

Aug. 16, 1966

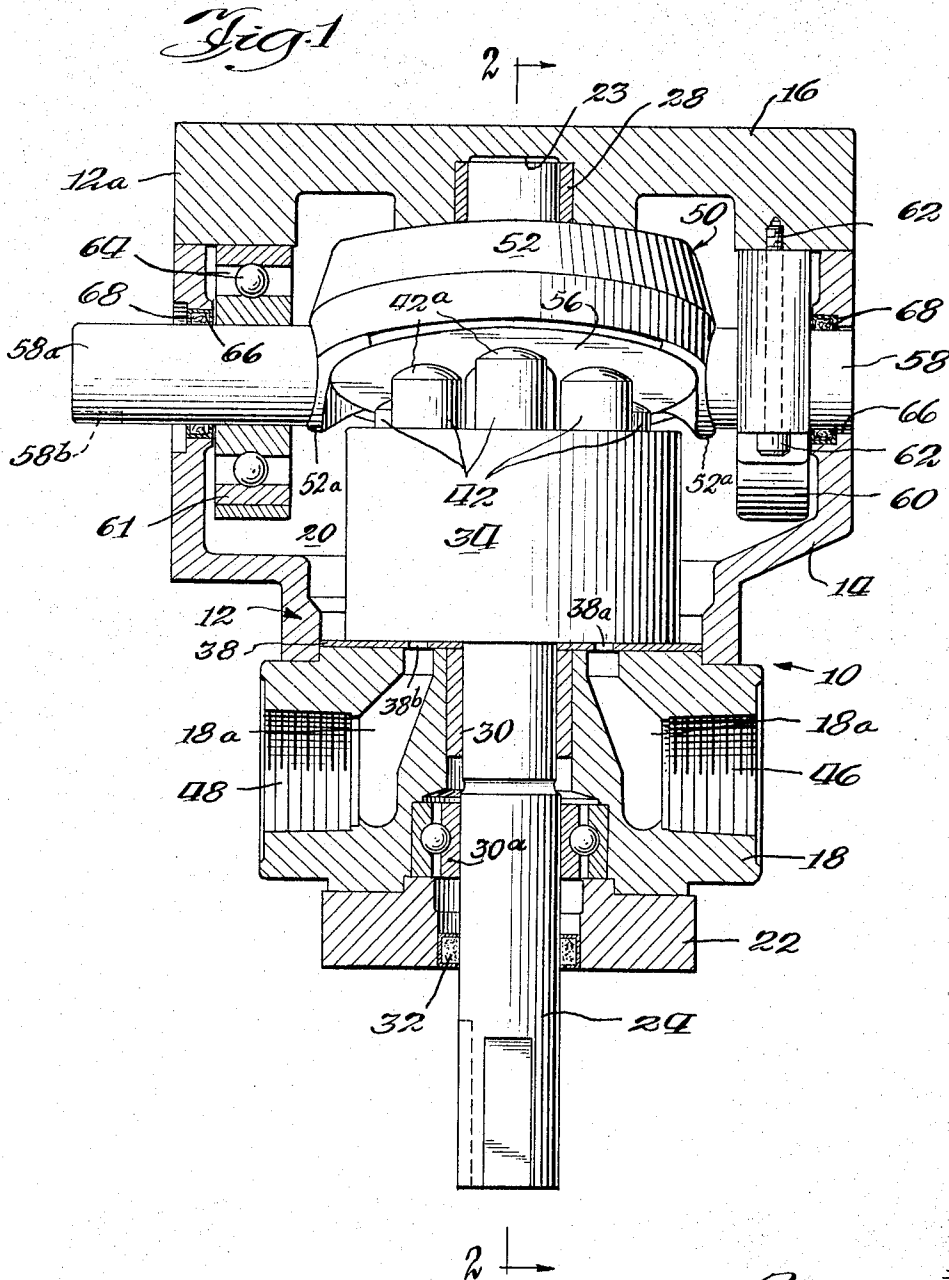
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3,266,434

VARIABLE OUTPUT PUMP

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4 Sheets-Sheet 1



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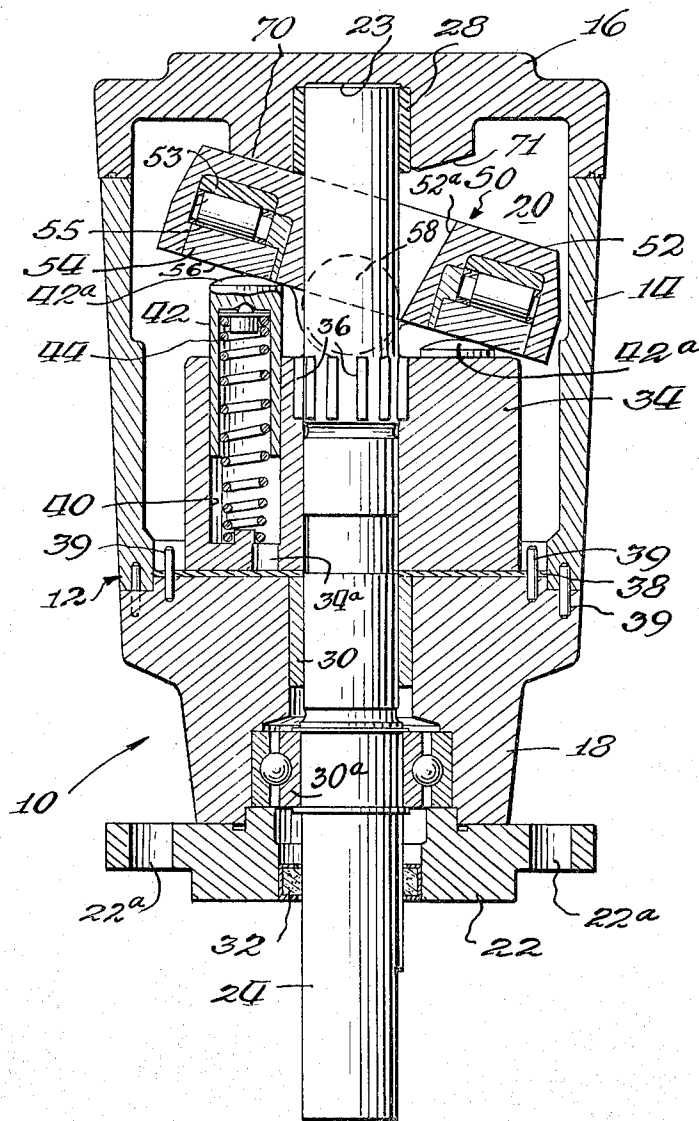
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VARIABLE OUTPUT PUMP

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Fig. 2



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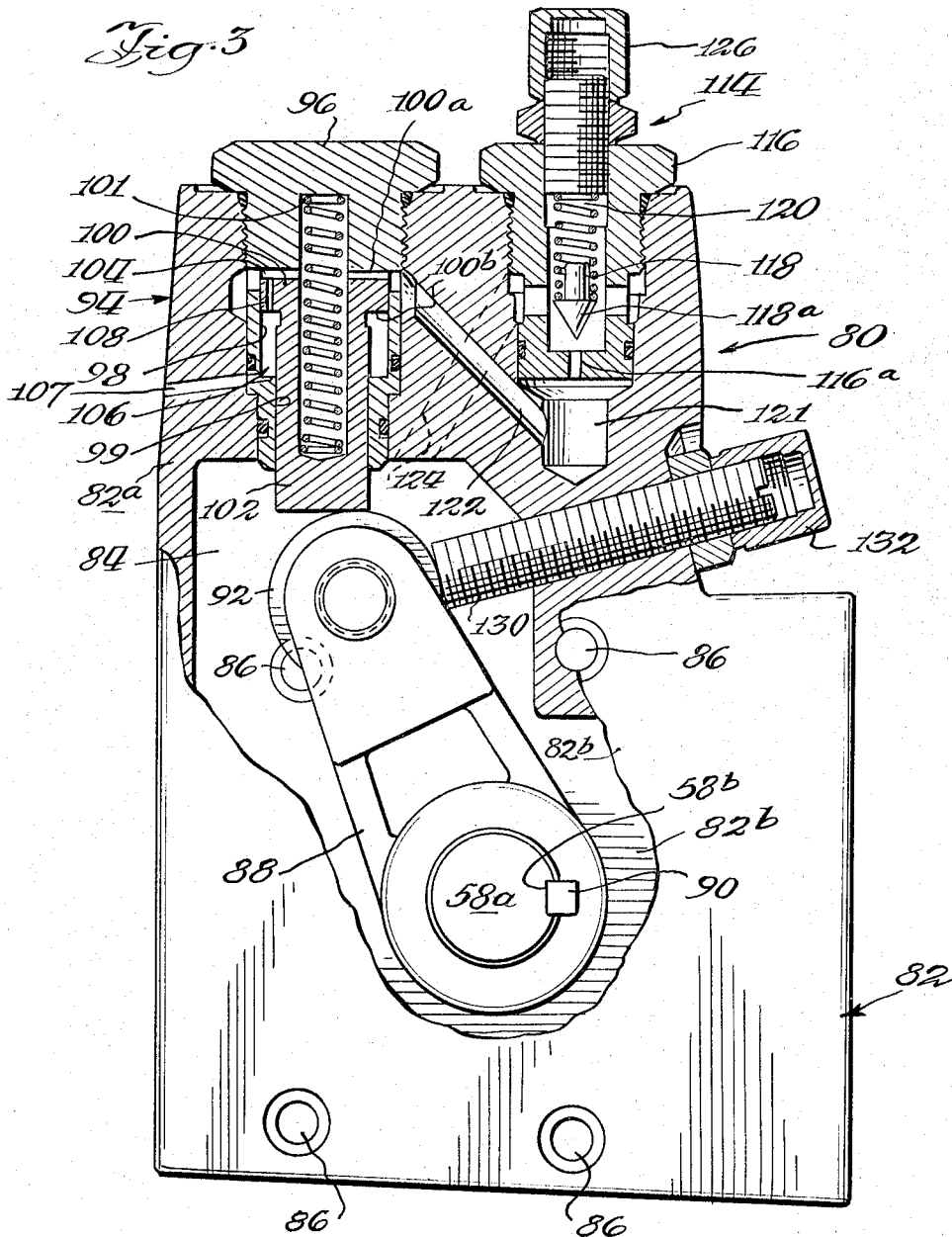
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VARIABLE OUTPUT PUMP

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4 Sheets-Sheet 3



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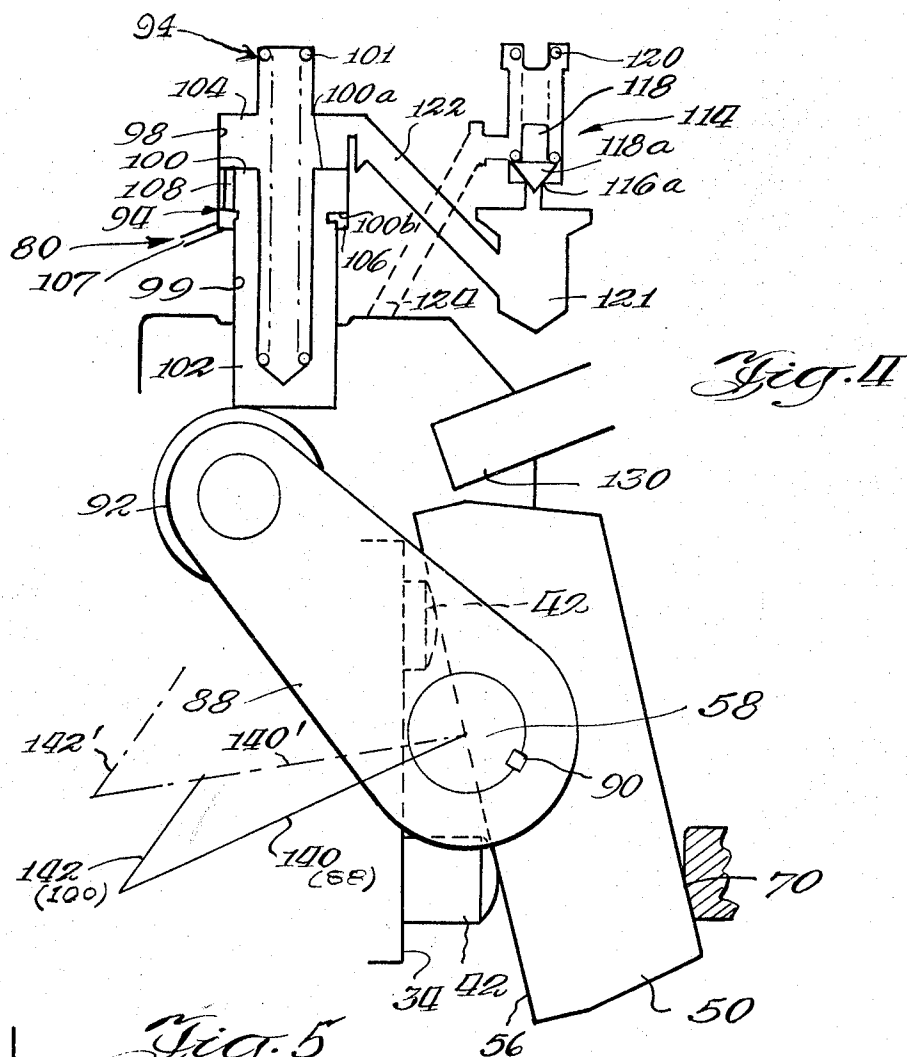
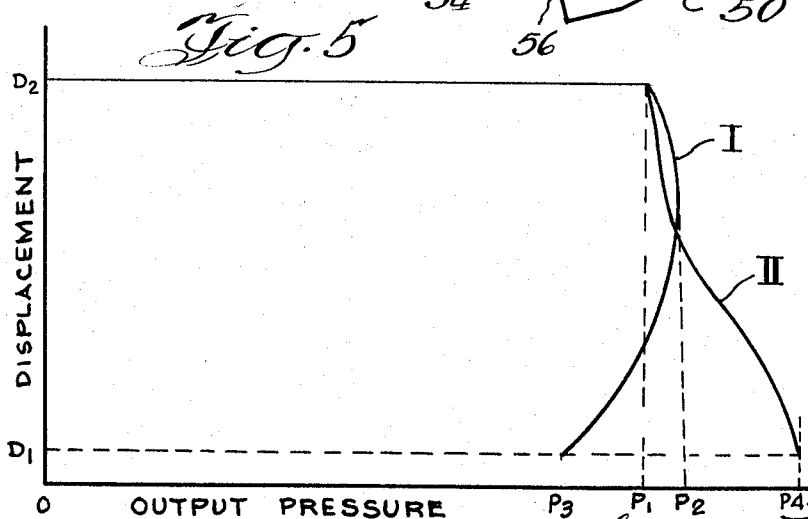
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VARIABLE OUTPUT PUMP

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4 Sheets-Sheet 4



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3,266,434

VARIABLE OUTPUT PUMP

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6 Claims. (Cl. 103-162)

The present invention relates to variable output pumps and has for its primary objects the provision of a new and improved variable output pump of the swash plate type.

Another object of the present invention is to provide a new and improved variable output pump of the swash plate type in which the pistons produce forces tending to return the plate to its minimum output position characterized by control means including a hydraulically unbalanced control piston having a first side communicating with the pump outlet and a second side having restricted communication with the first and having associated with it a relief valve communicating with and solely responsive to pressure at the second side of the piston for maintaining the swash plate in maximum output position until a predetermined pump output pressure is reached and thereafter reducing the pressure acting at the second side of the piston for effecting movement of the swash plate toward its minimum output position.

A further object of the present invention is the provision of a new and improved variable output pump of the type described above wherein the swash plate is moved directly to its minimum output position when the pump output pressure reaches a predetermined value.

A still further object of the present invention is the provision of a new and improved variable output pump in which the swash plate is moved gradually with increasing pressures to decrease the output of the pump.

A further object of the present invention is to provide a variable output pump of the type described above wherein the control piston has associated with it light spring means at its second side to hold the swash plate in its maximum output position when operation is initiated and until output pressure is generated.

A further object of the present invention is to provide a control of type described about wherein a swash plate and piston are interconnected by cam means or a lever, the effective length of which is varied in predetermined manner responsive to the angular position of the swash plate and, more particularly, wherein for a first mode of operation the effective length of the lever arm is decreased as the wash plate moves from its maximum output to its minimum output position and wherein for a second mode of operation the effective length of the lever arm is increased.

Another object of the present invention is the provision of a new and improved variable output pump that is simple in construction, operates efficiently, is readily modified to provide different modes of operation, utilizes but a light spring initially to hold the swash plate at maximum output position and in which pump output pressure is utilized to maintain the swash plate in maximum output position until a predetermined maximum pressure is reached.

In brief, the variable output pump of the present invention includes an assembly of annularly disposed pistons having spherical end faces. The assembly is rotatable about a first axis and the end faces of the pistons engage a swash plate which may have a planar surface tiltable about a tilt axis normal to the first mentioned axis. The swash plate is tiltable between minimum and maximum output positions determined by stops and the minimum position is such that only the pump or system losses are supplied. The planar surface passes substantially through the tilt axis and is substantially normal to the first axis at zero output of the pump. The pistons

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reciprocate along axes parallel to the axis of rotation (the first axis) and the arrangement is such that the pistons produce forces tending to return the swash plate to its minimum output position. It has been found that the torque on the swash plate due to the pistons varies substantially linearly from a minimum to a maximum with the angular change of the swash plate angle from its minimum to maximum output position, which change in the present embodiment is about 15°. The control of the present invention includes a cylinder and a piston in the cylinder responsive to pump output pressure. The piston is hydraulically unbalanced sufficiently to overcome the forces generated by the pistons. This unbalancing is achieved by providing restricted communication between a first side of the piston, which is connected to the pump output, and a second larger area side of the piston. A light spring is disposed in the cylinder to act on the larger area side of the piston to move it to a control position corresponding to maximum output in the absence of output pressure. The control means includes also a relief valve operable above a predetermined pressure and communicating with and solely responsive to pressure at the second side of the piston and effective to maintain the piston and swash plate in maximum output position until the predetermined pump output pressure is reached. Thereafter, the relief valve opens to reduce the pressure acting on the second side of the piston to effect movement of the swash plate to its minimum output position. The piston and swash plate are interconnected by cam means, such as a lever, movable about the tilt axis and which may be disposed at a desired angle relative to the swash plate surface engaged by the pistons. The lever and line of piston movement have different angular relations for different desired modes of operation, the arrangement being such that the effective lever arm provided by the lever varies with the position of the swash plate. For a mode of operation in which the pump output is quickly and effectively reduced from a maximum to the minimum, the lever and piston are at an angle of about 135° relative to each other in the maximum output position of the swash plate and at an angle of about 150° relative to each other in the minimum output position. The forces due to the operation of the pump and the counteracting forces from the control piston are such so that the control piston forces overbalance the pump forces until the relief valve opens at a predetermined high pressure. When the relief valve opens, the control piston forces decrease and the control piston is moved by the lever arm toward the minimum output position of the lever arm and swash plate. During such movement, the effective length of the lever arm is decreased and, as a result, the pump generated forces overcome those exerted by the piston and the swash plate is quickly moved to its minimum output position. For a mode of operation in which the pump pressure gradually increases as the output or displacement of the pump is decreased, the lever and piston are at an angle of about 30° relative to each other in the maximum output position and at an angle of about 45° relative to each other in the minimum output position. In this mode of operation the opening of the relief valve and resulting movement of the piston increases the effective lever arm by which the piston acts on the swash plate as the swash plate moves to its minimum output position. As a result, the decreasing piston forces are made more effective by the increasing length of the lever arm so that the pump output is gradually decreased at gradually increasing pressures.

The invention, both as to its organization and manner of operation, together with further objects and advantages, will best be understood from the following detailed de-

scription considered in conjunction with the accompanying drawings, wherein:

FIGS. 1 and 2 are fragmentary axial sectional views of a variable volume pump to which the present invention is applied, FIG. 2 being taken along line 2—2 of FIG. 1;

FIG. 3 is an enlarged partly sectional view showing the control of the present invention applied to the pump of FIGS. 1 and 2;

FIG. 4 is a fragmentary, enlarged and partly diagrammatic view of the pump and control assembly of FIGS. 1 through 3 with much of the structure broken away, better to illustrate the invention and illustrating diagrammatically a modified embodiment; and

FIG. 5 is a graph illustrating some of the characteristics of operation of the pump with the control assembly of FIGS. 1 through 3 and of the modified embodiment.

Referring now to the drawings and more particularly to FIGS. 1 and 2, there is illustrated a variable output pump of the swash plate type designed generally as 10. The pump has a casing 12 comprising a hollow housing portion 14, an end closure plate 16 and a shaft receiving end portion 18—these providing a chamber 20. To secure the pump 10 in position there is provided a mounting plate 22 secured to end portion 18 and having suitable bolt holes 22a.

The pump 10 is provided with a drive shaft 24, one end of which projects through the mounting plate 22 and the end portion 18 into the chamber 20 and which terminates in a recess 23 in the end plate 16. The shaft 24 is journaled for rotation about a first axis in the needle bearings 28 and 30 and ball bearings 30a carried in the recess 23 and end portion 18, respectively. A suitable seal 32 may be provided to prevent leakage around the shaft where it projects outside the casing.

The pump includes a rotatable cylinder barrel 34 mounted upon the shaft 24 within the enclosed chamber 20. The cylinder barrel 34 is keyed for rotation with the shaft by means of splines 36, and has one end separated from the pump end portion 18 by a fixedly mounted valve plate 38. The pump end portion 18, the casing 14 and the valve plate 38 may be held in position by means of alignment pins 39 (see FIG. 2) adapted to seat in holes drilled for the purpose.

The cylinder barrel 34 is provided with a plurality of cylinders 40 opening into the chamber 20 and disposed parallel to the axis of rotation of shaft 24 and cylinder barrel 34. Each cylinder is provided with a generally cup-shaped pumping piston 42 mounted for reciprocal axial movement and projecting into the chamber. The pistons 42 are biased outwardly into the chamber by springs 44 located in the cylinders 40 and each has a spherical closed end 42a abutting against a swash plate assembly, indicated as a whole by reference character 50.

The pump is provided with a pair of ports 46 and 48, which may serve as input and output ports for the pump, and which may be connected to suitable fluid carrying conduits. Ports 46 and 48 are in the body portion 18 and communicate with the various cylinders 40 by means of passageways 18a through inlet and outlet openings 38a and 38b of known construction in the valve plate 38 and the passages 34a in the cylinder barrel leading to the cylinders 40.

The pump is provided with a swash plate assembly 50 located in the chamber 20 and tiltable to control the piston stroke and thus the displacement or output of the pump. The assembly includes a yoke or cradle 52 of generally cup-shaped cross section provided with a central opening 52a through which the shaft 24 extends. Within an annular recess 53 in the member 52 there are mounted an annular thrust plate 54 and a thrust bearing assembly 55 to take the thrust of the pistons. The thrust plate has a surface 56 against which the spherical ends 42a of the pistons abut and which in the illustrated embodiment is a planar surface passing through the tilt axis of the swash plate assembly.

The swash plate assembly 50 is mounted for pivotal

or tilting movement upon a pair of opposed trunnion shafts 58 which laterally extend outwardly from the swash plate 50 along a second axis normal to the first axis, i.e., the axis of rotation of shaft 24 and the pistons. The trunnion shafts 58 are formed integrally with the cradle 52, and are joined to a pair of bosses 52a provided on the cradle 52 for that purpose. The shafts 58 are mounted in pillow blocks 60 and 61 which are held against the end plate 16 by suitable mounting bolts or other fasteners 62. The blocks 60 and 61 carry suitable bearing assemblies 64 (only one of which is visible in FIG. 1) rotatably mounting the shafts 58.

The housing portion 14 is provided with opposed annular openings 66 through which the trunnions 58 extend. Leakage through these openings is prevented by suitable seals 68. It should be noted that one of the shafts 58 includes a portion 58a which projects outside of the pump casing 12, where it is accessible for operation by the control of the present invention.

In order to limit the pivotal motion of the swash plate assembly 50 the end plate 16 is provided with abutment surfaces forming maximum output or displacement stops 70 and 71, and of which only one is normally used for a single direction of rotation, this being stop 70, as will be described later herein.

The shaft 24 may be rotated by any suitable means, such as an external motor or the like. The shaft rotates the cylinder barrel 34 thereby axially to reciprocate the pistons 42 with their spherically shaped faces 42a bearing against the surface 56 of the swash plate assembly 50. The displacement of the pump will depend upon the angular position of the swash plate 50, with the pump being at zero displacement when the surface 56, is normal to the pumping pistons 42. Actually, the swash plate is provided with a minimum displacement position determined by adjustable stop 130 (FIG. 3) at which the pump output is not zero but such as to supply pump or system leakage losses. This position may be at an angle of about one-half degree off normal. As the swash plate 50 is tilted away from its normal position, the displacement or output of the pump 10 will increase, due to the increased stroke of the pumping pistons 42. As will be readily understood, the swash plate 50 could be pivoted in either direction, and the cylinder barrel 34 could be rotated in either direction. Thus, the ports 46 and 48 may each serve either as an input or output.

In FIGS. 1 and 2 the pump 10 is illustrated in its position of maximum displacement, with the swash plate 50 abutting the stop 70. In a pump constructed in accordance with the present invention, when the swash plate is in its position of maximum displacement against the stop 70, it is tilted approximately 15° from its zero displacement position normal to the pumping pistons.

It has been found that in the operation of a pump built as hereinbefore described, the pistons exert forces on the swash plate tending to force the latter towards its position of minimum displacement. Stated in another way, whenever the swash plate 50 is rotated to a position not normal to the pumping pistons 42, the pistons exert a force on the swash plate 50 which tends to return the swash plate to its normal position. This force has been measured as a torque on the trunnion shafts 58, and has been found to be linearly related to the angular position of the swash plate. Thus, the more the swash plate is tilted, the larger is the torque on the shaft 58 which tends to force the swash plate back to its normal position. In the illustrated construction the swash plate surface 56 passes through the tilt axis and the plane of the centers of the radii for the spherical ends of the pistons is displaced from the surface 56.

In order to overcome the forces exerted or generated by the pumping pistons, and in accordance with the present invention, there is provided a novel control unit 80 (FIGS. 3 and 4) which is adapted to be connected to the output of pump 10 in order to control the position of the swash plate 50.

The control unit 80 includes a control piston assembly 94 with a control piston 100 supplied with pump outlet pressure and an associated relief valve assembly 114 for controlling the pump output through control of the position of the swash plate assembly 50 by a lever 88 actuated by the control piston and connected to the swash plate trunnion 58a, as by a key 58b. The control is such that when the pump output pressure exceeds a predetermined value at which the relief valve assembly 114 is substantially fully open, the pump output is quickly reduced to a minimum supplying only leakage losses. Alternatively, and as described later, the control can be modified by changing the angle between the lever 88 and line of movement of piston 100 so that the pump output is gradually reduced with increasing pressures. The arrangement is such that the effective length of the lever arm provided by lever 88 changes with the angular position of the swash plate assembly about its tilt axis. In the first arrangement mentioned above, the effective lever arm decreases in movement of the swash plate assembly from maximum to minimum output position. In the alternative arrangement, the effective length of the lever arm increases as the swash plate assembly is moved from maximum output position toward the minimum position.

The control unit 80 includes a casing 82 having a central body portion 82a sandwiched between a pair of side plates 82b. The body portion 82a has an opening forming a chamber 84 in which the lever 88 is located.

In order to mount the control unit 80 on the pump 10, the control unit is provided with mounting holes 86 which align with suitable threaded mounting holes in the pump casing, which are not visible in the drawings, but which lie on a flat surface 12a (see FIG. 1) on the pump housing 12. Thus, the control unit 80 may be securely bolted in position against the surface 12a on the pump 10 with lever 88 attached to trunnion 58a.

In order to control the position of the swash plate assembly 50, the control unit 80 includes a cam means, such as the above referred to lever arm 88, located within the chamber 84 and which is fixed in a position normal to the shaft 58. The lever is provided with a roller 92 at its outer free end for engagement by control piston 100. It should be understood that since the lever 88 is keyed to the shaft 58, the position of the lever 88 is directly related to the angular position of the swash plate 50. In addition, the lever arm 88 extends from shaft 58 at an angle from the plane of the swash plate surface, although it is perpendicular to the shaft 58. In the illustrated device constructed in accordance with the present invention, the lever arm is offset from the swash plate surface 56 by an angle in the range of about 30°, although other angular relationships may be utilized, as noted further herein, the important angular relationship being that between the lever and the line of movement of the control piston 100.

The control piston 100 is mounted within a cylinder 98 and is biased downwardly, as viewed in FIG. 3, by a light spring 101. The piston 100 has an integral smaller diameter end 102 projecting through an opening 99 to engage the roller 92 on the lever 88. The piston divides the cylinder into two pressure chambers 104 and 106 which are interconnected by a restricted passageway 108 of small diameter which may extend through the head of the piston 100. The chamber 106 is in constant communication with the output of the pump as through a fluid passageway formed of drillings in the pump casing 12, not shown, but which has been illustrated diagrammatically by the reference character 107.

The pressure chambers 104 and 106 are defined in part by a pair of opposed surfaces 100a and 100b on the piston 100. The surface 100a, at the second side of the piston, is larger than the surface 100b, at the first side of the piston, due to the piston rod 102. Consequently,

the introduction of pressurized fluid from the pump outlet through passageway 107 into the pressure chamber 106, and through passage 108 into the chamber 104, provides a hydraulic unbalance tending to force the piston 100 downwardly, as seen in FIG. 3, against the lever arm roller 92. This in turn will tend to pivot the swash plate assembly 50 to its maximum stroke and output position, as can best be seen in FIG. 4.

The piston 100 is biased to maximum displacement position during start up and until output pressure is generated by a light spring 101. The latter is of sufficient strength merely to force the pump to its position of maximum displacement when there is no output pressure. Once output pressure is generated, the pressure exerted thereby on the piston 100 acts to hold the pump in its position of maximum displacement. The force of the spring is negligible once output pressure is generated.

The relief valve assembly 114 includes a valve housing 116. A restricted annular opening at the bottom of the valve housing 116 includes a valve seat 116a. A normally closed valve member 118 has a portion 118a held against the valve seat 116a by means of a spring 120. A chamber 121 adjacent the valve assembly 114 is connected to the upper piston assembly pressure chamber 104 by a passageway 122 and openings at the upper end of cylinder 98. The downstream side of the relief valve assembly 114 is connected to the cavity 84, by means of a suitable passageway 124. The cavity 84 is at low pressure, and may be suitably connected to sump.

The relief valve 114 communicates with and is solely responsive to pressure at the second or upper side of the control piston. The arrangement is such that the piston is hydraulically unbalanced sufficiently to overcome the forces tending to return the swash plate assembly to its minimum output position until a predetermined pump output pressure is reached at the second or upper side of the piston. When this pressure reaches a predetermined value, the relief valve opens to reduce the pressure acting on the second side of the piston, whereupon the forces generated by the pump pistons are effective to move the swash plate toward its minimum output position. The pressure at which the relief valve operates may be adjusted by the adjustment mechanism, indicated as a whole by reference character 126, by means of which the compression of the spring 120 may be varied.

In order to assure that the pump 10 in its position of minimum displacement will maintain sufficient displacement to make up any leakage, the control assembly 80 includes an adjustable stop 130 which prevents the lever arm 88 from returning to the zero displacement position. In order to obtain proper adjustment of the lever stop 130, an adjustment mechanism 132 is provided on the exterior of the casing 82. The control unit 80 is illustrated in FIG. 3 with roller 92 abutting the stop 130, this being the position occupied by it in the minimum output position of the pump.

Reviewing now the operation of the pump, and assuming first that the pump is not in use, the various parts will be in the positions in which they are illustrated in FIGS. 1, 2 and 4. At this time the swash plate will be at its maximum output position as determined by the stop 70 and to which it is actuated by the control piston 100 and, specifically, the relatively light spring 101 forcing the control piston downwardly and moving the lever arm 88 to the position illustrated in FIG. 4. Also, the swash plate surface 56 engaged by the piston 42 is at an angle of about 15° from normal. The lever and piston are at an angle of about 135° relative to each other. The relief valve 118 is closed by the spring 120.

When the pump is started with the parts in maximum output or displacement position as described above, the pump begins to build up pressure which is transmitted to the control piston 100 through the passageway 107. This pressure is effective at both sides of the piston, being transmitted from the first (under) side to the second

(upper) side through the restricted passageway 108. The second side of the piston has an area exceeding that of the first side with the result that the control piston is hydraulically unbalanced sufficiently to overcome the forces produced by the pump pistons 42 tending to return the swash plate to minimum output position. The pressure at the second side of the piston is maintained by the relief valve 118, which is held closed until a predetermined maximum pressure is reached.

When the pump output pressure reaches a predetermined value, the relief valve, which communicates with and is solely responsive to pressure at the second side of the control piston 100, opens. In the illustrated embodiment of the invention, the relief valve opens relatively gradually to begin with against the pressure of spring 120 but when fully opened the pressure at the second side of the control piston is reduced and the pressure at the first or under side is effective to move the piston to the position shown in FIG. 3. This movement, in the described embodiment of the invention, is rapid so that the output of the pump is quickly reduced to a minimum just sufficient to overcome leakage losses in the pump and system, the minimum output position being determined by the stop 130. As the lever arm moves from its maximum to its minimum position, the effective length of the lever arm provided by the lever and through which the control piston acts on the swash plate is reduced. It is this reduction that provides for the quick movement of the swash plate from maximum to minimum displacement position.

FIG. 5 is a graph in which curve I graphically illustrates the output or pump displacement against output pressure. Normally the output or displacement is at a maximum value D_2 . This maximum displacement occurs until a pressure P_1 is reached. This is the pressure at which the relief valve 118 begins to open. As the relief valve opens fully, the pressure increases slightly with decreased displacement resulting from angular movement of the swash plate assembly toward its minimum flow position but when a pressure P_2 is reached the relief valve is fully opened and because of the gradually decreasing effective lever arm, the control piston is quickly overcome by the forces tending to force the swash plate to minimum displacement with the result that this is quickly reached at a slightly reduced pressure P_3 at the minimum displacement D_1 .

Once the minimum displacement has been reached, the pump will not return to maximum displacement until the output pressure has been considerably reduced. When such occurs, the apparatus goes from the position of FIG. 3 to the position of FIG. 4, the relief valve closing and the control piston being returned to its maximum displacement position by the light spring 101 and the hydraulic unbalance created by output pressure acting on both sides of the piston with the relief valve closed.

It is possible to achieve different operating characteristics, such as those indicated by curve II in FIG. 5, by changing the angle between the line of movement of the control piston and lever arm so that the effective lever arm through which the piston acts on the swash plate assembly is gradually increased with movement of the assembly from maximum toward minimum output position. Referring now to FIG. 4, the angular relations are diagrammatically shown by the solid lines 140 and 142, the former corresponding to the angle of the lever 88 and the latter the line of movement of the control piston 100. In FIG. 4, the line of connection of the lever 88 to the swash plate has been shown as approximately 90°, this illustrating the fact that the angle of attachment of lever 88 to the swash plate assembly 50 may be varied. In the maximum output position the angle between the lever and line of movement of piston 100 is about 30°. In the minimum output position the angle is about 45°, as shown by the line 140' indicating the position of lever 88 by line 142'. Actually, the line

of movement of the piston does not vary but the angular position of lever arm 88 does, just as in the first described embodiment. In this mode of operation the effective length of the lever arm connecting the piston and swash plate assembly increases with movement of the swash plate toward minimum output position and results in an operating characteristic corresponding to curve II illustrating increasing pump output pressure with decrease in output or displacement.

While the present invention has been described in connection with detailed embodiments thereof, it should be understood that the details are not intended to be limitative of the invention except insofar as set forth in the accompanying claims.

What is claimed as new and desired to be secured by Letters Patent of the United States is:

1. A variable output pump, including in combination, an assembly of annularly disposed pistons, the assembly being rotatable about a first axis, a swash plate engaged by the pistons and tiltable about a second axis normal to the first axis between minimum and maximum output positions to vary the output of the pump, said pistons producing forces tending to return the swash plate to its minimum output position, means including a cylinder, a piston in said cylinder responsive to pump output pressure and operably interconnected with said swash plate, said piston being hydraulically unbalanced sufficiently to overcome said forces by restricted communication from a first side of the piston connected to the pump output pressure to a second and larger area side of the piston, and a relief valve operable above a predetermined pressure communicating with and solely responsive to pressure at the second side of the piston for maintaining the swash plate in maximum output position until the predetermined pump output pressure is reached and for thereafter reducing the pressure acting on the second side of the piston for effecting movement of the swash plate toward its minimum output position.

2. A variable output pump, including in combination, an assembly of annularly disposed pistons, the assembly being rotatable about a first axis, a swash plate engaged by the pistons and tiltable about a second axis normal to the first axis between minimum and maximum output positions to vary the output of the pump, said pistons producing forces tending to return the swash plate to its minimum output position, means including a cylinder, a piston in said cylinder responsive to pump output pressure and operably interconnected with said swash plate, said piston being hydraulically unbalanced sufficiently to overcome said forces by restricted communication from a first side of the piston connected to the pump output pressure to a second and larger area side of the piston, and a relief valve operable above a predetermined pressure communicating with and solely responsive to pressure at the second side of the piston for maintaining the swash plate in maximum output position until the predetermined pump output pressure is reached and for thereafter reducing the pressure acting on the second side of the piston for movement of the swash plate directly to its minimum output position.

3. A variable output pump, including in combination, an assembly of annularly disposed pistons, the assembly being rotatable about a first axis, a swash plate engaged by the pistons and tiltable about a second axis normal to the first axis between minimum and maximum output positions to vary the output of the pump, said pistons producing forces tending to return the swash plate to its minimum output position, means including a cylinder, a piston in said cylinder responsive to pump output pressure and operably interconnected with the swash plate, said piston being hydraulically unbalanced sufficiently to overcome said forces by restricted communication from a first side of the piston connected to the pump output pressure to a second and larger area side of the piston, and a relief valve operable above a predetermined pres-

sure communicating with and solely responsive to pressure at the second side of the piston for maintaining the swash plate in maximum output position until the predetermined pump output pressure is reached and for thereafter reducing the pressure acting on the second side of the piston for effecting gradual movement of the swash plate toward its minimum output position with increasing pump output pressure.

4. A variable output pump, including in combination, an assembly of annularly disposed pistons, the assembly being rotatable about a first axis, a swash plate engaged by the pistons and tiltable about a tilt axis normal to the first axis between minimum and maximum output positions to vary the output of the pump, said pistons producing forces tending to return the swash plate to its minimum output position, means including a cylinder, a piston in said cylinder responsive to pump output pressure said piston being hydraulically unbalanced sufficiently to overcome said forces by restricted communication from a first side of the piston connected to the pump output pressure to a second and larger area side of the piston, cam means movable about the tilt axis of the swash plate interconnecting the piston and swash plate for varying in predetermined manner the effective lever arm through which the piston acts on the swash plate in response to the angular position of the swash plate, and a relief valve operable above a predetermined pressure communicating with and solely responsive to pressure at the second side of the piston for maintaining the swash plate in maximum output position until the predetermined pump output pressure is reached and for thereafter reducing the pressure acting on the second side of the piston for effecting movement of the swash plate toward its minimum output position.

5. A variable output pump, including in combination, an assembly of annularly disposed pistons, the assembly being rotatable about a first axis, a swash plate engaged by the pistons and tiltable about a tilt axis normal to the first axis between minimum and maximum output positions to vary the output of the pump, said pistons producing forces tending to return the swash plate to its minimum output position, means including a cylinder, a piston movably mounted in said cylinder responsive to pump output pressure said piston being hydraulically unbalanced sufficiently to overcome said forces by restricted communication from a first side of the piston connected to the pump output pressure to a second and larger area side of the piston, a lever connected to the swash plate and movable about the tilt axis and having an angle of about 135° to the line of movement of the piston in the

maximum output position and of about 150° in the minimum output position, and a relief valve operable above a predetermined pressure communicating with and solely responsive to pressure at the second side of the piston for maintaining the swash plate in maximum output position until the predetermined pump output pressure is reached and for thereafter reducing the pressure acting on the second side of the piston for effecting movement of the swash plate toward its minimum output position.

6. A variable output pump, including in combination, an assembly of annularly disposed pistons, the assembly being rotatable about a first axis, a swash plate engaged by the pistons and tiltable about a tilt axis normal to the first axis between minimum and maximum output positions to vary the output of the pump, said pistons producing forces tending to return the swash plate to its minimum output position, means including a cylinder, a piston movable in said cylinder responsive to pump output pressure said piston being hydraulically unbalanced sufficiently to overcome said forces by restricted communication from a first side of the piston connected to the pump output pressure to a second and larger area side of the piston, a lever connected to the swash plate and movable about the tilt axis and having an angle of about 30° to the line of movement of the piston in the maximum output position and of about 45° in the minimum output position, and a relief valve operable above a predetermined pressure communicating with and solely responsive to pressure at the second side of the piston for maintaining the swash plate in maximum output position until the predetermined pump output pressure is reached and for thereafter reducing the pressure acting on the second side of the piston for effecting movement of the swash plate toward its minimum output position.

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