March 15, 1966 — E. D. HARTLEY — 3,240,156

ROTARY VANE PUMP

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FIG. 1.

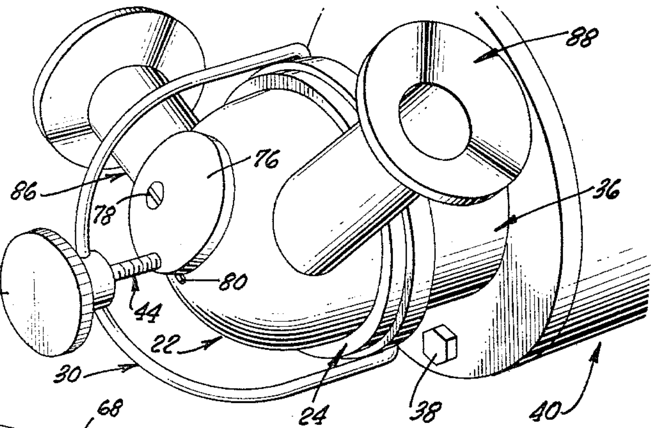

FIG. 2.

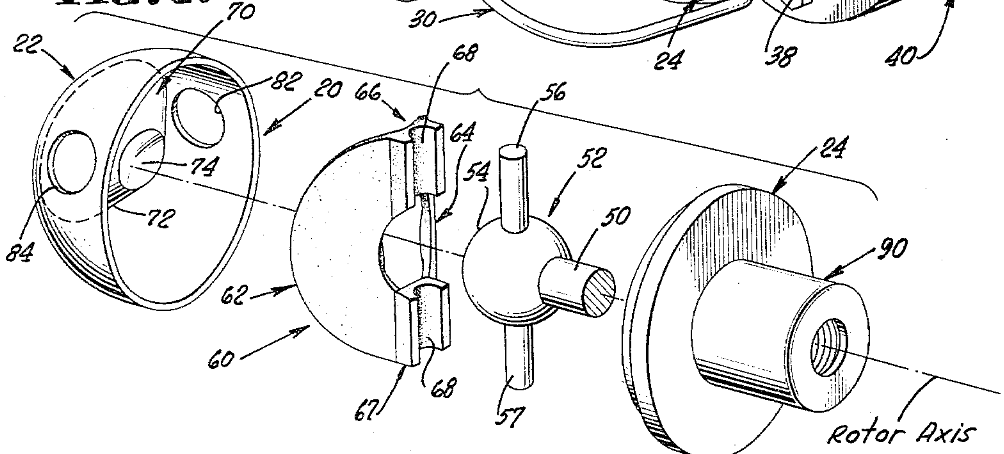

FIG. 3.

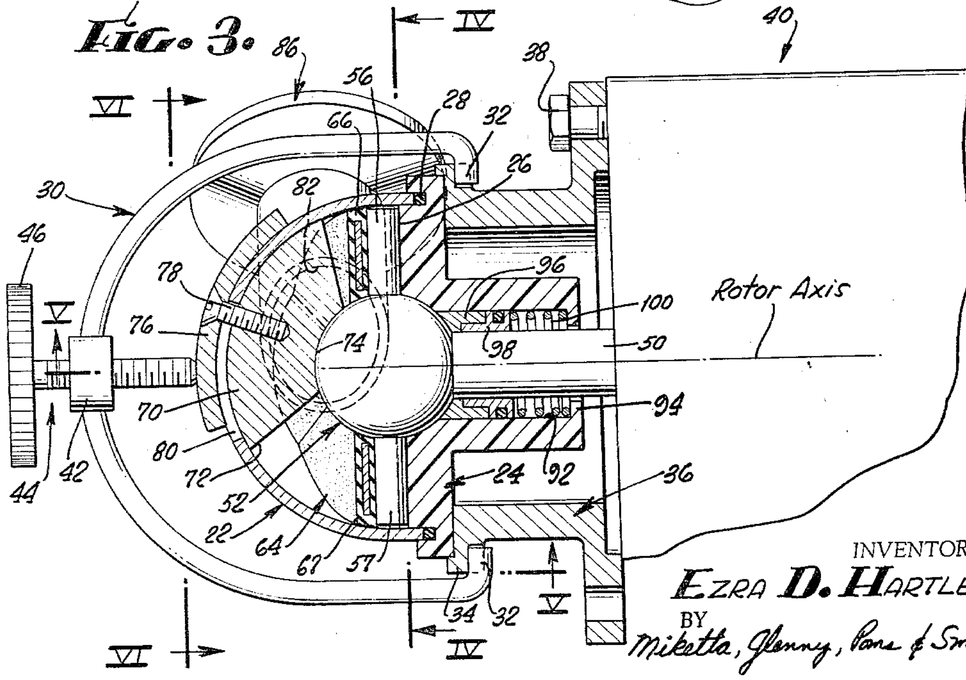

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FIG. 4.

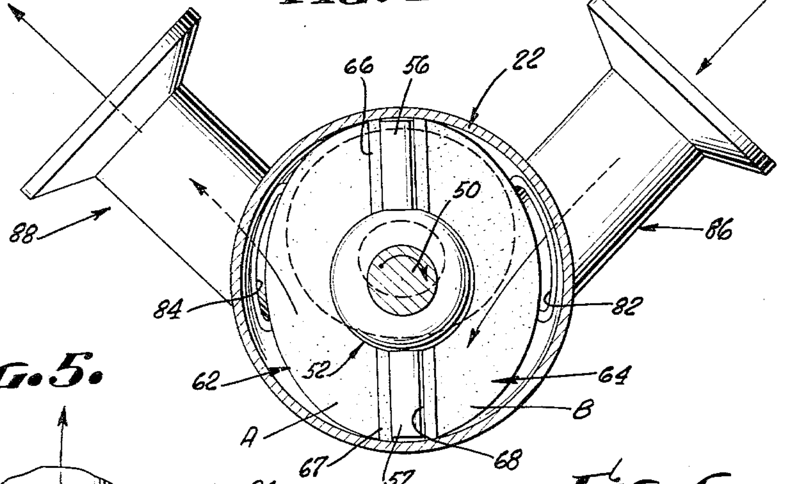

FIG. 5.

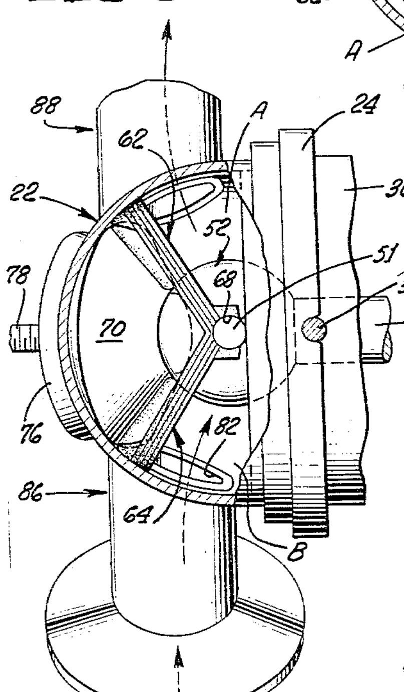

FIG. 6.

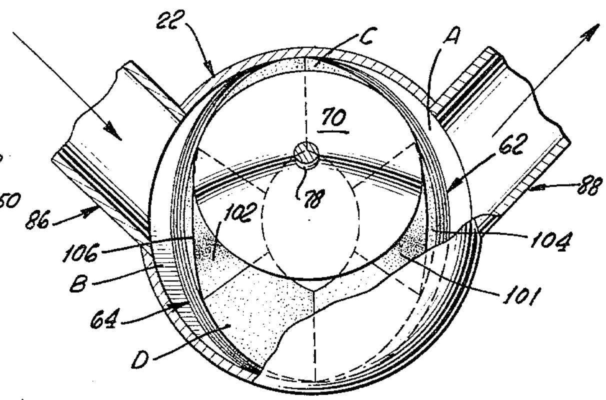

FIG. 7.

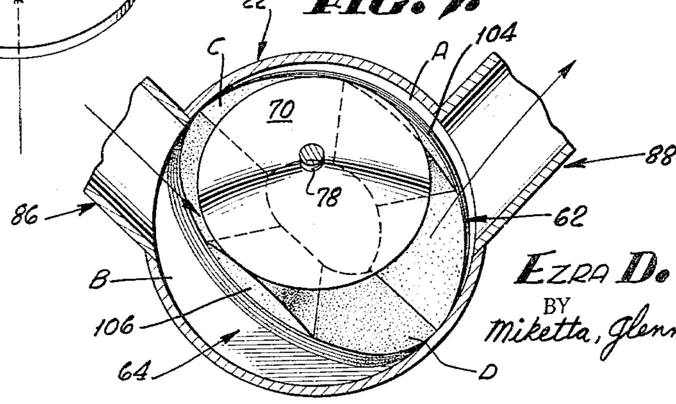

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FIG. 8.

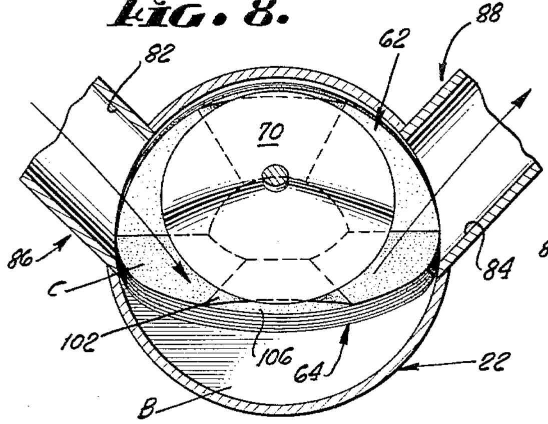

FIG. 9.

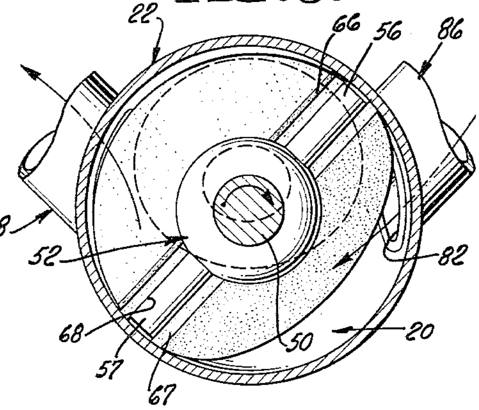

FIG. 10.

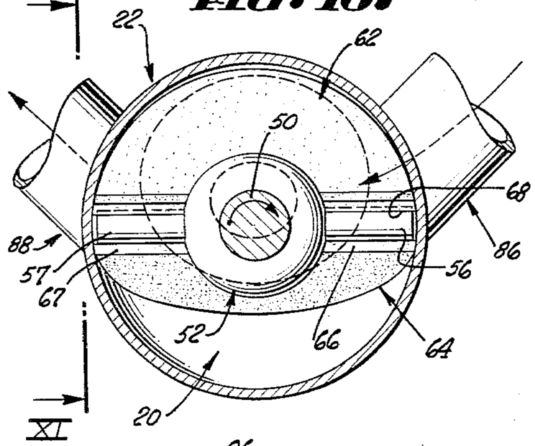

FIG. 12.

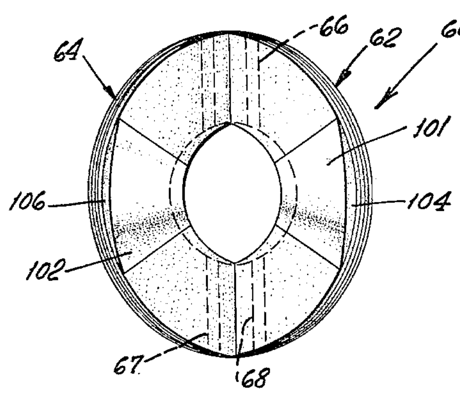

FIG. 11.

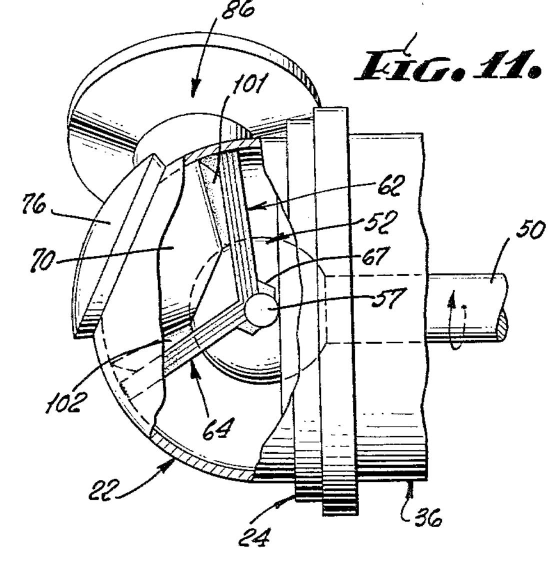

FIG. 13.

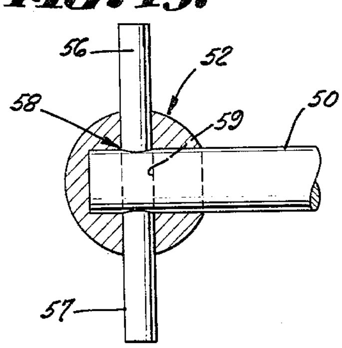

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FIG. 14.

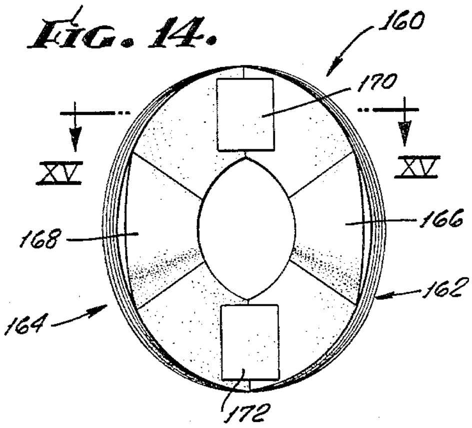


FIG. 15.

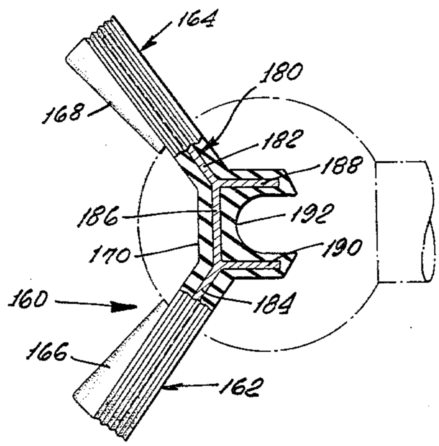


FIG. 16.

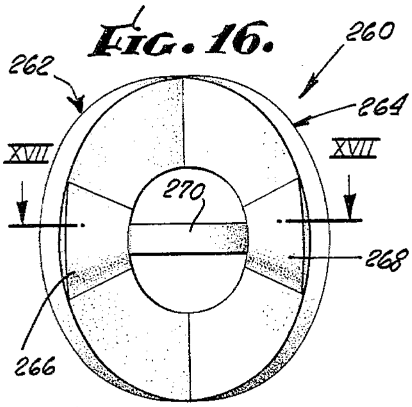


FIG. 17.

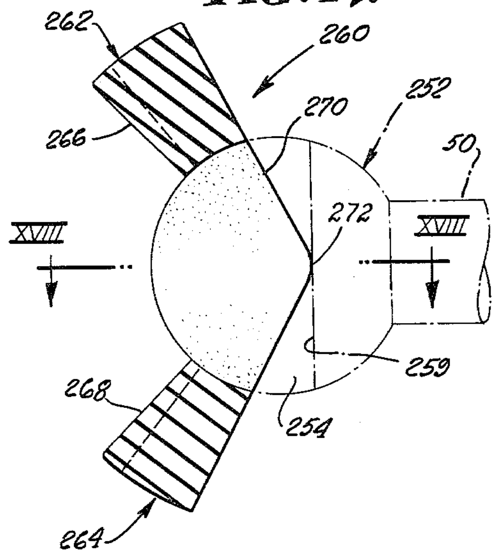
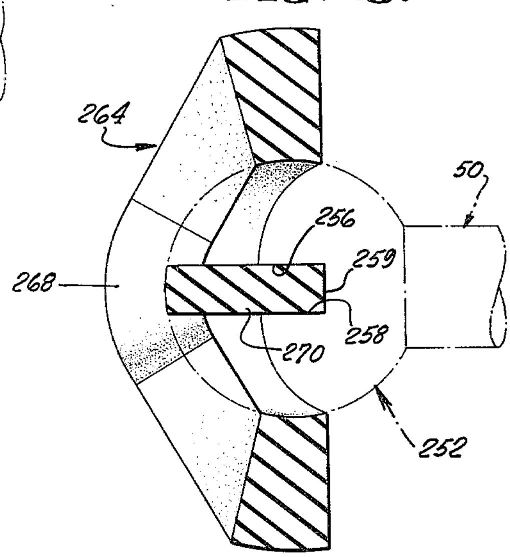


FIG. 18.



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3,240,156

ROTARY VANE PUMP

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12 Claims. (Cl. 103—120)

This invention relates generally to positive displacement pumps and more particularly to a pump having a generally hemispherical chamber and means including a rotatable dihedral impeller mounted therein for dividing the chamber into a plurality of compartments of cyclically changing volumes.

In a preferred embodiment of the invention hereinafter illustrated and described in detail, means are provided forming a chamber having a concave hemispherical front wall and a flat rear wall provided with a central aperture. Through the aperture a rotatable drive shaft extends forwardly into the chamber, terminating inwardly in rotor means having a forwardly directed convex hemispherical surface and a pair of oppositely directed drive pins projecting radially therefrom. Within the chamber there is mounted a dihedral impeller including a pair of semi-annular vanes, and the outer edges of the vanes are in slidable sealing contact with the concave inner wall while the inner edges of the vanes are in slidable sealing contact with the convex hemispherical surface of the rotor.

Thus the vanes divide the chamber into two sections, a forward section bounded by the concave hemispherical front wall and a rear section bounded by the flat rear wall. Each section is further divided into a pair of hermetically separated compartments. In the rear section such division is accomplished by the hub portion of the dihedral impeller, the hub being in rockable sealing contact with the radial drive pins of the rotor which in turn are in slidable sealing contact with the flat rear wall. The forward section is divided into a pair of hermetically separated compartments by slidable sealing engagement between the inner faces of the impeller vanes and the frusto conical surface of a cam member extending into the chamber from the concave hemispherical wall. The cam is desirably selectively positionable arcuately along the great circle of the concave hemispherical wall which intersects the axis of the drive shaft.

The cam just mentioned serves to cause the dihedral impeller to cyclically rockably pivot on the drive pins of the rotor during rotation of the drive shaft. The angle through which the impeller so pivots is a function of the angular displacement of the axis of the frusto-conical cam from the axis of the drive shaft. When such axes are coincident, no rocking or pivotal movement of the impeller occurs during shaft rotation and, as will be later understood, no pumping action takes place. When, however, the cam is positioned with its axis angularly displaced from the drive shaft axis, then the resulting rocking movement of the impeller during shaft rotation causes the volumes of the compartments to cyclically vary between maximum and minimum values. Inlet and outlet ports are angularly spaced at substantially 180° in the hemispherical wall of the chamber and serve to communicate fluid into and out of the compartments.

The construction is such that the rocking or pivotal movement of the impeller corresponds geometrically to a cyclic swinging of the bisector plane of the impeller dihedral angle to one side and then the other of a neutral or central position wherein the bisector plane passes through the drive shaft axis. The maximum excursion of the bisector plane corresponds to minimum volume of one of the rear compartments and maximum volume of the other rear compartment, while the central position of the bisector plane corresponds to maximum volume

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of one of the front compartments and minimum volume of the other front compartment.

The cyclic volume change of each compartment is substantially sinusoidal, and the cycles of the four compartments are spaced by 90° in phase. The amount of fluid pumped per cycle by each compartment depends of course upon the difference between the maximum and minimum volumes of the compartment during the cycle. Although such cyclic volume change is somewhat smaller for the front compartments than for the rear compartments, nevertheless the difference is not great, the ratio being in the neighborhood of 42 to 58 in a preferred form of the invention. This fact, in conjunction with the uniform 90° spacing in phase of the compartment volume cycles previously mentioned, minimizes pulsation and resulting turbulence in the fluid flow through the present pump, and the pump is accordingly particularly well adapted for pumping fluids such as milk where turbulence is disadvantageous.

As above mentioned, the inner faces of the impeller vanes are in slidable sealing contact with the frusto-conical cam during operation, in order to divide the forward section of the chamber into two hermetically separated compartments. If the inner faces are planar or flat over the area of such sliding contact, the geometry is such that the dihedral angle varies several degrees during each revolution of the drive shaft, causing continuous flexing of the impeller. If the material of which the impeller is made can withstand such flexing over an extended period without adverse effects, the impeller should be designed so that its interior dihedral angle, when the impeller is free and unstressed, is somewhat smaller than the apex angle of the frusto-conical cam. For example, if the cam apex angle is 110°, then the unstressed interior dihedral angle of the impeller should be of the order of 100°. Under these conditions, when the pump is assembled with the impeller vane inner faces in slidable contact with the cam, the resilience of the impeller material serves to bias the vanes toward the cam and thus maintain sealing contact therewith.

However, in order to avoid possible adverse effects of continuous impeller flexing as above described, the preferred form of the present invention contemplates that the inner faces of the impeller vanes, over the area of their sliding contact with the cam, be specially configured to maintain sealing contact without continuous flexing of the impeller. Specifically, the inner face of each vane is provided with a follower ramp in the central zone of its arcuate extent. The surface of the ramp is itself a portion of a frusto-conical surface having an apex angle equal to the supplement of the cam apex angle when the pump is assembled.

In an alternative form of the invention the dihedral impeller has integrally formed therein a driving web extending between the impeller vanes, and the rotor carried by the drive shaft is provided with a centrally disposed forwardly directed slot for slidably and sealably receiving the impeller web therein. During rotation of the drive shaft and consequently of the impeller, cyclic rocking or swinging of the impeller resulting from its sliding sealing contact with the cam causes the web to rock within the rotor slot. As in the case of the impeller first above mentioned, the inner faces of the vanes are desirably provided with centrally disposed ramps having frusto-conical contours for continuous contact between the cam and impeller vanes without flexing of the latter.

Accordingly, it is a principal object of the invention to provide novel improvements in rotary vane pumps. Other objects are to provide, in such a pump, a hemispherical chamber having means including a rotatable impeller dividing the interior of the chamber into a plurality of compartments of cyclically varying volumes; to provide an impeller having a pair of generally semi-annular vanes forming a dihedral angle; to provide means in the pump for cyclically swinging or rocking the impeller about the vertex of such dihedral angle as an axis; to provide in such a pump a frusto-conical cam within the interior angle of the impeller for causing the rocking movement of the impeller, the cam being adjustably positionable within the chamber; to disclose dihedral impeller vanes in such a pump wherein the inner faces of the vanes are provided with ramps for slidably and sealably contacting the cam, the ramps being so configured as to eliminate continuous flexing of the impeller during operation; and for additional objects and purposes as will be understood from a study of the following description of a preferred embodiment of the invention in conjunction with the accompanying drawings in which:

FIG. 1 is an isometric view of a pump embodying a preferred form of the present invention and, fragmentarily shown, a motor connected thereto, taken from the front end of the pump;

FIG. 2 is an exploded isometric view of the major component parts of the pump taken from the rear end thereof;

FIG. 3 is a vertical sectional view of the pump with the motor partially cut away;

FIG. 4 is a sectional view taken in the direction of the arrows IV—IV of FIG. 3 showing the rear faces of the impeller vanes as well as the rear pair of compartments;

FIG. 5 is a view taken along the broken line V—V of FIG. 3 with a portion of the hemispherical shell cut away;

FIG. 6 is a view taken on plane VI—VI of FIG. 3, with most of the hemispherical shell broken away, showing portions of the front faces of the impeller vanes.

FIGS. 7 and 8 are views similar to FIG. 6 with the hemispherical shell completely omitted and showing the impeller rotated, respectively, 45° and 90° counterclockwise from its position in FIG. 6.

FIGS. 9 and 10 are views similar to FIG. 4 showing the impeller rotated, respectively, 45° and 90° clockwise from its position in FIG. 4.

FIG. 11 is a view taken along plane XI—XI of FIG. 10 with a portion of the hemispherical shell broken away.

FIG. 12 is a front elevational view of the impeller.

FIG. 13 is a fragmentary view, partially sectionalized, showing the construction of the pivot pin and rotor head connected to the end of the drive shaft.

FIG. 14 is a front elevational view of a modified form of impeller in accordance with the invention, including strengthening ribs between the vanes.

FIG. 15 is a fragmentary view on the arrows XV—XV of FIG. 14 showing one form of internal spider in the impeller.

FIG. 16 is a front elevational of another modified form of impeller shown in the relationship corresponding to that of FIG. 5.

FIG. 17 is a fragmentary sectional view taken on line XVII—XVII of FIG. 16.

FIG. 18 is a sectional view looking downwardly on the arrows XVIII—XVIII of FIG. 16.

FIGS. 1, 2 and 3 show the general construction of one embodiment of the pump in accordance with the present invention. As there shown, a generally hemispherical chamber indicated generally at **20** is formed by a forward or front member indicated generally at **22** having a generally hemispherical wall and constituting a shell attached to a rear plate member indicated generally at **24**, the latter member having a forwardly directed flat annular face **26**. Hermetically sealing means are provided between the shell and the plate, such as circumferential gasket **28** in an annular groove of the plate **24**. Means are provided for holding the parts in assembled relation as shown, the means here including a bail indicated generally at **30** having a pair of inturned end fingers **32** received in notches formed in an annular flange **34** of a sleeve mounting member indicated generally at **36**. The latter member is attached to a driving means such as an electric motor indicated generally at **40** by suitable attachment means **38**. With further reference to bail **30**, there is provided a central hub **42** in which is threadedly engaged the shank of a retaining member indicated generally at **44** and provided with a knurled handwheel **46**. It will be seen that unscrewing of the retaining member **44** permits the bail fingers **32** to be disengaged from their notches and the bail thereby removed, permitting disassembly of the front shell member **22** from the plate **24**.

Means are provided in accordance with the invention within the chamber **20** for dividing the interior of the chamber into four compartments of cyclically changing volumes. Thus the drive shaft **50** of motor **40** terminates inwardly of the chamber in an enlarged rotor indicated generally at **52** having a forwardly directed convex hemispherical surface **54**. The rotor **52** is provided with impeller driving means, here shown as including a pair of oppositely disposed coaxial outwardly projecting cylindrical drive pins **56** and **57**, which may desirably be (see FIG. 13) opposite end portions of a single pin indicated generally at **58** extending through a radial bore **59** in drive shaft **50**.

An impeller indicated generally at **60** includes a pair of semicircular vanes indicated generally at **62** and **64** joined by a pair of hub portions indicated generally at **66** and **67** respectively. Each of the hubs **66** and **67** is provided with a radially disposed semicylindrical seat **68** adapted to slidably and sealably engage pins **56** and **57**, whereby impeller **60** may be rockably swung or pivoted within the chamber **20** about the common axis of pins **56** and **57**.

Within chamber **20** means are provided for rockably swinging the impeller **60** during rotation of the drive shaft **50** and the rotor **52** fixed thereto. In the present embodiment of the invention such means include a cam member indicated generally at **70** having a frusto-conical side wall **72** terminating inwardly in a spherically concave seat **74** adapted to slidably and sealingly engage the forwardly directed hemispherical surface **54** of rotor **52** when the parts are assembled as seen in FIG. 3.

Cam **70** is attached to shell **22**, preferably by means permitting selective adjustment of the axis of the cam along a great circle of the shell. Thus, with particular reference to FIG. 3, a bracket **76** may extend arcuately over a portion of the outer face of shell **22**, the bracket being provided wtih a fastening member **78** threadedly received in the cone **70**, the shank of the member **78** extending through a slot **80** formed in the outer wall of shell **22**. It will be understood that the length of slot **80** and the arcuate extent of the base of the cam **70** must be so chosen as to insure that chamber **20** remains isolated from atmosphere regardless of the adjusted position of cam **70** selected by the user. The only fluid communication with chamber **20** is provided by a pair of ports **82** and **84** located in the wall of hemispherical shell **22** and spaced laterally on either side of the cam **70**. Ports **82**, **84** communicate externally with suitable conduits indicated generally at **86** and **88** respectively. For any given set of operating conditions, one of the ports **82**, **84** will be the inlet port for the pump and the other will be the outlet port. In the present description it will be assumed that port **82** is the inlet port and port **84** is the outlet port. It will be understood that the roles of these ports may be reversed by reversal of the rotation of the drive shaft **50**; the roles may also be reversed if the length of the arcuate slot **80** in the shell **22** is great enough to permit cam **70** to be positioned either above or below the meridian of shell **22**.

With further reference to FIGS. 2 and 3, the plate member **24** is desirably provided with a rearwardly projecting sleeve portion indicated generally at **90** having an axially extending bore **92** terminating rearwardly in an inner annular shoulder 94. In the forward portion of the bore 92 there is slidably mounted a sealing member 96 having a forwardly directed annular face of spherically concave contour for sealingly contacting the rear face of the rotor 52. The seal 96 is biased leftwardly as seen in FIG. 3 by a collar 98 and a resilient member in the form of a helical spring 100 bearing, at one end, against collar 98 and at its other end against annular shoulder 94 of sleeve 90. Rotor pins 56 and 57 carried by rotor 52 are urged rightwardly as seen in FIG. 3 into slidable sealable contact with the forwardly directed annular face 26 of plate 24.

With the parts assembled as seen in FIG. 3, the inner faces of the vanes 62 and 64 of the dihedral impeller 60 are in slidable sealing contact with the frusto-conical cam 70. Moreover, the outer edges of the vanes are semicircular in contour and are in slidable sealing engagement with the inner hemispherical surface of shell 20. The inner edges of vanes 62 and 64 are likewise semicircular in contour and are in slidable sealing engagement with the convex hemispherical surface 54 of rotor 52. It will thus be understood that the interior of the chamber 20 is divided into four compartments by the impeller 60 and the slidable engagement of its vanes 62 and 64 just referred to. As will now be described in connection with FIGS. 4–10, the volumes of these compartments vary cyclically during rotation of drive shaft 50. It will be especially observed that, of the two forward compartments lying within the dihedral angle of impeller 60, one such forward compartment at any one instant is receiving fluid from inlet port 82, while the other such forward compartment is pumping fluid outwardly through outlet port 84. The rear pair of compartments, that is the compartments between the rear faces of vanes 62 and 64 and the annular face 26 of plate 24, similarly cyclically change in volume during rotation of the drive shaft 50; and it is an important feature of the present invention that the cycles of the rear compartments are spaced in phase by 90° from the cycles of the forward compartments. As will be understood, this arrangement minimizes the creation of turbulence in the fluid being pumped, not only within the pump proper but also immediately upstream and downstream of the pump.

The construction and relationship of the various parts within the chamber will be further understood by reference to FIGS. 4, 5 and 6. It will be especially noted, as best seen in FIG. 5, that the bisector plane of the dihedral angle of impeller 60 is momentarily coincident with the axis of drive shaft 50, and the volumes of the two rear chambers A and B are thus momentarily equal. Assuming clockwise rotation of drive shaft 50, as indicated by the arrow thereon in FIG. 4, the volume of compartment A is momentarily decreasing, thus causing the pumped fluid to be forced outwardly of that compartment through outlet port 84 into outlet conduit 88. Simultaneously, as indicated by the arrows in the lower portion of FIG. 5, compartment B is momentarily increasing in volume, thereby drawing into this compartment fluid from inlet conduit 86 through inlet port 82. In FIG. 6, the two forward compartments are shown at C and D, compartment C being momentarily at its point of minimum volume and compartment D being momentarily at its point of maximum volume. Thus, keeping in mind that the direction of rotation of drive shaft and impeller as seen in FIG. 6 is opposite that seen in FIG. 4, it will be seen that compartment D is at the beginning of the portion of its cycle for delivery of pumped fluid to the outlet conduit 88, having received such fluid from inlet conduit 86 during the portion of the cycle immediately preceding the position of the parts seen in FIG. 6. In FIG. 7, the parts are shown 45° later than FIG. 6, the volume of compartment C having increased and the volume of compartment D having decreased from their values in FIG. 6. Furthermore, shortly after the condition shown in FIG. 6, the outer semicircular edge of vane 64 commences to uncover inlet port 82 for communication therefrom to compartment C. It will be noted also that compartment B increases in volume from its condition seen in FIG. 6 to its condition seen in FIG. 7, thereby also drawing pumped fluid from inlet conduit 86 during this portion of its cycle.

In FIG. 8 the parts are seen 45° later than in FIG. 7. Thus in FIG. 8 compartment B has attained its maximum volume, and the outer edge of vane 64 is just closing off communication from inlet conduit 86 to compartment B, and is providing fully open communication from the inlet conduit to compartment C. Simultaneously, as further seen in FIG. 8, vane 64 is moving so that its outer semicircular edge is commencing to uncover the outlet port 84 to communication with compartment B, so that the fluid contained in compartment B, a moment following the position of the parts seen in FIG. 8, will commence to flow outwardly of that compartment into outlet conduit 88.

FIGS. 9 and 10 show, sequentially, the position of the parts at 45° intervals following their position as seen in FIG. 4, keeping in mind that the rotation of the parts as seen in FIGS. 4, 9 and 10 is clockwise. Thus in FIG. 4, pumped fluid is being drawn into compartment B from inlet conduit 86 and is being pumped out of compartment A into outlet conduit 88. These conditions continue in the position of the parts seen in FIG. 9 and up to the position of the parts seen in FIG. 10. In the last-named position of the parts, the volume of compartment B has attained its maximum value during its cycle, and the outer semicircular edge of vane 64 has just passed inlet port 82, thereby closing off fluid communication from that port to compartment B. Simultaneously, the same outer semicircular edge is just commencing to open communication with outlet port 84, thereby permitting the fluid contained in compartment B to commence being pumped out of the compartment through outlet port 84 into outlet conduit 88.

The volumetric geometry of the parts is such that, whenever two compartments are in communication with one of the ports, the rate of change of volume of one of such compartments is decreasing, while the rate of change of volume of the other compartment is increasing. The change of volume of each compartment is substantially sinusoidal throughout its cycle. Also, the cycles of front and rear compartments which at any moment are in communication with a given port are spaced 90° in phase from one another. The result is that the net flow of pumped fluid from the inlet port into the two compartments instantaneously in communication with the inlet port is substantially constant; and the net flow of fluid out of a front and rear compartment in communication with the outlet port at any one instant is similarly substantially constant. As previously mentioned, the pumped fluid is therefore subjected to minimum turbulence, both within the pump and in the conduits upstream and downstream of the pump.

It is of course important that continuous sealing contact be maintained between the inner faces of the vanes of the dihedral impeller and the frusto-conical surface of cam 70. If the inner vane faces are planar, the geometry of operation is such that the impeller must flex during operation; that is, the dihedral angle between the vanes varies cyclically. In order to maintain the necessary sealing contact between vanes and cam, the impeller may be initially formed with a dihedral angle between its vanes which is somewhat smaller than the apex angle of the frusto-conical cam. Thus, if the apex angle of the cam is, say, 120°, then the dihedral angle of the impeller, while unstressed, should be, say, 110°. In such an arrangement, when the parts are assembled as seen in FIG. 3, the vanes are stressed slightly outwardly, maintaining sliding sealing contact with the cam. However, with some materials of which the impeller may be made, the resulting cyclical flexing of the impeller may lead to failure of the impeller. In order to obviate this, it is preferred to provide on the inner faces of the impeller vanes configurations which provide constant sealing contact with the cam, while eliminating any flexing of the impeller during operation.

Thus there are desirably provided on the inner faces of the vanes, centrally of their semicircular extent, enlarged portions or ramps having contours which are frusto-conical to thereby mate with the frusto-conical surface of cam **70**. With particular reference to FIGS. 11 and 12, the inner face of vane **62** is provided with a ramp **101**, while the inner face of vane **64** is similarly provided with a ramp **102**. The contours of the two ramps are frusto-conical about axes passing through the axis of pin **58** of the rotor.

As seen in FIG. 12 the ramps **101** and **102** extend over a substantial portion of their respective vanes, and have their thickest portions **104** and **106** at the centers of the semicircular extent of the vanes. From such thickest portions the ramps extend symmertically along the inner vane faces to an extent at least necessary to insure that contact between the vanes and the cam will be maintained along the ramps throughout the entire cycle of operation of the pump, regardless of the position of the axis of cam **70** relative to the axis of the drive shaft **50**. In a typical construction wherein the maximum inclination of the axis of the cone relative to the drive shaft axis is of the order of 20°, the ramps on the impeller vanes may extend approximately 75° of arc, the remaining portions of the inner faces of the vanes being planar.

The material of which the impeller is made must of course be resistant to deterioration by the fluid being pumped, and moreover the semicircular edges, both inner and outer, of the vanes desirably present a slightly flexible contact with, respectively, the hemispherical surface of the rotor and the hemispherical inner wall of the shell, in order to maintain sealing contact with those surfaces during operation. Thus the impeller may be made of rubber or a material of generally comparable characteristics, and may be strengthened by a spider or the like embedded in the material of the impeller or affixed to the outer surfaces thereof. In FIGS. 14 and 15 there is illustrated a form of impeller in accordance with this construction. As there shown, an impeller indicated generally at **160** includes semicircular vanes indicated generally at **162** and **164**, the inner faces of the vanes being provided with ramps **166** and **168** respectively having frusto-conical contours as previously described in connection with FIGS. 11 and 12. Additionally, the impeller **160** is provided with strengthening ribs **170** and **172** preferably integrally formed with the impeller body, and, as best seen in FIG. 15, an internal spider indicated generally at **180** may be provided in the impeller, including a pair of arms **182** and **184** and a central leg **186**. The spider may be made of sheet metal or the like and desirably includes arm portions **188** and **190** extending in parallel spaced relation into the hub portions of the impeller, in order to insure continuous sealing contact with the drive pins of the rotor, such pins being received in the semicylindrical portion **192**.

In FIGS. 16, 17 and 18 there is shown a modified form of rotor and impeller construction, wherein the rotor, instead of being provided with outwardly projecting drive pins as in the embodiments previously described, is provided with a forwardly directed radially disposed slot for receiving therein a driving web portion of the modified impeller there shown. Such impeller is seen in elevation in FIG. 16, and is seen in section mounted on the rotor in FIGS. 17 and 18.

Thus, drive shaft **50** terminates in a rotor indicated generally at **252** having formed therein a slot **254**, the slot being forwardly open and being defined by spaced parallel side walls **256** and **258** terminating inwardly in a flat base **259** extending transversely of the axis of shaft **50** and spaced rearwardly of the center of rotor **252**.

The impeller is indicated generally at **260** and includes a pair of generally semicircular vanes indicated generally at **262** and **264**, each of the vanes being provided on its inner face with a ramp **266** and **268** having a frusto-conical contour of the same characteristics as those of ramps **101** and **102** previously described. In the rear portion of the impeller **260**, and formed integrally with the vanes thereof, there is provided a central driving web **270** which is slidably received in the rotor slot **254**. The innermost extent of web **270** (see FIG. 17) is desirably rounded at **272** for rolling contact with the base **259** of slot **254** during the cyclic swinging of the impeller in operation.

It may be noted, with reference to the construction of FIGS. 16, 17 and 18, that the only fluid path permitting leakage between the compartments within the chamber is along the side walls of the slot **254**, between such walls and the sides of the web **270** received in the slot. As will be seen, this leakage path is comparatively long and desirably very narrow, so that leakage therethrough is minimized; it will further be noted that during rotation of drive shaft **50**, the driving torque transmitted from the drive shaft to the impeller through web **270** tends to force approximately one-half of the area of each of the sides of the web **270** into tight contact with the side walls of the slot **254**, thereby further minimizing leakage through the slot.

Accordingly, it will be seen that the pump of the present invention provides remarkably high capacity within a samll space, and the amount of fluid pumped per revolution of the drive shaft may be conveniently adjusted by the user by positioning the frusto-conical cam within the chamber at desired inclination of the cam axis relative to the axis of the driving shaft. It may be noted that if the cam is positioned with its axis coincident with the drive shaft axis, no change of volume of the four compartments takes place during rotation of the shaft, and consequently no fluid is pumped. The direction of flow of pumped fluid may be readily reversed, either by reversing the direction of rotation of the motor or other prime mover driving the shaft, or by adjusting the position of the cam to the opposite side of the drive shaft axis, i.e. to below the shaft axis as seen in FIG. 3.

Modifications and changes from the specifically illustrative forms of the invention hereinabove described and illustrative will occur to those skilled in the art. All such modifications and changes not substantially departing from the spirit of the invention are intended to be embraced within the scope of the appended claims.

I claim:

1. A rotary pump comprising:

means forming a generally hemispherical chamber including a centrally apertured flat rear wall and a concave hemispherical front wall;

a rotatable drive shaft extending into the chamber through the rear wall aperture and terminating forwardly in a rotor having a forwardly directed convex hemispheical surface and a pair of oppositely directed pivot pins projecting radially of the drive shaft axis from said convex surface and in slidable sealing contact with said rear wall;

an impeller including a pair of semi-annular vanes joined at a hub portion to form a dihedral angle between the vanes, the hub being rockably and sealably mounted on said pins, the outer and inner arcuate perimeters of the vanes being in sealing relation with, respectively, said concave front wall and said convex surface;

means for pivoting said impeller about the vertex of said dihedral angle during rotation of said shaft, the impeller and said pivoting means dividing said chamber into a plurality of compartments of cyclically varying volumes;

and inlet and outlet ports formed in said concave front wall.

2. The invention as stated in claim **1** wherein said pivoting means comprises a cam having a frusto-conical contour extending into the chamber from said front wall.

3. The invention as stated in claim **2** including means permitting adjustable positioning of the cam with its axis at a selected angle with the drive shaft axis.

4. The invention as stated in claim **2** including ramps on the impeller vane faces contacting the cam, the ramps having frusto-conical contours, the ramp axes intersecting the axis of said pivot pins.

5. The invention as stated in claim **4** wherein the apex angle of each of the frusto-conical ramps is the supplement of the apex angle of the cam.

6. A rotary pump comprising:
- means forming a generally hemispherical chamber including a centrally apertured flat rear wall and a concave hemispherical front wall;
- a rotatable drive shaft extending into the chamber through the rear wall aperture and terminating forwardly in a rotor having a forwardly directed convex hemispherical surface;
- an impeller including a pair of semi-annular vanes joined at a hub portion to form a dihedral angle between the vanes, the outer and inner arcuate perimeters of the vanes being in sealing relation with, respectively, said concave front wall and said convex surface;
- means interengaging the rotor and impeller whereby rotation of the rotor and shaft causes rotation of the impeller;
- means for pivoting said impeller about the vertex of said dihedral angle during rotation of said shaft;
- the impeller and said pivoting means dividing said chamber into a plurality of compartments of cyclically varying volumes;
- and inlet and outlet ports formed in said concave front wall.

7. The invention as stated in claim **6** wherein said interengaging means include a forwardly directed centrally disposed slot formed in said rotor and a web extending rearwardly between the impeller vanes and formed integrally therewith, the web being slidably and sealably received in said slot and being rockable therein.

8. The invention as stated in claim **6** wherein said pivoting means includes a frusto-conical cam carried by the front wall and projecting into the chamber therefrom.

9. The invention as stated in claim **8** wherein said impeller vanes slidably and sealably contact said cam.

10. The invention as stated in claim **9** wherein the vane faces contacting the cam are provided with ramps of frusto-conical contour.

11. A rotary pump comprising:
- means forming a hemispherical chamber having a concave front wall provided with inlet and outlet ports;
- a shaft rotatable about the axis of said chamber terminating forwardly in a hemispherical rotor within the chamber and concentric therewith;
- an impeller including a pair of semi-annular vanes joined at a hub portion to form a dihedral angle between the vanes, the outer and inner arcuate perimeters of the vanes being in sealing relation with, respectively, said concave front wall and with said rotor;
- means interengaging the rotor and impeller whereby rotation of the rotor and shaft causes rotataion of the impeller;
- a frusto-conical cam carried by the front wall and projecting into the chamber, the inner end of the cam being in sealing relation with the rotor and the axis of the cam being adjustably positionable in selected angular relation with and on either side of the shaft axis, the impeller and cam dividing said chamber into four compartments of cyclically varying volumes.

12. The invention as stated in claim **11** wherein the faces of the vanes include frusto-conical ramps for sealingly contacting the cam.

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