Sept. 15, 1964 K. R. BOYDELL 3,148,628

HYDRAULIC APPARATUS

Filed May 24, 1962 2 Sheets-Sheet 1

FIG.1.

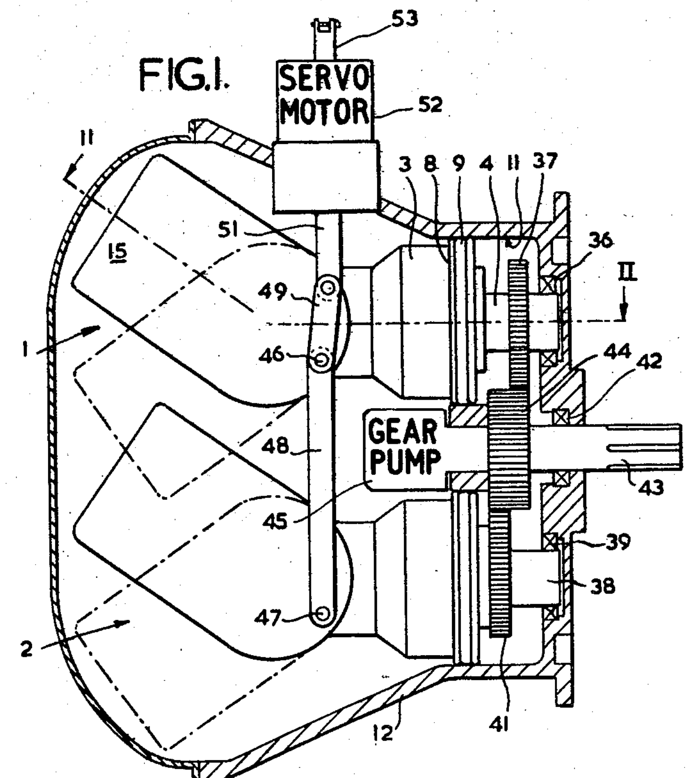

FIG.2.

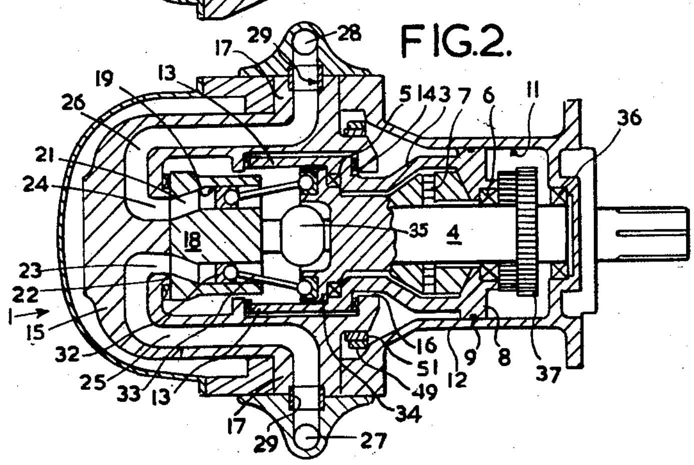

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FIG.4.

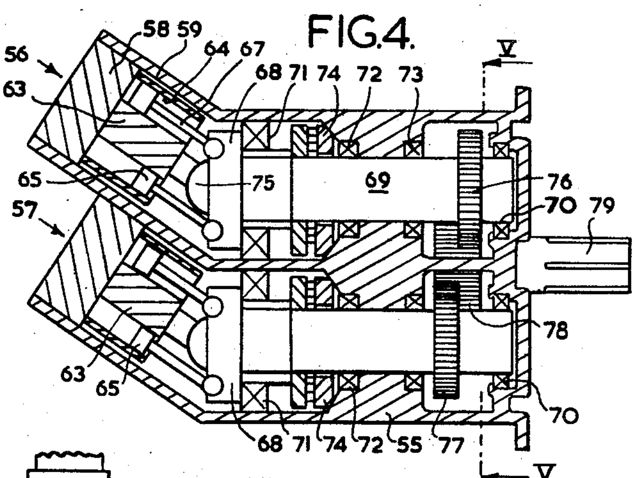


FIG.3.

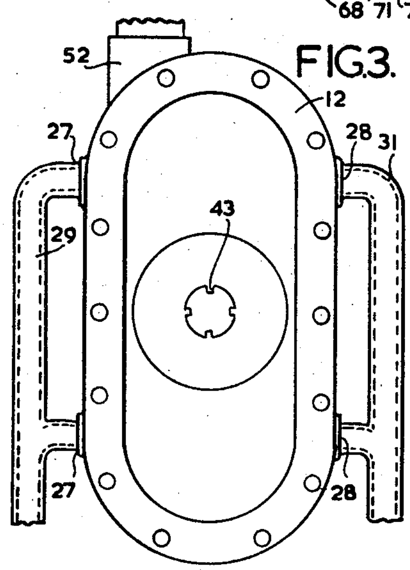
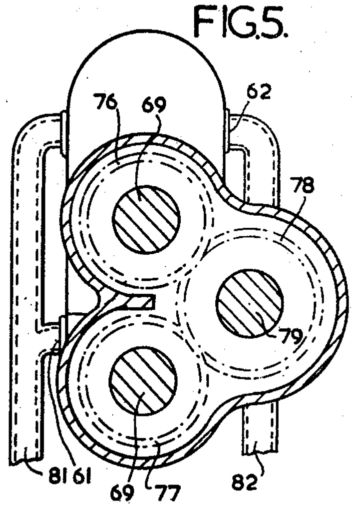


FIG.5.



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United States Patent Office 3,148,628 Patented Sept. 15, 1964

3,148,628
HYDRAULIC APPARATUS

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Filed May 24, 1962, Ser. No. 197,348
Claims priority, application Great Britain June 2, 1961
6 Claims. (Cl. 103—162)

This invention relates to hydraulic apparatus and more particularly to hydraulic pumps or motors of the tilting head type which are of substantial length as compared with their breadth and depth and in which the drive shaft extends from one end of the length substantially parallel to the length. Examples of such pumps or motors may have the inclination of the cylinder barrel to the drive shaft either fixed or adjustable. The present invention attempts on such pumps or motors of any desired displacement to reduce the overall length as compared with breadth and depth.

A pump or motor unit according to the invention includes a plurality of similar small pumps or motors each being of substantial length compared to breadth and depth and each having a drive shaft extending from one end of the length, this plurality of pumps or motors being fixed together in close parallel relationship with their individual drive shafts adjacent to one another and a gear train to connect all drive shafts for similar rotation speeds from a common main drive shaft.

Each small pump or motor may be of any known type which itself is compact as determined by the largeness of the ratio between the hydraulic displacement of the pump or motor and its total volume, of which examples have been given above.

In their length the individual small pumps or motors may not be straight but may be bent or curved and further in accordance with the invention such pumps or motors may be arranged in the unit with the bent or curved parts in interfitting relation. In this way the space within the unit is usefully employed as far as possible.

Further, in their lengths such pumps or motors may include moving parts which during operation move to alter the degree of bending along the length. The invention further provides that such pumps or motors should be mounted close together in the unit with interconnecting links or other means to ensure similar bending of the length of each pump or motor. The function resulting from the bending of the length of the pump or motor may be a variation in hydraulic displacement.

In order that the invention may be clearly understood two embodiments thereof will be described with reference to the accompanying drawings, in which

FIGURE 1 is a cross-section through the first embodiment, but showing the pumps and motors in side elevation.

FIGURE 2 is a cross-section on the line II—II of FIGURE 1,

FIGURE 3 is an end elevation of the embodiment shown in FIGURE 1,

FIGURE 4 is an axial cross-section through the second embodiment of the invention, and

FIGURE 5 is a cross-section on the line V—V of FIGURE 4.

Reference is made initially to FIGURES 1, 2 and 3 of the accompanying drawings. In this embodiment each pump or motor used is of the tilting head variable displacement type, such for example, as is shown in Patent No. 2,978,006 issued to Bowers and Thoma. Two pumps or motors indicated generally at 1 and 2 are employed and for convenience the pump or motor 1 only will be

described in detail. This pump or motor includes a bearing housing 3 enclosing a drive shaft 4 and locating the drive shafts therein by means of a pair of radial thrust bearings 5 and 6 and an axial thrust bearing 7. One end of the bearing housing 3 includes a flange 8 grooved to receive a rubber sealing ring 9 around its periphery, the flange being in slidable engagement in a bore 11 formed within a casing 12 which mounts the pumps or motors 1 and 2. The opposite end of a bearing housing 3 includes a pair of disc like projections 13 engaging within recesses 14 formed within a tilting yoke 15. The yoke is in the form of an almost complete casing having an opening 16 through which the bearing housing 3 enters. The yoke is mounted within the casing 12 by means of a pair of opposed trunnions 17 about which the yoke is angularly movable over a limited range of angular movement. Interiorly of the yoke the recesses 14 are coaxially arranged with the trunnions 17 so that angular movement of the yoke 15 about the trunnions causes as far as practicable no movement of the bearing housing 3, although of course it will be appreciated that due to errors in machining a slight angular and/or translational movement of the bearing housing 3 may occur. It is for this reason that the bearing housing is supported within the casing by the flange 8 so that it is capable of sliding and slight angular movement within the bore 11.

Within the yoke 15 a cylinder block 18 is mounted for rotary movement. The cylinder block contains a plurality of cylinders 19 parallel to the axis of rotation and at one end these cylinders terminate in ports 21 in one end face of the cylinder block 18. This end face is in contact with a valve surface 22 formed as part of the yoke, this valve surface including a pair of ports 23 and 24 for cooperation with the ports 21. From the ports 23 and 24 passages 25 and 26 extend through the walls of the yoke 15 to the trunnions 17. Externally of the trunnions 17 pipe connections 27 and 28 carried by casing 12 effect hydraulic connection with the hydraulic passages, a rotary seal 29 being provided in each case. Externally of the casing as seen more particularly in FIGURE 3 the two connections, 27 on one side of the pump and 28 on the other side of the pump, are interconnected by connecting pipes 29 and 31 which form the supply and delivery pipes to and from the pump unit (not shown, but in construction and arrangement similar to that described).

Within each cylinder 19 a piston 32 is slidably mounted from which a connecting rod 33 extends through the open end of the cylinder. The drive shaft 4 terminates within the yoke 15 in a drive flange 34 within which are socketed the opposite ends of the connecting rods 33. A constant velocity universal joint 35 interconnects the drive shaft 4 with the cylinder block 18 to drive the cylinder block at the same speed as the shaft 4 irrespective of the angular displacement of yoke 15 about its trunnions. If the shaft is driven at a constant angular rate, so too is the cylinder block, hence the primary consideration herein is to locate the pumps or motors in a compact relationship, driving the two alike.

When rotational drive is supplied to the shaft 4 both the drive flange 34 and the cylinder block 18 rotate within the yoke 15. Assuming that the yoke 15 has an angular position about its trunnions 17 as illustrated in FIGURE 1 such rotation will cause cyclic reciprocation of pistons 32 within cylinders 19 causing flow of liquid through the pump between the pipe connections 27 and 28.

Externally of the bearing housing 3 the drive shaft 4 of the pump 1 is journaled within a bearing 36 within the casing 12 and carries a gear wheel 37. The pump 2 includes a drive shaft 38 projecting from its bearing housing which engages in a bearing 39 formed within the casing 12 and carries a gear wheel 41. Extending from the casing 12 through bearings 42 is a main drive shaft 43 suitably splined for driving connection to an engine or the like. Within the casing 12 the drive shaft 43 carries a gear wheel 44 in engagement with the two gear wheels 41 and 37. Conveniently the gear wheel 44 is greater in width than either the gear wheels 37 or 41 and these latter gears engage in axially spaced parts of the periphery of gear 44 to prevent excessive wear of the gear 44.

In between the two bearing housing 3 of the pumps 1 and 2 a small gear pump 45 is located. The purpose of this gear pump is to maintain the pumps 1 and 2 primed with liquid when in use.

For the purpose of adjusting displacements of the pumps 1 and 2 the yokes 15 are adjustable in parallel relation about the trunnions 17. The pump 1 includes a pin 46 on its yoke, offset from its tilting axis, whilst the pump 2 includes a pin 47 on its yoke. In between the pins 46 and 47 a connecting link 48 extends, being pivotally mounted on the pins 46 and 47. From the pin 46 a short link 49 extends oppositely to the link 48 for pivotal connection to a linearly movable plunger 51 extending from a servo motor 52 mounted in the casing 12. The servo motor, whose structure is quite conventional, is controlled by means of a control plunger 53, the arrangement being such that linear movement of plunger 53 into or away from the servo motor 52 will cause similar movement of the plunger 51 but with substantially greater power. A further function of the gear pump 45 is to supply hydraulic power for energisation of the servo motor 52.

In operation of the pump unit, rotation applied to the drive shaft 43 will cause similar rotations of the gear wheels 37 and 41 which in turn will cause rotation of the drive shafts 4 and 38 of the pumps 1 and 2. Each pump 1 and 2 will displace liquid similarly and for example the two connections 28 may be inlet connections and the two connections 27 may be delivery connections. The actual direction of flow of liquid through the pump will depend on the angular displacement of the yokes 15 about their trunnions 17. Since the two yokes are connected together for movement by the link 48 the two pumps will always have similar displacements and of course the two yokes will always occupy substantially parallel positions. In FIGURE 1 the two pump yokes are indicated in full lines at the limit of their angular movement about the trunnion 17 in one direction and are indicated in chain dotted lines at the limit of their angular movement in the opposite direction. It will be seen that the yoke of pump 1 in the chain dotted position overlaps some of the space occupied by the yoke of pump 2 in the full line position. In other words by mounting the two pumps 1 and 2 together in a casing and arranging for the yokes to be and remain in parallel relation as they are moved it is possible to economise in the size of the casing and to use a casing of a total volume which is less than the total volume of the two separate casings capable of enclosing the pumps 1 and 2 separately. The length of each pump extends from the bearing housing at one end to the yoke at the other end and is substantial compared with the breadth and depth. Angular movement of the yoke will effectively comprise bending of the length of the pump. The link ensures similar bending of the length of each pump.

The total displacement of the two pumps 1 and 2 might be said to be equivalent to the displacement of a single similar pump which has twice the volumetric capacity of either of the pumps 1 or 2. However, in practice it is possible to drive a smaller pump at a higher rotational speed than a larger but otherwise similar pump and it can therefore be said that the unit illustrated in FIGURES 1, 2 and 3 effectively has a displacement greater than a single pump of double the volumetric capacity of either of the pumps 1 or 2 by virtue of the fact that the individual pumps 1 and 2 can be driven at a higher speed than would a single pump of double the capacity. The speed of driving of the pumps 1 and 2 may be arranged as a result of the ratio between gears 37, 41 and the gear 44 to have any desired value relative to the speed of rotation of the drive shaft 43. Therefore it can be said that the total

volume of the unit showing the FIGURES 1, 2 and 3 is substantially smaller than the total volume occupied by an equivalent single pump of double the volumetric capacity of either of the pumps 1 or 2 firstly by virtue of the fact that swinging movement of the yokes about the trunnion 17 enables the same space to be occupied by one or the other yoke and secondly by virtue of the fact that the pumps 1 and 2 may be rotated at a higher speed than an equivalent pump of double the capacity so that in fact the total capacity of pumps 1 and 2 may be less than the total capacity of a single pump capable of the same volumetric pumping rate as the pumps 1 and 2 together.

Reference is now made to FIGURES 4 and 5 of the accompanying drawings. The example illustrated is a fixed displacement motor which comprises a casing 55 enclosing a pair of motors 56 and 57. Since both of the motors are exactly similar the motor 56 only will be described in detail. In the motor 56 a valve plate 58 is located in a chamber 59 of the casing. This valve plate includes a pair of ports (not shown) from which pipe connections 61 and 62 extend on opposite sides of the casing 55. Rotatably mounted on the valve plate 58 is a cylinder block 63 having a plurality of cylinders 64 disposed parallel to the axis of rotation. The face of the cylinder block 63 which engages the valve plate 55 cooperates with the said ports in the valve plate so that the cylinders are connected alternately to these ports during rotation of the cylinder block. Within each cylinder 64 a piston 65 is slidably mounted from which a connecting rod 67 extends through the opening of the cylinder 64. At their opposite ends the connecting rods 67 are secured by articulating joints into a rotary drive flange 68 integrally formed at the end of a drive shaft 69. The drive shaft 69 is mounted in the casing 55 by four radial thrust bearings 70, 71, 72 and 73 and an end thrust bearing 74. A universal joint 75 interconnects the drive flange 68 with the cylinder block 63 to ensure that they rotate at the same speeds about their respective rotation axes. The chamber 59 within which cylinder block 63 and valve plate 58 are located is so formed within the casing 55 that the rotation axis of cylinder block 63 is inclined to the rotation axis of the shaft 69 whereby rotation of shaft 69 will result from reciprocation of piston 65 within cylinder 64 as a result of liquid pressure being supplied to either of the connections 61 or 62.

At the end of the shaft 69 remote from the drive flange 68 a gear wheel 76 is located. The motor 57 is exactly similar to the motor 56 with the exception that the gear wheel 77 on its shaft is displaced axially to a small extent from the gear wheel 76.

Within the casing 55 a further gear wheel 78 is mounted for rotation on a main drive shaft 79 carried by suitable bearings (not shown) within casing 55. The drive shaft 79 extends from the casing 55 whilst the two shafts 69 do not extend from the casing. The gear 78 meshes with both gears 76 and 77, the axial width of the gears 78 being such that gears 76 and 77 engage different parts of its periphery thus preventing undue wear.

It will be seen that each of the motors 56 and 57 individually is quite long having regard to its breadth and depth, the length effectively being measured along the rotation axes of the shaft 69 and the cylinder block 63. It will also be seen that there is a bend in the length of each motor at the position of the drive flange 68 in order that the rotation axis of the cylinder block 63 may be inclined to the rotation axis of the shaft 69. The two motors 56 and 57 are so arranged in the casing 55 that the drive shafts 69 are parallel and the rotation axes of the cylinder blocks 63 are parallel so that in effect the bends in the lengths of the two motors are arranged to fit one within the other thus ensuring that the casing 55 is not unnecessarily large.

The pipe connections 61 and 62 of each motor are connected in parallel to supply and return pipes 81 and 82.

Since the motors 56 and 57 are each capable of higher rotational speed than a similar motor of larger dimensions it follows that the combined motors **56** and **57** are the equivalent to a single motor of more than twice the hydraulic capacity of each of the individual motors **56** and **57**. Further the shape of the casing **55** is now more conveniently proportioned than the casing for a single motor similar to the motor **56** or **57** but of larger dimensions since the ratio of length to either breadth or width has been reduced. The provision of gears **76**, **77** and **78** for driving the motors **56** and **57** may be selected to match the operational speeds of the motors with the operational speeds of the load which the motor drives.

Whilst the two described embodiments relate to particular kinds of pumps or motors known more particularly as the tilting head type, it will be clear that other kinds of pumps or motors having substantial length compared with breadth and width may be combined together in a similar manner. For example the invention may equally apply to swash plate pumps or motors.

I claim as my invention:

1. A pump or motor unit of the character described, comprising a plurality of pumps or motors each of substantial length compared to its breadth and depth, and each including an individual drive shaft, a cylinder block rotative about an axis intersecting its drive shaft's axis at a given angle when in use, the several pumps or motors being similarly oriented with their drive shafts projecting in parallelism at the same end of their length, and their cylinder blocks' axes also parallel at the opposite end, all corresponding axes being disposed closely adjacent, and a main drive shaft common to and positively joining the respective individual drive shafts.

2. A pump or motor unit as claimed in claim 1 in which the individual drive shaft and the rotative axis of the cylinder block of each individual small pump or motor is disposed in fixed angular relationship along its length, the individual motors being so arranged in the unit that the angularly disposed parts of the length are in interfitting relation.

3. A pump or motor unit as claimed in claim 1 in which the individual pumps or motors include moving parts shiftable angularly relative to their individual drive shafts, and means interconnecting such parts of the several pumps or motors for similar angular movements each in its plane.

4. A pump or motor unit as claimed in claim 3 including at least one link interconnecting the angularly shiftable parts to ensure similar bending movement for all pumps or motors in the unit.

5. A pump or motor unit as claimed in claim 1 including flow and return pipes hydraulically connecting all pumps or motors forming a unit, in parallel.

6. A pump or motor unit of the character described, comprising a plurality of pumps or motors each of substantial length compared to its breadth and depth, and each including an individual drive shaft, a cylinder block rotative about an axis intersecting its drive shaft's axis at an obtuse angle when in use, and a constant-velocity type universal joint interconnecting the drive shaft with the cylinder block for rotation of the two at a constant rate; the several pumps or motors being similarly oriented with their drive shafts projecting in parallelism at the same end of their length, and their cylinder blocks' axes also parallel at the opposite end, all corresponding axes being disposed closely adjacent, and a main drive shaft paralleling and common to, and positively joining the respective individual drive shafts.

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