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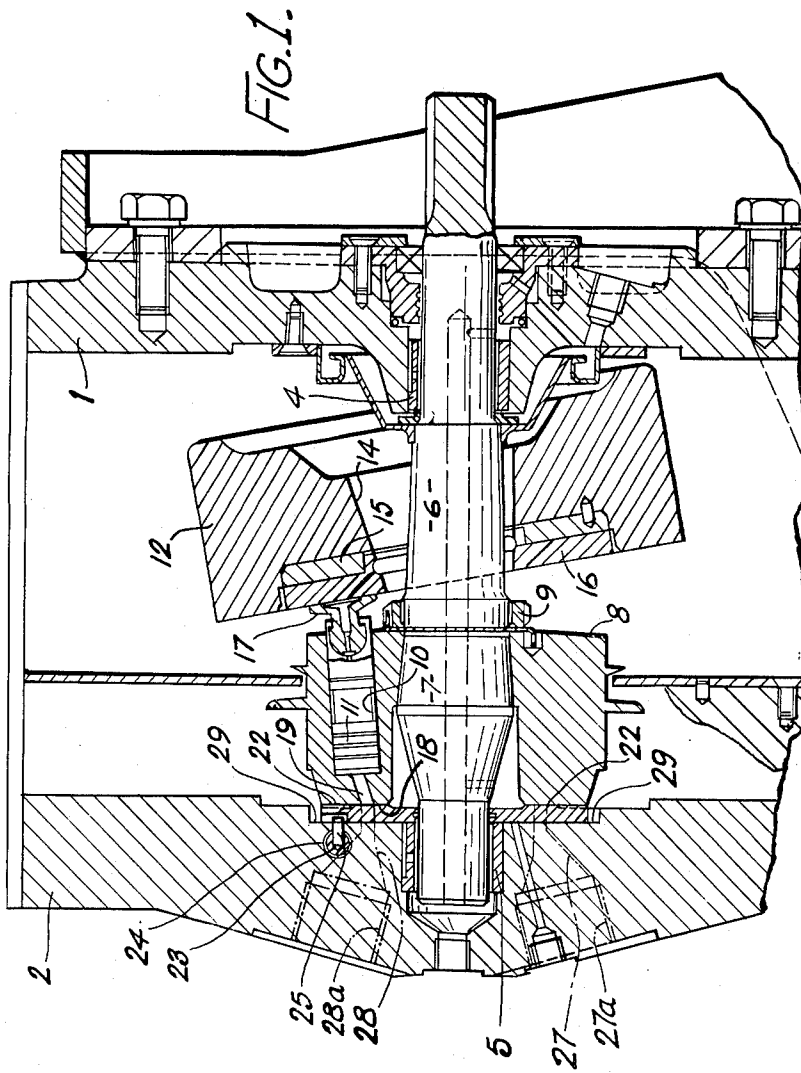
D. FIRTH ETAL

3,202,106

HYDRAULIC POSITIVE DISPLACEMENT ROTARY MACHINES

Filed March 1, 1963

3 Sheets-Sheet 1



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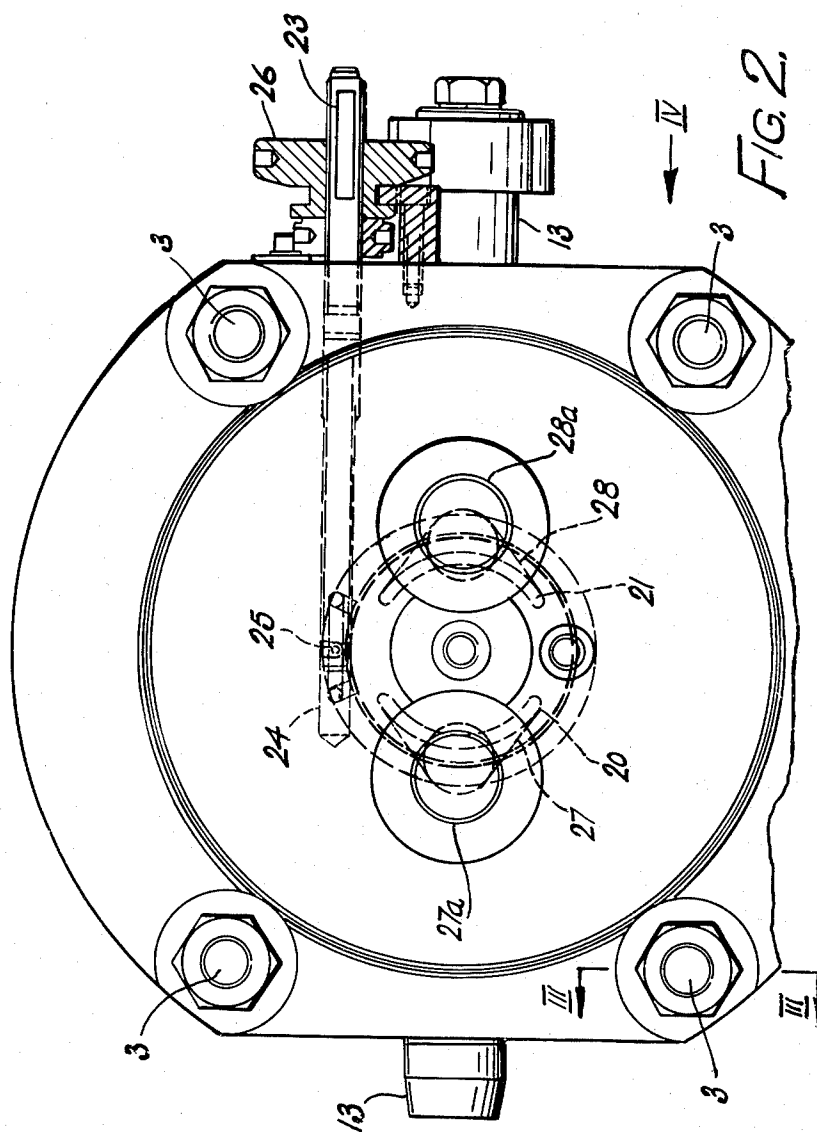
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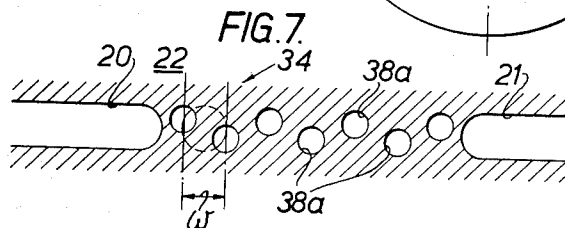
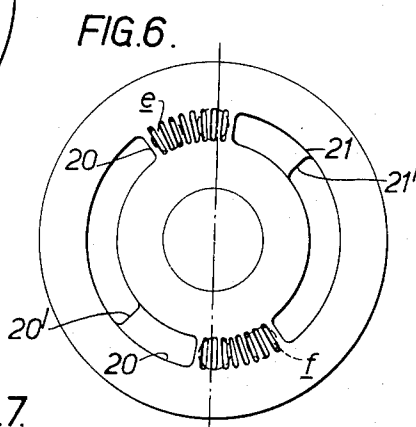
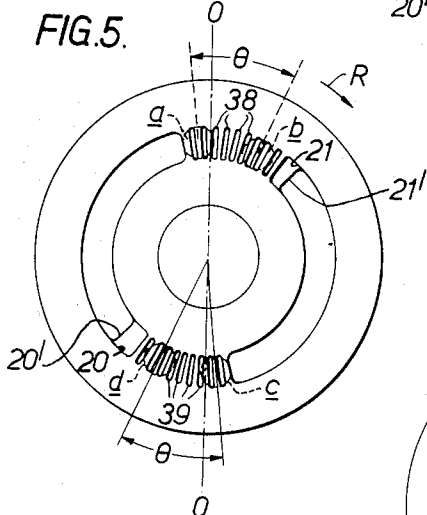
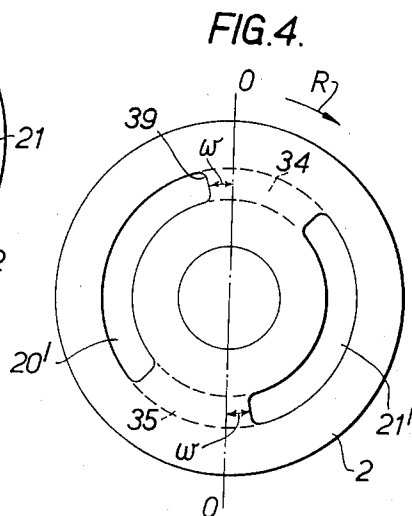
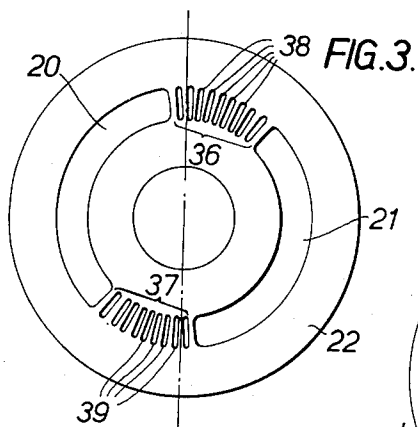
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HYDRAULIC POSITIVE DISPLACEMENT ROTARY MACHINES

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HYDRAULIC POSITIVE DISPLACEMENT ROTARY MACHINES

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Claims priority, application Great Britain, Mar. 13, 1962, 9,533/62

4 Claims. (Cl. 103-162)

This invention relates to hydraulic positive displacement rotary machines of the kind (hereinafter referred to as the kind described) in which a cylinder block which is rotatable relative to a cam member and a port member has a plurality of cylinders containing pistons reciprocable under the control of the cam member and ports communicating with the cylinders, each port being arranged to communicate in the course of said rotation alternately with inlet and outlet ports in the port member.

The invention is particularly but not exclusively applicable to swash plate hydraulic machines in which a cylinder block having a plurality of cylinders lying generally parallel to the axis of rotation of the block, is rotatable between a stationary back plate or port block and a non-rotatable swash plate, the latter usually being adjustable for inclination of its plane in order to vary the stroke of the pistons in the cylinder block in accordance with the demands of the system to which the machine is coupled.

The smooth and quiet operation of machines of the kind described, especially at relatively high line pressures, is largely determined by the timing of the port events for each cylinder. As each cylinder comes into communication with a high pressure port or a low pressure port, there is a risk of the setting up of a shock wave in the hydraulic fluid at the instant of each new registration as a result of the fluid in the cylinder being at a substantially different pressure from the pressure of the fluid in the inlet or outlet port. For example, a cylinder moving into communication with the outlet port may contain fluid at substantially the same pressure as exists in the inlet port. The shock waves not only cause noise in the hydraulic circuit but also impose shock loads on both the cylinder block and port member of the machine and the equipment associated with the hydraulic circuit.

In order to overcome this difficulty, it has already been proposed, in Patent Number 3,089,427, to interpose an angularly adjustable port plate between the working surface of the cylinder block and the port block of a swash plate machine. This port plate has arcuate ports of generally similar angular extent to those in the port block and in register therewith, and means is provided for angularly adjusting this port plate so as to change the angular positions of register of each cylinder with the arcuate ports in the port plate. This enables each piston to be displaced within its cylinder to compress or decompress oil therein before the cylinder is exposed to the next port pressure. For example, when a cylinder is transferring from register with a low pressure port into register with a high pressure port, the above-mentioned adjustment can be made so that the piston begins to compress the oil trapped therein while the cylinder is still blanked off by the space between the adjacent ends of the two arcuate ports. This pre-compression of the cylinder charge should, theoretically, continue until the oil pressure is equal to that in the high pressure port. No shock wave is then set up in the oil in the cylinder or the port at the instant of commencement of register between

the two. These earlier proposals have the disadvantage that changes in the timing of cylinder opening and changes in the timing of cylinder closing always accompany each other, whereby the efficiency of the machine is impaired under many operating conditions. It is an object of the present invention to provide means by which this disadvantage of the earlier proposals can be avoided.

The invention provides a hydraulic positive displacement rotary machine of the kind referred to wherein a control member is disposed between the cylinder block and the port member and has inlet and outlet ports registering with those in the port member, a plurality of small, independent ports being provided in the control member at positions between the inlet and outlet ports. Ports in the cylinder block communicating with said cylinders open through a face of the cylinder block directed towards said control member and register with the inlet and outlet ports and said independent ports in the control member in the course of said relative rotation. Adjustment means is provided for adjusting the angular position of the control member about the axis of rotation whereby the number of said independent ports which is blanked off by the port member can be varied. The angle of rotation during which each cylinder is sealed before communicating with an inlet or outlet port thus starts or finishes at a point fixed relative to the port member and can be varied as desired by adjustment of the control member.

The independent ports may comprise radially-extending slots or circular holes of less diameter than the widths of the inlet and outlet ports in the control member, the centres of the holes being staggered from a circle about the axis of rotation.

As hereinbefore mentioned, the invention is particularly applicable to swash plate machines. In a preferred form of swash plate machine in accordance with the invention, the control member comprises a flat plate disposed between flat faces of the port member and the cylinder block, the plate having arcuate inlet and outlet ports registering with arcuate inlet and outlet ports in the flat face of the port member.

The following is a description, by way of example, of two embodiments of the invention, as applied to a swash plate machine (described in detail for use as a control, but also capable of use as a motor), reference being made to the accompanying drawings in which:

FIGURE 1 is an axial cross-section of the complete pump assembly,

FIGURE 2 is an elevation of the discharge end of the pump,

FIGURE 3 is an elevation of a port plate for the pump shown in FIGURES 1 and 2,

FIGURE 4 is a corresponding elevation of the operative portion of the port block on which the port plate of FIGURE 3 rests,

FIGURES 5 and 6 illustrate alternative positions of adjustment of the port plate of FIGURE 3 relative to the port block of FIGURE 4, and

FIGURE 7 is a developed diagram of a modified arrangement of intermediate ports for the port plate of FIGURES 3, 5 and 6.

The pump illustrated consists of a main frame or body having a front end plate 1 and a ported back end plate or port block 2 clamped by four pillars 3. Each end plate 1, 2 carries a journal bearing 4, 5 respectively for a short rigid drive shaft 6. Adjacent the bearing 5 in the back end plate 2, the shaft 6 is formed with a locking taper section 7 on which is locked a cylinder block 8. This block is drawn up on the taper by a backnut 9 on the shaft. The cylinder block 8 contains a number of cylinders 10 whose axes are mutually inclined inwards towards the back end plate 2. A piston 11 in each cylinder is

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reciprocable under the control of a normally fixed swash plate 12 carried on trunnions. The swash plate 12 has a central conical aperture 14 through which the shaft 6 passes, the dimensions of this aperture being sufficient to allow for adjustment of the angle of the swash plate to the shaft 6.

The working face of the swash plate is recessed to accommodate an annular bearing pad 15 and an annular slipper plate 16. The latter is free to rotate under the frictional drag of slippers 17 each of which is engaged with a respective piston 11. For clarity of illustration in FIGURE 1, only one cylinder 10, piston 11 and slipper 17 is shown.

The back face 18 of the cylinder block 8 is pierced by inlet/outlet ducts or ports 19, one to each cylinder 10, the openings to which register successively with arcuate inlet and outlet ports 20, 21 respectively in a floating port plate 22. This port plate is not anchored to the back end plate 2 except for angular orientation about the shaft 6 with respect to the swash plate 12. This angular orientation is controlled by means of a threaded rod 23 which is slidable in a bore 24 in the back end plate 2 and which engages, at its inner end, a locating peg 25 fastened to the port plate 22 and projecting into the bore 24. The rod 23 is axially adjustable by means of a captive capstan nut 26. The ports 20, 21 communicate with an external circuit by way of flared ducts 27, 28 respectively and inlet and outlet sockets 27a, 28a in the back end plate 2. The ducts 27, 28 open through a bearing surface 29 on the back end plate in the form of two arcuate ports registering with the arcuate ports 20, 21 respectively in the port plate 22.

The port plate 22 forms a kind of washer between the mutually opposed faces 18 of the cylinder block 8 and 29 of the back end plate 2, and has a limited freedom to float radially between the two. This radial floating action is hydrostatically controlled by means of internal ducts and cavities. The port plate 22 also has leakage oil layers between its flat faces and the opposed faces 18 and 29 giving substantially equal and opposite axial loadings on the port plate and thus has a limited freedom to float axially. The pump as illustrated in FIGURES 1 and 2 is described in greater detail in Patent Number 3,089,427 aforesaid.

Referring now to FIGURES 3 and 4, the arcuate ports 20, 21 of the port plate which register with the arcuate ports 20', 21' in the port block 2 are of slightly greater angular extent than the ports 20', 21'. Between the adjacent ends of the ports 20, 21 lie two plain zones 36, 37 which are pierced by respective series of radial slots 38, 39 whose inner and outer ends lie on the inner and outer radii respectively of the arcuate ports 20, 21. The slots 38, 39 are spaced at equiangular intervals, and when the port plate 22 is superimposed on the port block 2 with ports 20, 21 symmetrically in register with the ports 20', 21' all the slots 38, 39 are blanked off by the plain zones 34, 35 of the port block 2 between the ports 20', 21'. This is the full retard condition and is illustrated in FIGURE 5 of the drawing. Here, a cylinder port at *a* which is moving in a clockwise direction after leaving the port 20 will register successively with all the slots 38 in the arcuate zone 36 up to the position *b* before registering with the port 21. The slots 38, however, are all blanked off by the plain zone 34 (FIGURE 4) between the arcuate ports 20', 21' in the port block and hence oil is trapped in each successive cylinder over the angle θ . Top dead centre occurs on the axis O—O and since the port 20 is the inlet port and the port 21 is the outlet port of the pump, whose rotation is indicated by the arrow R, the angle θ represents the maximum degree of precompression of the oil in each cylinder which can be achieved with this design of port plate.

Similarly, when a cylinder port leaving the high pressure delivery port 21 at the position *c* has moved round to the position *d*, it will have registered in turn with all

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slots 39 between these two ports, but these are all blanked by the plain zone 35 (FIGURE 4) in the port block. Hence, substantially the whole of the angle θ is available for decompression of the oil in each cylinder prior to registration of a cylinder port with the inlet port 20' via the overlap shown in FIGURE 5 immediately beyond the position *d*.

As the maximum delivery pressure of the pump decreases, so the precompression requirements of the machine decrease. Hence an angle less than θ will suffice for the required precompression. The port plate 22 is accordingly rotated counter to the direction of rotation R of the cylinder block so as to advance the leading end of the port 21 in the port plate. At the same time, this rotation of the port plate advances the leading end of the port 20 in the port plate by the same amount. Simultaneously, the trailing ends of the ports 20, 21 are advanced with respect to the corresponding ends of the ports 20', 21' in the port block so that, nominally, cut-off of each cylinder would be effected earlier in the stroke. However, the radial ports 38, 39 are successively brought into register with the ports 20', 21' in the port block, thereby effectively extending the period of register of the cylinder with respective port. Consequently, as θ is reduced towards zero, the period of communication between each cylinder and one or other of the ports 20', 21' in the port block is increased and hence the amount of precompression and pre-decompression of the oil in each cylinder is reduced.

By orientating each of the ports 20', 21' asymmetrically with respect to the axis O—O, so that the minimum distance between the trailing edge of each port 20', 21' and the top dead centre (or bottom dead centre) position is of the order of the arcuate length *w* of the cylinder port, it is possible to set the machine for zero precompression (or pre-decompression).

FIGURE 6 represents approximately the limiting position of adjustment of the port plate 22 relative to the port block 2. If the direction of rotation of the machine is required to be reversed, the port block 2 must be rotated in the new direction of rotation through about θ° .

FIGURE 7 is a developed diagram of the adjacent ends of the ports 20, 21 in the port plate 22 showing intermediate ports 38a in the form of circular holes of less diameter than the radial width of the arcuate ports 20, 21 and stretching in a staggered row between these two arcuate ports. The ports 38a are contained wholly within the extensions of the inner and outer boundaries of the arcuate ports, and function in similar manner to the radial slots shown in FIGURES 3, 5 and 6.

As will be understood, the need for angular adjustment of the port plate 22 to equalise cylinder and port pressure does not only arise when there are fluctuations in line pressure, but also when the stroke of the pistons is changed by changes in the angle of inclination of the swash plate. The latter has the effect of varying the rate of change of cylinder pressure with angle of rotation, and hence the angular position of the port plate 22 should be made a function of both line pressure and swash plate inclination.

The machine shown in FIGURES 1 and 2 can be used as a hydraulic motor as well as a pump. In the case of a motor, pressure fluid must be supplied to each cylinder as its piston moves from bottom dead centre to top dead centre and each cylinder must be connected to exhaust as its piston moves from top dead centre to bottom dead centre. It is therefore desirable to seal off the cylinder as it approaches top dead centre and bottom dead centre so that oil therein is pre-decompressed before the cylinder communicates with exhaust and pre-compressed before the cylinder communicates with the pressure source. Consequently, when the machine is used as a motor, pressure oil is supplied to port 21' and port 20' is connected to exhaust. As a result, the cylinder block rotates anti-clockwise, in the opposite direction to the arrow R,

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and the arrangements of FIGURES 3 to 7 are operable to adjust the degree of precompression and pre-decompression of the oil in each cylinder before it reaches bottom dead centre and top dead centre respectively.

We claim:

1. A hydraulic positive displacement rotary machine comprising a cam member, a port member, a cylinder block rotatable relative to the cam member and port member, a plurality of cylinders in the cylinder block, pistons reciprocable in said cylinders under the control of the cam member, a control member disposed between the cylinder block and the port member, registering inlet and outlet ports in the control member and port member, a plurality of smaller, independent ports in the control member at positions between the inlet and outlet ports, ports in the cylinder block communicating with said cylinders and opening through a face of the cylinder block directed towards said control member, each of said cylinder block ports registering with the inlet and outlet ports and said independent ports in the control member in the course of said relative rotation, and adjustment means for adjusting the angular position of the control member about the axis of rotation whereby the number of said independent ports which is blanked off by the port member can be varied.

2. A hydraulic positive displacement rotary machine according to claim 1 wherein said independent ports comprise radially-extending slots.

3. A hydraulic positive displacement rotary machine according to claim 1 wherein said independent ports com-

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prise circular holes of less diameter than the width of the inlet and outlet ports in the control member and whose centres are staggered from a circle about the axis of rotation.

4. A swash plate hydraulic machine comprising a swash plate, a port block, a rotatable cylinder block, a plurality of cylinders in the cylinder block, pistons reciprocable in the cylinder block under the control of the swash plate, a port plate disposed between the cylinder block and the port block, registering arcuate inlet and outlet ports in the port plate and port block, a plurality of angularly-spaced, separate, smaller ports in the port plate in arcuate zones between the arcuate inlet and outlet ports, said zones having the same inner and outer radii as the arcuate inlet and outlet ports, ports in the cylinder block communicating with said cylinders and opening through a face of the cylinder block directed towards the port plate, said arcuate ports in the port plate and port block, said arcuate zones containing the small ports and said cylinder block ports all being disposed at the same radius from the axis of rotation, and adjustment means for adjusting the angular position of the port plate about the axis of rotation.

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30 LAURENCE V. EFNER, *Primary Examiner*.