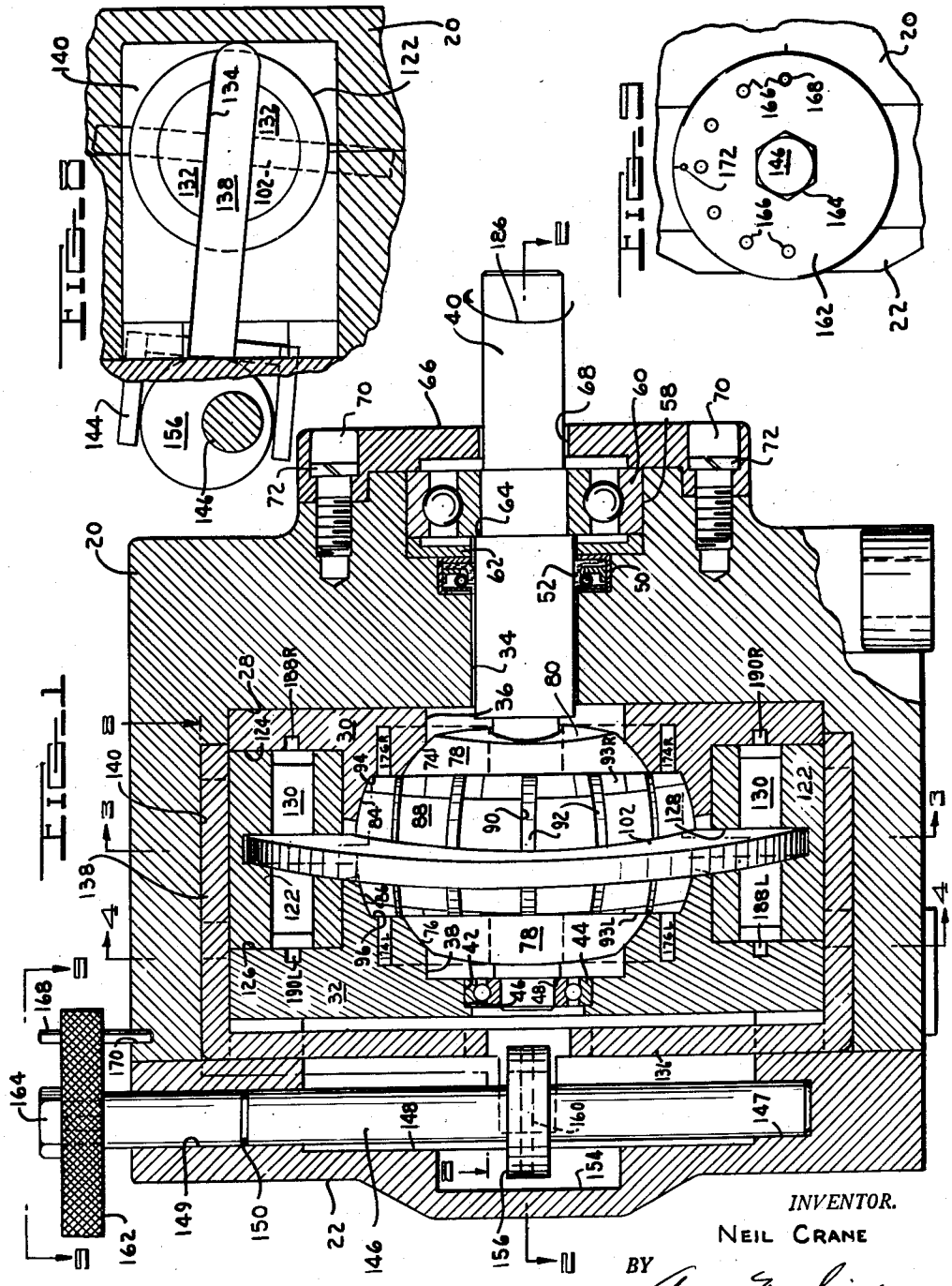
Feb. 5, 1952 N. CRANE 2,584,426

VARIABLE DELIVERY VANE-TYPE HYDRAULIC PUMP

Filed March 2, 1948 5 Sheets-Sheet 1



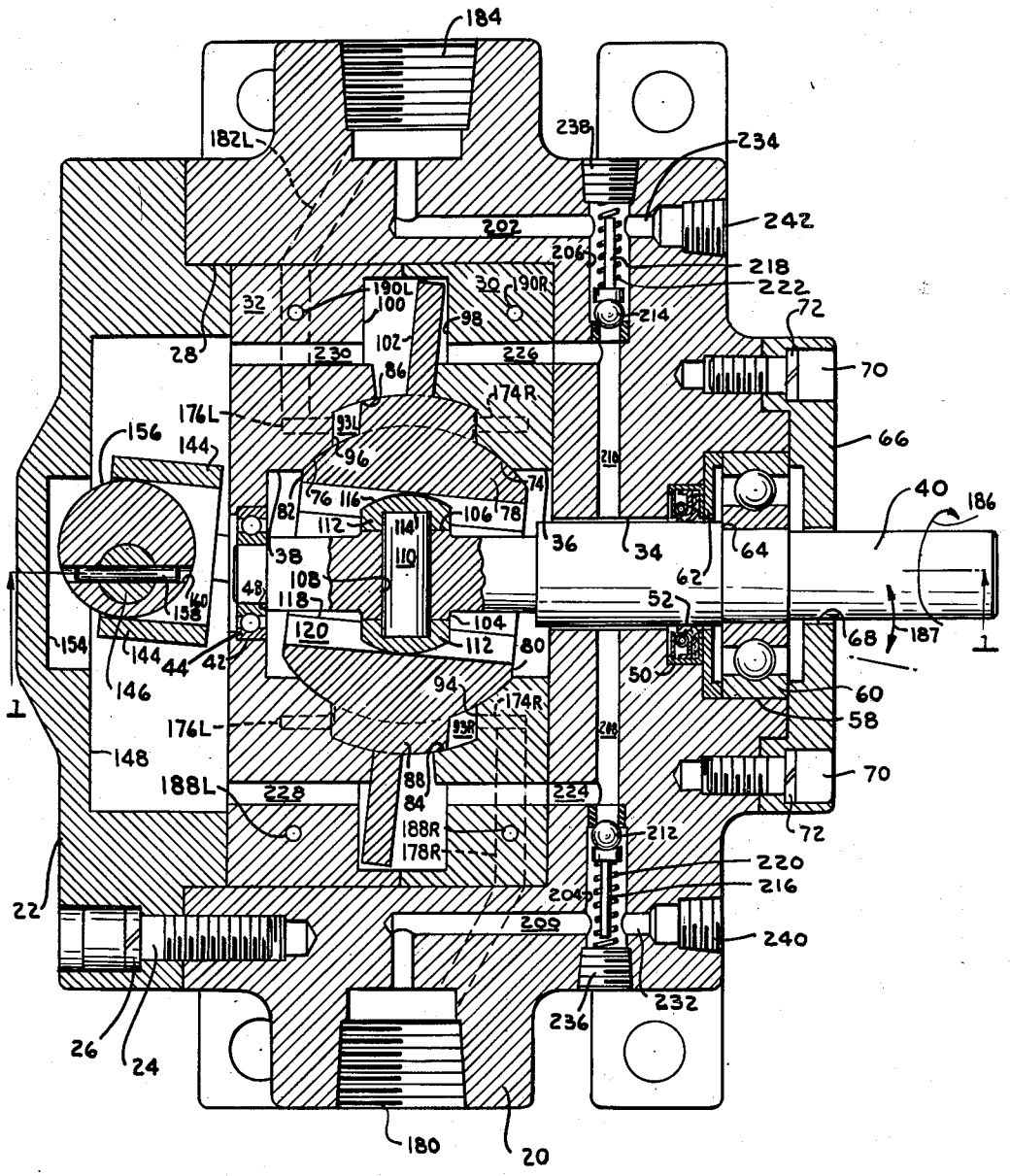
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VARIABLE DELIVERY VANE-TYPE HYDRAULIC PUMP

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FIG. 2



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VARIABLE DELIVERY VANE-TYPE HYDRAULIC PUMP

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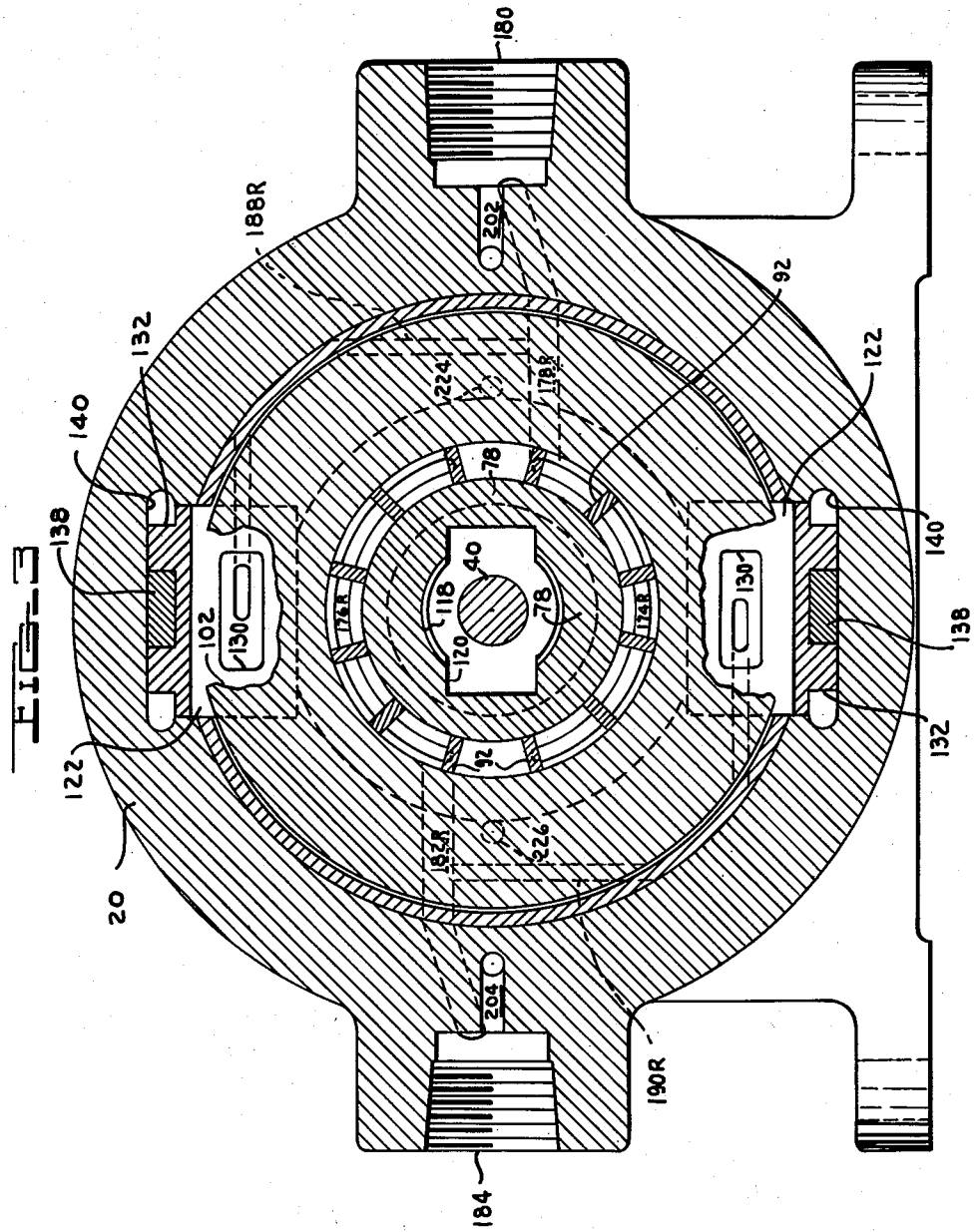


FIG. 3

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VARIABLE DELIVERY VANE-TYPE HYDRAULIC PUMP

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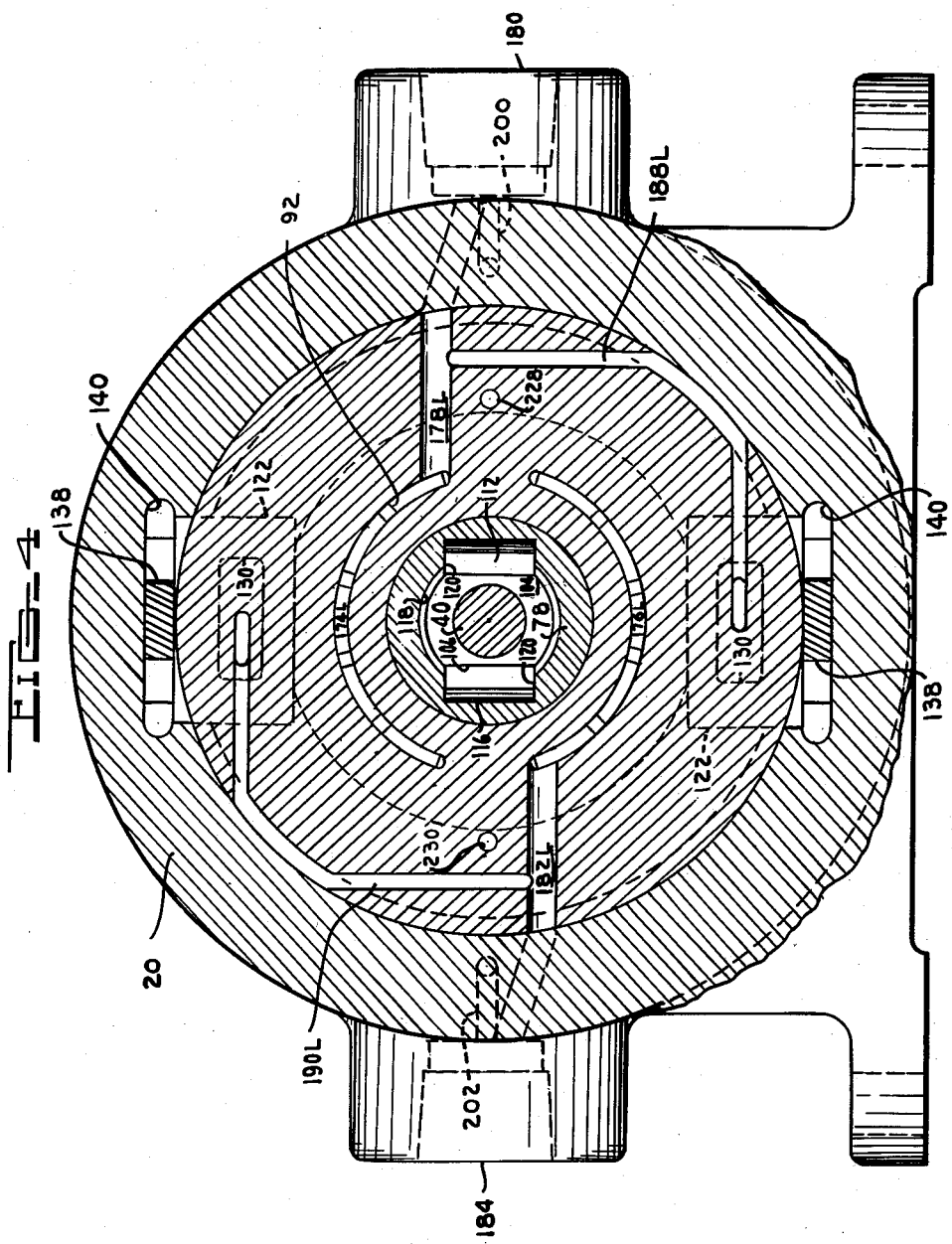


FIG. 4

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VARIABLE DELIVERY VANE-TYPE HYDRAULIC PUMP

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FIG. 11

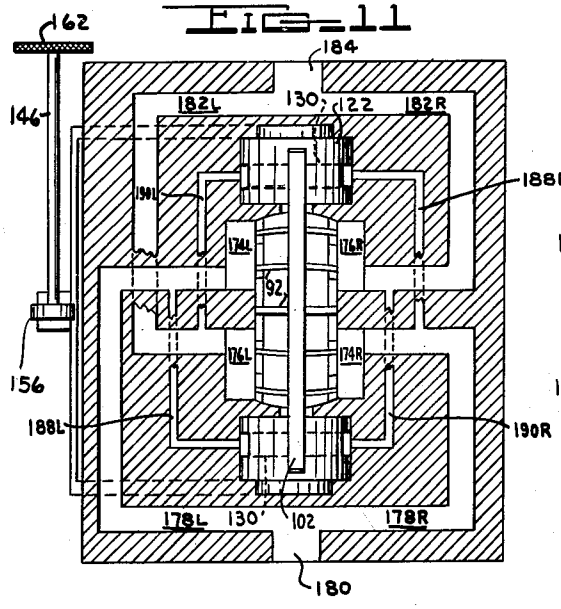


FIG. 10

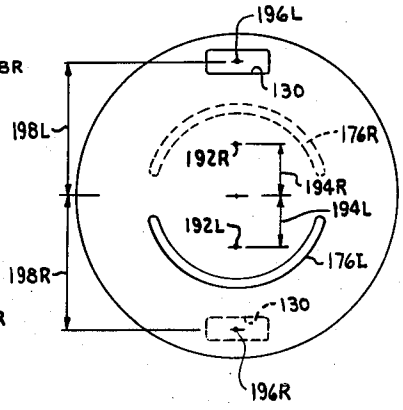


FIG. 7

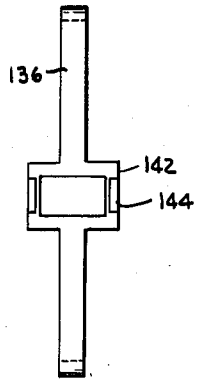


FIG. 6

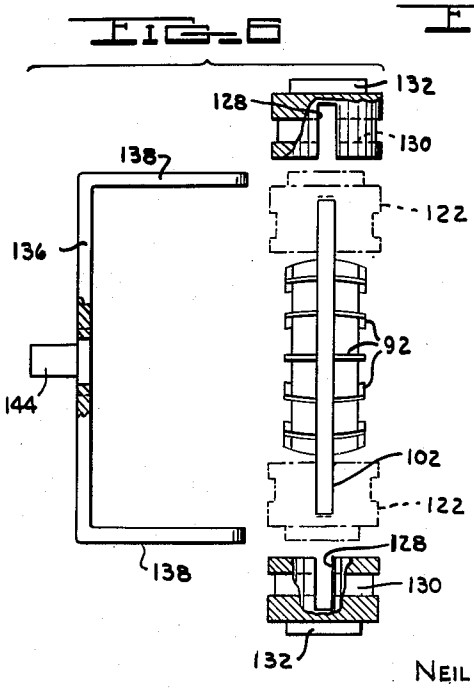
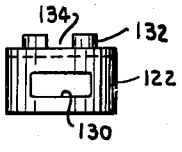


FIG. 5



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Patented Feb. 5, 1952 2,584,426

UNITED STATES PATENT OFFICE

2,584,426

VARIABLE DELIVERY VANE-TYPE HYDRAULIC PUMP

Neil Crane, Detroit, Mich., assignor, by direct and mesne assignments, to Eugene A. Casaroll, Detroit, Mich., as trustee

Application March 2, 1948, Serial No. 12,604

16 Claims. (Cl. 103—120)

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The present invention relates to a hydraulically balanced, variable delivery, reversible vane-type hydraulic pump.

A preferred embodiment of the present invention provides a symmetrical hydraulically balanced pump comprising a vane carrying rotor rotating between the spaced sidewalls of a stationary housing and disposed to provide a pair of annular pumping recesses formed between the sides of the rotor and housing, one on each axially opposed side of the rotor. The rotor is universally mounted relative to its drive means to permit pivoting of the rotor's axis of rotation in either direction about an axis perpendicular thereto. Thus the rotor is pivotal from a neutral position, whereat the rotor is symmetrically disposed equidistant from said spaced housing sidewalls, to an oblique position, whereat diametrically opposed portions of the rotor are tilted toward one housing sidewall and away from another.

The vanes are equally spaced circumferentially and mounted on the rotor for relative sliding movement transverse to the direction of rotation to permit said oblique tilting of the axis of rotation. The vanes project from the axially opposed sides of the rotor to partition each pumping recess into a plurality of individual fluid carrying pumping chambers.

Upon rotation of the rotor about an oblique axis relative to said housing, the pumping chambers within a semi-annular inlet portion of each pumping recess gradually increase in volume and thereby develop a low pressure into which hydraulic fluid flows by way of inlet ports communicating with said inlet portions. The entering fluid is carried by the individual pumping chambers to a semi-annular discharge portion of each pumping recess whereat the pumping chambers gradually decrease in volume and discharge the hydraulic fluid under pressure by way of discharge ports communicating with said discharge portions.

By the arrangement described, each axially opposed side of the rotor serves as an active pumping element, the output of the pump being dependent upon the rate of change of volume of the pumping chambers as they rotate within the pumping recesses. Thus the output of the pump is variable or reversible merely by varying or reversing the angle of the tilt of the axis of rotation of the rotor relative to the housing, but without otherwise changing the direction or speed of rotation.

The torque resulting from the hydraulic inlet and discharge pressures exerted on the portions of the rotor bounding the pumping recesses is counterbalanced in the present invention by porting said inlet and discharge pressures against portions of the rotor external to the pumping recesses, so as to hydraulically balance the rotor for torque about all axes other than the axis of rotation, thereby obviating torque between the rotor and its drive means except about the axis of rotation and permitting a "finger-tip" control over the mechanism for varying the rotor's axis of rotation and rate and direction of output.

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Prior to the present invention, conventional variable delivery vane-type hydraulic pumps have utilized a rotor and integral drive shaft journaled in heavy, expensive, oversized bearings required to compensate for the thrust or back pressure of the hydraulic fluid on the rotor. In such constructions, the rotor itself frequently comprised a "wobble plate" or eccentric member rotating so as to vary its axis of symmetry constantly, thereby placing additional strains on the rotor shaft bearing supports and rendering such pumps unfeasible for relatively large outputs.

Another difficulty frequently encountered with the conventional variable delivery hydraulic pump employing slidable vanes carried by the rotor is that centrifugal force tends to throw the vanes against stationary portions of the rotor housing, resulting in undue friction and wear between the vanes and housing, lowered operational efficiency of the pump, and untimely leakage of fluid by-passing the vanes.

Accordingly, important objects of the present invention are:

(1) To provide a hydraulic pump wherein the axes of rotation and symmetry of the rotor remain constant for uniform delivery of the pump; and

(2) To provide a vane-type pump having an infinitely variable delivery characteristic within the limits of the pump, wherein the output and direction of operation of the pump may be readily varied by changing the axis of rotation of the rotor.

Other objects of the present invention are to provide an improved, economically manufactured, vane-type hydraulic pump having high operating efficiency characteristics wherein the rotor is at all times maintained in hydraulic balance regardless of its angle of rotation or the hydraulic inlet and discharge pressures acting thereon; and wherein the rotor is floated freely

relative to its drive shaft so as to substantially eliminate torque on the drive shaft about all axes other than the axis of rotation, thereby reducing the initial and maintenance costs of the pump and permitting the use of relatively inexpensive light bearings to journal the drive shaft.

Another object of the present invention is to provide a slidable vane-type pump wherein the vanes rotating with the rotor are restrained against centrifugal force by means rotating with the rotor, thereby prolonging the operating efficiency of the pump and avoiding a primary cause of wear which otherwise results in conventional vane-type pumps wherein the vanes are thrust by centrifugal force against stationary portions of the pump housing.

Other objects of the present invention are to provide a vane-type variable delivery hydraulic pump which is completely reversible in its operation; wherein the rotor may be operatively rotated in either direction; wherein the hydraulic inlet and outlet ports may be selectively reversed merely by changing the axis of rotation of the rotor, without changing its direction of rotation; and wherein the output of the pump is readily infinitely variable between the limits of maximum output in one direction, through zero output, and maximum output in the reverse direction, merely by changing the axis of rotation of the rotor and without otherwise changing its speed or direction of rotation.

Other objects of this invention will appear in the following description and appended claims, reference being had to the accompanying drawings forming a part of this specification wherein like reference characters designate corresponding parts in the several views.

In the drawings:

Fig. 1 is essentially a vertical mid-section through the drive shaft of a hydraulic pump embodying the present invention, taken in the direction of the arrows along the line 1—1 in Fig. 2, the rotor and integral pressure equalizing member being shown in side elevation and tilted relative to the rotor housing to show portions of the right sides thereof.

Fig. 2 is essentially a horizontal section through the drive shaft, taken in the direction of the arrows along the line 2—2 of Fig. 1, the rotor being rotated slightly from its position shown in Fig. 1 and the vanes being removed.

Fig. 3 is a vertical section through the rotor, taken in the direction of the arrows essentially along the broken line 3—3 of Fig. 1, the rotor being shown in the central neutral position and slightly rotated from the position of Fig. 1.

Fig. 4 is a vertical section taken in the direction of the arrows along the line 4—4 of Fig. 1, the rotor being shown in the central neutral position and slightly rotated from the position of Fig. 1.

Fig. 5 is a reduced elevation of one of the forked hydraulic bearings embodying the present invention.

Fig. 6 is a reduced elevation showing the rotor, together with the hydraulic bearings and pivotal yoke for controlling the axis of rotation of the rotor. The hydraulic bearings and yoke are shown partially sectioned and displaced from their assembled positions. The hydraulic bearings are shown in phantom in their assembled positions engaged with the pressure equalizing member.

Fig. 7 is an elevation of the pivotal yoke taken from the left end of Fig. 6.

Fig. 8 is a fragmentary section taken in the direction of the arrows along the broken line 8—8 of Fig. 1, showing the eccentric means and pivotal yoke for pivoting the hydraulic bearings.

Fig. 9 is a fragmentary elevation taken in the direction of the arrows along the line 9—9 of Fig. 1 and showing the indexing means for selectively determining the axis of rotation of the rotor.

Fig. 10 is a diagrammatic view indicating the hydraulic pressure balance on the rotor.

Fig. 11 is a schematic section showing the system of hydraulic inlet and discharge ducts and the ducts for hydraulically balancing the rotor.

Before explaining the present invention in detail, it is to be understood that the invention is not limited in its application to the details of construction and arrangement of parts illustrated in the accompanying drawings, since the invention is capable of other embodiments and of being practiced or carried out in various ways. Also it is to be understood that the phraseology or terminology employed herein is for the purpose of description and not of limitation.

A particular embodiment of the present invention is described by way of example in connection with the drawings. Figs. 1 and 2 show the housing 20, having the large recess 28 for the right and left rotor housing members 30 and 32 respectively. The recess 28 is enclosed by the end cover 22 secured to the housing 20 by the plurality of bolts 24 and lock washers 26. The housing members 20, 30, and 32 provide the coaxial shaft openings 34, 36 and 38 respectively for the rotatable drive shaft 40, its bearing supports, and the rotor.

An annular reduced portion 42 of the opening 38, concentric with the shaft 40, is provided for the shaft bearing 44 which rests against and is prevented from leftward movement, Fig. 1, by the shoulder 46 of the rotor housing member 32. The reduced left end of the shaft 40 is journaled within the bearing 44 and held against leftward movement by the annular shoulder 48 of the shaft 40, resting against the inner race of the bearing 44.

Communicating concentrically with the opening 34 is the annular recess 50 provided for the hydraulic pressure seal 52 around the shaft 40. A similar and somewhat larger concentric annular recess 58 is provided for the shaft bearing 60 which is spaced from the hydraulic seal 52 by the annular spacer 62. The reduced right end of the shaft 40 is journaled within the bearing 60 and held in the assembled position against movement to the right, Fig. 1, by the annular shoulder 64 of the shaft 40. The bearing 60 is held within the recess 58 by the end cover 66 which is secured to the housing 20 by the plurality of bolts 70 and lock washers 72.

The walls of the openings 36 and 38 provide the paired concentric spherical portions 74 and 76 respectively which provide bearing surfaces for the paired spherical segments of the rotor body 78. The latter is bounded between its right and left parallel sidewalls 80 and 82 respectively, Fig. 2, perpendicular to the rotor's axis. Similarly, the walls of the openings 36 and 38 provide the paired concentric spherical portions 84 and 86 having only an operating clearance from the segmental spherical surface of the annular vane holder 88, which latter is integral and coaxial with the rotor body 78. The vane holder 88 provides the plurality of equally circumferentially

spaced radial slots 90 for the plurality of thin flat slidable vanes 92, which extend laterally from opposite sides of the vane holder 88 for rotation within the paired annular pumping recesses 93L and 93R formed between the sidewalls of the rotor and stationary housing members on the axially opposed left and right sides respectively of the rotor.

The lateral projecting portions of each vane 92 essentially fills the cross sectional area of its portion of the pumping recesses 93L and 93R so that the latter is partitioned into a plurality of rotating pumping chambers bounded between adjacent vanes and the surfaces of the rotor and housing and adapted to carry hydraulic fluid upon rotation of the rotor. The adjacent surfaces between the vanes and the rotor and housing are accurately machined to conform to each other so as to minimize fluid leakage from the individual pumping chambers. The outer and inner peripheral edge portions of the vanes 92 are spherical to conform respectively to the spherical surfaces 84—86 and to the spherical surface of the rotor body 78. The lateral ends of the vanes 92 abut the parallel annular sidewall portions 94 and 96, which are concentric with and perpendicular to the axis of rotation of the shaft 40 and are provided by the housing members 30 and 32 respectively. The lateral ends of the vanes 92 are also slightly convex so as to maintain a sliding contact at all times with the said surfaces 94 and 96 regardless of the angle of rotation of the rotor.

It is to be noted that the rotor in Figs. 2, 3 and 4 has been rotated slightly from its position of Fig. 1. In Fig. 2 the section does not pass through any of the vanes and the pumping recesses 93L and 93R are clearly shown in section at the upper left and lower right respectively of the rotor.

The recesses within the members 30 and 32 for the spherical vane holding segment 88 are continuous with the paired annular recesses 98 and 100, Fig. 2, provided for the pressure balancing member 102 comprising an annular disc secured coaxially to the outer periphery of the vane holder 88 for rotation therewith. The rotor body 78, vane holding annulus 88, and pressure balancing member 102 are preferably secured together to complete a concentric and coaxial integral rotor unit. The body 78 and annulus 88 may be suitably formed from a single element. The vane slots 90 are then preferably milled, and the member 102 is thereafter concentrically secured to the annulus 88 so as to hold the vanes 92 against centrifugal force which would otherwise cause undue frictional wear between the stationary surfaces 84 and 86 and the outer peripheries of the vanes 92.

The spacing between the parallel annular faces 94 and 96 is somewhat greater than the width of the vane holder 88 to permit rotation of the rotor out of coaxial alignment with the shaft 40, Figs. 1 and 2, thus forming the expanding and contracting pumping chambers. As the axis of rotation of the rotor is tilted out of coaxial alignment with the shaft 40, the vanes 92 move slidably within their slots 90 relative to the vane carrier 88 to maintain their positions for rotation within the said pumping recesses 93L and 93R essentially coaxially about the shaft 40.

Changing of the rotor's axis of rotation relative to the axis of the drive shaft 40 is permitted by a universal coupling best shown in Figs. 2, 3 and 4. Within the rotor body 78, the shaft 40 provides an enlarged portion 104, Figs. 2 and 4, having the two opposed parallel faces 106 parallel to the axis of the shaft 40. A pinhole 108 extends through the axis of the shaft 40 and receives the pin 110 which projects perpendicularly through the opposed parallel faces 106 to receive the paired rectangular caps 112 at its opposite ends. Each cap 112 provides the recess 114 for its respective end of the pin 110 and also provides the outer cylindrical surface 116, Fig. 2. The latter allows adequate clearance between the rotor and caps 112 when the axis of rotation of the rotor is at an angle to the axis of the shaft 40. The rotor body 78 provides the central axial bore 118 of slightly larger diameter than the diameter of the portion of the shaft 40 therein to permit tilting of the rotor body 78 relative to the shaft 40. Driving engagement between the rotor and shaft 40 is effected by the lateral sides of the pair of diametrically opposed slots 120, Fig. 3, extending axially of the bore 118. Each slot 120 is adapted to receive one of the caps 112 with the lateral sides of the slots 120 and adjacent sides of the caps 112 providing bearing surfaces for pivotal movement of the rotor about an axis perpendicular to the axes of both the shaft 40 and the pin 110, and also providing a driving contact between the rotor and shaft 40.

Tilting of the axis of rotation of the rotor relative to the axis of rotation of the shaft 40 is effected by the coaxial, pivotal, diametrically opposed forked hydraulic bearings 122, Figs. 1 and 5, mounted within the paired semi-cylindrical openings 124 and 126 within the rotor housing member 30 and 32 respectively for pivoting about the diametrical axis therebetween. Each bearing 122 provides the slot 128 which receives the pressure balancing member 102, the hydraulic pressure balancing chamber 130 which extends through the bearing 122 perpendicularly to the slot 128, and the slotted cylindrical segmental bosses or prongs 132 having the channel or slot 134 between them to receive one of each of the pair of parallel arms 138 of the pivotal yoke 136, Fig. 8. The arms 138 extend along the two longitudinal recesses 140 provided therefor within the housing 20, above and below the rotor, Figs. 1, 3 and 4, and also extend into their respective slots 134 at diametrically opposed positions above and below the pressure balancing member 102 for pivoting the bearings 122. The central part of the yoke 136 provides the lateral extensions 142 from which project the parallel arms 144, Figs. 6 and 7, on opposite sides of the indexing shaft 146, Figs. 2 and 8. The indexing shaft 146 is rotatably mounted at opposite ends at 147 and 149 within the cover 22 and extends upward within the recess 148 of the cover 22 and through the upper portion of the latter. An oil seal ring 150 is provided around the shaft 146 within the upper journal 149.

Within the cover 22 and communicating with the recess 148 is the recess 154 for the cam 156 mounted eccentrically on the indexing shaft 146 and secured thereto by the pin 158 within the pinhole 160 provided by the shaft 146 and cam 156. Rotation of the indexing shaft 146 is effected by the knurled disc 162 secured to its upper end by the nut 164. The knurled disc 162 provides the plurality of spaced semi-circularly arranged indexing holes 166 and is selectively held in one of a plurality of indexed positions by inserting the pin 168 through one of the indexing holes 166 and into the pinhole 170 provided there-

for within the upper surface of the housing 20, Figs. 1 and 9.

It is apparent from the structure shown that as the shaft 146 and eccentric cam 156 are rotated, the latter pivotally moves the arms 144 and 136 through an arc about the center of the coaxial bearings 122, Fig. 8, for pivoting the latter. The pressure balancing member 102 which rides within the diametrically opposed hydraulic bearing slots 128 is thus pivoted about the axis of the bearings 122 to change the axis of rotation of the rotor on its aforementioned universal coupling. The position of the zero indicator 172, Fig. 9, shows the axis of rotation of the rotor tilted to the limit in one direction relative to the axis of the shaft 40. By rotating the knurled knob 162 ninety degrees clockwise in Fig. 9 the rotor will be placed in the neutral or central position in coaxial alignment with the shaft 40. Upon continued clockwise rotation of the knurled disc 162 through another 90°, the rotor will be tilted to the limit of its movement in the opposite direction from that shown in Figs. 1 and 2.

Hydraulic fluid is supplied to and discharged from the pumping recesses 93L and 93R by four arcuate hydraulic ports, two on each axially opposed side of the rotor and extended concentrically adjacent each pumping recess 93L and 93R for communicating therewith, each arcuate port being somewhat less than a semi-circle in length and being symmetrically disposed relative to the plane of the pivot axes of the bearings 122 and shaft 40. These ports are best shown in Figs. 3 and 4 and include the arcuate ports 174L and 174R, in hydraulic communication with each other and provided on opposite sides of the axis of rotation of the shaft 40 within the housing members 32 and 30 respectively, and also include the arcuate ports 176L and 176R, in hydraulic communication with each other and provided on opposite sides of the axis of rotation of the shaft 40 within the housing members 32 and 30 respectively. The adjacent ends of the arcuate ports 174L and 176L, Fig. 4, and correspondingly the adjacent ends of the arcuate ports 174R and 176R, Fig. 3, are preferably circumferentially spaced by a distance somewhat greater than the circumferential spacing between adjacent vanes 92. Thus as each individual pumping chamber between adjacent vanes 92 is carried from one of the said arcuate ports to another by rotation of the rotor, the pumping chamber will be completely shut off from the one port before opening to the other port, Fig. 3.

The ports 174L, 174R are in hydraulic communication with the conduits 178L and 178R respectively, Figs. 3 and 4, which communicate with the hydraulic port 180 at the exterior of the pump. Similarly, the ports 176L, 176R are in hydraulic communication with each other by way of the ducts 182L and 182R respectively, which communicate to the exterior of the pump at the hydraulic port 184.

Assuming for the sake of illustration that the rotor is tilted as shown in Figs. 1 and 2 and that the shaft 40 is rotating in the direction of the arrow 186, i. e., clockwise as seen from the right end in Fig. 2, the rotation of the rotor will be clockwise similarly, but around an axis at an angle 187 to the axis of rotation of the shaft 40. In this situation, the individual pumping chambers between adjacent vanes 92 in the upper portion of the pumping recess 93L and the lower portion of the pumping recess 93R, i. e., in communication with the arcuate ports 174L and 174R, gradually increase in volume from minimum to maximum as they pass over the said ports 174L and 174R, creating a suction in these pumping chambers toward which the inlet hydraulic fluid flows from the port 180 by way of the conduits 178L and 178R.

Similarly, the individual pumping chambers between adjacent vanes 92 in the lower portion of the pumping recess 93L and the upper portion of the pumping recess 93R, i. e., in communication with the arcuate ports 176L and 176R, gradually decrease in volume from maximum to minimum as they pass over the said ports 176L and 176R. The fluid is thus forced out of these pumping chambers and through the port 184 by way of the conduits 182L and 182R.

Accordingly, with the rotor tilted as shown in Figs. 1 and 2, the upper portion of the pumping recesses 93L and the lower portion of the pumping recess 93R, the arcuate ports 174L and 174R, the conduits 178L and 178R, and the port 180, all in communication with each other, become the complete hydraulic inlet portion of the pump. The lower portion of the pumping recess 93L and the upper portion of the pumping recess 93R, the ports 176L and 176R, the conduits 182L and 182R, and the port 184, all in hydraulic communication with each other, become the complete discharge portions of the pump. It is apparent from the structure shown that the hydraulic ports 180 and 184 may be interchangeably the inlet or outlet ports, depending upon the direction in which the axis of rotation of the rotor is pivoted relative to the axis of the shaft 40. It is not necessary to reverse the direction of rotation in order to reverse the direction of operation of the pump. Likewise, it is apparent that the volume output of the pump depends upon the rate of change of the volume of the individual pumping chambers as they rotate within the pumping recesses 93L and 93R, which in turn depends upon the angle 187 between the axes of rotation of the rotor and shaft 40.

The relatively low hydraulic pressure within the inlet portions of the pumping recesses 93L and 93R and the relatively high hydraulic pressure within the discharge portions of the pumping recesses 93L and 93R exert a torque on the rotor tending to rotate the latter about a horizontal axis perpendicular to its axis of rotation. For example, with the rotor tilted as shown and rotating in the aforesaid clockwise direction, the hydraulic pressure within the discharge portions of the pumping recesses 93L and 93R tends to force the lower portion of the rotor to the right and the upper portion of the rotor to the left, Fig. 1. Torque of comparatively smaller magnitude is also exerted on the rotor as a result of the pressure within the inlet portions of the pumping recesses 93L and 93R.

The above mentioned torques exerted on the rotor during normal operation are counterbalanced in the present invention by means of the diametrically opposed pressure balancing chambers 130 within the forked bearings 122, each communicating with axially opposed sides of the pressure balancing member 102. The conduits 188L and 188R, communicating with the ducts 178L and 178R respectively, conduct fluid to the pressure balancing chambers 130 at the lower left and upper right sides of the member 102 respectively. Similarly, the ducts 190L and 190R, communicating with the ducts 182L and 182R respectively, conduct fluid to the pressure balancing chambers 130 at the upper left and lower right sides respectively of the member 102, Fig. 1. Thus the arcuate ports 174L, 174R and the por-

tions of the pressure equalizing chambers 130 at the lower left and upper right of the disc 102 are in hydraulic communication with each other and at the same hydraulic pressure. Similarly, the arcuate ports 176L, 176R and the portions of the pressure equalizing chambers 130 at the lower right and upper left of the disc 102 are in hydraulic communication with each other and at the same hydraulic pressure.

The areas of the pressure balancing chambers 130 which open to the opposite sides of the member 102 are selected in consideration of their distances from the center of the rotor so as to completely balance the torque on the rotor resulting from the hydraulic pressures within the pumping recesses 93L and 93R. The balancing of the pressures on the rotor is indicated in Fig. 10, which may be considered a schematic vertical section perpendicular to the axis of rotation of the shaft 40. The port 176L and the portion of the chamber 130 opening to the left side of the disc 102 are shown in solid lines. The port 176R and the portion of the chamber 130 opening to the right side of the disc 102 are shown in dotted lines. 192L and 192R represent the centers of gravity of the areas A_{192L} and A_{192R} respectively (indicated in the mathematical expressions below) within the pumping recesses 93L and 93R respectively and in contact with the surface components of the rotor which are perpendicular to its axis of rotation and also in communication with the ports 176L and 176R respectively.

The torque T resulting from hydraulic pressure acting on the said areas A_{192L} and A_{192R} for which 192L and 192R respectively represent the centers of gravity, and tending to rotate the rotor about a horizontal axis perpendicular to its axis of rotation, is given by the expression:

$$T=P(A_{192L}D_{194L}+A_{192R}D_{194R})$$

wherein P is the pressure on the areas A_{192L} and A_{192R}; and D_{194L} and D_{194R} are the distances 194L and 194R respectively of the centers of gravity 192L and 192R respectively from the axis of rotation of the rotor. By the symmetry of construction, $A_{192L}=A_{192R}$, and $D_{194L}=D_{194R}$. Obviously, $PA_{192L}D_{194L}$ is the torque tending to force the lower portion of the rotor to the right in Fig. 1. $PA_{192R}D_{194R}$ is the torque tending to force the upper portion of the rotor to the left in Fig. 1.

The points 196R and 196L represent the centers of gravity of the areas of the right side of the lower pressure balancing chamber 130 and the left side of the upper pressure balancing chamber 130 in contact with the member 102. The size and disposition of the chambers 130 are determined so that the following equalities exist:

$$A_{196R}D_{198R}=A_{192L}D_{194L}$$

and

$$A_{196L}D_{198L}=A_{192R}D_{194R}$$

wherein A_{196R} and A_{196L} are the areas for which the points 196R and 196L respectively are the centers of gravity; and D_{198R} and D_{198L} are the distances 198R and 198L respectively. Also by the symmetry of construction,

$$A_{196L}=A_{196R}, \text{ and } D_{198L}=D_{198R}$$

Since the lower right side and the upper left side of the pressure balancing chambers 130, and the areas A_{192L} and A_{192R} are in hydraulic communication with each other and at the same hydraulic pressure, the torque on the rotor, resulting from the hydraulic pressure within the pumping recesses 93L and 93R and directed against the upper right and lower left sides of the rotor to rotate the latter about a horizontal axis perpendicular to its axis of rotation, is counterbalanced.

Similarly, the torque on the rotor about the horizontal axis perpendicular to its axis of rotation and resulting from hydraulic pressure within the upper and lower portions respectively of the pumping recesses 93L and 93R and in hydraulic communication with the arcuate ports 174L and 174R is counterbalanced by communicating the pressure within the ports 174L and 174R to the portions of the pressure balancing chambers 130 at the upper right and lower left sides of the pressure balancing member 102. This symmetry of construction is particularly desirable as a feature permitting reversal of the pressure within the pump while maintaining the rotor in hydraulic balance. Obviously, by the symmetry of the construction, there is no torque tending to rotate the rotor about a vertical axis perpendicular to its axis of rotation. The centers of gravity 192L, 192R and 196L, 196R all lie on a diameter parallel to the said vertical axis. Thus every moment of force on one side of the vertical axis is counterbalanced by a corresponding moment of force on the other side thereof.

It is also to be noted that the hydraulic balancing of axially opposed portions of the rotor effected in the present invention by the pressure balancing chambers 130 within the forked bearings 122, provides a simple and efficient hydraulic bearing action for the said forked bearings 122, which guides the rotation of the rotor about an axis at a selected angle relative to the axis of the drive shaft 40.

In order to relieve hydraulic pressure which may occasionally develop within various portions of the pump housing as a result of leakage outside of the operating chambers or ducts of the pump, pressure relief ducts 200 and 202 within the housing 20 communicate with the ports 180 and 184 respectively, Fig. 2, and with the pressure relief valve chambers 204 and 206 respectively, which in turn communicate respectively with the ducts 208 and 210 within the housing 20. Ball valves 212 and 214 within the chambers 204 and 206 respectively are seated against the openings to the ducts 208 and 210 respectively, and are resiliently held in their seated positions by the arcuate heads of the plungers 216 and 218 respectively, which in turn are spring-pressed toward their respective ball valves 212 and 214 by the coiled springs 220 and 222. The ducts 224 and 226, partly within each of the housing members 20 and 30, communicate with the ducts 208 and 210 respectively and with the right side of the chamber 98—100 within which the rotor member 102 rotates. The left side of the chamber 98—100 communicates with the chamber 148 by way of the ducts 228 and 230 within the rotor housing member 32.

The ends of the ducts 200 and 202 removed from the ports 180 and 184 are suitably plugged by the respective screw-threaded tapered plugs 240 and 242. Similarly, screw-threaded tapered plugs 236 and 238 are provided to close the exterior ends of the valve chambers 204 and 206 respectively. By suitably adjusting the tension in the springs 220 and 222, the pressure at which the ball valves 212 and 214 open to discharge fluid from the ducts 208 and 210 may be readily predetermined, which pressure is preferably approximately atmospheric pressure or the hydraulic inlet pressure. The seated ball valves

212 and 214 serve as one way check valves to prevent the hydraulic fluid at the discharge pressure from entering either of the ducts 208 and 210.

From the foregoing, it is believed that the operation of the pump of the present invention is readily apparent. We may assume the rotation of the shaft 40 to be clockwise as indicated in Figs. 1 and 2, although the pump is completely reversible in every sense and performs equally well regardless of the direction of rotation of the shaft 40. Upon rotation of the knurled knob 162 in one direction or the other, as for example to the position shown in the drawings, the eccentric cam 156 keyed to the shaft 146 pivots the arms 144 of the yoke 136 about the pivot axis of the rotatable hydraulic bearings 122 and thereby tilts the axis of rotation of the rotor about the vertical axis of the bearings 122 by virtue of the forked engagement between the sides of the slots 128 and the rotor member 102.

The operation of the pump may be readily followed by reference to the schematic plan of the hydraulic system, Fig. 11, wherein the rotor is shown in the neutral position in coaxial alignment with the shaft 40. In this position, no pressures are developed by the pump and the output is zero. With the rotor tilted as shown in Figs. 1 and 2, the ports 180 and 184 become the hydraulic inlet and discharge ports respectively. The ducts 178L and 178R, the arcuate ports 174L and 174R, and the pressure equalizing ducts 188L and 188R, are all in hydraulic communication and become the complete inlet body of hydraulic fluid at the inlet fluid pressure. The complete discharge body of hydraulic fluid at the hydraulic discharge pressure is contained within the port 184, the conduits 182L and 182R, the arcuate ports 176L and 176R, and the pressure equalizing ducts 190L and 190R.

Considering first the action within the pumping recess 93R upon the aforesaid clockwise rotation of the rotor, hydraulic fluid enters the individual pumping chambers which are exposed to the arcuate port 174R, Fig. 1. As each individual pumping chamber on the right side of the rotor is carried across the port 174R, the said pumping chamber gradually increases in volume and creates a partial vacuum therein toward which hydraulic fluid flows from the arcuate port 174R, duct 178R, and inlet port 180. Upon continued rotation, the pumping chambers carry the entrapped fluid into the upper or discharge portion of the pumping recess 93R and across the arcuate port 176R. As the pumping chambers gradually rotate across the port 176R, they gradually decrease in volume and force the hydraulic fluid therein through the port 176R and out the discharge port 184 via the duct 182R. In a like manner, hydraulic fluid is conducted from the inlet port 180 to the pumping chambers on the left side of the rotor via the arcuate port 174L and is discharged through the arcuate port 176L to the discharge port 184.

As may be readily observed in Fig. 11, assuming the rotor to be tilted as shown in Figs. 1 and 2, the inlet pressure on the lower right side of the rotor in communication with the arcuate inlet port 174R is counterbalanced by the inlet pressure delivered to the lower pressure balancing chamber 130 on the left side of the member 102 via the duct 188L. The inlet pressure on the upper left side of the rotor in communication with the arcuate inlet port 174L is counterbalanced by the inlet pressure communicated to the upper pressure balancing chamber 130 on the right side of the member 102 via the duct 188R. The hydraulic discharge pressure on the lower left side of the rotor in communication with the arcuate discharge port 176L is counterbalanced by the discharge pressure conducted to the lower pressure balancing chamber 130 on the right side of the member 102 by way of the duct 190R. The discharge pressure on the upper right side of the rotor in communication with the arcuate port 176R is counterbalanced by the discharge pressure conducted to the upper pressure balancing chamber 130 on the left side of the member 102 via the duct 190L. Thus the rotor is maintained in hydraulic balance regardless of the angle of its axis of rotation. Thrust between the rotor member 102 and the forked bearings 122 is essentially eliminated and pivoting of the axis of rotation of the rotor is permitted without appreciable effort. The output of the pump is thereby readily varied or reversed in direction without appreciable strain on the pump mechanism, except for changes in the driving torque. Since the rotor is floated freely relative to the drive shaft 40, the only appreciable torque on shaft 40 is about its axis of rotation. Accordingly, the use of relatively small bearings 44 and 60 is permitted for journaling the shaft 40, increasing both the operating economy and efficiency of the pump.

The angle between the axis of rotation of the rotor and the shaft 40 determines the rate of volume variation of the pumping chambers upon rotation of the rotor and thereby determines the output of the pump. The pump will accordingly be at its maximum output in one direction or the other when tilted in either direction to the maximum allowable tilt, and will have zero output when the rotor is in coaxial alignment with the shaft 40. Thus there is provided a balanced, infinitely variable vane-type pump, which is reversible as to inlet and discharge ports without changing the direction of rotation of the drive shaft 40. Inasmuch as the rotor rotates about a constant axis of symmetry for uniform output, strains, which are ordinarily set up in the wobble-plate type of pump or the type of pump wherein the rotor is an integral part of the drive shaft, are avoided in the present invention.

Although the vanes 92 are slidable within their slots 90, they are restrained by the inner periphery of the member 102 from radial movement resulting from centrifugal force. Thus friction contact and wear between the vanes 92 and the stationary surfaces of the housing resulting from centrifugal force is avoided. It follows as a corollary that leakage of hydraulic fluid around the vanes within the pumping recesses 93L and 93R, as a result of wear, is also minimized, assuring optimum operating efficiency throughout prolonged use.

By the above disclosure, novel and important improvements have been provided in a variable delivery reversible vane-type hydraulic pump, whereby the volume and direction of output may be readily varied merely by tilting the axis of rotation of the rotor, whereby an efficient and economically maintained operation is achieved with a minimum of wear between the rotating vanes and stationary parts of the pump, whereby simplified and improved hydraulic bearing means are provided for tilting and maintaining the axis of the rotor in a preselected position, and whereby the hydraulic pressures exerted on

the rotor during normal operation are hydraulically counterbalanced.

I claim:

1. In a rotor type pump including a rotor having an operative pumping portion and an external portion and also including a rotor housing, a pumping recess in said rotor housing, the pumping portion of the rotor being rotatable within said pumping recess, means to counterbalance forces on said rotor and including means to conduct pressure from said recess against portions of said rotor external to said recess, said external portions being spaced radially outwardly from the axis of rotation of said rotor and also being spaced radially outwardly from said pumping portion.

2. In a pump having a rotor operatively mounted for changing the axis of rotation thereof relative to stationary portions of said pump, said rotor having annular portions, means to change said axis of rotation and including pivotally mounted forked bearing means having the annular portions of said rotor disposed between and slidable within the fork prongs.

3. In a pump having a pumping recess formed between a stationary housing and a rotor, the latter being mounted for changing its axis of rotation, the combination of a forked hydraulic bearing means pivotally mounted within said housing and having portions of the rotor disposed between the fork prongs and adapted to engage the same for pivoting the axis of rotation of said rotor, said hydraulic bearing means including a hydraulic pressure balancing chamber in hydraulic communication with the pressure of said pumping recess and opening against portions of said rotor.

4. In a variable delivery vane-type hydraulic pump having a stationary housing and a rotor, the combination of a pumping recess having spaced sidewalls comprising portions of said housing and said rotor, hydraulic inlet and discharge ports communicating with separate portions of said pumping recess, means to carry fluid from one portion of said pumping recess to another and including a plurality of vanes extending outwardly from and carried by said rotor for rotation therewith within said pumping recess and adapted for partitioning the latter into a plurality of rotating pumping chambers, said rotor being universally mounted for pivoting its axis of rotation so that the volume of said pumping chambers becomes progressively larger upon rotation within the portions of said pumping recess in communication with said inlet port and becomes progressively smaller upon rotation within the portions of said pumping recess in communication with said discharge port, said vane being movably mounted on said rotor to conform to variations in the spacing between the side walls of said housing and said rotor effected by pivoting of the axis of rotation of said rotor, means for selectively controlling said pivoting of the axis of rotation, and means external to said pumping recess to counterbalance operational pressures therein directed against said rotor and including inlet and discharge pressure balancing chambers in hydraulic communication with said inlet and discharge ports respectively and opening against portions of said rotor in opposition to the said operational pressures within said pumping recess.

5. The combination as claimed in claim 4 and being further characterized in that said rotor provides a peripheral pressure balancing member secured thereto in concentricity with the axis of rotation thereof, and in that said inlet and discharge pressure balancing chambers open against said pressure balancing member.

6. The combination as claimed in claim 5 and being further characterized in that said means for controlling the pivoting of said rotor's axis of rotation include a pair of diametrically opposed forked hydraulic bearings, the fork prongs of each bearing being engaged with opposed sides of said pressure balancing member for pivoting thereof upon the pivoting of said forked bearings, and in that said inlet and discharge pressure balancing chambers are provided within said forks.

7. The combination as claimed in claim 4 and being further characterized in that said means for controlling the pivoting of said rotor's axis of rotation include a pair of diametrically opposed pivotally mounted forked bearings having portions of said rotor disposed between and engaging the fork prongs thereof, and in that the said inlet and discharge pressure balancing chambers are provided within said prongs.

8. In a variable delivery vane-type hydraulic pump, the combination of a stationary housing, a rotor within said housing, an annular pumping recess on each of the axially opposed sides of said rotor, each recess having spaced sidewalls comprising portions of said housing and said rotor, said housing and said rotor being operatively mounted for tilting relative to each other to provide inlet and discharge portions within each of said pumping recesses wherein the volume per unit circumferential distance taken in the direction of rotation of said rotor becomes progressively larger throughout each inlet portion and becomes progressively smaller throughout each discharge portion, hydraulic inlet and outlet conduits communicating with each pumping recess at the inlet portions and outlet portions thereof respectively, vane means carried by said rotor for moving fluid within said pumping recesses from the inlet portions thereof to the discharge portions thereof, means for controlling the said relative tilting between said housing and rotor so as to selectively vary the progressive circumferential volume variation within said pumping recesses, said rotor also having portions extending externally of the recesses, and means to counterbalance operational forces on said rotor and including pressure balancing chamber means in hydraulic pressure communication with said pumping recesses and opening against portions of said rotor external to said recesses and in opposition to said forces.

9. The combination as claimed in claim 8 and being further characterized in that said pressure balancing chamber means include a pair of discharge pressure balancing chambers, one of each being disposed to counterbalance torque on said rotor perpendicular to its axis of rotation and resulting from the pressure within the discharge portions of one of each of the said two pumping recesses, and a pair of inlet pressure balancing chambers, one of each being disposed to counterbalance torque on said rotor perpendicular to its axis of rotation and resulting from the pressure within the inlet portions of one of each of said two pumping recesses.

10. The combination as claimed in claim 8 and being further characterized in that said means for controlling the relative tilting between said housing and said rotor include a pair of diametrically opposed pivotally mounted

forked bearings having the fork prongs engaged with said rotor for pivoting thereof.

11. The combination as claimed in claim 10 and being further characterized in that said diametrically opposed pivotally mounted forked bearings are pivotal about the diametrical axis therebetween, each of said forked bearings provides a pair of spaced forked prongs extending radially inward to engage axially opposed sides of said rotor for pivoting the latter about said diametrical axis, said pressure balancing chamber means include four pressure balancing chambers, one pressure balancing chamber being provided by each of the said four prongs engaged with said rotor, two of said pressure balancing chambers are in hydraulic pressure communication with the discharge pressure of said pumping recesses, the other two of said pressure balancing chambers are in hydraulic pressure communication with the inlet pressure of said pumping recesses.

12. The combination as claimed in claim 8 and being further characterized in that said rotor provides a peripheral pressure balancing member secured thereto in concentricity with the axis of rotation thereof, and in that said pressure balancing chamber means open against portions of said pressure balancing member.

13. In a variable delivery vane-type hydraulic pump, the combination of a rotor housing having internal sides, a rotor rotatable within said housing and having axially opposed sides, a pair of pumping recesses formed between the axially opposed sides of said rotor and the sides of said rotor housing, a plurality of spaced vanes carried by said rotor for rotation within said pumping recesses and extending transverse to the direction of rotation to partition each of said pumping recesses into a plurality of pumping chambers, said vanes being mounted on said rotor for relative slidable movement transverse to its direction of rotation, a drive means for said rotor, a universal coupling between said drive means and rotor to permit changing of the axis of rotation of said rotor so that said pumping chambers gradually decrease in volume while rotating within one portion of each of said pumping recesses and gradually increase in volume while rotating within another portion of each of said pumping recesses, means for selectively changing the axis of rotation of said rotor, hydraulic inlet and discharge conduits communicating with each of said pumping recesses at the portions thereof whereas the pumping chambers increase in size and decrease in size respectively, a peripherally disposed pressure balancing member secured to said rotor concentrically with its axis of rotation, a plurality of pressure balancing chambers, each chamber being in hydraulic communication with either the discharge pressure or the inlet pressure of said pumping recesses and opening against selected portions of said pressure balancing member to counterbalance said rotor against the corresponding inlet or discharge pressure exerted on said rotor within said pumping recesses.

14. The combination as claimed in claim 13 and being further characterized in that said means for changing the axis of rotation of said rotor include a pair of diametrically opposed pivotally mounted forked bearings pivotal about the diametrical axis therebetween, each of said forked bearings having a pair of spaced forked prongs extending radially inward to engage axially opposed sides of said pressure balancing member for pivoting said rotor about said diametrical axis, one of each of said pressure balancing chambers being provided by one of each of the said prongs engaged with said pressure balancing member.

15. The combination as claimed in claim 14 and being further characterized in that the inner periphery of said peripherally disposed pressure balancing member engages portions of the outer periphery of each of said vanes to resist the centrifugal force of said vanes.

16. In a variable delivery vane-type hydraulic pump, the combination of a stationary housing, a rotor mounted within said housing for selectively pivoting its axis of rotation, a pumping recess formed between said rotor and said housing, means to carry fluid from one portion of said pumping recess to another and including a plurality of vanes carried by said rotor for rotation therewith, and mounted thereon for partitioning said pumping recess into a plurality of rotating pumping chambers, said vanes being movably mounted on said rotor to permit said selective pivoting of its axis of rotation so that said pumping chambers gradually decrease in volume while rotating within one portion of said pumping recess and gradually increase in volume while rotating within another portion of said pumping recess, an inlet port opening into the portion of said pumping recess whereat said pumping chambers increase in volume, an outlet port opening from the portion of said pumping recess whereat said pumping chambers decrease in volume, and means to control the said selective pivoting of the rotor's axis of rotation, said means for controllng the selective pivoting of the axis of rotation of said rotor including a pivotally mounted forked bearing having the forked prongs engaged with opposite portions of said rotor for pivoting the latter upon selective pivoting of said forked bearing.

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REFERENCES CITED

The following references are of record in the file of this patent:

UNITED STATES PATENTS

Number	Name	Date
1,777,923	Johansson	Oct. 7, 1930
2,017,825	Woodford	Oct. 15, 1935
2,353,780	Neuland	July 18, 1944

FOREIGN PATENTS

Number	Country	Date
426,928	Great Britain	Apr. 11, 1935
444,970	Great Britain	Apr. 1, 1936
485,660	Great Britain	May 24, 1938
626,506	Germany	Feb. 27, 1936