PUMP

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Fig. 1

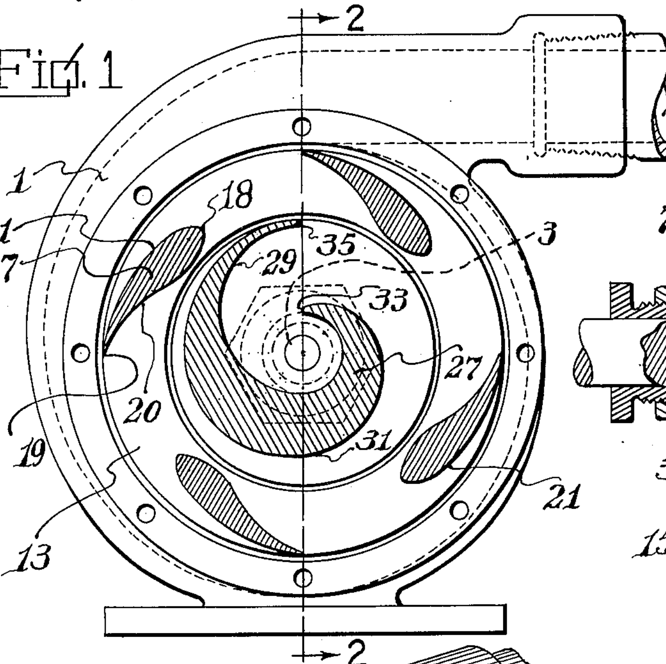


Fig. 2

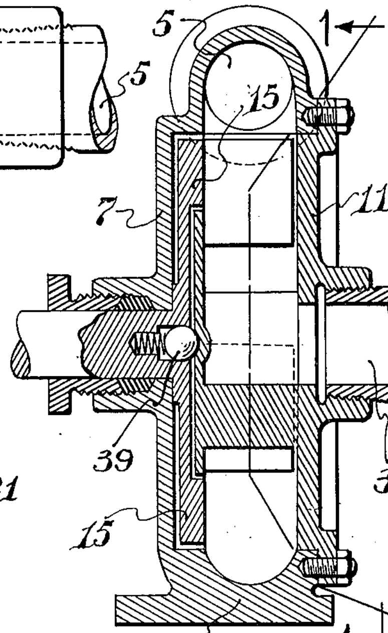


Fig. 3

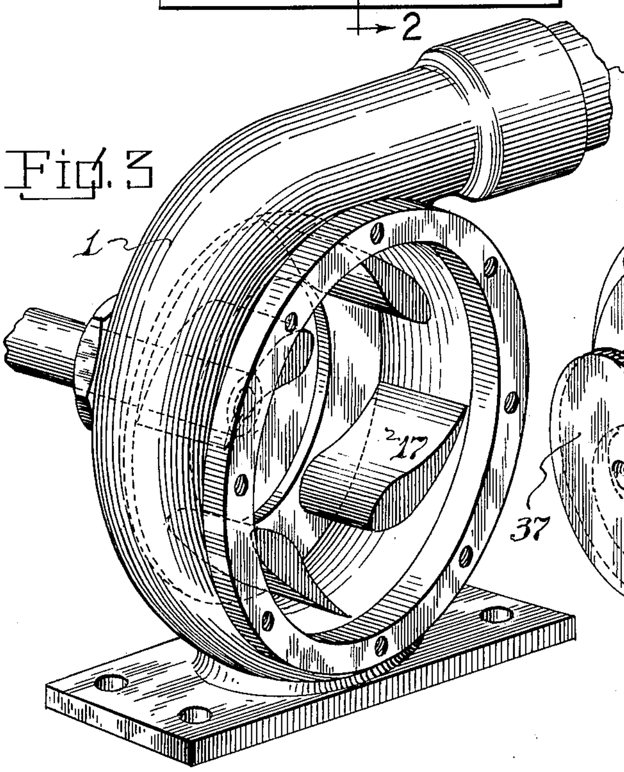
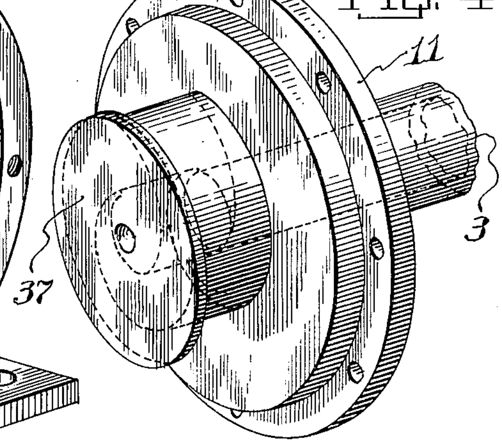


Fig. 4



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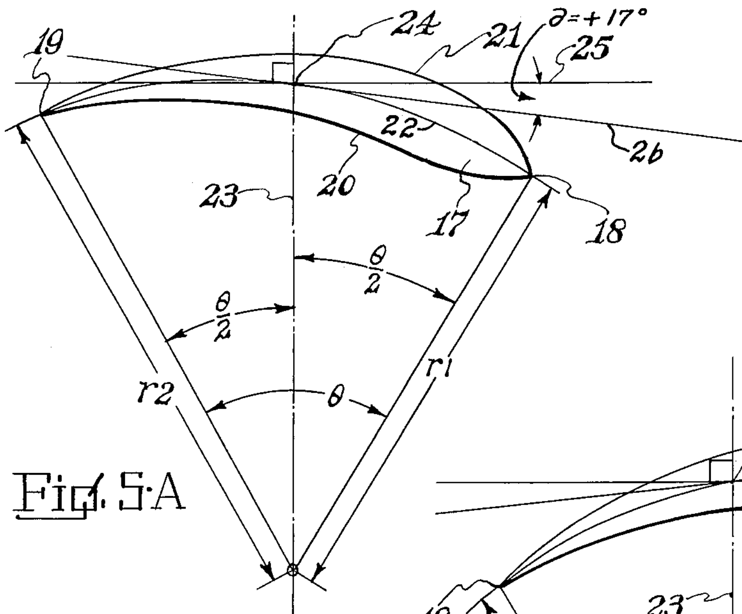


Fig. 5A

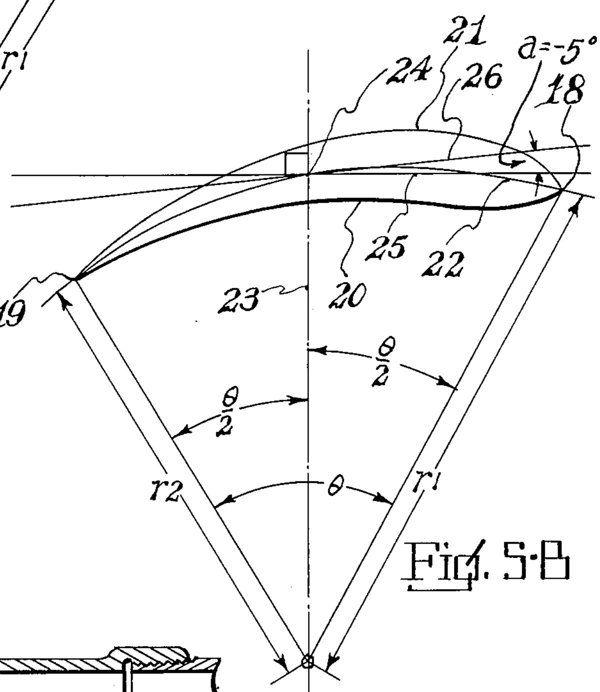
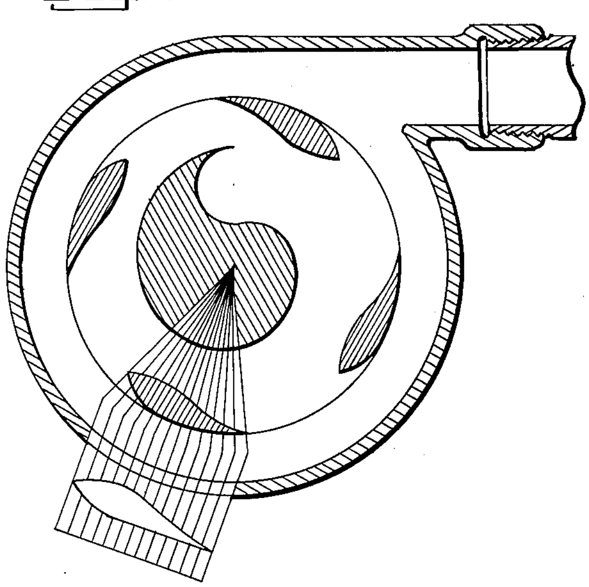


Fig. 5B

Fig. 6



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PUMP

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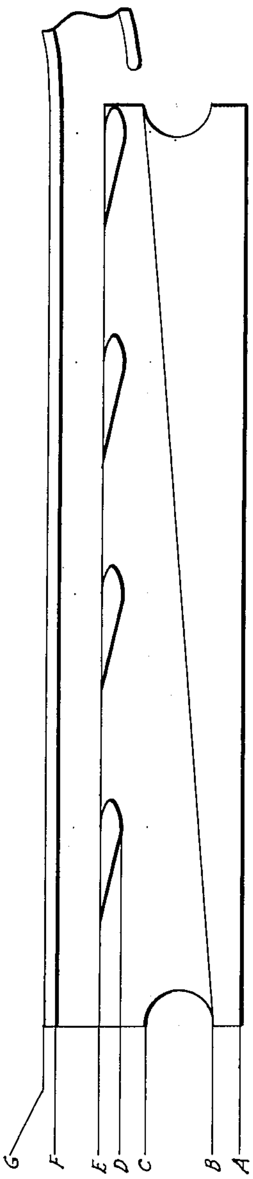

Fig. 7

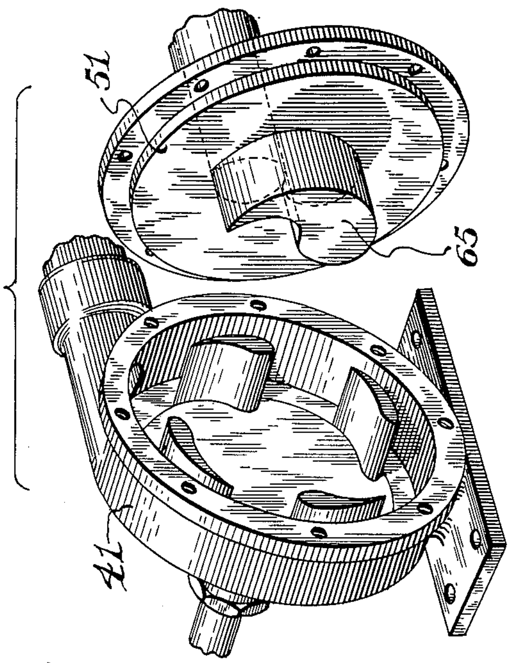

Fig. 9

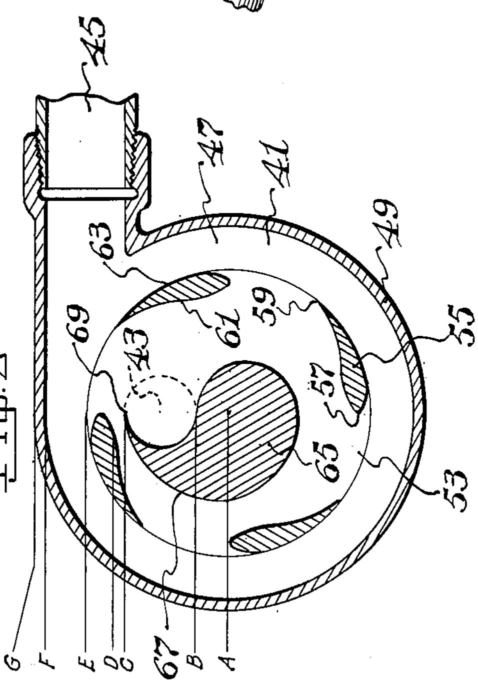

Fig. 8

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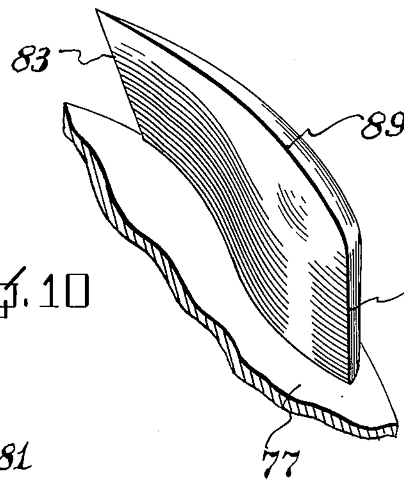

Fig. 10

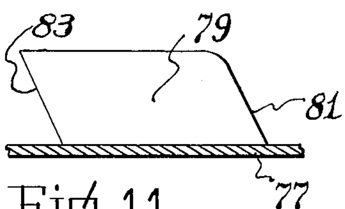

Fig. 11

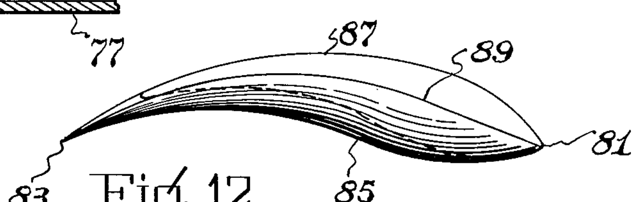

Fig. 12

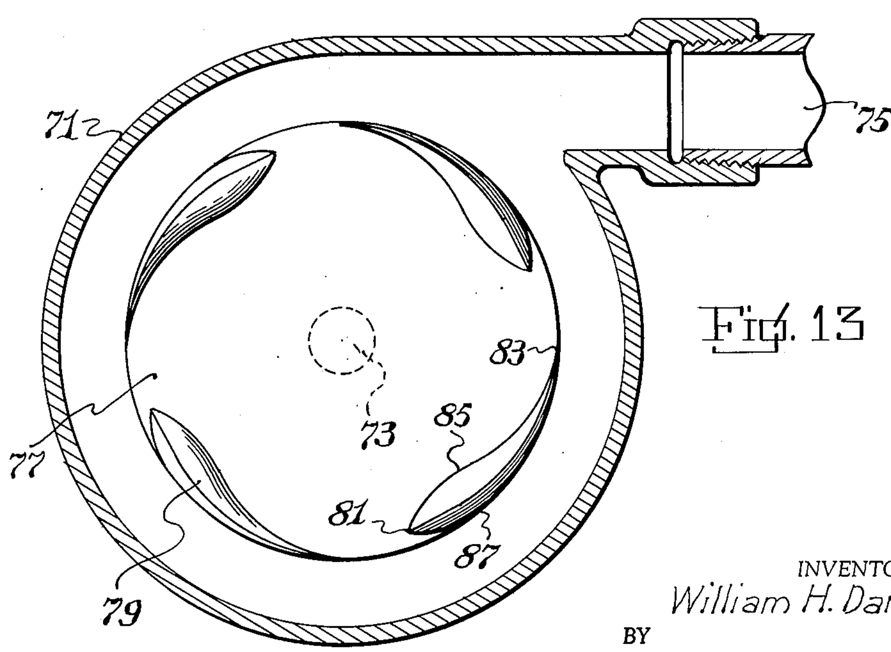

Fig. 13

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3,261,297
Patented July 19, 1966

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PUMP

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Filed May 24, 1965, Ser. No. 458,115
6 Claims. (Cl. 103—103)

This application is a continuation-in-part of copending application Serial No. 81,997, filed January 11, 1961, now abandoned.

The present invention relates to pumps, more particularly of the centrifugal type, in which a series of spaced vanes moves in a circular path and fluid enters at a point within the circular path and moves outward through the revolving vanes and leaves the pump at a point outside the circular path.

The present invention is termed a "pump" and will be described in connection with a pump for increasing the pressure and/or the flow rate of liquids with or without entrained solids. It is to be understood, however, that the term "pump" as used herein also includes compressors for increasing the pressure and/or the velocity of gases, and that the term "fluid" as used herein includes both liquids and gases.

The present invention comprises a fundamental departure from the principle of centrifugal pumps as ordinarily understood. In the more common type of centrifugal pumps, a plurality of vanes are provided which act as scoops or paddles to contact the fluid on their leading surfaces and push the fluid along a path having a substantial radially outward component. Such paddle-type pumps will be referred to from time to time as the description of the present invention proceeds, for purposes of comparison. In general, they are characterized by limited vacuum suction characteristics, low efficiency, and low pressure heads.

Accordingly, it is an object of the present invention to provide pumps of the centrifugal type which are characterized by improved performance in the above categories.

It is a further object of the present invention to provide pumps of the centrifugal type which enable the production of relatively high pressure differentials in the pumped fluid upstream and downstream of the pump.

Still another object of the present invention is the provision of pumps of the centrifugal type which are relatively free from turbulence in the pump chamber.

A still further object of the present invention is the provision of pumps relatively free of internal friction within the fluid in the pump chamber.

It is also an object of the present invention to provide pumps in which the fluid passing between the inlet and the outlet is characterized by a maximum of laminar flow.

The invention also contemplates the provision of pumps having improved priming characteristics.

A further object of the present invention is the provision of pumps of the centrifugal type, with improved non-clogging characteristics, which are well adapted to handle liquid having relatively large pieces of solid material entrained therein.

Still a further object of the present invention is the provision of pumps of the centrifugal type in which relatively large manufacturing tolerances are inherent in the design with no detrimental effects on performance.

Another object of the present invention is the provision of pumps of the centrifugal type which are well adapted to handle air that collects in the pump chamber.

It is also an object of the present invention to provide improved pumps of the centrifugal type which can be readily adapted from existing types of pumps.

The invention also contemplates the provision of pumps of the centrifugal type in which thrust on the pump bearings can be minimized.

Finally, it is an object of the present invention to provide pumps of the centrifugal type which are relatively simple and inexpensive to manufacture, easy to operate, clean, maintain and repair, and rugged and durable in use.

Other objects and advantages of the present invention will become apparent from a consideration of the following description, taken in connection with the accompanying drawings, in which:

FIGURE 1 is a partial sectional view of a pump according to the present invention, taken on the line **1—1** of FIG. 2;

FIGURE 2 is an axial cross-sectional view of a pump according to the present invention, taken on the line **2—2** of FIG. 1;

FIGURE 3 is a perspective view of a portion of the pump casing and the rotor of the pump of FIGS. 1 and 2; and

FIGURE 4 is a perspective view of another portion of the pump casing and an attached volute, for assembly with the structure of FIG. 3.

FIGS. 1–4 in fact represent a less preferred form of the present invention, as might be produced by adapting an existing type of centrifugal pump to the invention.

FIGURE 5A shows diagrammatically the geometric relationships of an impeller vane of the present invention, in one extreme position thereof; and

FIGURE 5B is a view similar to FIG. 5A but showing the vane in the other extreme position thereof.

FIGURES 6–9 show a second and more preferred embodiment of the present invention, in which:

FIGURE 6 is a view showing a preferred form of pump and illustrating the manner of deriving the shape of the vanes;

FIGURE 7 is a rectilinear projection of a preferred form of pump, demonstrating how the preferred configuration of the elements within the pump chamber can be developed;

FIGURE 8 is a view of an actual pump chamber according to the present invention, showing how the shapes derived from the projection of FIG. 7 are translated into their corresponding shapes in the rotary pump; and

FIGURE 9 is an exploded perspective assembly view of a preferred form of pump, opened to show the possible configuration of the parts within the pump chamber.

FIGURES 10–13 are illustrative of a third embodiment of pump according to the present invention, which differs from the embodiment of FIGS. 5–9 both as to the configuration of the vanes and as to the presence of the volute. Specifically:

FIGURE 10 is a perspective view of a modified form of impeller vane;

FIGURE 11 is a side elevational view of the vane of FIG. 10;

FIGURE 12 is an end or edge view of the vane of FIGS. 10 and 11; and

FIGURE 13 is a view of a pump including the impeller vanes of FIGS. 10–12, without a central volute.

Referring now to the drawings in greater detail, and first with reference to the less preferred embodiment of FIGS. 1–4, it will be seen that there is provided pump of the centrifugal type, comprising a rounded casing **1** having a central inlet **3** and a peripheral tangentially disposed outlet **5**. Casing **1** is generally comprised of two principal separable portions by which access may be had to the interior of the pump chamber. One of those portions comprises a plate **7** having a peripheral scroll **9**. The other of those portions comprises a plate **11** that may be releasably secured about its periphery to scroll **9** by means of bolts or the like.

Disposed within casing **1** for rotation about a horizontal axis is a rotor **13** having a drive shaft that extends through and out beyond plate 7. Motor means (not shown) are provided for selectively driving the pump by rotating the drive shaft. Rotor 13 has a peripheral flange 15 thereon that extends toward plate 11. Flange 15 bears a plurality of vanes 17, each of airfoil configuration, spaced equal distances about the periphery of rotor 13. Vanes 17 extend across the interior of the pump chamber from flange 15 toward and almost to plate 11. In general, of course, the path of liquid movement is from inlet 3 radially outwardly between vanes 17, and then out through outlet 5.

Each vane 17 has a leading edge 18 and a trailing edge 19, an inner surface 20 and an outer surface 21. Leading edges 18 are disposed closer to the axis rotation of rotor 13 than are trailing edges 19. The mean line or median line or camber line 22 of each vane 17 is the line that lies in a plane perpendicular to the axis of rotation and that interconnects the leading edge 18 with the trailing edge 19 of a vane 17 and that follows the lengthwise contour of the cross section of the vane and is at all points along its length spaced equal distances from inner surface 20 and outer surface 21 measured in a direction perpendicular to line 22 at the point in question. Camber line 22 thus subtends an arc about the axis of revolution that extends from radius r_1 (between the axis and leading edge 18) through an angle θ to radius r_2 (between the axis and trailing edge 19). The bisector 23 of angle θ intersects camber line 22 at a point 24. At point 24, the perpendicular 25 to bisector 23 is disposed at a small angle to the tangent 26 to camber line 22 at point 24. That small angle varies between extremes of about $-5°$ (FIG. 5B) and $+17°$ (FIG. 5A), more preferably $-2°$ to $+8°$ and most preferably $0°$ to $+5°$. The sign of the angle is chosen the same way as in the design of an airfoil for an aircraft: namely, remembering that the radially inner side of the vanes is the low pressure side and the radially outer side is the high pressure side, those angles indicative of positive camber are given a plus sign and those indicative of negative camber are given a minus sign. Stated another way: moving the leading edge of the vanes radially inwardly tends to shift the sign of the angle toward the positive; while moving the trailing edge of the vane radially inwardly tends to shift the sign of the angle toward the negative. The particular angle selected will vary according to such factors as the viscosity of the fluid, its temperature, the solids content of the fluid, and, in the use of a liquid, its tendency to cavitate. It will thus be understood that the ratio of r_1 to r_2 remains near unity, in contrast to the prior art, in which the ratio is much less than unity.

In this and other embodiments of the present invention, it is especially to be noted that the vanes are substantially closer to the outer periphery of the pump chamber, as defined for example by the scroll 9, than they are to the axis of rotation of the rotor. Specifically, point 24 is closer to scroll 9 than it is to the axis of rotation of the rotor; and preferably, all points on inner surface 20 are also closer to scroll 9 than they are to the axis of rotation of the rotor.

Mounted fixedly on plate 11 is a volute 27 that extends from plate 11 across the pump chamber almost to rotor 13. Volute 27 has a generally central recess in alignment with axial inlet 3. Volute 27 presents a pair of boundary surfaces 29 and 31 which spiral radially outwardly in the direction of rotation of rotor 13, and which bound the flow of fluid from inlet 3 as it moves radially outwardly toward vanes 17. Volute 27 has a leading or inner edge 33 and a trailing or outer edge 35. Boundary surface 31 on the outer side of volute 27 extends about 360° from leading edge 33 to trailing edge 35. An extent of 360° is preferred for boundary surface 31, although it may vary from about 330° of arc to about 390° of arc. Trailing edge 35 is in radial alignment with that point at which the axis of tangential outlet 5 and the inner wall of flange 9 begin to converge. The common radius that passes through this point and through leading edge 33 and trailing edge 35 is marked by the section line 2—2 in FIG. 1. Trailing edge 35 is preferably in radial alignment with this point, although it may vary from radial alignment with this point by about ±30° of arc. For air-handling characteristics, it is preferred that outlet 5 be uppermost. In that case, leading edge 33 and trailing edge 35 will also be disposed straight up from inlet 3, and the axis of rotor 13 will be horizontal.

Volute 27 may carry a fixed plate 37 in unitary assembly therewith. Plate 37 has an outer periphery which is disposed within and closely adjacent the inner periphery of flange 15 on the rotor 13. Preferably, the inner face of plate 37 is flush with the outer face of flange 15 on rotor 13. A thrust bearing 39 between rotor 13 and plate 37 is in axial alignment with inlet 3 and the axis of rotation of rotor 13.

As was noted above, the embodiment of FIGS. 1–4 is a less preferred form of the present invention and could be adopted when it is desired to convert an existing centrifugal pump to the present invention. The embodiment of FIGS. 6–9 is more preferred. In this latter embodiment, a casing 41 is provided which has an off-center inlet 43 and a peripheral tangential outlet 45. Casing 41 is comprised of a pair of separable sections, including a circular plate 47 having a circular flange or scroll 49 thereon and a circular plate 51 detachably connectible to scroll 49. The inner peripheral wall of the chamber is accordingly circular or cylindrical in the embodiment of FIGS. 6–9, and this is an important feature of the invention as will be seen later on. In this connection, it should be noted that it is proper to call flange 49 a "scroll," despite the fact that it is circular, in conformity with standard pump terminology.

A rotor 53 has a drive shaft that extends rotatably through plate 47. Rotor 53 rotates about an axis that coincides with the axis of the circular pump chamber. Rotor 53 is provided with a plurality of spaced vanes 55 of airfoil configuration, each having a leading edge 57 and a trailing edge 59, an inner surface 61 and an outer surface 63. As before, the angle of the camber line of the cross section of the bisector radius from the axis of rotation is a small acute angle of about $-5°$ to $+17°$, preferably about $-2°$ to $+8°$, and more preferably about $0°$ to $+5°$.

Plate 51 carries a fixed volute 65 of monad configuration. Volute 65 extends from plate 51 into close adjacency with rotor 53 and has a continuous radially outwardly spiraling surface 67 that extends 360° from immediately below inlet 43 to immediately above inlet 43 and terminates in a trailing edge 69 that marks the end of volute 65. The inlet 43 is thus nestled in the concavity of volute 65, directly above the axis of rotation of the rotor and directly below the point at which the axis of outlet 45 begins to converge with flange 49. Thus, the radially inner and outer ends of surface 67 and the axis of rotation and the axis of inlet 43 and trailing edge 69 and the point at which the axis of outlet 45 begins to converge with flange 49 are all in vertical alignment in a common vertical plane. As before, outlet 45 is uppermost; and in the embodiment of FIGS. 6–9, inlet 43 is also in its highest position, trailing edge 69 lying on the upper periphery of inlet 43.

Still another modification is shown in FIGS. 10–13. The embodiment of FIGS. 10–13 is characterized by a different shape of vane. In FIGS. 10–13, a pump is provided comprising a casing 71 having an inlet 73 and an outlet 75, only the projection of inlet 73 being shown in FIG. 13. A rotor 77 has a drive shaft that extends through the casing wall and is rotatable and carries a plurality of vanes 79 about its periphery and extending from rotor 77 toward the opposite side of the pump chamber (not shown).

Vanes **79** have leading edges **81** and trailing edges **83** which are both inclined outwardly rearwardly relative to rotor **77** and with respect to the direction of rotation of rotor **77**. Vanes **79** also have inner surfaces **85** and outer surfaces **87** and a camber line, disposed much as in the preceding embodiments, except that toward the outer ends of inner and outer surfaces **85** and **87**, that is, remote from rotor **77**, the surfaces **85** and **87** are tapered and converge at a thin edge **89** which is a continuation of leading and trailing edges **81** and **83** and that in fact preferably lies in the same plane as the camber line or camber plane of the vane. FIGS. 12 and 13 thus provide a visual indication of the camber line which underlies edge **89** therein.

The significance of the structural features of the invention as disclosed above will now be explained. A number of the features can be understood by reference to and comparison of FIGS. 7 and 8.

FIG. 7 is in effect a Mercator projection of the circular system of FIG. 8. A radius from the axis of rotation in FIG. 8, sweeping clockwise from the 12 o'clock position, would move over the same structure and in the same sequence as a vertical line moving horizontally to the right and starting from the left end of FIG. 7. To understand FIG. 7, therefore, let it be imagined that fluid enters inlet **43** at the left of FIG. 7 and tends to move horizontally to the right in that figure. At the same time, vanes **55** are moving to the right. The vanes **55** as they move to the right in FIG 7 have their pressure side uppermost and their vacuum side lowermost. Their vacuum side, which corresponds to the upper side of an airplane wing, thus tends to draw the fluid progressively upwardly. At the same time, the surface **67** of volute **65** tends to urge the fluid toward the vanes at an even and regulated rate, so that each vane **55** continuously receives all the fluid it is capable of handling.

The circular flange or scroll **49** of casing **41** is represented by horizontal lines in FIG. 7, because it is perfectly circular. Also, the outer surfaces **63** of vanes **55** are represented by straight horizontal lines along most of their extent, parallel to flange **49**, because in fact they are cylindrical and concentric with the pump casing and the axis of rotation thereof, in the illustrated embodiment. This corresponds to the position of the underside of the wing of an airplane in level flight or "neutral trim," the flange **49** corresponding to the ground over which the airplane flies.

It will thus be recognized that the present invention resembles the flight of an airplane much more than it resembles the operation of a conventional pusher-type or scoop-type pump as described above. The pump of the present invention differs from an aircraft, however, in that instead of the air strata remaining approximately horizontal and parallel to the ground and the airplane rising through the air, in the present invention the airfoils remain at a fixed elevation above the ground (flange **49**) while the fluid moves downwardly (radially outwardly) between the airfoils, under the influence of the vacuum on the upper (radially inner) sides of the airfoils and as guided by the progressively lowering (radially outwardly spiraling) surface **67** of volute **65**. In other words, the pump of the present invention differs from a normal airfoil, such as the wing of an aircraft, in that instead of the airfoil remaining horizontal, it is radially disposed about the axis of rotation; and the fluid medium, which is confined radially by the casing, is exposed to the aerodynamic forces of the upper and lower surfaces of the airfoil. Under the influence of the pressure differential which is inaugurated by these upper and lower surfaces, the fluid is caused to progress radially outwardly. In addition to this aerodynamic outward thrust of the liquid, the drag component of the vane as it progresses through the fluid imparts rotational velocity to the fluid. This rotational velocity is identical to that of conventional centrifugal pumps, but its radial pressure components are additive to the aerodynamic forces that result from the airfoil action described above. Thus, the present invention adds an aerodynamic pump action to the impeller action of centrifugal pumps known heretofore.

A comparison of the reference letters of FIGS. 7 and 8 shows how once the optimum relationships have been developed on the rectilinear projection of FIG. 7, they may be translated to the rotary system. Thus, the configuration of surface **67** of volute **65** can be determined if it is recognized that the center of rotation is at A, the inner end of surface **67** at B, the upper margin of inlet **43** and the trailing edge **69** at C, the radially innermost portion of vane **55** at D, the outer margin of rotor **53** and the outer surfaces **63** of vanes **55** at E, the inner circular periphery of the pump chamber and the point at which the upper edge of outlet **45** is tangent to that periphery at F, and the other or upper or outer side of scroll **49** at G. These points, when located on the rectilinear projection and transposed back to the circular system, dictate that the parts be arranged as in FIG. 8, as described above. It will also be seen that it is preferable to have trailing edge **69** at about the same level as the underside of outlet **45**.

A representative projection of the vanes **55** from a rectilinear system to a circular system is shown in FIG. 6. As can there be seen, once the optimum shape for the vanes **55** is worked out along parallel and perpendicular axes, as at the bottom of FIG. 6, the axes can then be simply translated back to radial and concentric axes to derive the particular curves of the preferred forms of the vanes of the present invention.

It will also be recognized in connection with the embodiment of FIGS. 6–9 that there are a number of advantages in the particular shape of volute **65** and its relationship to inlet **43**. In the first place, it is preferable that inlet **43** be disposed above the axis of rotation as this assures that when the pump drains, there will be a quantity of liquid retained in the pump chamber, so as to facilitate priming the pump. Also, the positioning of the pump inlet a relatively short vertical distance from the pump outlet **45** ensures that fluid moving from inlet **43** to outlet **45** will have to travel only a minimum distance, preferably only about one full revolution about the interior of the pump chamber. Thus, volute **65** is an improvement over volute **27**, for in the case of volute **27**, the fluid has to travel farther from the inlet to the outlet than in the case of volute **65**. The portion of volute **65** which is in effect filled in as compared with volute **27** thus serves in effect to move the fluid farther along its path between the inlet and the outlet, but without the expenditure of work.

Also, it will be recognized that the larger is the volute **65**, the less fluid occupies the interior of the pump chamber. The less fluid in the pump chamber, the less is the possibility of turbulence and other power losses due to fluid friction.

Moreover, the fact that volute **65** in effect restricts the flow of fluid to the path most clearly seen in FIG. 7 ensures that fluid entering inlet **43** will not diverge and move randomly, but rather will move in a fairly uniform single stream that does not cross the path of the vanes as much as it moves parallel to the vanes. By contrast, in the pusher-type pumps as initially defined, with their unconfined central regions, the fluid entering the central intake is liable to move randomly from the intake and to cross the path of the paddles at sharp angles thereto. Moreover, in those paddle-type pumps, the region between the paddles or pushers is largely occupied by fluid in turbulent flow, the fluid tending to rotate in vortices whose axes are parallel to and spaced radially outwardly from the axis of rotation.

The earlier pusher-type pumps as initially defined are characterized by scrolls or volutes that define the periphery of the pump chamber and that spiral radially outwardly in the direction of rotation of the rotor. The periphery of the pump chamber thus diverges from the paddles in the direction of movement of the fluid. It will accordingly be recognized that those spiral scrolls or radially outermost volutes of the earlier pusher-type pumps correspond roughly to the inner scrolls or volutes of the present invention. The differences, however, include the facts that the volutes of the present invention inside the paths of the vanes have the advantages set forth above, and also have the advantage that they converge with the inner periphery of the casing in the direction of fluid travel. The fluid thus is forced to travel faster adjacent the periphery of the pump chamber than it does when it is closer to the axis of rotation. This fact is highly advantageous in preventing turbulence in the pump chamber, as the radially outermost fluid, traveling at a greater speed than the radially innermost fluid, tends to travel at the same angular velocity as the radially inner fluid. Indeed, all the fluid in the casing except in the immediate area of the vanes tends to turn with about the same angular velocity, so that there is no tendency for adjacent layers of fluid to cause turbulence in each other.

The position of trailing edge **69** in or approximately in radial alignment with the point at which the axis of outlet **45** and flange **49** begin to converge, with a margin of variation of about 30° of arc in either direction, is also an important feature of the invention. This is because as surface **67** of volute **65** spirals outwardly into close adjacency with vanes **55**, moving clockwise in FIG. 8, the surface **67** tends to spoil the airfoil effect of vanes **55**. Indeed, the close approach of surface **67** to vanes **55** adjacent trailing edge **69** ensures that the attraction of the vane for the liquid is practically spoiled at that point. As a result, the fluid can freely leave the vane and leave the pump chamber through outlet **45**, with a minimum tendency of vane **55** to recirculate the fluid through a second needless revolution about the pump chamber. Recirculation is the nemesis of pump design, and the location of trailing edge **69** of volute **65** at or adjacent this particular point minimizes recirculation. After the vanes **55** pass trailing edge **69**, they then attract radially outwardly not the discharged fluid, but rather the fluid entering through inlet **43**. If trailing edge **69** were spaced angularly too far past the 12 o'clock position of FIG. 8, then the airfoil action of the vanes **55** would not be spoiled soon enough to prevent recirculation. Similarly, if trailing edge **69** is disposed too far counterclockwise in advance of the 12 o'clock position in FIG. 8, then the vanes **55** resume their attraction for the exiting fluid before that fluid is in the outlet, which again promotes recirculation. Accordingly, recirculation is at a minimum when the fixed parts are in the 12 o'clock position shown in FIG. 8; and recirculation is kept within preferred bounds when the displacement from that 12 o'clock position does not exceed about 30° of arc in either direction. Also, the air-handling properties of the device, in the case of a liquid pump, are best when the inlet and outlet are as high as possible, that is, in the 12 o'clock position of FIG. 8.

The importance of the small angle of incidence is that in the case of a vane acting in effect as an airfoil, as in the present invention, the lower the angle of incidence, the higher the efficiency due to reduced turbulence. As angle of incidence increases, efficiency declines, until a stall point is reached, beyond which the force of the oncoming fluid against the outer side of the vane is greater than the vacuum on the inner side of the vane. At this point, the vane stalls and the present invention functions as a normal centrifugal pump, its aerodynamic characteristics becoming ineffective. It is beyond this stall point that the pushers of the centrifugal pumps common in the prior art are disposed, and accordingly their paddles can act only as scoops to dig into the entering fluid to project it radially outwardly.

The disposition of the vanes a substantial distance radially outwardly from the axis of rotation, and specifically nearer to the scroll than to the axis of rotation, also solves the problem of cavitation. Cavitation in a pump results from the fact that the pressure adjacent the inlet is substantially lower than the pressure adjacent the outlet. This low pressure adjacent the inlet often causes a vapor to flash off from the pumped liquid. This vapor, in turn, moves radially outwardly with the pumped liquid, into a region of increasing pressure. As the pressure increases above the vapor pressure of the liquid at the temperature in question, the pockets of vapor recondense and collapse, with implosive force. The implosion following cavitation causes knocking and noise and actual erosion of the impellers when it takes place adjacent the paddles of a centrifugal pump. But the present invention, by spacing the vanes radially outwardly a proportionately much greater distance than in the prior art, ensures that the implosion following cavitation will take place radially inwardly from the vanes and not against the vanes themselves. As a result, the noise and knocking and erosion attendant upon the cavitation in pumps known to the prior art are absent from the present invention.

It will also be recognized that the provision of the casing as a simple circle greatly simplifies the manufacture of pumps according to the present invention, as no variable configuration need be imparted to their casing. Also, it will be evident that the present invention is well adapted to handle solids. Primarily, the tolerances of the relatively moving parts of the present invention can be quite great with no detrimental effect, in contrast to conventional paddle-type centrifugal pumps in which the tolerances must be quite small. These wider tolerances or relatively large spaces between moving parts make it easy to handle solids having even large particle sizes. Secondarily, the small pitch angle of the vanes minimizes the impact of solids against the vanes, in contrast to the pushers or paddles of the more usual centrifugal pumps which are struck broadside and can be injured by solids entrained in the fluid.

It will also be recognized that the offsetting of the inlet from the axis of rotation of the rotor provides the mechanical means of centering an axial thrust bearing to absorb impeller or rotor thrust.

Furthermore, it is a simple matter to unclog pumps according to the present invention, because solids tend to clog in the outlet rather than the inlet. This is because the passageway toward the outlet is progressively restricted, as is evident from FIG. 7. Therefore, to unclog the pump, it is necessary only to shut off the inlet and operate the pump, whereupon the vacuum on the radially inner side of the vanes will draw fluid back through the outlet into the pump chamber and in effect suddently backwash the pump.

It will also be noted that the vanes are spaced substantial angular distances apart about the periphery of the rotor. Even when the outer surfaces of the vanes lie on a common cylinder, the leading and trailing edges of adjacent vanes are quite widely spaced. This is another feature by which the present invention is distinguished from the more common paddle-type pumps initially described above, and this feature is important in that it virtually eliminates the tendency of a vane to induce turbulence adjacent the immediately succeeding vane.

The particular vane shape of FIGS. 10–13 is advantageous for several reasons. In the first place, swept-back leading and trailing edges ensure that solids will have a minimum of opportunity to become caught on the vanes. In the second place, the fact that the leading and trailing edges are parallel to each other ensures that the fluid dynamic characteristics of the vane are not altered by the sweeping back of the leading edge. In the third place, the provision of a relatively thin edge **89** permits the positioning of that thin edge **89** relatively close to the opposed wall of the casing, without the production of turbulence.

From a consideration of the foregoing disclosure, therefore, it will be evident that all of the initially recited objects of the present invention have been achieved.

Although the present invention has been described and illustrated in connection with preferred embodiments, it is to be understood that modifications and variations may be resorted to without departing from the spirit of the invention, as those skilled in this art will readily understand. Such modifications and variations are considered to be within the purview and scope of the present invention as defined by the appended claims.

Having described my invention, I claim:

1. A pump comprising a pump casing defining a pump chamber and having an inlet and an outlet, a rotor disposed in the pump chamber and rotatable about an axis, a plurality of vanes in unitary assembly with the rotor, the inlet being disposed inside the path of the vanes and the outlet being disposed outside the path of the vanes, the vanes having airfoil configuration with relatively low pressure sides and relatively high pressure sides, the vanes having their low pressure sides on their radially inner sides and their high pressure sides on their radially outer sides, the camber line of the cross section of the vanes forming a small acute angle of −5° to +17° with a line perpendicular to the bisector of the angle about said axis that is subtended by the vanes at the intersection of said camber line and said bisector, and a fixed volute disposed inside the path of the vanes, the volute presenting to fluid entering the pump chamber from the inlet at least one boundary surface that spirals radially outwardly in the direction of rotation of the rotor, said inlet being offset radially outwardly a substantial distance from said axis.

2. A pump as claimed in claim **1**, said axis being horizontal, said inlet being above said axis.

3. A pump comprising a pump casing defining a pump chamber and having an inlet and an outlet, a rotor disposed in the pump chamber and rotatable about an axis, a plurality of vanes in unitary assembly with the rotor, the inlet being disposed inside the path of the vanes and the outlet being disposed outside the path of the vanes, the vanes having airfoil configuration with relatively low pressure sides and relatively high pressure sides, the vanes having their low pressure sides on their radially inner sides and their high pressure sides on their radially outer sides, the camber line of the cross section of the vanes forming a small acute angle of −5° to +17° with a line perpendicular to the bisector of the angle about said axis that is subtended by the vanes at the intersection of said camber line and said bisector, and a fixed volute disposed inside the path of the vanes, the volute presenting to fluid entering the pump chamber from the inlet at least one boundary surface that spirals radially outwardly in the direction of rotation of the rotor, said casing peripherally bounding the pump chamber, said outlet having a wall portion that is farthest from said axis and that is tangential to the inner wall of said casing, said volute surface terminating outwardly at a point within approximately 30° of arc of the point of tangency of said wall portion of the outlet and said inner wall of the casing.

4. A pump as claimed in claim **3**, said volute being in the form of a bent-over teardrop with the tail of the

teardrop directed toward the outlet and said inlet nested in the bend of the tail and above said axis but below the outlet.

5. A pump comprising a pump casing defining a pump chamber and having an inlet and an outlet, a rotor disposed in the pump chamber and rotatable about an axis, a plurality of vanes in unitary assembly with the rotor, the inlet being disposed inside the path of the vanes and the outlet being disposed outside the path of the vanes, the vanes having airfoil configuration with relatively low pressure sides and relatively high pressure sides, the vanes having their low pressure sides on their radially inner sides and their high pressure sides on their radially outer sides, the camber line of the cross section of the vanes forming a small acute angle of −5° to +17° with a line perpendicular to the bisector of the angle about said axis that is subtended by the vanes at the intersection of said camber line and said bisector, the vanes extending laterally from the rotor in one direction and closely approaching a side wall of the casing and terminating in free edges closely adjacent said side wall, the leading and trailing edges of the vanes being inclined rearwardly in a direction away from the rotor.

6. A pump having an inlet, a rotor rotatable about an axis, a plurality of vanes in unitary assembly with the rotor, the inlet being disposed inside the path of the vanes, the vanes having airfoil configuration with relatively low pressure sides and relatively high pressure sides, the vanes having their low pressure sides on their radially inner sides and their high pressure sides on their radially outer sides, the camber line of the cross section of the vanes forming a small acute angle of −5° to +17° with a line perpendicular to the bisector of the angle about said axis that is subtended by the vanes at the intersection of said camber line and said bisector, and a fixed volute disposed inside the path of the vanes, the volute presenting to fluid entering the pump chamber from the inlet at least one boundary surface that spirals radially outwardly in the direction of rotation of the rotor, said inlet being offset radially outwardly a substantial distance from said axis.

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