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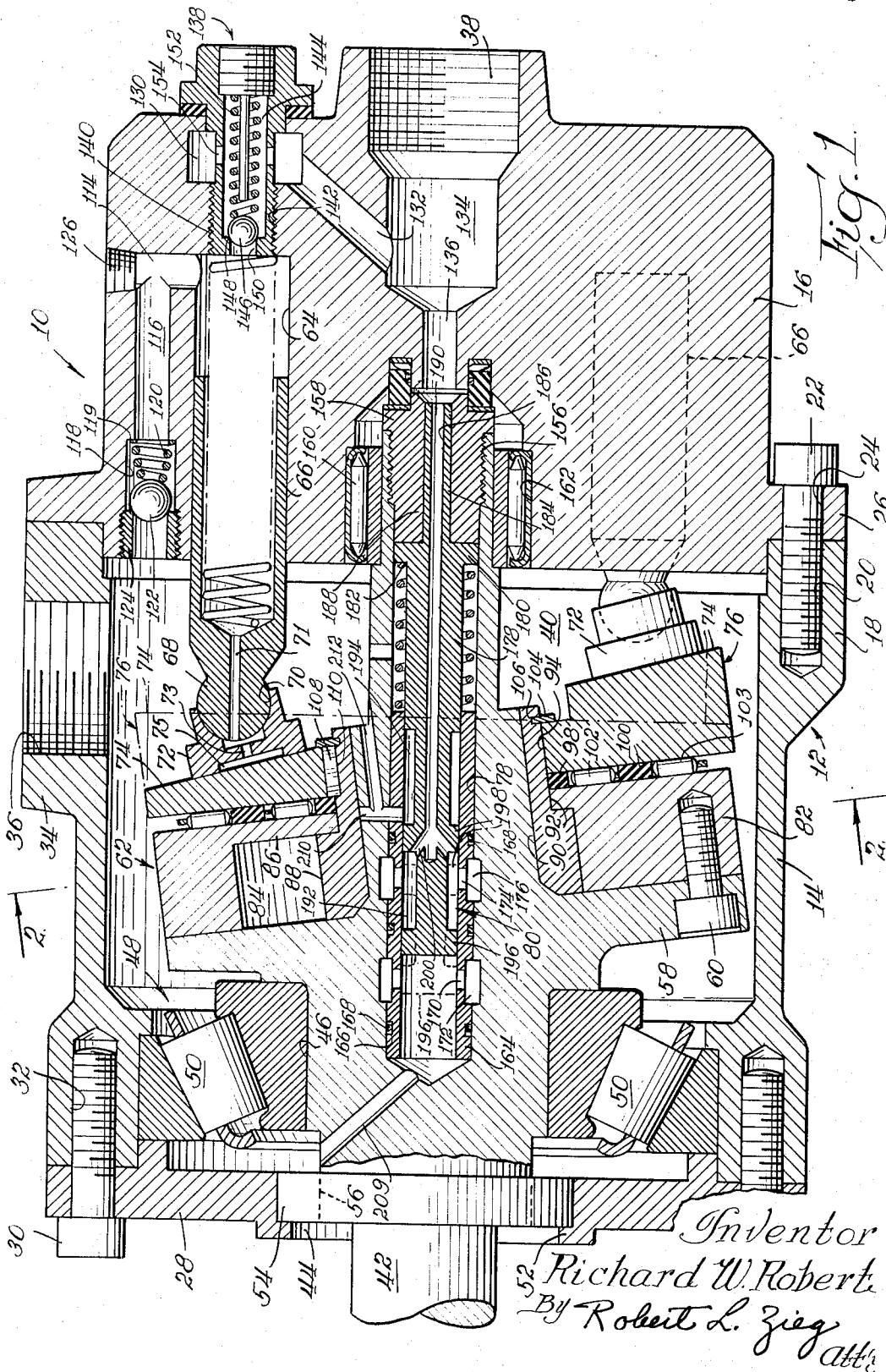
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VARIABLE DISPLACEMENT CHECK VALVE PUMP

Filed Nov. 12, 1965

2 Sheets-Sheet 1



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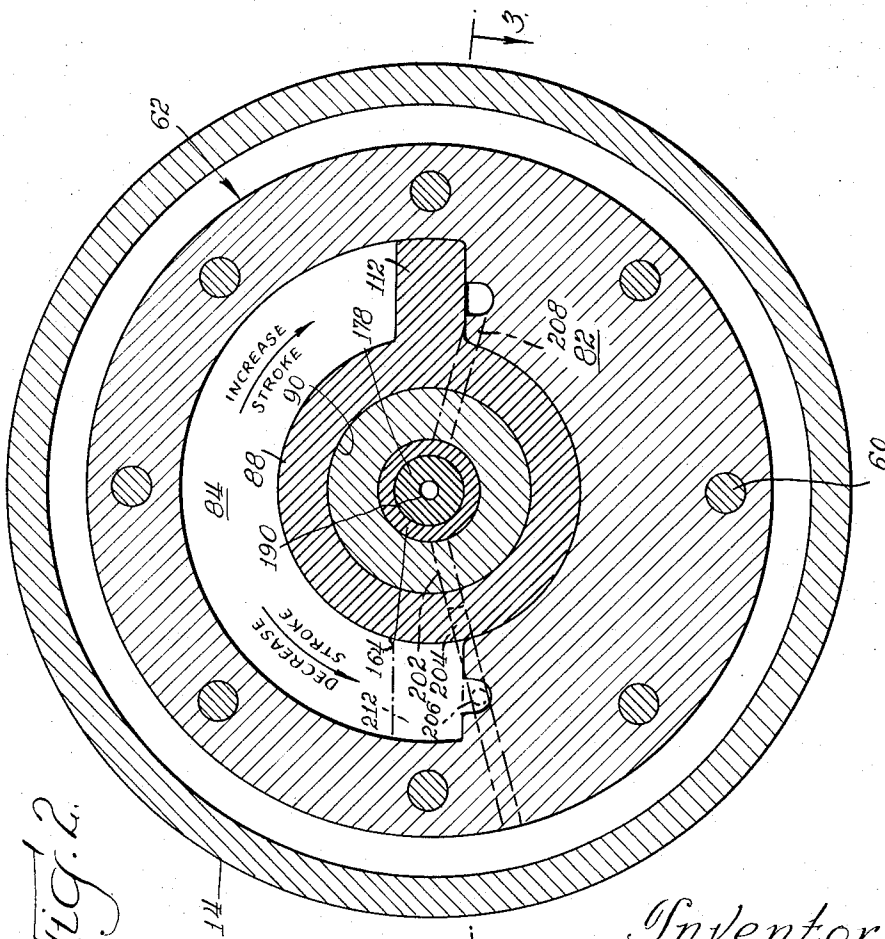
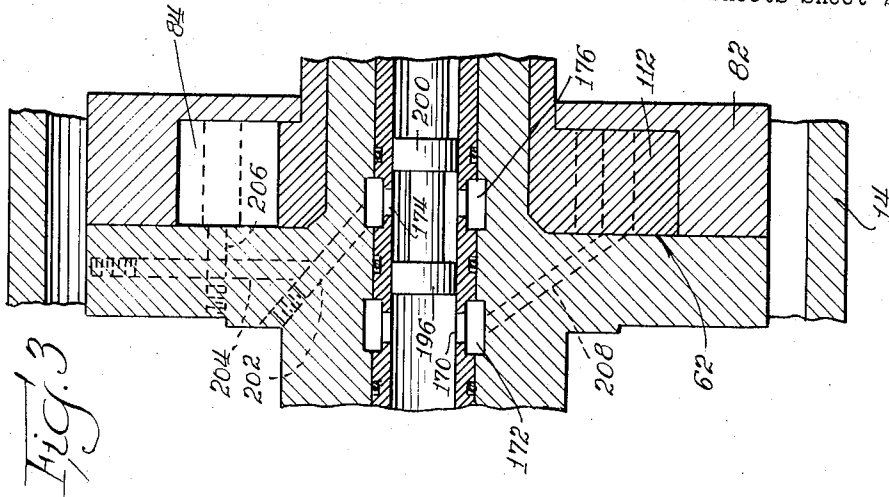
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2 Sheets-Sheet 2



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VARIABLE DISPLACEMENT CHECK VALVE PUMP
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7 Claims. (Cl. 103-173)

This invention relates to pumps and more particularly to a pump of the swash plate type in which a plurality of cylindrical bores are formed in a housing and each bore is provided with a reciprocal piston, the pistons being successively reciprocated by the swash plate upon rotation thereof.

A principal object of the invention is to provide a pump of the stated type in which the displacement may be infinitely varied and in which the drag torque at zero delivery is minimal.

An important feature of the invention is to provide a pump of the swash plate type in which the pistons are operated by a cam which may be relatively rotated with respect to its drive shaft to present a working surface which is angularly disposed with respect to the axis of the drive shaft for maximum piston displacement and which may be moved to positions in which the angularity is diminished and the displacement correspondingly decreased.

Another important feature of the invention is that the present pump is constructed and arranged so that only a very small area at one end of the constantly rotating drive shaft is subject to high discharge pressure. Furthermore, means are provided to keep high pressure fluid away from the pistons when they are no longer reciprocating with the result that the drive shaft, at zero output, may spin with minimal load on the bearings.

A further object of the invention is to provide an improved variable displacement pump of the swash plate type in which the effective stroke of the pistons may be varied from maximum to minimum by varying the effective angularity of the swash plate in response to the output pressure.

These and other objects of this invention will be apparent from the following specification, when taken with the accompanying drawings, wherein the same reference numerals are used to refer to like parts and in which:

FIGURE 1 is a vertical sectional view of a pump embodying the principles of the invention;

FIGURE 2 is a vertical sectional view taken substantially on line 2-2 of FIGURE 1; and

FIGURE 3 is a sectional plan view taken substantially on line 3-3 of FIGURE 2.

Referring now to the drawings, and more particularly to FIGURE 1 the pump of the present invention is indicated generally by reference numeral 10 and includes a housing 12 comprised of two sections 14 and 16. The section 14 assumes the form of a hollow cylinder having a plurality of circumferentially spaced integrally formed bosses 18 each of which is provided with a threaded bore 20 for reception of a cap screw 22. The cap screws 22 pass through bores 24 in flange 26 integral with the section 16 to secure the sections 14 and 16 together. At the left side of the section 14 is an end plate 28 secured to the section 14 by means of a plurality of circumferentially spaced cap screws 30 received in threaded bores 32 at the left end of the section 14 as viewed in FIGURE 1.

Also formed in the section 14 is a boss 34 having a threaded bore 36 forming the inlet for the housing 12. At the right side of the section 16 is a threaded bore 38 forming the outlet of the housing 12.

The hollow cylindrical section 14 forms a chamber

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40 into which low pressure fluid flows by means of the inlet port 36 and in which is positioned a rotary drive shaft 42 which extends through an opening 44 in the end plate 28 and is formed with a step 46 of increased diameter. The step 46 is mounted in a thrust bearing 48 having a plurality of frusto-conical rollers 50. The opening 44 is defined in part by an axially outwardly flared and radially inwardly extending flange 52 for retaining in position a sealing ring 54. The inner periphery of which rests on a step 56 of the same or less diameter than the step 46.

Integrally formed with the drive shaft 42 is a flange 58 extending angularly with respect to the axis of the drive shaft 42 and to which is secured, by means of a plurality of circumferentially spaced cap screws 60, an actuator assembly 62 more fully described hereinafter.

The section 16 is formed with a plurality of circumferentially spaced bores 64 in each of which is reciprocally mounted a piston assembly 66. Each piston assembly has at the left end thereof, as viewed in FIGURE 1, a ball 68 received in a correspondingly formed socket 70 in a slipper 72. Each of the slippers 72 is adapted to slide on a face 74 of a swash plate 76. Lubrication is supplied to the hydrostatic bearing pocket 75 in the slipper through the passages 71 and 73 in the piston and slipper respectively in the well known manner.

According to an important feature of the present invention the swash plate 76 may be moved from the position of maximum piston displacement illustrated in solid lines in FIGURE 1 toward the position of zero piston displacement illustrated in dotted lines in that figure in response to output pressure at the port 38. To effect this result, the end of the drive shaft 42 is formed with an elongated bore 78 in which is positioned a pilot valve assembly 80 which is operable, in response to output pressure, to control the actuator assembly 62 to rotate the swash plate 76 from the position illustrated in full lines in FIGURE 2 toward the position illustrated in dotted lines in that figure.

The actuator 62 include a thrust member and housing 82 having an arcuate cavity 84 defined in part by the flange 58 and in part by a radially extending flange 86. Forming the inner periphery of the cavity 84 is a hub 88 mounted for rotation on a cylindrical step 90 which is integrally formed with the drive shaft 42 and whose axis is disposed at an angle to the axis of drive shaft 42. The hub 88 has a step 92 of reduced diameter on which is journaled the inner peripheral edge of the flange 86. The swash plate 76 has a central opening 94 within which the step 92 is received. Between the thrust member 82 and the plate 76 are a pair of centering rings 98 and 100 between which are disposed a plurality of radial needle thrust bearings 102 and 103. The plate 76 is secured with respect to the step 92 by means of a retainer ring 104 received in a peripheral groove 106 in the step 92 and is secured for rotation with the hub 88 by means of a key 108 received in a keyway 110.

Referring now to FIGURE 2, a vane 112 is integrally formed with the hub 88 and is disposed within the cavity 84. Fluid pressure within the cavity 84 normally maintains the vane 112 in the position illustrated. In that position the plate 76 is in the maximum stroke position illustrated in FIGURE 1. As the output pressure reaches a predetermined design level the vane 112 is moved in a counterclockwise direction, as viewed in FIGURE 2, to rotate the plate 76 toward the position illustrated in dotted lines in FIGURE 1. This result is obtained by operation of the pilot valve assembly 80 in a manner hereinafter described.

Each of the cylinder bores 64 is connected to the inlet cavity 40 by inlet passages 114 and 116 in body section

16. Passage 116 has an enlarged bore 118 in which is located the inlet valve spring 120 between the step 119 and the inlet ball check valve 122. The ball check 122 seats against the threaded insert 124 to make a fluid tight seal against flow coming from the right through passage 116 and unseats at a very low pressure differential to allow flow from chamber 40 into passage 116. It will be understood that other types of valves may be used for this purpose.

As the pistons 66 move in their pumping stroke to the right, as viewed in FIGURE 1, fluid is forced into an annular chamber 130 from which it flows, by means of a plurality of inclined radial passages 132 to an outlet chamber 134 which communicates with the pilot valve 80 by means of an axial bore 136. Back flow of high pressure fluid into the bores 64 is prevented by a plurality of check valve assemblies 138, one for each of the cylindrical bores 64. Each check valve assembly 138 includes an externally threaded housing 140 received in a correspondingly threaded bore 142 coaxial with the associated bore 64. Each housing 140 is formed with a bore 144 within which is disposed a check ball 146 biased into engagement with a seat 148, surrounding an opening 150 communicating with the bore 64 by means of a spring 152. It will be understood that fluid may flow to the right as viewed in FIGURE 1 but will not flow to the left because of the seating of the ball 146. The housing 140 has a plurality of radial openings 154 through which the fluid passes into the chamber 130.

Referring to FIGURE 1 again, the right end of the drive shaft 42 is journaled in a bearing 160 which is received in a counterbore 162 in the housing section 16 and the right end of the bore 78 is internally threaded at 156 for reception of a plug 158. Within the bore 78 is positioned an elongated sleeve 164 having at the outer periphery thereof a plurality of longitudinally spaced grooves 166 for reception of sealing rings 168. Formed in the sleeve 164 are a plurality of circumferentially spaced radial openings 170 connecting with an annular passage 172 and a plurality of circumferentially spaced radial passages 174 communicating with an annular passage 176. Slidably disposed within the bore 78 is a plunger 178 of a diameter to be received within the sleeve 164 and having a radially outwardly extending flange 180 dimensioned to be slidably received in the bore 78. Disposed between the right edge of the sleeve 164 and the flange 180 is a spring 182 which normally urges the plunger 178 to the right, as viewed in FIGURE 1. The plunger 178 has, in the right end thereof, an elongated sleeve portion 184 of reduced diameter received within an axial bore 186 in the plug 158. Sealing is effected by means of a sealing ring 188. Within the plunger 178 is an elongated bore 190 which communicates at the right end thereof with bore 136, chamber 134 and chamber 130. At the left end of the plunger 178 are a pair of longitudinally spaced grooves 192 and 194 defined in part by lands 196 and 198. The groove 192 preferably is normally in register with the openings 174. A plurality of angular passages 200 are provided in the plunger 178 to afford fluid communication between the bore 190 and the groove 192. Referring now to FIGURE 3, the chamber 176 is in fluid communication with the cavity 84 by means of drilled passages 202, 204 and 206. When the fluid pressure in chamber 134 reaches a predetermined design value, because of a decrease in demand, the high pressure fluid acts against the end area of the reduced diameter extension 184 of plunger 178 so that the plunger moves to the left against the force of spring 182. The groove 192 initially moves into register with the openings 170 while the groove 194 moves into register with the openings 174. Fluid pressure flows to the right side of the vane 112 by means of the openings 170, the chamber 172 and a drilled passage 208. At the same time low pressure fluid is exhausted to the chamber 40 from the left side of the vane 112 by means of the drilled passages 202, 204, 206, chamber 176, openings 174,

groove 194 and drilled passages 210 and 212. The plate 76 is rotated toward the minimum stroke position indicated in dotted lines in FIGURE 2. When demand again increases the pressure drop momentarily in the chamber 134 and the plunger 178 moves to an equilibrium position indicated in dot and dash lines in FIGURE 1. In that position the land 196 blocks the openings 170 and the land 198 blocks the openings 174. A further decrease in pressure in the chamber 134 permits the plunger 178 to move further to the right so that fluid communication is again established with the openings 174 for movement of the vane 112 in the clockwise direction, as viewed in FIGURE 2. As this occurs, fluid at the right side of the vane 112 is exhausted to the chamber 140 by means of passage 208, chamber 172, openings 170 and drilled passage 209.

In operation, a decrease in demand results in a pressure increase in the chamber 134 which moves the plunger 178 to the left against the force of the spring 182 to supply fluid to force the vane 112 in a counterclockwise direction for decreased stroke of the piston 66. In the same manner an increase in demand causes a momentary pressure drop in the chamber 134 and the spring 182 returns the plunger 178 to the position illustrated in solid lines in FIGURE 1. Under zero demand, assuming no external leakage, the plate 76 is in the dotted line position and the entire pump is completely unloaded.

If desired, the control valve 80 may be designed to maintain the actuator 62 in the minimum stroke position. When so arranged, a pressure drop below a predetermined value terminates the flow of pressure fluid to the right side of the vane 112 and drag torque is permitted to rotate the swash plate to the maximum position. The setting of the control valve 80, as illustrated, is determined by the choice of spring and preload at assembly and cannot be adjusted except by replacement of the spring or by addition or removal of shims. If desired, an adjustable external control could be provided by using a spring of relatively light preload and the high pressure fluid could be routed through an external adjustable pilot valve.

The pump of the present invention exhibits important advantages over swash plate pumps heretofore known. One advantage is that the present pump is characterized by minimum drag torque when operating at zero delivery and when subject to high output pressure. Another advantage is that the present pump quickly and accurately varies the displacement of the pistons in response to the pressure requirements of the system. Another advantage is only a very small area at the end of the drive shaft is subject to high discharge pressure. Furthermore, the check valves 138 keep high pressure fluid away from the pistons when they are no longer reciprocating and the drive shaft may spin in the oil-filled housing with minimal load on the bearings.

While this invention has been described in connection with certain specific embodiments thereof, it is to be understood that this is by way of illustration and not by way of limitation and the scope of this invention is defined solely by the appended claims which should be construed as broadly as the prior art will permit.

I claim:

1. In a pump having a housing provided with an inlet and an outlet, means defining a plurality of circumferentially spaced cylindrical bores in said housing, a piston mounted for reciprocation in each of said bores, a rotary drive shaft, a cam mounted on said drive shaft for reciprocating said pistons, actuator means responsive to output pressure for rotating said cam to a position in which the effective stroke of said pistons is varied as required, a thrust member carried by said drive shaft and being angularly disposed with respect to the axis of said drive shaft, said cam mounted for rotation with said thrust member, and including a surface operatively associated with said pistons, said cam being of wedge cross section and being relatively rotatable with respect to said thrust member so as to present said surface angularly disposed

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with respect to said drive shaft or perpendicular to said drive shaft, and said actuator means effecting rotation of said cam with respect to said drive shaft in response to output pressure from said pump.

2. A pump in accordance with claim 1, wherein said cam is biased to the maximum output position and is rotated for decreased effective stroke of said pistons by a pilot valve operated by fluid at discharge pressure.

3. A pump as claimed in claim 1 wherein said cam is movable from a first position in which said surface is disposed in angular relation to the axis of said drive shaft to a second position in which said surface is perpendicular to the axis of said drive shaft, and said actuator means being operable in response to output pressure to progressively rotate said cam from said first position to said second position.

4. A pump in accordance with claim 3, wherein said actuator means includes a cavity having a pair of ports and a vane disposed in said cavity, and a pilot valve slidable in response to an increase in output pressure of said pump to afford fluid communication through one of said ports to move said vane for rotation of said cam toward said second position.

5. A pump as claimed in claim 1 wherein said pistons are reciprocated by said surface on said cam, said actuator means including a cavity within said thrust member, a hub mounted on said drive shaft and relatively rotatable with respect to said drive shaft, said cam being mounted for rotation with said hub, a vane carried by said hub and disposed within said cavity, port means affording fluid communication between the outlet of said pump and said cavity to bias said cam to the maximum stroke or first position; and control means operative in

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response to output pressure for moving said cam plate toward the minimum stroke or second position.

6. A pump in accordance with claim 6, wherein said control means includes a pilot valve operable to terminate the supply of high pressure fluid urging the cam to the maximum stroke position and permitting drag torque to move the cam plate toward the minimum stroke position.

7. A pump in accordance with claim 5 wherein valve means are provided to prevent the back flow of high pressure fluid to said pistons.

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