Feb. 20, 1968 V. R. SLIMM 3,369,458

HYDRAULIC APPARATUS

Filed July 5, 1966 3 Sheets-Sheet 1

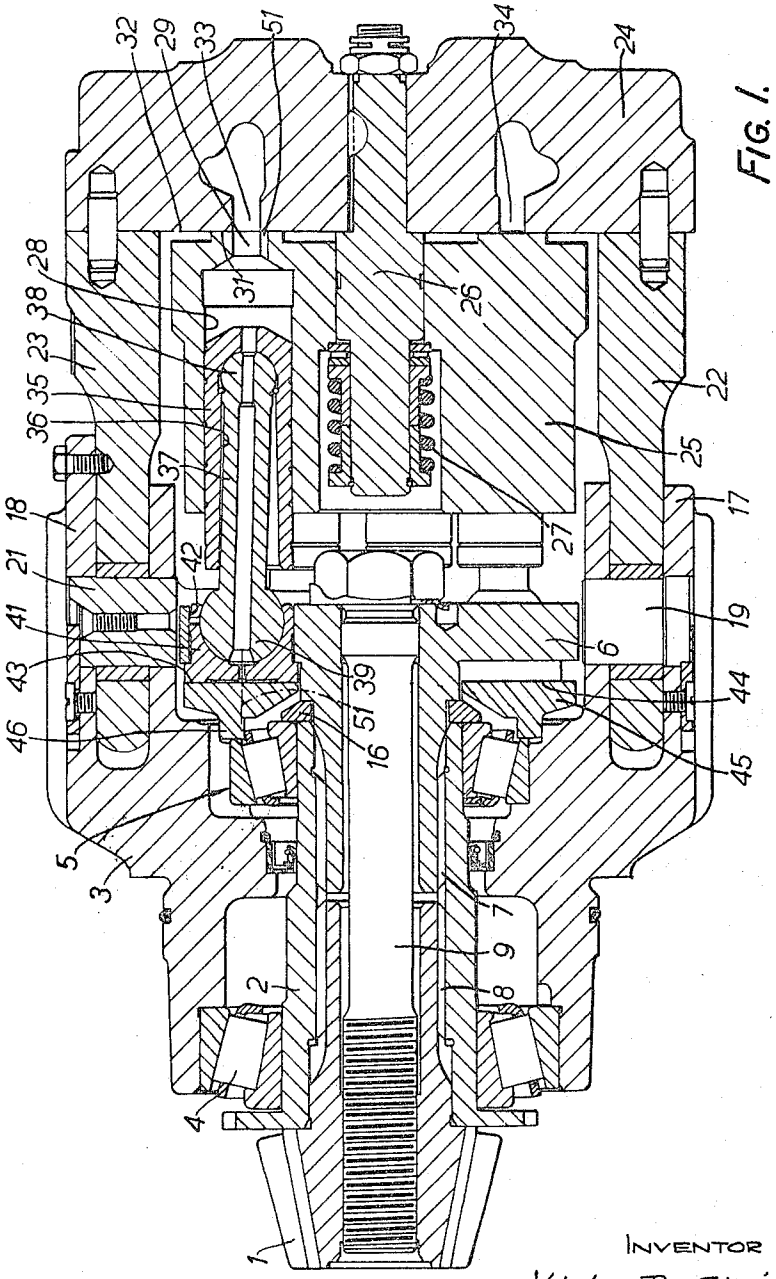


FIG. 1.

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HYDRAULIC APPARATUS

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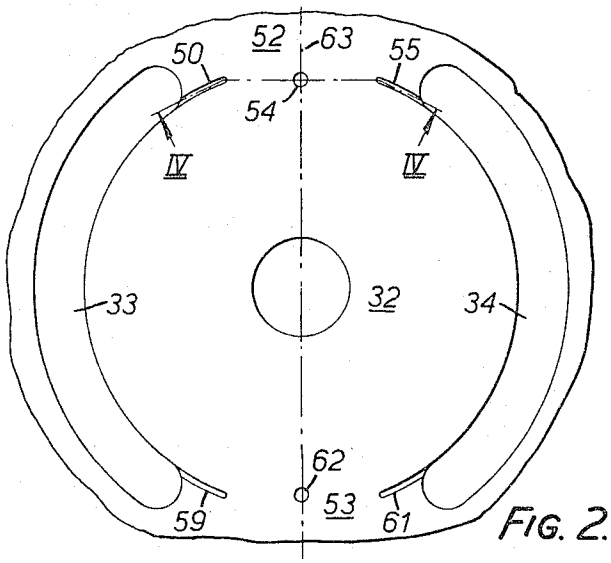


FIG. 2.

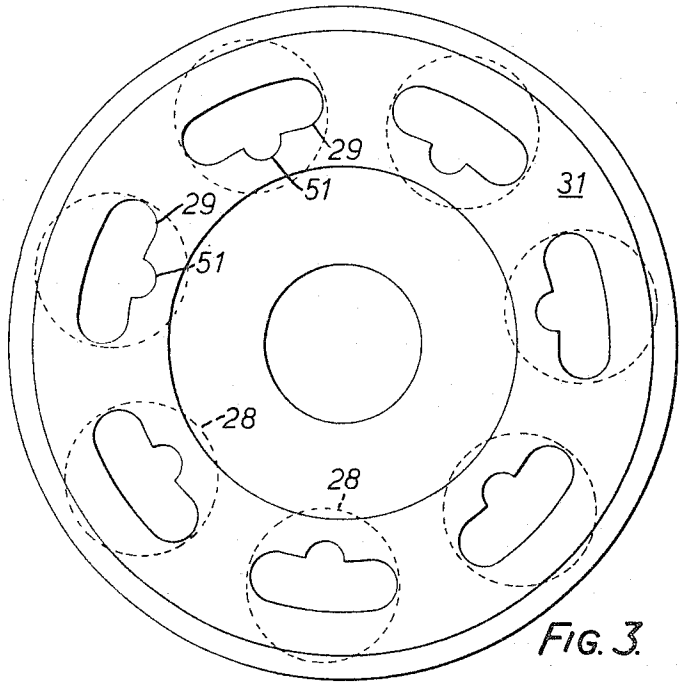


FIG. 3.

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HYDRAULIC APPARATUS

Filed July 5, 1966 3 Sheets-Sheet 3

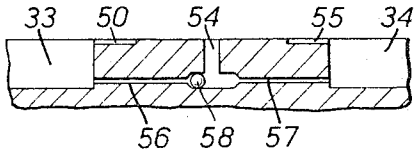


FIG. 4.

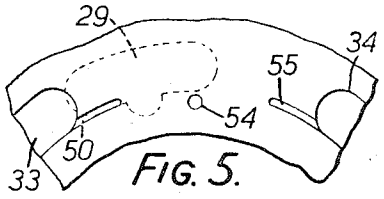


FIG. 5.

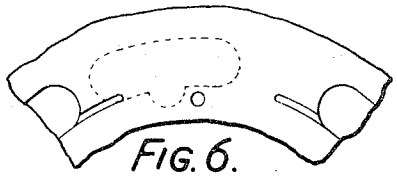


FIG. 6.

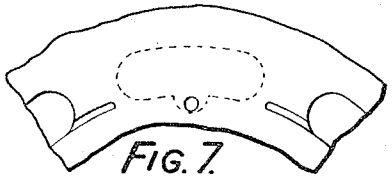


FIG. 7.

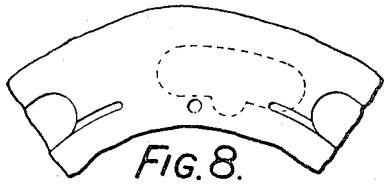


FIG. 8.

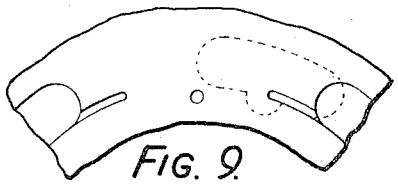


FIG. 9.

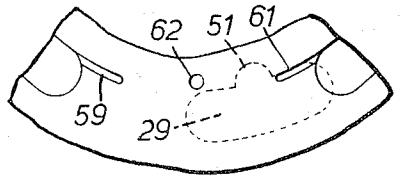


FIG. 10.

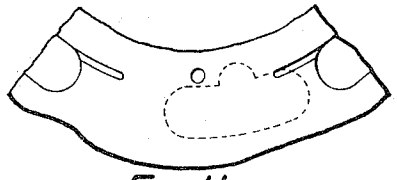


FIG. 11.

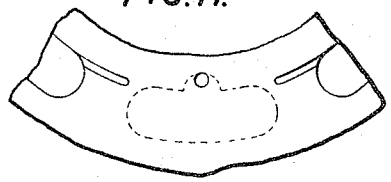


FIG. 12.

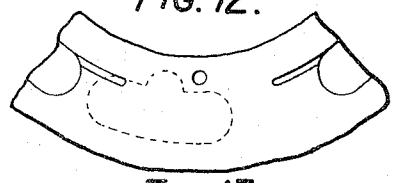


FIG. 13.

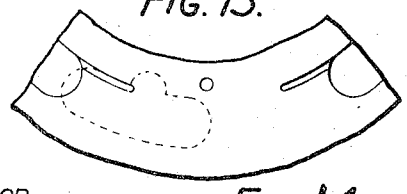


FIG. 14.

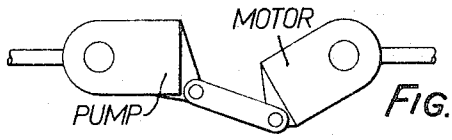


FIG. 15.

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United States Patent Office

3,369,458

Patented Feb. 20, 1968

3,369,458

HYDRAULIC APPARATUS

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Filed July 5, 1966, Ser. No. 562,667

11 Claims. (Cl. 91—31)

This invention relates to hydraulic apparatus and more particularly to a hydraulic motor of fixed or variable displacement having the following features:

(a) a rotatable cylinder block having or supporting cylinders parallel or inclined to the block rotation axis,

(b) pistons in the cyclinders reciprocated during block rotation by means external to the block such for example, as a swash plate,

(c) a non-rotary valve on which the block is arranged to rotate,

(d) a flat valve surface of the valve in rotary contact with a flat block surface of the block,

(e) a pair of main ports in the valve surface having supply and return functions,

(f) cylinder ports in the block surface arranged to pass alternately over the main ports during block rotation,

(g) the cylinder block being arranged for axial and tilting movement to ensure that the valve and block surfaces remain in close contact, and,

(h) the holding force exerted on the block by the pressure in the cylinders holding the block against axial or tilting movement away from the valve surface by the parting force generated by hydraulic pressure at the ports. This holding force is reacted through the pistons.

A motor including the above features will be referred to as a motor of the kind referred to. Normally a motor of the kind referred to will be either a tilting head motor or a swash plate motor.

In a motor of the kind referred to, the main ports are of such arcuate length that during block rotation the number of cylinder ports in connection with a main port will vary. If the number N of cylinders is odd, the number of cylinder ports in connection with a main port may be alternately

$$\frac{N+1}{2} \quad \text{or} \quad \frac{N-1}{2}$$

Where the number N of cylinders is even, there are alternately either

$$\frac{N}{2} \quad \text{or} \quad \frac{N}{2}-1$$

cylinder ports in connection with a main port. Where the greater number of cylinder ports are in connection with a main port, there is considerable overlap of the cylinder ports at the two ends of the main port so that the arcuate pressure area between the valve and block surfaces is substantially enlarged. Where the smaller number of cylinder ports is in connection with a main port, there is little or no overlap at the ends of the main port. Thus the hydraulic parting force developed between the valve and the block surfaces will vary in magnitude in accordance with the number of cylinder ports in connection with a main port. Also the centre of pressure of the hydraulic parting force will vary its position. The holding force on the cylinder block will vary in accordance with the number of cylinders in connection through their cylinder ports with the main port under pressure. The holding and parting forces will thus vary by differing amounts and the centres of pressure of the holding and parting forces will vary differently during block rotation to produce a vary tipping movement on the block.

In accordance with the present invention, a hydraulic motor of fixed or variable displacement includes the following features, in combination:

(a) a rotatable cylinder block intended for rotation in either direction having or supporting cylinders parallel or inclined to the block rotation axis,

(b) pistons in the cylinders reciprocated during block rotation by means external to the block, such for example as a swash plate,

(c) a nonrotary valve on which the block is arranged to rotate,

(d) a flat valve surface of the valve in rotary contact with a flat block surface of the block,

(e) a pair of main ports in the valve surface having supply and return functions,

(f) cylinder ports in the block surface arranged to pass alternately over the main ports during block rotation,

(g) the cylinder block being arranged for axial and tilting movement to ensure that the valve and the block surfaces remain in close contact,

(h) the holding force exerted on the block by pressure in the cylinders holding the block against axial or tilting movement away from the valve surface by a parting force generated by hydraulic pressure at ports,

(i) the two pairs of adjacent ends of the main ports in the valve surface are spaced apart by portions of the valve surface referred to as bridges of which at least one bridge is of considerably greater angular extent than a cylinder port,

(j) as each cylinder port passes over the bridge its associated piston passes a dead centre position at or near the centre of the bridge,

(k) from each main port a restricted flow passage opens into the valve surface in the bridge in the path swept by the cylinder ports,

(l) a small auxiliary valve port is located near the bridge but spaced from the path swept by the cylinder ports,

(m) the auxiliary port is connected by connecting means to the pressure of the main port on to which each cylinder will pass from the bridge near the auxiliary port in accordance with the direction of rotation, and

(n) a plurality of auxiliary cylinder ports extend from the cylinder parts, each auxiliary cylinder port being arranged for connection to the auxiliary valve port when the associated cylinder port is passing over the bridge.

Where this invention is provided for the valve at the bridge corresponding to the inner dead centre position of the pistons, the connecting means comprises a shuttle valve to connect the auxiliary valve port to the main port at the higher pressure.

Where this invention is provided for the valve at the bridge corresponding to the outer dead centre position of the pistons, the connecting means for the auxiliary port may be vent to a low pressure zone.

Where the motor is intended for equal rotational speeds and torques in either direction, the two restricted flow passages in a bridge are substantially identical. Where the motor is intended principally for rotation in one direction, the restrictive flow passages in a bridge may differ considerably to favour smoother running in the said one direction.

Each auxiliary cylinder port may be formed as an extension from the side of the associated cylinder port so as to sweep over the portion of the valve surface including the auxiliary valve port.

The restricted flow passages are preferably formed as grooves in the valve surface.

How the invention can be carried into effect will now be particularly described with reference to the accompanying drawings, in which,

FIGURE 1 is a cross-section through the motor,

FIGURE 2 is a plan view of the valve surface of the motor,

FIGURE 3 is a plan view of the block surface which rotates over the valve surface of FIGURE 2,

FIGURE 4 is a cross-section taken on the line IV—IV of FIGURE 2,

FIGURES 5 to 9 are views illustrating stages in the movement of a cylinder port over one bridge in the valve plate,

FIGURES 10 to 14 are views indicating the stages in the movement of a cylinder port over the other bridge, and

FIGURE 15 is a diagrammatic view of a complete transmission.

Reference is made initially to FIGURE 1 of the drawings. This illustrated embodiment of the invention is a hydraulic tilting-head motor for use in vehicle propulsion which includes a bevel pinion **1** on the drive shaft **2** for engagement with the crown wheel of a conventional differential gear assembly. The drive shaft **2** is located within the bearing housing **3** by means of a pair of taper roller bearings **4** and **5**. Internally of the motor the drive shaft **2** includes a drive flange **6** fixedly secured thereto by means of spline **7**. The pinion **1** is secured to the shaft **2** by splines **8** and a screw threaded bolt **9** extends through the shaft to hold the drive flange **6** and the pinion tightly to the shaft.

Extending from the bearing housing **3** are a pair of bifurcated lugs **17** and **18**. Pins respectively **19** and **21** extend through these bifurcated lugs and support in them a pair of arms respectively **22** and **23**. In turn the arms support a valve plate **24** by means of bolt or like securing means. In between the arms **22** and **23** a rotary cylinder block **25** is mounted on the valve plate **24**. A central axle **26** secured in the valve plate locates the cylinder block for rotation and spring means **27** urge the block against the valve plate. The mounting of the cylinder block **25** on the axle **26** is such as to permit both axial movement and tilting movement of the block relative to the valve plate **24**.

Within the block **25** a plurality of cylinders **28** are formed whose axes are parallel to the rotation axis and which are equally spaced about the rotation axis. Alternatively these cylinders may be such that their axes are inclined to the rotation axis. These cylinders connect respectively to cylinder ports **29** opening into the block surface **31** which is in rotating contact with the valve plate surface **32**. A pair of main ports **33** and **34** open into the valve surface **32** and cooperate with the cylinder ports **29** during rotation of the block. These main ports are connected externally of the valve plate by flexible or pivotable connections to high and low pressure zones. Within each cylinder a piston **35** is slidably mounted. Each piston is of substantial length and includes a long counterbore **36** which accommodates a connecting rod **37**. A ball joint **38** secures each connecting rod into its piston at the inner end of the counterbore **36**. The opposite end of each connecting rod **37** is formed with a ball joint **39** which engages within a slipper **41**. Each slipper is slidably mounted in a bore **42** in the drive flange **6** so as to be capable of sliding motion in the direction parallel to the axis of the drive shaft **2**. Each slipper includes a slipper surface **43** which makes sliding contact with the wear surface **44** of a wear plate **45**. Also for preference each slipper **41** is mounted so as to be capable of slight tipping within its bore **42** so that the slipper surface **43** may accommodate itself to slight variations of the wear surface **44**. The wear surface **44** of the wear plate is of annular form whose radial width is very slightly larger than the diameter of each of the slipper surfaces **43**.

An annular projection **46** extends from the wear plate **45** oppositely to the wear surface **44** and engages the outer race member of the bearing **5**.

In operation of the hydraulic motor, as shown, pressure liquid is supplied to one of the main ports **33** and **34**. The tilting head assembly formed by the arms **22** and **23**, the valve plate **24** and the cylinder block **25** is located by suitable adjusting means so that the rotation axis of the block is inclined to the rotation axis of the drive shaft **2**. Pressure liquid fed for example to the main port **33** will pass to the cylinders **28** whose ports **29** connect with the port **33**. The action of such pressure on the pistons **35** will produce a thrust which is transferred through the connecting rod **37** and slippers **41** to the wear plate **45**. Due to the inclination of the axes of rotation of the shaft **2** and the block **25**, the pistons **35** under pressure will then move outwardly from their cylinders causing a driving torque to be applied to rotate the drive flange **6** through the medium of the slippers **41**. Connecting rods **37**, due to such rotation, will contact the sides of the bores **36** in their pistons and rotate the cylinder block in synchronism with rotation of the drive flange **6**.

The valve plate surface **32** is shown by FIGURE 2 and the kidney shape of the main ports **33** and **34** will be appreciated. The block surface **31** at the end of the cylinder block is of annular form as shown in FIGURE 3. The block surface **31** includes a plurality of equally-spaced cylinder ports **29** which communicate directly with the cylinders **28** in the cylinder block indicated by dotted lines. Each cylinder port **29** includes an auxiliary port **51** formed as a small extension from the edge thereof nearer to the centre of the block. Whilst the cylinder ports **29** are formed with a radial dimension which exactly fits the radial dimension of the main ports **33** and **34**, the cylinder auxiliary ports **51** extend over the inner edges of the main ports **33** and **34**. The axis of tilt of the cylinder block relative to the drive flange about the trunnions **19** and **21** is so arranged that at the inner dead-centre position of each piston its associated cylinder port will pass over the bridge **52** between two adjacent ends of the main ports **33** and **34**, whilst when the pistons are at their outer dead-centre positions the associated cylinder ports will be passing over the bridge **53** between the other two adjacent ends of the main ports **33** and **34**.

A pair of restricted flow passages **50** and **55** formed as grooves in the surface **32** extend from the adjacent ends of the main ports **33** and **34** into the bridge **52** so that they are swept over by the cylinder ports **29** during their rotation. The angular extent of the bridge **52** is considerably greater than the angular extent of a cylinder port **29**. For preference the arrangement is that the angular movement of a cylinder port over the bridge during which it connects to neither main port directly is $360°/2N$ where N is the number of cylinders in the block. In the present embodiment where there are seven cylinders, the angular extent of the bridge **52** is 60° and the angular extent of each cylinder port **29** is 36°. The movement of each cylinder port over the bridge **52** without connecting directly to either main port is therefore 24° which approximates very closely to $360°/2N$.

Adjacent to the bridge **52** a small auxiliary valve port **54** is formed in the valve surface. As seen in FIGURE 4, the port **54** is connected beneath the valve surface **32** to a shuttle valve **58** from which a pair of passages **56** and **57** extend respectively to the main ports **33** and **34**. The shuttle valve **58** includes a valve member which moves in accordance with the pressure difference existing between the passages **56** and **57** such that the passage at lower pressure is closed and the passage at higher pressure is connected to the port **54**.

In the bridge **53** a pair of restricted flow passages **59** and **61** extend from the ends of the main ports **33** and **34** into the bridge **53**. The angular widths of the bridge **53** and of the restricted flow passages **59** and **61** are the same

as described for the bridge **52**. An auxiliary valve port **62** is provided in the valve surface **32** close to the bridge **53** but radially inwards of the path swept by the cylinder ports **29**. The port **62** is connected to any convenient low pressure zone adjacent to the motor. For either bridge **52** or **53** the auxiliary valve port and the cooperating auxiliary cylinder ports are so arranged that the connection of an auxiliary cylinder port to an auxiliary valve port extends over an angle of $360°/6N$ where N is the number of cylinders in the block. In the present case where there are seven cylinders this angular movement amounts approximately to 8°. For either bridge the movement of a cylinder port is such that as it breaks connection with a restricted flow passage the auxiliary cylinder port connects to the auxiliary valve port and as the auxiliary cylinder port breaks connection with the auxiliary valve port the cylinder port will make connection with the following restricted flow passage. In other words there is only a very small angular range of movement for a cylinder port on a bridge in which it can be said that the cylinder port and its auxiliary cylinder port are not in connection with a passage or port in the valve surface.

The chain dotted line **63** drawn through the valve surface **32** to the centres of the bridges **52** and **53** passes through or near to the centres of the cylinder ports on the valve plate where the pistons in the cylinders reach their inner and outer dead-centre positions.

In operation of the motor a high pressure liquid source is connected to one of the main ports in accordance with the direction in which it is desired that the cylinder block should rotate. Assume clockwise rotation of the cylinder block mounted on the valve surface **32**, as seen in FIGURE 2, at substantial speed. The main port **34** will then be connected to the high pressure supply and the main port **33** will be connected to carry low pressure return liquid. Each cylinder port **29** when connected to the main port **34** will carry high pressure liquid to its cylinder to urge the piston outwardly whereby to rotate the cylinder block. The outward movement of the piston will continue until the piston reaches its outer dead-centre position at which point the associated cylinder port **29** will have moved on to the bridge **53** and will be disconnected from the port **34** and ready for connection to the low pressure port **33**. When the cylinder port moves over the low pressure port **33**, it will move from its outer to its inner dead-centre position and will discharge liquid at low pressure through the port **33**.

In the passage of each cylinder port **29** over the bridge **52** the pressure in the associated cylinder will change from low to high whilst in the passage of each cylinder port over the bridge **53** the pressure in the associated cylinder will change from high to low. FIGURES 5 to 9 illustrate in stages the passage of a cylinder port over the bridge **52**. For the clockwise direction of rotation the port **34** is at the higher pressure and such high pressure is supplied to the auxiliary port **54**. In FIGURE 5 the cylinder port **29** is just passing from the main port **33** but is in connection with the restricted flow passage **50**. In FIGURE 6 the cylinder port **29** has passed from the main port **33** and is in connection with the restricted flow passage **50**. At this position the piston in the associated cylinder is still approaching its inner dead-centre position and therefore the volume in the cylinder is diminishing tending to compress liquid within it. Some liquid will escape through the restricted flow passage **50** but in effect the pressure in the cylinder will rise. In FIGURE 7 the cylinder port has reached the position where its piston lies at its inner dead-centre position and here the auxiliary cylinder port **51** has connected to the auxiliary valve port **54**. High pressure from the port **34** may thus pass through passage **57** and port **54** into the cylinder port **29** to raise pressure in the associated cylinder to that of port **34**. The small size of the passage **57** will however restrict the flow rate. In FIGURE 8 the cylinder port **29** has moved so that the auxiliary ports break connection and the cylinder port **29** makes connection with the restricted flow passage **55**. At this position the associated piston is moving away from its inner dead-centre position and is thus tending to enlarge cylinder volume to reduce pressure. The connection of the restricted flow passage **55** to the cylinder port **29** will counteract such reduction in pressure, and from the dead-centre position of FIGURE 7 to the position of FIGURE 9 where the port **29** finally makes full connection with the main port **34**, the pressure in the associated cylinder will remain substantially constant at the pressure of the main port **34**. Thus it will be seen that from the FIGURE 5 to the FIGURE 7 position there is a graduated pressure rise in the cylinder port **29** which although not a constant pressure rise is one that does not take place at an excessive rate.

For rotation of the cylinder block in the anticlockwise sense, as seen in FIGURE 2, hydraulic liquid is supplied to the main port **33**. The sequence of events when a cylinder port **29** passes over the bridge **52** is as described with reference to FIGURES 5 to 9 with the exception that the movement now takes place from the FIGURE 9 to the FIGURE 5 position. Since there is symmetry about the inner dead-centre position the pressure rise in the cylinder port **29** will be exactly the same for both clockwise and anticlockwise directions of movement over the bridge **52**, other conditions being equal. Reference is now made to FIGURES 10 to 14 which illustrate movement of a cylinder port **29** over the bridge **53**. Assume that the cylinder block rotates in the clockwise sense at substantial speed and that the main port **34** receives liquid at pressure. FIGURE 10 shows the entry of the cylinder port **29** on to the bridge **53**. In FIGURE 11 the cylinder port **29** has left the main port **34** but still retains connection with the restricted flow passage **61**. Movement of the associated piston towards its outer dead centre will then reduce pressure in the cylinder. In FIGURE 12 the piston associated with the cylinder port **29** is completely at the outer dead-centre position and connection has been broken with restricted flow passage **61**. Connection is made between the auxiliary ports **51** and **62** and some flow will take place from the cylinder through the auxiliary ports to the low pressure zone reducing cylinder pressure to substantially that of the port **33**. In FIGURE 13 the auxiliary ports have parted and the cylinder port now makes connection with the restricted flow passage **59**. The associated piston is now moving towards its inner dead-centre position and there will be slight tendency to increase pressure. At the same time the restricted flow passage will carry liquid away from the cylinder port to maintain pressure substantially constant in the cylinder at the pressure of main port **33**. In FIGURE 14 the cylinder bore **29** makes connection with the main port **33**. The reduction in pressure in the cylinder port **29** is smooth during movement over the bridge **53** from the FIGURE 10 position to the FIGURE 12 position, although such pressure reduction is not necessarily constant. If the cylinder block rotates in the anticlockwise direction following the supply of high pressure liquid to the main port **33**, the sequence of events will be as described except that movement of the cylinder port **29** will now take place from the FIGURE 14 position to the FIGURE 10 position, and the pressure change occurs from the FIGURE 14 position to the FIGURE 12 position. Due to symmetry of the port arrangement about the outer dead-centre position, the smooth pressure reduction at bridge **53** in each cylinder port **29** will be the same whether or not the cylinder block is rotating in a clockwise or an anticlockwise direction.

The graduated pressure rise in a cylinder port passing the bridge **52** and the graduated pressure fall in a cylinder port passing the bridge **53** will ensure a minimum change in the relative positions of the centres of pressure of the holding and parting forces and thus will give rise to a minimum variation in tipping movement on the cylinder block. In this way the excess of the holding force over the parting force need not be very great. Where rotational

drive for the cylinder block is effected by engagement between the connecting rods and the pistons, a tipping force is applied to the cylinder block by the side forces exerted on the connecting rods. Such tipping can be counteracted by arranging that the relative spacing of the centres of pressure of the holding and parting forces are such as to produce an opposite tipping moment on the block.

One advantage obtained by the present invention is silence of operation in either direction of rotation. This advantage may also be obtained if the invention is applied to the swash plate kind of motor.

At very slow speeds the rise and fall of cylinder pressures at the bridges will take place over a much smaller angle as the cylinder port leaves the restricted flow passage and the auxiliary cylinder port connects to the auxiliary valve port. The frequency with which pressure rises and falls in the cylinders is however considerably reduced at very slow speeds and is therefore not really objectionable. At slow speeds the restrictive action of the auxiliary valve ports **54** and **62** will reduce noise resulting from pressure changes in the cylinder as each auxiliary cylinder port connects to each auxiliary valve port.

The motor of the present invention, when combined with a hydraulic pump, constructed as set out in our copending patent application No. 479,231 provides a hydraulic power transmission of righ efficiency and silence in operation. In such a transmission both the pump and the motor are of the tilting head kind, as illustrated in the drawings of said application and the accompanying drawings. The pump and the motor when of the tilting head kind may be arranged as disclosed in Patent 3,142,963 with a link connecting the pump and the motor heads to ensure joint movement of the heads during variation of speed ratio between the pump and the motor. This arrangement is shown in FIGURE 15.

Whilst the described and illustrated embodiment of the invention shows a structure in which the cylinders are formed within the cylinder block it is within the scope of the present invention for the cylinders to be supported by the cylinder block rather than being formed within it. For example the cylinders and pistons could be formed as separate telescopic units supported by ball joints between the drive flange **6** and the cylinder block **25**, the cylinder block then being connected by a universal joint to the drive flange to rotate at the same speed as the drive flange. Alternatively the cylinders may be formed in an auxiliary cylinder block, hollow sleeves extending from the main cylinder block to engage the cylinders in the auxiliary block. In this latter case the auxiliary cylinder block may be rotatably mounted without provision for axial or tipping movement, and the location of the main block by sleeves in the auxiliary block will give the required freedom of the main block for axial and tipping movement.

I claim as my invention:

1. A hydraulic motor having the following features in combination:

(a) a rotatable cylinder block intended for rotation in either direction having or supporting cylinders parallel or inclined to the block rotation axis,

(b) pistons in the cylinders reciprocated during block rotation by means external to the block, such for example, as a swash plate,

(c) a non-rotary valve on which the block is arranged to rotate,

(d) a flat valve surface of the valve in rotary contact with a flat block surface of the block,

(e) a pair of main ports in the valve surface having supply and return functions,

(f) cylinder ports in the block surface arranged to pass alternately over the main ports during block rotation,

(g) the cylinder block being arranged for axial and tilting movement to ensure that the valve and the block surfaces remain in close contact,

(h) the holding force exerted on the block by the pressure in the cylinders holding the block against axial or tilting movement away from the valve surface by a parting force generated by hydraulic pressure at the ports,

(i) the two pairs of adjacent ends of the main ports in the valve surface are spaced apart by portions of the valve surface referred to as bridges of which at least one bridge which is of considerably greater angular extent than a cylinder port,

(j) as the center of each cylinder port passes at or near the center of the bridge, the associated piston passes a dear-centre position,

(k) from each main port a restricted flow passage opens into the valve surface in the bridge in the path swept by the cylinder ports,

(l) a small auxiliary valve port is located near the bridge but spaced from the path swept by the cylinder ports,

(m) the auxiliary port is connected by connecting means to the pressure of the main port on to which each cylinder will pass from the bridge near the auxiliary port in accordance with the direction of rotation, and

(n) a plurality of auxiliary cylinder ports extend from the cylinder ports each being arranged for connection to the auxiliary valve port when the associated cylinder port is passing over the bridge.

2. A hylraulic motor, as claimed in claim **1**, in which as each cylinder port passes over the said one bridge its associated piston passes its inner dead-centre position, and in which said connecting means comprises a shuttle valve to connect the auxiliary valve port to the main port at the higher pressure.

3. A hydraulic motor, as claimed in claim **1**, in which as each cylinder port passes over the said one bridge, its associated piston passes its outer dead-centre position and in which said connecting means comprises a passage extending from the auxiliary valve port to a low pressure zone.

4. A hydraulic motor, as claimed in claim **1**, including:

(a) a small auxiliary valve port for each bridge spaced from the path swept by the cylinder ports,

(b) a restricted flow passage extending from each main port into the valve surface of each bridge in the path swept by the cylinder ports,

(c) a shuttle valve in connection with the auxiliary valve port in the bridge corresponding to the inner dead-centre position of the pistons so as to connect the auxiliary valve port to the main port at higher pressure,

(d) a low pressure connection for the auxiliary valve port in the bridge corresponding to the outer dead-centre position of the pistons.

5. A hydraulic motor, as claimed in claim **1**, wherein the two restricted flow passages extending in the valve surface of the said one bridge are identical in shape and dimensions.

6. A hydraulic motor, as claimed in claim **5**, wherein the said restricted flow passages are formed as grooves in the valve surface.

7. A hydraulic motor, as claimed in claim **1**, wherein each auxiliary cylinder port is formed as an extension from the side of the associated cylinder port so as to sweep over a portion of the valve surface including the auxiliary valve port.

8. A hydraulic motor, as claimed in claim **1**, in which the restricted flow passages in the said one bridge are such that when an auxiliary cylinder port connects to the auxiliary valve port, the associated cylinder port connects with neither restricted flow passage.

9. A hydraulic motor, as claimed in claim **8**, wherein the angular movement of a cylinder port on the said one bridge when it and its associated auxiliary cylinder

port are completely closed by the valve surface is very small.

10. A hydraulic motor, as claimed in claim **1**, wherein the angular dimensions of the said one bridge and each cylinder port are such that each cylinder port will move through an angle of $360°/2N$ on the bridge between leaving one main port and meeting the other main port, N being the number of cylinders in the cylinder block.

11. A hydraulic motor, as claimed in claim **10**, wherein the connection of each auxiliary cylinder port to the auxiliary valve port extends over an angle of $360°/6N$, N being the number of cylinders in the block.

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