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FLUID PUMP OR MOTOR

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Fig. 1.

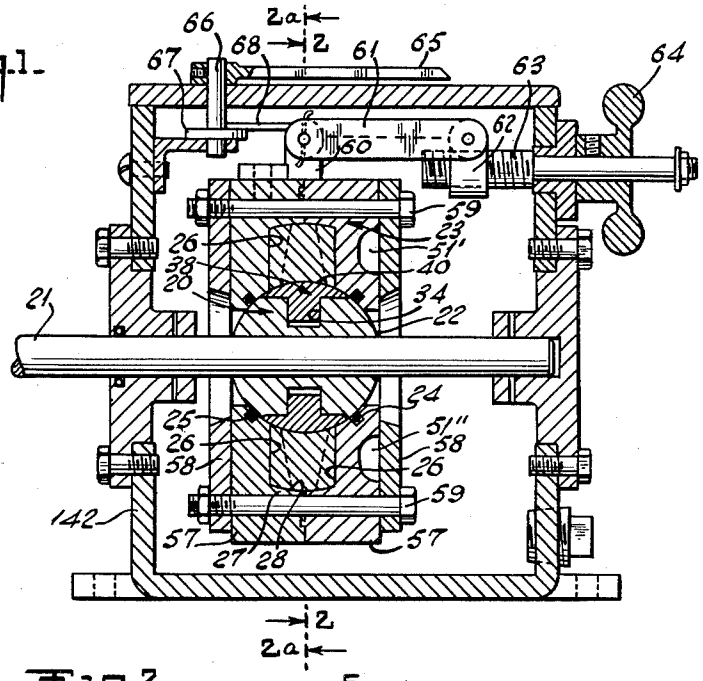



Fig. 2.

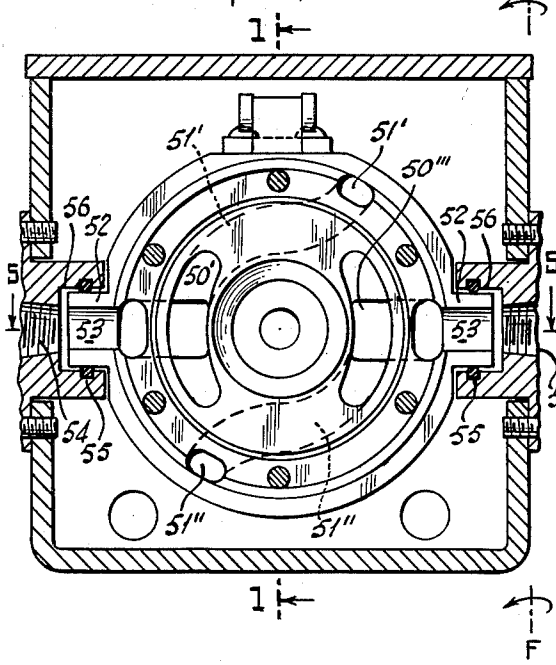
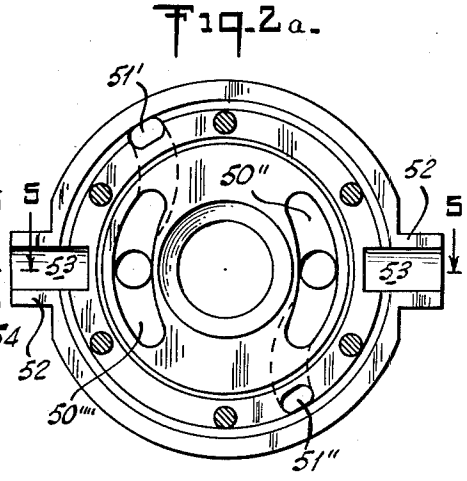



Fig. 2a.




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Fig. 3.

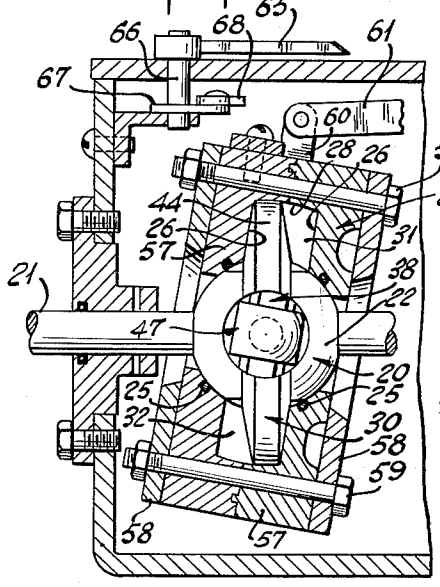



Fig. 4.

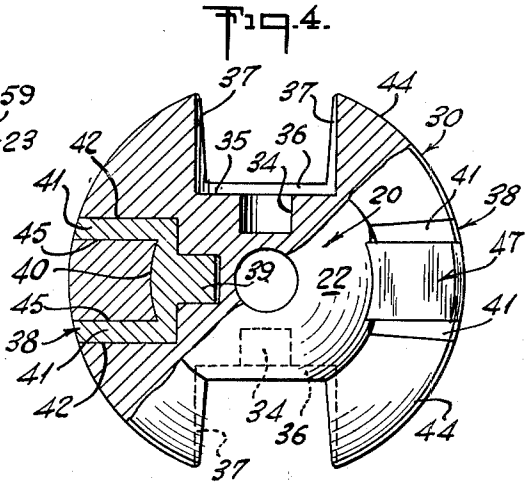



Fig. 6.

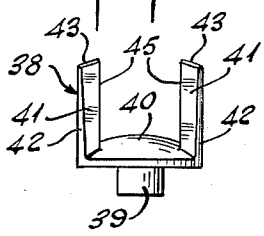



Fig. 9.

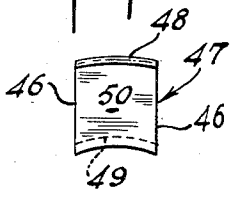



Fig. 5.

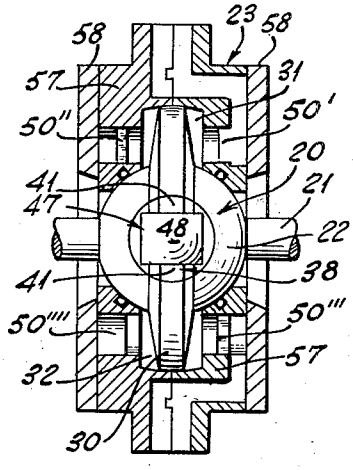



Fig. 7.

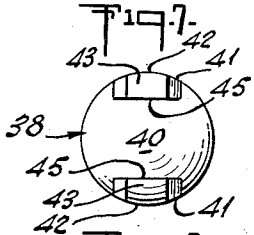



Fig. 10.

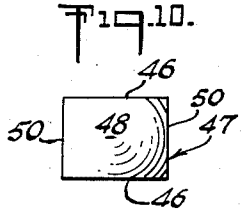



Fig. 8.

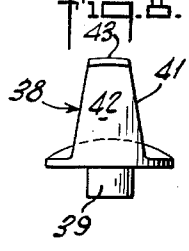
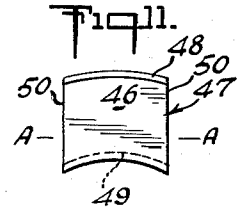



Fig. 11.




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Fig. 12a.

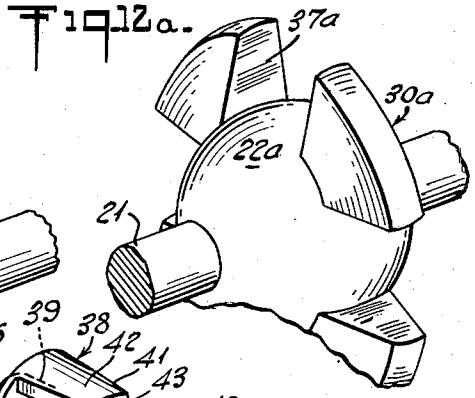



Fig. 12.




Fig. 13.

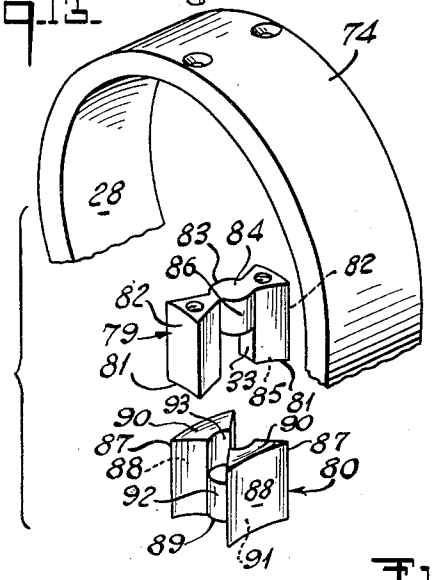



Fig. 14.

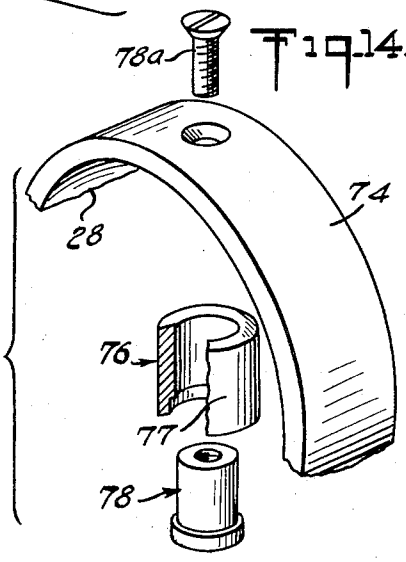



Fig. 16.

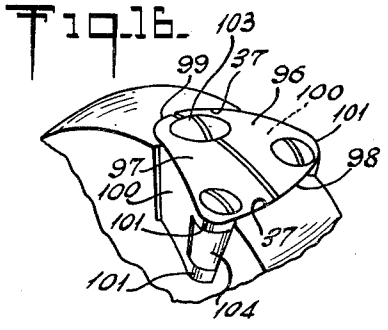



Fig. 17.

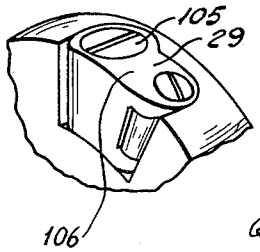
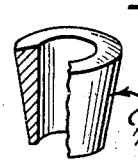



Fig. 15.




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Fig. 18.

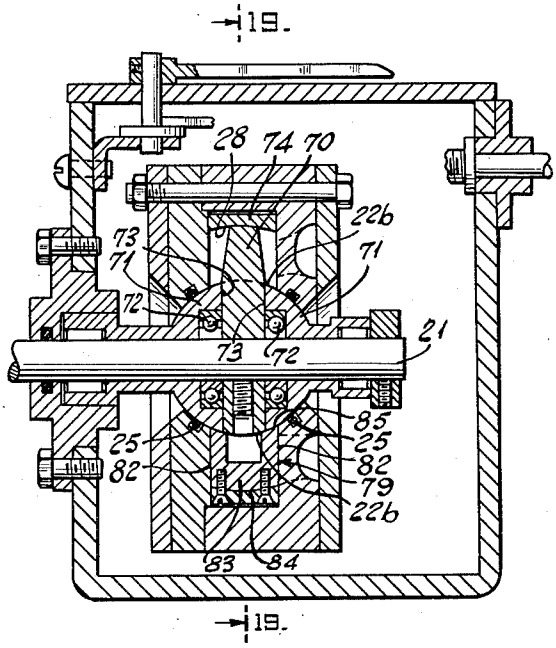
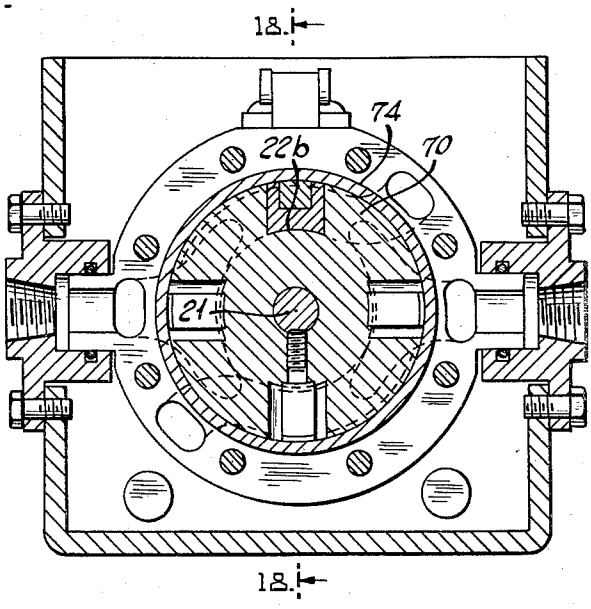



Fig. 19.




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Fig. 20.

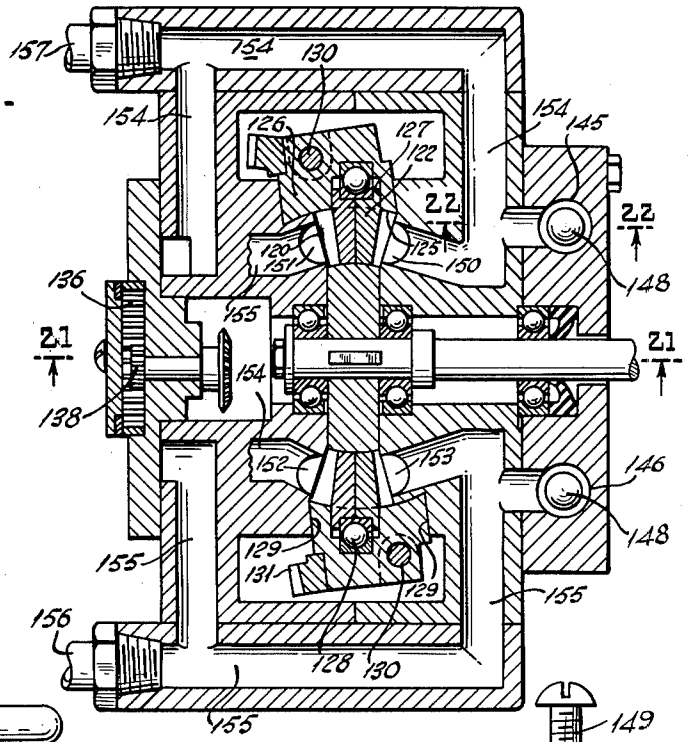



Fig. 21

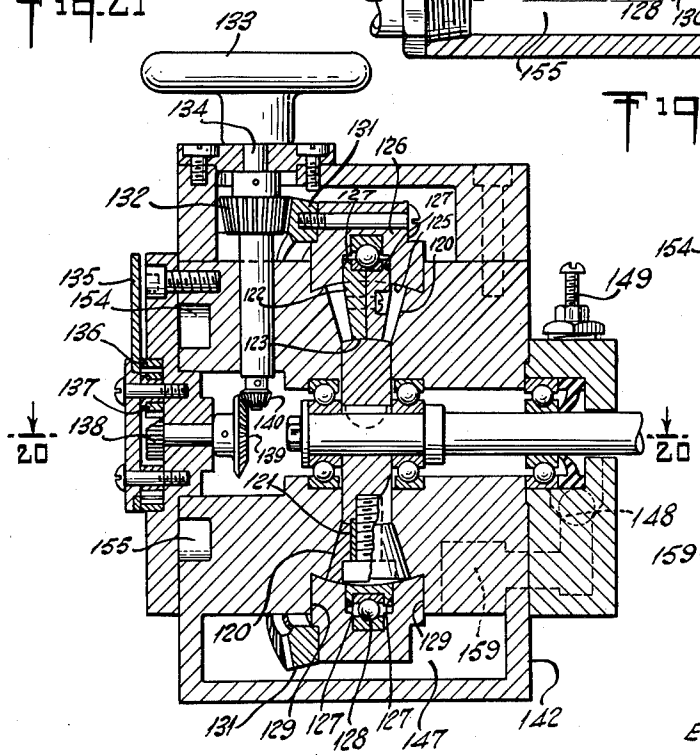
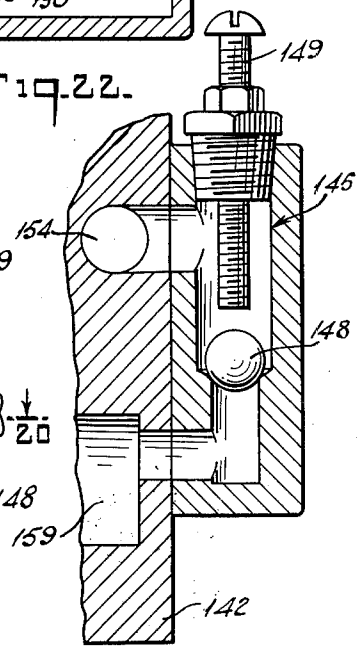



Fig. 22.




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Fig. 23.

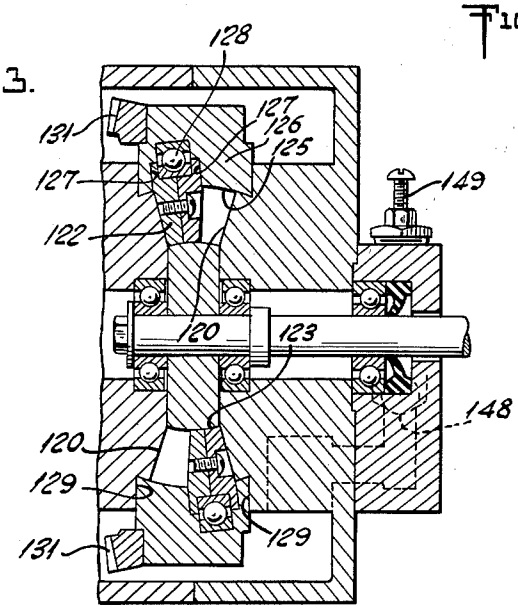



Fig. 24.

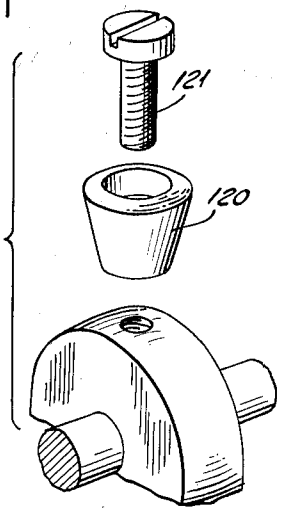



Fig. 25.

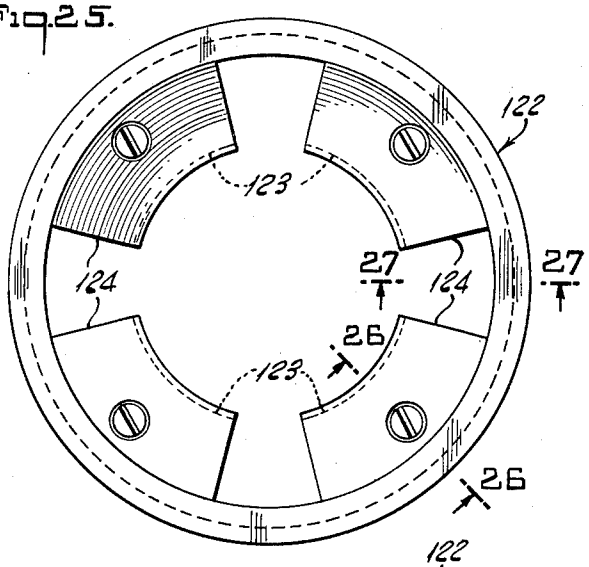



Fig. 29.

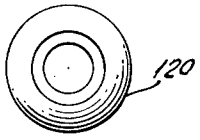



Fig. 28.

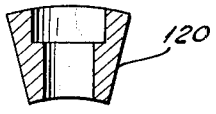



Fig. 26.

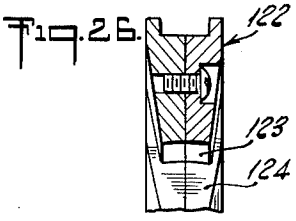
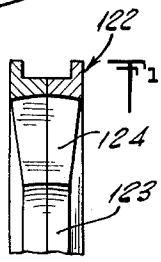



Fig. 27.




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Fig. 30.

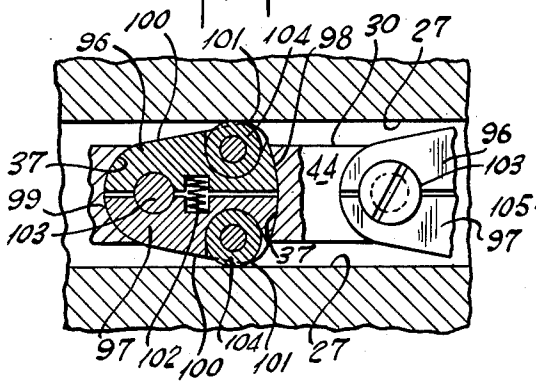



Fig. 31.

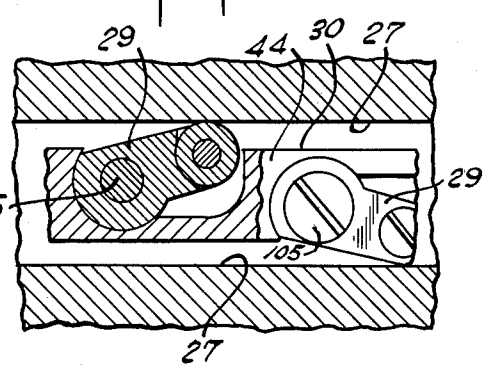



Fig. 32.

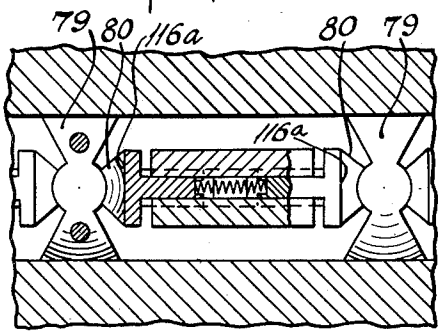



Fig. 33.

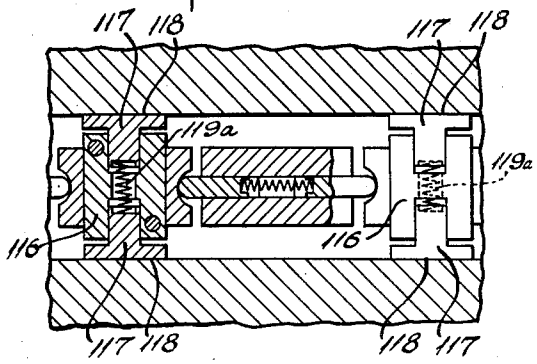



Fig. 35.

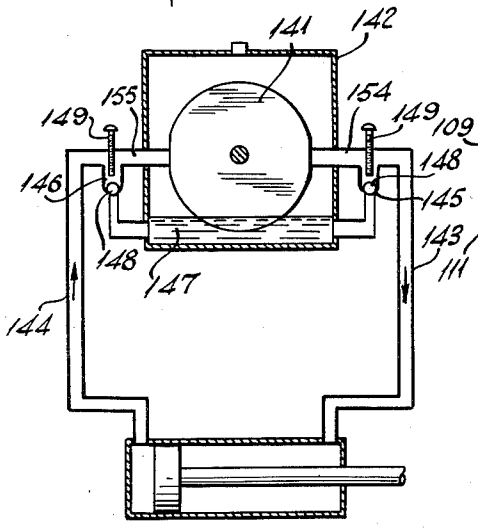
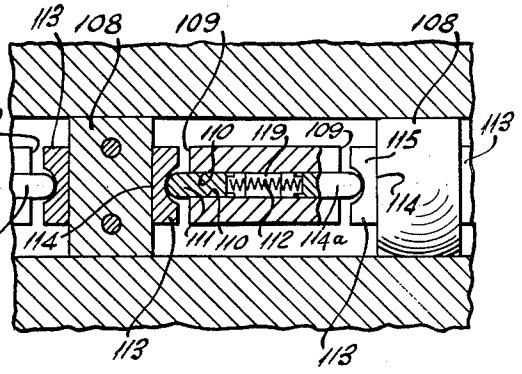



Fig. 34.




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United States Patent Office 3,101,059 Patented Aug. 20, 1963



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# FLUID PUMP OR MOTOR

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Filed June 30, 1959, Ser. No. 824,104
14 Claims. (Cl. 103—142)

This invention relates to a positive displacement rotary fluid flow device, capable of being used as either a pump or a motor, in which the rate and direction of flow may be varied.

An object of the invention is the provision of a pump or motor construction allowing variation of the fluid flow rate in continuous fashion from a maximum flow rate in one direction through a neutral position of no flow to a maximum flow rate in the opposite direction.

Another object is the construction of a device as described in which the leakage and inefficiency caused by wear on the moving parts and by tolerance inaccuracies in manufacture may be minimized.

A further object is the provision of accurate means for varying the flow rate and direction without weakening the structure.

A further object is the construction of a device as described which is free of reciprocating parts and unbalanced pressure forces likely to cause vibration and wear.

Further objects of the invention will be evident from the following description, in which

FIG. 1 is a cross-sectional side view of one embodiment of the invention taken on plane 1—1 of FIG. 2;

FIG. 2 is a cross-sectional end view taken on plane 2—2 of FIG. 1 with the rotating parts removed;

FIG. 2*a* is a section through 2*a*—2*a* showing one-half the outer casing. It mates with the casing half of FIG. 2 by folding over about line F—F;

FIG. 3 is a cross-section similar to that of FIG. 1 with the outer casing in a tipped position and with the rotating parts unsectioned;

FIG. 4 is a partial cross-section of some of the rotating parts of the embodiment taken on plane 2—2 of FIG. 1;

FIG. 5 is a cross-section view of the outer casing and rotating parts of the embodiment taken on plane 5—5 of FIG. 2;

FIGS. 6–8 are respectively end, top, and side views of one type of vane holder;

FIGS. 9–11 are respectively end, top, and side views of one type of vane adapted to cooperate with the vane holder shown in FIGS. 6–8;

FIG. 12 is an exploded view of the rotating parts of one embodiment of the invention;

FIG. 12*a* is a partial perspective view of one of the rotating parts in a second embodiment of the invention;

FIG. 13 is an exploded view of some of the rotating parts in a second embodiment of the invention;

FIG. 14 is an exploded view corresponding to FIG. 13 of a different type of vane for use in the second embodiment;

FIG. 15 is a perspective view of still another type of vane for the second embodiment;

FIGS. 16 and 17 are different types of vanes for the first and second embodiments seen in perspective;

FIG. 18 is a cross-section of the second embodiment of the invention taken on plane 18—18 of FIG. 19;

FIG. 19 is a cross-section of the second embodiment taken on plane 19—19 of FIG. 18;

FIG. 20 is a cross-sectional top view of a third embodiment of the invention taken on plane 20—20 of FIG. 21;

FIG. 21 is a cross-sectional side view of the third embodiment taken on plane 21—21 of FIG. 20;

FIG. 22 is a cross-sectional view of a check valve taken on plane 22—22 of FIG. 20;



FIG. 23 is a cross-section corresponding to FIG. 21 with the flange in a different position;

FIG. 24 is an exploded view of several of the rotating parts of the third embodiment;

FIG. 25 is a side view of the flange of the third embodiment;

FIG. 26 is a cross-sectional view of the flange of FIG. 25 taken on plane 26—26;

FIG. 27 is a cross-sectional view of the flange of FIG. 25 taken on plane 27—27;

FIG. 28 is a cross-sectional view of the conical vane of FIG. 24;

FIG. 29 is a top view of the conical roller of FIG. 24;

FIGS. 30–34 are views of the developed top surface of flanges showing various vane constructions in partial transverse cross-section; and

FIG. 35 is a schematic diagram of the invention in use as a pump driving a hydraulic ram.

Several embodiments of the invention are shown. In the first, illustrated in FIGS. 1–12, an inner casing 20 is mounted on shaft 21. The inner casing carries spherical inner working surface 22 ("spherical" means that a surface is part of a sphere; not necessarily a complete sphere). Outer casing 23 surrounds the rotor and embraces the inner working surface. Annular grooves 24 retain rubber O rings 25 which help seal the joints between the outer casing and the inner working surface. The outer casing bears opposed interior side walls 26 and peripheral wall 27 bearing spherical outer working surface 28. The outer and inner spherical working surfaces have a common center and together with the side walls define an annular pumping volume. Annular flange 30 (FIGS. 4 and 5) is located in the pumping volume in an equatorial position with respect to the inner working surface. In the embodiment of FIG. 4 it is integral with the inner casing. The flange spans the gap between the inner and outer working surfaces and divides the pumping volume into first pumping space 31 and second pumping space 32. Four sockets are drilled down through the flange and into the inner working surface in a radial direction at equal intervals about the periphery of the flange. The drilling produces cylindrical inner socket 34, flat surface 35, and a slight cylindrical wall 36. Where the flange is cut gripper surfaces 37 are produced. These opposed gripper surfaces define a vane holder gap in the flange which receives vane holder 38. Projection 39 fits into the inner socket with a rotatable sliding fit therein. Bottom surface 40 is spherical, has the same radius of curvature as the inner working surface and is flush therewith, continuing this surface. Clasp arms 41 (see FIGS. 6–8) project from the bottom surface. Outer cylindrical surfaces 42 make sliding surface contact with the adjacent cylindrical gripper surfaces "cylindrical" means that the surface is part of the surface of a cylinder; not necessarily the whole surface). The outer ends 43 of the clasp arms are spherical surfaces abutting the outer working surface and continuing the spherical outer surface 44 of the flange.

The opposed plane parallel vane holding surfaces 45 on the clasp arms define between them a vane slot and make sliding surface contact with plane parallel end surfaces 46 of vane 47 (FIGS. 9–11). Vane 47 may be called "rectangular" because of its rectangular cross-section when cut by a transverse plane such as plane A—A of FIG. 11. The upper face 48 and lower face 49 of the vane are spherical with the same radii of curvature as the outer and inner working surfaces, respectively. The upper vane face makes sliding surface contact with the outer working surface 28 and the lower vane face makes sliding surface contact with both the vane holder bottom surface 40 and the inner working surface 22. Side faces 50 make slid-

ing surface contact with the side walls 26 ("surface contact" refers to the condition in which one surface contacts another over an area, as contrasted with "line contact" in which contact is along a line. An example of the latter is the contact between a knife edge and a surface). The four vanes, together with the flange, divide the pumping volume into eight charge chambers.

Four duct openings 50', 50'', 50''' and 50'''' are provided, two in each side wall at diametrically opposite positions. As shown duct openings 50' and 50'', located in different side walls, are opposed to each other across the pumping volume, as are 50''' and 50''''. Each duct opening extends over approximately 90° of arc. By means of duct 51' (FIG. 2) duct openings 50' and 50'''' are connected and by means of duct 51'', duct openings 50'' and 50''' are connected.

Hollow trunnions 52 carry passages 53 connecting ducts 51' and 51'' with outlets 54. O rings 55 seal the joints between the trunnions and the trunnion sockets 56.

The outer casing is comprised of annular inner halves 57 and annular cover plates 58. This construction allows the ducts 51' and 51'' to be formed as grooves in the outer surface of the inner halves and covered over with the cover plates (FIG. 1). Easy cleaning and inspection is therefore possible by removing the cover plates. Bolts 59 compress the inner halves and the cover plates together to form the outer casing.

Post 60, rigidly attached to the outer casing, is pivotally attached to link 61 which in turn is pivotally attached to nut 62. This nut rides on threaded shaft 63 which is rigidly fastened to handwheel 64. An indicator assembly comprised of indicator hand 65 mounted on indicator shaft 66 communicates by means of crank 67 and indicator link 68 with nut 62 showing the position of the outer casing.

When the device is used as a pump, a motor is attached to shaft 21 and rotates the shaft, inner casing, flange, vane holders and vanes within the stationary outer casing. The O rings 25 seal the joint between the inner and outer casing during rotation. By turning the handwheel the outer casing may be made to rotate in the trunnions. As shown in FIG. 3 the axis of the annular flange and the axis of the annular pumping volume may be made to diverge by this rotation (by the "axis" of an annular structure is meant the line normal to the plane of the annulus and passing through the center of the annulus). Rotation of the shaft will then cause the volume of each charge chamber to change and fluid will be pumped from one outlet 54 to the other. By adjusting the angle between the flange axis and the pumping volume axis to zero a condition of no flow in the passages will result. Further adjustment will reverse the flow direction. Variation of the flow rate and direction is thus possible without varying the speed or direction of shaft rotation.

The device may be used as a motor by providing fluid under pressure at one of the outlets. The pressure will rotate the shaft 21, which may be connected to a load. By varying the setting of the outer casing the speed and torque of shaft 21 may be varied, as well as the direction of rotation of the shaft.

As shown in FIGS. 1 and 2, the ducts 51' and 51'' are so constructed that the device, when used as a pump, operates as a single stage pump. Both pumping spaces 31 and 32 receive fluid from the same inlet, and both discharge to the same outlet. They pump in parallel. However, by changing the ducts the pumping spaces may be made to operate in series as a two stage pump. Thus, duct 51' may be modified to connect duct opening 50''' with duct opening 50'''' rather than with duct opening 50' as shown in FIGS. 2 and 2*a*. The connection shown between duct opening 50''' and outlet 54 may then be blocked. With these modifications, fluid may, for example, follow a path from the left hand outlet 54 of FIG. 2 to duct opening 50', from duct opening 50' through the first pumping space 31 to duct opening 50''', through duct 51' to duct opening 50'''', through the second pumping space 32 to duct opening 50'', through duct 51'' to the right hand outlet 54 of FIG. 2, and from there out of the pump. Operation as a two stage pump will result in axial pressure unbalance, which will be compensated for by increased pressure between the spherical inner working surface 22 and surface of the outer casing on the low pressure side which abuts the inner working surface.



During rotation of the shaft the surface contact of the vane side walls against the side faces constrains these surfaces to remain substantially parallel. As a result, the vanes continually rotate relative to the flange about vane axes (instantaneous axes passing through the vanes and the center of the spherical inner working surface). In addition, the vanes slide from side to side relative to the flange. These rotating and sliding motions must be allowed for without leaving clearances which will allow substantial leakage between charge chambers. The vane holders achieve this result. They rotate in the vane holder gaps about radial axes through the center of the spherical inner working surface so that their vane holding surfaces remain parallel to the end faces of the vanes while the vanes slide through the vane slots.

FIGS. 12*a*–15 show variations in vane and flange design. FIG. 12*a* shows a portion of a shaft, inner casing and flange, corresponding generally to those of FIG. 12. In FIG. 12*a*, however, the inner socket 34, flat surface 35, and cylindrical wall 36 of FIG. 12 are omitted, and the spherical inner working surface 22*a* continues through the vane holder gap from one side of the flange 30*a* to the other. In this variation gripper surfaces 37*a* are plane surfaces, not cylindrical as in FIG. 12. A vane such as vane 76 of FIG. 14 having a circular cross-section in cutting planes normal to its vane axis may be used. The vane side surfaces 77 are cylindrical, while the top and bottom surfaces are spherical. The side surfaces make line contact with the side walls and the gripper surfaces 37*a*. Another vane 76*a* is shown in FIG. 15 in which the side surfaces are conical and would have, if extended, an apex at the center of the spherical inner working surface. Such conical vanes may roll on one side wall or the other as the flange rotates. Other shapes having cylindrical transverse cross-section are possible, as for example, a barrel shape with spherical top and bottom end surfaces. The gripper surfaces 37*a* and the side walls 26 need only be modified to allow close contact with the vane shape chosen and to allow arcuate sliding of the vane through the vane gaps in the flange.

FIGS. 13, 14, 18 and 19 illustrate a modified second construction having certain advantages over the first construction described above. In the second construction the flange 70 is rigidly connected to the shaft 21. Inner casing 71 supports the shaft and flange by means of antifriction bearings 72. A running clearance between the inner casing and the flange surfaces 73 is provided. Wear of the O rings 25 is prevented since the inner casing does not revolve with the shaft. Wear is further prevented by the provision of an annular peripheral wall 74 bearing the outer working surface. The peripheral wall rotates with the vanes and is driven by fastening it to a vane or to two diametrically opposed vanes. Spherical surface 22*b* (FIG. 18) extends from one side of the flange to the other, continuing inner spherical working surface 22*b* of the inner casing, a construction analogous to surface 22*a* of FIG. 12*a*. Where conical or cylindrical vanes are used with a rotating peripheral wall, two diametrically opposed vanes may be rotatably fastened to the wall by means of stud 78 projecting inward from the peripheral wall and screw 78*a*, as shown in FIG. 14.

A further vane variation is shown in FIGS. 13, 18, 19 and 32. As is most clearly shown in FIGS. 13 and 32, the assembled vane 79 and vane holder 80 have the form of a cross patée in a cross-section formed by a transverse plane (a plane normal to the vane axis). (As used herein "cross patée" refers to a cross having arms narrow at the center and expanding towards the ends and flat at the

outer edges.) Vane 79 comprises two vane arms 81 having side faces 82 in sliding surface contact with the side walls. These vane arms join in a central vane hub 83. While the vane 79 extends from the inner working surface to the outer working surface and comprises a spherical upper face 84 and a spherical lower face 85 in contact with these surfaces, the vane hub contacts only one of the working surfaces extending only part way to the other (the one contacted is a matter of choice; in FIG. 13 it is the outer). The vane hub carries vane hub surfaces 86.

Vane holder 30 comprises opposed vane holder arms 87 having outer surfaces 88 in sliding surface contact with the gripper surfaces. These vane holder arms join in a central vane holder hub 89. Like vane 79 the vane holder extends from the inner working surface to the outer working surface and comprises a spherical upper face 90 and a spherical lower face 91 in contact with these surfaces. The vane holder hub contacts only one working surface (the inner in FIG. 13) and extends toward the other far enough to make sliding contact with the vane hub. The vane holder hub carries vane holder hub surfaces 92. These make sliding contact with hub engaging surfaces 33 on the vane while hub engaging surfaces 93 on the vane holder make sliding contact with the vane hub surfaces 86.

The cross patée construction of the assembled vane and vane holder allows limited rotation of the vane relative to the vane holder about an instantaneous axis of rotation through the center of the vane hub and the center of the spherical inner working surface. As a result, vane side faces 82 may remain parallel to the side walls while vane holder outer surfaces 88 remain parallel to gripper surfaces 37*a*. (As used in this specification the term "instantaneous axis" is used to indicate that the axis about which the rotation in question occurs is not fixed in space. Actually the instantaneous axis rotates about the center of the spherical inner working surface in the same manner that a spoke in a wheel rotates about the axis of the wheel. Each vane rotates in a circle about this center, while at the same time twisting about the instantaneous axis through the center in a back-and-forth manner.)

As in the case of the cylindrical or conical vanes described, a pair of diametrically opposed vanes of the cross patée type may be fastened to the rotating peripheral wall, where such wall is used. See FIG. 13 in which two screws 95 are employed for this purpose.

A modified vane structure is shown in FIGS. 16 and 30 in which a vane is split into two vane halves 96 and 97. The assembled vane is comprised of wide end face 98 and narrow end face 99, both of cylindrical structure as shown, although they might be conical or of other shape. These end faces make sliding surface contact with gripper surfaces 37. Side faces 100 converge, connecting the wide and narrow end faces. At the junctions of the side faces and the end face are located contact surfaces 101 which make sliding contact with the side walls. To aid in maintaining this contact a vane coil spring 102 located between the vane halves urges them apart. The vanes pivot about vane stud 103 which may be screwed into the inner casing or otherwise fixed with respect to the flange. These contact surfaces may be further improved by adding rollers 104. Where faces 98 and 99 are conical, conical roller may be used, having an apex (if extended) at the center of the spherical inner surface, thus converting sliding contact with the side walls to rolling contact. As in the other vanes, the upper and lower vane faces are spherical.

Another modified vane structure related to that just described is shown in FIGS. 17 and 31 in which vane 29 pivots about vane stud 105 which is fixed with respect to the flange. These vanes have spherical upper face 106 and spherical lower face 107, and travel to the right as seen in FIG. 31. Unlike the various constructions previously set forth this modification employs recesses in the flange to receive the vanes instead of gripper surfaces defining slots in the flange. Larger numbers of vanes are required, eight being the equivalent of four of the other vanes so far described. The surfaces of the vanes in contact with the side walls may be improved by conical rollers of the type described in relation to the split vane of FIG. 16.

It may be desirable to fasten every vane to the rotating peripheral wall. Such a construction helps avoid leakage between charge chambers through the space between the upper vane face and the outer working surface. Due to the geometry involved when all vanes are fastened to the peripheral wall, an attempt to tilt the axis of the flange relative to the axis of the pumping volume in the constructions so far described will fail unless fairly wide clearance is left between the end faces of the vanes and the gripper surfaces of the flange. The leakage through such spaces may be reduced by means of the shutter construction shown in FIGS. 32 to 34. FIG. 34 shows a vane 108 of rectangular cross-section in a plane normal to a line through the vane and the center of the spherical inner working surface. Vane gap surfaces 109 define vane gaps in the flange. Opposed interior flange surfaces 110 define a central groove in the flange in which is located shutter 111. Spring 112 urges the shutter into the vane gap. Between the shutter and the vane end surface contact plate 113 is positioned. Surface 114 of the contact plate makes sliding surface contact with the vane end surface. The contact plate makes a rockable joint with the shutter. Spherical upper faces 114*a* and 115, on the shutter and contact plate respectively, make sliding surface contact with the upper working surface. Center section 119 is fixed to the flange.

The simple rectangular vane of FIG. 34 may be modified as shown in FIG. 33, in which vane is an assembly of an H shaped central portion 116 fastened to the peripheral wall and two T shaped side portions 117 having side faces 118 in sliding surface contact with the side walls. Spring 119*a* urges the T shaped side portions laterally outward against the side walls.

The use of a contact plate may be avoided as shown in FIG. 32 in which the shutter is provided with outer face 116*a* in sliding surface contact with the end face of a cross patée type vane holder of the type already described. The other arms of the cross patée (the vane) are fastened to the rotating peripheral wall.

FIGS. 20, 21 and 23 to 29 illustrate a third modified construction of the basic design. The variations so far described have employed an annular pumping volume having an axis which diverges from the axis of rotation of the shaft. The third construction keeps these axes parallel, and tilts the axis of the annular flange with respect to the shaft axis of rotation. In the embodiment shown conical rollers 120 are used, two diametrically opposite rollers being carried on studs 121 fastened to the inner working surface. The flange 122 is free to oscillate relative to the inner working surface, which it contacts through spherical lower flange surface 123, and relative to the conical rollers, which it contacts with gripper surfaces 124.

Outer working surface 125 is carried by peripheral wall 126. Groove surfaces 127 define an annular groove extending into the outer working surface. The groove surfaces make sliding surface contact with the flange while anti-friction ball bearing 128 guides the flange and absorbs side thrust on the flange due to unequal pressure forces on its sides. The peripheral wall is annular and is confined in an annular wall groove defined by guide surfaces 129 in the outer casing. The annular peripheral wall can rotate about its axis. The peripheral wall rotational axis diverges from the axis of the annular pumping volume by a first angle, while the flange rotates about a flange rotational axis diverging from the peripheral wall rotational axis by a second angle. While the magnitudes of the first and second angles are fixed by geometry of

the pump, rotation of the peripheral wall varies the angle of divergence between the flange rotational axis and the axis of the annular pumping volume. This angle of divergence may be brought to zero, i.e., the latter two axes made parallel. In this case flow through the pump is zero. Further rotation of the peripheral wall in the same direction past the zero point will reverse the fluid flow direction.

The peripheral wall is made in two halves joined by bolts **130**, seen in cross-section in FIG. 20. Rotation is effected by means of bevel gear **131** bolted to the peripheral wall and meshing with bevel gear pinion **132**. The bevel gear pinion is connected in driven relation to handwheel **133** through shaft **134**. Indicator hand **135** is fastened to ring gear **136** which is rotated by planet gears **137**, sun gear **138**, and bevel gears **139** and **140**, the latter driven by shaft **134**. The indicator hand thus shows the position of the flange and consequently the rate and direction of fluid flow.

The duct system is analogous to that of the first embodiment, and may be seen in FIGS. 20, 21 and 22. Four duct openings **150**, **151**, **152** and **153** are provided, two in each side wall at diametrically opposite positions, duct opening **150** being opposed to duct opening **151** and duct opening **152** opposed to duct opening **153**. Duct **154** connects duct openings **150** and **152** while duct **155** connects duct openings **151** and **153**. Duct **155** connects with outlet **156** and duct **154** with outlet **157**.

Sump **147** (FIG. 21) is provided in the bottom of the pump casing or shell **142**. An extension **159** of sump **147** extends upward on either side of the pump as shown in dotted lines in FIG. 21 and in section in FIG. 22.

FIG. 35 is a schematic diagram of a system in which a device of the type previously described is used to drive a hydraulic ram. The pump **141** is enclosed in a shell **142** which collects fluid leakage past the various oil seals employed in the pump construction. Pipes **143** and **144** connect the pump with the ram. These pipes, the pump, and the ram form a closed circuit for fluid flow (except for pump leakage into the shell). Check valves **145** and **146** (shown in detail in FIG. 22) connect pipes **143** and **144** with extension **159** of the sump **147** of the shell which accumulates pump leakage. When flow is in the clockwise direction indicated by the arrows in FIG. 35 the pressure in pipe **143** will be above atmospheric and check valve **145** will remain closed, the surface of the liquid in the shell being under atmospheric pressure. Pressure in pipe **144** will be below atmospheric if leakage takes place into the base from the pump and check valve **146** will open, allowing fluid flow from the base into pipe **144** to restore fluid lost in the closed system. Reversal of the flow direction will close check valve **146** and open **145**. The check valves may be kept permanently closed by screwing down on balls **148** with screw **149**. This may be desirable when the device is used as a motor driven by fluid under pressure.

One advantage common to all the designs shown is a superior resistance to wear of the vanes, such wear either being avoided or automatically compensated for by the design employed. Thus, the cylindrical and conical vanes shown may roll on the side walls when forced into contact therewith. Sealing contact between conical and cylindrical vanes and the side walls is line contact only, but rotation of these vanes distributes wear over the whole vane side surface rather than a portion of the surface only. Thus, wear of the vanes and the side walls is reduced and distributed over a much greater surface area of the vane, prolonging vane life and reducing leakage past the vanes.

The vanes shown in FIGS. 16 and 30 also automatically compensate for wear. The coil spring **102** keeps the vane halves in contact with the side walls even after some wear has taken place on the contact surfaces **101**. The addition of rollers **104** making rolling contact with the side walls aids in preventing frictional wear. This design also compensates for variations in the lateral dimensions of the pumping volume caused by variations in the distance between the side walls at various points of the pumping volume. The vanes shown in FIGS. 17 and 31 compensate for wear in an analogous manner, reaching out far enough to contact the side walls and make line contact therewith. A coil spring may be employed to press them against the side walls.

Vanes such as the cross patée vane and the rectangular vane of FIGS. 13 and 12 compensate for wear in a somewhat different way. They make sliding surface contact with the side walls, so that wear is distributed over their side surfaces. In addition, these vanes can bridge variations in the distance between the side walls at various points around the periphery by rotating slightly about an axis through the vane perpendicular to the inner working surface, so that they contact the side walls with diagonally opposed edges. Such twisting is a natural result of the pressure forces exerted on the vane by the fluid being pumped.

Vanes which are fastened to a rotating peripheral wall as in FIG. 32 are protected from wear on their side faces because the peripheral wall prevents them from continually scraping against the side walls, at the same time supporting them close to the side walls so that leakage past their side faces is substantially prevented.

The lack of reciprocating parts in this device helps prevent unwanted vibration and wear. There is little or no axial force in the device due to fluid pressure, since the pressure forces in the first pumping volume offset those in the second. The result of the fluid pressure forces is a torque about a fixed axis perpendicular to the shaft axis. This torque is resisted by the bearings which carry the ends of the shaft.

What is claimed is:

1. In a rotary fluid flow device comprising an inner casing with a spherical inner working surface; an outer casing embracing the inner working surface and bearing opposed interior side walls; a spherical wall rotatable about the axis of an annular pumping volume and bearing a spherical outer working surface spaced from and opposed to the inner working surface, said outer working surface being radially outside said inner working surface, said annular pumping volume being defined by the inner and outer working surfaces and the side walls; an annular flange in the pumping volume spanning the space between the spherical working surfaces and thereby dividing the pumping volume into first and second pumping spaces; opposed gripper surfaces defining vane gaps in the flange; at least three transverse vanes extending between the flange and the side walls, thereby dividing the first and second pumping spaces into charge chambers, each vane having upper and lower faces conforming respectively to the outer working surface and the inner working surface, at least one vane connected in driving relation to the peripheral wall; means for rotating the flange about its axis together with the vanes and peripheral wall, with the axes of the pumping volume and the flange diverging from the center of the spherical inner working surface, thereby changing the volume of each charge chamber, and duct means for introducing fluid from a fluid supply into the charge chambers during the increase in volume thereof and for removing fluid to a fluid discharge from the charge chambers during the decrease in volume thereof, the improvement comprising non-rotating interior side walls; vanes rotatable during the rotation of the flange, said vanes rotating about an instantaneous vane axis extending through the center of the spherical inner working surface, and said vanes having spherical upper and lower faces of the radius of curvature respectively of the outer working surface and the inner working surface, and side faces adapted to make sliding surface contact with the side walls whereby rotary motion of the vane relative to

the side walls about the vane axis is substantially prevented.

2. In a device as described in claim 1, a vane holder located in each vane gap in transverse sliding contact with the gripper surfaces whereby rotary motion of the vane holder relative to the flange about an axis through the center of the spherical inner working surface is substantially prevented, and a vane held by each vane holder.

3. The vane and vane holder unit of claim 2, said unit being, in a cross section of the assembled vane and vane holder taken in a plane normal to the vane axis, constructed in the shape of a cross patée having opposed arms, one pair of opposed arms being formed by the vane and the other by the vane holder.

4. A device as described in claim 3 comprising a central vane hub of circular cross section in a plane normal to the vane axis, said vane hub joining the opposed arms of the cross patée formed by the vane; a vane holder hub of circular cross section in a plane normal to the vane axis, said vane holder hub joining the opposed arms of the cross patée formed by the vane holder, said vane hub and said vane holder hub being superimposed axially; opposed hub engaging surfaces on the vane forming a sliding fit with the hub of the vane holder; and opposed hub engaging surfaces on the vane holder forming a sliding fit with the hub of the vane.

5. The device of claim 1 in which the outer casing comprises two abutting annular shells, a side wall on each annular shell, duct openings in each annular shell communicating with the pumping volume, duct means in each annular shell communicating with the duct openings, said duct means comprising walls formed and constructed in the outer faces of the annular shells defining channels therein, and annular cover plates abutting the outer faces of the annular shells and covering the channels.

6. The device of claim 5 in which the annular shells and cover plates are secured together by fastening means compressing the cover plates toward each other.

7. The device of claim 1 in which two diametrically opposed vanes are associated with the peripheral wall in driving relation thereto.

8. A rotary fluid flow device comprising an inner casing with a spherical inner working surface; an outer casing embracing the inner working surface and bearing opposed non-rotating interior side walls; a peripheral wall rotatable about the axis of an annular pumping volume and bearing a spherical outer working surface spaced from and opposed to the inner working surface, said annular pumping volume defined by the inner and outer working surfaces and the side walls; an annular flange in the pumping volume spanning the space between the spherical working surfaces and thereby dividing the pumping volume into first and second pumping spaces; opposed gripper surfaces defining vane gaps in the flange; at least three transverse vanes extending between the flange and the side walls, thereby dividing the first and second pumping spaces into charge chambers, each vane having upper and lower faces conforming respectively to the outer working surface and the inner working surface, at least one vane connected in driving relation to the peripheral wall; means for rotating the flange about its axis together with the vanes and peripheral wall, with the axes of the pumping volume and the flange diverging, thereby changing the volume of each charge chamber, and duct means for introducing fluid from a fluid supply into the charge chambers during the increase in volume thereof and for removing fluid to a fluid discharge from the charge chambers during the decrease in volume thereof.

9. The device of claim 8 comprising duct means whereby the fluid removed from the charge chambers of the first pumping space is introduced into the charge chambers of the second pumping space, thereby achieveing two stage flow.



10. A vane and vane holder unit for use in a fluid flow device, said device having an annular pumping volume defined by inner and outer working surfaces, said outer working surface being radially outside said inner working surface and side walls and having an annular flange spanning the space between the inner and outer working surfaces, said flange having opposed gripper surfaces defining vane gaps in the flange, said vane and vane holder unit comprising a vane holder; vane holder outer surface means on the vane holder adapted to make transverse sliding contact with the gripper surfaces, said contact preventing rotary motion of the vane holder relative to the flange about an axis through the center of the inner working surface, and a vane held by the vane holder and rotatable with respect thereto about a vane axis, said vane having upper and lower surface means for conforming respectively to the outer and inner working surfaces and said vane having side face means adapted to make sliding surface contact with the side walls and thereby preventing rotary motion of the vane relative to the side walls about the vane axis.

11. The vane and vane holder unit of claim 10 in which in a cross section in a plane normal to the vane axis the assembled vane and vane holder exhibit the shape of a cross patée of which one pair of opposed arms is formed by the vane and the other by the vane holder.

12. The vane and vane holder unit of claim 11 in which the opposed arms of the cross patée formed by the vane join a central vane hub of circular cross-section in a plane normal to the vane axis and carry opposed hub engaging surfaces and the opposed arms of the cross patée formed by the vane holder join in a vane holder hub of circular cross-section and carry opposed hub engaging surfaces, the vane hub and vane holder hub being superimposed axially and the hub engaging surfaces of the vane holder forming a sliding fit with the hub of the vane and the hub engaging surfaces of the vane forming a sliding fit with the hub of the vane holder.

13. The vane and vane holder unit of claim 10, said unit being, in a cross section of the assembled vane and vane holder taken in a plane normal to the vane axis, constructed in the shape of a cross patée having opposed arms, one pair of opposed arms being formed by the vane and the other by the vane holder.

14. A device as described in claim 13 comprising a central vane hub of circular cross section in a plane normal to the vane axis, said vane hub joining the opposed arms of the cross patée formed by the vane; a vane holder hub of circular cross section in a plane normal to the vane axis, said vane holder hub joining the opposed arms of the cross patée formed by the vane holder, said vane hub and said vane holder hub being superimposed axially; opposed hub engaging surfaces on the vane forming a sliding fit with the hub of the vane holder; and opposed hub engaging surfaces on the vane holder forming a sliding fit with the hub of the vane.

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