

June 9, 1953

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2,641,195

SLIDING VANE TYPE HYDRODYNAMIC MACHINE

Filed Nov. 28, 1947

4 Sheets-Sheet 1

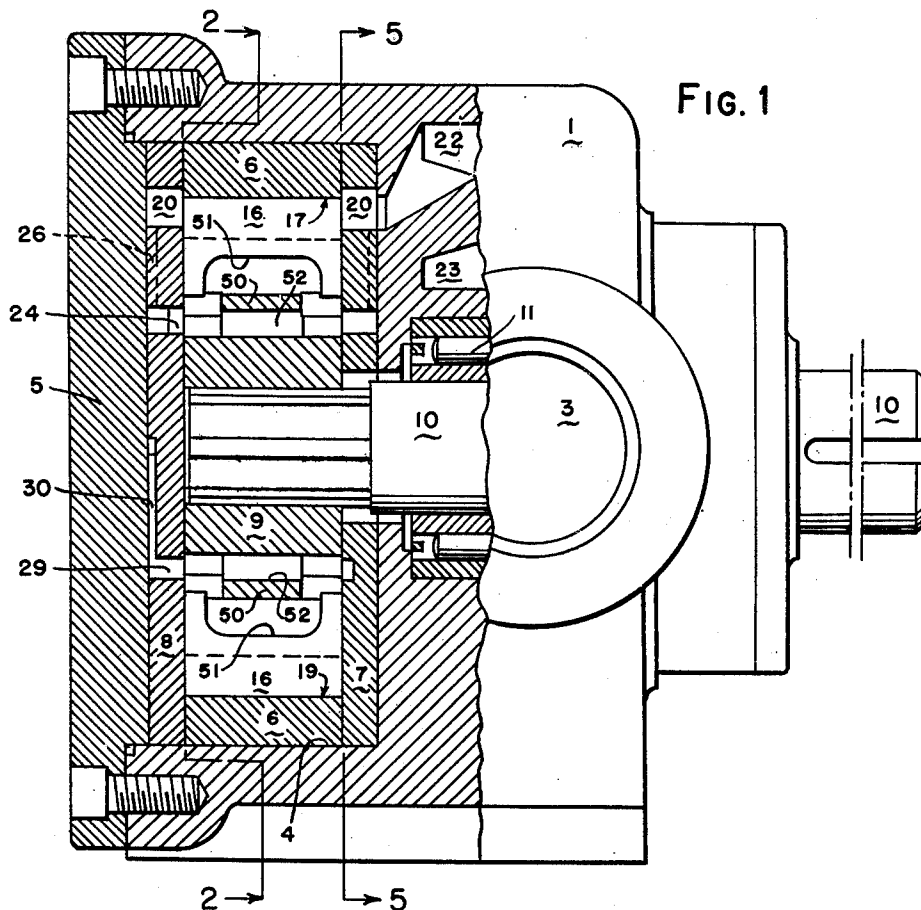


FIG. 4

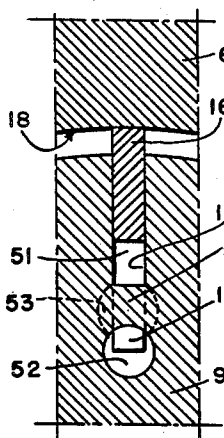
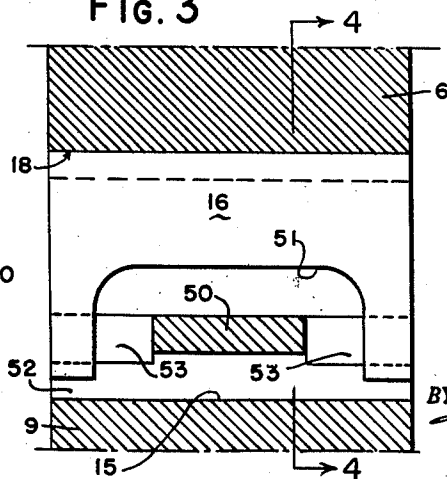


FIG. 3



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FIG. 2

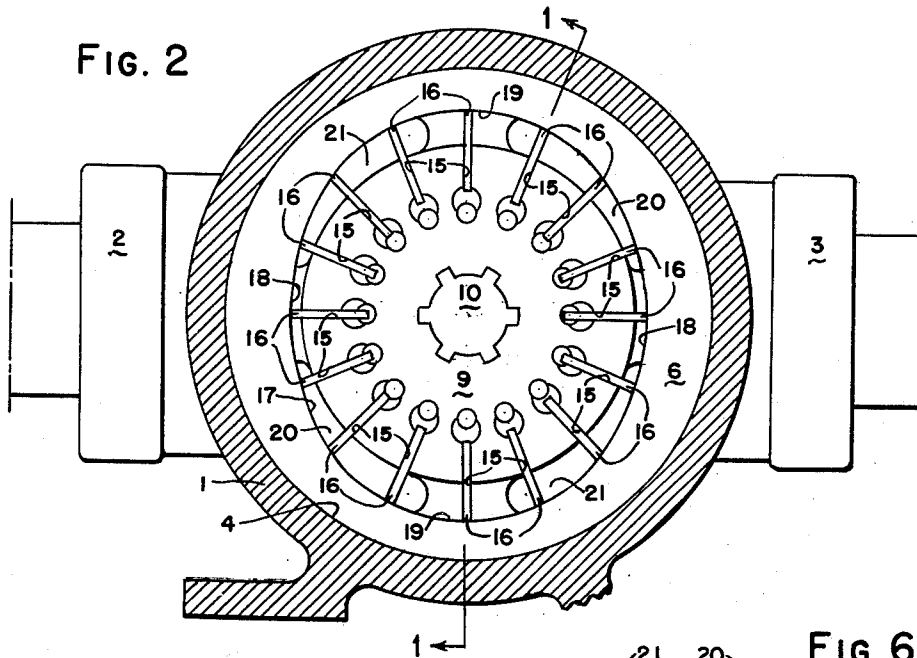


FIG. 6

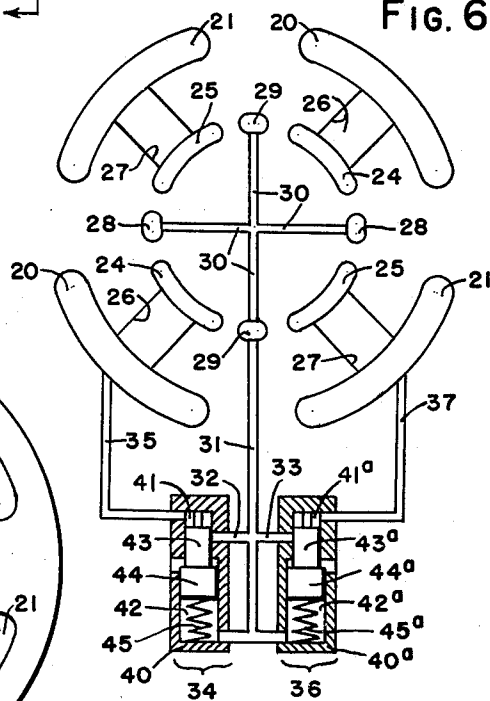
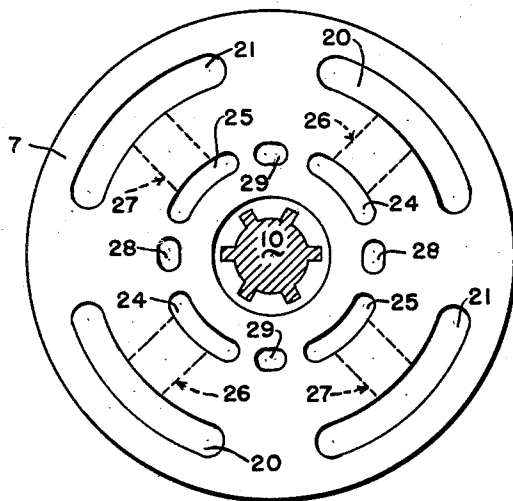


FIG. 5



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FIG. 8

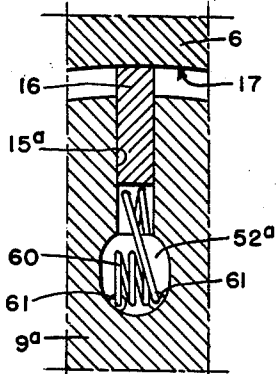


FIG. 7

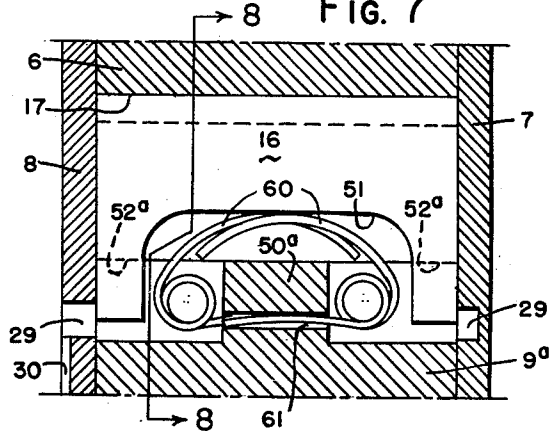


FIG. 14

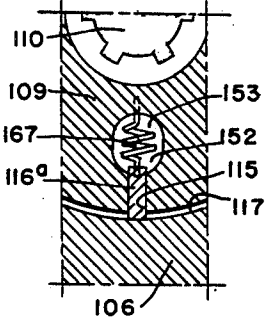


FIG. 13

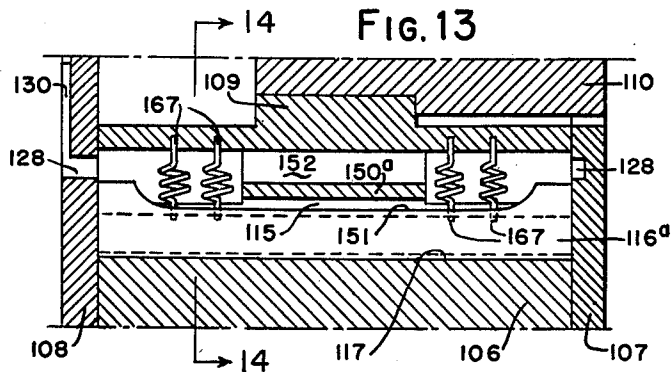


FIG. 16

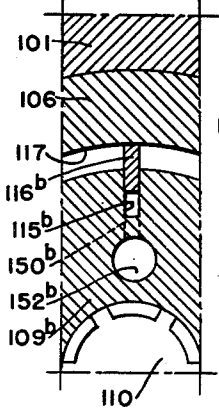
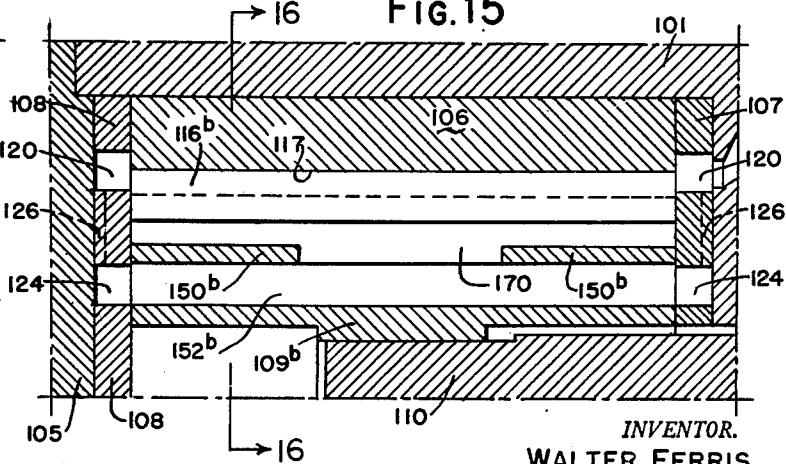


FIG. 15



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2,641,195

SLIDING VANE TYPE HYDRODYNAMIC MACHINE

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Application November 28, 1947, Serial No. 788,453

12 Claims. (Cl. 103—136)

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This invention relates to hydrodynamic machines of the sliding vane type. Such a machine includes a rotor which is enclosed in a chamber having inlet and outlet ports for the flow of liquid to and from the rotor, a plurality of vanes which are slidable in slots extending radially inward from the periphery of the rotor, and an endless vane track which extends around the rotor to engage the outer ends of the vanes.

In order that the machine may be hydrostatically balanced, it ordinarily is provided with two diametrically opposed inlet ports and with two outlet ports which are spaced ninety degrees from the inlet ports, the vane track is provided with two diametrically opposed sealing arcs and with two working arcs which are spaced ninety degrees from the sealing arcs, and each of the arcs is arranged between the adjacent ends of an inlet port and an outlet port.

The vane track may be stationary, in which case the displacement of the machine is constant, or it may be adjustable to vary the displacement of the machine. If the vane track is stationary, or if it is adjustable and the machine is adjusted to perform useful work, the sealing arcs are arranged close to the periphery of the rotor and the working arcs are spaced farther from the periphery of the rotor so that the vanes are caused to move inward and outward of the rotor as the outer ends thereof ride upon the vane track during rotation of the rotor.

The vanes in contact with the sealing and working arcs cooperate therewith to form seals between adjacent ports. If the rotor is rotated, the vanes will transfer liquid from the inlet ports to the outlet ports as they pass across the working arcs. If liquid under pressure is supplied to the inlet ports, it will act upon the vanes in contact with the working arcs and cause the rotor to rotate. The machine will thus function either as a pump or as a motor.

Each of the sealing and working arcs must be at least as long as the angular distance between the outer ends of two adjacent vanes in order that at least one vane may at all times be in contact with each of the arcs. However, the sealing and working arcs should not be any longer than necessary for the reason that, if they were too long and the sealing arcs were spaced far enough from the rotor to provide a satisfactory rate of liquid delivery when the machine is functioning as a pump or to provide a satisfactory torque when the machine is functioning as a motor, the vane track between bridges would have so steep a pitch that the vanes would tend to abrade it when passing from a working arc

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to a sealing arc and might not stay in contact with it when passing from a sealing arc to a working arc.

Limiting the length of each sealing and working arc thus necessarily limits the angular distance between the outer ends of adjacent vanes. Since the vane slots extend radially inward from the periphery of the rotor, they divide the outer portion of the rotor into segments and the cross-sectional area of each segment at its inner end is necessarily small.

When the machine is performing useful work, the portion of each vane extending beyond the periphery of the rotor is subjected upon one side thereof to the pressure of the working liquid and upon the other side thereof to a low or zero pressure each time the vane passes across a working arc regardless of whether the machine is functioning as a pump or as a motor.

The force exerted by the liquid on the high pressure side of a vane in contact with a working arc tends to cause the segment on the low pressure side of that vane to be deflected toward the adjacent vane and, due to the limited cross-sectional area of the segment at its inner end, a pressure of sufficient magnitude will cause that segment to be deflected enough to cause it to pinch the adjacent vane in its slot and thereby momentarily prevent further movement of the pinched vane if it is moving outward or momentarily add considerable resistance to the movement of the pinched vane if it is being forced inward by the vane track.

The present invention has as an object to provide the rotor of a vane type machine with means for preventing the vanes from being pinched in the vane slots.

Another object is to provide a vane type hydrodynamic machine in which the vanes are at all times positively maintained in contact with the vane track.

Another object is to provide a hydrodynamic machine of the sliding vane type which is capable of operating at high pressures.

These and 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 one of its aspects, the rotor of a vane type hydrodynamic machine has a separator arranged in each of its vane slots to prevent deflections of the rotor segments between the vane slots.

According to the invention in another aspect, the vanes are urged outward against the vane

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track by fluid pressure, by springs, or by both acting upon the inner edges thereof.

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

Fig. 1 is in part an elevation and in part a longitudinal sectional view of a hydrodynamic machine in which the invention is embodied, the sectional view being taken along the irregular line 1—1 of Fig. 2.

Fig. 2 is a transverse section drawn to a smaller scale and taken across one end of the rotor as indicated by the irregular line 2—2 of Fig. 1.

Fig. 3 is a fragmentary sectional view showing one of the vanes near its innermost position, the view being taken approximately at right angles to Fig. 1 but drawn to a larger scale.

Fig. 4 is a sectional view taken on the line 4—4 of Fig. 3.

Fig. 5 is a face view of one of the two cheek plates which are arranged upon opposite ends of the rotor, the view being taken in the plane indicated by the line 5—5 of Fig. 1.

Fig. 6 is a hydraulic circuit diagram illustrating how different pressures are maintained on the inner ends of each vane during different parts of a revolution of the rotor.

Fig. 7 is a sectional view somewhat similar to Fig. 3 but showing springs for urging the vane against the vane track.

Fig. 8 is a section taken on the irregular line 8—8 of Fig. 7.

Figs. 9 and 10 are similar, respectively, to the upper and lower halves of Fig. 1 but illustrate machines having longer rotors and springs for urging the vanes against the vane track.

Fig. 11 is a fragmentary sectional view showing one of the vanes of Fig. 9 near its innermost position, the view being taken approximately at right angles to Fig. 9.

Fig. 12 is a transverse section taken on the irregular line 12—12 of Fig. 11.

Fig. 13 is a fragmentary sectional view showing one of the vanes of Fig. 10 near its innermost position, the view being taken approximately at right angles to Fig. 10.

Fig. 14 is a transverse section on the line 14—14 of Fig. 13.

Fig. 15 is a view similar to a portion of Fig. 9 but showing the rotor provided with separators which extend inward from the ends of the rotor.

Fig. 16 is a transverse section on the line 16—16 of Fig. 15.

Figures 1-6

The machine shown in these figures is of the general type shown in Patent No. 2,335,567 to which reference may be had for details of construction. Such a machine will function as a pump when it is driven mechanically and it will function as a motor when supplied with liquid under pressure. In order to simplify the description, the machine has been shown as being of the constant displacement type and it will be described as being a motor but it is to be understood that the invention is equally applicable to both pumps and motors and to both constant and variable displacement machines.

As shown, the motor has its mechanism arranged within a casing 1 having two connections 2 and 3 by means of which the motor may be connected into a hydraulic circuit and which may function interchangeably as the inlet and outlet of the machine.

Casing 1 has a circular chamber 4 formed therein and closed by a removable end head 5.

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Chamber 4 has a spacer ring 6 fitted therein between two cheek plates 7 and 8 which engage the inner wall of chamber 4 and the inner face of head 5 respectively. Spacer ring 6 and cheek plates 7 and 8 enclose a cylindrical rotor 9 which is fixed for rotation with a shaft 10 and is just enough shorter than spacer ring 6 to permit it to rotate freely between cheek plates 7 and 8 and at the same time maintain substantially liquid tight seals between its opposite ends and the cheek plates. Shaft 10 extends outward through casing 1 for connection to a source of power or to a device to be driven and it is rotatably supported by suitable bearings, one bearing being shown at 11.

Rotor 9 has a plurality of vane slots 15 extending inward from its periphery and a vane 16 slidably fitted in each slot. The outer ends of vanes 16 engage an endless vane track 17 which in the present instance has been shown as being formed upon the inner periphery of spacer ring 6 but which may be a separate structure and be adjustable in any suitable manner to vary the displacement of the machine such, for example, as shown in Patent No. 2,385,069.

In the embodiment shown, vane track 17 is approximately elliptical and includes diametrically opposed arcs 13 in the region of its least diameter and two diametrically opposed arcs 18 in the region of its greatest diameter. Arcs 18 are preferably but not necessarily concentric with rotor 9 and are designated herein as "sealing arcs." Arcs 19 are designated herein as "working arcs" and preferably are nearly but not quite concentric with rotor 9 so that the portions of vane track 17 intermediate arcs 18 and 19 may be given a curvature which will produce satisfactory rates of inward and outward movements of vanes 16 as rotor 9 rotates. The length of each of arcs 18 and 19 is at least as great as the angular distance between the outer ends of two adjacent vanes 16.

In order that the hydraulic forces acting upon rotor 9 in radial directions may be balanced, the space between vane track 17 and the periphery of rotor 9 is divided into two equal and diametrically opposed fluid sections by the vanes 16 in contact with sealing arcs 18, and each fluid section is divided into an inlet area and an outlet area by the vane or vanes in contact with a working arc 19. Motive liquid is admitted between the outer ends of the vanes as they pass through the inlet areas, and this motive liquid acts upon the vanes in contact with the working arcs 19 and effects rotation of rotor 9. If the machine were to operate as a pump, rotor 9 would be rotated mechanically and the vanes would transfer liquid from the inlet areas to the outlet areas as they passed across working arcs 19.

Cheek plate 7 has two diametrically opposed ports 20 and two diametrically opposed ports 21 formed therein adjacent the periphery of rotor 9. Each port 20 extends from a point near one end of an arc 19 to a point near the adjacent end of an arc 18 and each port 21 extends from a point near the other end of arc 19 to a point near the adjacent end of the other arc 18. Both ports 20 communicate with an arcuate passage 22 which is formed in casing 1 and communicates with connection 2 through a passage not shown. Both ports 21 communicate with an arcuate passage 23 which is formed in casing 1 and communicates with connection 3 through a passage not shown.

Ports 20 and 21 may function interchangeably

as inlet and outlet ports and the space between vane track 17 and rotor 9 adjacent each port may be designated an "inlet area" if that port is functioning as an inlet port or designated an "outlet area" if that port is functioning as an outlet port. Cheek plate 8 is also provided with two ports 20 and two ports 21 each of which is in axial alignment with the corresponding port in cheek plate 7 so that hydraulic forces acting upon rotor 9 in an axial direction are balanced.

As vanes 16 move inward and outward in slots 15 during rotation of rotor 9, liquid will flow into each vane slot as the vane therein moves outward and liquid will be expelled from each vane slot as the vane therein moves inward.

In order to provide for this flow of liquid to and from the vane slots and also to hydrostatically balance the vanes as the outer ends thereof pass through the inlet and outlet areas, each of cheek plates 7 and 8 has two arcuate grooves or vane slot ports 24 and two arcuate grooves or vane slot ports 25 formed in its inner face upon a radius equal to the radius of the inner ends of vane slots 15 so that vane slots 15 will register successively with the vane slot ports as rotor 9 rotates. Each vane slot port 24 is radially inward from a port 20 and is connected thereto by a groove 26 formed in the outer face of the cheek plate. Each vane slot port 25 is radially inward from a port 21 and is connected thereto by a groove 27 formed in the outer face of the cheek plate.

The arrangement is such that both the inner and outer ends of the vanes are subjected to the same pressure when the outer ends of the vanes are moving through the inlet areas and when the outer ends of the vanes are moving through the outlet areas so that the vanes may be kept in contact with the vane track by application of a relatively small radial force.

In order that the vanes whose outer ends are in contact with arcs 18 and 19 may have their inner ends subjected to pressure, each of cheek plates 7 and 8 has formed in the inner face thereof two vane slot ports 28, each of which is radially inward from a sealing arc 18 and is midway between the adjacent ports 24 and 25, and two vane slot ports 29 each of which is radially inward from a working arc 19 and is midway between the adjacent ports 24 and 25.

Ports 28 and 29 are supplied with liquid from a port 20 or a port 21 whichever is a high pressure port. As shown in Fig. 6, all four of the ports 28 and 29 in cheek plate 8 communicate with a groove 30 which is formed in the outer face of cheek plate 8 and communicates with a channel 31 having two branches 32 and 33 which are connected, respectively, through a valve 34 and a channel 35 to a port 20 and through a valve 36 and a channel 37 to a port 21.

Valves 34 and 36 may be ordinary check valves, in which case the pressure in ports 28 and 29 is the same as in high pressure port 20 or 21, but valves 34 and 36 preferably are pressure reducing valves for the reason that a vane in contact with a sealing arc or a working arc has high pressure on one side thereof and a low pressure on the other side thereof so that the pressure on the outer end of the vane decreases from a high pressure at one edge thereof to a low pressure at the other edge thereof and the average pressure on the outer end of the vane is less than the working pressure. It is therefore desirable that the vanes in contact with the sealing and working arcs have the inner ends there-

of subjected to a pressure which is somewhat less than the working pressure. This may be accomplished by valves 34 and 36 which will reduce the pressure in ports 28 and 29 a predetermined amount below the working pressure.

As shown, valve 34 includes a casing 40 having a bore 41 and a counterbore 42 formed therein, a valve 43 fitted in bore 41, a piston 44 fitted in counterbore 42 and ordinarily formed integral with valve 43, and a light spring 45 arranged between piston 44 and the end wall of counterbore 42 to normally hold valve 43 in its closed position and having only a little more strength than is necessary to overcome the friction and inertia of valve 43 and piston 44. Bore 41 has channel 35 connected thereto adjacent the end thereof, it has branch 32 of channel 31 connected thereto at such a distance from its end that valve 43 blocks the end of branch 32 when valve 43 is in its closed position, and counterbore 42 has channel 31 connected thereto adjacent the end thereof.

Since valve 36 is exactly the same as valve 34 except that it has channel 37 and branch 33 connected thereto instead of channel 35 and branch 32, a description of one will suffice for both as corresponding parts have been designated by corresponding reference numerals with the exponent "a" added to the reference numerals applied to valve 36.

The arrangement is such that, when pressure increases in port 20, pressure will extend therefrom through channel 35 to bore 41 and shift valve 43 against the resistance of spring 45. As soon as valve 43 starts to uncover the end of branch 32 of channel 31, pressure will extend through channel 31 to ports 28 and 29 and also to the counterbores 42 and 42^a. The pressure in counterbore 42 will act upon piston 44 and tend to close valve 43 and the pressure in counterbore 42^a will act upon piston 44^a and cause it to assist spring 45^a in holding the valve 43^a closed.

Valve 43 and piston 44 are so proportioned that, when port 20 is the high pressure port, valve 34 maintains in ports 28 and 29 a pressure equal to a given percentage of the pressure in port 20. For example, if it is desired that the pressure in ports 28 and 29 be twenty per cent less than the working pressure, valve 43 and piston 44 are so proportioned that the force exerted upon valve 43 by the working liquid will be balanced by the forces exerted on piston 44 when the pressure in counterbore 42 is eighty per cent of the working pressure. Therefore, an increase in the working pressure or a decrease in the pressure in counterbore 42 will cause valve 43 to open and a decrease in working pressure or an increase in the pressure in counterbore 42 will cause valve 43 to close so that the pressure in counterbore 42 and in ports 28 and 29 is maintained at substantially eighty per cent of the working pressure.

When port 21 becomes the high pressure port, valve 36 opens to admit pressure to ports 28 and 29 and counterbores 42 and 42^a, the pressure in counterbore 42 assisting spring 45 in holding valve 43 closed. Thereafter, the pressure in ports 28 and 29 is maintained at a given percentage, such as eighty per cent, of the working pressure by valve 36 which operates in the same manner that valve 34 operates when port 20 is the high pressure port.

When a hydrodynamic machine of the sliding vane type is performing useful work either as a

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pump or as a motor; the portion of each vane extending beyond the periphery of the rotor has one side thereof exposed to high pressure liquid and the other side thereof exposed to liquid at a low or zero pressure each time the vane passes across a working arc. The force exerted by the high pressure liquid upon the vane reacts upon the walls of its vane slot and tends to move them away from each other.

Since the vane slots extend radially inward from the periphery of the rotor, they divide the outer portion of the rotor into a plurality of segments. If the vanes are spaced close enough together to obtain the desired operating characteristics, the inner ends of the segments are so narrow that, if each segment were connected to the adjacent segments and to the inner portion of the rotor solely at its inner end as in the prior machines, it would not have sufficient rigidity to prevent it from being deflected by a large force applied to the outer portion of the adjacent vane. Under such circumstances, the force applied by liquid at a very high pressure to the outer portion of a vane in contact with a working arc would cause the segment at the low pressure side of that vane to be deflected and to pinch the adjacent vane in its slot, thereby momentarily preventing further movement of the pinched vane if it were moving outward or momentarily adding considerable resistance to the movement of the pinched vane if it were being forced inward by the vane track.

The present invention prevents the vanes from being pinched in their slots and thereby permits the vanes to follow the vane track when moving outward and avoids abrasion of the vane track and/or the ends of the vanes when the vanes are being forced inward by the vane track. This is accomplished by providing in each vane slot 15 a separator or web 50 which prevents the adjacent segments of rotor 9 from being deflected when the adjacent vanes have the exposed portions thereof subjected to high pressure. As shown, a separator 50 is arranged in each slot 15 and the vane 16 in each slot is provided with a notch or recess 51 to accommodate the separator in that slot.

As best shown in Figs. 3 and 4, separator 50 is spaced radially outward from the inner end of slot 15 and has its ends spaced inward from opposite ends of rotor 9. Vane 16 is full width at its ends but it is reduced in width intermediate its ends by recess 51 which extends radially outward from the inner edge of vane 16 and is longer than separator 50 so that vane 16 may move inward and outward without interference.

The vane slots in the rotor of a vane type machine ordinarily are of such depth that the inner end of each slot is spaced only a very short distance from the inner edge of the vane therein when that vane is in its innermost position for the reason that extending the slots farther inward would weaken the rotor. If each vane slot were of uniform width, liquid could not flow into and out of the inner end of the vane slot fast enough to maintain the proper pressures upon the inner edge of the vane throughout its entire length as the vane approached and receded from its innermost position. Therefore, the inner end portion of each vane slot ordinarily is formed by a bore, such as the bore 52 shown in Figs. 3 and 4, which extends completely through the rotor and should have a diameter enough greater than the width of the vane to

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provide unrestricted flow of liquid along the entire length of the inner edge of the vane.

Each vane slot may be provided with a separator which may be made as an individual element and then fastened in the vane slot outward from bore 52 but preferably the separators are formed integral with the rotor.

As shown in Figs. 3 and 4, separator 50 forms the outer wall of bore 52. The vane slot may be formed by drilling bore 52 through rotor 9, milling a slot radially inward from the periphery of rotor 9 to the radially outward edge of separator 50 and cutting away the end portions of separator 50 to provide spaces for the end portions of vane 16. The end portions of separator 50 may be cut away in any suitable manner such as by milling or by forming in opposite ends of rotor 9 two bores 53 each of which extends inward a predetermined distance and intersects bore 52 and the milled slot.

Vane slot ports 24 and 25 in both of cheek plates 7 and 8 have been shown connected to the main ports 20 and 21 which are radially outward therefrom so that liquid may flow through both cheek plates to and from the inner ends of vane slots 15 but it is not necessary that liquid flow through both cheek plates as the inner ends of vane slots 15 are of such width that liquid may flow through the vane slot ports in only one cheek plate to and from the inner ends of the vane slots and maintain therein and in the opposed vane slot ports in the other cheek plate the same pressures that prevail in the vane slot ports through which the liquid flows.

When the machine shown in Figs. 1-6 is functioning as a pump and is being driven at the speed at which pumps are ordinarily driven, the vanes will be held against the vane track by centrifugal force for the reason that the vanes are hydrostatically balanced as the outer ends thereof pass from one to the other of the sealing and working arcs but if the machine is to be driven at low speed when functioning as a pump or if the machine is to function as a motor, means must be provided to hold the vanes in contact with the vane track.

The vanes may be held in contact with the vane track by eliminating the grooves 26 and 27 in cheek plates 7 and 8 and supplying liquid to each of vane slot ports 24 and 25 at a pressure which is higher than the pressure prevailing in the main port 20 or 21 which is radially outward from that vane slot port so that the inner end of each vane is exposed to a pressure which is higher than the pressure to which the outer end of that vane is exposed. This may be accomplished in any suitable or well known manner such, for example, as shown in Patents 2,312,891 and 2,335,567.

Instead of the vanes being held in contact with the vane track by hydraulic pressure, they may be hydrostatically balanced as explained above and held in contact with the vane track by suitable springs such as shown in Figs. 7-14. For example, springs similar to the springs shown in Figs. 9, 11 and 12 but with shorter legs may be inserted under vanes 16 with the coils thereof arranged in the widened portions of the vane slots at the ends of separator 50. Each spring may be restrained from movement axially of rotor 9 by hooking the end of its inward leg over the far end of separator 50.

Figures 7 and 8

These figures show a portion of a rotor 9^a which

is the same as rotor 9 except that it has in each of its vane slots 15^a a separator 50^a which corresponds to separator 50 and extends to the bottom of the vane slot. A vane 16 is fitted in each slot 15^a and is urged outward against vane track 17 by two torsion springs 60 having the coils thereof arranged in the widened outer ends 52^a of vane slot 15^a at opposite ends of separator 50^a. Each spring 60 has one leg thereof curved and in contact with the inner wall of the notch 51 in vane 16 and its other leg arranged in a small hole 61 formed in separator 50^a adjacent the bottom of slot 15^a. Springs 60 need not be very strong for the reason that vane 16 is hydrostatically balanced so that only a small force is required to hold vane 16 in positive contact with vane track 17. Movement of each spring 60 axially of the rotor may be prevented in any suitable manner such as by curving the lower leg thereof so that it is frictionally held in hole 61.

Figures 9-14

The two machines shown in Figs. 9 and 10 are alike except that different types of springs are employed for holding the vanes in contact with the vane track. The machines differ from the machine shown in Figs. 1-6 only in having springs under their vanes and in being considerably longer and thereby being of considerably greater capacity. Therefore, corresponding parts have been indicated by corresponding reference numerals with 100 added to the numerals applied to Figs. 9-14 so that only a brief description will be necessary.

Each of the machines has its mechanism arranged within and carried by a casing 101 having a connection 193 and a second connection (not shown) by means of which the machine may be connected into a hydraulic circuit. Casing 1 has a circular chamber 104 formed therein, two cheek plates 107 and 108 arranged in chamber 104 at opposite ends thereof, a spacer ring 106 closely fitted in chamber 104 between cheek plates 107 and 108 and having a vane track 117 formed upon its inner surface, and an end head 105 attached to the end of casing 101 and rigidly clamping the spacer ring and cheek plates together. A rotor 109 is closely fitted between cheek plates 107 and 108 and is fixed for rotation with a shaft 110 which is journaled in suitable bearings one of which is shown at 111.

Cheek plates 107 and 108 are provided with ports and grooves as shown in Figs. 5 and 6 but only one pair of main ports 120, one pair of vane slot ports 124, one pair of vane slot ports 129, one pair of grooves 126 and one passage 130 appear in Figs. 9-14. Alternate main ports in cheek plate 107 are connected to opposite sides of an external circuit through passages 122 and 123 formed in casing 101 as explained above.

Rotor 109 has a plurality of vane slots 115 extending radially inward from its periphery and the inner portion of each slot is enlarged by extending a bore 152 completely through rotor 109 and extending two bores 153 inward from each end of rotor 109 as explained above. The material radially outward from bore 152 and between the inner ends of bores 153 constitutes a separator which has been designated 150 in Figs. 9, 11 and 12 and designated 150^a in Figs. 10, 13 and 14. A vane (designated 116 in Figs. 9, 11 and 12 and designated 116^a in Figs. 10, 13 and 14) is fitted in each slot 115 and has a notch 151 formed in its inner edge portion to accommodate the separator in that slot.

The vanes are hydrostatically balanced, as explained above, and are urged outward against vane track 117 by suitable springs. As shown in Figs. 9, 11 and 12, each vane 116 is urged against vane track 117 by two torsion springs 165 having the coils thereof arranged in the widened portions of slot 115 at opposite ends of separator 150. Each spring 165 has its outward leg curved and in contact with vane 116 and its inward leg in contact with the inner wall of slot 115. Movement of springs 165 axially of rotor 109 may be prevented by hooking the inward leg of each spring over the far end of separator 150 or by inserting the end of the inward leg in a hole 166 in separator 150. Springs similar to springs 165 but with shorter legs may be employed under the vanes of the machine shown in Figs. 1-6. Spring 165 has been shown in Fig. 12 as having only one and one-half turns in its coil for the reason that additional turns could not be clearly illustrated on such a small scale but in practice the coils preferably consist of a plurality of turns as indicated in Fig. 8 which is drawn to a larger scale.

As shown in Figs. 10, 13 and 14, each vane 116^a is urged against vane track 117 by compression springs 167 arranged in the widened portions of vane slot 115 at opposite ends of separator 150^a. Each spring 167 is retained in position by extending the end portion thereof axially of the coil and inserting one end portion in a small hole formed in vane 116^a and inserting the other end portion in a small hole formed in the inner wall of vane slot 115. The springs may be cut to the proper length and the holes may be drilled to the proper depth so that the end portions of the spring will bear upon the bottoms of the holes, as shown, or opposite ends of the coiled portion of each spring may bear upon the inner wall of the slot and upon the inner edge of the vane, respectively, and the end portions of the spring may extend only far enough into the holes to prevent displacement of the spring.

In each of the machines, the end portions of each vane are of such width that the contacts between the cheek plates and the ends of the vanes are long enough to provide seals between opposite sides of adjacent vanes and to prevent the vane from tilting in its slot as it moves inward and outward, and the intermediate portion of each vane is of such width that it has ample bearing area to contact with the walls of the vane slot and form a substantially fluid tight seal therewith. The springs when employed positively hold the vanes in contact with the vane track and enable the machine to start under load and to operate at slow speeds. Since the vanes are hydrostatically balanced and the separators prevent the vanes from being pinched in their slots, only very light springs are required.

Figs. 15 and 16

It is not necessary that the ends of the separators be spaced from both ends of the rotor as shown in Figs. 1-14. It is only necessary that the separators have sufficient cross-sectional area to prevent the segments of the rotor from being deflected by hydraulic forces and that ample spaces be provided for the flow of liquid between the bottoms of the vane slots and the portions of the vane slots outward from the separators.

For example, the separators may extend inward from both ends of the rotor and have the inner ends thereof spaced from each other as shown in Figs. 15 and 16. These figures show a portion of a machine which is the same as the machine shown in Fig. 9 except that the sep-

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arators and the vanes are different. Therefore, a complete description thereof is deemed unnecessary as like parts have been indicated by like reference numerals and corresponding but dissimilar parts have been indicated by corresponding reference numerals with the exponent "b" added to the reference numerals applied to Figs. 15 and 16.

As shown, the machine is provided with a rotor 109^b which is fixed for rotation with a shaft 110 and is arranged within a spacer ring 106 and between two cheek plates 107 and 108 all of which are arranged within a casing 101 having a removable end head 105.

Rotor 109^b has a plurality of vane slots 115^b formed therein and a vane 116^b slidably fitted in each slot, each vane 116^b being of a uniform width throughout its length. Each slot 115^b extends inward from the periphery of rotor 109^b and terminates in a bore 152^b which extends into rotor 109^b from both ends thereof and is adapted to register successively with the several vane slot ports of which only two ports 124 appear in Fig. 15.

Each vane slot 115^b has two separators 150^b arranged therein with the inner ends thereof spaced from each other to provide therebetween a passage 170 through which liquid may freely flow between bore 152^b and the outer portion of the slot, separators 150^b preferably being formed integral with rotor 109^b. Each slot 115^b may be formed by drilling a bore 152^b through the rotor, milling a slot from the periphery of the rotor inward to a line spaced from bore 152^b to leave a separator between bore 152^b and the milled portion of the slot, and then cutting away an intermediate portion of the separator such as by sinking a milling cutter through an intermediate portion of the separator into communication with bore 152^b or by drilling a plurality of holes through an intermediate portion of the separator.

The machine will function in the same manner as the machine shown in Figs. 1-6. If the machine should be used as a motor which must operate at slow speeds, the vanes may be mechanically held in contact with the vane track, such as by springs arranged in passages 170 and acting upon the inner edges of the vanes, or the vanes may be hydraulically held in contact with the vane track by applying to the inner edges of the vanes pressures which are higher than the pressures at the outer ends of the vanes and which are applied in any suitable manner such as shown in Patents 2,312,891 and 2,335,567.

The invention set forth herein may be modified in various ways and be embodied in other forms of vane type machines without departing from the scope of the invention which is hereby claimed as follows:

I claim:

1. In a hydrodynamic machine of the sliding vane type having a casing, two cheek plates arranged within said casing and an annular vane track arranged between said plates and forming therewith a chamber, the combination of a rotor arranged within said chamber and having an axial bore to receive a shaft and a plurality of vane slots extending inward from its periphery with the inner ends thereof spaced a substantial distance from said bore, vanes fitted in said slots and adapted to ride upon said track and to reciprocate in said slots during rotation of said rotor, said slots dividing said rotor into so many segments that the cross-sectional area of each segment at the inner end thereof is so small that

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a high pressure acting upon one side only of the outer portion of a vane would cause the adjacent segment to be deflected and to pinch the vane in the slot at the other side of that segment, and a separator arranged in each of said slots with its outer edge spaced far enough from the bottom of that slot to prevent the segment on either side of that slot from being deflected enough to pinch the vane in the adjacent slot and with its inner edge spaced from the bottom of that slot to provide a passage therebetween.

2. The combination as set forth in claim 1 in which said separators are formed integral with said rotor.

3. The combination as set forth in claim 1 in which said vanes have notches formed in the inner portions thereof and said separators are shorter than said notches and are arranged between the ends thereof.

4. The combination set forth in claim 3 in which said separators are formed integral with said rotor.

5. The combination as set forth in claim 1 in which said separators are considerably shorter than said rotor and springs are arranged at opposite ends of each of said separators to urge said vanes against said vane track.

6. In a hydrodynamic machine having a casing, two cheek plates arranged within said casing, an annular vane track arranged between said cheek plates and forming therewith a chamber, and a shaft extending into said chamber, at least one of said plates having a plurality of vane slot ports formed therein upon a radius greater than the radius of said shaft, the combination of a rotor mounted upon said shaft within said chamber and having a plurality of vane slots extending inward from its periphery with the inner ends thereof upon a radius substantially the same as the radius of said vane slot ports so that the inner end of each slot will register with said ports successively as said rotor rotates, vanes fitted in said slots and adapted during rotation of said rotor to ride upon said track and to reciprocate in said slots and thereby cause a flow of liquid between said slots and said ports, said slots dividing said rotor into so many segments that the cross-sectional area of each segment at the inner end thereof is so small that a high pressure acting upon one side only of the outer portion of a vane would cause the adjacent segment to be deflected and to pinch the vane in the slot at the other side of that segment, and a separator arranged in each of said slots with its radially outward edge spaced a substantial distance from the bottom of that slot to thereby prevent the segment on either side of that slot from being deflected enough to pinch the vane in the adjacent slot, the radially inward portions of said slots being increased in width and the lengths of said separators being enough less than the length of said rotor to provide between the inner and outer portions of said slots ample spaces through which liquid may freely flow to and from said vane slot ports as said vanes reciprocate in said slots.

7. The combination as set forth in claim 6 in which said separators are formed integral with said rotor.

8. The combination as set forth in claim 6 in which said vanes have notches formed in the inner portions thereof and said separators are shorter than said notches and are arranged between the ends thereof.

9. The combination set forth in claim 8 in

which said separators are formed integral with said rotor.

10. The combination as set forth in claim 6 in which said separators are considerably shorter than said rotor and springs are arranged at opposite ends of each of said separators to urge said vanes against said vane track.

11. The combination set forth in claim 10 in which said springs are torsion springs having coils formed therein and the inner ends of said vane slots are widened sufficiently to receive said coils.

12. The combination as set forth in claim 6 in which each of said vane slots terminates in a bore which has a greater diameter than said slot

and is arranged radially inward from the separator in that slot.

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