March 2, 1943.

W. FERRIS

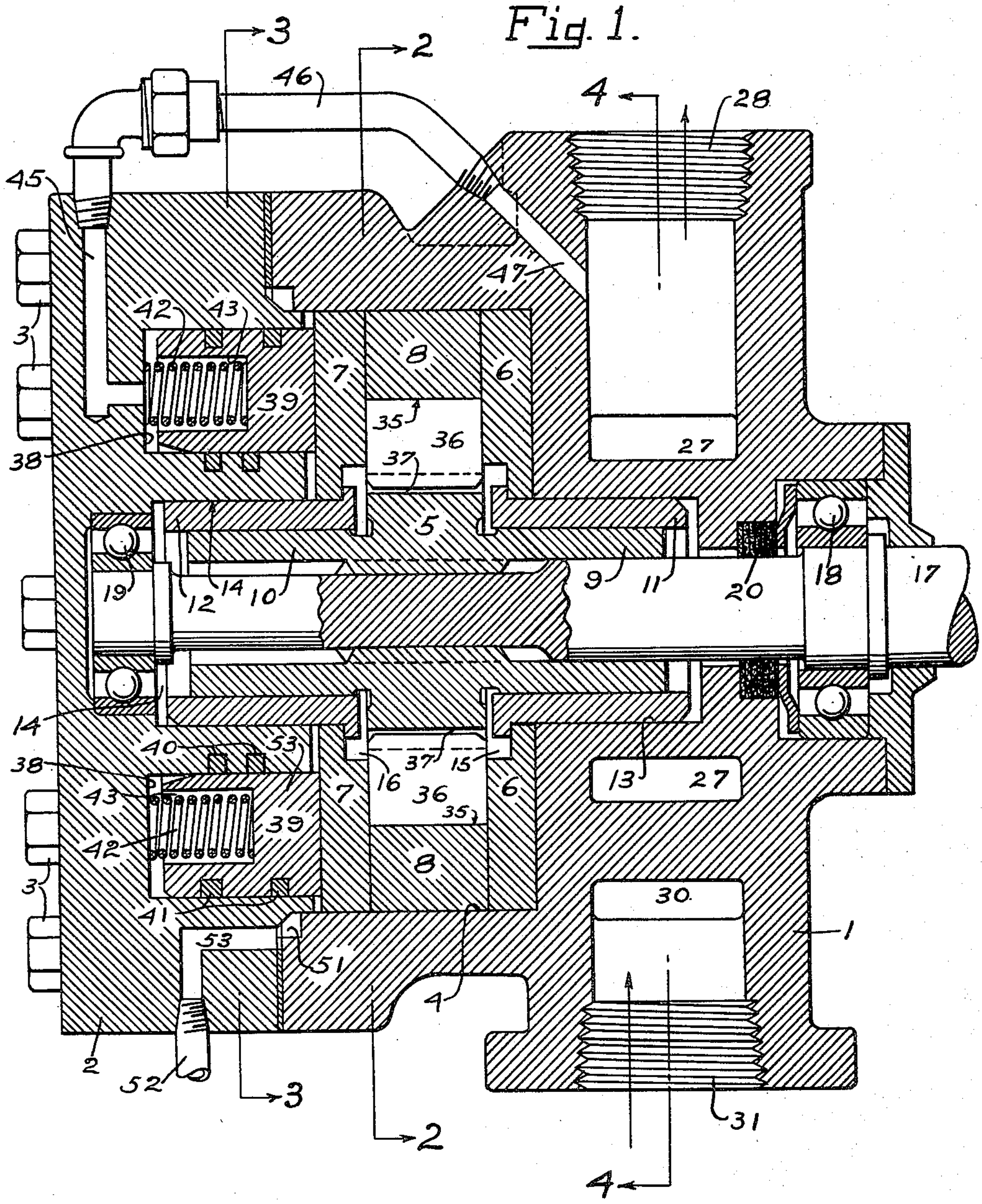
2,312,891

HYDRODYNAMIC MACHINE

Filed May 19, 1939

4 Sheets-Sheet 1

Fig. 1.



INVENTOR.
WALTER FERRIS
BY
Wesley P. Merrill
ATTORNEY.

March 2, 1943. W. FERRIS 2,312,891

HYDRODYNAMIC MACHINE

Filed May 19, 1939 4 Sheets-Sheet 2

Fig. 2.

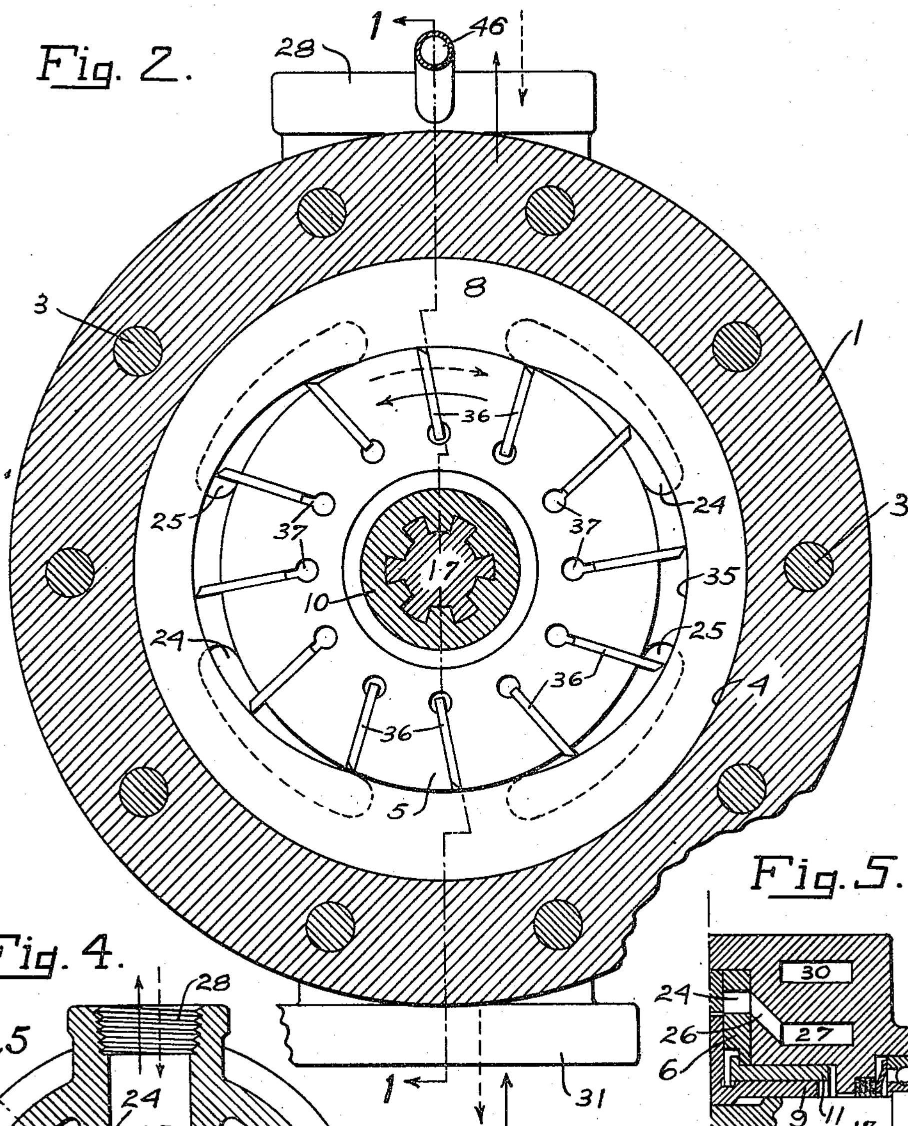


Fig. 4.

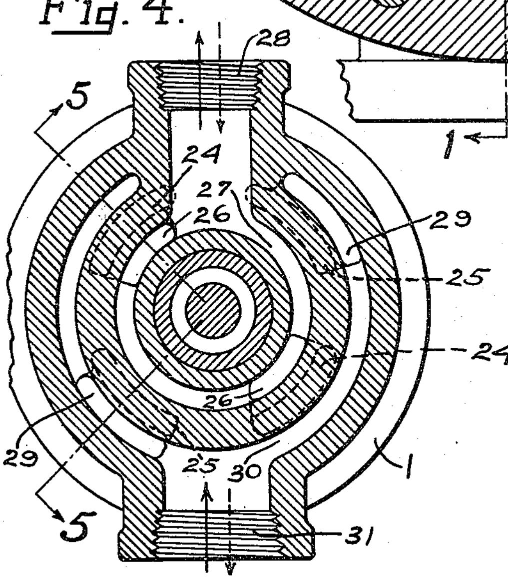
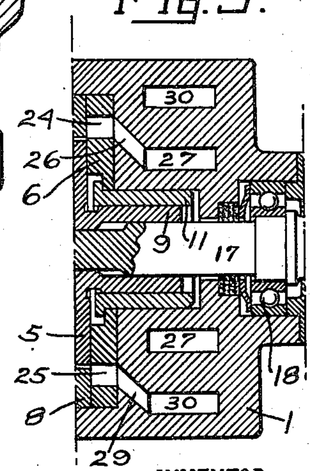


Fig. 5.



INVENTOR.
WALTER FERRIS

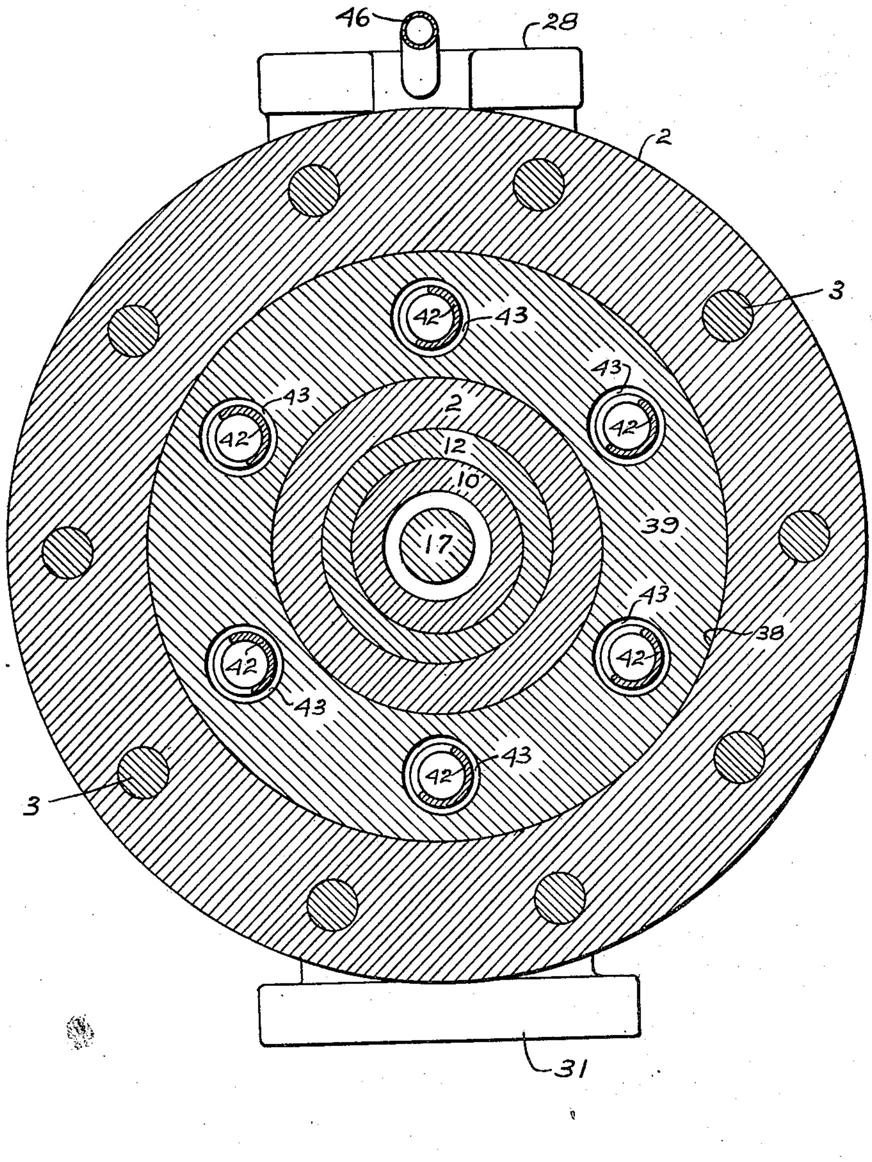
BY Wesley P. Merriel
ATTORNEY.

March 2, 1943. W. FERRIS 2,312,891

HYDRODYNAMIC MACHINE

Filed May 19, 1939 4 Sheets-Sheet 3

Fig. 3.



INVENTOR.
WALTER FERRIS
BY Wesley P. Merrill
ATTORNEY.

March 2, 1943. W. FERRIS 2,312,891

HYDRODYNAMIC MACHINE

Filed May 19, 1939 4 Sheets-Sheet 4

Fig. 6.

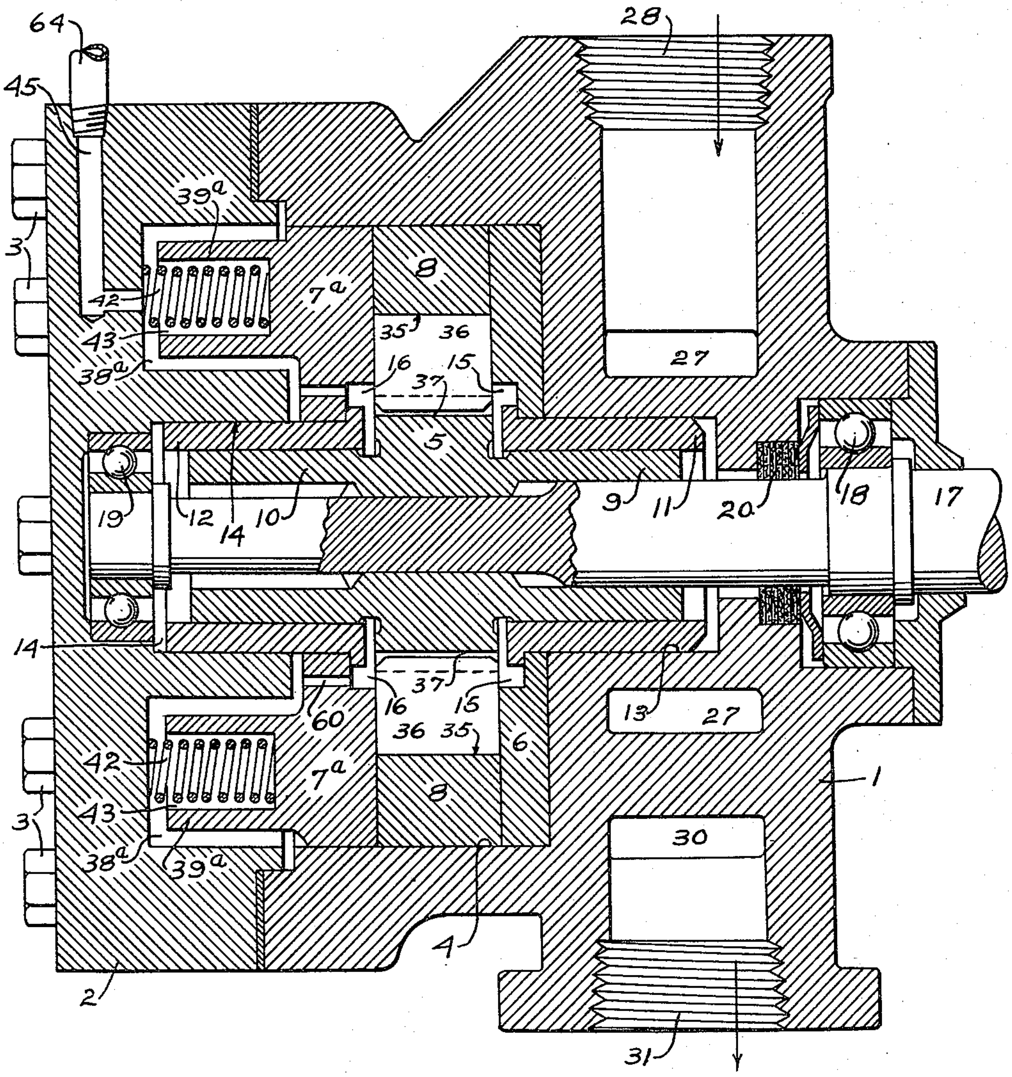
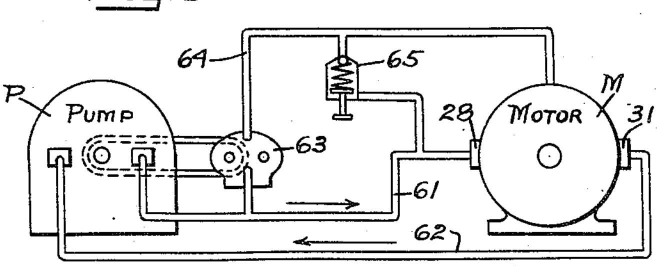


Fig. 7.



INVENTOR.
WALTER FERRIS
BY
ATTORNEY.

Patented Mar. 2, 1943

2,312,891

UNITED STATES PATENT OFFICE

2,312,891

HYDRODYNAMIC MACHINE

Walter Ferris, Milwaukee, Wis., assignor to The Oilgear Company, Milwaukee, Wis., a corporation of Wisconsin

Application May 19, 1939, Serial No. 274,544

7 Claims. (Cl. 103—135)

This invention relates to vane type hydrodynamic machines. The machine to which the invention relates in particular has two parallel cheek plates arranged in a casing and spaced apart by a spacer ring consisting of either a single part or a plurality of related parts and having an approximately elliptical inner periphery, an end head bolted to the casing and clamping the spacer ring between the cheek plates, a circular rotor having a plurality of radial slots and arranged inside the spacer ring to have a running fit between the cheek plates, high and low pressure ports formed in one of the cheek plates to provide communication between an external circuit and the spaces between the rotor and the inner periphery of the spacer ring, and vanes fitted in the rotor slots and urged outward as by centrifugal force or by hydraulic pressure against a continuous approximately elliptical vane track arranged within the spacer ring or formed upon the inner peripheral surface thereof, the vanes forming movable seals between each high pressure port and the adjacent low pressure port so that, if the rotor is rotated from an external source of power and the low pressure port is connected to a source of liquid, the vanes will transfer liquid from the low pressure ports to the high pressure ports and thereby cause the machine to function as a pump and, if high pressure liquid is supplied to the high pressure port, it will act upon the vanes and rotate the rotor to thereby cause the machine to function as a motor.

In order that the rotor may turn freely, there must be a slight clearance between it and the cheek plates, and this clearance permits liquid to leak from the high pressure ports across the face of the rotor to the low pressure ports. If this clearance is too little, the rotor will not turn freely and, if it is too great, the leakage will be excessive.

It therefore follows that the parts of the machine must be finished to exact size in order to provide the correct clearance between the rotor and the cheek plates but it has been found in actual practice that, even with the machine parts finished as nearly to the exact size as is commercially practical, the clearance between the rotor is either too little or too much. Also, due to deflection of the parts and to the fact that the flow through a restricted passage varies in accordance with variations in the drop in pressure thereacross, the leakage increases as the pressure of the motive liquid increases and it becomes excessive at ordinary operating pressures.

This excessive leakage has not prevented machines of this type from going into extensive commercial use as pumps but, since the speed of a motor will vary in accordance with the variations in both its own leakage and the leakage of the pump which supplies it with motive liquid, it has not heretofore been practical to use machines of the above described type as motors for driving machine elements which must be driven at closely regulated speeds.

The present invention has as an object to provide a hydrodynamic machine of the above type with means for controlling the leakage thereof.

Another object is to provide a vane type hydrodynamic machine which may be commercially used as a motor.

Other objects and advantages will appear from the description hereinafter given of hydrodynamic machines in which the invention is embodied.

According to the invention in its general aspect and as ordinarily embodied in practice, a hydrodynamic machine of the above type is provided with means for pressing the cheek plates and the spacer ring together with a force which varies in accordance with variations in the pressure of the motive liquid.

The invention is exemplified by the hydrodynamic machines illustrated in the accompanying drawings in which the views are as follows:

Fig. 1 is a horizontal longitudinal section through a machine in which the invention is embodied, the view being taken upon the irregular line 1—1 of Fig. 2.

Fig. 2 is a transverse section taken on the line 2—2 of Fig. 1.

Fig. 3 is a transverse section taken on the line 3—3 of Fig. 1.

Fig. 4 is a transverse section taken on the line 4—4 of Fig. 1.

Fig. 5 is a longitudinal section taken on the irregular line 5—5 of Fig. 4.

Fig. 6 is a view similar to Fig. 1 but showing a different arrangement for pressing the cheek plates and spacer ring together.

Fig. 7 is a diagram of a hydraulic circuit in which the machine shown in Fig. 6 is employed as a motor.

The machine shown in Figs. 1 to 5 and the machine shown in Fig. 6 are substantially the same except for the means for pressing the spacer ring and cheek plates together. Each machine is capable of functioning as either a pump or a motor but, in order to simplify the description, the machine shown in Figs. 1 to 5 will be described as a pump and the machine shown in Fig. 6 will be described as a motor.

Referring now to Figs. 1 to 5, the machine has its mechanism arranged within a casing 1 having an end head 2 attached thereto by a plurality of bolts 3 and enclosing a circular recess 4 formed within the body of the casing.

Recess 4 has a circular rotor 5 arranged therein between two annular cheek plates 6 and 7 which are fitted in recess 4 and spaced apart by a spacer ring 8 which is fitted in recess 4 and is just enough thicker than rotor 5 to permit rotor 5 to have a running fit between cheek plates 6 and 7.

Rotor 5 has integral hollow hubs 9 and 10 extending from its opposite faces and fitted, respectively, in tubular bearing bushings 11 and 12 which extend, respectively, through cheek plates 6 and 7 and are closely fitted in bores 13 and 14 formed, respectively, in casing 1 and in end head 2 concentric with recess 4. Bushings 11 and 12 have annular flanges formed upon their inner ends and arranged in grooves 15 and 16 which are formed in the adjacent faces of cheek plates 6 and 7 respectively, each bushing forming a fluid tight joint with a cheek plate through which it extends.

Rotor 5 is splined upon a shaft 17 which extends loosely through hubs 9 and 10 and is journaled in two bearings 18 and 19 carried by casing 1 and end head 2 respectively, suitable packing 20 being provided to prevent liquid from escaping along shaft 17 from the interior of casing 1.

The inner peripheral surface of spacer ring 8 is approximately elliptical as shown in Fig. 2 and the spaces between rotor 5 and ring 8 communicate with two diametrically opposed outlet ports 24 and two diametrically opposed intake ports 25. As shown in Fig. 4 and 5, each outlet port 24 communicates through a short passage 26 with an annular passage 27 which is formed in casing 1 and terminates in an outlet 28, and each intake port 25 communicates through a short passage 29 with an arcuate passage 30 which is formed in casing 1 and terminates in an intake 31.

The elliptical inner surface of spacer ring 8 forms a continuous track 35 for a plurality of vanes 36 which are the same width as rotor 5 and are fitted in slots 37 formed therein and extending approximately radially inward from the periphery thereof. Vanes 36 are urged outward against track 35 by centrifugal force when rotor 5 is rotated to cause the machine to function as a pump, and the distance between adjacent vanes is less than the distance between adjacent ports so that there is always at least one vane in contact with track 35 between each two adjacent ports, thereby providing movable seals between adjacent ports.

As shown in Fig. 2, the minor axis of vane track 35 is but slightly greater than the diameter of rotor 5 while the major axis thereof is considerably larger so that, during rotation of rotor 5, each vane 36 moves outward when passing from a point on one side of track 35 adjacent the minor axis thereof to a point on track 35 adjacent to major axis and then it is moved inward as it moves towards a point on the other side of the track adjacent to the minor axis.

The arrangement of the vane track, rotor, vanes and ports is according to the usual practice and the manner in which the pump operates is well known. It is therefore deemed sufficient to state herein that, when intake 31 is connected to a source of liquid and rotor 5 is rotated in a counterclockwise direction as indicated by the arrow shown in full lines on Fig. 2, the spaces between adjacent vanes will be filled with liquid while in communication with low pressure ports 25 and the vanes will transfer this liquid to high pressure ports 24 and force it therethrough as the vanes move toward the minor axis of vane track 35, thereby causing the pump to discharge liquid through outlet 28 and, if the discharge of liquid is resisted as by the liquid being employed to drive a motor, the pump will create pressure in outlet 28 and ports 24.

Regardless of whether the machine is functioning as a pump or as a motor, there is ordinarily a considerable drop in pressure between the high pressure ports and the low pressure ports and, due to the necessary cleareance between the rotor and the cheek plates, this pressure differential causes liquid to flow from the high pressure ports across the face of the rotor to the low pressure ports.

Since this flow of liquid is under pressure, it will tend to separate the cheek plates from the rotor and thereby increase the clearance therebetween, and since the flow of liquid through a restricted passage will increase as the pressure differential increases, the leakage across the face of the rotor will become excessive at ordinary operating pressures.

In order to reduce this leakage to a minimum and to compensate for slight errors in the finished sizes of the parts so that the machine may either operate with greater efficiency as a pump or be employed as a motor which has heretofore been impractical due to the excessive leakage of this type of machine, means are provided for pressing the cheek plates and spacer ring together with a force which varies in accordance with variations in the pressure of the motive liquid.

This is accomplished in the machine shown in Figs. 1 to 5 by providing end head 2 with piston and cylinder means which act upon cheek plate 7 and are energized by liquid at a pressure proportional to the pressure of the motive liquid.

While end head 2 may have a plurality of individual pistons and cylinders arranged therein in a circle concentric with shaft 17, it has been shown as having a single annular cylinder 38 formed therein concentric with shaft 17 and an annular piston 39 fitted in cylinder 38 and in contact with cheek plate 7, cylinder 38 having piston rings 40 fitted in suitable grooves formed in its inner peripheral surface and piston 39 having piston rings 41 fitted in suitable grooves formed in its outer peripheral surface to prevent the escape of liquid from cylinder 38.

Piston 39 is initially urged against cheek plate 7 by a plurality of helical springs 42 which bear against the end of cylinder 38 and are arranged in suitable recesses 43 formed in piston 39 and, when the machine is in operation, piston 39 is urged against cheek plate 7 by liquid supplied to cylinder 38 by the pump. As shown, cylinder 38 communicates through a channel 45, which is formed in end head 2, with one end of an external pipe 46 the other end of which communicates with outlet 28 through a channel 47 formed in casing 1.

It will be obvious that cylinder 38 will be supplied with liquid at a pressure equal to the pressure created by the machine when it is functioning as a pump. Consequently, the force exerted by piston 39 upon cheek plate 7 increases as the pressure of the pumped liquid increases and thereby prevents deflection of the parts due to an increase in the pressure of the pumped liquid. In fact, it has been found by actual tests that the invention reduces the leakage across the face of the rotor at ordinary operating pressures by more than 70%.

Any liquid which may escape from cylinder 38 past piston rings 40 and 41 is collected by a drainage groove 51 which is formed by cutting away the inner corner of casing 1 as shown in Fig. 1. The liquid collected by groove 51 is drained therefrom through a drain pipe 52 which is connected to groove 51 by a channel 53 formed in end head 2.

Figure 6

The machine shown in this figure differs primarily from the machine shown in Figs. 1 to 5 in that it is provided with somewhat different means for urging the cheek plates and spacer ring together and in that it has been shown in Fig. 7 as being employed as a motor. Since the two machines are otherwise substantially the same, like parts have been indicated by like reference numerals and no further description thereof will be given.

The principal difference between the two machines is that, instead of the outer cheek plate being acted upon by a hydraulic piston as in the machine shown in Figs. 1 to 5, the outer cheek plate of the machine shown in Fig. 6 has its outer face acted upon by liquid the pressure of which is at all times substantially proportional to the pressure of the motive liquid, and the outer cheek plate is made rigid enough to prevent it from being distorted by the pressure of the liquid.

Since end head 2 must be of sufficient thickness to accommodate bushing 12 and bearing 19, the machine has been shown provided with an outer cheek plate 7ª having formed thereon an annular stiffening rib 39ª which corresponds to piston 39 and which is arranged in a recess 38ª formed in end head 2 and corresponding to cylinder 38.

Cheek plate 7ª is initially urged against spacer ring 8 by a plurality of springs 42 arranged in recesses 43 formed in rib 39ª and, when the motor is in operation, it is urged against the spacer ring 8 by liquid supplied to recess 38ª through channel 45 at a pressure which is at all times approximately proportional to the pressure of the motive liquid as will presently be explained. The arrangement is such that the entire outer face of cheek plate 7ª is exposed to this pressure so that cheek plate 7ª is urged against spacer ring 8 with a force substantially proportional to the pressure of the motive liquid, and cheek plate 7ª is rigid enough to prevent this pressure from distorting it.

Since vanes 36 are inclined to the radii of rotor 5, ports 24 should be high pressure ports and ports 25 should be low pressure ports regardlss of whether the machine is operating as a pump or as a motor. Therefore, when the machine is to operate as a motor, connection 28 should be connected to the source of motive liquid so that it becomes the inlet and connection 31 becomes the outlet of the motor, thereby reversing the direction of flow of liquid and the direction of rotation of rotor 5 as indicated by the arrows on Fig. 2, the arrows shown in full lines indicating the directions of flow and rotation when the machine functions as a pump and the arrows shown in dotted lines indicating the directions of flow and rotation when the machine functions as a motor.

When motive liquid is supplied to high pressure ports 24, it will act upon one side of the vanes in contact with track 35 near the major axis thereof and move the vanes toward low pressure ports 25, thereby causing rotor 5 to rotate in the direction of the arrow shown in dotted lines on Fig. 2, and the liquid between adjacent vanes will be discharged through ports 25.

If vanes 36 were not in contact with track 35, the motive liquid would flow from high pressure ports 24 to low pressure ports 25 without rotating rotor 5. Therefore, in order that vanes 36 may be positively held in contact with track 35, the inner ends of vane slots 37 are supplied with high pressure liquid. This may be accomplished by connecting groove 16 in cheek plate 7ª to recess 38ª by means of one or more ducts 60 which extend through cheek plate 7ª so that vanes 36 are urged outward by a pressure equal to the pressure prevailing in recess 38ª.

Since the outer ends of the vanes are subjected to the pressure of the motive liquid as they pass high pressure ports 24, it follows that the inner ends of slots 37 must be supplied with liquid at a higher pressure in order to positively move the vanes outward against track 35. Liquid at a pressure higher than the pressure of the motive liquid may be supplied to recess 38ª and to the inner ends of vane slots 37 by means of an auxiliary pump as shown in Fig. 7 in which the motor has been designated by the reference numeral M.

As shown, motor M is energized by motive liquid supplied thereto by a power pump P, motor M having its inlet 28 connected to the outlet of pump P by a channel 61 and its outlet 31 connected to the intake of pump P by a channel 62. Liquid for pressing cheek plate 7ª against spacer ring 8 and for moving vanes 36 outward is supplied by a small capacity auxiliary pump 63 which is driven in unison with pump P. Auxiliary pump 63 draws liquid from channel 61 and discharges it into a channel 64 which is connected to end head 2 and communicates with recess 38ª through channel 45.

The liquid discharged by pump 63 in excess of requirements is returned to channel 61 through a low pressure relief valve 65 which enables pump 63 to maintain in channel 64 a pressure which exceeds the pressure of the motive liquid by an amount equal to the resistance of relief valve 65. Consequently, vanes 36 are urged outward by a pressure greater than the pressure of the motive liquid, the cheek plates and rotor are urged together with a force which varies in accordance with and is substantially proportional to the pressure of the motive liquid, and the power loss at valve 65 is small due to the small pressure drop thereacross and to the small capacity of pump 63.

The invention herein set forth is susceptible of various modifications without departing from the scope thereof as hereafter claimed.

The invention is hereby claimed as follows:

1. In a vane type hydrodynamic machine having a casing provided with a recess and high and low pressure ports communicating with said recess, a cheek plate arranged against the inner end of said recess, a cheek plate arranged in the outer end of said recess, a spacer ring arranged between said cheek plates and a circular rotor arranged within said ring, the combination of an end head

attached to said casing for closing said recess and having an annular chamber formed in the inner face thereof concentric with said cheek plates, a rigid annular member arranged upon the outer face of said outer cheek plate and within said chamber, means for supplying liquid to said chamber at a pressure which varies in accordance with variations in pressure at said high pressure port whereby said liquid urges said outer cheek plate inward and presses said cheek plates and spacer ring together with a force proportional to the pressure at said high pressure port, and means for limiting the area of said outer cheek plate to which said force is applied to thereby limit said force.

2. In a vane type hydrodynamic machine having a casing provided with a recess and high and low pressure ports communicating with said recess, a cheek plate arranged against the inner end of said recess, a cheek plate arranged in the outer end of said recess, a spacer ring arranged between said cheek plates and a circular rotor arranged within said ring, the combination of an end head attached to said casing for closing said recess and having an annular chamber formed in the inner face thereof concentric with said cheek plates, a rigid annular member arranged upon the outer face of said outer cheek plate and within said chamber, spring means arranged within said chamber and extending into said member for initially urging said outer cheek plate against said spacer ring, means for supplying liquid to said chamber at a pressure which varies in accordance with variations in pressure at said high pressure port whereby said liquid urges said outer cheek plate inward and presses said cheek plates and spacer ring together with a force proportional to the pressure at said high pressure port, and means for limiting the area of said outer cheek plate to which said force is applied to thereby limit said force.

3. In a vane type hydrodynamic machine having a casing provided with high pressure and low pressure ports, a pair of circular cheek plates arranged within said casing, a spacer ring arranged between said cheek plates and a rotor arranged within said ring, the combination of a stationary annular cylinder having a greater outside diameter than said rotor, a rigid annular piston fitted in said cylinder in engagement with one of said cheek plates and radially overlapping said spacer ring and said rotor, and means for directing liquid from said high pressure port to said cylinder to cause said piston to urge said cheek plates and said spacer ring together.

4. In a vane type hydrodynamic machine having a casing provided with a recess and high pressure and low pressure ports communicating with said recess, cheek plates arranged in said recess, a spacer ring arranged between said cheek plates, and a circular rotor arranged within said ring, the combination of an end head attached to said casing for closing said recess and having cylinder means arranged therein around the axis of said rotor, rigid piston means arranged in said cylinder means and engaging the outer cheek plate opposite the space between said rotor and ring, and means for directing pressure liquid to said cylinder means to cause said piston means to urge said cheek plates and said spacer ring together.

5. In a vane type hydrodynamic machine having a casing provided with a recess and high pressure and low pressure ports communicating with said recess, cheek plates arranged in said recess, a spacer ring arranged between said cheek plates, and a circular rotor arranged within said ring, the combination of an end head attached to said casing for closing said recess and having cylinder means arranged therein around the axis of said rotor, rigid piston means arranged in said cylinder means and engaging the outer cheek plate opposite the space between said rotor and ring, and means for directing liquid from said high pressure port to said cylinder means to cause said piston means to urge said cheek plates and said spacer ring together.

6. In a vane type hydrodynamic machine having a casing provided with a recess and high pressure and low pressure ports communicating with said recess, cheek plates arranged in said recess, a spacer ring arranged between said cheek plates, and a circular rotor arranged within said ring, the combination of an end head attached to said casing for closing said recess and having an annular cylinder arranged therein, a rigid annular piston fitted in said cylinder and engaging the outer cheek plate opposite the space between said rotor and ring, and means for directing pressure liquid to said cylinder to cause said piston to urge said cheek plates and said spacer ring together.

7. In a vane type hydrodynamic machine having a casing provided with a recess and high pressure and low pressure ports communicating with said recess, cheek plates arranged in said recess, a spacer ring arranged between said cheek plates, and a circular rotor arranged within said ring, the combination of an end head attached to said casing for closing said recess and having an annular cylinder arranged therein, a rigid annular piston fitted in said cylinder and engaging the outer cheek plate opposite the space between said rotor and ring, and means for directing liquid from said high pressure port to said cylinder to cause said piston to urge said cheek plates and said spacer ring together.

WALTER FERRIS.