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(54) FROTH HANDLING PUMP

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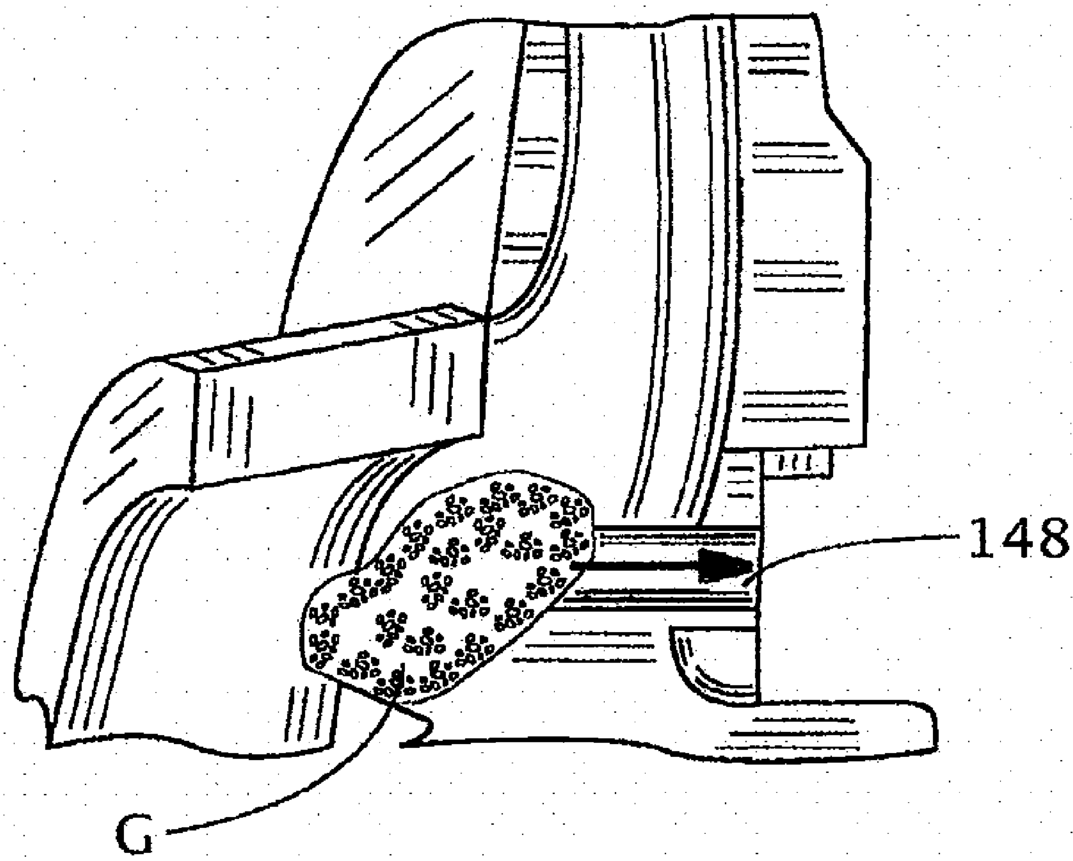
F04D 29/30 (2006.01)

(52) **U.S. Cl.** **415/169.1**

(57) **ABSTRACT**

A froth handling pump includes a pump casing, an impeller mounted within the casing, and a de-aeration chamber mounted to the rear side of the pump casing. The impeller comprises multiple pumping vanes, each of the vanes having an inlet angle and an outlet angle, wherein the outlet angle is greater than the inlet angle, the outlet angles terminating at a rear shroud. The rear shroud includes multiple vent holes for the passage of gases therethrough. The de-aeration chamber, which comprises an inner volume, includes an inlet formed on the inner side for receiving gases passing through the plurality of vent holes. At least one vent outlet is provided for the discharge of gases from the de-aeration chamber.



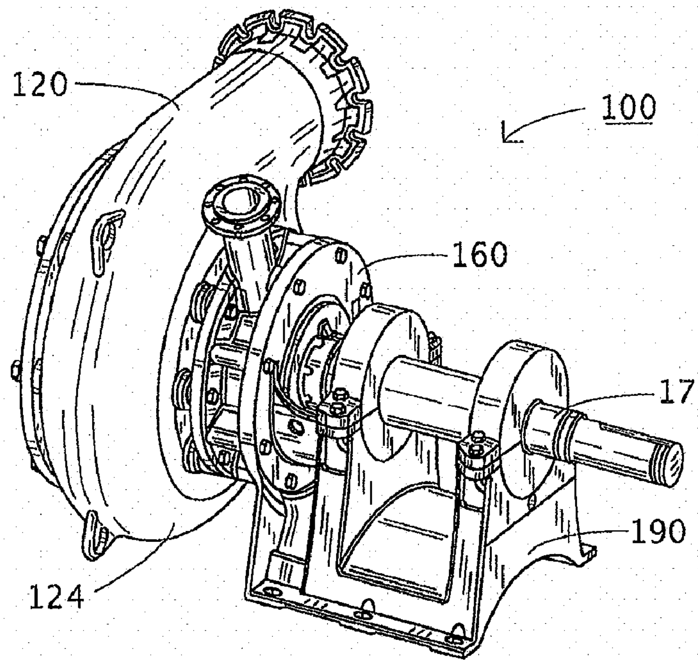


FIG. 1

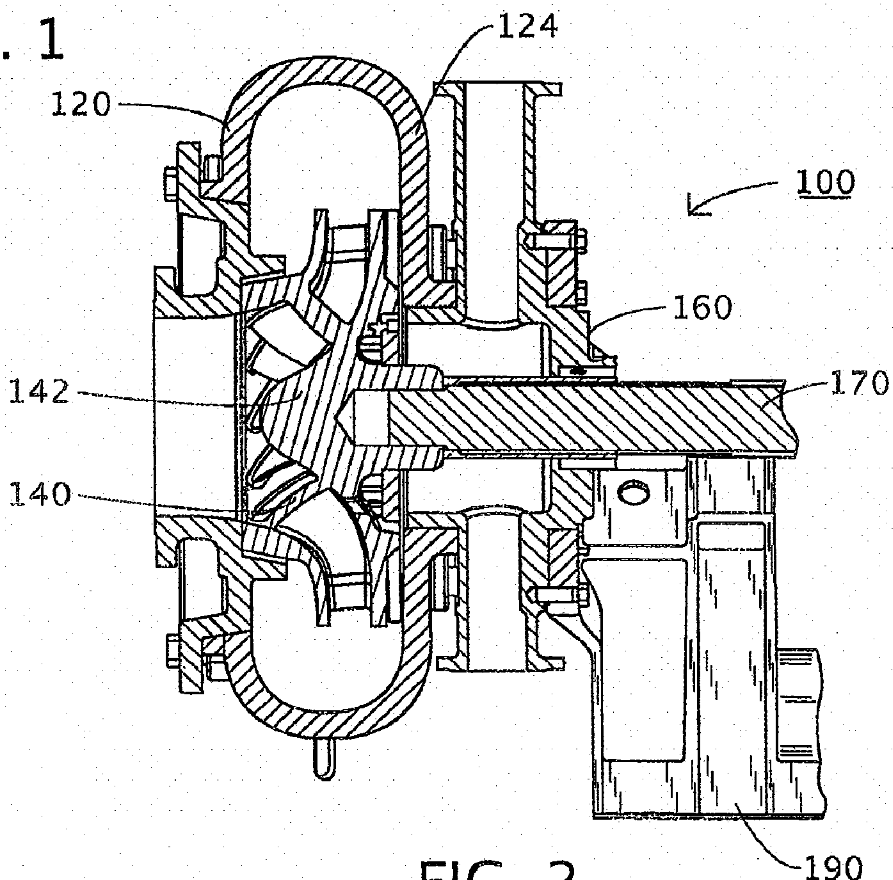


FIG. 2

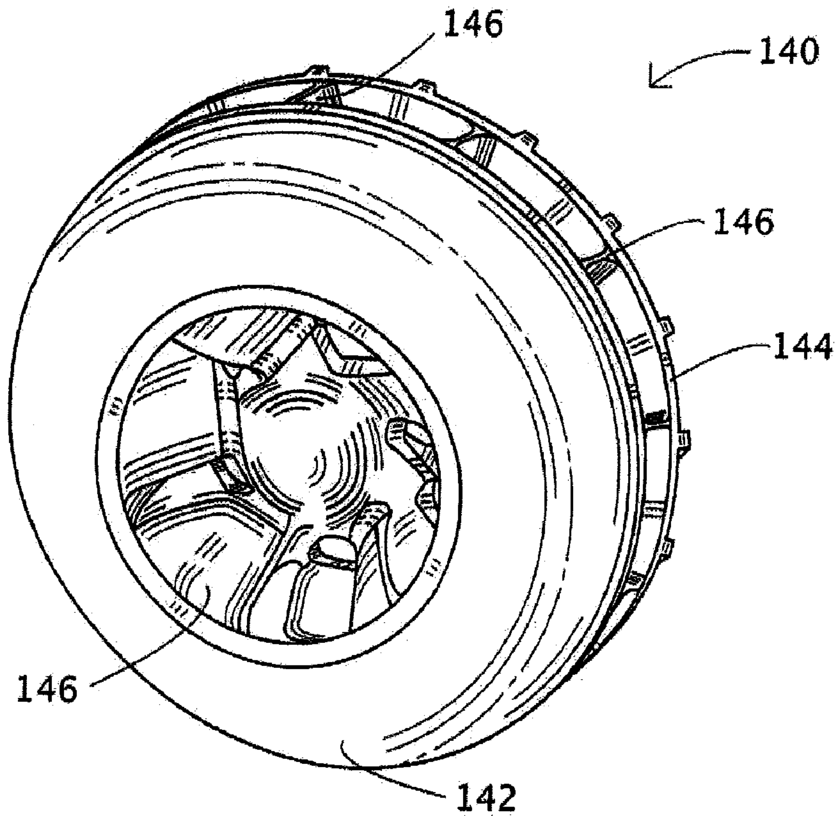


FIG. 3

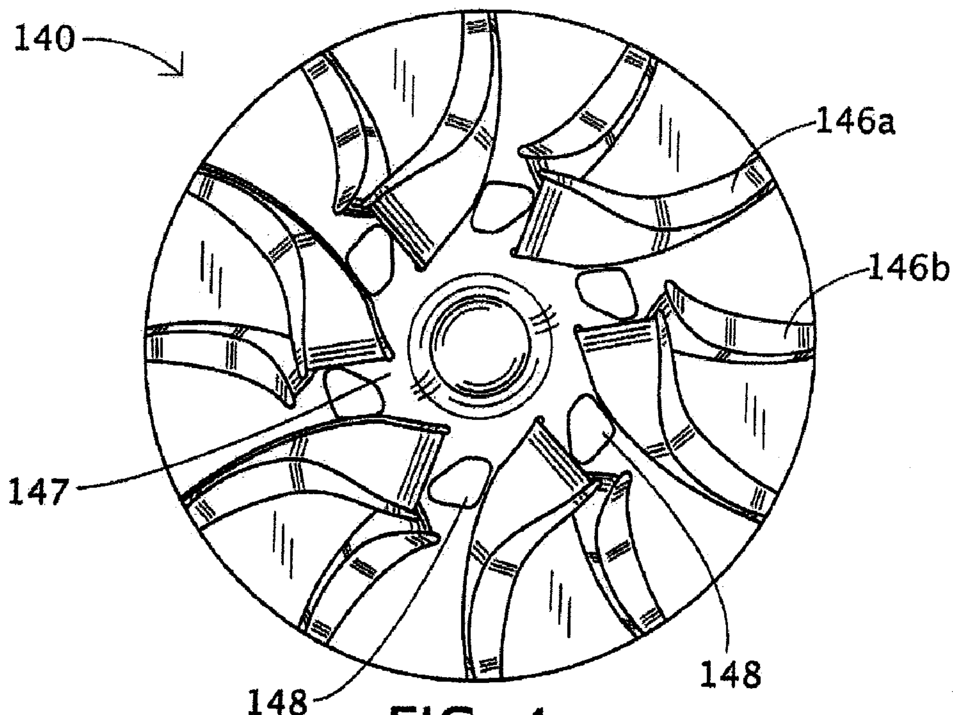


FIG. 4

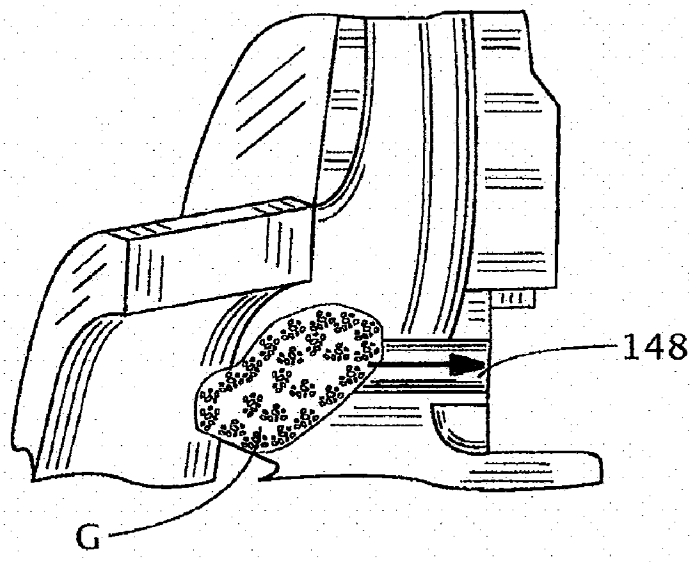


FIG. 5

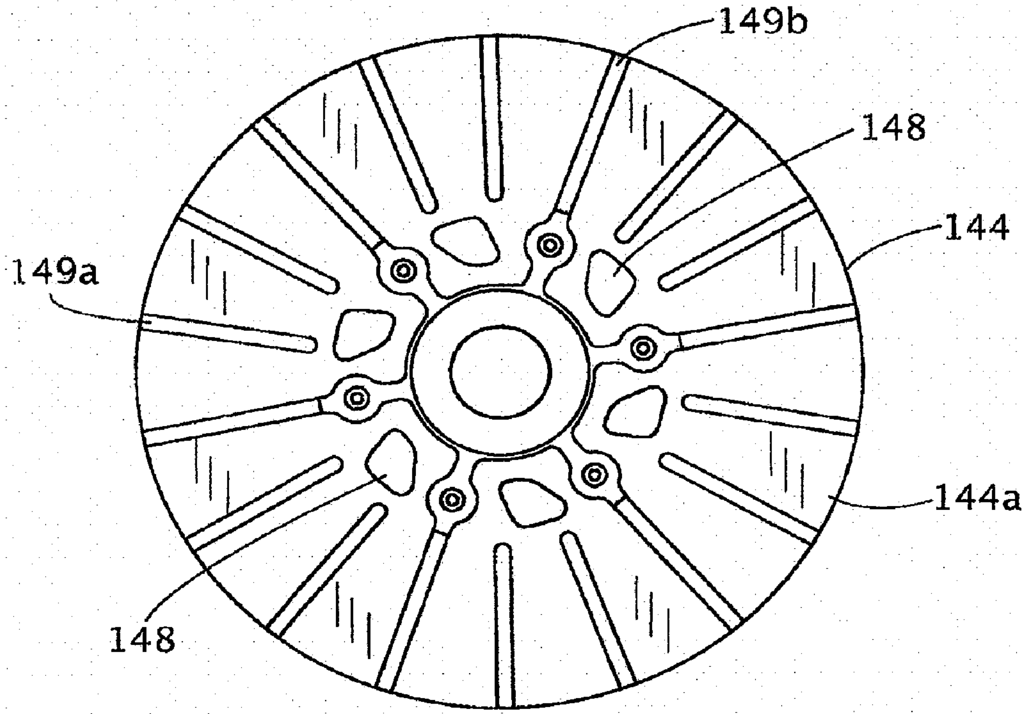


FIG. 6

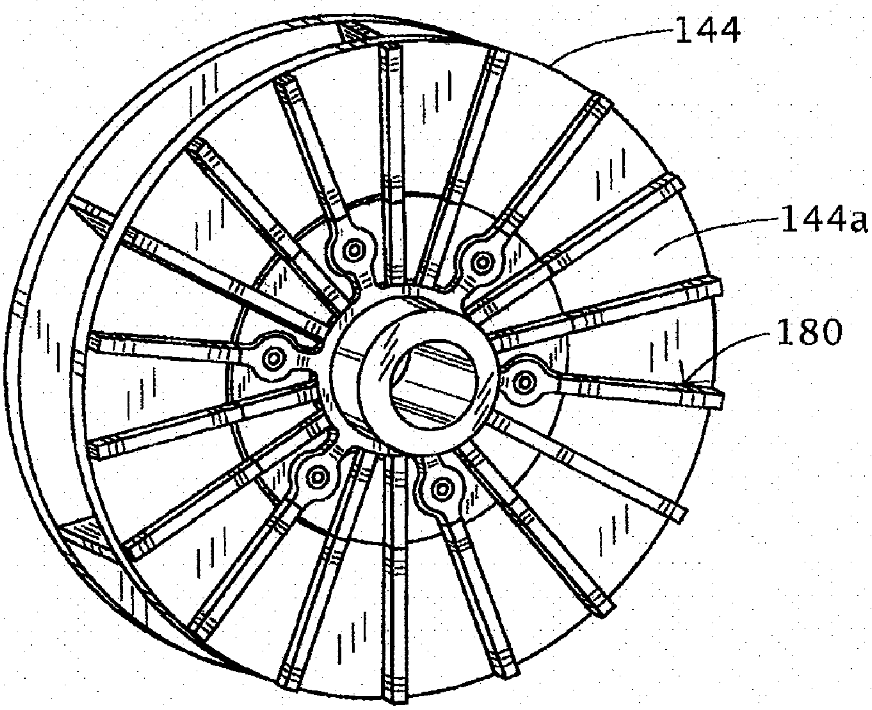


FIG. 7

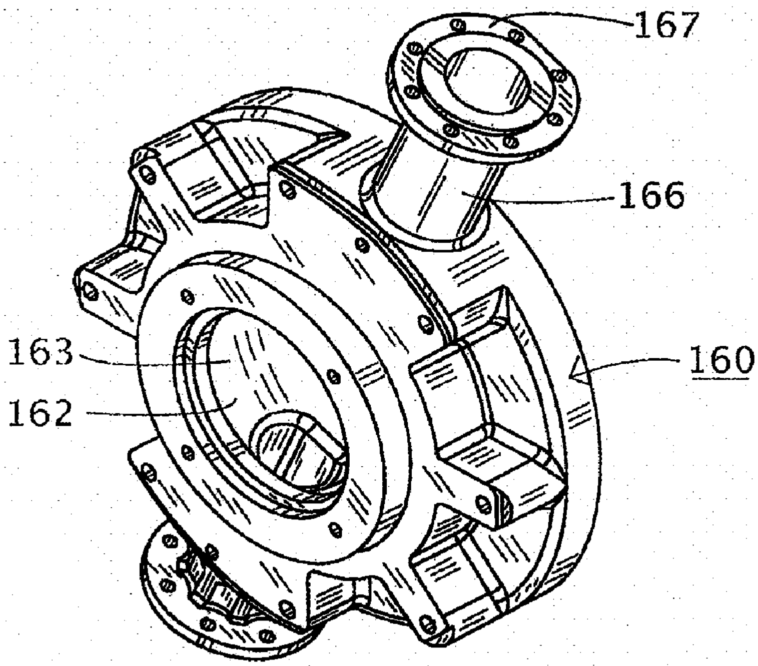


FIG. 8

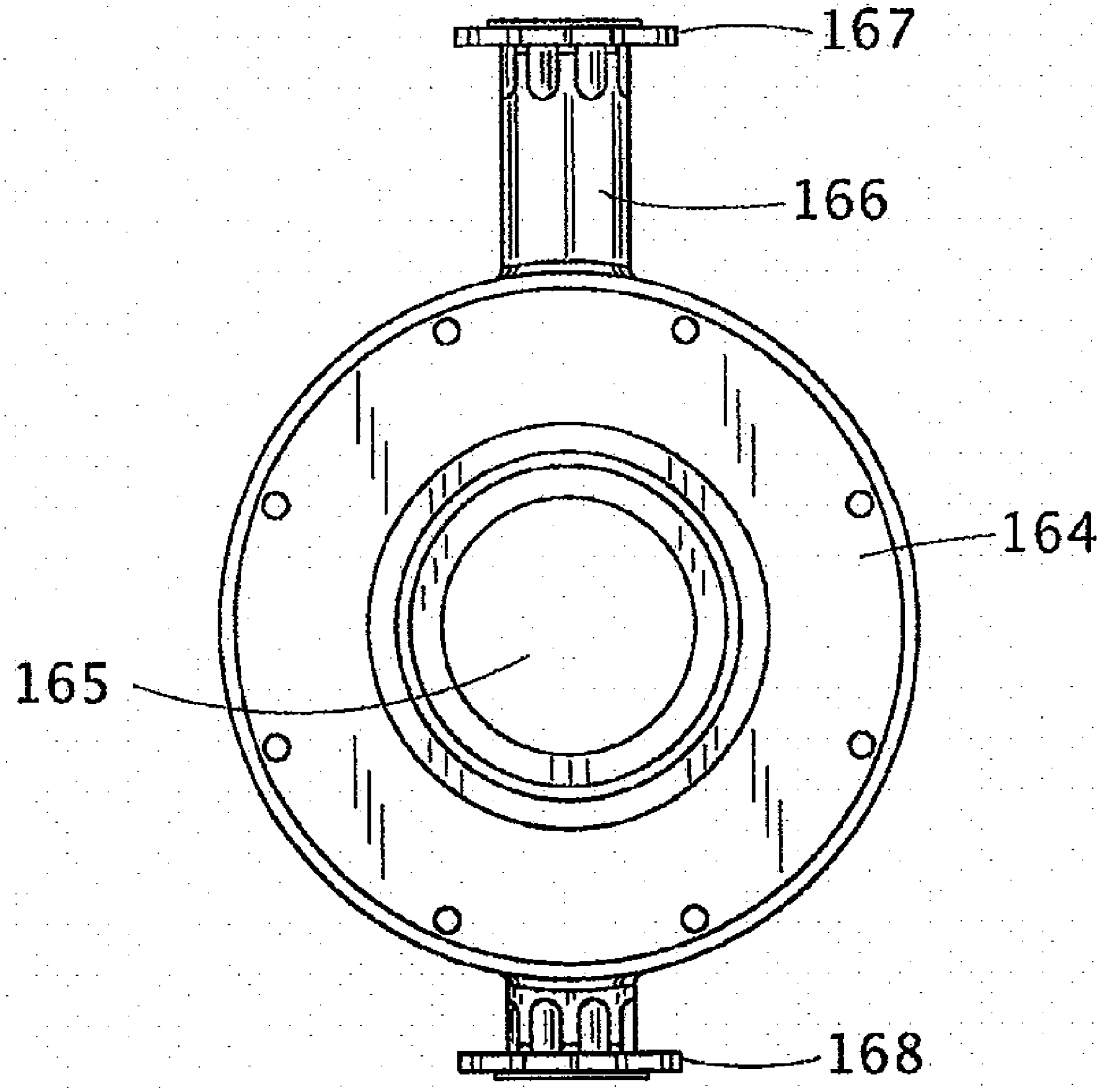


FIG. 9

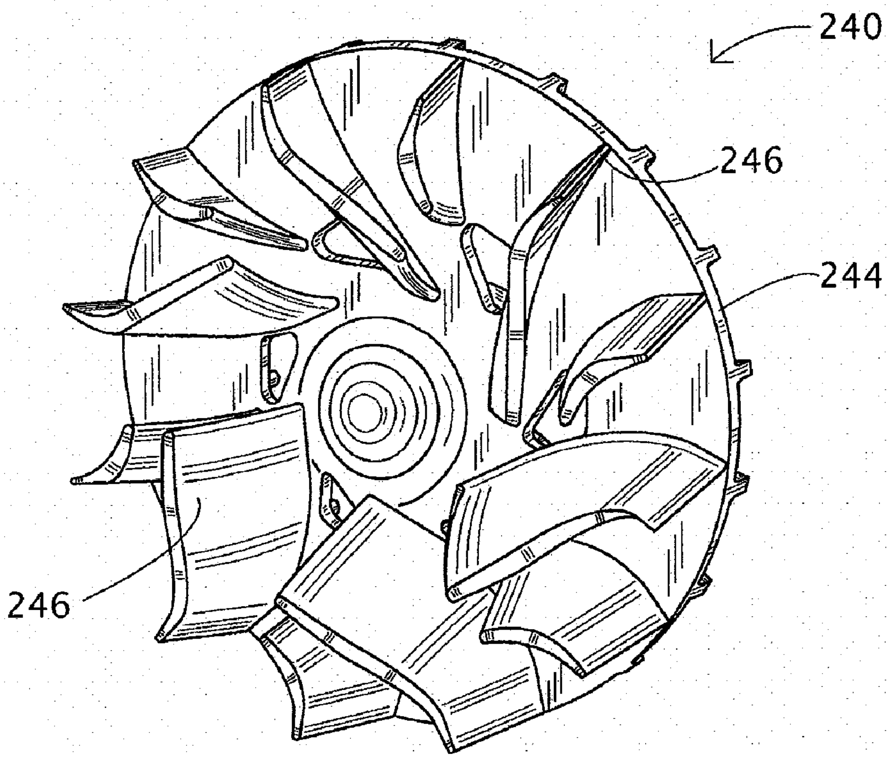


FIG. 10

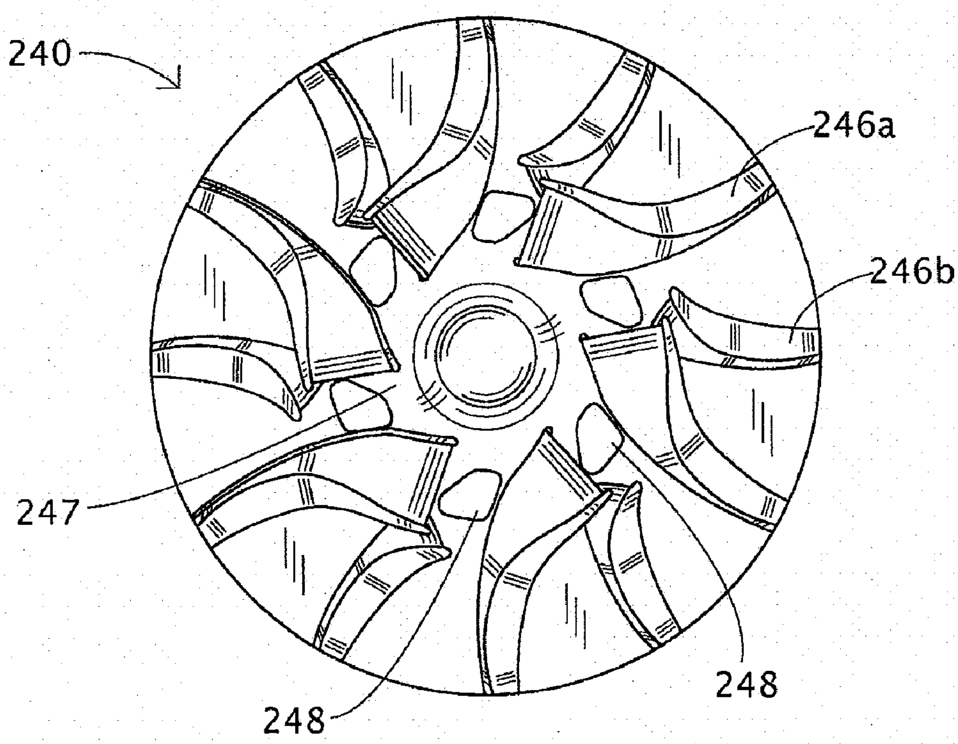
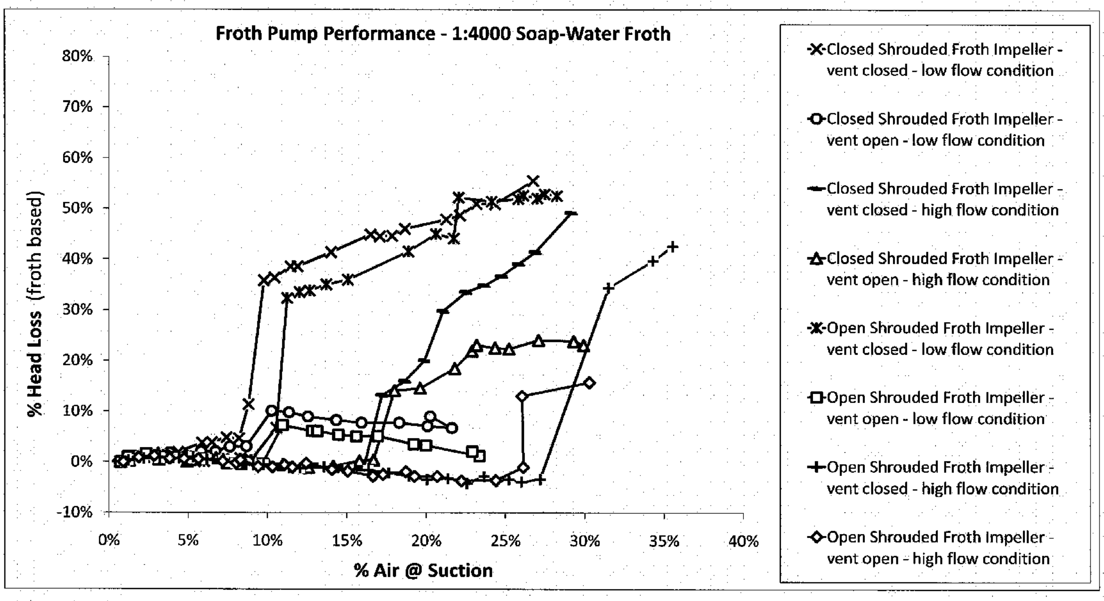


FIG. 11



Froth Pump Performance - 1:4000 Soap-Water Froth
80%
70%
60%
50%
40%
30%
20%
10%
0%
-10%
% Head Loss (froth based)
0%
5%
10%
15%
20%
25%
30%
35%
40%
% Air @ Suction
Closed Shrouded Froth Impeller - vent closed - low flow condition
Closed Shrouded Froth Impeller - vent open - low flow condition
Closed Shrouded Froth Impeller - vent closed - high flow condition
Closed Shrouded Froth Impeller - vent open - high flow condition
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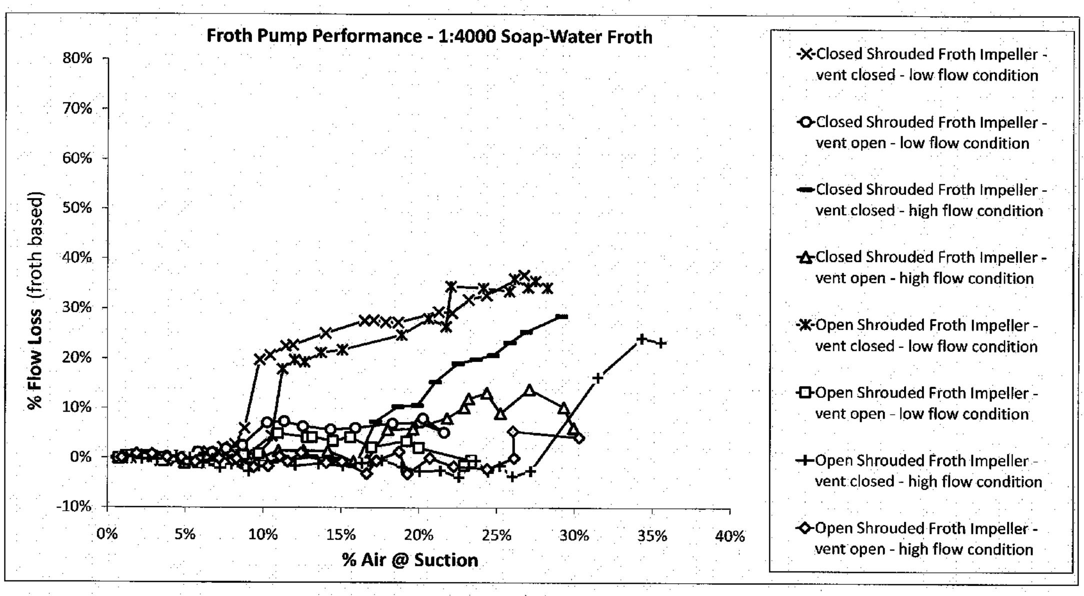
Open Shrouded Froth Impeller - vent open - low flow condition
Open Shrouded Froth Impeller - vent closed - high flow condition
Open Shrouded Froth Impeller - vent open - high flow condition

FIG. 12


Froth Pump Performance - 1:4000 Soap-Water Froth
% Flow Loss (froth based)
80%
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40%
30%
20%
10%
0%
-10%
0%
5%
10%
15%
20%
25%
30%
35%
40%
% Air @ Suction
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Closed Shrouded Froth Impeller - vent open - low flow condition
Closed Shrouded Froth Impeller - vent closed - high flow condition
Closed Shrouded Froth Impeller - vent open - high flow condition
Open Shrouded Froth Impeller - vent closed - low flow condition
Open Shrouded Froth Impeller - vent open - low flow condition
Open Shrouded Froth Impeller - vent closed - high flow condition
Open Shrouded Froth Impeller - vent open - high flow condition

FIG. 13

FROTH HANDLING PUMP

RELATED APPLICATIONS

[0001] This is a continuation-in-part of application Ser. No. 12/208,747, filed Sep. 11, 2008, the content of which is incorporated herein in its entirety.

FIELD OF THE INVENTION

[0002] The present invention relates to the field of centrifugal slurry pumps, and particularly, to froth pumps for mining applications where flotation methods are utilized.

BACKGROUND OF THE INVENTION

[0003] Centrifugal pumps, as the name implies, employ centrifugal force to lift liquids from a lower to a higher level or to produce a pressure. This type of pump, in its is simplest form, comprises an impeller consisting of a connecting hub with a number of vanes and shrouds, rotating in a volute collector or casing. Liquid drawn into the center, or eye, of the impeller is picked up by the vanes and accelerated to a high velocity by rotation of the impeller. It is then discharged by centrifugal force into the casing and out the discharge branch of the casing. When liquid is forced away from the center of the impeller, a vacuum is created and more liquid flows into the center of the impeller. Consequently, there is a flow through the pump. There are many forms of centrifugal pumps, including the type used to pass solid and liquid mixtures. These are known as slurry pumps.

[0004] Froth handling pumps are a special application of centrifugal slurry pumps. The need to pump froth occurs in many mining applications where flotation methods are utilized. These pumps take advantage of the surface tension effects between pulverized ore and fine bubbles to separate the ore from the waste rock by floating one away from the other. The various mining applications include mining for metallic ores such as copper, iron, etc., and in the oil sand industry, where the components of froth include bitumen, water, and air. In the process of mining oil sands, for example, a mixture of approximately 10% bitumen and 90% sand is mined directly from the ground and the bitumen is separated from the sand for conversion to synthetic crude oil. As the separation takes place, gas develops, creating a bitumen froth with approximately a 15 percent to 30 percent gas/air content.

[0005] While froth is widely pumped in mining applications and much is known about the process, a number of problems exist with froth pumps themselves and the pumping process. First, froth handling pumps often "air lock." This occurs when gases accumulate in the suction of the pump under the action of the centrifugal forces operating on the fluid in the passages of a rotating impeller to form an air/gas bubble, which partially blocks the suction and significantly degrades pump performance (as much as 40 percent to 70 percent loss in both flow and head). With viscous flows like bitumen, for example, this air lock can be particularly difficult to remedy due to the laminar, or near laminar, nature of the high viscosity flow. Even if the pump is stopped, the bubble can remain within the pump casing or connecting piping and may be drawn back into the pump suction upon restart. Second, froth pumps cannot typically produce as much head as non-froth applications, being limited by the presence of air (which cannot be effectively energized by the centrifugal pump), by the blockage which occurs as the air lock begins to form, and by the maximum speed at which the pump can be run before net positive suction head available (NPSHA) to the pump suction falls below the minimum required to prevent cavitation in the pump impeller. The head may be limited to as little as 30 meters to 40 meters in viscous froth applications, due to the additional viscous friction losses. This often necessitates that a number of pumps be placed in service to provide the necessary capacity for the mining and pumping process.

SUMMARY OF THE INVENTION

[0006] The present invention is directed to a froth handling pump, which significantly minimizes or eliminates the problems described herein during ore or bitumen froth pumping. As used herein, "ore" refers to any of the many minerals and metals, which may be extracted through mining. Also, as used herein, "bitumen" refers to any of various flammable mixtures of hydrocarbons and other substances, occurring naturally or obtained by distillation from coal or petroleum.

[0007] Broadly, one aspect of the present invention is directed to a froth handling pump, which comprises either a conventional, or modified, pump casing having an inlet side and a rear (hub) side. A novel impeller has been invented, which can produce a head equal to or greater than existing froth slurry pumps, but without the application of some of the conventional methods for reducing the NPSH required, such as an enlarged suction diameter, an inducer or auxiliary impeller, etc., or by increasing the NPSHA beyond what is normally present. This, in effect, keeps the size of the froth handling pump smaller and more economical.

[0008] The pump achieves heads of 50 meters or higher at viscosities up to 3,000 cP and with NPSHA less than 10 meters by application of a very high vane outlet angle. While typical centrifugal pump outlet angles range from between about 15 degrees and 40 degrees, with 20 degrees to 25 degrees considered optimal, the impeller of the present invention has a vane outlet angle of between about 80 degrees and 100 degrees, with 90 degrees being optimal. Unexpectedly, the resulting efficiency is at least about 73 percent peak efficiency (with clear water).

[0009] The rear shroud of the impeller includes an inner face and an outer face, with a plurality of vent holes formed through the shroud for the passage of gases to an attached de-aeration chamber. A plurality of generally radially oriented clearing vanes are formed on the outer face of the rear shroud. The clearing vanes are configured to create a pressure at the back side of the vent holes that is less than the fluid side so that vented gases are drawn into the de-aeration chamber. An outlet vent is provided proximate the top of the de-aeration chamber for venting the gases to the atmosphere or to a connected vent line.

[0010] Further, while front shrouds are generally used in froth pump impellers, including one embodiment described herein, it has been found that removal of the front shroud of the impeller further serves to reduce the occurrence of air locks and to maintain maximum pump head and flow.

[0011] These and other aspects of the present invention will become apparent to those skilled in the art after a reading of the following description of exemplary embodiments when considered in conjunction with the drawings. It should be understood that both the foregoing general description and the following detailed description are exemplary and explanatory only and are not restrictive of the invention as claimed.

BRIEF DESCRIPTION OF THE DRAWINGS

[0012] FIG. 1 is a perspective view of an embodiment of the froth handling pump of the present invention.

[0013] FIG. **2** is a side elevational cross-sectional view of the froth handling pump of FIG. **1**.

[0014] FIG. **3** is a perspective view of one embodiment of the impeller of the froth handling pump of FIG. **1**.

[0015] FIG. **4** is a front view of the impeller of FIG. **3** with the front shroud removed to show the vanes.

[0016] FIG. **5** is a schematic illustration of the gaseous venting scheme of the froth handling pump of FIG. **1**.

[0017] FIG. **6** is a side rear view of the shroud of the impeller of FIG. **3**, illustrating the arrangement and geometry of the clearing vanes.

[0018] FIG. **7** is a rear perspective view illustrating the optional auxiliary impeller on the rear shroud of the impeller of FIG. **3**.

[0019] FIG. **8** is a perspective view of the de-aeration chamber of the froth handling pump of FIG. **1**.

[0020] FIG. **9** is a side rear view of the de-aeration chamber of FIG. **8**.

[0021] FIG. **10** is a perspective view of an alternative embodiment of the impeller of the froth handling pump of FIG. **1**.

[0022] FIG. **11** is a front view of the impeller of FIG. **10**.

[0023] FIG. **12** graphically demonstrates the head loss performance of the froth handling pump of the present invention with the closed-shroud configuration pumping a water-soap froth.

[0024] FIG. **13** graphically demonstrates the flow loss performance of the froth handling pump of the present invention with the open-shroud configuration pumping a water-soap froth.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0025] Referring to the Figures in general, and to FIGS. **1** and **2** in particular, the froth handling pump of the present invention is shown generally as **100**. In its simplest embodiment, the froth handling pump **100** comprises a centrifugal pump casing **120**, a novel impeller **140** mounted in the casing, and a de-aeration chamber **160** mounted to the rear side **124** of the pump casing **120**. A conventional pump shaft **170** passes through the de-aeration chamber **160** and attaches to the hub **141** of the impeller **140**. The shaft **170** is then mounted on a conventional pedestal **190** via a conventional bearing and bearing housing arrangement (not shown).

[0026] As shown in FIG. **2**, the pump casing **120** of the froth handling pump of the present invention is a conventional design for centrifugal slurry pumps; however, a modified, or more open inlet side may be contemplated for a particular froth handling application, or for alternative impeller configurations, as described below. Alternatively, as described in detail below, the front shroud may be eliminated in its entirety.

[0027] Referring to FIGS. **2** through **5**, the novel impeller **140** of the froth handling pump **100** is illustrated in detail. As best shown in FIG. **3**, one embodiment of the impeller **140** comprises a front shroud **142**, a rear shroud **144**, and a plurality of pumping vanes **146**. As shown in FIG. **3**, the front shroud **142** is conventional for a centrifugal slurry pump; however, in an alternative embodiment, the front shroud **142** also may be modified for a particular froth handling application and could include a more open configuration, having a larger suction inlet diameter. As shown in FIG. **4**, the impeller **140** of this illustrated embodiment comprises a novel pumping vane **146** arrangement. To maximize the number of pumping vanes **146**, as shown in FIG. **4**, full size vanes **146*a*** and splitter vanes **146*b*** are arranged in an alternating fashion about the circumference of the impeller **140**. Splitter vanes **146*b***, as used herein and as shown in the Figures, are shorter, thus not extending radially inwardly as far toward the suction eye **147** as the fuller size pumping vanes **146*a***. As will be appreciated by those skilled in the pump art, the number of pumping vanes **146*a***, **146*b*** is maximized within the constraints of vane thickness and minimum required passage size. It has been found, however, that the use of splitter vanes **146*b*** helps to increase the effective number of pumping vanes **146** without "choking" the suction eye **147** of the impeller.

[0028] For froth handling applications, it has been found that a minimum passage size of about two inches is sufficient. As used herein, "passage size" refers to the minimum mid-channel clearance between two adjacent pumping vanes **146**. As best shown in FIG. **3**, the pumping vane **146** geometry extends between the front **142** shroud (when included) and rear **144** shroud of the impeller **140** in a manner that provides maximum efficiency. The inventors have found that the size of the impeller **140**, and thus the overall size of the pump **100**, can be minimized by employing pumping vanes **146** that have a combination of high angle outlets, for maximum head, and conventional lower angle inlets for developing sufficient NPSH performance. In the exemplary embodiments shown and described herein, an outlet vane angle may be between about 80 degrees and 100 degrees, with 90 degrees being optimal. As used herein, pumping vane **146** angles are defined relative to the tangent of the impeller circumference; e.g., an outlet angle of 0 degrees would be tangential to the circumference of the impeller, while an outlet angle of 90 degrees is radial with respect to the center of the impeller, or perpendicular to the tangent of the impeller.

[0029] While the exemplary embodiments shown herein comprise an arrangement of 12 alternating full size **146*a*** and splitter **146*b*** pumping vanes, other pumping vane configurations also may provide suitable head and pumping efficiencies. For the pumping vane **146** configuration, as shown, having outlet angles of about 90 degrees, the inventors have found unexpectedly that a relative efficiency of at least about 73 percent may be achieved when pumping clear water.

[0030] As further shown in FIG. **4**, a plurality of vent holes **148** are formed through the rear shroud **144** of the impeller **140**. The vent holes **148** are located for the effective venting of gases therethrough. For the bitumen application, for example, the vent holes **148** must provide a minimum opening of about 2 inches in diameter, or, if not circular, an area of about 3.14 square inches.

[0031] Turning now to FIG. **5**, the principle of operation of the novel froth handling pump **100** is schematically illustrated. As will be appreciated by those skilled in the art, when pumping a two-phase (gas and liquid, such as froth) flow, due to the centrifugal forces within the impeller, the gas (shown as G in FIG. **5**) separates from the liquid at the inlet of the impeller. This causes the gas to accumulate on the trailing faces of the impeller pumping vanes **146**. As will also be appreciated, the continuous accumulation of gas during operation of the pump will eventually create "choking" of the impeller passage, resulting in cavitation and air lock of the impeller.

[0032] By providing vent holes **148**, as shown in FIG. **6**, at the appropriate circumferential locations through the rear shroud **144** of the impeller **140**, the gases have outlets to escape from the impeller main passages. The size, shape, and relative positions of these vent holes **148** are influenced by the quantity and anticipated location for gas accumulation. In the illustrated embodiments shown in the Figures, the positions of the vent holes **148** correspond approximately to the suction diameter of the impeller.

[0033] Although the vent holes **148** provide outlets for the gaseous phase to escape, the passage of the gases may be facilitated by creating a differential pressure between the main impeller passages and the outer face **144***a* of the rear shroud **144**. Accordingly, and as shown in FIG. **6**, the present invention comprises an impeller **140** having a plurality of clearing vanes **149***a*, **149***b* formed on the outer face **144***a* of the rear shroud **144**. These clearing vanes serve several purposes: (1) they assist in balancing the axial thrust of the rotating impeller, and (2) they exert a static pressure equal to or greater than the main impeller vanes to restrict the inwardly entry of main (liquid) flow from the impeller outlet. Additionally, the clearing vanes **149***a* and **149***b* are formed such that, as the impeller rotates, the clearing vanes **149***a*, **149***b* create a pressure at the outer face **144***a* that is lower than the pressure in the impeller suction eye **147**. By creating this differential pressure, the gases are drawn through the impeller vent holes **148** into the attached de-aeration chamber **160**. As shown in FIG. **6**, the clearing vanes **149***a*, **149***b* are radially-oriented (90 degrees) and extend substantially perpendicularly outward from the outer face **144***a* of the rear shroud **144**. In the embodiment shown, there are 18 clearing vanes **149***a*, **149***b*, comprising 12 short vanes **149***a* and **6** long vanes **149***b*; however, the total number of clearing vanes is not critical to the operation of the froth handling pump **100** of the present invention. Rather, the number, geometry, and angles of the clearing vanes are dependent upon the particular froth handling application. By forming the clearing vanes in the manner shown in FIG. **6**, i.e., with short and long vanes, the number of clearing vanes **149***a*, **149***b* may be maximized. In this embodiment, it also has been found that the clearing vanes **149***a*, **149***b* may need to be larger in diameter than the pumping vanes **146** by as much as 10 percent to obtain the desired pressure differential between the impeller suction eye **147** and the de-aeration chamber **160**. This means that the clearing vanes **149***a*, **149***b* extend radially inwardly further than the pumping vanes **146**.

[0034] In one embodiment, as shown in FIG. **7**, an auxiliary impeller configuration **180** may be rigidly mounted on the outer face **144***a* of the rear shroud **144**. The inventors have found that this configuration assists in creating a negative pressure relative to the pumping vanes **146**. As shown in FIG. **7**, the outer radius of the auxiliary impeller configuration **180** is greater than the maximum radial position of the vent holes **148** to prevent gases from being trapped on the outer face **144***a*.

[0035] Turning now to FIGS. **8** and **9**, the de-aeration chamber **160** is illustrated. As shown in the Figures, the de-aeration chamber **160** has an inlet opening **162** having a diameter that is dimensioned to extend outwardly beyond the maximum radial position of the vent holes **148** in the rear shroud **144**. The de-aeration chamber is thus rigidly coupled to the rear side **124** of the pump casing **120** by bolting or other conventional fastening means. As will be appreciated, pump casing **120** is modified from a conventional centrifugal pump casing, with an opening formed in the rear side **124** of the pump casing **120** corresponding in size to the inlet opening **162** of the de-aeration chamber **160**.

[0036] As shown the Figures, the de-aeration chamber **160** comprises a housing **163** having an inner volume. As shown, the de-aeration chamber **160** is a passive component of the froth handling pump **100** construction; i.e., the chamber **160** has no moving or movable parts. As best shown in FIGS. **2** and **9**, an opening **165** is formed on the rear face **164** of the de-aeration chamber **160** for passage of the to pump shaft **170** therethrough the chamber **160** for mounting to the impeller hub **142**. At least one outlet **166** is formed for discharging the gases from the chamber **160**. Depending on the particular froth handling application, the de-aeration chamber **160** may comprise a second outlet **168**. For bitumen froth handling, for example, it has been found that the outlets **166**, **168** should be at least about 3 inches in diameter to prevent clogging and to adequately vent the anticipated volume of gases. For the bitumen froth handling application, for example, it has been found that the outlet **166** should be located at about 22.5 degrees or less of vertical (in either direction from the vertical) for sufficiently releasing the gases. The outlet **166** may be provided with a flange **167** so that it may be interconnected to a discharge line (not shown) leading to a location suitable for discharging the vented gases. As will be understood, the vented flow may include some liquid discharge that should be diverted to a sump or other drainage location. Further, outlet **168** may be utilized for cleaning and drainage, as necessary.

[0037] Turning now to FIGS. **10** and **11**, an alternative embodiment of the novel impeller **240** of the froth pump **100** of the present invention is shown. As shown in FIG. **10**, the impeller is an open-shroud configuration, comprising only a rear shroud **244** and a plurality of pumping vanes **246**, including full size vanes **146***a* and splitter vanes **146***b*. In this embodiment, with elimination of a front shroud, the pumping vanes **246** may be geometrically extrapolated outwardly axially toward the suction liner to compensate for the thickness of a front shroud. The inventors again have found that an outlet vane angle may be between about 80 degrees and 100 degrees, with 90 degrees being optimal. In all other respects, the configuration of the pump **100**, including the de-aeration chamber **160**, are similar to the closed-shroud configuration of the pump **100**.

[0038] It is believed that the open-shroud configuration creates greater shear and turbulence between the pumping vanes and the suction liner of the pump, which breaks up air bubbles and further delays the formation of an air lock bubble. The inventors have found that this effectively increases the suction diameter, which reduces the velocity at the inlet edge of the impeller, and thereby increases the static pressure at the inlet edge. Optionally, the diameter of the suction inlet of the pump casing **120** may be increased for the open-shroud impeller to provide more open suction, which is less subject to air blockage. This effectively reduces the velocity at the inlet edge of the impeller, and thereby increases the static pressure there, which delays vapor formation (cavitation).

[0039] Turning lastly to FIGS. **12** and **13**, testing and performance data for both embodiments of the pump **100** are graphically illustrated. The testing was performed under similar conditions for both embodiments. A water-soap froth was formulated for the testing of the novel impellers. FIGS. **12** and **13** demonstrate the is performance of the open-shroud froth handling impeller compared to the closed-shroud embodiment described herein. Data is provided with the venting system open and closed, and at two different flowrates above and below the pump design flowrate. The open-shroud froth impeller resists air lock at a higher percentage of air than the closed-shroud froth impeller. The open-shroud froth impeller also exhibits a lower degree of losses than the closed-shroud design after air lock, with the venting system operational.

[0040] Although the present invention has been described with exemplary embodiments, it is to be understood that modifications and variations may be utilized without departing from the spirit and scope of the invention, as those skilled in the art will readily understand. Such modifications and variations are considered to be within the purview and scope of the appended claims and their equivalents.

We claim:

1. A froth handling pump, comprising
(a) a pump casing having an inlet side and a rear side;
(b) an impeller mounted within the casing, the impeller comprising:
(i) a rear shroud, comprising:
(A) an inner face and an outer face;
(B) a plurality of vent holes formed through the rear shroud for the passage of gases therethrough;
(ii) a plurality of pumping vanes, each of the pumping vanes comprising:
(A) inlet ends affixed to the inner face of the rear shroud and extending radially inwardly from the rear shroud;
(B) an inlet angle and an outlet angle, wherein the outlet is angle is greater than the inlet angle, the outlet angles terminating at the rear shroud;
(c) a de-aeration chamber mounted to the rear side of the pump casing and comprising:
(i) an inner volume;
(ii) an inner side mounted to the rear side of the pump casing;
(iii) an inlet formed on the inner side for receiving gases passing through the plurality of vent holes; and
(iv) at least one vent outlet for the discharge of gases therethrough.

2. The pump of claim **1**, wherein the plurality of pumping vanes extending radially inwardly from the rear shroud terminate at free ends.

3. The pump of claim **2**, wherein the space between the free ends of the pumping vanes and the inlet side of the pump casing being free of a front shroud;

4. The pump of claim **1**, wherein the outlet angles of the pumping vanes are between about 80 degrees and about 100 degrees.

5. The pump of claim **4**, wherein the outlet angles of the pumping vanes are about 90 degrees.

6. The pump of claim **1**, wherein the pumping vanes comprise full size main pumping vanes, and splitter vanes of a lesser radial dimension.

7. The pump of claim **6**, wherein the impeller comprises 12 pumping vanes comprising:
(a) 6 main pumping vanes;
(b) 6 splitter vanes; and
wherein the pumping vanes and splitter vanes are arranged in an alternating configuration, having passages therebetween.

8. The pump of claim **1**, wherein the passage size between adjacent pumping vanes is at least about 2 inches.

9. The pump of claim **1**, further comprising a plurality of clearing vanes formed on the outer face of the rear shroud.

10. The pump of claim **9**, wherein the plurality of clearing vanes are configured to create a pressure on the outer face of the rear shroud less than the pressure created by the pumping vanes.

11. The pump of claim **10**, wherein the clearing vanes project outwardly from the outer face of the rear shroud at about a 90 degree angle.

12. The pump of claim **11**, wherein the rear shroud has a central hub and wherein the clearing vanes have differing lengths extending radially outwardly relative to the central hub.

13. The pump of claim **9**, wherein the clearing vanes are at least about 5 percent larger in diameter than the pumping vanes.

14. The pump of claim **1**, wherein the vent holes in the rear shroud each have a minimum area of at least about 3.14 square inches.

15. The pump of claim **1**, wherein the at least one vent outlet on the de-aeration chamber is positioned at an angle of less than about 45 degrees with respect to the vertical.

16. The pump of claim **15**, wherein the at least one vent outlet is positioned at an angle of about 22.5 degrees with respect to the vertical.

17. The pump of claim **1**, wherein the at least one vent outlet has an outlet diameter of at least about 3 inches.

18. The pump of claim **1**, where the de-aeration chamber further comprises a drain outlet.

19. The pump of claim **1**, further comprising an auxiliary impeller mounted to the outer face of the rear shroud.

20. The pump of claim **19**, wherein the auxiliary impeller has an outer radius that is greater than the maximum radial position of the plurality of vent holes.

21. The pump of claim **1**, wherein the impeller comprises a front shroud.

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