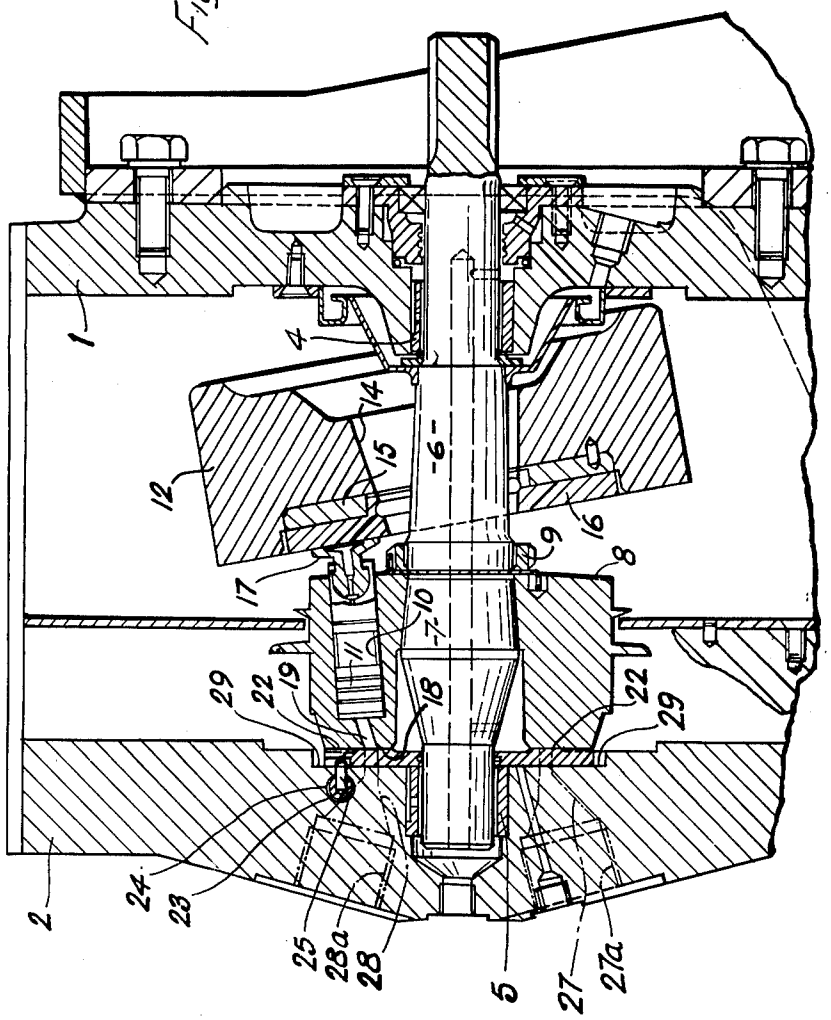
Aug. 17, 1965 D. FIRTH ETAL 3,200,761

HYDRAULIC POSITIVE DISPLACEMENT ROTARY MACHINES

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Fig. 1.

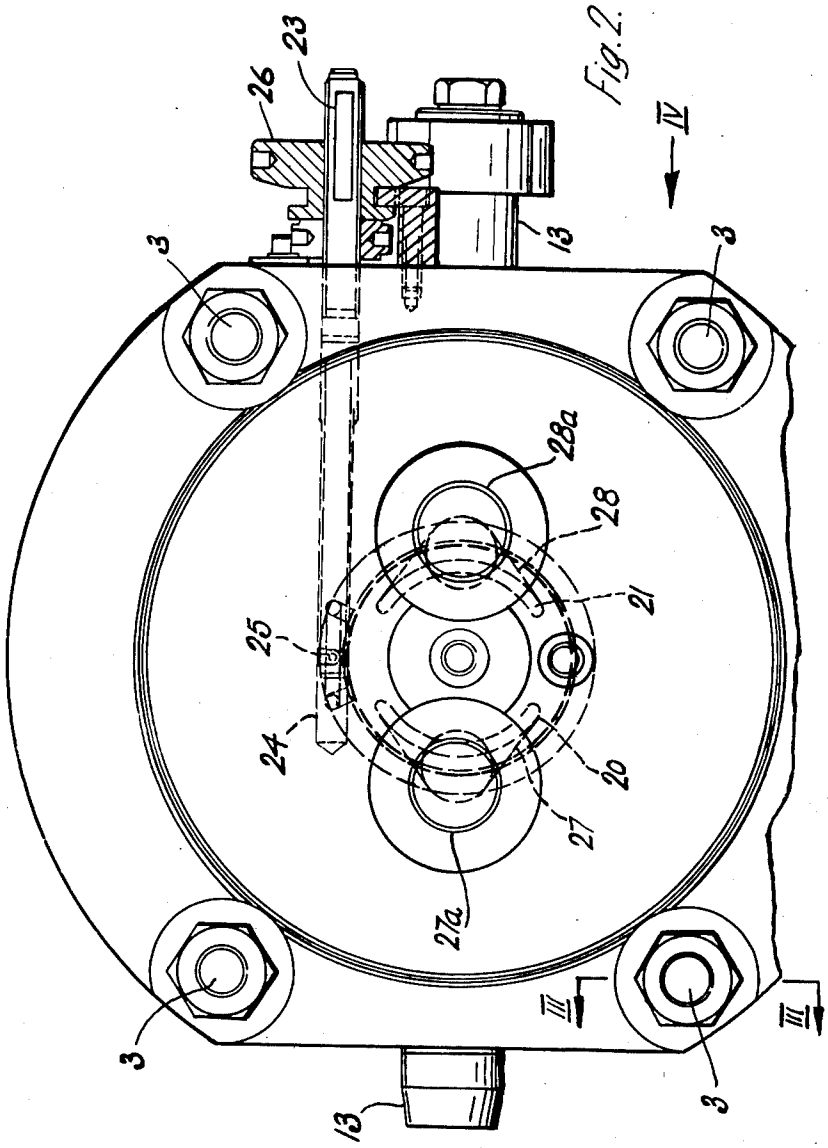


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HYDRAULIC POSITIVE DISPLACEMENT ROTARY MACHINES

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Fig. 2.



HYDRAULIC POSITIVE DISPLACEMENT ROTARY MACHINES

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Fig. 3.

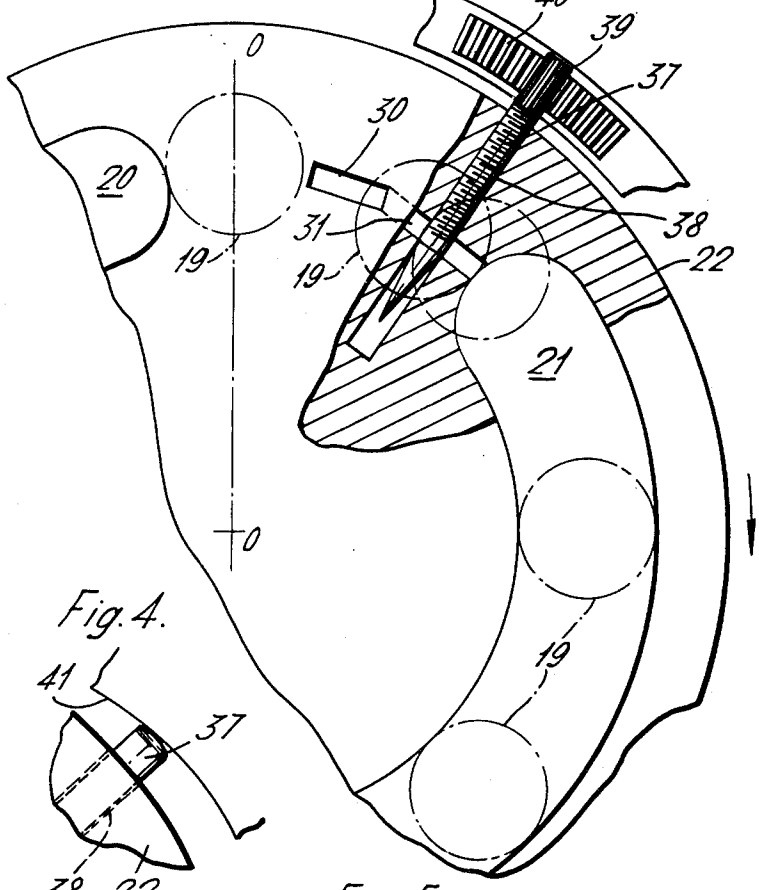
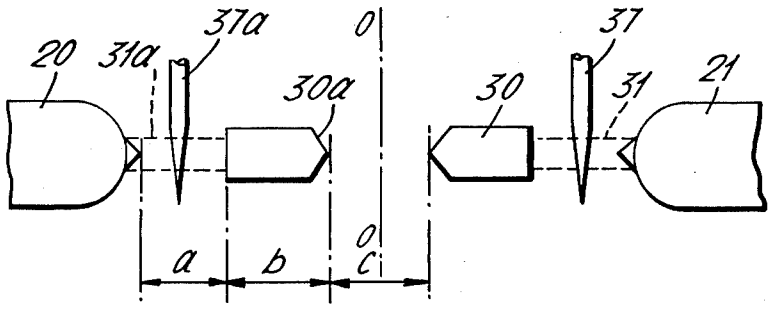


Fig. 4.

Fig. 5.



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HYDRAULIC POSITIVE DISPLACEMENT ROTARY MACHINES

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Fig. 6.

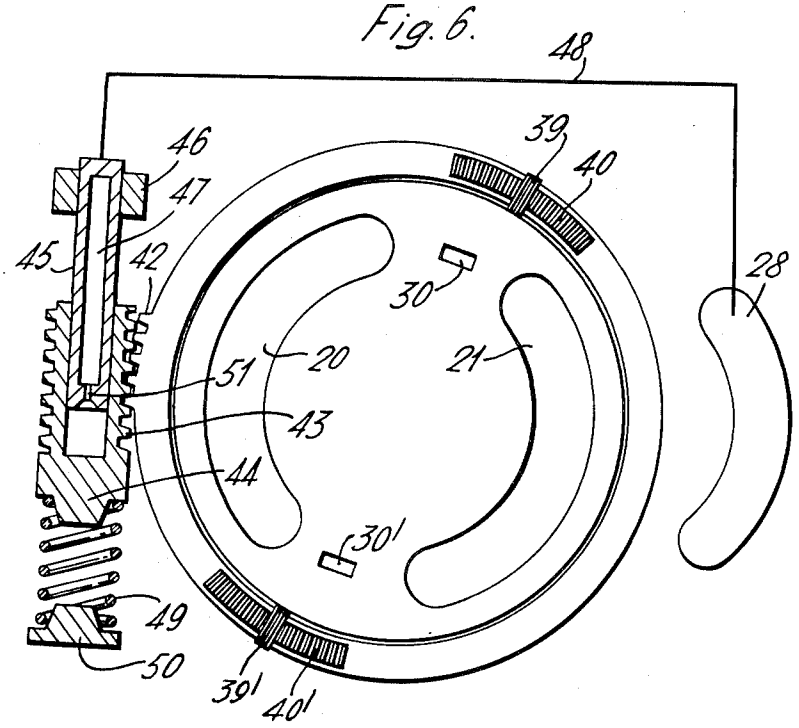
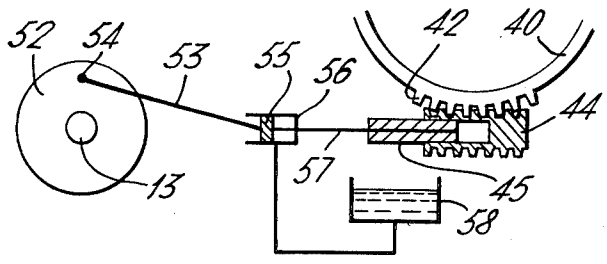


Fig. 7.



United States Patent Office 3,200,761 Patented Aug. 17, 1965

3,200,761

HYDRAULIC POSITIVE DISPLACEMENT ROTARY MACHINES

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Filed May 1, 1963, Ser. No. 287,166
Claims priority, application Great Britain, May 12, 1962, 18,349/62
15 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 register in the course of said rotation alternately with main inlet and outlet ports in the port member. Examples of such machines are swash plate and ball piston pumps and motors.

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.

In machines of the kind described, the transition from registration of a cylinder port with one main port to registration with another is liable to cause shock waves to be set up in the hydraulic circuit as a result of the pressure of fluid in the cylinder being substantially different from that in the inlet or outlet port with which it comes into communication. The present invention aims at minimising or eliminating shock waves when a cylinder port comes into communication with a main port by effectively extending the main port aperture in a manner which permits controlled and progressive equalisation of pressures between the main port and the cylinder port.

This object is achieved according to the present invention by providing the port member between the main ports with one auxiliary port connected to one of the main ports through an obturator and registrable with the cylinder ports as they move towards registration with the main port to which the auxiliary port is connected, said obturator being adjustable by control means outside the port member to provide an adjustable restriction in the connection between the auxiliary port and the main port. Thus, when a cylinder port approaches the main port and before it begins to register therewith, it must first register with the auxiliary port, and hydraulic pressure acts between the cylinder and the main port in the sense for equalising the pressures in both. The rate of pressure change is controllable by the obturator so that there is little or no cause for the generation of shock waves in the hydraulic fluid. The invention thus promotes smooth and quiet operation of the machine.

Advantageously means is provided for automatically adjusting the obturator in accordance with the prevailing operating conditions. Thus, the control means may comprise a fluid-pressure motor connected to one of the main ports whereby said restriction is adjusted automatically in accordance with the pressure in the main port to which the motor is connected. In another arrangement, the control means may be operatively connected to the cam member whereby adjustment of the cam member automatically causes adjustment of said restriction.

Preferably, the port member is provided with two of said auxiliary ports, one auxiliary port being connected to the main inlet port and the other auxiliary port being connected to the main outlet port. The port member may be provided between the main ports with two additional auxiliary ports connected to the main inlet port and the main outlet port respectively through adjustable obturators and each registrable with the cylinder ports as they move away from registration with the main port to which the respective additional auxiliary port is connected.

Preferably, each adjustable obturator is constituted by a tapered needle.

In a swash plate machine of the kind described, an auxiliary port or ports according to the present invention may be formed in the port block, or in a port or wear plate in cases where such a plate is interposed between the port block and the cylinder block, and the needle or like obturator conveniently projects radially beyond the circumference of the port or wear plate, or the circumferential limit of contact between the port block and cylinder block to engage a cam, ring gear, or the like adjuster mechanism for governing the degree of obturation applied by the needle.

The following is a description, by way of example, of various embodiments of the invention, as applied to a swash plate machine (described in detail for use as a pump, 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 a fragmentary section through the port plate of the pump, taken on a transverse radial plane normal to the axis of the shaft,

FIGURE 4 is a fragmentary view of a modified detail,

FIGURE 5 is a developed diagram of a modified construction of port plate,

FIGURE 6 shows one means for automatically adjusting the obturator, and

FIGURE 7 shows another means for automatically adjusting the obturator.

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 reciprocable under the control of a normally fixed swash plate **12** carried on trunnions **13**. 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 main inlet and outlet ports **20**, **21** respectively in a floating port plate **22** which constitutes the aforementioned port member. 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 27*a*, 28*a* 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 our application Ser. No. 22,334 filed April 14, 1960, now U.S. Patent No. 3,089,427.

Referring now to FIGURE 3 of the drawings, the adjacent ends of the arcuate main ports 20, 21 of the port plate 22 are separated, on their common circular axis, by a normally blank plane surface extending for about two or three diameters of a cylinder port 19. It will be assumed that the cylinder mouths 19 are moving clockwise as viewed in FIGURE 3. Just over one diameter of a cylinder port 19 and beyond the trailing end of the main port 20 is an auxiliary port 30 in the form of a relatively narrow slot extending along the common circular axis of the main ports for a length approximately equal to the diameter of the cylinder port 19. The auxiliary port 30 is connected to the main outlet port 21 by a duct 31 which is intersected by a tapered needle 37. The needle acts as a variable obturator for the duct 31 and is threaded into a radial bore 38 in the port plate, appropriate provision (not illustrated) being made for sealing the needle against leakage of hydraulic fluid through the bore 38.

The outer end of the needle 37 projects from the circumference of the port plate 22 and has gear teeth 39 cut therein for engagement with a circular rack 40 which is angularly adjustable relative to the port plate 22 in accordance with the prevailing hydraulic circuit conditions, and possibly also speed of rotation and rate of flow. Angular adjustment of the circular rack 40 causes corresponding axial movement of the needle in its bore and thereby varies the degree of obturation by the needle.

In operation, each cylinder port 19 leaves the inlet port 20 and crosses the bottom dead centre axis 0—0 towards the outlet port 21. Before registering with the latter, the cylinder port 19 encounters the slot 31 which is in communication with the outlet port 21 via the needle-controlled duct 31. So long as the mouth of the slot 30 is sealed by the cylinder block, the pressure in the slot will be equal to the line pressure in the outlet port 21. As soon as the cylinder containing oil at a comparatively low pressure registers with the slot 30, oil acts through the slot to commence raising the pressure of the oil in the cylinder to the desired value at a rate determined by the degree of obturation by the needle 37. Ideally the needle is adjusted so that the pressure in the cylinder reaches the outlet port pressure at exactly the same time that the cylinder port registers with the outlet port 21.

As can be seen from FIGURE 3, the slot 30 is spaced from the outlet port 21 for a distance less than the diameter of a cylinder port, so that each cylinder port remains in register with the slot until after it has registered directly with the outlet port.

Another auxiliary port is arranged between the trailing end of the outlet port 21 and the leading end of the inlet port 20 in the same way that auxiliary port 30 is arranged between the trailing end of the inlet port and the leading end of the outlet port. Thus, this other auxiliary port is connected through its needle-controlled duct to the inlet port 20 to equalise pressures in the cylinder port and the outlet port before they register directly. (FIGURE 6 shows this other auxiliary port at 30′, the needle having gear teeth 39′ engaging a circular rack portion 40′.)

FIGURE 4 illustrates a minor modification of the needle 37 and its control mechanism. Here the needle 37 is a sliding fit in the bore 38, and its outer end is plain and bears against an edge cam 41. The needle may require to be spring-loaded to maintain contact with the cam 41.

In the modified arrangement as illustrated in FIGURE 5, both the leading and the trailing ends of the main ports are connected by ducts to respective auxiliary ports. Only the trailing end of the main port 20 and the leading end of the main port 21 are shown, the auxiliary port 30 and its bleed passage 31 and needle valve 37 being as described in connection with FIGURE 3 or 4. A symmetrical arrangement of auxiliary port 30*a*, bleed passage 31*a* and needle 37*a* is provided in respect of the trailing end of the main port 20. Identical arrangements are provided at the opposite ends (not shown) of the main ports.

The system of FIGURE 5 allows the direction of rotation of the machine to be reversed without loss of the smoothing and silencing action of the auxiliary ports. Normally, for any given direction of rotation, the trailing auxiliary ports would be cut off by their associated obturators, or the latter would be set to a minimum opening, and only the leading auxiliary ports would be operative. (With the direction of rotation such that the cylinder ports move in the direction indicated by the arrow in FIGURE 5, auxiliary port 30*a* is a trailing port and auxiliary port 30 is a leading port.) To achieve this, the control system for each needle 37, 37*a* may be ganged to a directional relay or detector device so that, on reversal of the direction of rotation of the cylinder block, the needle valves controlling the trailing ports are shut or set to a predetermined minimum aperture.

The dimensions marked, respectively, *a*, *b*, and *c* in FIGURE 5 may be selected according to the specific requirements of the machine. Normally the distance *a* would be slightly less than the diameter of a cylinder port 19 whilst the distances *b* and *c* would be equal to or greater than such diameter. It may, however, sometimes be advantageous to make the distance *c* less than the diameter of a cylinder port 19, whereby intercommunication between the main ports 20, 21 and the cylinder port is temporarily established each time a cylinder traverses this distance.

FIGURE 6 shows control means for automatically adjusting the circular rack of FIGURE 3, and thus the degree of obturation, in accordance with the prevailing pressure in the outlet port 21. The circular rack 40 has gear teeth 42 formed on its periphery. With these teeth meshes a cylindrical rack 43 formed on the outside of a reciprocable cylinder 44. A stationary piston 45 adjustably mounted in a block 46 fits at one end within the cylinder 44. An axial bore 47 through the piston 45 communicates with the interior of the cylinder and is connected by a pipe 48 with the outlet (i.e. the high pressure) duct 28 in the back end plate 2 with which duct the outlet port 21 registers. The cylinder 44 is loaded by a helical compression spring 49 mounted between the end of the cylinder and an axially adjustable abutment thimble 50. The axial position of the cylinder 44 relative to the piston 45, and thus the angular position of the circular rack 40 and the degree of obturation by the needle, is therefore dependent on the pressure in the

outlet port 21. The bore 47 through the piston 43 communicates with the interior of the cylinder 44 through a restriction 51 which prevents pressure pulses in the outlet port 21 from influencing the setting of the needle, or at least minimises the effect of such pulses on the needle setting. The piston and cylinder of the control means are described in more detail in appln. Ser. No. 83,089 filed Jan. 16, 1961, now U.S. Patent No. 3,117,529, in relation to angular adjustment of a port plate.

FIGURE 7 shows control means for automatically adjusting the circular rack 40 in accordance with the angle of the swash plate. A plate 52 is mounted to move angularly with the swash plate, e.g. by being fastened to one of the swash plate trunnions 13. A connecting rod 53 links a crank pin 54 on the plate 52 with a piston 55 reciprocable in a cylinder 56 containing hydraulic fluid. The interior of the cylinder 56 is connected by a pipe 57 with the bore 47 of a stationary piston 45 arranged to drive the circular rack 40 through a reciprocating cylinder 44 having a cylindrical rack engaging with gear teeth 42 on the circular rack, as described with reference to FIGURE 6. Movement of the swash plate causes displacement of the piston 55 and thus adjusts the position of the circular rack 40. Leakage of hydraulic fluid from the hydraulic system of the control means is made up from a reservoir 58 connected to the system.

The cam 41 of FIGURE 4 may if desired be adjusted automatically by the same means as shown in FIGURES 6 and 7 for adjustment of the rack 40.

Where the auxiliary ports are formed in an angularly adjustable port plate, as shown in the accompanying drawings, an appropriate form of interconnection may if desired be provided between the port plate adjusting mechanism and the obturator control.

We claim:

1. A hydraulic positive displacement rotary machine comprising a cam member, a port member having a main inlet port and a main outlet port, a cylinder block which is rotatable relative to the cam member and port member, a plurality of cylinders in the cylinder block having ports each arranged to register in the course of said relative rotation alternately with the main inlet and outlet ports in the port member, pistons in the cylinders reciprocable under the control of the cam member, at least one auxiliary port in the port member disposed between said main inlet and outlet ports, which auxiliary port has a pressure-fluid connection to one of the main ports and is registrable with the cylinder ports as they move towards registration with the main port to which the auxiliary port is connected to permit fluid flow due to differential pressure between the main port and a cylinder connected through the auxiliary port to the main port, an adjustable obturator in the connection between the auxiliary port and main port, and control means connected to said obturator to regulate the rate of fluid flow between the main port and said cylinder.

2. A machine according to claim 1 wherein the auxiliary port is spaced from the main port to which it is connected for a distance less than the width of a cylinder port and from the other main port for a distance greater than the width of the cylinder port.

3. A hydraulic positive displacement rotary machine comprising a cam member, a port member having a main inlet port and a main outlet port, a cylinder block which is rotatable relative to the cam member and port member, a plurality of cylinders in the cylinder block having ports each arranged to register in the course of said relative rotation alternately with the main inlet and outlet ports in the port chamber, pistons in the cylinders reciprocable under the control of the cam member, at least one auxiliary port in the port member disposed between said main inlet and outlet ports, which auxiliary port has a pressure-fluid connection to one of the main ports and is registrable with the cylinder ports as they move towards registration with the main port to which the auxiliary port is connected to permit fluid flow due to differential pressure between the main port and a cylinder connected through the auxiliary port to the main port, an adjustable obturator in the connection between the auxiliary port and the main port, a fluid pressure motor outside the port member, coupling means between the motor and the obturator whereby operation of the motor adjusts the obturator to regulate the rate of fluid flow between the main port and the said cylinder, and a pressure-fluid connection between the motor and one of said main ports in the port member whereby the motor is operated by changes in fluid pressure in that main port.

4. A hydraulic positive displacement rotary machine comprising a cam member, a port member having a main inlet port and a main outlet port, a cylinder block which is rotatable relative to the cam member and port member, a plurality of cylinders in the cylinder block having ports each arranged to register in the course of said relative rotation alternately with the main inlet and outlet ports in the port member, pistons in the cylinders reciprocable under the control of the cam member, at least one auxiliary port in the port member disposed between said main inlet and outlet ports, which auxiliary port has a pressure-fluid connection to one of the main ports and is registrable with the cylinder ports as they move towards registration with the main port to which the auxiliary port is connected to permit fluid flow due to differential pressure between the main port and a cylinder connected through the auxiliary port to the main port, an adjustable obturator in the connection between the auxiliary port and the main port, and control means operatively connecting the cam member and the obturator whereby adjustment of the cam member automatically causes adjustment of the obturator to regulate the rate of flow between the main port and the said cylinder.

5. A hydraulic positive displacement rotary machine comprising a cam member, a port member having a main inlet port and a main outlet port, a cylinder block which is rotatable relative to the cam member and port member, a plurality of cylinders in the cylinder block having ports each arranged to register in the course of said relative rotation alternately with the main inlet and outlet ports in the port member, pistons in the cylinders reciprocable under the control of the cam member, two auxiliary ports in the port member disposed between the main inlet and outlet ports, one of the auxiliary ports having a pressure fluid connection to the main inlet port and the other auxiliary port having a pressure fluid connection to the main outlet port and each auxiliary port being registrable with the cylinder ports as they move towards registration with the main port to which the respective auxiliary port is connected, an adjustable obturator in the connection between each auxiliary port and its main port, and control means outside the port member connected to said obturator adapted to adjust the respective obturators in the pressure fluid connections between the inlet and outlet ports and the auxiliary ports disposed in leading relationship to those ports and thereby to regulate the rates of fluid flow due to differential pressures between the inlet and outlet ports and cylinders severally connected through the said auxiliary ports and the inlet and outlet ports.

6. A machine according to claim 5, wherein the said control means include a fluid pressure motor, coupling means between the motor and the obturators whereby operation of the motor adjusts the obturators and a pressure fluid connection between the motor and one of said main ports in the port member whereby the motor is operated by changes in fluid pressure in that main port.

7. A machine according to claim 5, wherein the control means include a connection between the cam member and the obturators whereby adjustment of the cam

member automatically causes adjustment of the obturators.

8. A hydraulic positive displacement rotary machine comprising a cam member, a port member having a main inlet port and a main outlet port, a cylinder block which is rotatable relative to the cam member and port member, a plurality of cylinders in the cylinder block having ports each arranged to register in the course of said relative rotation alternately with the main inlet and outlet ports in the port member, pistons in the cylinders reciprocable under the control of the cam member, four auxiliary ports in the port member between the main ports and each having a pressure fluid connection to the nearest adjacent main port, the auxiliary ports being successively registrable with the cylinder ports as they move between the main ports, an adjustable obturator in the connection between each auxiliary port and its main port, and control means outside the port member connected to said obturator adapted to adjust the respective obturators in the pressure fluid connections between the inlet and outlet ports and the auxiliary ports disposed in leading relationship to those ports and thereby to regulate the rates of fluid flow due to differential pressures between the inlet and outlets ports and cylinders severally connected through the said auxiliary ports and the inlet and outlet ports.

9. A hydraulic positive displacement rotary machine comprising a cam member, a port member having a main inlet port and a main outlet port, a cylinder block which is rotatable relative to the cam member and port member, a plurality of cylinders in the cylinder block having ports each arranged to register in the course of said relative rotation alternately with the main inlet and outlet ports in the port member, pistons in the cylinders reciprocable under the control of the cam member, at least one auxiliary port in the port member disposed between said main inlet and outlet ports, which auxiliary port has a pressure-fluid connection to one of the main ports and is registrable with the cylinder ports as they move towards registration with the main port to which the auxiliary port is connected to permit fluid flow due to differential pressure between the main port and a cylinder connected through the auxiliary port to the main port, an adjustable obturator comprising a tapered needle in the connection between the auxiliary port and the main port, and control means outside the port member for adjusting the needle to vary the obturation and thereby the rate of fluid flow due to differential pressure between the main port and a cylinder in communication with the auxiliary port.

10. A machine according to claim 9 wherein said needle is screw-threaded and carried in a screw-threaded mounting in the port member, and an adjustable circular rack is provided outside the port member, said needle carrying gear teeth engaging the rack, whereby angular adjustment of the rack causes axial movement of the needle.

11. A machine according to claim 9 wherein said needle slidably engages in a mounting in the port plate and a cam member is provided outside the port member, said cam member engaging the needle whereby movement of the cam member adjusts the needle.

12. A machine according to claim 9 wherein the port member comprises a port plate disposed between the cylinder block and an end block.

13. A hydraulic positive displacement rotary machine comprising a cam member, a port member having a main inlet port and a main outlet port, a cylinder block which is rotatable relative to the cam member and port member, a plurality of cylinders in the cylinder block having ports each arranged to register in the course of said relative rotation alternately with the main inlet and outlet ports in the port member, pistons in the cylinders reciprocable under the control of the cam member, two auxiliary ports in the port member disposed between the main inlet and outlet ports, one of the auxiliary ports having a pressure fluid connection to the main inlet port and the other auxiliary port having a pressure fluid connection to the main outlet port and each auxiliary port being registrable with the cylinder ports as they move towards registration with the main port to which the respective auxiliary port is connected, an adjustable obturator in the connection between each auxiliary port and its main port, and control means outside the port member adapted to adjust the respective obturators in the pressure fluid connections between the inlet and outlet ports and the auxiliary ports disposed in leading relationship to those ports and thereby to regulate the rates of fluid flow due to differential pressures between the inlet and outlet ports and cylinders severally connected through the said auxiliary ports and the inlet and outlet ports, the said control means including an obturator operating ring rotatable about the axis of the cylinder block and provided with a plurality of obturator actuating means adapted to adjust the respective obturators.

14. A machine according to claim 13, wherein the obturators are slidably mounted and the obturator actuating means are in the form of cams.

15. A hydraulic positive displacement rotary machine comprising a cam member, a port member having a main inlet port and a main outlet port, a cylinder block which is rotatable relative to the cam member and port member, a plurality of cylinders in the cylinder block having ports each arranged to register in the course of said relative rotation alternately with the main inlet and outlet ports in the port member, pistons in the cylinders reciprocable under the control of the cam member, two auxiliary ports in the port member disposed between the main inlet and outlet ports, one of the auxiliary ports having a pressure fluid connection to the main inlet port and the other auxiliary port having a pressure fluid connection to the main outlet port and each auxiliary port being registrable with the cylinder ports as they move towards registration with the main port to which the respective auxiliary port is connected, an adjustable and slidably mounted obturator in the connection between each auxiliary port and its main port, and control means including respective obturator actuating cams outside the port member adapted to adjust the respective obturators in the pressure fluid connections between the inlet and outlet ports and the auxiliary ports disposed in leading relationship to those ports and thereby to regulate the rates of fluid flow due to differential pressures between the inlet and outlet ports and cylinders severally connected through the said auxiliary ports to the inlet and outlet ports.

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