April 28, 1964 D. FIRTH ETAL 3,130,684

SWASH PLATE ROTARY MACHINES

Filed May 22, 1961 3 Sheets-Sheet 1

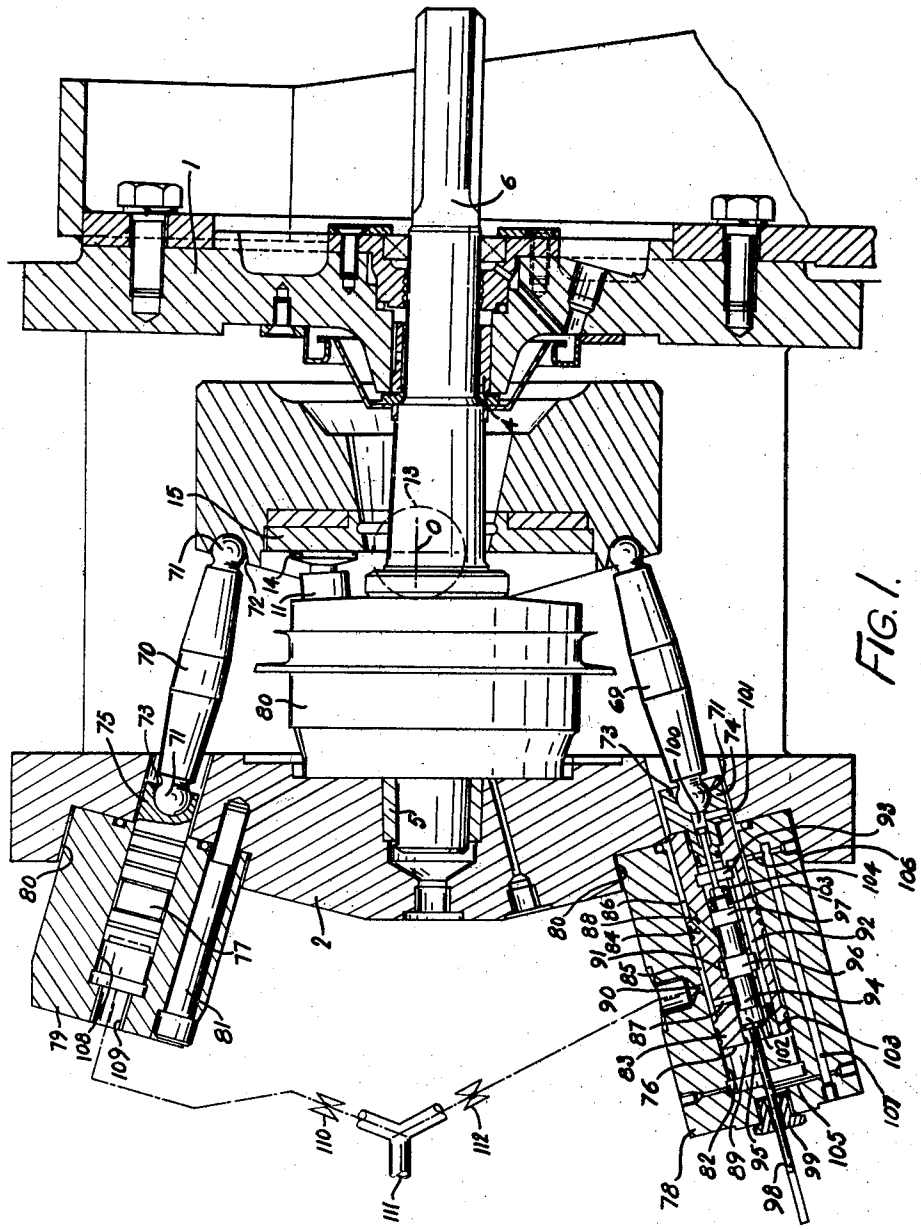


FIG. 1.

April 28, 1964 D. FIRTH ETAL 3,130,684

SWASH PLATE ROTARY MACHINES

Filed May 22, 1961 3 Sheets-Sheet 2

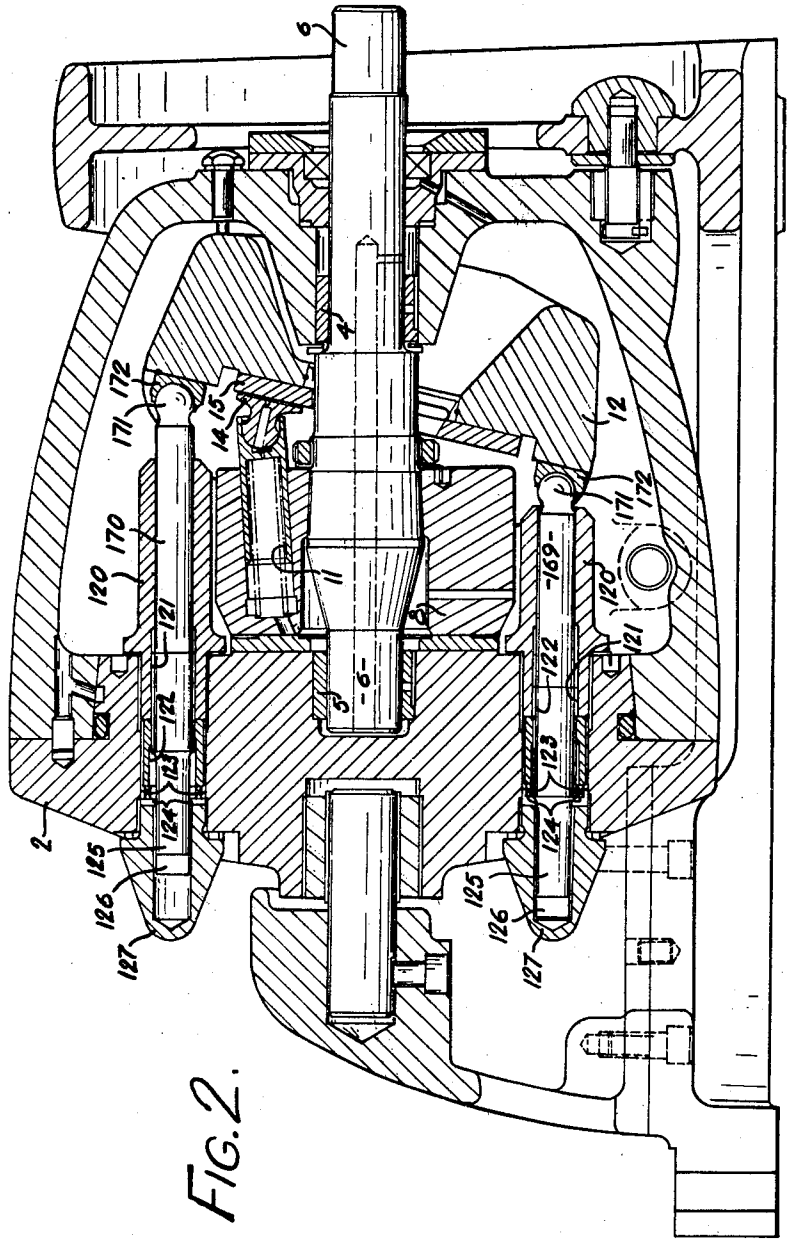


FIG. 2.

April 28, 1964 D. FIRTH ETAL 3,130,684

SWASH PLATE ROTARY MACHINES

Filed May 22, 1961 3 Sheets-Sheet 3

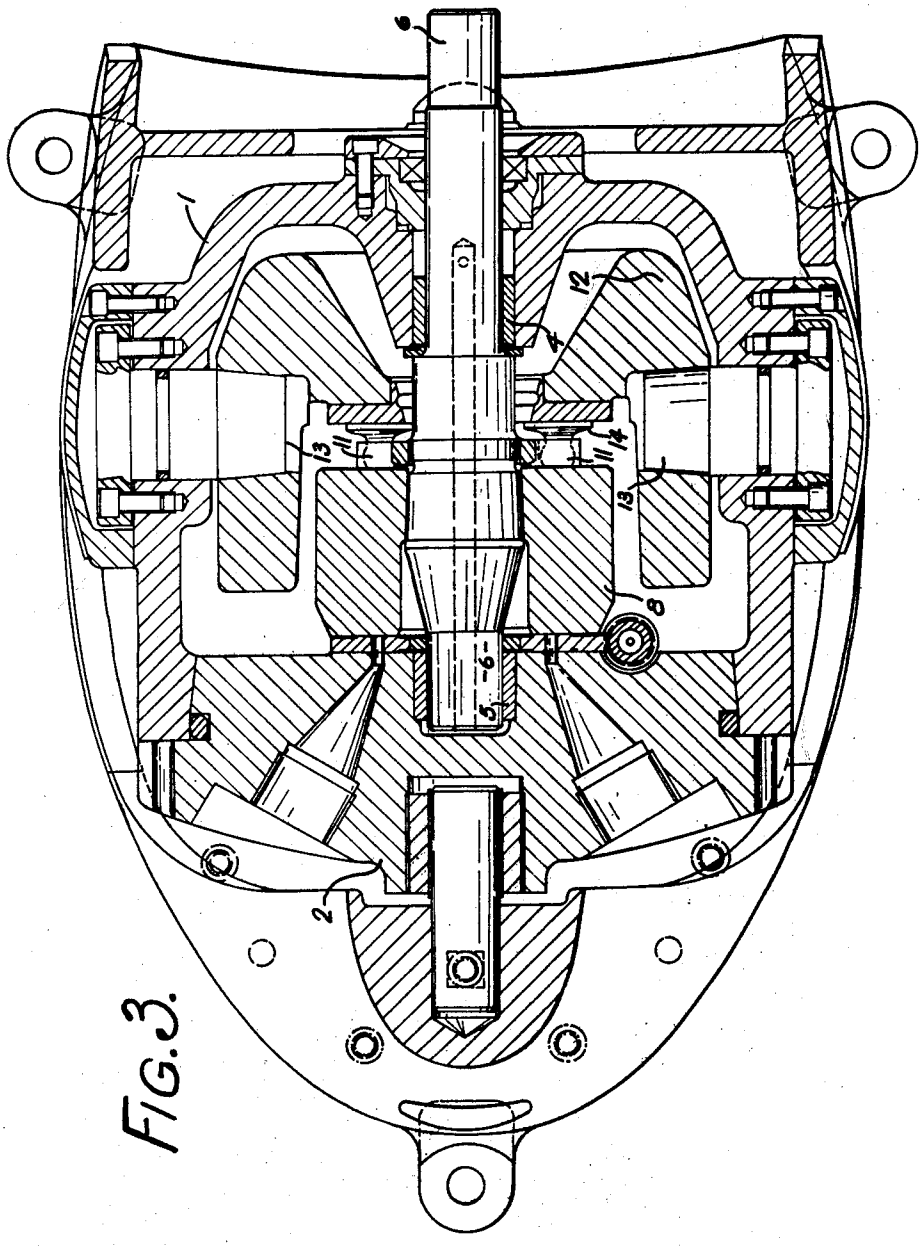


FIG. 3.

United States Patent Office 3,130,684 Patented Apr. 28, 1964

3,130,684

SWASH PLATE ROTARY MACHINES

Donald Firth and Roger Harvey Yorke Hancock, both of East Kilbride, Glasgow, Scotland, assignors to Council for Scientific and Industrial Research, London, England, a corporation of the United Kingdom

Filed May 22, 1961, Ser. No. 111,724
Claims priority, application Great Britain May 25, 1960
10 Claims. (Cl. 103—162)

This invention relates to swash plate rotary mechanisms such as pumps or motors of the kind described for example, in the co-pending patent applications Nos. 22,334, filed April 14, 1960, and 22,335, filed April 14, 1960.

A swash plate motor (or pump) has one particular advantage which makes it especially suitable for driving machine tools, vehicles, and the like, in that it has a relatively high power to weight ratio. However, such applications demand both stability in the maintenance of a chosen speed and flexibility of speed control.

Variations of the speed of a motor can be achieved in two ways—variations of the rate of supply of working fluid and variations of the working stroke of the pistons. In swash plate pumps and motors, both requirements can be satisfied by adjustment of the angle of tilt of the swash plate. Provision for such adjustment, however, may lead to loss of rigidity of the swash plate, which then becomes subject to vibration during operation of the machine, with resultant fluctuations in output and increased noise, both of which may reach unacceptable levels.

The present invention accordingly aims at providing for ready adjustment of the angle of tilt of the swash plate while avoiding or minimising any loss of rigidity.

According to the invention there is provided a swash plate rotary machine having its swash plate mounted for tilting about a pivot axis and means for clamping the swash plate at a desired angle of tilt comprising two or more struts engaged between abutment members and the swash plate at points located around the swash plate adjacent its periphery and remote from the pivot axis, the struts being adapted to maintain a state of stress in the swash plate.

Preferably, a pair of struts is provided engaging the swash plate at two points located diametrically opposite each other on a line at right angles to the pivot axis.

Advantageously, each strut is adjustable for effective length in order to determine the angle of tilt.

Stressing of the swash plate may be achieved mechanically, by means such as captive rotatable nuts, sleeves or the like, or by hydraulic means, each strut being constituted by an hydraulic ram or plunger. Automatic valve means may be associated with at least one such ram or plunger for maintaining the position of adjustment of the swash plate.

Preferred embodiments of the invention will now be particularly described, by way of illustration only, with reference to the accompanying drawings in which:

FIGURE 1 is a fragmentary longitudinal section (partly in elevation) through a rotary swash plate pump having hydraulic struts for adjusting and maintaining the angle of tilt of the swash plate, and

FIGURE 2 is a similar view of a pump having a mechanical arrangement of strut, and

FIGURE 3 is a sectional view at right angles to the section of FIGURE 2.

The drawings depict swash plate pumps constructed generally as described and illustrated in the specification

and drawings of co-pending patent applications Nos. 22,334, filed April 14, 1960, and 83,089, filed January 16, 1961. If desired, the pumps may be employed without structural modification, as hydraulic motors.

Referring first to FIGURE 1 of the drawings, the pump illustrated has end-covers 1, 2 carrying bearings 4, 5 respectively for the pump shaft 6. This shaft carries a cylinder block 8, and passes through a swash plate 12 whose angle of inclination determines the output of the pump. The swash plate is mounted on trunnions 13 for pivotal adjustment about an axis O which is offset from the axis of the shaft 6 and lies in a direction at right angles thereto.

The cylinder block 8 contains a plurality of cylinders with pistons 11 (only one of which is shown in the drawing, for the sake of clarity) reciprocable therein. Each piston carries a slipper 14 which bears against an annular slipper plate 15 mounted on the swash plate 12. The end-cover 2 has inlet and outlet ports with which the cylinders in the block 8 communicate in turn as the block rotates and the pistons 11 reciprocate under control of the swash plate.

The swash plate 12 is anchored in the required position of angular adjustment by means of a pair of struts 69, 70 having hemispherical ends 71 which rest in respective hemispherical sockets 72 on the swash plate 12 and 73 in abutment pads 74, 75 on the inner ends of respective hydraulic pistons or rams 76, 77. These pistons or rams work in respective cylinder blocks 78, 79 located in sockets 80 in the end cover 2 and secured therein by bolts 81. The sockets 72 lie on a common diameter of the swash plate 12 at right angles to the axis O so that they are removed angularly as far as possible from the axis of tilt of the swash plate and thus offer the greatest control moment about this axis.

In the above-described arrangement the ram 76 is a control ram and the ram 77 is a reaction thrust ram, the latter being of slightly smaller effective diameter than the former.

The control ram 76 works in a bore 82 in the cylinder block 78 and has axially spaced outer and inner lands 83, 84 between which is an annular relief 85. Inwards of the inner land 84 the ram is also relieved as shown at 86. A main oil pressure inlet port 90 opens into the relief 85 between the lands 83, 84. Each relief 85, 86 communicates through a respective port 87, 88 with an axial valve chamber 89, the port 87 being radial and the port 88 being inclined. The transfer ports open into the valve chamber on opposite sides of an annular groove 91. This groove breaks into a channel 92 which runs parallel to the valve chamber and communicates with a second or inner annular groove 93 near the abutment pad 74 which closes the inner end of the valve chamber 89. The outer end of the channel 92 is in open communication with the cylinder bore 82 behind the control ram 76.

In the chamber 89 lies a piston valve 94 having outer, middle, and inner lands 95, 96, 97 respectively. The outer and middle lands 95, 96 straddle the transfer port 87, and the middle and inner lands 96, 97 straddle the transfer port 88. The middle land 96 normally seals the annular groove 91. The valve is mounted with radial play on a control rod 98 which passes through a gland nut 99 on the closed outer end of the cylinder block 78 and at the other end passes into a cavity 100 in the abutment pad 74, this cavity communicating through a radial drain port 101 with the annular relief 86 around the inner end of the control ram 76. The radial play in the mounting of the piston valve 94 on the control rod 98

is sufficient to allow it to align itself accurately in the valve chamber **89** without constraint from the rod, but the valve **94** is axially located on the control rod **98** by means of a collar **102** fixed on the rod and against which the valve is urged by a helical compression spring **103** which is compressed between the inner end of the valve and a washer held in place by a nut **104** threaded on the control rod **98**. Any oil which leaks along the control rod **98** to the gland **99** or into the relief **86** around the inner end of the control ram **76** is drained off through ducts **105**, **106** and a drain channel **107**.

The reaction thrust ram **77** is a plain piston without ports or valves working in a plain bore **108** which is connected at a port **109** through a constriction **110** to the same supply **111** of high pressure oil as that which feeds, through another constriction **112**, the control ram **76**, through its inlet port **90**.

The system operates as follows:

Oil under pressure is fed from the supply **111** to the inlet ports **90** and **109** of the two rams. In the absence of any other checks or controls, this would result in the progressive tilting of the swash plate **12** to its maximum angle, due to the larger effective piston area of the control ram **76** than of the reaction ram **77**. The valve **94**, however, prevents this from happening.

The control valve **94** is axially positioned by the control rod **98** to correspond with the desired angle of tilt of the swash plate **12**. With the parts in the positions shown in the drawings, the swash plate **12** is in its neutral position of zero tilt in which no pumping takes place. In order to tilt it, therefore, the control ram **76** must move to the right. Oil fed to the inlet port **90** fills the annular relief space **85**, the transfer port **87**, and the annular space between the outer and middle lands **95**, **96** of the control valve **94**. The middle land **96**, however, closes the groove **91**, so no oil can leave this part of the unit.

If now the control valve **94** is moved by the control rod **98** to the right, the land **96** immediately uncovers the outer—i.e. left-hand—edge of the groove **91**, and oil under pressure passes into the channel **92**, filling the inner end of the valve chamber **89** and the outer ends of both this chamber and the ram bore **82**. The resulting thrust to the right on the end face of the control ram **76** in the ram bore **82** causes the ram **76** to move to the right, tilting the swash plate **12** against the reaction thrust provided by the ram **77**, which is thereby forced outwards. Oil in the cylinder bore **108** behind this ram is transferred through the constriction **110**, **112** in series to the inlet port **90** of the control ram.

As the control ram **76** moves inwards, the groove **91** gradually becomes closed by the middle land **96** of the control valve **94** until it eventually becomes shut off. At this point, the supply of oil to the cylinder space behind (i.e. to the left of) the ram **76** ceases and the ram cannot travel any further. The oil behind the ram is now trapped and forms a lock against any tendency for the swash plate **12** to be returned to its zero tilt position—for example, by a resultant mechanical thrust from the pump pistons.

The control valve **94** is hydraulically balanced under these conditions, and can therefore be moved by the control rod **98** to a new position. If it is retracted—i.e. moved to the left in the drawing—the middle land **96** immediately uncovers the inner (right-hand) edge of the groove **91** and places the channel **92** in communication with the oblique transfer port **88**. Oil thus flows to exhaust via the inner annular relief **86**, port **106**, and exhaust channel **107**, the thrust of the reaction thrust ram **77** causing the swash plate **12** to force the control ram **76** back until it overtakes the control valve **94** and the groove **91** is again sealed by the middle land **96**. Equilibrium conditions are then restored and the swash plate is again locked, the control valve **94** automatically maintaining the required angle of tilt of the swash plate.

The opposing thrusts of the two rams **76**, **77** maintain a state of stress in the swash plate **12** which assists in reducing vibration from the cyclic unbalance of the reactions from the pump cylinders. If these vibration forces reach sufficient magnitude to cause displacement of the control ram **76** and reaction thrust ram **77**, oil will tend to be transferred between the two cylinder bores **82** and **108**, and the two constrictions **110**, **112** are in series in the interconnecting circuit to act as dampers. The system is thus inherently stable to maintain the swash plate **12** in its position of adjustment and thus to promote smooth operation of the pump.

In order to reduce any tendency of the control ram **76** to hunt about its preset position, a constriction **113** is preferably inserted in the channel **92** to damp the oil flow through the valve **94**.

The source of oil pressure at **111** is preferably the output or line pressure of the machine—whether the latter is acting as a pump or as a motor—although an independent supply of oil under pressure may be used if preferred. The control rod **98** may be manually operated, or it can be linked to an automatic controller responsive to an external condition such as output pressure of a pump or output speed or torque of a motor.

In the alternative construction shown in FIGURES 2 and 3, the pump, as before, has end-covers **1**, **2** carrying bearings **4**, **5** for the pump shaft **6** which carries a cylinder block **8** and passes through a swash plate **12** whose angle of inclination determines the output of the pump. The swash plate is mounted on trunnions **13** for pivotal adjustment about an axis which lies in a direction at right angles to the axis of the shaft **6**. The block **8** contains a plurality of pistons **11** (only one being shown in FIGURE 2 and only two in FIGURE 3, for clarity of illustration) and each piston has a slipper **14** bearing against a slipper plate **15** on the swash plate. In this alternative construction, the hydraulic rams **76**, **77** are replaced by mechanical "jacks." The struts **69**, **70** of FIGURE 1 have their counterparts in similarly acting struts **169**, **170** in FIGURE 2, the latter, however, having their hemispherical ends **171** resting in complementary sockets formed in bearing pads **172** which rest against the flat surface of the swash plate **12**.

Each strut **169**, **170** passes through a tubular guide pillar **120** which is screwed into the end cover **2** of the pump (or motor). Each strut is threaded into the outer (left-hand) end of its tubular guide as shown at **121**, and the outer projecting portion of the screw thread on the strut carries a tubular lock nut **122** which is accommodated in a plain extension **123** of the threaded socket which receives the guide pillar **170**. The outer end of each nut **122** is castellated at **124** for engagement by a tubular key.

Each strut **169**, **170** has its outer end **125** of reduced diameter and terminating in a standard hexagon head **126** for engagement by a spanner, this end of the strut being shielded by a hollow cap nut **127**. By removing the cap nuts and slackening off the tubular lock nuts **122**, the struts **169**, **170** can be screwed in or out in opposite senses to adjust the angle of tilt of the swash plate **12**, the latter being finally clamped in the desired position by the opposing thrusts of the struts.

If desired, the struts **169**, **170** may be splined in their guide pillars **120** in place of the threaded formations at **121** and their outer ends **125** may be threaded to engage captive nuts (not shown) which are driven from a common shaft to adjust the struts in opposition. The shaft may then be operated by an automatic controller. In order to ensure the maintenance of the necessary compressive stress in the struts **169**, **170** and at the same time allow for manufacturing tolerances and wear in the threaded parts, the drive to each captive nut may be transmitted through a torque limiting clutch from a conventional form of differential gear.

In a further alternative construction also not illustrated in the drawings, the struts **169**, **170** may be adjusted by means of cams in place of the captive nuts, the cam fol-

lowers consisting, if desired, of hydraulic plungers whose hydraulic circuits are fed at constant pressure to maintain equal stresses in the struts.

In all forms of the invention, the swash plate **12** is pre-loaded to an extent sufficient to overcome the fluctuating reaction thrust exerted thereon by the cyclic variation in the number of pump or motor cylinders which are operating at maximum load during each revolution of the cylinder block. This pre-loading also results in a higher bearing pressure on the swash plate trunnions which produces higher frictional resistance to oscillation of the swash plate, and hence increased damping action is obtained which promotes smoother and quieter running of the machine.

Although in the foregoing description two struts **69, 70** or **169, 170** have been shown placed at opposite ends of a diameter of the swash plate **12**, it is to be understood that more than two struts may be equiangularly spaced around the axis of the shaft **6**.

We claim:

1. In a swash plate rotary machine, the combination of a tiltable swash plate mounted between two pivots, a pair of struts having ends engaging diametrically opposite parts of the swash plate adjacent its periphery and on a line at right angles to the pivot axis, abutment members engaged by the struts at their other ends, hydraulic rams carrying said abutment members, cylinders containing said rams each having a pressure-fluid inlet and containing a working space at one end of the ram, a pressure-fluid interconnection between said inlets, a pressure-fluid supply connection to said interconnection, a damping constriction between the supply connection and each inlet, a piston valve reciprocable within a bore in one of the rams, and ports connecting said bore with the pressure-fluid inlet into the cylinder, with the cylinder working space and with an exhaust outlet, said piston valve being movable to different positions connecting the pressure-fluid inlet with the cylinder working space, connecting the cylinder working space with the exhaust outlet and sealing the cylinder working space.

2. The combination according to claim 1 wherein the piston valve has a control land which normally closes the port connecting said bore with the cylinder working space and the ports to the pressure fluid inlet and the exhaust outlet are disposed on opposite sides of said port to the working space.

3. The combination according to claim 2 wherein the port to the pressure fluid inlet is in a position between the cylinder working space and the port thereto, whereby movement of the piston valve opening the port to the working space results in movement of the ram in a direction to restore the piston valve to its normal position relative to the ram.

4. The combination according to claim 3 wherein the piston valve has two lands spaced axially beyond the ports to the pressure fluid inlet and the exhaust outlet.

5. The combination according to claim 4 wherein said port to the pressure fluid inlet communicates with a recess on the outside of the piston valve, the pressure-fluid inlet opening into said recess.

6. A swash plate rotary machine comprising a swash plate, a rotatable cylinder block, a plurality of pistons reciprocable in cylinders of the cylinder block under control of the swash plate, a stationary port block having inlet and outlet ports co-operating with ports in the cylinder block leading to the cylinders therein, pivots supporting the swash plate, the pivot axis being transverse to the axis of rotation of the cylinder block, a plurality of struts each of which at one end engages the swash plate at a point adjacent its periphery and remote from said pivot axis and at the other end bears against an abutment member, and loading means acting on the struts to stress the swash plate, said loading means comprising hydraulic rams carrying said abutment members, cylinders containing said rams each having a pressure-fluid inlet and containing a working space at one end of the ram, a pressure-fluid interconnection between said inlets, a pressure-fluid supply connection to said interconnection, a damping constriction between the supply connection and each inlet, a piston valve reciprocable within a bore in one of the rams, and ports connecting said bore with the pressure-fluid inlet into the cylinder, with the cylinder working space and an exhaust outlet, said piston valve being movable to different positions connecting the pressure-fluid inlet with the cylinder working space, connecting the cylinder working space with the exhaust outlet and sealing the cylinder working space.

7. In a swash plate rotary machine, the combination of a tiltable swash plate, hydraulic ram means engaging the swash plate at substantially diametrically opposite positions distant from the tilting axis, a common pressure fluid connection to said ram means, pressure-fluid interconnection between said ram means into which said common pressure-fluid connection opens, a damping constriction in said interconnection between said common pressure-fluid connection and each ram means, rams in said ram means having different effective areas exposed to pressure fluid, whereby one ram means exerts a lower pressure on the swash plate than the other ram means, a piston valve reciprocable within a bore in a ram of the last-mentioned ram means, a cylinder within which said ram reciprocates, said cylinder having a pressure fluid inlet communicating with said common pressure fluid connection and an exhaust outlet, and ports in the ram connecting the bore therein with the pressure-fluid inlet into the cylinder, with the cylinder working space and with the exhaust outlet from the cylinder, said piston valve being movable to different positions connecting the pressure-fluid inlet with the cylinder working space, connecting the cylinder working space with the exhaust outlet and sealing the cylinder working space and said piston valve having a control land which normally closes the port connecting said bore with the cylinder working space, the ports to the pressure fluid inlet and the exhaust outlet being disposed on opposite sides of said port to the working space and the port to the pressure fluid inlet being in a position between the cylinder working space and the port thereto.

8. The combination according to claim 7 wherein a constriction is provided between the cylinder working space and the port thereto.

9. The combination according to claim 7, wherein a control rod is provided for moving the piston valve axially, said control rod passing with radial play through the piston valve.

10. In a swash plate rotary machine, the combination of a tiltable swash plate, first hydraulic ram means acting on the swash plate on one side of the tilting axis for tilting the swash plate in one direction, second hydraulic ram means acting on the swash plate on the other side of the tilting axis for tilting the swash plate in the opposite direction against the action of the first ram means, said first and second ram means acting on the swash plate at positions distant from the tilting axis, a pressure fluid interconnection between the first and second ram means, a pressure fluid supply connection to said interconnection for supplying hydraulic fluid to both the first and second ram means, valve means in said interconnection between the pressure fluid supply connection and the second ram means for selectively connecting said second ram means to pressure and exhaust, said valve means comprising a follow-up valve having a part coupled to the swash plate to move therewith and a control member movable relatively to said part for selectively connecting the second ram means to pressure and exhaust, a first damping constriction in said interconnection between the pressure fluid supply connection and the first ram means and a second damping constriction in said interconnection between the pressure fluid supply connection and said valve means.

(References on following page)

References Cited in the file of this patent

UNITED STATES PATENTS

1,794,946	Crain	Mar. 3, 1931
2,265,314	Rose	Dec. 9, 1941
2,409,185	Blasutta	Oct. 15, 1946
2,696,189	Born et al.	Dec. 7, 1954

5

2,915,985	Budzich	Dec. 8, 1959
2,953,099	Budzich	Sept. 20, 1960
3,051,092	Lambeck	Aug. 28, 1962

FOREIGN PATENTS

812,927	Great Britain	May 6, 1959