in claim **6**, wherein said valve means has second port means, said second port means being positioned to be opened by said valve member after said first port means as the valve member moves in said second direction, cooling means, said second port means communicating with said cooling means.

8. A hydraulic pump unit as defined in claim **6**, wherein said valve means has second port means, said second port means being positioned to be opened by said valve member after said first port means as the valve member moves in said second direction, bypass passage means for returning charge fluid from the outlet of the charge pump directly to the inlet of the charge pump, said second port means communicating with said bypass passage.

9. A hydraulic pump unit, comprising: a rotary cylinder block having a plurality of axially disposed cylinders therein, valve means having inlet and outlet port means therein serially communicable with said cylinders, pistons slidable in said cylinders, a pivotal cam for reciprocating the pistons, displacement varying means for said pump unit including a fluid operable control motor, a biasing piston and cylinder device for biasing when pressurized said cam member toward a maximum displacement position, control valve means for porting fluid to said control motor to selectively reduce the displacement of the pump unit, passage means for supplying fluid to said inlet port means, a charge pump for delivering charge fluid to said passage means and to said biasing piston and cylinder device, a charge relief valve communicating with said

passage means to control the pressure in said passage means at a predetermined value, said relief valve including a movable valve member responsive to a predetermined increase in fluid pressure from said charge pump for porting a portion of the fluid from said charge pump to said biasing piston and cylinder device.

10. A hydraulic pump unit comprising: a rotary cylinder block having a plurality of axially disposed cylinders therein, valve means having inlet and outlet port means therein serially communicable with said cylinders, pistons slidable in said cylinders, a pivotal cam for reciprocating the pistons, displacement varying means for said pump unit including a fluid operable control motor, a biasing piston and cylinder device for biasing when pressurized said cam member toward a maximum displacement position, control valve means for porting fluid to said control motor to selectively reduce the displacement of the pump unit, passage means for supplying fluid to said inlet port means, a charge pump for delivering charge fluid to said passage means and to said biasing piston and cylinder device, a charge relief valve communicating with said passage means to control the pressure in said passage means at a predetermined value, said relief valve including a movable valve member responsive to fluid pressure from said charge pump for porting a portion of the fluid from said charge pump to said biasing piston and cylinder device, a return passage from said biasing piston and cylinder device to said passage means, and check valve means in said return passage preventing the flow of fluid to said piston and cylinder device, said return passage permitting fluid to expel from said biasing piston and cylinder device when the relief valve member is in a position blocking the return of fluid therefrom across the relief valve.