July 31, 1945. G. A. WALDIE 2,380,886

BALANCED BALL TYPE VANE PUMP OR MOTOR

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FIG. 1

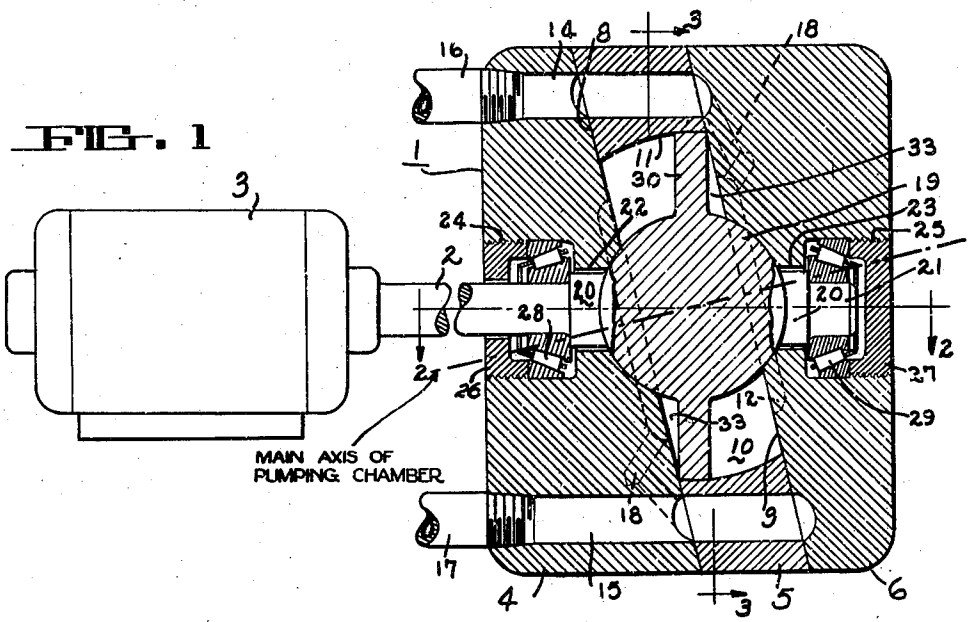



FIG. 2

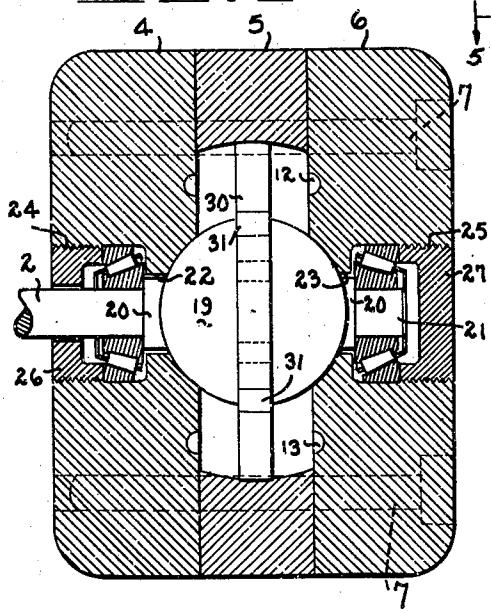
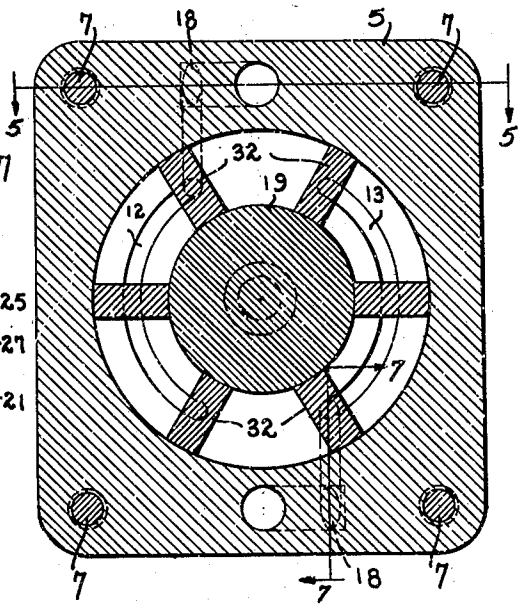


FIG. 3



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FIG. 5

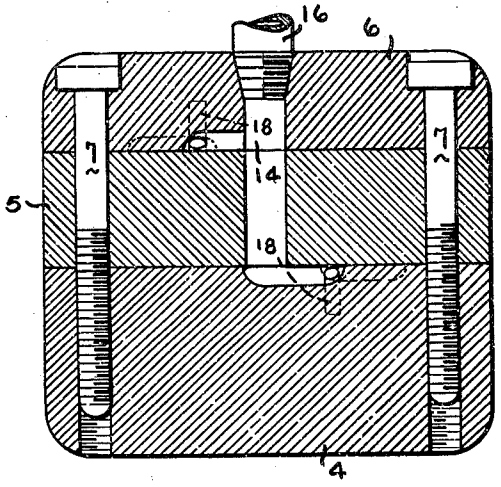



FIG. 4

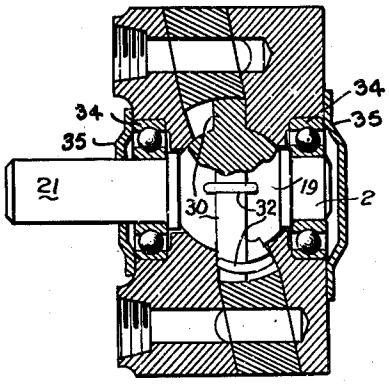



FIG. 6

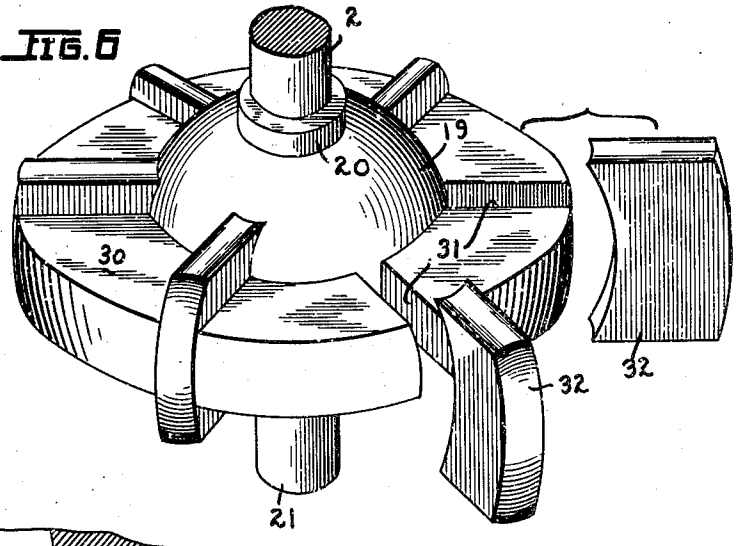
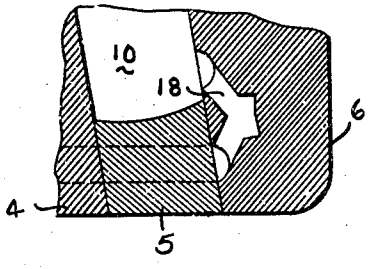



FIG. 7




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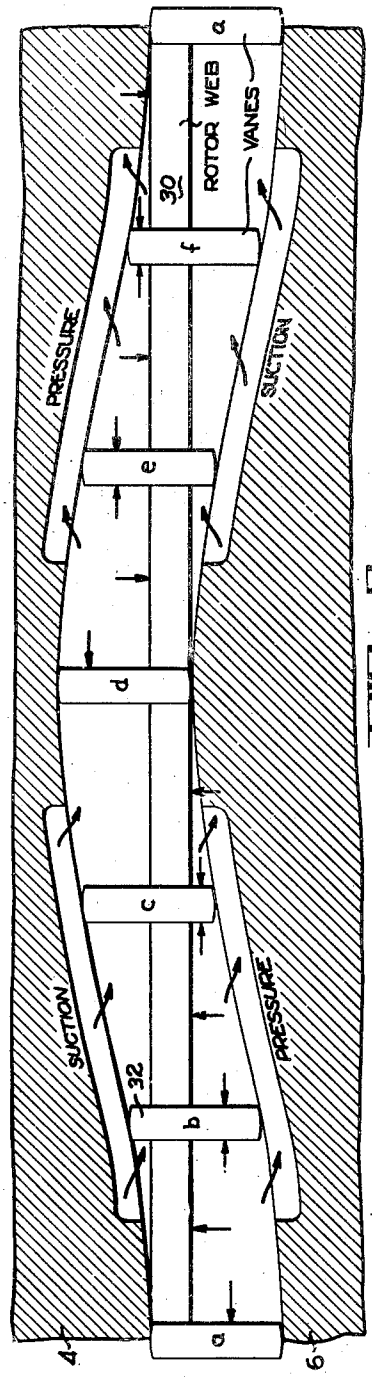



FIG. 8

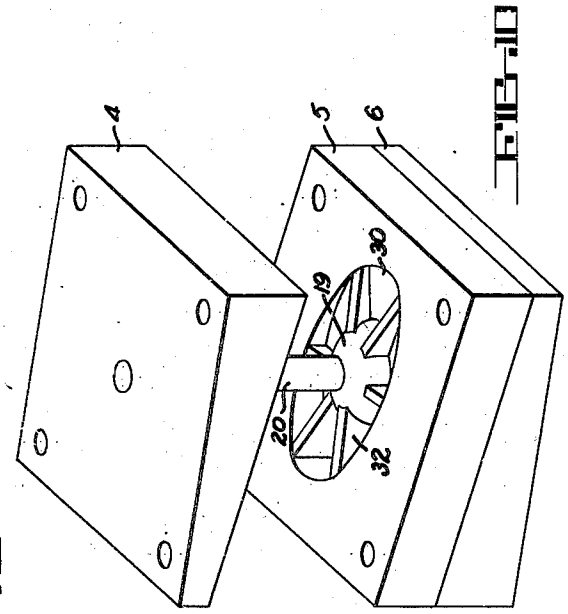



FIG. 10

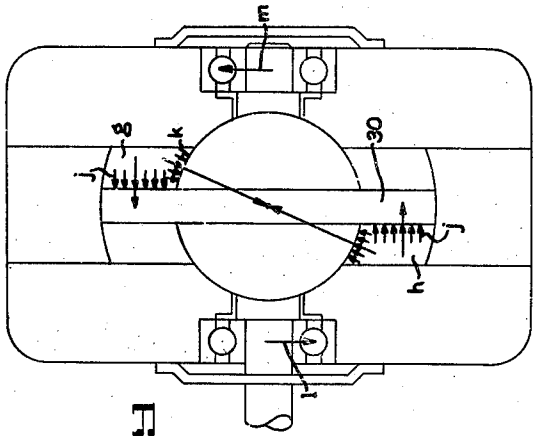



FIG. 9

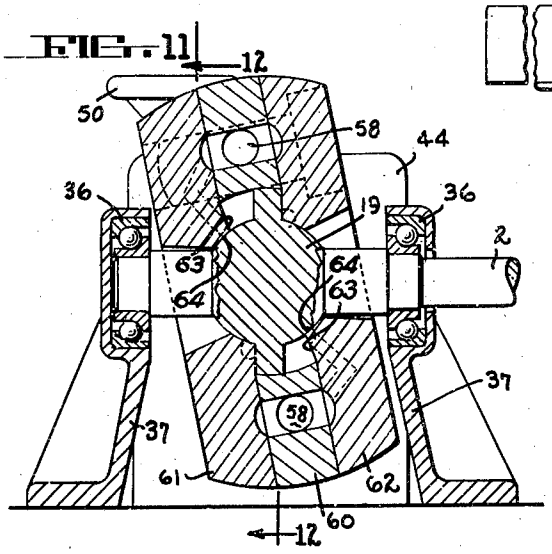
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FIG. 11



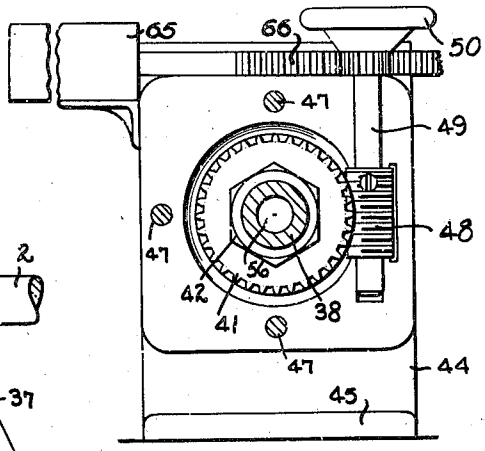




FIG. 14

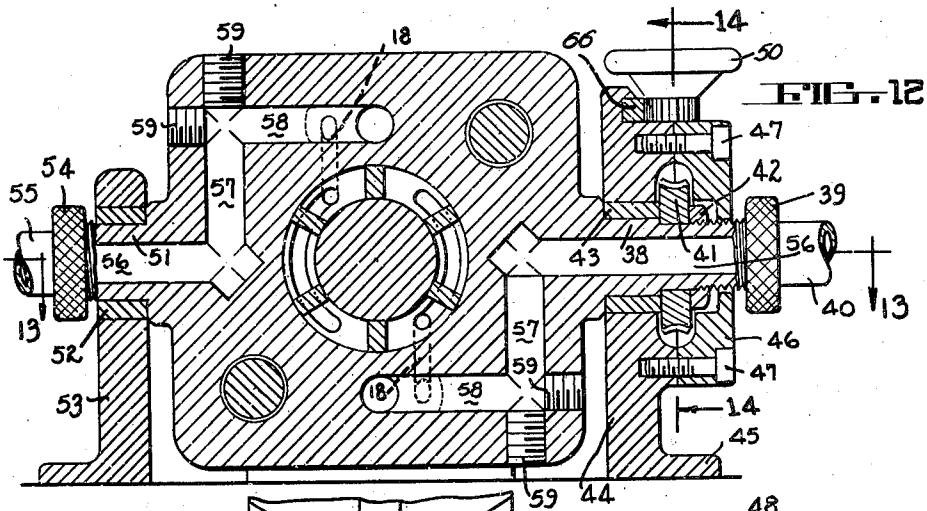



FIG. 12

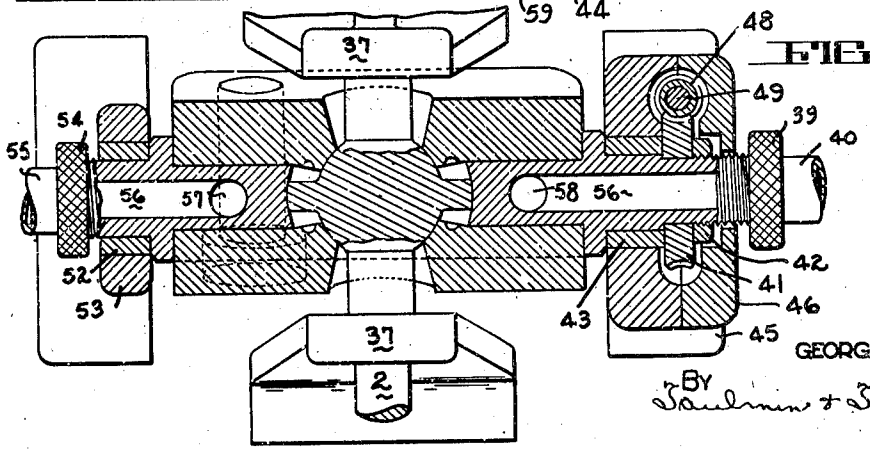



FIG. 13

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Patented July 31, 1945 2,380,886

# UNITED STATES PATENT OFFICE

2,380,886

## BALANCED BALL TYPE VANE PUMP OR MOTOR

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Application December 18, 1941, Serial No. 423,486

5 Claims. (Cl. 103—134)

The present invention relates to pumps, and more particularly to high pressure oil pumps.

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 air planes, 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 use 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 comparatively 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 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 assembly 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 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 view of a combined motor and pump mechanism showing the motor in elevation and the pump in section.

Figure 2 is a section of the pump taken along the line 2—2 in Figure 1.

Figure 3 is a vertical section taken along the line 3—3 of Figure 1.

Figure 4 shows a modified form of the improved pump including the use of ball bearings instead of roller bearings for rotatably supporting the rotor.

Figure 5 is a section taken along the line 5—5 in Figure 3.

Figure 6 is a perspective view of the rotor, showing the movability of the blades with respect to the rotor disc or web.

Figure 7 is a fragmentary corner view of the pump block, showing one of the passageways leading from the pumping chamber to the exterior port.

Figure 8 is a developmental view of the pumping chamber and rotor to show the action of the rotor blades in forming suction and pressure areas.

Figure 9 is a diagrammatic view of the improved pump to illustrate the directions in which the various pressures on the rotor operate, and the direction of the reacting thrust which must be provided at the bearings.

Figure 10 is a top perspective view of the pump, with the upper block portion partly removed to show the rotor and blades; also to indicate the manner in which the portions of the pump block are tapered.

Figure 11 is a vertical sectional view of a modified form of the improved pump, in which provision is made for reversing the direction of flow at the pump.

Figure 12 is a sectional view taken along the line 12—12 in Figure 11.

Figure 13 is a sectional view taken along the line 13—13 in Figure 12.

Figure 14 is a view taken along the line 14—14 in Figure 12, i. e. with the right-hand bolted cover member of Figure 12 removed to expose the worm and gear wheel mechanism. In Figure 14 the hand wheel which operates the worm gear and the worm gear are shown in elevation.

Referring more particularly to Figure 1, reference numeral 1 generally designates the improved pump from which a driving shaft 2 extends into a prime mover 3, which is usually an electric motor.

The improved pump 1 is constituted essentially of a plurality of blocks, indicated 4, 5, and 6, secured together at their corners by four or more bolts 7. These blocks may take any suitable shape, such as rectangular, and may be made of any tough material such as metal, Bakelite, etc., and if weight is of importance, magnesium or aluminum alloys may be used to advantage. In case weight is not important, these blocks may be made of cast iron or steel.

The two outer blocks 4 and 6 are provided with flat tapered surfaces, indicated at 8 and 9, these surfaces being preferably machined and extending substantially parallel to one another. These surfaces are spaced apart by the intermediate block 5 which, if desired, may form an integral portion of either of the two outer blocks. This intermediate block is cut on the bias so that when the blocks 4, 5 and 6 are assembled the outer surfaces of the blocks 4 and 6 extend in parallel directions, but the surfaces 8 and 9 extend diagonally across the combined block unit. The intermediate block 5 is provided with a large opening 10, which constitutes the pump chamber, this opening being of circular configuration, as shown in Figure 3, and having a curved periphery indicated at 11, for reasons which will be explained hereinafter. The main axis of the chamber has been indicated in Figure 1, and as shown is positioned at an angle with respect to the main axis of the motor.

The block 4 is provided with a pair of arcuate shaped slots, shown at 12, 13, these slots being arranged about a circle which is preferably concentric with the main axis of the pump, the end of one slot terminating at a considerable distance from the end of the adjacent slot so that the two slots are not interconnecting. The width and depth of these slots depend on the amount of fluid to be accommodated, and a section taken through the slots may show a semicircle or a rectangle. As will be explained hereinafter, these slots alternate as pressure and suction ports for the fluid which has been forced into or withdrawn from the slots by a rotating rotor, the details of which will be described presently.

In order to admit fluid into the pump chamber 10 through the slots 12, 13, ported openings 14, 15 are provided, these openings passing all the way through the block 4 and the intermediate block 5, and terminating at a position just below the tapered surface 9 of the block 6. The openings 14, 15 communicate with tubings 16, 17, one of which passes into the fluid supply tank (not shown), depending on the direction in which the pump is delivering fluid, and the other is taken to the position at which work is to be performed. This work may consist, for example, of moving an aileron or other control surface of an airplane (not shown), in which case the fluid pressure could be translated into a reciprocatory movement by a plunger and cylinder mechanism.

The right-hand block 6 (Figure 1) is provided with a pair of slots or grooves 12, 13, similar to those formed in the block 4, and the general arrangement is such that the slot 12 in block 4, on one side of the rotor, is connected through one of the ports 14, 15 with the slot 13 in the other block on the opposite side of the rotor. The remaining slot 12 of the first-mentioned block is connected through the other of the ports 14, 15 to the other slot 13 on the opposite side of the rotor. In other words, the diagonally positioned slots on the opposite sides of the rotor are connected together, and each pair communicates respectively with the ports 14, 15. Communication is made between the various slots 12, 13 and their respective ports 14, 15 through passageways 18 shown more clearly in Figure 7, although the passageways are also shown by way of dotted lines in Figures 1 and 3. It will be noted that these passageways do not run parallel with the tapered surfaces 8, 9 but instead extend first downwardly into the metal of the blocks 4, 6 from the ports 14, 15, and then upwardly to reach the slots 12, 13. The reason for this arrangement will be clear when the rotor structure and its operation have been described.

*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 4 and 6 are provided with openings 22 and 23, respectively, which loosely receive the hubs 20, these openings terminating at their outer ends in countersunk bores 24, 25 which contain the journals for the shafts 2 and 21. The bores 24, 25 are threaded to receive cap nuts 26, 27, these nuts bearing against a pair of oppositely positioned roller bearings 28, 29 for rotatably supporting the rotor.

The blocks 4 and 6 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 3 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 tapered 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 6, 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 width of each blade is considerably greater than the vertical depth (Figure 6) of the ring 30. The blades take the form generally of a 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 as shown in Figure 3. 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.

*Operation*

When the motor 3 (Figure 1) is energized and the shaft 2 rotated, the rotor 19, together with the annular ring 30, is also caused to rotate within the chamber 10. Due to the fact that the surfaces 8, 9 of the blocks 4, 6 are provided with a taper, as seen more clearly in Figure 10, rotation of the ring 30 will force the blades 32 slidably to reciprocate within the slots 31. Further consideration of this operation will show that the presence of the large space contained in the chamber to the left of the upper portion of the ring 30 (Figure 1) and to the right of the lower portion of the ring, will cause a suction effect, as in the case of an ordinary rotor. Fluid is therefore drawn through that conduit 16 or 17 which communicates with this space through one of the annular slots 12 in the block 4, and also through one of the slots 13 in the other block 6. These slots, of which there are two in each block as shown in Figure 3, are diagonally connected together to form pairs, and when one pair is functioning as an inlet port the other pair will be operating as an outlet port. Thus fluid is drawn into the larger spaces between the ring 30 and the tapered surfaces 8 and 9 of the pump blocks through one of the ports 14, 15 and the passageways 18, into one of the pairs of slots 12, 13.

As the rotor continues to rotate, that body of fluid contained between an adjacent pair of blades 32 tends to be squeezed into the smaller space 33 (Figure 1) because, as pointed out hereinbefore, each vane 32 is caused to move either to the right or left as the annular ring is rotated. The fluid in the small space 33 is therefore forced outwardly through one of the diagonally positioned pairs of slots 12, 13 and through the suitably positioned passageways 18, into the outlet port 14 or 15, depending on the direction of rotation and the instantaneous positional relationship between these ports, their communicating passageways and the pumping or suction portions of the pumping chamber.

This operation is shown most clearly in developmental Figure 8, which illustrates the manner in which the blades *a* to *f*, inclusive, all take different positions through an operating cycle. It will be noted, for example, that the blade *a* extends temporarily almost entirely downwardly from the web 30, whereas the blade *d*, which would correspond with the position of the blade *a* after the latter has moved from its full pressure to its full suction position, extends almost entirely upwardly from the web or ring 30. Thus each blade passes from a full pressure position to a full suction position for each half revolution of the rotor. The cooperation of the slots 12, 13, in providing the necessary passageways for the suction and pressure effects, is also clearly shown in Figure 8, and it is apparent that each diagonally positioned pair of slots permanently functions either for suction or pressure as long as the rotor is rotated in the same direction, but will reverse its function when the rotor is rotated in the opposite direction. A study of Figure 8 will also indicate the reason for curving the upper and lower edges of the blades *a* to *f* because, as these blades move across the tapered surfaces 8, 9, different points throughout the thickness of each blade will contact these tapered surfaces, necessitating a curved shape.

Figure 9 illustrates in diagrammatic form the forces which are acting on the blades 32 and the sphere 19 during operation of the pump. Assuming, for example, that the upper right-hand space *g* and the lower left-hand space *h* of the pump chamber 10 are momentarily pressure chambers, the pressure of the fluid can be resolved into forces indicated at *j* which act in the horizontal direction against opposite sides of the ring 30, and also forces indicated at *k* which operate in a direction toward the center of the sphere. The forces *k* tend to balance one another out so that no thrust is caused thereby at the bearings, but the forces *j* cause a rotating moment about the center of the sphere, and as illustrated in Figure 9, this rotating force would cause the rotor to turn in the counter-clockwise direction. The net result of all of these forces is that there is a thrust downwardly, indicated at *l* at the left-hand bearing, and a thrust *m* which operates upwardly at the right-hand bearing. These thrusts, of course, can be readily accommodated by the bearings. It will be noted that there is no resultant end thrust, so that the bearings for the shaft need not be of the expensive roller type but instead can be of the ordinary ball bearing type. Such a modification is shown in Figure 4, in which the ball bearings 34 replace the roller bearings shown in Figure 1, and since there is no end thrust it requires only a little effort to hold the ball bearings in place longitudinally. In fact, a mere end closure plate 35, screwed tot he blocks 4, 6 will suffice.

Due to the fact that the rotor is well balanced, not only from the static but also the dynamic force standpoint, the rotor may be turned at very fast speeds and the output of the pump would be limited only by the volume of the pumping chambers *g*, *h* (Figure 9), which in turn, is a measure of the distance between the blocks 4, 6 and the width of the rings 30. It is apparent that inasmuch as the blades 32 are only slidably held within the ring 30, these blades can be readily replaced. There is no welding, bolting or other expensive labor to be performed in positioning these blades with respect to the web 30. The blocks 4, 6 can be taken apart merely by removing the bolts 7, and the arrangement is such (Figure 1) that the rotor 19 does not even have to be removed from the shaft 2 in order to inspect the condition of the blades and of the tapered surfaces 8 and 9.

When it is desired to reverse the direction of flow at the delivery end, it is only necessary to reverse the direction of rotation of the rotor at the motor 3. However, as will be explained presently, the pump may be modified in such a way as to reverse the direction of delivery while permitting the motor 3 to continue to run in the same direction. There is shown in Figures 11 to 14 a reversible pump of this character. In general, the construction is such that the chamber which had 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 blocks 4, 6 are 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 similar to those described in connection with Figure 1, all bolted together, except that 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. The casing is provided at its right-hand end, as seen in Figure 12, with a multi-shouldered shaft 38 which is threaded at one end to receive a thumb nut 39 rotatably secured to a conduit 40, the purpose of which will be explained hereinafter. 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 the pump 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 the arcuate slots 12, 13 (Figure 3), 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 connected to the slots 12, 13 by the passageways 18, which are most clearly shown in Figure 7. 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 11 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 be moved in the lateral direction with respect to the rotor, the intermediate block 60, which corresponds to the block 5 in Figure 1, 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 11 is always positioned at an angle with respect to the rotor shaft instead of being positioned normally thereto, as in the case of Figure 1. But the general operation of the rotor within the chambers formed between the blocks is similar to that described in connection with Figure 1, so that no additional description of the details is necessary.

When the pump casing, for example, is canted to the left, as shown in Figure 11, 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.

In Figure 14 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 41. In other words, the gear 41, shown in Figure 14, 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.

In the reversing form of pump as shown in Figures 11 to 14, the taper of the pump chamber 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 and the invention.

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 mounted on a shaft therein, 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, said rotor having a spherical portion, said chamber having an arcuately curved outer peripheral wall whose center is removed from the center of said rotary shaft and curved side walls, each vane having inner and outer edges curved both in vertical and horizontal directions to conform to the spherical portions of said rotor and outer chamber wall, and side edges convexly curved to continuously contact the curved side walls of said chamber.

2. In a fluid pump having a housing which forms a pumping chamber, a rotor mounted on a shaft therein, the walls of said chamber being parallel and 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, said rotor having a spherical portion, said chamber having an arcuately curved outer peripheral wall whose center is removed from the center of said rotary shaft and curved side walls, each vane having inner and outer edges curved both in vertical and horizontal directions to conform to the spherical portions of said rotor and outer chamber wall, and side edges convexly curved to continuously contact the curved side walls of said chamber.

3. In a fluid pump having a housing which forms a pumping chamber, a rotor mounted on a shaft therein 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, said rotor having a spherical portion, said chamber having an arcuately curved outer peripheral wall whose center is removed from the center of said rotary shaft and curved side walls, each vane having inner and outer edges curved both in vertical and horizontal directions to conform to the spherical portions of said rotor and outer chamber wall, and side edges convexly curved to continuously contact the curved side walls of said chamber.

4. In a fluid pump having a housing which forms a pumping chamber, a rotor mounted on a shaft therein, 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, 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, said rotor having a spherical portion, said chamber having an arcuately curved outer peripheral wall whose center is removed from the center of said rotary shaft and curved side walls, each vane having inner and outer edges curved both in vertical and horizontal directions to conform to the spherical portions of said rotor and outer chamber wall, and side edges convexly curved to continuously contact the curved side walls of said chamber.

5. A fluid pump comprising a casing formed of two outer blocks of metal spaced apart by an apertured intermediate block of metal to form a pumping chamber, a rotor adapted to rotate in said chamber, said outer blocks having a pair of aligned openings to receive a shaft carrying the rotor, the joints between said outer blocks and intermediate block extending in parallel planes angularly positioned with respect to the axis of the shaft whereby the pumping chamber is arranged at an angle with respect to the rotor, a plurality of pairs of vanes slidably received by the rotor and extending in the direction of the shaft, said vanes having a width substantially equal to the thickness of the pumping chamber as determined by the thickness of said intermediate metal block, an inlet conduit formed in one of said outer blocks and being effectively in communication with the pumping chamber, and an outlet conduit formed in the same outer metal block as the inlet conduit and being effectively in communication with the pumping chamber, said rotor having a spherical portion, said chamber having an arcuately curved outer peripheral wall whose center is removed from the center of said rotary shaft and curved side walls, each vane having inner and outer edges curved both in vertical and horizontal directions to conform to the spherical portions of said rotor and outer chamber wall, and side edges convexly curved to continuously contact the curved side walls of said chamber.

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