March 15, 1949. G. A. WALDIE 2,464,736

SPHERICAL EXPANSIBLE CHAMBER ROTARY MOTOR OR PUMP
OF THE AXIALLY MOVING SLIDING VANE TYPE

Original Filed Dec. 18, 1941 2 Sheets-Sheet 1

FIG. 1

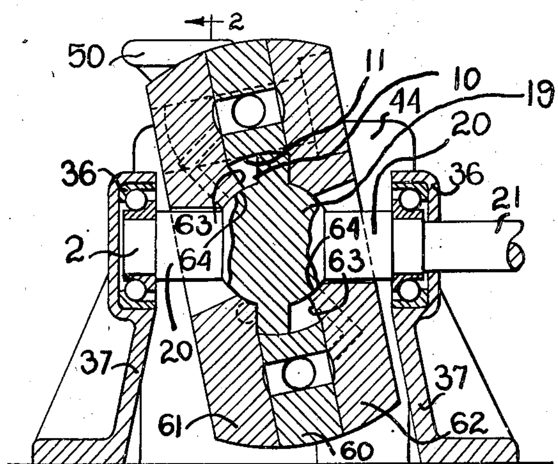
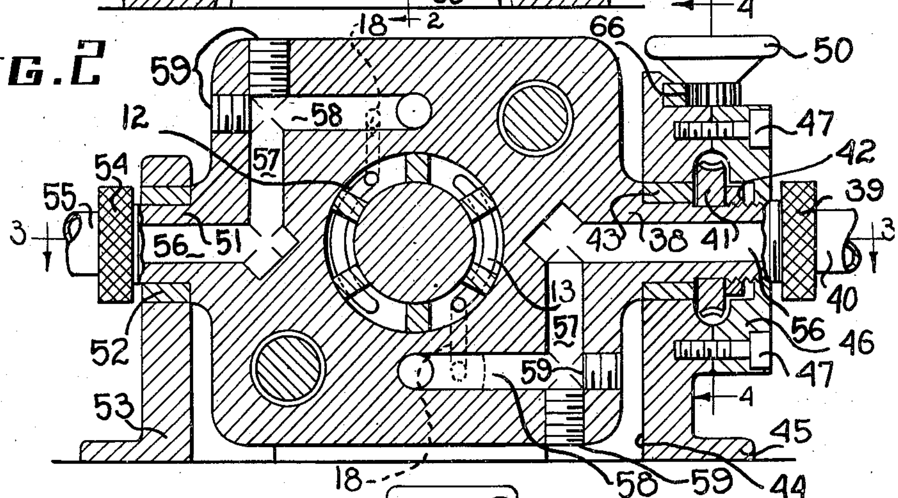


FIG. 2



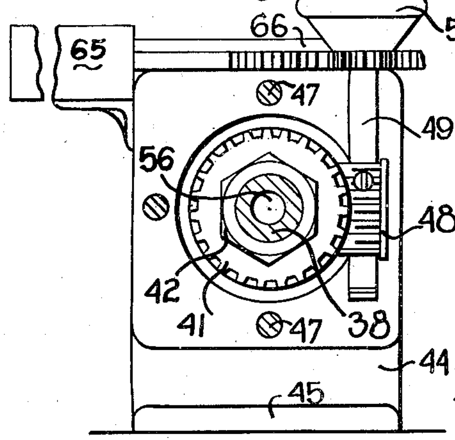


FIG. 4

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FIG. 3

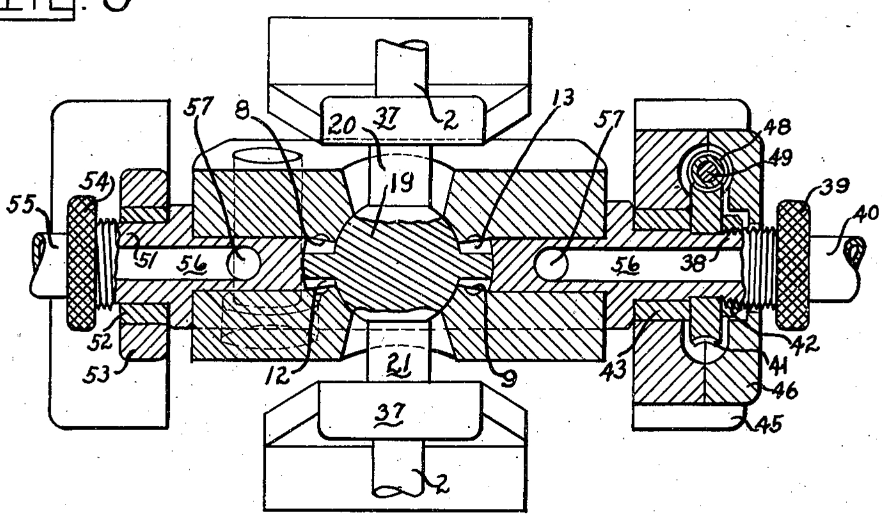


FIG. 5

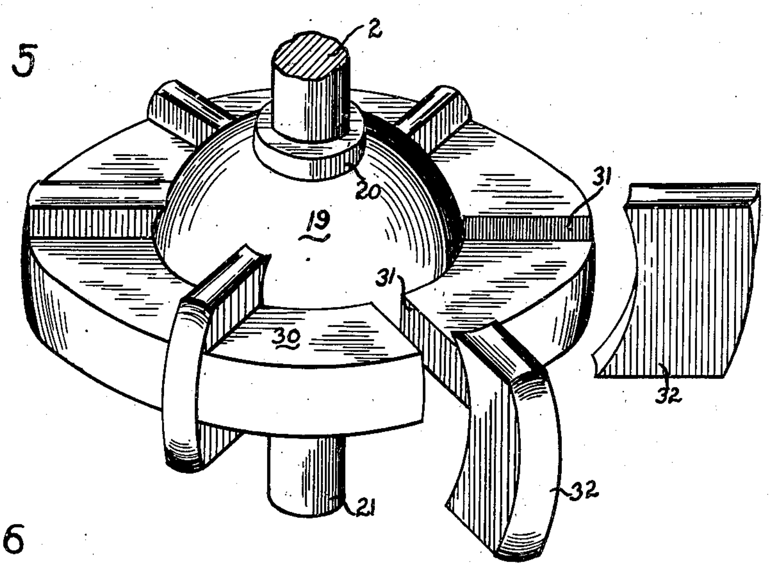
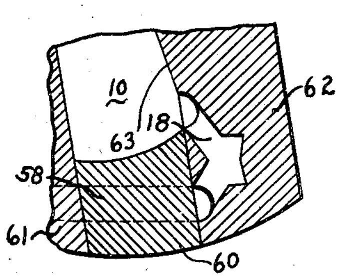


FIG. 6



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SPHERICAL EXPANSIBLE CHAMBER ROTARY MOTOR OR PUMP OF THE AXIALLY MOVING SLIDING VANE TYPE

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Original application December 18, 1941, Serial No. 423,486, now Patent No. 2,380,886, dated July 31, 1945. Divided and this application April 28, 1943, Serial No. 484,809

11 Claims. (Cl. 103—139)

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The present invention relates to pumps, and more particularly to high pressure oil pumps. This application is a division of my prior application, Serial No. 423,486, filed December 18, 1941, which issued as Patent No. 2,380,886, July 31, 1945, and entitled "Balanced ball type vane pump or motor."

A real need exists, in a number of important uses, for a light-weight, fast-moving oil pump of smaller size and which can handle relatively large amounts of fluid at fairly high pressure to perform work or to exercise a control function of a positive character. For example, in the case of airplanes, it may be desirable to move the control surfaces of the wing and tail by hydraulic pressure produced by a pump. In the case of a pump, the pressure is instantaneously available for fast control, whereas in the case of control exercised by an electric motor the energy of the motor is not available until the motor shall have come up to speed. The main disadvantage of the prior-art pumps, when used in this particular connection, is the weight and bulk of the pump, particularly when the pump must handle large quantities of pressure fluid to exercise a considerable number of control functions, perhaps simultaneously.

The primary object of the present invention is to provide a pump which can handle large quantities of fluid at high pressure, such as oil, and yet is of camparatively small size. From one aspect, therefore, the invention contemplates a pressure pump which has a high volumetric fluid capacity, as compared to its size.

Another object is to provide a pump of this character, in which the prime mover which actuates the pump (usually an engine or an electric motor) will rotate in the same direction, but delivery at the pump can be reversed without the use of reversing valves so that the reversal of flow is accomplished within the pump.

A further object is to provide a pump which may be made of relatively few parts, easily machined, and of light weight when desired, and which can be readily assembled and disassembled for inspection purposes.

These objects are attained, in brief, by providing a closed compartment formed of blocks of any suitable material having tapered, active surfaces, and by rotating a rotor within the compartment in such a manner that the space on each side of the rotor is divided by the rotor blades into suction and pressure chambers. The blocks may be rotated or rocked about an axis, angularly disposed with respect to the axis of

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the rotor shaft to change the suction and pressure action of the various parts of the rotor and thus to reverse the direction of fluid delivery.

The invention will be better understood when the following specification is read in connection with the accompanying drawings.

In the drawings:

Figure 1 is a vertical sectional view of the improved pump, in which provision is made for reversing the direction of flow at the pump.

Figure 2 is a sectional view taken along the line **2—2** in Figure 1.

Figure 3 is a sectional view taken along the line **3—3** in Figure 2.

Figure 4 is a view taken along the line **4—4** in Figure 2, i. e., with the right-hand bolted cover member of Figure 2 removed to expose the worm and gear wheel mechanism. In Figure 4 the hand wheel which operates the worm gear is shown in elevation.

Figure 5 is a perspective view of the rotor, showing the movability of the blades with respect to the rotor disc or web.

Figure 6 is an enlarged fragmentary vertical sectional view taken through the pump casing and disclosing the relationship between the pumping chamber and its communicating passages.

The drawings show a reversible pump in which the actuating motor or prime mover is permitted to run in the same direction and yet provide for a reversal of delivery. In general, the construction is such that the chamber which has been momentarily exerting a pressure effect when the rotor is turned and the pumping chamber extends at a definite angle with respect to the rotor shaft, now becomes an exhaust or suction chamber when the pumping chamber extends at an opposite angle with respect to the shaft. For this purpose, the pump casing is permitted to rotate in the horizontal plane.

Describing this modification specifically, the rotor **19** and its shaft **2** are journalled in the ball bearings **36** carried on a pair of pedestals **37**. The pump casing is constructed of a number of blocks all bolted together and provision is made for rotating the casing about a horizontal axis and to provide an improved port arrangement by which the pump casing can be rotated.

Construction of the rotor

The rotor forms a continuation of the main driving shaft **2** and takes on a spherical configuration, as indicated at **19**. Hubs **20** extend laterally from opposite sides of the rotor, the left-hand hub (Figure 1) merging with the shaft 2 and the right-hand hub terminating in a shaft portion 21. The blocks 61 and 62 are provided with openings which loosely receive the hubs 20.

The blocks 61 and 62 are provided with recesses of a partial spherical shape to conform to the shape of the spherical rotor and to permit the rotor to rotate between the blocks when the motor (not shown) is energized. The central or spherical portion of the rotor is provided with a radially extending and vertically directed web 30 which extends around the sphere 19 as an annular ring, and preferably is formed integral with the sphere. The web and sphere may be formed of any hard wearing material, such as metal or certain types of plastics, and in case weight is an important consideration the metal may be a magnesium or aluminum alloy. It will be noted from Figure 1 that the size and position of the pumping chamber 10 and the positional relationship of the annular web 30 are such that the outermost peripheral edges on opposite sides of the web 30 coincide with the joint formed between each arcuate shaped surface 11 and the surfaces 8 and 9 of the two blocks.

The annular ring 30 is provided with a plurality of radially extending slots 31 (six as shown) and illustrated more clearly in Figure 5, these slots extending inwardly as far as the peripheral surface 19. These slots snugly but slidably receive the vanes or blades 32, these blades being formed of a tough, long-wearing material and are preferably machined on all sides. It will be noted that the height of each blade is considerably greater than the vertical depth (Figure 5) of the ring 30. The blades may take the form generally of a trapezoid or rectangle, but their inner edges are curved both in the vertical and horizontal directions to conform with the spherical shape of the element 19. The outer vertical edges are curved in the vertical and horizontal directions to conform to the arcuate shape of the surface 11 (Figure 1) and also to the circular configuration of the chamber 10. The top and bottom edges of each blade are also given a convex curvature to accommodate the blade to the tapered surfaces 8, 9 as the rotor is rotated.

The casing is provided at its right-hand end, as seen in Figure 2, with a multi-shouldered shaft 38 which is threaded at one end to receive a thumb nut 39. This nut may be secured to the conduit 40 through any suitable and well known form of slip joint to permit the pump casing to swing with respect to the conduit. A worm gear 41 is fixedly secured to the shaft by a nut 42, this worm gear being spaced from the pump casing by a bearing bushing 43. The latter is journalled in a plate 44, provided with a flanged leg 45. A cover plate 46 is bolted as at 47 to the plate 44, this cover plate leaving exposed only a portion of the worm gear 41. A screw 48 carried on a rod 49 is adapted to mesh with the worm gear 41 when the rod is rotated by the hand wheel 50.

At the opposite side of the pump the casing terminates in a multi-shouldered shaft 51, which is journalled through a bushing 52 in an upstanding plate 53. The shaft 51 carries screw threads which receive a thumb nut 54, the latter rotatably carrying a conduit 55. It is apparent that when the hand wheel 50 is rotated the worm

gear 41, which is rigidly fixed to the shaft 38, will cause the pump casing to be rotated around a horizontal axis which extends through the journals 43, 52. In order to provide for the inlet and outlet ports which communicate with the pressure and suction chambers on opposite sides of the rotor through arcuate slots 12, 13, holes 56 are drilled in line with the openings in the conduits 40, 55 and therefore along the axis of rotation. These openings communicate with openings 57 which extend outwardly and communicate with the horizontal openings 58. The latter are connected to the slots 12, 13 by the passageways 18 (Figure 2). These passageways do not run parallel with the tapered surfaces 63 but instead extend first downwardly into the metal of the blocks 61, 62 from the ports 58 and then upwardly to reach the slots 12, 13 as is indicated in Figure 6.

In order to facilitate the formation of the holes 57, 58, these may be drilled from the side and outer surfaces of the pump casing and the excess length of the openings tapped and filled by a set screw 59. Consequently, as the hand wheel 50 is rotated to move the pump casing from one side of the vertical axis to the other side, the pumping cavities of the chambers on both sides of the rotor web undergo reversals of function. The pressure cavities will exert a suction effect and the suction cavities will exert a pressure effect so that the passage of fluid through the pump is completely reversed, notwithstanding the fact that the shaft 2 continues to rotate in the same direction.

It is apparent from a consideration of Figure 1 that only a small rotary movement of the pump is necessary to reverse the pressure and suction effects of the pumping cavities formed between the vanes 32 and the casing blocks 61, 62. In order that the pump casing may swing in the longitudinal direction with respect to the rotor shaft, the intermediate block 60 is given substantially parallel sides, and the blocks 61, 62 are also given a corresponding shape. Actually, only the abutting surfaces of the blocks 61, 62 are arranged parallel because the sides of the pumping chamber directly adjacent the rotor web are given inwardly extending flared portions, as indicated at 63. These portions serve to lengthen the distance indicated at 64 over which leakage would have to take place between the blocks 61, 62 and the peripheral surface of the sphere 19. The pump casing in Figure 1 is always positioned at an angle with respect to the rotor shaft.

When the pump casing, for example, is canted to the left, as shown in Figure 1, let us assume that the position of the ports and of the interconnected pair of slots 12, 13 on opposite sides of the rotor and the remaining interconnected pair of slots 12, 13 is such that the pump delivers pressure fluid at the conduit 40. However, when the pump casing is given a cant to the right by the wheel 50, pressure fluid will now be delivered at the conduit 55, assuming that the shaft 2 is being rotated in the same direction as before. Consequently, the hand wheel 50 serves as a means for reversing the flow of delivery of the pump. This arrangement may be advantageous in those cases where an electric motor is designed to operate more efficiently in one direction than in the other, and also to save the cost of a reversing switch in the motor circuit. It is further apparent that inasmuch as the motor never stops during the reversal of the fluid delivery, the flow of the fluid is available immediately. This would not be true in case the electric motor were reversed, because a definite time would elapse to stop the motor and then to start the motor in the reverse direction, and during this time the pump would not be delivering fluid at its predetermined pressure.

The wheel **50** may also be employed to swing the pump casing through any angle, in either direction, and less than its full limit of movement in order to vary the output of the pump in either direction. The swingable form of pump shown in Figure 1 is also adapted to rock to its neutral or no-delivery position when, for example, the back pressure at the outlet becomes excessive, or if as a safety measure it is desired the discharge of the pump shall cease. It will be noted in Figure 4 that the gear **41** and worm **48** transmit power only in one direction, so that when the pump has been given any desired cant by the wheel **50** it will maintain this position and will produce a constant output of pressure fluid in any desired amount until the wheel **50** has been further rotated.

However, on occasion, it may be desirable to permit the pump to swing to its vertical or no-delivery position when the back pressure on the pump becomes excessive. Auxiliary and additional hydraulic areas responsive to this back pressure may be provided for this purpose if necessary. In such case a reversible form of mechanical connection (not shown) would be provided between the control wheel **50** and the pump swinging mechanism. The back pressure within the pump would then tend to swing the pump casing to such a position as to relieve the excessive back pressure, and if necessary would move the casing all the way to its neutral or no-delivery position. In Figure 1 the no-delivery position would cause the casing to move into a vertical plane, in which position the volumes of the pumping and suction compartments on the same side of the rotor but on opposite sides of the shaft would be equal, and the fluid would merely flow as eddies within the pump, producing no pressure at the outlet.

In Figure 4 there is shown a mechanism by which the pump casing can be automatically moved to its neutral or no-delivery position without sacrificing the non-reversible character of the mechanical connection between the control wheel **50** and the pump swinging mechanism. Reference numeral **65** designates any suitable and well known form of device which responds to any type of impulse, pneumatic, electrical or mechanical, as for example, when the back pressure developed at the pump becomes excessive or when the device **65** is actuated by the platen of a press supplied with fluid from the pump. Under the conditions of excessive back pressure, or when the platen has reached a predetermined position, the device **65** may be actuated in any suitable manner to move a rack **66** and thus to rotate the worm **48**. In other words, the gear **41**, shown in Figure 4, may be operated either manually at the wheel **50** or automatically in response to any desired form of impulse operating on the device **65**. This device may even be a time-operated relay which would serve to cut off the pump at any given predetermined time of the day or night, and vice versa. The device **65** may also be employed to start the pump in one or the other direction, as may be desired at any predetermined time.

From the foregoing it is evident that I have disclosed a pump which operates on an entirely different principle from that heretofore employed, in that the change-over from suction pressure effect and vice versa is rapidly effected by the transverse movement of the vanes or blades **32**, which are constrained to make such a movement by the tapered contour of the pump chamber. In the reversing form of pump as shown in Figures 1 to 4, this taper may be changed from one side to the other by merely rotating the pump casing about a lateral axis with respect to the rotor, thus simultaneously reversing the action of all of the spaces contained between the blades of the rotor.

While I have described my invention as pertaining to a relatively small pump, such for example as may be used for control purposes in an airplane or other place where space is at a premium, it will be understood that the principles of the invention apply equally well to pumps of much larger size. In the case of large size pumps, for example those pumps which may be employed in connection with hydraulic presses, it may be feasible to mount the blades **32** on roller bearings in order to reduce friction in the slots **31**, but in general it is sufficient to provide merely a nicety of fit between the blades and the slots **31** and to case harden, if desired, the sliding surfaces. In order to cut down weight it may be advisable to cast the rotor **19** with a hollow interior, because obviously the shell of the spherical portion need not be thick, due to the self-supporting action inherent in a sphere.

It will be understood that I desire to comprehend within my invention such modifications as come within the scope of the claims.

Having thus fully described my invention, what I claim as new and desire to secure by Letters Patent, is:

1. A fluid pump having a housing which forms a pumping chamber, a rotor shaft, a rotor mounted on said shaft within said chamber, said chamber being of symmetrical cross section and the line of symmetry extending at an angle other than normal with respect to the axis of the shaft, a plurality of pairs of vanes slidably received by the rotor at equidistant positions thereabout and extending in the direction of the shaft, inlet and outlet conduits in communication with opposite sides of the pumping chamber, each of said conduits extending over a distance subtended by at least three adjacent vanes and means for varying the angularity between the axes of the pumping chamber and the rotor in order to vary the delivery of the pump.

2. A fluid pump having a housing which forms a pumping chamber, a rotor shaft, a rotor mounted on said shaft within said chamber, said chamber being of symmetrical cross section and the line of symmetry extending at an angle other than normal with respect to the axis of the shaft, a plurality of pairs of vanes slidably received by the rotor at equidistant positions thereabout and extending in the direction of the shaft, inlet and outlet conduits in communication with opposite sides of the pumping chamber, each of said conduits extending over a distance subtended by at least three adjacent vanes, and means for moving the housing to a position such that the main axis of the pumping chamber is parallel to the axis of rotation of the rotor whereby the delivery of the pump becomes zero.

3. A fluid pump having a housing which forms a pumping chamber, a rotor shaft, a rotor mounted on said shaft within said chamber, the walls of said chamber extending at an angle other than normal with respect to the axis of the

shaft, a plurality of pairs of vanes slidably received by the rotor and arranged equidistantly thereabout, said vanes extending in the direction of the shaft, an inlet conduit effectively in communication with the suction side of the pump and an outlet conduit effectively in communication with the pressure side of the pump, and means for moving the housing between two positions in one of which the line of symmetry of the housing extends at a predetermined angle with respect to the axis of the shaft and in the other of which the line of symmetry of the housing extends at an opposite angle with respect to the axis of the shaft.

4. A fluid pump having a housing which forms a pumping chamber, a rotor shaft, a rotor mounted on said shaft within said chamber and adapted slidably to receive a plurality of vanes extending longitudinally of the shaft and equidistantly positioned about the rotor, the interior surface of said chamber having a configuration such that when the rotor is turned the vanes slide with respect to the rotor from one side of the chamber to the other side and independently of one another, and an inlet conduit communicating with the suction side of the pump and an outlet conduit communicating with the pressure side of the pump, a frame, said housing being pivotally mounted on said frame to permit the housing to to swing in a direction substantially transverse of the shaft axis to control the direction of flow and amount of discharge from the pump.

5. A fluid pump having a housing which forms a pumping chamber, a rotor shaft, a rotor mounted on said shaft within said chamber and adapted slidably to receive a plurality of vanes extending longitudinally of the shaft and equidistantly positioned about the rotor, the interior surface of said chamber having a configuration such that when the rotor is turned the vanes slide with respect to the rotor from one side of the chamber to the other side and independently of one another, and an inlet conduit communicating with the suction side of the pump and an outlet conduit communicating with the pressure side of the pump, a frame, said rotor extending between diagonal corners of the pumping chamber and said housing pivotally mounted on said frame to permit the housing to swing in a direction substantially transverse of the rotor axis to control the direction of flow and amount of discharge from the pump.

6. A fluid pump having a housing which forms a pumping chamber, a rotor shaft, a rotor mounted on said shaft within said chamber, said chamber having a symmetrical shape in cross-section and the line of symmetry extending at an angle other than normal with respect to the axis of the shaft, a plurality of pairs of vanes slidably received by the rotor, said vanes extending in the direction of the shaft and equidistantly positioned about the rotor, an inlet conduit effectively in communication with the suction side of the pump and an outlet conduit effectively in communication with the pressure side of the pump, the sliding movements of said vanes within the rotor being independent of one another and determined solely by the changing shape of the pumping chamber as the rotor is turned, the vertical center line of the rotor being displaced at an angle with respect to the main axis of the pumping chamber whereby the housing makes an angle with respect to the rotor shaft, and means for rocking the housing about a lateral axis which extends through said shaft.

7. A fluid pump having a housing which forms a pumping chamber, a rotor shaft, a rotor mounted on said shaft within said chamber, said chamber having a symmetrical shape in cross-section and the line of symmetry extending at an angle other than normal with respect to the axis of the shaft, a plurality of pairs of vanes slidably received by the rotor, said vanes extending in the direction of the shaft and equidistantly positioned about the rotor, an inlet conduit effectively in communication with the suction side of the pump and an outlet conduit effectively in communication with the pressure side of the pump, the sliding movements of said vanes within the rotor being independent of one another and determined solely by the changing shape of the pumping chamber as the rotor is turned, the vertical center line of the rotor being displaced at an angle with respect to the main axis of the pumping chamber whereby the housing makes an angle with respect to the rotor shaft, and means for rocking the housing about a lateral axis which extends through said shaft, said means comprising a manually controlled device.

8. A fluid pump having a housing which forms a pumping chamber, a rotor shaft, a rotor mounted on said shaft within said chamber, said chamber having a symmetrical shape in cross-section and the main axis of the chamber extending at an angle other than normal with respect to the axis of the rotor whereby a pumping compartment and a complementary suction compartment are formed on each side of the rotor, a plurality of vanes slidably received by the rotor, said vanes extending in the direction of the shaft and equidistantly positioned about the rotor, a conduit effectively in communication with the suction side of the pump and a second conduit effectively in communication with the pressure side of the pump, the sliding movements of said vanes within the rotor being independent of one another and determined solely by the change in shape of the pumping chamber as the rotor is turned, and means for swinging said housing about a lateral axis which extends through the axis of the rotor to cause the pumping chamber to move as a whole with respect to the rotor whereby the pumping compartments on opposite sides of the rotor now become the suction compartments and the initial suction compartments become complementary pumping compartments in order to reverse the flow of fluid through the pump.

9. A fluid pump having a housing which forms a pumping chamber, a rotor shaft, a rotor mounted on said shaft within said chamber, said chamber being of symmetrical cross-section and the line of symmetry extending at an angle other than normal with respect to the axis of the shaft, a plurality of pairs of vanes slidably received by the rotor at equidistant positions thereabout and extending in the direction of the shaft, inlet and outlet conduits in communication with opposite sides of the pumping chamber, each of said conduits extending over a distance subtended by at least three adjacent vanes, an actuator for turning said rotor, and means for swinging the housing about a lateral axis which extends through the main axis of said rotor whereby the output of the pump is reversed notwithstanding the unidirectional movement of the rotor.

10. A fluid pump having a housing which forms a pumping chamber, a rotor shaft, a rotor mounted on said shaft within said chamber and extending between diagonal corners of said chamber, the walls of said chamber extending at an

angle other than normal with respect to the axis of the shaft, a plurality of pairs of vanes slidably received by the rotor and arranged equidistantly thereabout, said vanes extending in the direction of the shaft, an inlet conduit effectively in communication with the suction side of the pump and an outlet conduit effectively in communication with the pressure side of the pump, a frame, said housing being pivotally mounted on said frame to permit the housing to be rotated along an axis which extends laterally of said shaft, and means for moving the housing about said lateral axis to cause the rotor to extend between the opposite diagonal corners of said pumping chamber whereby the direction of fluid delivery is reversed.

11. In a fluid displacement device comprising a blade carrying element and a blade actuating element, said elements having opposed annular surfaces forming between them a work chamber of progressively varying width, one of said elements being rotatable with relation to the other element, each portion of said surface of said blade actuating element being in a line extending through and inclined with relation to the axis of rotation of said rotatable element, and a blade slidably mounted in said blade carrying element for longitudinal movement into and out of said work chamber about an axis transverse to the axis of rotation of said rotatable element and having constant engagement with said inclined surface of said blade actuating element for movement thereby.

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