

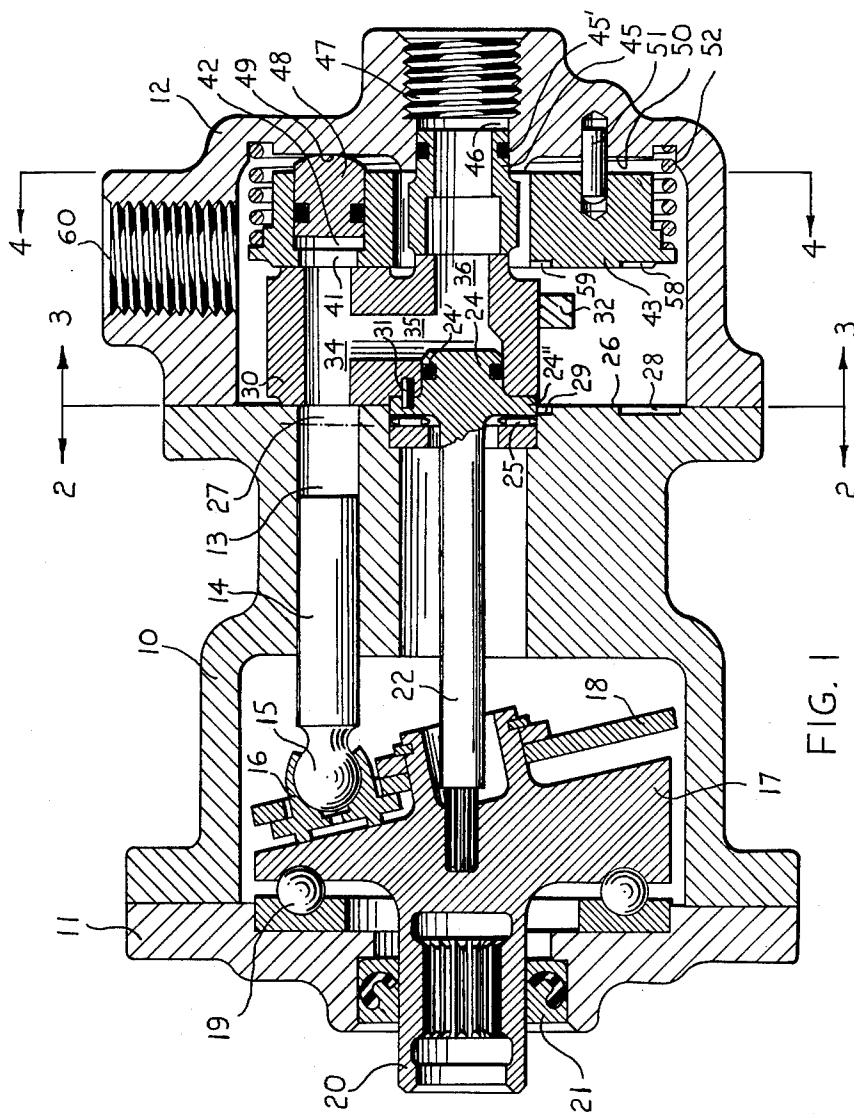
May 16, 1961

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FLUID APPARATUS

2,984,223

Filed Nov. 27, 1959

2 Sheets-Sheet 1



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2 Sheets-Sheet 2

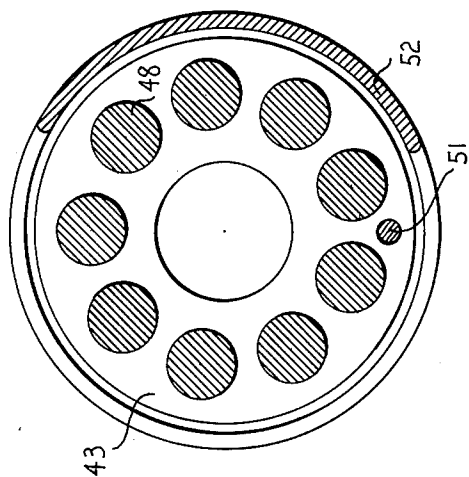


FIG. 4

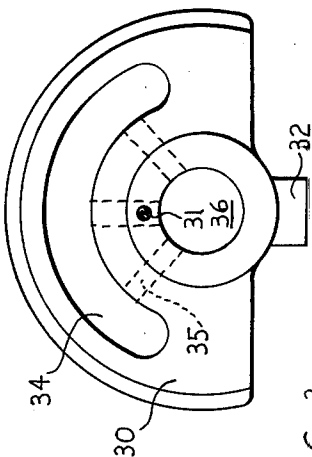


FIG. 3

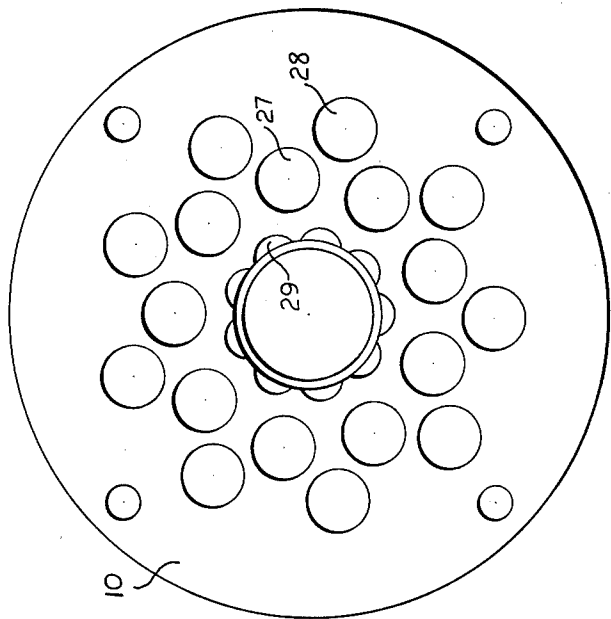


FIG. 2

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FLUID APPARATUS

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Filed Nov. 27, 1959, Ser. No. 855,559

12 Claims. (Cl. 121—121)

The present invention relates to fluid pressure energy translating devices of the piston pump or motor type, and has particular significance in connection with fluid piston pumps and motors employing a stationary cylinder barrel and a rotary cam plate driving a rotary valving means which sequentially conducts fluid to and from multiple cylinders of the stationary cylinder barrel.

In general, piston pumps and motors employing a non-rotating cylinder barrel are operative at much higher speeds than rotating barrel types due to the absence of centrifugal forces acting on the piston assemblies. In both types with a properly supported and universally mounted cylinder barrel, capable of aligning itself to a valve plate equipped with a kidney-shaped fluid conducting passage of the type well-known in the art, high volumetric and mechanical efficiencies can be obtained. To make valving possible, many ingenious devices have been used in the past to support the cylinder barrel in such a way as to eliminate the influence of the piston forces and make it free floating. One well-known method of balancing barrel to valve utilizes small kidney-shaped slots in the face of the cylinder block and in communication with the pump cylinders. Due to the requirements of balance, the area of such slots must be substantially smaller than the cross-section area of the pistons, resulting in severe flow losses and inlet throttling. At the same time, the machining of such kidney shaped slots is very expensive, and usually results in loss of dimensional accuracy.

It is an object of the present invention to provide inexpensive means for overcoming the above mentioned difficulties.

Another object of the invention is to provide a rotary valving means capable of aligning itself to the end face of a stationary cylinder barrel.

A further object is to provide rotary valving means with hydrostatically balanced distribution surfaces resulting in minimum mechanical and volumetric losses.

A further object is to eliminate substantially all forces associated with introduction of high pressure fluid to a rotary valve thus to reduce bearing pressure on sealing surfaces.

A further object is to provide a rotary valve plate of a balanced self-aligning type capable of working in contact with circular openings of straight through cylinder bores thus providing a lower cost and more accurate construction while eliminating a flow loss and permitting higher speed of operation with minimum inlet and outlet throttling.

Other objects and advantages will become apparent and the invention may be better understood from consideration of the following description taken in connection with the accompanying drawings, in which:

Fig. 1 is a sectional elevation of a fluid pump or motor embodying the present invention, but with valve plate rotated by 90° from its working position;

Fig. 2 is an end view of cylinder barrel taken on the line 2—2 of Fig. 1;

Fig. 3 is a mating end view of valve plate taken along the line 3—3 of Fig. 1; and

Fig. 4 is an end view of balancing plate taken on the line 4—4 of Fig. 1.

Description

Although the illustrated device will be described as a motor it can work equally well as a pump. A housing body 10 is closed at one end by an end cover 11 and at the other end by a valve cover 12 both secured by bolts not shown. Formed integral with housing 10 is a cylinder barrel equipped with circumferentially spaced longitudinal bores 13 in which pistons 14 are slideably mounted for reciprocation. Pistons 14 have part-spherical ends 15 with swaged over universally mounted piston shoes 16 which work in contact with a flat face of a cam plate 17 and are axially restrained from leaving this flat surface by a nutating plate 18. This cam plate is mounted for rotation with respect to the housing cover by bearings 19 and drives an external shaft 20. A shaft seal 21 is provided between shaft and cover and, as thus far described, the arrangement may be considered more or less conventional except that the cylinder barrel is an integral part of the outer housing. A central shaft 22 is at one end in splined engagement with cam plate 17 and at the other end terminates in a reaction piston 24 which carries a sealing ring 24'. Piston 24 has a piston flange portion 24" by which it is mounted with respect to the cylinder block by needle thrust bearings 25.

The associate (valve plate mating) end 26 of the cylinder block is provided with circumferentially spaced openings 27 leading to the cylinder bores 13 (and in accordance with one aspect of the present invention these openings are of the same size as, or merely continuations of, said bores). End face 26 is also provided with circumferentially spaced shallow recesses 28 (outside) and 29 (inside the circle of centers of cylinder openings 27) which shallow recesses are located angularly midway between cylinder bores (see Fig. 2).

A valve plate 30 (see Fig. 3) is secured with respect to the reaction piston 24 by a pin 31, and is thus secured for rotation with the cam plate 17 and shaft 20. A portion of the valve plate 30 is dispensed with (so as not to impede discharge fluid) and the missing part is mechanically compensated for by a weight moment 32.

The valve plate has a kidney-shaped timing slot 34 for sequentially mating with the various cylinders 13, and this slot 34 is connected by a series of drilled passages 35 with a central passage 36. In accordance with the present invention the slot 34 extends right through the valve plate to connect the registering cylinder bores 13 with openings 41 communicating with cylinders 42 in a balancing plate 43 (see Figs. 1 and 4).

The valve plate central passage 36 at one end terminates in a cylinder bore accommodating the reaction piston 24 and its sealing ring 24', and at the other end passage 36 terminates in a circular face which works in operational contact with a balancing lip of a high pressure sleeve 45 which is mounted with partial universal freedom in a cylindrical hole 46 provided adjacent a high pressure port 47. The high pressure sleeve 45 carries a sealing ring 45'.

The balancing plate 43 flat face equipped with circular passages 41 leading to balancing cylinders engages a face of the valve plate. Balancing plungers 48 work in sliding engagement within the balancing cylinders 42 and are provided with part spherical heads 49 for engaging a flat face 50 of the end cover or housing. The balancing plate 43 is prevented from rotation by a pin 51 which acts in a clearance to permit axial movement of balancing plate and partial freedom of angular alignment. A compression spring 52 is interposed between the cover 12 and

the balancing plate 43 to maintain the balancing plate in contact with the valve plate and the valve plate in contact with the cylinder block during starting. Like the flat face 26 of the cylinder block, the (valve plate mating) face of the balancing plate 43 is equipped with shallow circular curved depressions 58, 59 located angularly at mid-points between cylinder bore openings for reasons which will hereafter become apparent. The end cover locating the high pressure sleeve and providing a reaction surface for the balancing plungers also forms an enclosed cylindrical space in which the valve plate works and outside of which there is a low pressure area from (or, in the case of pump action, to) which outside communication is afforded by a low pressure port 60.

Operation

As shown in Fig. 1, the cylinder barrel is formed as an integral part of the pump housing and contains a series of horizontally extending cylinder bores in which the motor pistons are arranged to reciprocate. The motor pistons with their part-spherical ends equipped with piston shoes work in operational contact with the inclined face of the cam plate and are maintained on the low pressure stroke in contact therewith by the nutating plate engaging flange ends of the piston shoes in well-known manner. High pressure oil from the valve plate is conducted through passages (not shown) extended along the axes of the pistons to balancing surfaces of the piston shoes in known manner. With the unit acting as a motor and with pistons subjected to hydraulic pressure located on one side of the principal axis, due to the action of the inclined plane rotational motion will be induced in the cam plate and it revolves while supported by the anti-friction bearings. The cam plate and the valve plate rotate in timed relationship because connected by the timing shaft 22 and pin 31. For the unit to operate as a motor, all of the pistons subjected to pressure are located on one side of the principal axis of the cam. Actually the valve plate as shown in Fig. 1 for the purposes of demonstration of valve plate construction is not in its usual position but rotated by 90°. It should be noted that with the angular relationship between the valve plate and the cam plate shown in Fig. 1 the motor would be inoperative, an approximately equal number of cylinders and pistons under pressure being located on each side of the principal axis of the cam. But with the 90° rotation suggested this difficulty is corrected.

With the construction herein illustrated and described the cylinder barrel, being part of the housing, is incapable of aligning itself to the valve plate for maximum volumetric and mechanical efficiency. Therefore, the valve plate must be made to work against the cylinder valve face and align itself to it. With the valve plate construction as shown in Figs. 1 and 3, the kidney-shaped timing slot extends right through the valve plate between parallel surfaces one working in contact with the flat face of the cylinder barrel and the other in contact with flat face of the balancing plate. Thus the timing slot connects the cylinder bores of the motor with the openings in the balancing plate leading to the balancing cylinders housing the balancing plungers while the timing slot is also connected by the series of radial drillings to the central passage of the valve plate terminating at one end in the cylinder housing the reaction pistons and at the other end in a flange which with its flat face works in operational contact with the high pressure sleeve communicating with the high pressure port. The high pressure sleeve cross-section is subjected to the high pressure oil at high pressure port end. The other end of the high pressure sleeve has its balancing land engaging the flat surface of the flange surrounding the central passage of the valve plate. These two parts are maintained in contact by the resultant hydraulic force induced by the difference between the area of the high pressure sleeve subjected to high pressure in high pressure port and the

area subjected to high pressure on the opposite side of the sleeve as enclosed by the balancing land plus the leakage pressure equivalent acting on this balancing land. Although the contact pressure between valve plate and high pressure sleeve is by proper balancing reduced to bare minimum the valve plate is still subjected to the full force equal to the cross-section area of the high pressure sleeve exposed to the high pressure port. This force would normally induce very high bearing loads between valve plate and flat end of the cylinder barrel. To eliminate or modify this force the reaction piston is introduced and located in the central passage opposite the high pressure sleeve. It should be noted that the area of the reaction piston is equal to the area established by the O.D. of the portion of the high pressure sleeve extending into the high pressure port. In this way two equal and opposite forces acting on the valve plate cancel each other and the valve plate is permitted to align itself to the front face of the cylinder barrel under the action of balancing forces coming from the balancing plungers as explained hereafter. Meanwhile the high pressure oil acting on the reaction piston produces force on the reaction piston which must be carried by some means. In the illustrated embodiment this force is carried on small anti-friction bearings positioned between the flange of the reaction piston and the pump housing. This force might have been carried to the bearings supporting the cam through the splined shaft, but in any event it is preferable to have the valve plate engage the piston in a slideable manner, as shown, so that small axial movements of valve plate are possible.

The purpose of balancing of surfaces of valve plate is to provide stationary and revolving mating surfaces with the fluid pressure so distributed on the areas in contact that these surfaces can carry large loads with very low bearing pressures and therefore low mechanical losses at relatively high rotational speeds. In the case of a conventional solution with a self-aligning cylinder barrel (either rotating or stationary) working against a flat surface of a valve plate, the load carried on hydrostatically balanced sealing surfaces is equal to the total combined area of the pistons subjected to pressure by the discharge or inlet pressure. This force then must be partially balanced by the fluid pressure distribution on the valve plate in contact with the cylinder barrel so that only a fraction of the total force holds the cylinder barrel against the valve plate preventing separation and reducing leakage at minimum mechanical losses. This immediately dictates the size of the balancing areas and therefore the width of the kidney shaped slot connecting the cylinder bores with the high pressure port and the width of sealing and balancing lands surrounding said slot. Therefore with the timing slot width substantially smaller than the cylinder bore diameter, placing of mating small kidney shaped slots in the end of the cylinder barrel has heretofore seemed necessary. This construction is not only more expensive (as compared with straight through bores) but it also makes the cylinder barrel longer since the pistons cannot approach the working surfaces between the cylinder barrel and the valve plate. Such obstructions at the end of the cylinder barrel also provide substantial flow losses at high speeds of operation of the unit inducing torque losses and limiting the maximum speed.

With the valve plate construction as shown in Fig. 1 the process of balancing is reversed. With the present invention each cylinder bore can run through to the flat face of the cylinder barrel in contact with the valve plate. The width of the timing slot may then be selected for minimum losses with the maximum operating speed. Advantageous sealing and the balancing lands may then be placed around the timing slot; with outer and inner radii of these lands overlapping cylinder bore openings.

This construction results in very large loads induced by the combined effects of timing slot area, area of the cylinder bores and the pressure distribution due to pressure gradient acting on sealing lands surrounding the timing slot. To partially reduce these loads the series of curved shallow depressions may be placed in the spaces between cylinder bores. These depressions are located radially away from the outer and inner edges of the timing slot and therefore define the width of the sealing lands between individual cylinder bores. At the same time these shallow depressions not only reduce the hydraulic loads acting on the valve plate but provide dirt traps to prevent scoring and damaging of the sealing surfaces.

In accordance with one aspect of the present invention the valve plate is equipped with two identical parallel faces with the second face mating with a surface of the balancing ring in which circular openings of the same diameter as the main cylinder bores are located opposite the main cylinder bores. In this way two parallel surfaces of the valve plate are subjected to identical loads caused by identical pressure distribution. The balancing plungers, working in balancing cylinders located in balancing plate, are of larger diameter than the main cylinder bores and thus provide a positive force maintaining the faces of the valve plate in contact with the cylinder barrel and the balancing plate. The diameter of the balancing plungers is so arranged that the excess holding pressure preventing separation is at a minimum for producing satisfactory sealing with minimum of mechanical losses. Preferably the center of each balancing plunger is located substantially near the center of pressure acting on a segment enclosed by imaginary lines passing from the center of rotation midway between cylinder bores. The balancing plungers with their part-spherical ends engage the flat surface of the motor cover and being slideably mounted in relation to the balancing plate provide a freedom of alignment of balancing plate with respect to valve plate. A keying pin secured in the cover prevents rotation of balancing plate and because of a clearance hole allows it a limited freedom of alignment. The sealing surface extending all around the timing slot encompasses all the ports of cylinder bores subjected to pressure while all the ports of cylinder bores subjected to low pressure are in direct communication with the cylindrical space provided in the end cover and thus with the low pressure port. With the balancing principal employed as described above, and with total elimination by use of a reaction piston of the force disturbance caused by introduction of high pressure oil to the valve plate, as described above, a floating and self aligning condition is achieved resulting in minimal losses, both mechanical and volumetric, while the machine can be employed at very high speeds.

While I have illustrated and described a particular embodiment, various modifications may obviously be made without departing from the true spirit and scope of the invention which I intend to have defined only by the appended claims taken with all reasonable equivalents.

I claim:

1. In a fluid pressure energy translating device of the type comprising a stationary cylinder block having a plurality of cylinder bores, pistons mounted for reciprocation in the cylinder bores, a cam plate operatively associated with reciprocation of the pistons, and a valve plate rotatable with respect to the cylinder block, said valve plate having two parallel faces with a port extending through the valve plate and through said faces to communicate at one end thereof sequentially with openings leading to the cylinder bores, a balancing plate contacting the second of said parallel faces, said balancing plate being generally non-rotatable while free to move

axially and tiltingly, said balancing plate having openings adjacent said second face, said openings leading to balancing cylinders within the balancing plate, fluid pressure plunger means slideable located in said balancing plate cylinders so that the fluid pressure plunger means are associated with openings communicating with said valve plate port at its end opposite the cylinder block for aligning valve plate with respect to cylinder block, and pressure fluid conducting means establishing communication with said valve plate port to and from the outside of the device, the centers of the openings leading to the balancing cylinders in the balancing plate being substantially co-axial each with a center of an opening leading to a cylinder bore in the stationary cylinder block.

2. The combination of claim 1 further characterized by an outer housing assembly and by the fluid pressure plunger means comprising a plurality of plungers each having a part-spherical head contacting an inner surface of said housing assembly for reaction while providing limited freedom of alignment to enable balancing plate to mate with valve plate.

3. The combination of claim 1 further characterized by the cylinder block having a face containing the openings for communicating with the cylinder bores, said face having shallow depressions located angularly midway between the openings communicating with the cylinder bores while radially displaced therefrom and partially overlapping the contact land on the adjacent face of the valve plate while not overlapping the valve plate port, whereby to reduce balancing loads.

4. The combination of claim 3 further characterized by the balancing plate surface adjacent the valve plate having similarly located shallow depressions.

5. The combination as in claim 1 further characterized by the valve plate having a central passage which is generally coaxial with the cylinder block, and the valve plate having plural radial drillings connecting said passage with the valve plate port, a non-rotating high pressure sleeve having one end in operational contact at one side of the valve plate and establishing communication with said central passage through said sleeve, an outer housing portion having a high pressure port communicating with the other end of said sleeve, a reaction piston located at the opposite side of the valve plate and having a face adjacent the central passage thereof with the diameter of the effective area of said piston face being equal to the area defined by the outer diameter of the high pressure sleeve portion exposed to the high pressure in the high pressure port, whereby to eliminate the forces otherwise exerted on the valve plate by the high pressure sleeve and reduce bearing pressures and maintain freedom of alignment of valve plate with respect to cylinder block.

6. The combination as in claim 5 further characterized by the sleeve having predetermined dimensions of end faces such that the sleeve is kept in contact with the valve plate by a positive force.

7. The combination as in claim 5 further characterized by a thrust bearing interposed between reaction piston and cylinder block.

8. The combination of claim 7 further characterized by the reaction piston being slideably mounted in an opening in the valve plate and keyed to said valve plate to permit torque to be transmitted from one to the other without affecting limited freedom of axial movement of valve plate with respect to piston.

9. The combination of claim 8 further characterized by the reaction piston having a stem terminating in splined engagement with the valve plate so that valve plate will rotate responsive to rotation of cam plate.

10. In a fluid pressure energy translating device, a stationary cylinder barrel arranged in annular form about a central axis and having a plurality of cylinder bores extending parallel to said axis and terminating with full diameter in end surfaces of said barrel, pistons mounted

for reciprocation in the cylinder bores, a rotatable cam plate operatively associated with reciprocation of the pistons and located at one end of the cylinder barrel for rotation about said axis, a rotatable valve plate located at the opposite end of the cylinder barrel for rotation about said axis, said valve plate having a port and one surface surrounding said port, with said surface and port operative against an end of the cylinder barrel in which end the cylinder bores terminate with full diameter, and a fluid pressure operated balancing plate to maintain contact between valve plate and cylinder barrel.

11. The combination of claim 10 further characterized by the balancing plate having cylinders containing fluid operated plungers equal in number to the cylinder barrel pistons but of a uniform diameter larger than that of said pistons while the balancing plate cylinders terminate in openings adjacent the valve plate which openings have a uniform diameter substantially equal to that of the cylinder barrel cylinder bores and are coaxial therewith, whereby to keep the valve plate in contact with the cylinder barrel and the balancing plate in contact with the valve plate to provide minimum leakage and minimum horsepower losses.

12. The combination as in claim 11 further characterized by the valve plate having an arcuate slot communicating with cylinder barrel openings and balancing plate openings and having a central passage communicating with said arcuate slot, a high pressure sleeve contacting the valve plate at one end of said central passage, a reaction piston contacting said valve plate at the opposite end of said central passage, and a thrust bearing supporting said reaction piston from one end of the cylinder barrel for minimizing the forces from the high pressure sleeve while maintaining the free floating and self aligning characteristics of the valve plate and providing minimal losses.

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