

Aug. 29, 1944.

P. D. BREWSTER

2,356,916

VARIABLE CAPACITY PUMP OR MOTOR

Filed Sept. 11, 1940

2 Sheets-Sheet 1

Fig. 1.

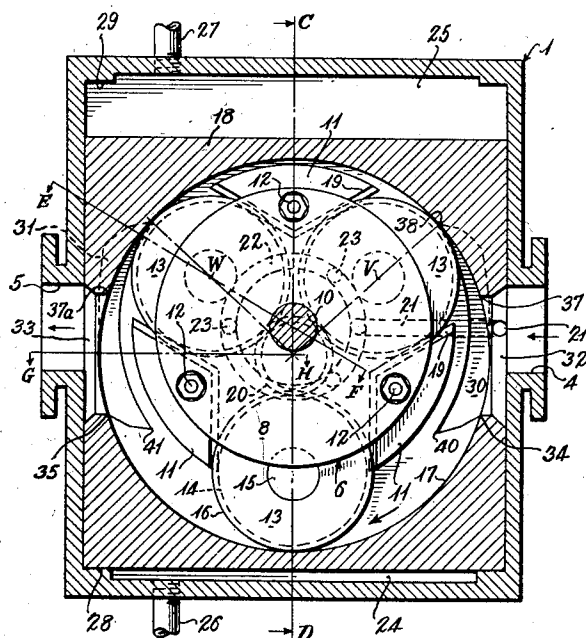


Fig. 2.

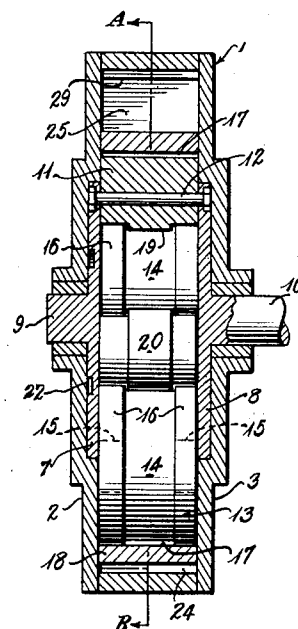


Fig. 4.

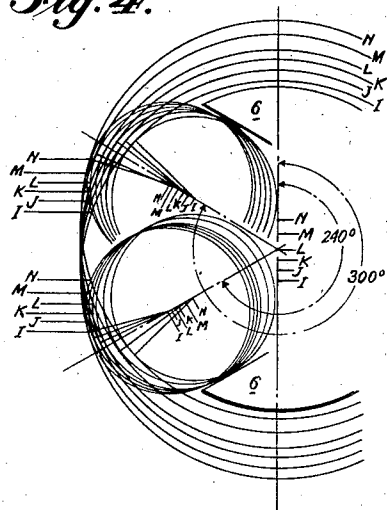
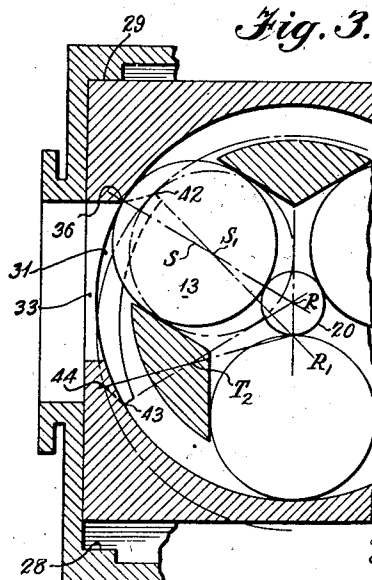


Fig. 3.



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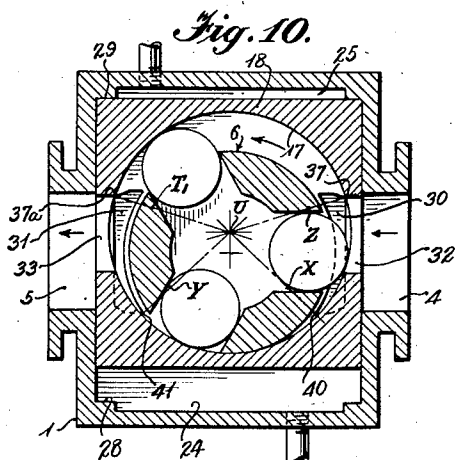
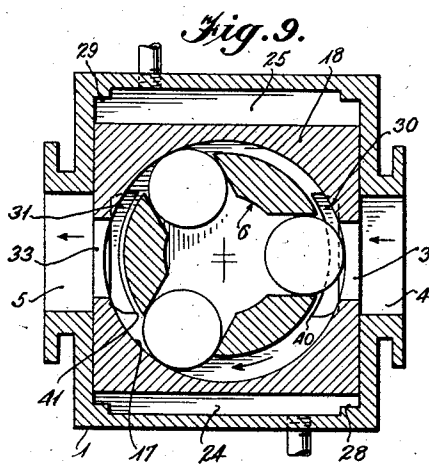
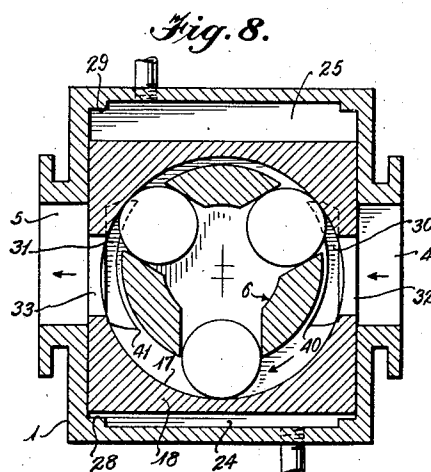
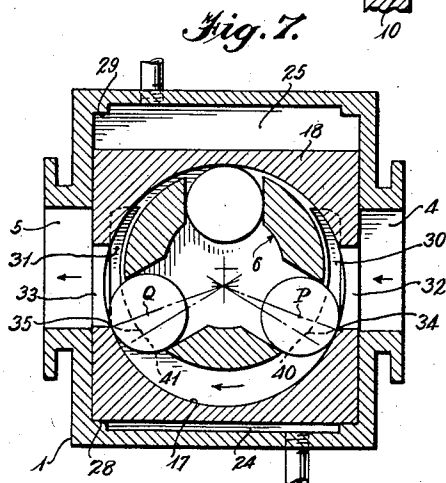
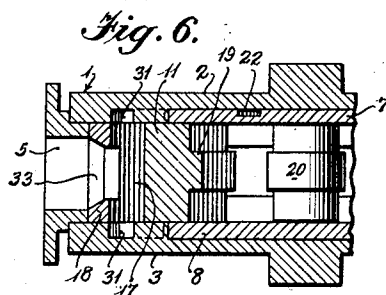
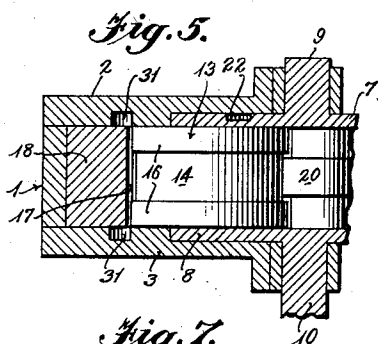
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2 Sheets-Sheet 2



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VARIABLE CAPACITY PUMP OR MOTOR

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4 Claims. (Cl. 103—120)

My invention relates to variable capacity-pressure rotary hydraulic pumps and variable torque-speed hydraulic rotary motors. It is particularly related to the type of pump or motor consisting of a round cylinder in which a rotor revolves which has a plurality of cavities or slots in its periphery containing rollers adapted to maintain contact with the rotor cavities and the cylinder bore.

In my copending patent applications Ser. Nos. 356,248 and 356,249 relating to pumps of the above type, I describe among other things compound rollers of different constructions adapted to maintain substantial contact between the rotor and cylinder. These compound rollers have in common the principle that one part of the roller rolls on the cylinder bore and another part of the roller, adapted to turn freely in relation to first part, rolls on the side of the rotor slots, no part touching both the cylinder and rotor. Improved means were also described in these applications for maintaining the rollers in substantial contact with the cylinder bore. Some of these ideas are shown in the accompanying drawing but are not particularly described herein.

Throughout the specification and claims the term engine is understood to include motors and pumps. The pumps, illustrated herein, have three slots in the periphery of the rotor connected together behind the rollers but it is to be understood that any number of slots or cavities may be used and that they be independent of each other or connected together without departing from my invention.

An object of my invention is to provide a variable capacity hydraulic pump adapted to operate efficiently at high rotative speeds. Another object is to convert the roller type pump into a variable capacity pump. A further object is to provide simple means, operated hydraulically, for controlling the output of the pump. Another object is to provide main inlet and discharge ports in the movable cylinder and auxiliary ports in the fixed cylinder heads. To these and other ends my invention comprises the novel features hereinafter described.

Fig. 1 in the drawings is a section on the center line AB of Fig. 2 with rotor and rollers shown as end elevations; Fig. 2 is a section on CD, Fig. 1; Fig. 3 is a section through a modified pump with rollers shown as side elevations; Fig. 4 is a diagram illustrating method of determining the positions of inlet and discharge ports; Fig. 5 is a section on line EF, Fig. 1; Fig. 6 is a section on line GH, Fig. 1; Figs. 7 to 9 are sections, except

for the rollers, of motors operating clockwise, and Fig. 10 is similar section of a motor reversing.

Figs. 1 and 2 and the diagram Fig. 4 illustrate a motor that without changing the position of its drive shaft or inlet and discharge ports is adapted to operate in either direction as a variable speed-torque motor.

The motor comprises a housing 1 that is practically square with the cylinder heads or end plates 2, 3 on either end. Oil under pressure is admitted to the motor through port 4 in the housing 1 and discharged through port 5. The rotor 6 consists of the two steel headers 7 and 8, Fig. 2, which are formed in one piece with the shafts 9, 10 respectively. Three triangular segments 11, 11, 11 are equally spaced about the periphery of the headers and the three parts are fastened together with bolts 12, 12, 12. The completed rotor contains three slots, formed by the segments, in which the compound rollers 13, 13, 13 are placed. These rollers consist of a roller 14 with two stub shafts 15, 15 at either end upon which the rings 16, 16 are free to revolve. These rings 16 are concentric with, but slightly larger in diameter, than the roller 14 and roll on the bore 17 of the cylinder 18, while the smaller roller 14 rolls on the ridge 19 in the center of the segments 11. The general principle of the compound roller is that one element rolls on the bore of the cylinder while other elements roll on the rotor slot but neither element touches both the rotor and cylinder bore. The rollers 13, 13, 13 are held in substantial contact with bore 17 of the cylinder by means of a "fourth" roller 20 in the center of the rotor that rolls in contact with the rollers 14, 14, 14. Fluid under pressure is preferably fed into the center of the rotor by passage 21 from the inlet port that registers with the annular groove 22 turned on one or both headers and reaches the center through holes 23, 23, 23. A number of constructions of rotors and rollers are described in my copending patent applications Ser. Nos. 356,248 and 356,249.

The motor, as shown in Fig. 1, runs clockwise and develops maximum torque at lowest speed for the rotor is in its nearest position to the top of the cylinder in which it will use the maximum amount of fluid per revolution. The cylinder 17 is bored in a square block 18 preferably of steel, which is fitted to slide in the housing 1. Fluid under pressure is admitted into the spaces 24 and 25 between the housing 1 and block 18 through pipes 26 and 27 respectively to move the block 18, in relation to rotor and housing 1. The rollers

continue to roll on the bore of the cylinder whenever the cylinder is located but take different positions radially in the rotor slots. Fluid admitted presses the roller forward at the bottom of the cylinder by the energy represented by the pressure multiplied by an effective area of one half of the diameter of the roller multiplied by its length, while, at the same time, the roller just entering the inlet port presses in the opposite direction with equal energy but the first roller delivers its pressure at a point on the rotor slot further from the center than the second roller does, so the rotor turns clockwise.

Fig. 7 shows the motor at its maximum torque and lowest speed in clockwise rotation, with the block 18 in contact with the stop 28 on the cylinder block; in Fig. 8 fluid admitted into space 24 has lifted the cylinder block away from the stop 28 and increased the distance between the rotor 6 and the cylinder bore which decreases the amount of fluid used for revolution and decreases the torque but using a fixed amount of fluid per minute increases the speed of the rotor. Fig. 9 illustrates a further movement of the cylinder block and consequently an increase in speed and a decrease in torque. Fig. 3 illustrates a condition when the center of the cylinder and the center of the rotor coincide, and when all the rollers press on the rotor slots at the same distance from the center and the pressure is balanced and the rotor stops. If operating as a pump there will be no discharge under these conditions.

The effect of a further movement of the cylinder block is shown in Fig. 10 in which the block 18 has reached the stop 29 at the top of the housing 1 and the rotor 6 is nearly touching the bottom of the cylinder bore. Under these conditions the motor operates at high torque and low speed in the counterclockwise rotation. The position of the cylinder block in relation to the rotor is controlled by the amount of fluid admitted or discharged from the spaces 24 and 25.

All the fluid may be admitted to the pump, Fig. 1, through passage 30 and discharged through passage 31 (later called by-passes) in the cylinder heads 2 and 3 to serve as a variable pump or to operate as a motor. The method of determining the shapes of these by-passes will be later described. It is desirable for efficiency in high speed pump operation to avoid small passages or abrupt change of direction of the fluid in passing through the pump or the inlet and discharge ports.

An important part of this invention is the provision in variable capacity pump of inlet and discharge ports in the movable cylinder block and fixed inlet and discharge by-passes in one or preferably both of the cylinder heads.

The maximum size of the inlet and discharge ports and position of the by-passes in a variable capacity pump are dependent on the number and size of the rollers, the bore of the cylinder and especially on the amount the capacity of the pump varies as that controls the movement of the cylinder block.

The method for locating these ports and by-passes, in accordance with my invention, is described for a three roller motor that is adapted to vary between full torque clockwise to full torque counter clockwise operation. All angles are based at the center of rotor (which does not change) and 0 degrees is at the point the rotor comes nearest to the cylinder bore when in clockwise operation.

In the case of a three-vane pump, that is a

pump having three rollers, the vanes are spaced equidistantly with respect to the center of the rotor. If lines are drawn through the center of each slot and through the center of each roller, adjacent lines will form angles of 120°. These lines will not necessarily intersect the bore of the cylinder at the point of tangency between the cylinder and each roller except when the eccentricity is reduced to zero.

When the eccentricity is not zero, lines drawn from the center of the cylinder through the center of each roller will not necessarily make angles of 120° with respect to each other; neither will lines drawn from the center of the cylinder to the point of tangency between each roller and the cylinders make such angles. The angles in such cases may be less than 120° and approach a maximum greater than 120° during a half revolution of the rotor, the angles thereafter being reduced until the minimum is reached.

Reference hereafter to the 60°, 120°, 180°, 240°, and 300° positions respectively of the rollers means the position of the roller when the line from the center of the rotor through the center of a roller makes the foregoing angles respectively, measured clockwise from the top of the vertical axis.

With the pump and its parts in the position shown in Fig. 1, a horizontal axis through the center of the rotor in the plane of the drawings will divide the cylinder bore into two unequal parts.

During a half revolution of the rotor a roller would traverse either of said parts of the cylinder. Thus, though the speed of the rotor may be constant, the speed of the rollers would change continuously from a minimum at zero degree position in Fig. 1 to a maximum at 180° position and then become gradually slower until the minimum is then reached at zero position.

For optimum operation of a three-roller vane pump, as shown in Fig. 1, operating in a clockwise direction, the upper right-hand roller should open the intake port with respect to the space between that roller, the cylinder, and the next adjacent roller, in a counter-clockwise direction, at the same instant that the said next roller closes the exhaust port with respect to the same space. These cut-off points should be when the said rollers are in the 60° and 300° positions.

Likewise when the rollers are in the 120° and 240° positions, as shown in Fig. 7, the right-hand roller should cut off the intake port and the left-hand roller open the discharge port at the same instant with respect to the space between the said rollers and the bottom of the cylinder.

The space or volume in Fig. 1 between the 60° and 300° rollers, the top of the cylinder, and the casing heads is at a minimum and gradually increases in volume during a half revolution until it is at a maximum when the rollers are in the 120° and 240° positions, as in Fig. 7.

Since the volume of the said space is continuously changing, it follows that the cut-off of the intake in one side must be simultaneous with the opening of the discharge in the other side, except that a very small lead or lag may be necessary, depending on pump and fluid characteristics. If in Fig. 7 the discharge opened before the intake closed, then the fluid would pass through without effective results. If the opening of the discharge is delayed for even an instant after the closing of the intake, disastrous results will follow when a non-compressible

fluid is involved, depending on whether during that instant the space or volume between the said rollers and the cylinder is increasing or decreasing. If it is decreasing the pump or motor must stop or burst, since the fluid is incompressible. If the space is increasing, a partial vacuum will be created, followed by suction and inefficient displacement of fluid when the port is subsequently opened, or by a hammer or pounding action when the said space or volume is again reduced.

The same is true when the rollers are in the position as shown in Fig. 1.

An important object of this invention is to determine the proper location of the ports for optimum operation.

A further object is to determine such ports for optimum operation in a variable capacity pump, that is, in a pump or motor where the capacity and operating conditions are varied by varying the eccentricity.

In the case of a variable capacity pump, ports 30 and 31 are shown in the casing headers which form the cylinder heads. It will be noticed that a portion of the ports in the cylinder headers is covered by the cylinder and that this portion varies and changes as the relative position of the cylinder is changed. The intake and exhaust passages 30 and 31 in the casing headers are so located that they compensate for shifting position of cut-off so that at varying points of adjustment—that is, at varying amounts of eccentricity—the cut-off and opening points of the ports will always be proper for the optimum operation as heretofore explained.

The method of defining the said passages in the casing headers is hereafter fully explained with respect to Fig. 4. The method may be more easily understood if it is realized that with the rotor in any position as in Fig. 1, the point of tangency between the upper rollers and the cylinders changes as the eccentricity is varied by raising the cylinder, and the ports must be so defined that its point of cut-off will be at the new and changing points of tangency at all points within the limits of the movement of the cylinder.

The cut-off points are shown at 38 and 39, which correspond to 40 and 41 when the cylinder is moved to the opposite limit by raising. If the rotor is turned 180° in Fig. 1 to the position in Fig. 7, the points of opening and cut-off will be 34, 35. Thus the line 34, 40 and 35, 41 and corresponding lines at the tops of the ports are the paths taken by the points of tangency between the rollers in the 60°, 120°, 240°, and 300° positions, and the cylinder, as the cylinder is moved from maximum eccentricity displacement in one direction as in Fig. 1, to a maximum eccentricity displacement in the opposite direction as in Fig. 10.

The ports 30 and 31 in the cylinder casing headers may be sufficient, but additional ports may be used and are shown at 32 and 33 through the cylinder and casing.

The inlet port 32 and discharge port 33 are located in the center of the cylinder block 18 on either side of the rotor and register with the inlet port 4 and discharge port 5 in the housing 1. The ports 32 and 33 are preferably located in the center of the cylinder block leaving an unbroken annular ring around the cylinder on either side on which the discs, 15, 15 may roll.

The maximum size of the ports 32 and 33 is determined by locating the bottom of the ports when the rotor is at full torque, clockwise rota-

tion, as in Fig. 7. The bottom of the ports is at the point of contact 34 and 35 of rollers at the 120 and 240 degrees positions respectively with the cylinder bore. The exact point may be determined by lines drawn from the center of the cylinder through P and Q (the centers of the rollers) respectively. The outside of the bottoms of the by-passes 30 and 31 are also fixed at points 34 and 35 respectively.

The tops of the ports 32 and 33 are determined when the motor is at full torque counter clockwise operation, as in Fig. 10. The centers of 60 and 300 degree rollers are indicated at Z and T₁ respectively. Lines drawn from the center U through Z and T₁ intersect the bore at 37 and 37a respectively which represent the tops of the ports 32 and 33 and outside point of the top of the by-passes 30 and 31.

The inside of the bottom of the by-passes 30 and 31 are also determined from Fig. 10. The points X and Y represent the centers of rollers at 120 and 240 degrees. Lines drawn from the center of the cylinder U through X and Y intersect the cylinder bore at 40 and 41 respectively which are the inside bottom limits of the by-passes 30 and 31.

The inside of the top of the by-passes are located from the full torque clockwise motor position, as shown in Fig. 1. V and W represent the center of rollers at 60 and 300 degrees and lines drawn from the cylinder center H through V and W intersect the cylinder at 38 and 39 respectively which are the inside top limits of the by-passes 30 and 31.

As shown in the drawings, the by-passes 30 and 31 are connected to inlet and discharge ports 4 and 5 through the cylinder ports 32 and 33 respectively but they may be connected directly through the cylinder heads with the source of fluid under pressure.

It is apparent that the cylinder ports 32 and 33 are always fully open irrespective of the position of the cylinder block but the by-passes are partly covered by the movement of the cylinder block, for example in Fig. 1 the top of the by-passes are closed by the cylinder. The cylinder ports 32 and 33, while they probably supply a major portion of the fluid to the pump could not operate the variable motor alone. Again referring to Fig. 1 it is apparent that there has been a minor amount of fluid discharged through by-pass 31 from in front of the 300 degree roller after this roller passed the top 37a of the discharge port 33. The movement of the cylinder block in the housing uncovers the top and bottom of the by-passes to admit fluid to an expanding area (formed by two rollers, the rotor and cylinder bore) and to receive fluid from a contracting area.

The shape of the top and bottom of by-passes 30 and 31 are shown in Fig. 4 which is a diagram of a half of motor showing the relationship of the position of the main cylinder discharge port and the upper and lower ends of discharge by-passes at six different positions of the cylinder in relation the rotor. The "full torque" clockwise rotation of the pump as shown in Figs. 1 and 7, is represented by letter "I," the position of the cylinder bore is shown by "I," the position of discharge port in the cylinder is indicated by the space between I—I, the positions of the upper and lower ends of by-passes are determined respectively by the intersection of lines from point "I," on the 240 and 300 degree lines from rotor center, with the cylinder bore "I."

The second position of the cylinder, as shown in Fig. 8, which develops reduced torque with clockwise rotation is represented by letter "J" and position of discharge port by the space J—J, and so forth.

The third position of the cylinder, as shown in Fig. 9 develops less torque still with clockwise rotation is represented by letter "K" with the positions of ports and by-passes determined as above.

Fourth position of the cylinder with its center and center of rotor coinciding, as illustrated in Fig. 3, shows the rotor on "dead center" and stationary. Position of ports and by-passes are represented by "L." The lines from L to its cylinder bore coincide with 240 and 300 degree lines.

Fifth position of the cylinder is represented by "M" with the center of the cylinder above the center of the rotor and motor operating counterclockwise under reduced torque. Position of ports are determined in the same manner.

Sixth position of the cylinder, as shown in Fig. 10, represents the motor at "full torque" in counterclockwise operation and is represented by letter "N." Position of ports and by-passes are determined in the same manner.

Any number of positions of the cylinder in relation to the rotor may be used to plot the points of contacts between the cylinder bore and the rollers at 60, 120, 240 and 300 degrees from the rotor center, lines drawn through these points determine shape of top and bottom of by-passes in the cylinder heads. The line of the top and bottom of the recesses curves slightly down to the common center position L when the angle changes materially for the reverse positions.

Fig. 3 illustrates a pump or motor that does not reverse but is adapted to vary between full torque as a motor or high pressure as a pump to a "dead center" position in which a motor would stop and a pump discharges no fluid. The upper end of cylinder discharge port 33 and the outside of the top of the by-pass 31 are located when the rotor is at the "dead center" position in which the centers of both the rotor and the cylinder coincide at R, by a line RS (S is center of a roller 13 at the 300 degree position) to the cylinder at 36, while the line R₁S₁ from the center of the rotor at full torque clockwise rotation through the center of the 300 degree roller 13 to 42 at inside of the top of the by-pass determines the top of the discharge by-pass 31. The inside of the bottom of the recess 31 is located by line RT₂ from common center at dead center through the center T₂ of a roller at the 240 degree position to point 43. The position of bottom of cylinder port 33 and the outside of the bottom of by-pass 31 are determined with the cylinder and roller (thin line in drawings) in the position for full torque clockwise rotation. A line drawn through R₁ the cylinder center, and T₂ the center of a 240 degree roller locate the bottom of the cylinder discharge port 33 and the outside of the bottom of the by-pass 31 at 44. The rollers are held against the cylinder bore by center roller 20 when rolls on the roller 14 which contacts the rotor slots. Fluid under pressure is led into the center of the rotor from inlet port 4 in case of a motor or discharge port 5 in case of a pump through passage 21, Fig. 1, through the cylinder head and into the ring groove 22 on the outside of the rotor header 8 and through holes 23, 23 into the center of the rotor.

In place of admitting fluid under pressure to

either side of the cylinder block in order to vary the position of the cylinder, I may use any mechanical means, such as screws, springs, etc., known to this art without departing from my invention.

While the form of apparatus herein described constitutes a preferred embodiment of my invention, it is to be understood that the invention is not limited to this precise form of apparatus, and that changes may be made therein without departing from the scope of the invention which is defined in the appended claims.

What is claimed is:

1. A variable capacity pump for non compressible fluids comprising a casing having heads on both ends, inlet and discharge ports in opposite sides of the casing, a movable block fitting between the sides of the casing which contain the said ports, a cylinder bored in the said block, a rotor journaled in at least one of the heads and adapted to revolve in the cylinder, a plurality of slots in the periphery of the rotor, a roller in each of the said slots, means for moving the cylinder block in relation to the rotor for varying the capacity of the pump, fixed inlet and discharge ports in the cylinder block connecting respectively with said inlet and discharge ports in the casing to admit and receive the major part of the fluid from the pump, and inlet and discharge passages in at least one head which, in conjunction with the position of the cylinder block, admit fluid from the inlet port in the cylinder block to all expanding areas within the pump while expanding, and allow fluid to escape through the discharge port in the cylinder block from all contracting areas while contracting.

2. In a hydraulic machine, a block having a cylinder therein movably supported in a casing provided with end plates, a rotor having a plurality of movable roller vanes therein and journaled to rotate eccentrically within said cylinder to form a plurality of variable capacity chambers within said cylinder during rotation, means to move the cylinder to vary the eccentric relation between the rotor and the cylinder, inlet ports in said cylinder and casing to admit fluid to said chambers, discharge ports in said cylinder and casing to discharge fluid from said chambers, auxiliary inlet and discharge passages in at least one of said end plates controlled by the movement of said cylinder block and adapted to permit passage of fluid from the inlet port in said cylinder to said chambers while expanding and to permit discharge of fluid through the discharge port in said cylinder while contracting.

3. A variable capacity pump for non-compressible fluids comprising a casing having heads on both ends and inlet and discharge ports in the opposite sides of the casing, a movable block fitting between the sides of the casing which contain the said ports, a cylinder bored in the said block, inlet and discharge ports in opposite sides of said cylinder in partial registry respectively with the inlet and discharge ports in said casing, a rotor journaled in at least one of the heads adapted to revolve in the cylinder, a plurality of spots in the periphery of the rotor, a roller in each of the said slots adapted to roll on the cylinder bore, means for holding the rollers against the cylinder bore, means for moving the cylinder block in relation to the rotor to vary the capacity of the pump, and inlet and discharge passages located in at least one of said heads and adapted to admit fluid from the cylinder inlet port to all expanding spaces within the pump while expand-

ing and to allow fluid to escape through the cylinder discharge port from all contracting spaces within the pump while contracting.

4. A variable capacity pump for non-compressible fluids comprising a casing having heads on both ends, inlet and discharge ports in the opposite sides of the casing, a movable block fitting between the sides of the casing which contain the said ports, a cylinder bored in the said block, inlet and discharge ports in opposite sides of said cylinder in partial registry respectively with the inlet and discharge ports in said casing, a rotor journaled in at least one of the heads adapted to revolve in the cylinder, a plurality

of slots in the periphery of the rotor, a roller in each of said slots adapted to roll on the cylinder bore, means for holding the rollers against the cylinder bore, means for moving the cylinder block in relation to the rotor to vary the capacity of the pump, and inlet and discharge passages in at least one head which, in conjunction with the position of the cylinder block, admit fluid from the cylinder inlet port to all expanding spaces within the pump while expanding and allow fluid to escape from the cylinder discharge port from all contracting spaces within the pump while contracting.

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