



(51) International Patent Classification:

B01D 19/00 (2006.01) C02F 1/20 (2023.01)

B03D 1/08 (2006.01)

(21) International Application Number:

PCT/IB2023/054945

(22) International Filing Date:

12 May 2023 (12.05.2023)

(25) Filing Language:

English

(26) Publication Language:

English

(30) Priority Data:

63/341,336 12 May 2022 (12.05.2022) US

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(81) Designated States (unless otherwise indicated, for every kind of national protection available): AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ,

CA, CH, CL, CN, CO, CR, CU, CV, CZ, DE, DJ, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IQ, IR, IS, IT, JM, JO, JP, KE, KG, KH, KN, KP, KR, KW, KZ, LA, LC, LK, LR, LS, LU, LY, MA, MD, MG, MK, MN, MU, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SA, SC, SD, SE, SG, SK, SL, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, WS, ZA, ZM, ZW.

(84) Designated States (unless otherwise indicated, for every kind of regional protection available): ARIPO (BW, CV, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SC, SD, SL, ST, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, ME, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, KM, ML, MR, NE, SN, TD, TG).

Declarations under Rule 4.17:

- as to applicant's entitlement to apply for and be granted a patent (Rule 4.17(ii))
- of inventorship (Rule 4.17(iv))

Published:

- with international search report (Art. 21(3))

(54) Title: FROTH TRANSPORT SYSTEM, DE-AERATION DEVICE, AND METHOD FOR EFFICIENTLY PUMPING FROTHY OR AERATED SLURRIES

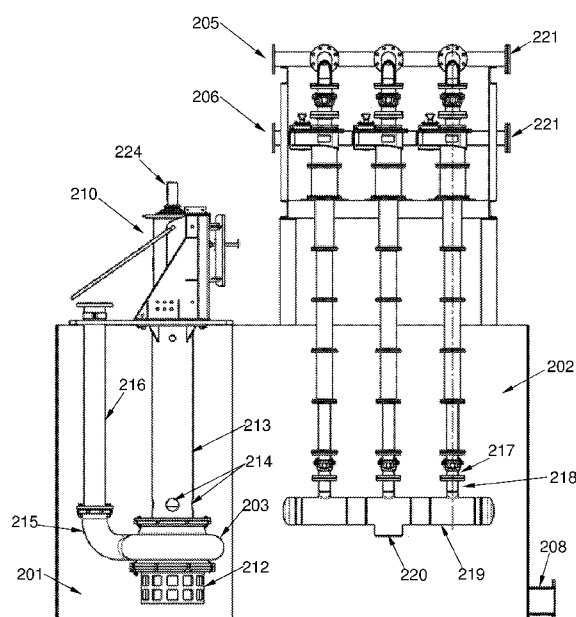


FIG. 5

(57) Abstract: A froth transport system (100) and de-aeration apparatus (200) is disclosed. Each comprise a first holding tank or sump (201) and a froth pump (203) for transporting aerated slurry from the sump 201 to one or more hydrocyclones (204). Overflow of the one or more hydrocyclones (204) containing fines and gas (114) may be recycled to the first holding tank or sump (201), or back to an inlet manifold (206) feeding the one or more hydrocyclones (204). The froth transport system (100) and/or de-aeration apparatus (200) may comprise a second holding tank or sump (202). De-aerated slurry (106) may be transferred from the second holding tank or sump (202) to one or more centrifugal pumps (107) to move the same to a downstream process step (108).

FROTH TRANSPORT SYSTEM, DE-AERATION DEVICE, AND METHOD FOR EFFICIENTLY PUMPING FROTHY OR AERATED SLURRIES

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FIELD OF THE INVENTION

Embodiments of the present invention pertain to improvements to pumping circuits which enable aerated slurries (such as froth from flotation circuit overflows) to be efficiently pumped using conventional slurry pumps. In particular, embodiments of
10 the present invention relate to a unique de-aeration device and associated transport system which may be used to facilitate the transport of aerated slurries to points of high elevation.

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BACKGROUND TO THE INVENTION

Reference to background art herein is not to be construed as an admission that such art constitutes common general knowledge in the arts.

20

In many industrial processes, pumps are used to convey liquids, slurries containing liquids and solids, and/or liquids containing gaseous fluids (e.g., froth) between components of processing circuit. In some processing circuits, inline pumps may be positioned between transport pipes at its respective inlet and outlet ends, in order to move material between areas of a processing circuit.

25

In processing circuits where gaseous liquid/solid slurry compositions are moved, holding tanks or sumps may be provided. These may be configured to hold or store an aerated slurry. They may deliver the same to a downstream pump (e.g., centrifugal slurry pump) for moving the aerated slurry to other locations of the circuit, including points within the processing circuit which are at higher elevations
30 than a holding tank or sump.

Generally speaking, when air-entrained liquids are transported, the pumps involved run less efficiently. Pump efficiency drops off with larger amounts of

entrained air in the pumped slurry, because there is a greater potential for drop in flow and/or head in the system. Air entrained in pumped slurry can also tend to “bind” regions proximate the central eye of the impeller. Said differently, heavier liquids and solids may be biased to move radially outwardly due to impeller-
5 induced centrifugation, leaving air to collect centrally, thus potentially blocking slurry flows adjacent the impeller eye at the pump inlet. Moreover, aerated froth within the pumped slurry takes up the usual liquid volume.

When pumping froths and aerated slurries, it can be quite difficult to predict how
10 much air might be pulled out from them when they are being pumped. Standard horizontal pumps which are gravity fed with aerated slurry often demonstrate unstable cyclical performance cycles due to swings between low to full flowrate and/or associated power surges. Such behaviour and low pump performance may be attributed to intermittent air-locking or “binding” phenomenon (described
15 above), wherein a growing bubble of trapped air can develop at the vertical entry of the horizontal pump’s impeller eye and can impede further aerated slurry flow to the pump.

As slurry builds above the bubble, head in the suction tank rises until the bubble
20 shrinks/compresses, allowing slurry to flow to the pump once again. These intermittent temporary air blockages to the pump, followed by temporary removal of the obstruction can lead to the deterioration of performance of a froth pump.

For a given percentage of air or gas in the pumped slurry, pump performance can
25 vary, based upon a number of factors (e.g., the number of pumping stages, pump rotating speed, discharge pressure, pump size, suction pressure, specific speed, pump design, etc.).

A pump sees incoming aerated and frothy slurries as fluids having increased
30 volume and decreased density. The pump froth factor is a measure of the air contained in the froth. Depending on the overall design of suction arrangements for a froth pump, froth factors can vary (e.g., from approximately 1 to 8 or more).

Centrifugal slurry pumps are not recommended for slurries having higher froth factors (e.g., above 6).

5 In summary, pumping slurry entrained in froth, particularly in flotation mineral processing, is a difficult and energy consuming process. Air entrained within slurry, or froth, is difficult to pump and impossible to pump at high heads, even with a multistage pumping system. Accordingly, there is a long-felt need for a technology which removes entrained air from within a slurry which would allow such slurries to be efficiently downstream at higher heads.

10

Defoamer has been used in industry to remove entrained air from slurries, but such products can be very expensive and may not work effectively. Defoaming agents may also compromise delicate downstream recovery processes.

15 To this end, pumps have also been disposed within a tank or sump (e.g., submersible/immersible pumps). Such devices might be referred to as tank pumps, vertical pumps, vertical sump pumps, vertical submerged pumps, and/or vertical tank pumps, without limitation. These devices may be used as holding tanks or buffering tanks and can be especially useful for aerated slurry, and/or froth
20 pumping purposes. For example, such devices may be used in mineral processing facilities to transport froth overflow recovered from froth flotation processes to one or more downstream processing steps. However, the aforementioned types of pumps are not configured to completely remove all of the gas fraction in the pumped aerated slurry.

25

U.S. Pat. No. 6,854,957, U.S. Pat. No. 6,315,530, U.S. Pat. No. 3,936,221, and International Patent Application Publication WO04022979A1, depict some relevant examples of froth-type pumps that have been proposed to date. Other examples of pumps that have been proposed to date include the Metso® brand VT vertical
30 tank pump, Sala VT-series vertical tank pump, Sala SPV-series vertical tank pump, the Weir Group's Warman® Hazleton®, and Floway® brand vertical slurry pumps (e.g., the Warman® WBV® ultra heavy-duty vertical cantilevered slurry pump), and FLSmidth's Krebs® vMAX™ vertical cantilever pump. Other existing solutions for

moving froth include specially-designed vertical slurry pumps, and horizontal froth pumps (e.g., Warman® AHF, MF and LF froth pumps). Weir Minerals' Continual Air Removal System (CARS) is another technology aimed at moving aerated liquid/solid slurries. Yet other existing solutions include specialized froth pumps
5 which use impellers having vanes extending into the eye suction inlet of the pump (see for example, WO2000034663A1 and related art citations).

GLCC's or "Gas Liquid Cylindrical Cyclones" have been used to separate gas from liquid in the oil industry; however, these are not configured for use with abrasive
10 slurries found in the minerals processing industry.

OBJECTS OF THE INVENTION

Embodiments of the present invention aim to improve upon existing pump
15 solutions for aerated slurries such as those used to transport flotation froth to downstream processing steps.

Embodiments of the present invention also aim to allow froth to be transported to downstream processing steps at high elevations (e.g., those having 50 to 100-
20 meter head requirements or greater).

Embodiments of the present invention also aim to provide a way to de-aerate froths so that centrifugal pumps may be used to convey and achieve high head requirements without significantly impacting performance.
25

Embodiments of the present invention also aim to remove air from slurries to reduce energy consumption (e.g., of pumps) and/or increase pump performance.

It is an aim that embodiments of the invention provide a pumping circuit, and
30 improved apparatus associated therewith, which overcomes or ameliorates one or more of the disadvantages or problems described above, or which at least provides a useful alternative to conventional froth-pumping apparatus.

Embodiments of the present invention also aim to provide a novel apparatus which is configured for removing entrained air from within a slurry, so that the slurry can be efficiently downstream at higher heads (e.g., using cheaper, more efficient conventional slurry pumps), without limitation.

5

Embodiments of the present invention also aim to process air entrained slurry through a de-frothing (i.e., "de-aeration") device, so that slurry can be pumped more efficiently and at higher heads downstream.

- 10 As suggested in FIG. 1, embodiments of the invention further aim to provide at least one underflow valve 101 downstream of a lower outlet 207 of one or more cyclones 204. The at least one valve 101 may be configured to throttle underflow throughput leaving the one or more cyclones 204 and/or otherwise serve as cyclone 204 underflow control apparatus. By controlling the at least one underflow
- 15 valve 101 downstream of a lower outlet 207 of one or more cyclones 204, optimal backpressure may be provided within the one or more cyclones 204, thereby forcing gas (e.g.,) to more easily discharge through one or more cyclone upper (overflow) outlets 207.
- 20 Other preferred objects of the present invention will become apparent from the following description.

SUMMARY OF INVENTION

- 25 According to some embodiments, a froth transport system (100) is disclosed. The froth transport system 100 may comprise a first holding tank or sump (201). The first holding tank or sump (201) may be provided with means for receiving aerated feed, froth, or slurry (104). The froth transport system 100 may comprise one or more cyclones (204). Each of the one or more cyclones (204) may be
- 30 provided with means (101, 206, 216, 222, 223) for receiving aerated feed, froth, or slurry (104) from the first holding tank or sump (201). Each of the one or more cyclones (204) may be provided with means (217, 218, 219, 220) for discharging de-aerated slurry (106) as underflow therefrom. Each of the one or more

cyclones (204) may be provided with means (101, 205, 207, 222) for discharging gas and fines (114) as overflow therefrom. The froth transport system 100 may comprise a froth pump (203) configured for conveying aerated feed, froth, or slurry (104) from the first holding tank or sump (201) to the one or more cyclones (204), for example, as pumped aerated feed, froth, or slurry (105), without limitation.

According to some embodiments, the froth transport system (100) may comprise means (107, 208) for transporting at least some de-aerated slurry (106) from the one or more cyclones (204) to a downstream process step (108).

According to some embodiments, the froth transport system (100) may comprise means (109) for recycling or recirculating at least some gas and fines (114) from the one or more cyclones (204) back to the one or more cyclones (204).

According to some embodiments, said means (109) for recycling or recirculating may be configured to combine at least some gas and fines (114) from the one or more cyclones (204) with the pumped aerated feed, froth, or slurry (105).

According to some embodiments, said at least some gas and fines (114) and pumped aerated feed, froth, or slurry (105) may be combined upstream of an inlet manifold (206). The inlet manifold (206) may fluidly communicate with or allow fluid communication with the one or more cyclones. The inlet manifold (206) may be configured for feeding the one or more cyclones (204) (e.g., with pumped aerated feed, froth, or slurry (105) delivered from the first holding tank or sump (201)).

According to some embodiments, the froth transport system (100) may comprise a second holding tank or sump (202), for example, for holding de-aerated slurry (106) discharged from the one or more cyclones (204).

According to some embodiments, the froth transport system (100) may comprise a valve (101) located in one or more of the following locations within the froth

transport system (100): between the froth pump (203) and the one or more cyclones (204), upstream of said one or more cyclones (204), upstream of said means (223) for receiving the aerated feed, froth, or slurry (104); downstream of said means (101, 205, 207, 222) for discharging gas and fines; downstream of said
5 means (217, 218, 219, 220) for discharging de-aerated slurry (106), without limitation.

According to some embodiments, the froth pump (203) of the froth transport system (100) may be situated within the first holding tank or sump (201) and/or
10 provided upstream of the one or more cyclones (204).

According to some embodiments, the froth pump (203) may be configured to be submerged in aerated feed, froth, or slurry (104) within the first holding tank or sump (201).

15

According to some embodiments, a de-aeration device (200) is disclosed. The de-aeration device 200 may be configured for use within a froth transport system (100). The de-aeration device (200) may be configured for de-aerating an
20 aerated feed, froth, or slurry (104). The de-aeration device (200) may comprise a first holding tank or sump (201). The first holding tank or sump (201) may comprise means for receiving aerated feed, froth, or slurry (104).

The de-aeration device (200) may comprise one or more cyclones (204). Each of
25 the one or more cyclones (204) may comprise means (101, 206, 216, 222, 223) for receiving aerated feed, froth, or slurry (104), for example, from the first holding tank or sump (201). Each of the one or more cyclones (204) may comprise means (217, 218, 219, 220) for discharging de-aerated slurry (106) as underflow therefrom. Each of the one or more cyclones (204) may comprise
30 means (101, 205, 207, 222) for discharging gas and fines (114) as overflow therefrom. The de-aeration device may comprise a froth pump (203). The froth pump (203) may be configured for pumping or conveying aerated feed, froth, or

slurry (104) from the first holding tank or sump (201) to the one or more cyclones (204), for example, as pumped aerated feed, froth, or slurry (105).

5 According to some embodiments, the de-aeration device (200) may comprise a second holding tank or sump (202). The second holding tank or sump (202) may have a discharge outlet (208), for example, at a lower portion thereof. The second holding tank or sump (202) may be configured to receive de-aerated slurry (106) from the one or more cyclones (204).

10 According to some embodiments, the de-aeration device (200) may comprise a froth pump drive motor (111). The froth pump motor may be operatively connected to the froth pump (203), for example, via a drive shaft (224). According to some embodiments, the de-aeration device (200) may comprise a froth pump drive (210). The froth pump drive (210) may be configured for operatively coupling the
15 froth pump drive motor (111) to the drive shaft (224). The froth pump drive (210) may be configured to serve as a speed reducer or torque increaser, without limitation.

According to some embodiments, the means (101, 206, 216, 222, 223) for
20 receiving the aerated feed, froth, or slurry (104) from the first holding tank or sump (201) may comprise one or more of the following: a pump outlet pipe (216), an inlet manifold (206), a volute inlet (223), a valve (101), an inlet flange (222), an end cap (221).

25 According to some embodiments, the de-aeration device (200) may comprise a pump outlet pipe (216). The pump outlet pipe (216) may be configured for allowing fluid communication and/or transport of aerated feed, froth, or slurry (104) between an outlet of the froth pump (203) and an inlet manifold (206). The inlet manifold (206) may be configured for distributing pumped aerated feed, froth, or slurry (105)
30 to the one or more cyclones (204). The pump outlet pipe (216) may extend entirely to the inlet manifold (206) or an intermediate apparatus (e.g., as depicted in FIG. 10) may be arranged between the pump outlet pipe (216) and inlet manifold (206), without limitation.

According to some embodiments, the de-aeration device (200) may comprise an endcap (221) at one end of the inlet manifold (206). According to some embodiments, the de-aeration device (200) may comprise an outlet manifold (205) for collecting gas and fines (114) from the one or more cyclones (204). According to some embodiments, the de-aeration device (200) may comprise an endcap (221) at one end of the outlet manifold (205).

According to some embodiments, the de-aeration device (200) may comprise means (109) for recycling or recirculating at least some gas and fines (114) from the one or more cyclones (204). According to some embodiments, said means (109) for recycling or recirculating may be configured to combine at least some gas and fines (114) from the one or more cyclones (204) with pumped aerated feed, froth, or slurry (105) delivered by the froth pump (203).

According to some embodiments, said means (109) for recycling or recirculating may be configured to combine at least some gas and fines (114) and pumped aerated feed, froth, or slurry (105) upstream of an inlet manifold (206) fluidly communicating with and feeding the one or more cyclones (204). According to some embodiments (not shown), the means (109) for recycling or recirculating may be configured to combine at least some gas and fines (114) and pumped aerated feed, froth, or slurry (105) into or at an inlet manifold (206) fluidly communicating with and feeding the one or more cyclones (204), without limitation.

According to some embodiments, the de-aeration device (200) may comprise a supporting frame (209) for directly or indirectly supporting one or more of the following: the one or more cyclones (204), an inlet manifold (206), and/or an outlet manifold (205), without limitation.

According to some embodiments, a method of transporting or conveying an aerated or frothy slurry is disclosed. The method may comprise the step of providing a froth transport system (100) or the de-aeration device (200) as described above. The method may comprise the step of providing aerated feed, froth, or slurry (104) to a first holding tank or sump (201). The method may

comprise the step of using the froth pump (203) to pump and deliver pumped aerated feed, froth, or slurry (105) to the one or more cyclones (204) from the first holding tank or sump (201). The method may comprise the step of using the one or more cyclones (204) to discharge de-aerated slurry (106) from one or more
5 cyclones (204). The method may comprise the step of using the one or more cyclones (204) to discharge the gas and fines (114) from the one or more cyclones (204).

According to some embodiments, the method may comprise the step of recycling
10 or recirculating the gas and fines (114); for example, by combining the gas and fines (114) with the pumped aerated feed, froth, or slurry (105). According to some embodiments, the method may involve the step of delivering recycled or recirculated gas and fines (114) and the pumped aerated feed, froth, or slurry (105) to the one or more cyclones (204).

15 According to some embodiments, the method may comprise the step of using at least one centrifugal slurry pump (107) to pump de-aerated slurry (106) (e.g., slurry discharged from the one or more cyclones (204)) to a downstream process step (108) located at a first height (Δh_{max1}) above a component of the froth transport
20 system (100) or the de-aeration device (200). The first height (Δh_{max1}) may be substantially greater than a second height (Δh_{max2}) above the same component of the froth transport system (100) or the de-aeration device (200) which is possible to achieve using *only* the froth pump (203), *or* the at least one centrifugal slurry pump (107) to move the aerated feed, froth, or slurry (104).

25 The second height (Δh_{max2}) may be associated with a maximum height or head achievable using the same number of slurry pumps (7) as the number of said at least one centrifugal slurry pump (107) used to transport stabilized aerated feed, froth, or slurry (6) from a holding tank (5) in the conventional manner shown in FIG.
30 11.

The method may comprise the step of operating each of the at least one centrifugal slurry pump (107) to overcome a first head (Δh_1). The first head (Δh_1) may be

substantially greater than a second head (Δh_2) overcome per slurry pump (7) moving stabilized aerated feed, froth, or slurry (6) from a holding tank (5) in the conventional manner shown in FIG. 11. Accordingly, using embodiments of the froth transport system (100) or de-aeration device (200) disclosed herein may enable pumping to greater heights using less pumps (107) than conventional froth transport systems (1).

Further features and advantages of the present invention will become apparent from the following detailed description.

10

BRIEF DESCRIPTION OF THE DRAWINGS

By way of example only, preferred embodiments of the invention will be described more fully hereinafter with reference to the accompanying figures.

15

FIG. 1 is a schematic representative view illustrating an exemplary froth transport system according to some non-limiting embodiments of the invention.

FIG. 2 depicts a top plan view of an exemplary, non-limiting embodiment of a de-aeration device in accordance with the invention.

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FIG. 3 shows a front plan view of the de-aeration device depicted in FIG. 2.

FIG. 4 shows a side plan view of the de-aeration device depicted in FIGS. 2 & 3.

25

FIG. 5 is a front cutaway sectional view of FIG. 3, showing internal features of the de-aeration device depicted in FIGS. 2-4.

FIG. 6 shows a first top isometric view of the de-aeration device depicted in FIGS. 2-5.

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FIG. 7 depicts second top isometric view of the de-aeration device depicted in FIGS. 2-6.

FIG. 8 schematically illustrates an example of a froth transport system 100 according to some embodiments in accordance with the invention.

5 FIG. 9 depicts a close-up view of a central portion of FIG. 8.

FIG. 10 depicts a non-limiting embodiment of apparatus which may be used as means for recycling or recirculating gas and fines 114 to one or more cyclones 204, within a froth transport system 100 or de-aeration device 200 thereof, without
10 limitation.

FIG. 11 depicts a froth transport system 100 in accordance with conventional prior art methods.

15 DETAILED DESCRIPTION OF THE DRAWINGS

Turning to FIG. 11, a conventional froth transport system 1 of the prior art may be used to transport aerated feed, froth, or slurry 4 (e.g., froth overflow) from a launder 3 of a flotation machine 2. The flotation machine 2 may receive air 9 by force (e.g.,
20 from a pressurized air source), or naturally (e.g., via naturally-aspirated air induction). The flotation machine 2 may also receive slurry 10 which is to undergo flotation processing within the flotation machine 2. The flotation machine 2 may comprise designs including the forced-air type, naturally-aspirated type, column-type, sparger-type, or other type, without limitation.

25 The aerated feed, froth, or slurry 4 from the launder 3 may be moved to a holding tank 5. A slurry pump 7 may be used to move stabilized aerated feed, froth, or slurry 6 from the holding tank 5 to a downstream process step 8. The slurry pump may be a froth pump or a centrifugal slurry pump, although as stated above in the
30 background, a centrifugal slurry pump would be ill advisable for higher froth factors/air concentrations.

As suggested, using such conventional prior art methods, a second head achieved per pump (Δh_2) remains relatively low, requiring a greater number of pumps 7 to reach a downstream process step 8 which requires a second max head (Δh_{max2}). Using more pumps at greater air concentrations can lead to poor performance, circuit/process disruptions, higher capital (CAPEX) and operating (OPEX) expenditures, and more frequent servicing to keep the conventional froth transport system 1 operational. Advantages of embodiments discussed below will become apparent from the following detailed description.

As suggested in FIGS. 1 and 8, embodiments of a froth transport system 100 are proffered. The embodiments aim to overcome the above drawbacks associated with conventional froth transport systems 1.

A froth transport system 100 according to embodiments may comprise a froth pump 203, such as a vertical pump, horizontal pump, tank sump pump, FLSmidth® hMAX™ pump, or the like, without limitation. A froth pump 203 within the froth transport system 100 may be used to move aerated feed, froth, or slurry 104 (e.g., frothy flotation overflow) from a first holding tank/sump 201 to one or more cyclones 204. The aerated feed, froth, or slurry 104 may be derived from an upstream process. For example, the aerated feed, froth, or slurry 104 may be collected from a launder 103 of a flotation machine 102, without limitation. Thus, a froth transport system 100 according to embodiments may be located downstream of a flotation circuit, flotation cell, or flotation cell bank, without limitation.

The one or more cyclones 204 may collectively form a cyclone bank or a portion of a cyclone bank. In some embodiments, the cyclones 204 may be hydrocyclones which preferably have wear-resistant features. Pumped aerated feed, froth, or slurry 105 is moved from the first holding tank/sump 201 to an inlet 223 of the one or more cyclones 204. The inlet 223 may be preferably selected to be of the volute-type. It is very important to understand that while cyclones have been conventionally used *upstream* of flotation cells (e.g., to separate out fines and prevent the fines from undergoing flotation), the cyclones 204 disclosed herein are configured for removing air from frothy or aerated slurries such as froth overflow

produced by flotation cells. Thus, cyclones 204 disclosed herein would be *downstream* of flotation cells, unlike those typically found in flotation circuits.

The one or more cyclones 204 receive and process the pumped aerated feed, froth, or slurry 105 by virtue of centrifugation. Gas and fines 114 within the pumped aerated feed, froth, or slurry 105 find their way to the center or “core” of each of the one or more cyclones 204, and the heavier solids (present within the received pumped aerated feed, froth, or slurry 105) make their way to outer peripheral portions of the one or more cyclones. These heavier solids are eventually discharged from a lower outlet 217 of each of the one or more cyclones 204 as de-aerated slurry 106. The gas and fines 114 leave each of the one or more cyclones 204 through an upper outlet 207 provided to the one or more cyclones 204.

In some embodiments, a number of valves 101 may be provided to the froth transport system 100. For example, one or a plurality of valves 101 may be practiced. As shown, one or more valves 101 may be placed between the froth pump 203 and each of the one or more cyclones 204, e.g., upstream of an inlet 223 of each cyclone 204. One or more valves 101 may be placed downstream of an upper outlet 207 of each of the one or more cyclones 204. One or more valves 101 may be placed in a recycle or recirculation stream 109 (see also, FIG. 10). One or more valves may be placed downstream of a lower outlet 217 of each of the one or more cyclones 204. It should be understood that not all cyclones 204 may have a valve 101 positioned upstream and/or downstream of it.

In some preferred embodiments, one or more valves 101 may be placed at, adjacent to, or downstream of a lower outlet 217 of one or more cyclones 204. For example, a valve 101 may be placed at, adjacent to, or downstream of a lower cyclone outlet 217, lower manifold 219, and/or manifold outlet 220, without limitation. If employed, these one or more downstream cyclone underflow valves 101 may be adjusted, used to control/limit cyclone 204 underflow discharge, and/or used to increase backpressure within the one or more cyclones 204 by restricting cyclone 204 underflow discharge through cyclone outlet(s) 217. By increasing backpressure within the one or more cyclones 204 by virtue of controlling these

one or more downstream valves 101, gas (e.g., entrained air) may be encouraged to be forced from the one or more cyclones 204 (e.g., out through a cyclone upper outlet 207 of the one or more cyclones 204). Accordingly, some valves 101 within embodiments of the disclosed froth transport system 100 and de-aeration device

5 200 may be used for purposes of facilitating de-gassing of aerated feed, froth, or slurry 4 – and/or for purposes of increasing the amount or percentage of gas/air being removed by the system via the one or more cyclones 204.

Methods of operating a froth transport system 100 or de-aeration device 200 may

10 similarly involve the steps of restricting underflow through a lower outlet 217 of one or more cyclones 204 by adjusting or closing off one or more valves 101, increasing backpressure within said one or more cyclones 204, and increasing the amount or percentage of gas (e.g., entrained air) discharged through an upper cyclone outlet 207 of the one or more cyclones 204 with gas and fines 114. By restricting

15 discharge flow from the one or more cyclones 204, system de-gassing efficiencies may be optimized, without limitation.

As suggested in FIG. 1 one or more valves 101 may be strategically placed in one or more bleed streams 111, 112, 113 within the froth transport system 100. For

20 example, a first bleed stream 111 may collect a feed sample of pumped aerated feed, froth, or slurry 105. This first bleed stream 111 may serve the purpose of sample collection or sampling of the same, without limitation. As another example, a second bleed stream 112 may collect a sample of gas and fines 114 (i.e., “overflow”) leaving the one or more cyclones 204. This second bleed stream 112

25 may serve the purpose of sample collection or sampling of the same, without limitation. As another example, a third bleed stream 113 may collect a sample of de-aerated slurry 106 (i.e., “underflow”) leaving the one or more cyclones 204. This third bleed stream 113 may serve the purpose of sample collection or sampling of the same, without limitation.

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One or more slurry pumps 107 (e.g., centrifugal slurry pump(s)) may be provided to downstream portions of the froth transport system 100 to move de-aerated slurry 106 leaving the one or more cyclones 204 to a downstream process step 108. The

downstream process step 108 may be located at a first height or vertical distance above one or more components of the froth transport system 100, such as above a lower discharge outlet 217 of the one or more cyclones 204 or a discharge outlet 108 of a second holding tank/sump 202. The first height or vertical distance may
5 be significant. Accordingly, embodiments aim to maximize a first head (Δh_1) performance per slurry pump 107 to achieve a first maximum head requirement (Δh_{max1}), using the least number of slurry pumps 107.

The froth transport system 100 may comprise a number of gauges 110. There
10 may be one or a plurality of gauges within the froth transport system. For example, a gauge 110 may be positioned upstream of an inlet 223 of a cyclone 204, downstream of an upper outlet 207 of a cyclone 204, and/or downstream of a lower outlet 217 of a cyclone 204, without limitation.

Moreover, a froth transport system 100 according to embodiments of the invention
15 may include a recycle or recirculation stream 109. The recycle or recirculation stream 109 may direct some or all of the gas and fines 114 leaving the one or more cyclones 204 back to an inlet 223 of the one or more cyclones 204. This may be done by virtue of special apparatus (e.g., that shown in FIG. 10), by plumbing the
20 upper outlet 207 of each of the one or more cyclones 204 to an inlet manifold 206 to the one or more cyclones 204, and/or by plumbing the upper outlet 207 of each of the one or more cyclones 204 back to the first holding tank/sump 201, without limitation. In some embodiments, it may be preferable to combine the pumped aerated feed, froth, or slurry 105 with the gas and fines 114 leaving the one or
25 more cyclones 204. Those skilled in the art would appreciate and anticipate a plethora of ways to accomplish this function.

Turning now to FIGS. 2-7, a novel and heretofore unobvious de-aeration device
30 200 may be provided to a froth transport system 100 according to some embodiments. The device 200 may comprise a first holding tank/sump 201. The device 200 may comprise a second holding tank/sump 202. The first 201 and second 202 holding tanks/sumps may be integrally-formed with one another (e.g., sharing a common wall as shown), or they may be separate tanks. In the latter

case, it would be preferable that the separate tanks 201, 202 be situated on a common platform (e.g., skid, chassis, frame, shipping container, box, unit, or the like).

- 5 The second holding tank/sump 202 may be provided with an outlet manifold 208. The outlet manifold 208 may be positioned at a lower portion of the second holding tank/sump 202.

10 The de-aeration device 200 may comprise an inlet manifold 206. The inlet manifold 206 may serve to feed the one or more cyclones 204 with pumped aerated feed, froth, or slurry 105. The inlet manifold 206 may optionally comprise an endcap 221 at one end as shown. The inlet manifold 206 may comprise one or more manifold branch pipes 222 to facilitate plumbing the inlet manifold 206 to each inlet 223 of the one or more cyclones 204. A valve 101 may be provided adjacent each inlet
15 223 or manifold branch pipe 222 of the inlet manifold 206. A valve 101 may be provided upstream of, and/or, on a portion of the inlet manifold 206, without limitation.

20 The de-aeration device 200 may comprise an outlet manifold 205. The outlet manifold 205 may serve to exhaust the one or more cyclones 204 of gas and fines 114. The outlet manifold 205 may optionally comprise an endcap 221 at one end as shown. The outlet manifold 205 may comprise one or more manifold branch pipes 222 to facilitate plumbing the outlet manifold 205 to each upper outlet 207 of the one or more cyclones 204. A valve 101 may be provided adjacent each outlet
25 207 or manifold branch pipe 222 of the outlet manifold 205. A valve 101 may be provided downstream of, and/or, on a portion of the inlet manifold 206, without limitation.

30 The de-aeration device 200 may comprise a supporting frame 209. The supporting frame 209 may be formed from one or more structural members or support beams, without limitation. The supporting frame may be used to support one or more of the following, without limitation: one or more cyclones 204, an inlet manifold 206, an outlet manifold. In the particular embodiment shown, the supporting frame 209

is shown to be secured to a portion of the second holding tank/sump 202; however, this may not necessarily be the case. For example, the supporting frame 209 may be integrally connected with a portion of a skid, chassis, frame, shipping container, box, unit, or the like, without limitation.

5

It should be understood that while the one or more cyclones 204 are shown to be submerged in, or otherwise disposed within the second holding tank/sump 202, they may be fashioned externally to the first 201 and/or second 202 holding tank/sump 202. The one or more cyclones 204 may be plumbed to feed de-aerated slurry 106 into the second holding tank/sump 202 in any fashion. In the depicted embodiment, to reduce footprint, streamline the profile, and reduce plumbing, the one or more cyclones 204 are disposed within the second holding tank/sump 202 and each of their lower outlets 217 fluidly communicate with a lower manifold 219. The lower manifold 219 may have one or more flanged inlets 218 which can be operably connected to lower outlets 217 of each of the one or more cyclones 204. A single manifold outlet 220 may be provided as shown, to allow de-aerated slurry 106 to exit the lower manifold 219 and enter the second holding tank/sump 202. As stated earlier, the lower manifold 219 may be positioned outside of the second holding tank/sump 202 if the one or more cyclones 204 are positioned outside of the second holding tank/sump 202.

As can be further appreciated from the figures, a froth pump 203 may be placed within the first holding tank/sump 201. The froth pump 203 may be configured to be submerged in aerated feed, froth, or slurry 104 received within the holding tank/sump 201. An impeller within the froth pump 203 may be driven by an operably connected to a rotatable drive shaft 224. The drive shaft 224 may be substantially vertically oriented as shown, but could be configured orthogonal to what is depicted, without limitation. The drive shaft 224 may be driven by a froth pump drive motor 211. The device 200 may have a direct drive (e.g., wherein the froth pump drive motor is coupled with a 1:1 reduction directly to the output shaft of the froth pump drive motor 211), or, the device may comprise an indirect drive (e.g., wherein a froth pump drive 210 is arranged between the froth pump drive motor 211 and the drive shaft 224 to the froth pump 203). Where utilized, the froth

pump drive 210 may comprise a speed reducer, a gearbox, a pulley system, a transmission, or other means for providing a mechanical advantage, without limitation.

5 An inlet to the froth pump 203 may comprise an inlet screen or cage 212 to prevent tramp material from entering the pump 203. A central column 213 may be disposed within the first holding tank/sump 201. The central column 213 may surround the drive shaft 224. The central column 213 may extend substantially vertically within the first holding tank/sump 201 as shown. The central column 213
10 may extend between the froth pump 203 and a froth pump drive 210 as shown. The central column 213 may comprise one or more venting orifices or “breather openings” 214 proximate the froth pump 203 as shown. Because the froth pump 203 may be submerged within the first holding tank/sump 201 and may not have seals behind the impeller therein, these breather openings 214 may be configured
15 to allow some slurry and/or air into or out of the froth pump 203 as necessary. Accordingly, they may allow passage of aerated feed, froth, or slurry 104 within the first holding tank/sump 201 therethrough, without limitation.

As suggested in FIGS. 5 and 10, the device 200 may comprise one or more elbows
20 215. For example, an elbow 215 may be disposed between an outlet of the froth pump 203 and a pump outlet pipe 216 (e.g., a substantially vertically-extending pump outlet pipe as depicted) to change a direction of flow of pumped aerated feed, froth, or slurry 105. The directional change of flow of the pumped aerated feed, froth, or slurry 105 may be between 0 degrees and 180 degrees, for example,
25 approximately 90 degrees as shown. An elbow 215 may be positioned between an upper end of pump outlet pipe 216 and an inlet manifold 206, without limitation. An elbow 215 may be positioned to allow an outlet manifold 205 to communicate with a flow of pumped aerated feed, froth, or slurry 105 – or plumb an outlet manifold 205 to an inlet manifold 206. For example, one or more elbows 215 may
30 be used in apparatus serving to provide a recycle or recirculation stream 109. The one or more elbows 215 may, thus, serve to provide a change in direction of flow of gas and fines 114 leaving the one or more cyclones 204.

It should be noted that the inventors contemplate froth transport system 100 and de-aeration device 200 embodiments which are configured such that the underflow from the one or more cyclones 204 may discharge slightly below the level of deaerated slurry 106 in the second holding tank/sump 202, in order to reduce froth reforming through agitation (e.g., reduce turbulence within the second holding tank/sump 202). Doing so may further assist with creating back pressure within the one or more cyclones 204 and help force gas/air out the overflow outlet 207 of the one or more cyclones 204.

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The inventors further contemplate that using the proposed substantially-submerged impeller feed pump design, in synergistic combination with throttling cyclone 204 underflow via one or more downstream valves 101 may help force gas (e.g., entrained air) out the cyclone overflow outlet(s) 207 with fines and air 114 and lead to better overall froth transport system 100 and deaeration device 200 efficiency.

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It is further anticipated that longer cyclones 204 (e.g., by having additional lengthening cylindrical sections provided to each cyclone 204) may help increase residence time and improve de-aeration. Accordingly, as shown, cyclones 204 used in a froth transport system 100 and/or deaeration device 200 therein may be chosen to have a larger aspect ratio of total axial length to maximum diameter, respectively (e.g., approximately 13:1 as shown in the figures). Of course, it is envisaged that the lengthening cylindrical sections may be combined to reduce the total number of sections required – or, the number of sections may be increased for the one or more cyclones 204, and may differ from what is shown. Preferably, a plurality of cyclones 204 are employed to the device 200, the cyclones 204 having a total length to maximum diameter aspect ratio of greater than 5:1, and more preferably greater than 7:1, and even more preferably greater than 10:1, without limitation.

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In this specification, adjectives such as first and second, and the like may be used solely to distinguish one element or action from another element or action without necessarily requiring or implying any actual such relationship or order. Where the

context permits, reference to an integer or a component or step (or the like) is not to be interpreted as being limited to only one of that integer, component, or step, but rather could be one or more of that integer, component, or step etc.

5 The above description of the present invention is provided for purposes of description to one of ordinary skill in the related art. It is not intended to be exhaustive or to limit the invention to a single disclosed embodiment. As mentioned above, numerous alternatives and variations to the present invention will be apparent to those skilled in the art of the above teaching. Accordingly, while some
10 alternative embodiments have been discussed specifically, other embodiments will be apparent or relatively easily developed by those of ordinary skill in the art. The invention is intended to embrace all alternatives, modifications, and variations of the present invention that have been discussed herein, and other embodiments that fall within the spirit and scope of the above-described invention.

15 In this specification, the terms 'comprises', 'comprising', 'includes', 'including', or similar terms are intended to mean a non-exclusive inclusion, such that a method, system or apparatus that comprises a list of elements does not include those elements solely, but may well include other elements not listed.

20 Where used herein, the terms "gas," "air," and "entrained air" may be used interchangeably. These terms, where mentioned herein and in the claims, may include entrained ambient air, one or more gasses other than oxygen, nitrogen, and carbon dioxide. They may be used to generally describe a gaseous
25 component of aerated feed, froth, or slurry 104 or pumped aerated feed, froth, or slurry 105. The same may refer to a gaseous fraction of aerated feed, froth, or slurry 104 or pumped aerated feed, froth, or slurry 105 being processed within the one or more cyclones 204. It should be understood that "air" should not be construed to be limited to only ambient air, but could include other process gasses
30 (e.g., used in dissolved gas flotation, induced gas flotation, gaseous reagents, or the like), without limitation. Where used herein (in reference to cyclones 204), the term "length" may also be broadly interpreted to mean "height".

LIST OF REFERENCE IDENTIFIERS

	1	conventional froth transport system
	2	flotation machine
5	3	launder
	4	aerated feed, froth, or slurry (e.g., froth overflow)
	5	holding tank
	6	stabilized aerated feed, froth, or slurry
	7	slurry pump
10	8	downstream process step
	9	air
	10	slurry
	100	froth transport system
	101	valve(s)
15	102	flotation machine
	103	launder
	104	aerated feed, froth, or slurry (e.g., frothy flotation overflow)
	105	pumped aerated feed, froth, or slurry
	106	de-aerated slurry
20	107	slurry pump (e.g., centrifugal pump)
	108	downstream process step
	109	recirculation stream
	110	gauge
	111	feed sample, sample collection, or sampling
25	112	overflow sample, sample collection, or sampling
	113	underflow sample, sample collection, or sampling
	114	finer and air (and/or other gas)
	115	air (and/or other gas)
	116	slurry
30	200	de-aeration device
	201	first holding tank/sump
	202	second holding tank/sump
	203	froth pump (e.g., vertical pump, tank sump pump, FLSmidth® hMAX™ pump)
	204	one or more cyclone(s) (e.g., cyclone bank, hydrocyclones)
35	205	outlet manifold
	206	inlet manifold
	207	cyclone upper outlet
	208	discharge outlet (e.g., @ lower portion of second holding tank)
	209	supporting frame (e.g., having structural members or support beams)
40	210	froth pump drive (e.g., speed reducer, gearbox, pulley system, transmission)
	211	froth pump drive motor
	212	inlet screen/cage
	213	central column

	214	breather opening/venting orifice
	215	elbow
	216	pump outlet pipe (e.g., substantially vertically-extending)
	217	cyclone lower outlet
5	218	one or more flanged inlets
	219	lower manifold
	220	manifold outlet
	221	endcap (optional)
	222	manifold branch pipe
10	223	volute inlet (cyclone(s))
	224	drive shaft
	Δh_1	first height or head achieved per pump (using embodiments of the invention)
15	Δh_{max_1}	first max achievable height or head required to reach downstream process step (using embodiments of the invention)
	Δh_2	second height or head achieved per pump (using conventional methods)
	Δh_{max_2}	second max achievable height or head required to reach downstream process step (using conventional methods)
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25		
30		
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CLAIMS

What is claimed is:

- 5 1. A froth transport system (100) comprising:
a first holding tank or sump (201) provided with means for receiving aerated
feed, froth, or slurry (104);
one or more cyclones (204), each of the one or more cyclones (204) being
provided with means (101, 206, 216, 222, 223) for receiving aerated feed, froth, or
10 slurry (104) from the first holding tank or sump (201), means (217, 218, 219, 220)
for discharging de-aerated slurry (106) as underflow therefrom, and means (101,
205, 207, 222) for discharging gas and fines (114) as overflow therefrom; and
a froth pump (203) configured for conveying aerated feed, froth, or slurry
(104) from the first holding tank or sump (201) to the one or more cyclones (204)
15 as pumped aerated feed, froth, or slurry (105).
2. The froth transport system (100) according to claim 1, further comprising
means (107, 208) for transporting at least some de-aerated slurry (106) from the
one or more cyclones (204) to a downstream process step (108).
- 20 3. The froth transport system (100) according to any one of the preceding
claims, further comprising means (109) for recycling or recirculating at least some
gas and fines (114) from the one or more cyclones (204) back to the one or more
cyclones (204).
- 25 4. The froth transport system (100) according to claim 4, wherein said means
(109) for recycling or recirculating is configured to combine at least some gas and
fines (114) from the one or more cyclones (204) with the pumped aerated feed,
froth, or slurry (105).
- 30 5. The froth transport system (100) according to claim 4 or 5, wherein said at
least some gas and fines (114) and pumped aerated feed, froth, or slurry (105) are
combined upstream of an inlet manifold (206) fluidly communicating and feeding
the one or more cyclones (204).

6. The froth transport system (100) according to any one of the preceding claims, further comprising a second holding tank or sump (202) for holding de-aerated slurry (106) from the one or more cyclones (204).

7. The froth transport system (100) according to any one of the preceding claims, further comprising a valve (101) located in one or more of the following locations within the froth transport system (100): between the froth pump (203) and the one or more cyclones (204), upstream of said one or more cyclones (204), upstream of said means (223) for receiving the aerated feed, froth, or slurry (104); downstream of said means (101, 205, 207, 222) for discharging gas and fines; downstream of said means (217, 218, 219, 220) for discharging de-aerated slurry (106).

8. The froth transport system (100) according to any one of the preceding claims, wherein the froth pump (203) is situated within the first holding tank or sump (201) and/or provided upstream of the one or more cyclones (204).

9. The froth transport system (100) according to any one of the preceding claims, wherein the froth pump (203) is configured to be submerged in aerated feed, froth, or slurry (104) within the first holding tank or sump (201).

10. A de-aeration device (200) configured for use within a froth transport system (100) and configured for de-aerating an aerated feed, froth, or slurry (104) comprising:

a first holding tank or sump (201) comprising means for receiving aerated feed, froth, or slurry (104);

one or more cyclones (204), each of the one or more cyclones (204) comprising means (101, 206, 216, 222, 223) for receiving aerated feed, froth, or slurry (104) from the first holding tank or sump (201), means (217, 218, 219, 220) for discharging de-aerated slurry (106) as underflow therefrom, and means (101, 205, 207, 222) for discharging gas and fines (114) as overflow therefrom; and

a froth pump (203) configured for conveying aerated feed, froth, or slurry (104) from the first holding tank or sump (201) to the one or more cyclones (204) as pumped aerated feed, froth, or slurry (105).

- 5 11. The de-aeration device (200) according to claim 10, further comprising a second holding tank or sump (202) having a discharge outlet (208); the second holding tank or sump (202) being configured to receive de-aerated slurry (106) from the one or more cyclones (204).
- 10 12. The de-aeration device (200) according to claim 10 or 11, further comprising a froth pump drive motor (111) operatively connected to the froth pump (203) via a drive shaft (224);
13. The de-aeration device (200) according to any one of claims 10-12, further
15 comprising a froth pump drive (210) operatively coupling the froth pump drive motor (111) to the drive shaft (224) and configured to serve as a speed reducer or torque increaser.
14. The de-aeration device (200) according to any one of claims 10-13, wherein
20 the means (101, 206, 216, 222, 223) for receiving the aerated feed, froth, or slurry (104) from the first holding tank or sump (201) comprises one or more of the following: a pump outlet pipe (216), an inlet manifold (206), a volute inlet (223), a valve (101), an inlet flange (222), an end cap (221).
- 25 15. The de-aeration device (200) according to any one of claims 10-14, further comprising a pump outlet pipe (216) configured for allowing fluid communication and/or transport of aerated feed, froth, or slurry (104) between an outlet of the froth pump (203) and an inlet manifold (206); the inlet manifold (206) being configured for distributing pumped aerated feed, froth, or slurry (105) to the one or more
30 cyclones (204).
16. The de-aeration device (200) according to claim 15, further comprising an endcap (221) at one end of the inlet manifold (206).

17. The de-aeration device (200) according to any one of claims 10-16, further comprising an outlet manifold (205) for collecting gas and fines (114) from the one or more cyclones (204).
- 5 18. The de-aeration device (200) according to claim 17, further comprising an endcap (221) at one end of the outlet manifold (205).
- 10 19. The de-aeration device (200) according to any one of claims 10-18, further comprising means (109) for recycling or recirculating at least some gas and fines (114) from the one or more cyclones (204).
- 15 20. The de-aeration device (200) according to claim 20, wherein said means (109) for recycling or recirculating is configured to combine at least some gas and fines (114) from the one or more cyclones (204) with the pumped aerated feed, froth, or slurry (105).
- 20 21. The de-aeration device (200) according to claim 19 or 20, wherein said means (109) for recycling or recirculating is configured to combine at least some gas and fines (114) and pumped aerated feed, froth, or slurry (105) upstream of or at an inlet manifold (206) fluidly communicating with and feeding the one or more cyclones (204).
- 25 22. The de-aeration device (200) according to any one of claims 10-21, further comprising a supporting frame (209) for directly or indirectly supporting one or more of the following: the one or more cyclones (204), an inlet manifold (206), and/or an outlet manifold (205).
- 30 23. A method of transporting or conveying an aerated or frothy slurry comprising the steps of:
providing the froth transport system (100) according to any one of claims 1-10 or the de-aeration device (200) according any one of claims 11-22;
providing aerated feed, froth, or slurry (104) to the first holding tank or sump (201);

using the froth pump (203), pumping and delivering pumped aerated feed, froth, or slurry (105) to the one or more cyclones (204) from the first holding tank or sump (201);

5 using the one or more cyclones (204), discharging the de-aerated slurry (106) from the one or more cyclones (204); and

using the one or more cyclones (204), discharging the gas and fines (114) from the one or more cyclones (204).

24. The method according to claim 23, further comprising the steps of:
10 recycling or recirculating the gas and fines (114) by combining the gas and fines (114) with the pumped aerated feed, froth, or slurry (105); and
delivering recycled or recirculated gas and fines (114) and the pumped aerated feed, froth, or slurry (105) to the one or more cyclones (204).

15 25. The method according to claim 23 or 24, further comprising the step of:
using at least one centrifugal slurry pump (107), pumping the de-aerated slurry (106) discharged from the one or more cyclones (204) to a downstream process step (108) located at a first height (Δh_{max1}) above a component of the froth transport system (100) or the de-aeration device (200), the first height (Δh_{max1})
20 being substantially greater than a second height (Δh_{max2}) above said component of the froth transport system (100) or the de-aeration device (200) which is possible to achieve using *only* the froth pump (203), *or* the at least one centrifugal slurry pump (107) to move the aerated feed, froth, or slurry (104).

25 26. The method according to claim 25, wherein the second height (Δh_{max2}) is associated with a maximum height or head achievable using the same number of slurry pumps (7) as the number of said at least one centrifugal slurry pump (107) used to transport stabilized aerated feed, froth, or slurry (6) from a holding tank (5).

30 27. The method according to any one of claims 23-26, further comprising the step of:

operating each of the at least one centrifugal slurry pump (107) to overcome a first head (Δh_1), the first head (Δh_1) being substantially greater than a second

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head (Δh_2) per slurry pump (7) moving stabilized aerated feed, froth, or slurry (6) from a holding tank (5).

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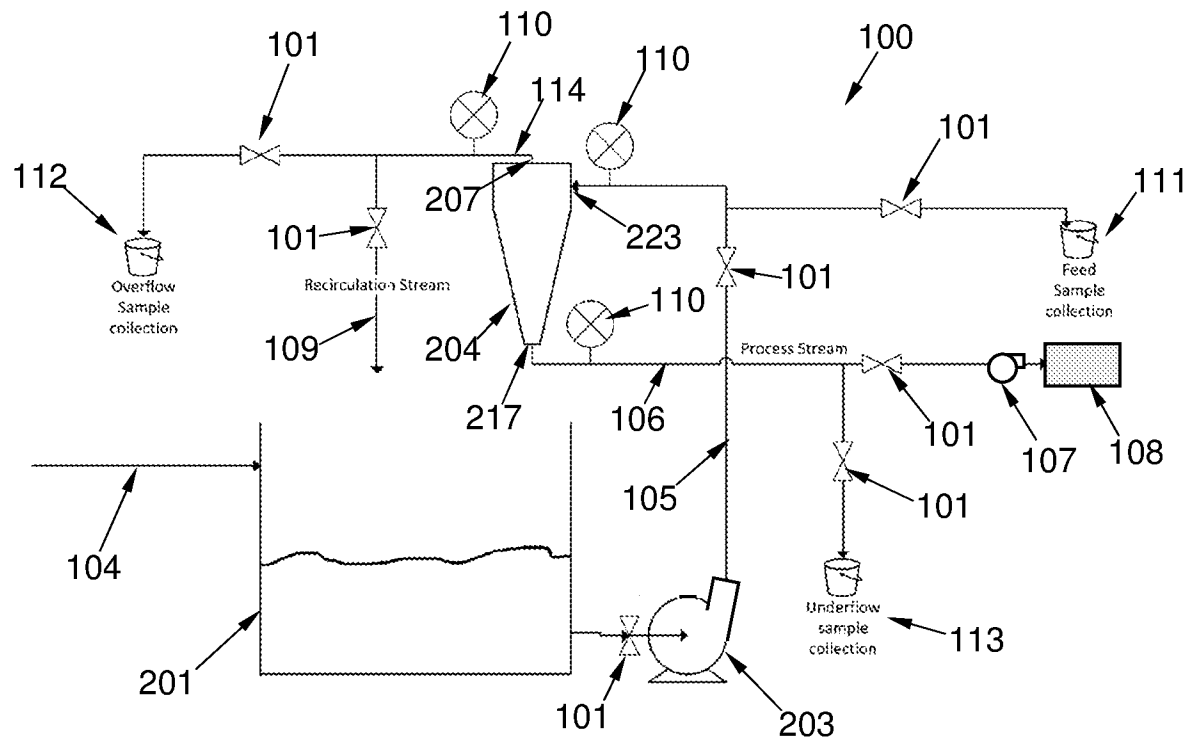


FIG. 1

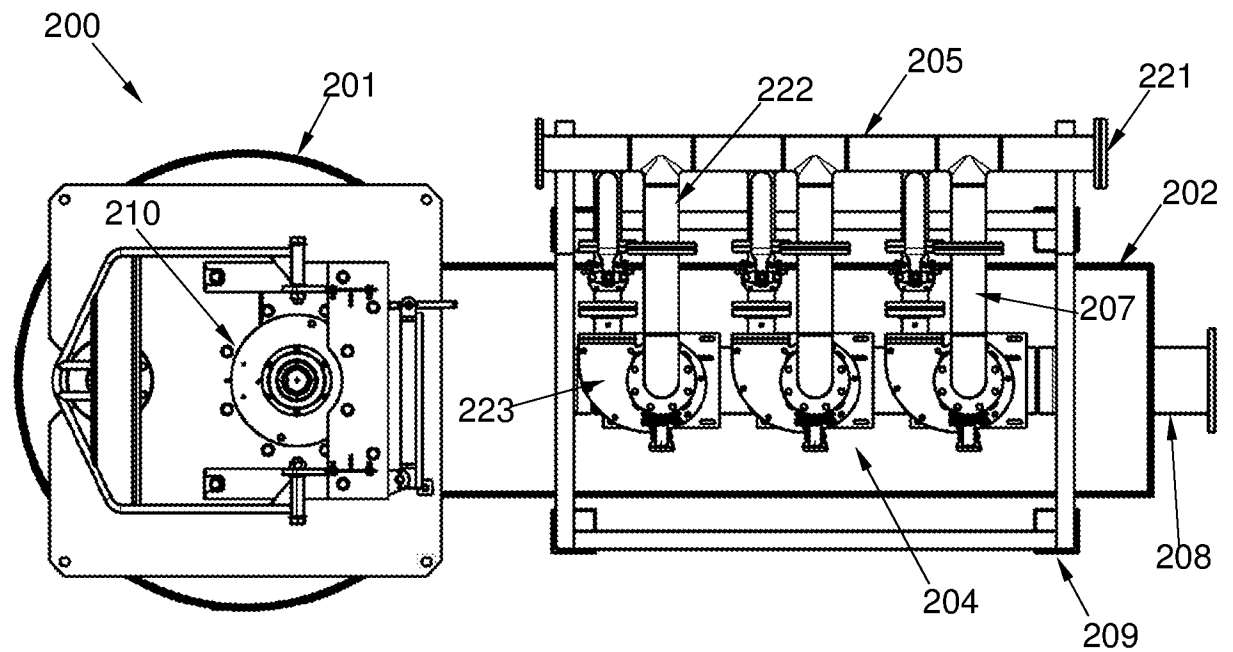


FIG. 2

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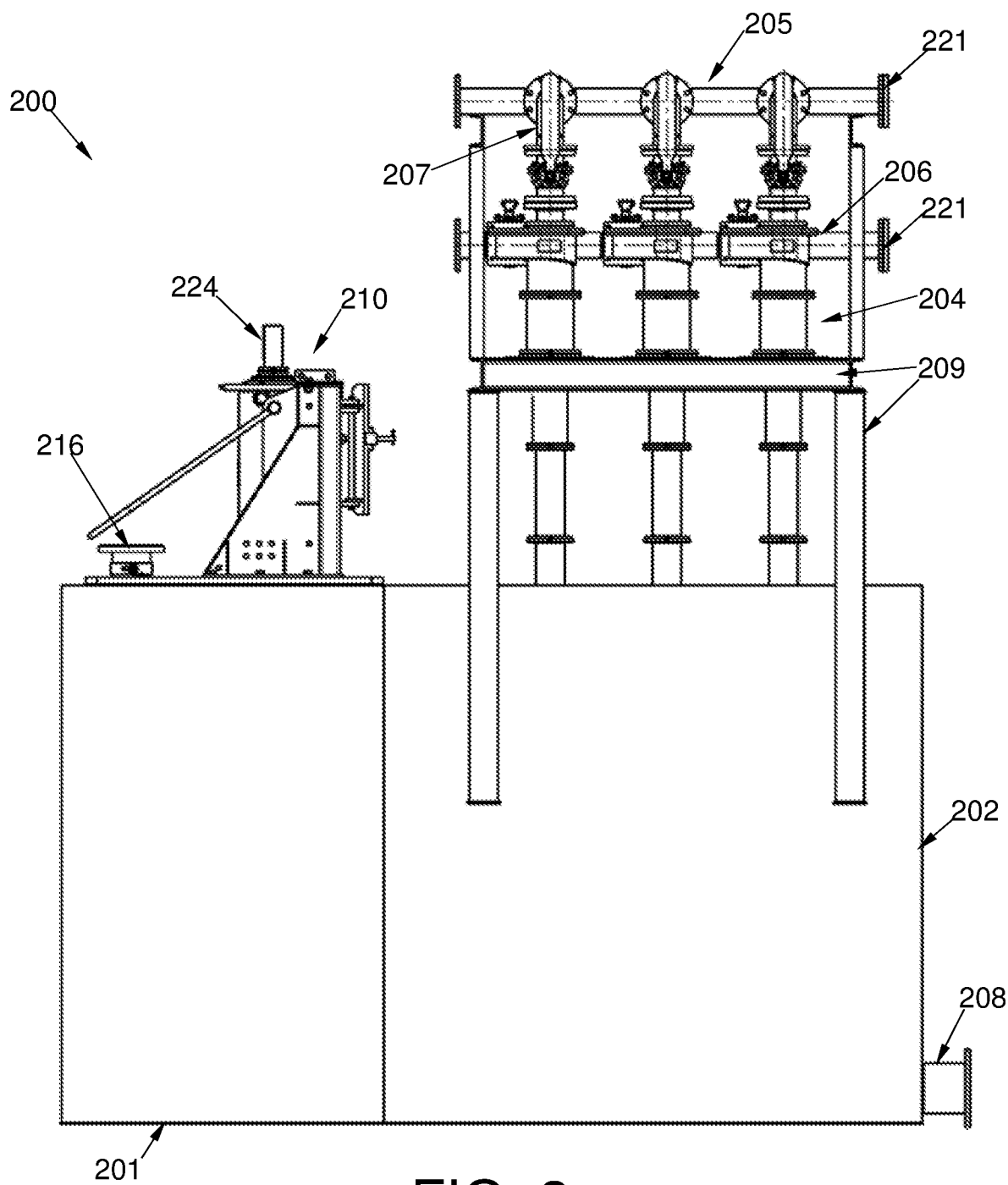


FIG. 3

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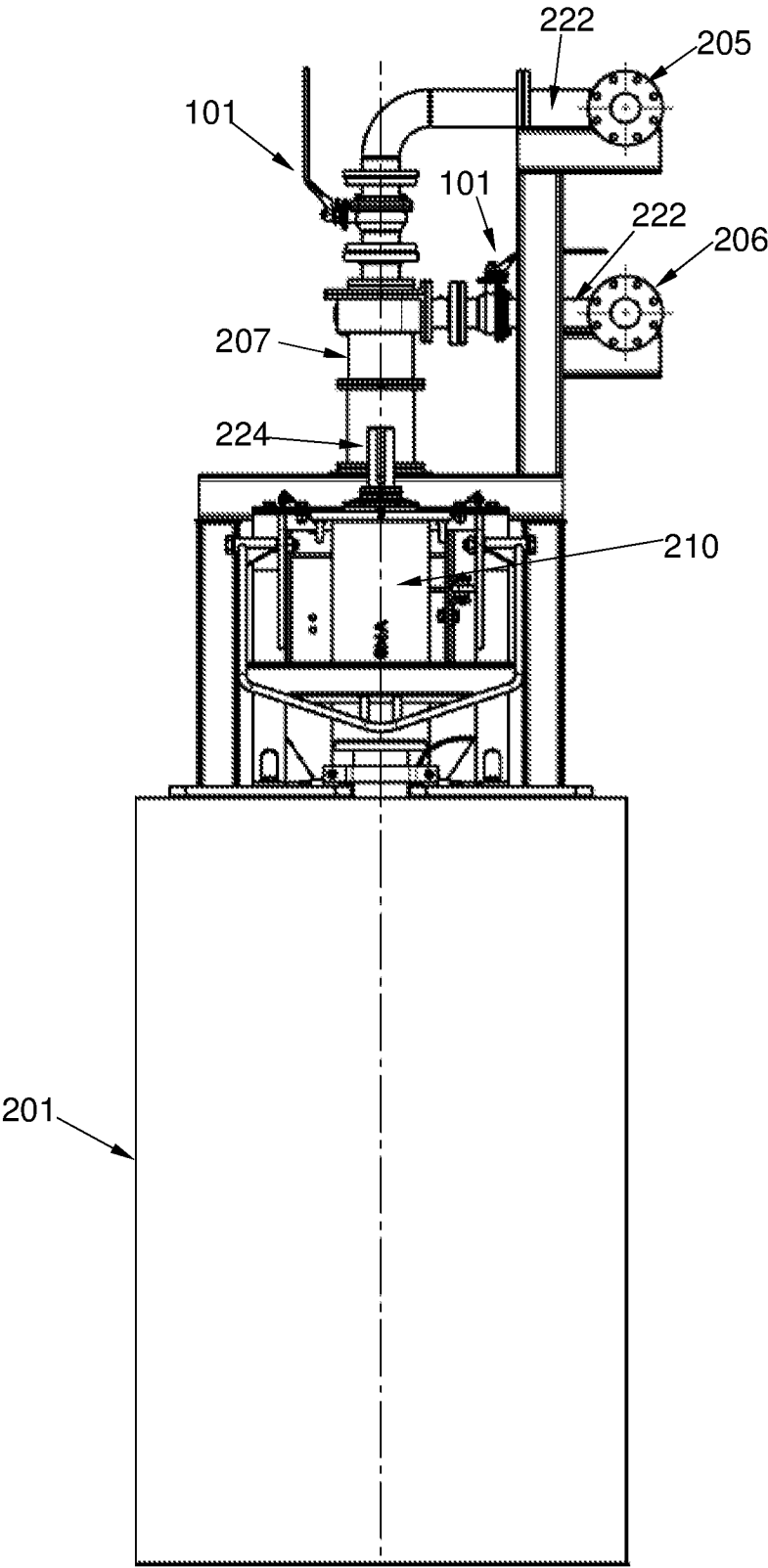


FIG. 4

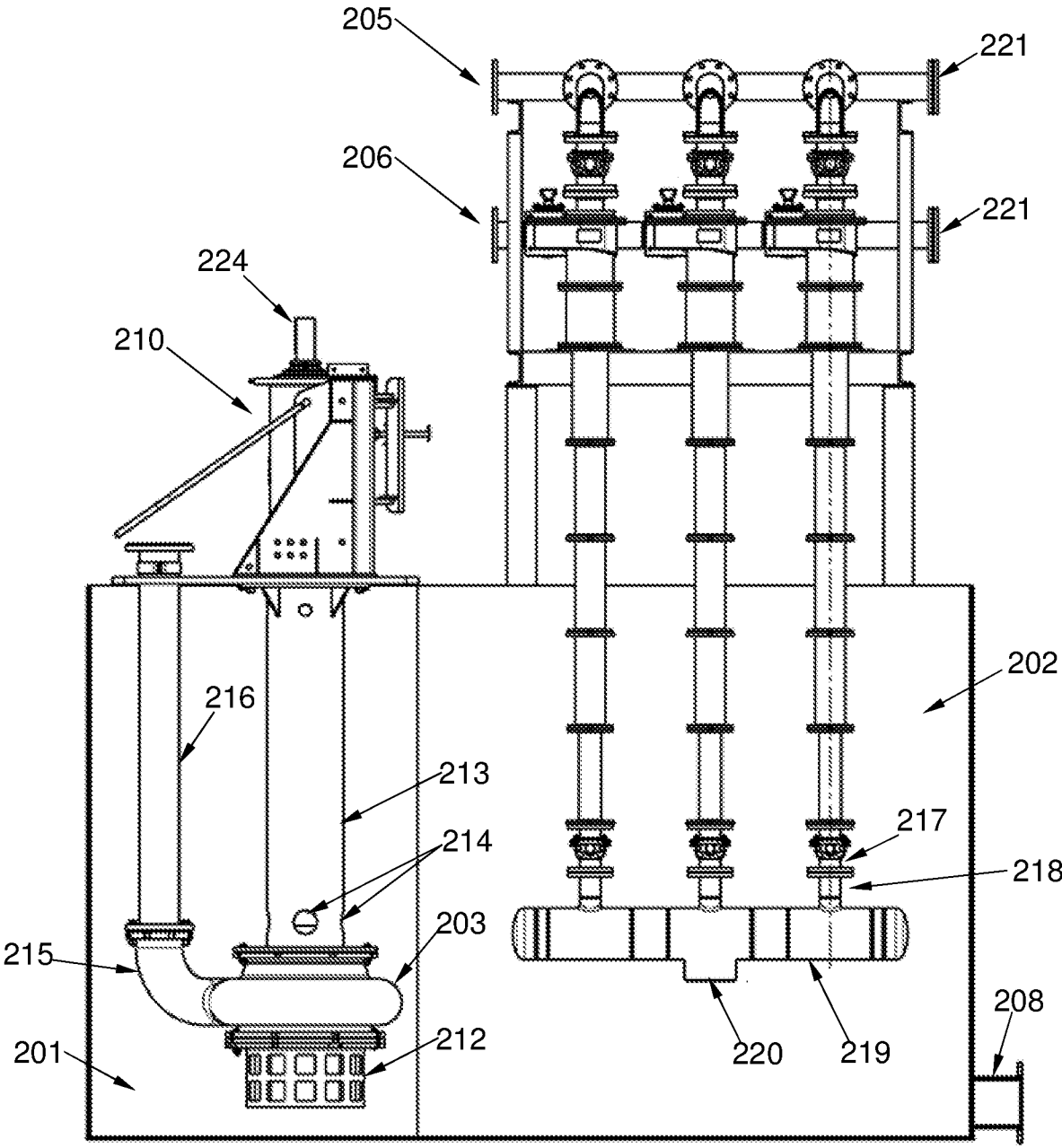


FIG. 5

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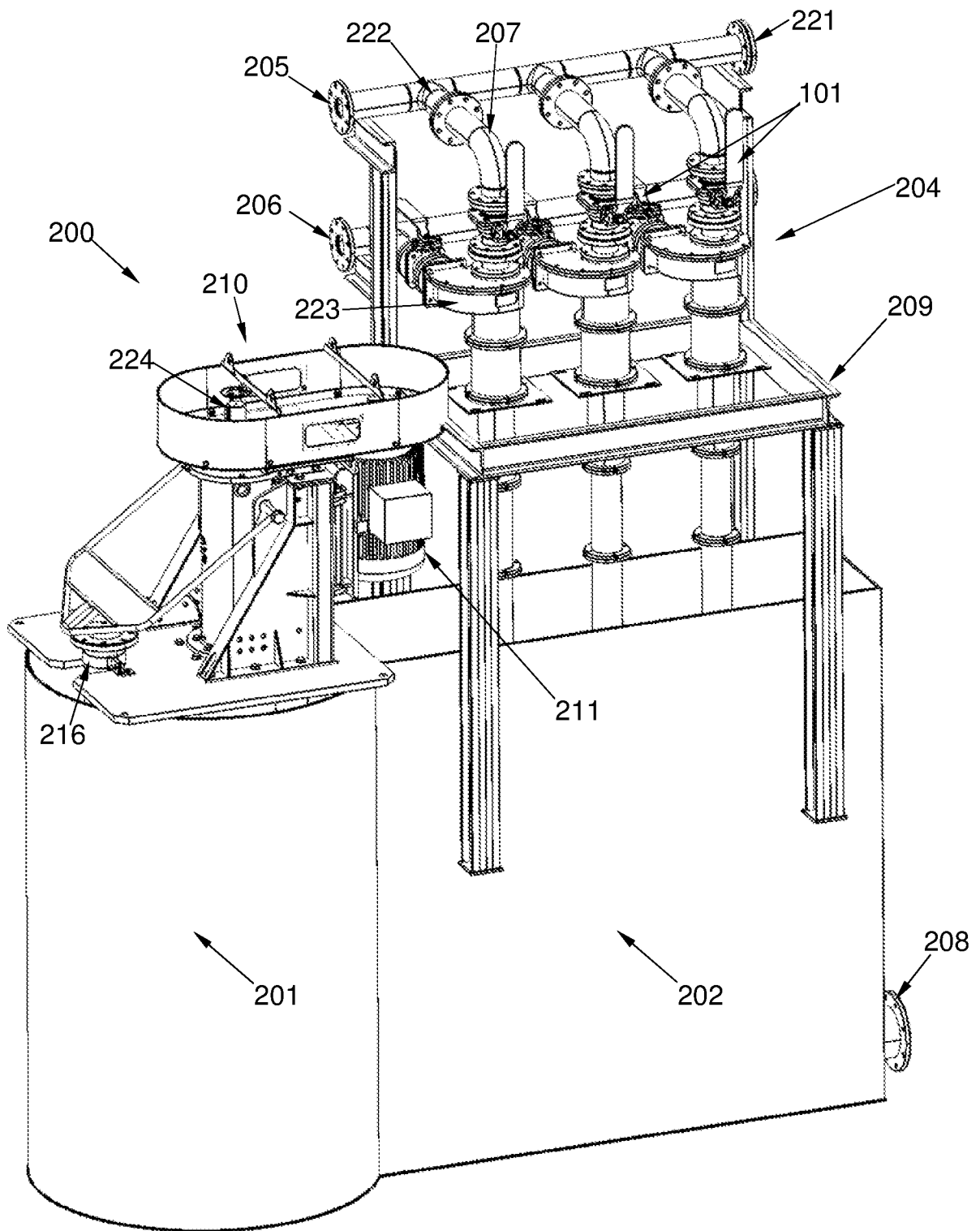


FIG. 6

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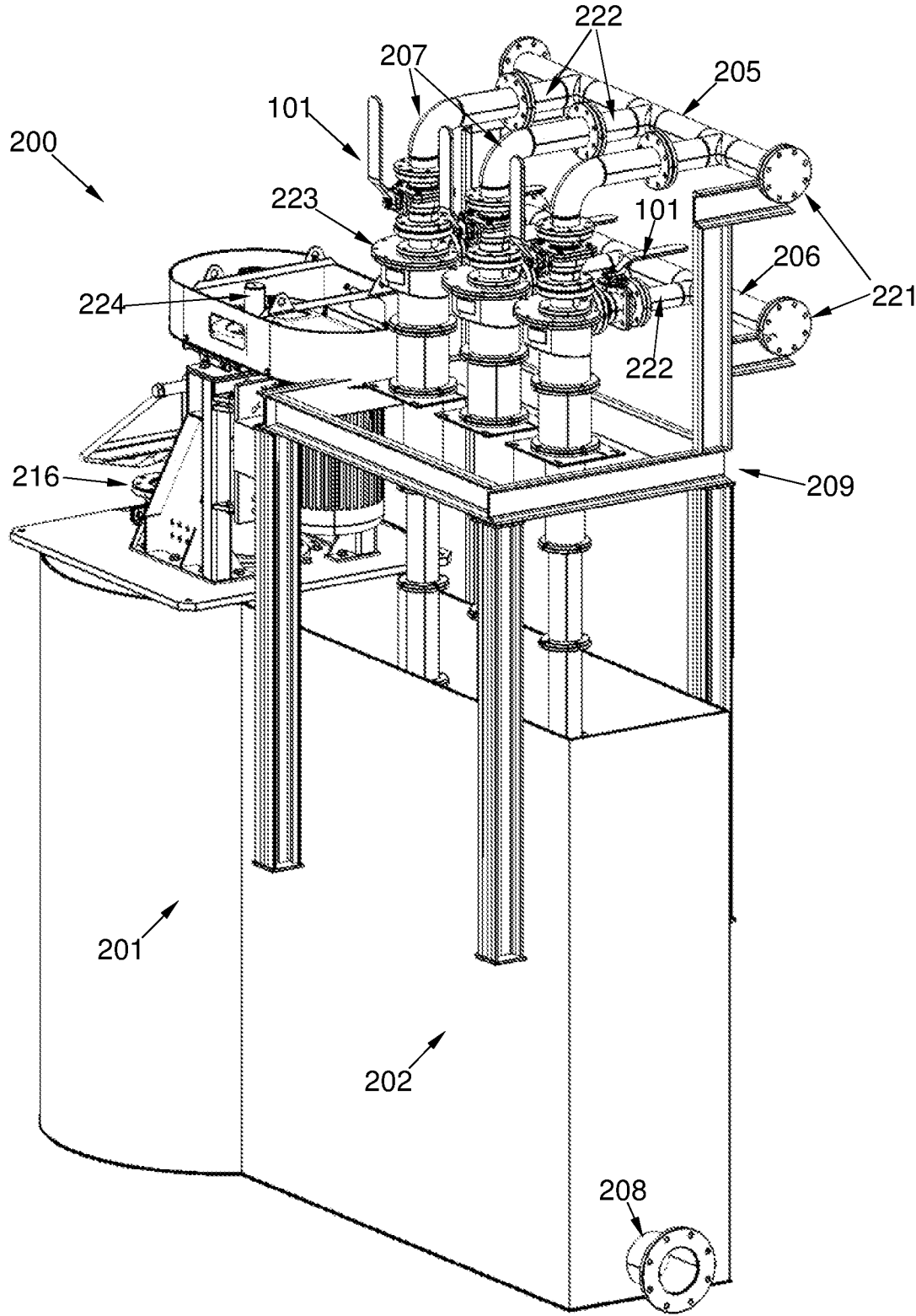


FIG. 7

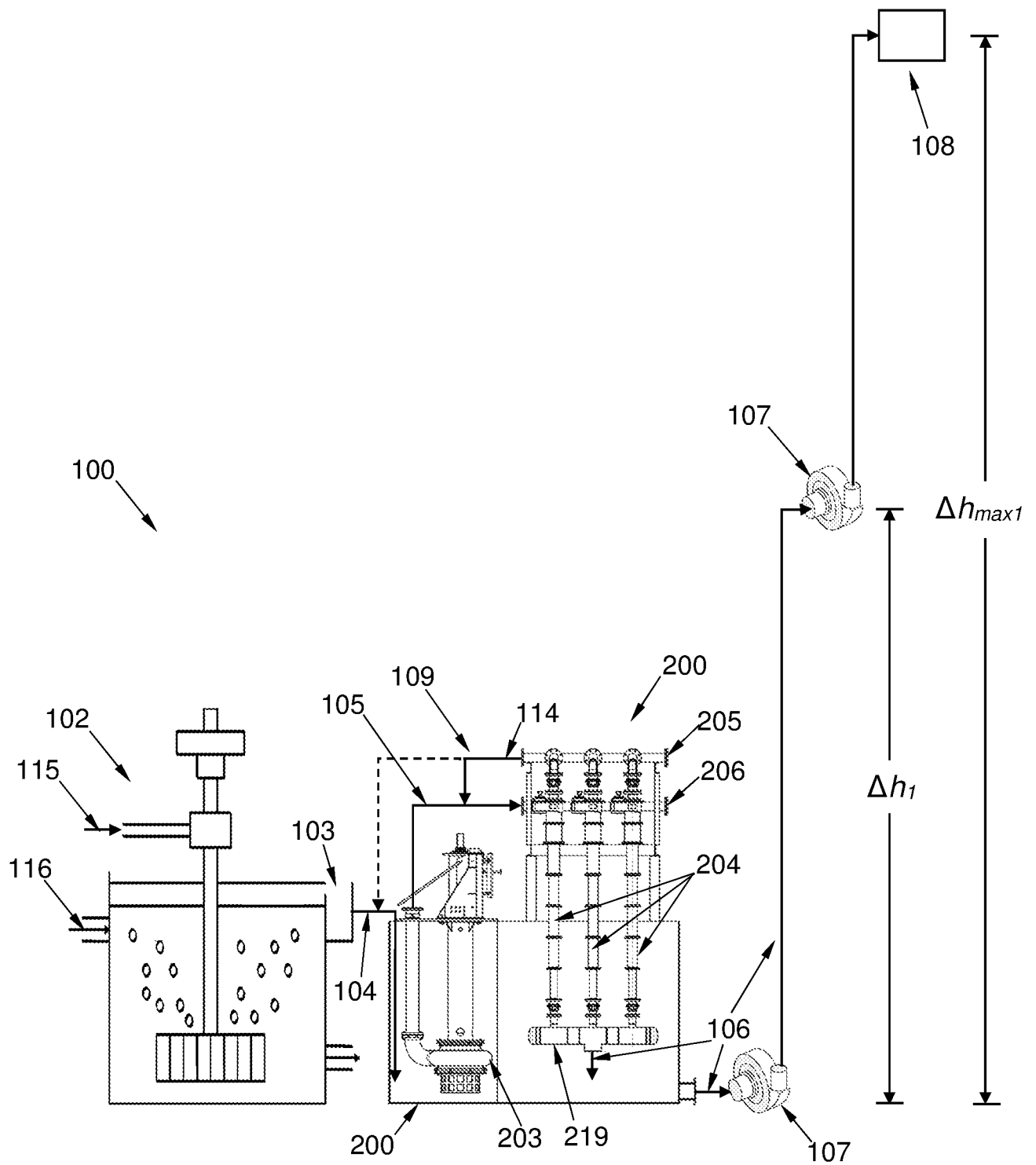


FIG. 8

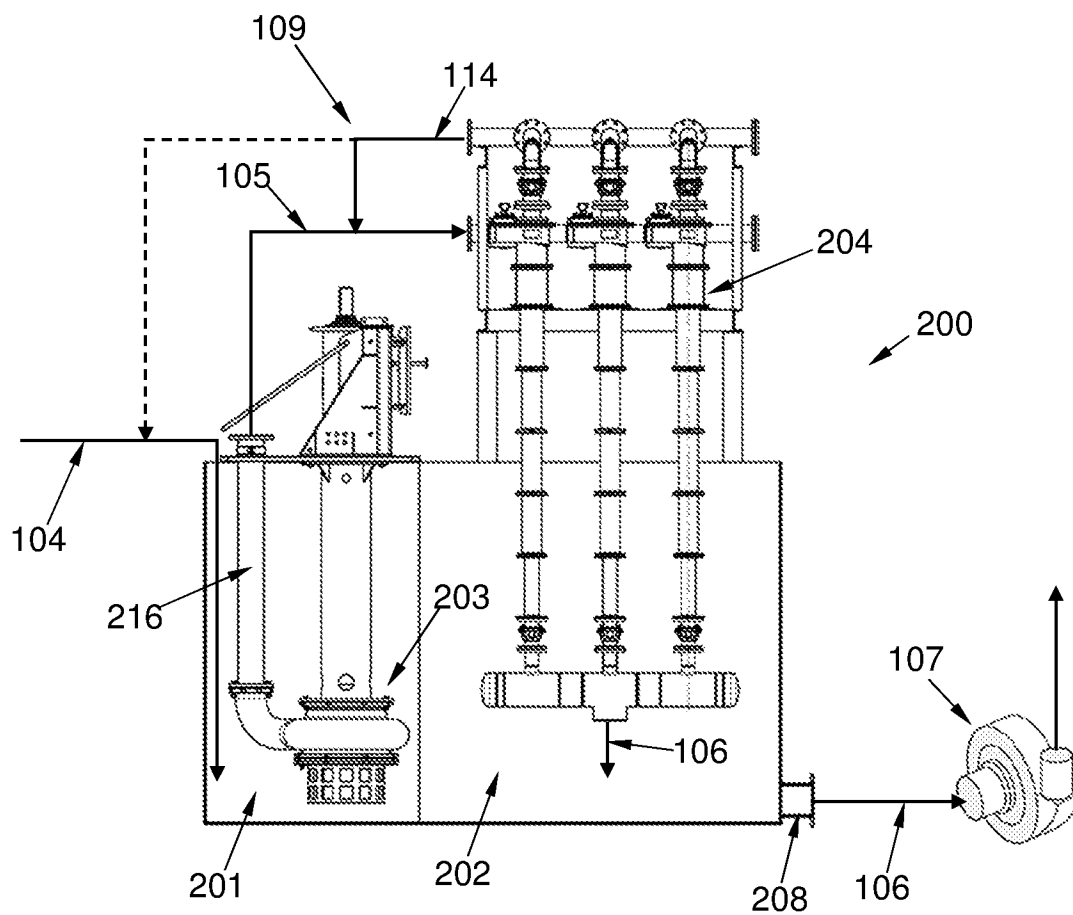


FIG. 9

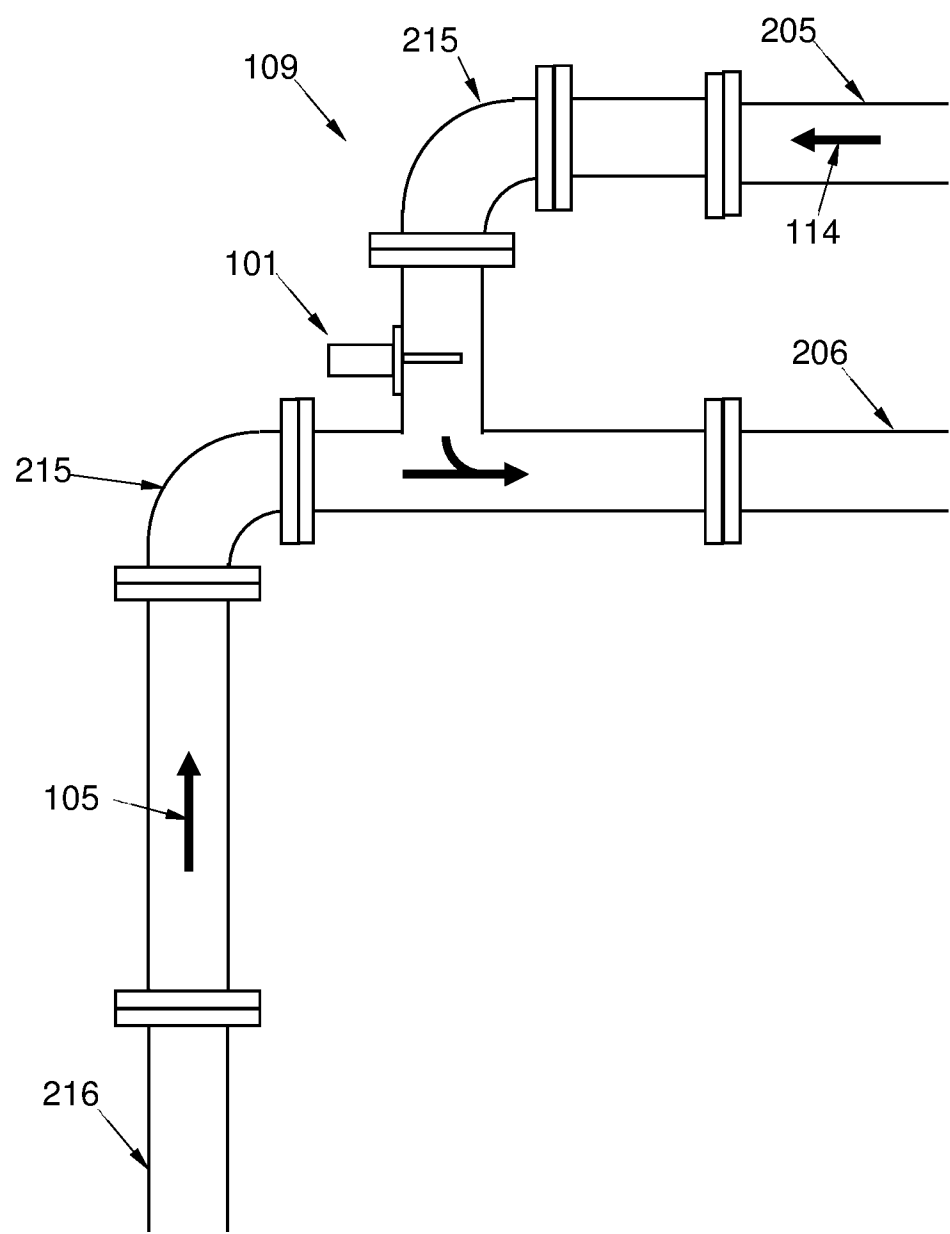
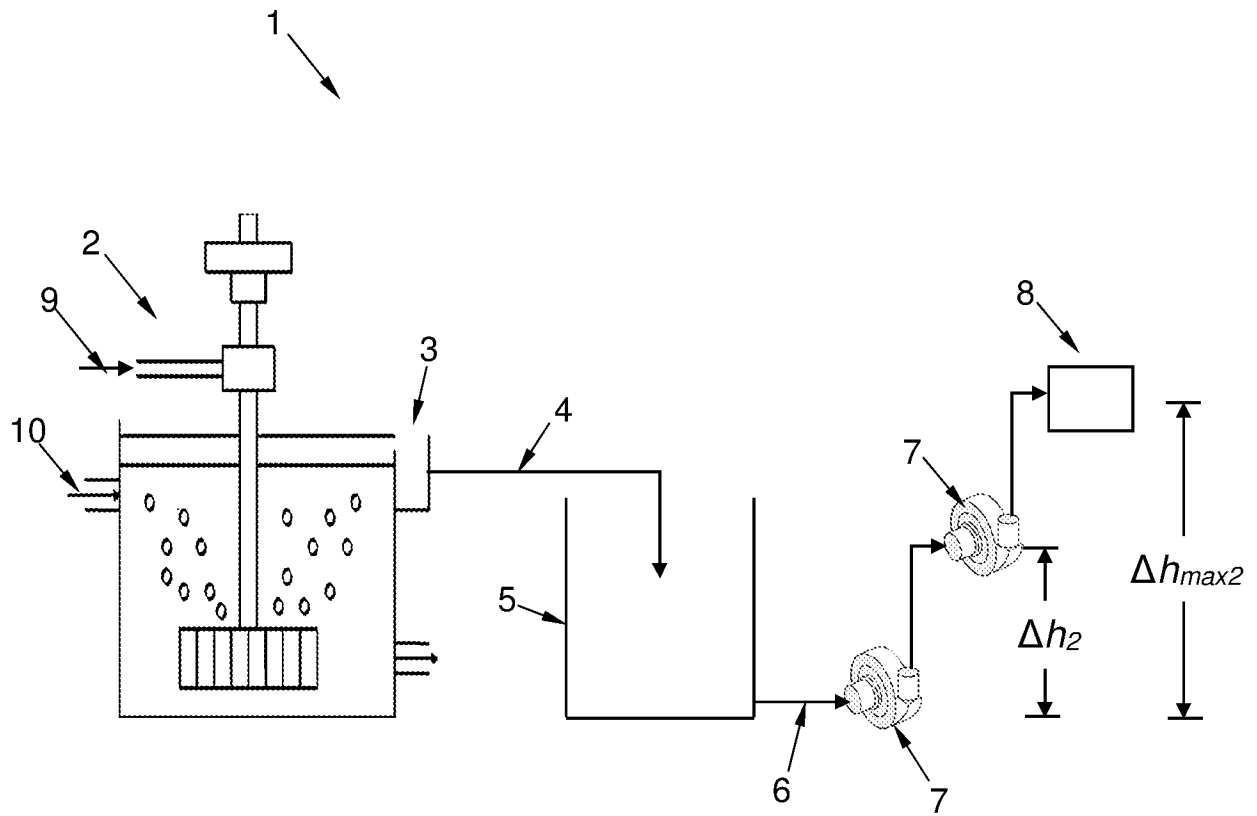


FIG. 10

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$$\Delta h_{max2} < \Delta h_{max1} \text{ (FIG. 8)}$$

$$\Delta h_2 < \Delta h_1 \text{ (FIG. 8)}$$

FIG. 11
(prior art)

INTERNATIONAL SEARCH REPORT

International application No

PCT/IB2023/054945

A. CLASSIFICATION OF SUBJECT MATTER

INV. B01D19/00 B03D1/08 C02F1/20
ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

B01D F17C B03D C02F

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 5 900 046 A (TAYLOR DAVID [AU]) 4 May 1999 (1999-05-04) Claims: 1 Figures: 1 column 3, lines 18-29 column 3, lines 9-17 column 1, lines 43-50 column 2, lines 41-43 -----	1-27



Further documents are listed in the continuation of Box C.



See patent family annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

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Date of the actual completion of the international search

14 August 2023

Date of mailing of the international search report

23/08/2023

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/IB2023/054945

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