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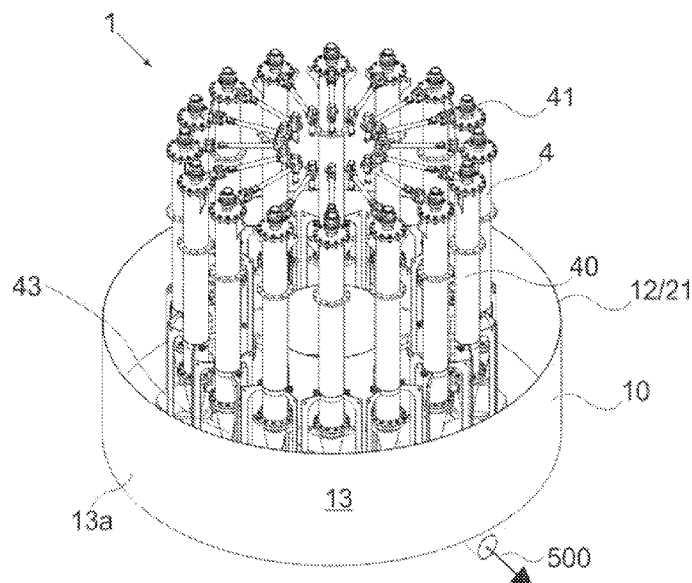


Fig. 1

(57) Abstract: A flotation cell for treating particles suspended in slurry is disclosed. The flotation cell comprises a flotation tank (10) comprising a centre (11), a perimeter (12), and a sidewall (13); a launder (2) and a launder lip (21) surrounding the perimeter (12) of the tank (11); and a downcomer (4). A height-to-diameter ratio of the flotation cell is 0.9 or lower. The downcomer (4) comprises an inlet nozzle (41) for feeding slurry infeed into the downcomer; an inlet (42) for pressurized air; an elongated chamber (40) arranged to receive under pressure the slurry infeed; and an outlet nozzle (43) configured to restrict the flow of slurry infeed from the outlet nozzle, and to maintain slurry infeed in the elongated chamber under pressure. In addition, a flotation line and use of the flotation line is disclosed.

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FLOTATION CELL**TECHNICAL FIELD**

The current disclosure relates to a flotation
5 cell for separating valuable material containing
particles from particles suspended in slurry and to a
flotation line and its use.

SUMMARY OF THE INVENTION

10 The flotation cell according to the current
disclosure is characterized by what is presented in
claim 1.

The flotation line according to the current
disclosure is characterized by what is presented in
15 claim 19.

Use of the flotation line according to the
current disclosure is characterized by what is
presented in claim 23.

A flotation cell is provided for treating
20 particles suspended in slurry and for separating the
slurry into an underflow and an overflow. The flotation
cell comprises a flotation tank comprising a centre, a
perimeter, and a sidewall with a vertical wall part and
a conical bottom part comprising a vertex; a launder
25 and a launder lip surrounding the perimeter of the tank;
and a downcomer through which slurry infeed is arranged
to be introduced into the flotation tank; wherein the
height, measured as the distance between the vertex and
the launder lip, to diameter, measured as the diameter
30 of the flotation tank at the perimeter of the straight
wall segment, ratio is 0,9 or lower. The flotation cell
is characterized in that the downcomer comprises an
inlet nozzle for feeding slurry infeed into the
downcomer; an inlet for pressurized air, the slurry
35 infeed subjected to the pressurized air as it is
discharged from the inlet nozzle; an elongated chamber
arranged to receive under pressure the slurry infeed;

and an outlet nozzle configured to restrict the flow of slurry infeed from the outlet nozzle, and to maintain slurry infeed in the elongated chamber under pressure.

According to an aspect of the invention, a flotation line is provided. The flotation line comprises a flotation stage, and it is characterized in that a first flotation stage comprises a flotation cell according to the invention.

According to a further aspect of the invention, use of the flotation line according to the invention is intended for treating coal particles suspended in slurry.

With the invention described herein, the recovery of fine particles in a flotation process may be improved. The particles may, for example, comprise mineral ore particles such as particles comprising a metal, or coal particles.

In froth flotation for mineral ore, upgrading the concentrate is directed to an intermediate particle size range between 40 μm to 150 μm . Fine particles are thus particles with a diameter of 0 to 40 μm , and ultrafine particles can be identified as falling in the lower end of the fine particle size range. Coarse particles have a diameter greater than 150 μm . In froth flotation of coal, upgrading the concentrate is directed to an intermediate particle size range between 40 μm to 300 μm . Fine particles in coal treatment are particles with a diameter of 0 to 40 μm , and ultrafine particles those that fall into the lower end of the fine particle size range. Coarse coal particles have a diameter greater than 300 μm .

Recovering very coarse or very fine particles is challenging, as in a traditional mechanical flotation cell, fine particles are not easily entrapped by flotation gas bubbles and may therefore become lost in the tailings. Typically in froth flotation, flotation gas is introduced into a flotation cell or

tank via a mechanical agitator. The thus generated flotation gas bubbles have a relatively large size range, typically from 0,8 to 2,0 mm, or even larger, and are not particularly suitable for collecting
5 particles having a finer particle size.

Traditionally, fine particle recovery has been improved by using column flotation cells, in which the lack of mechanical agitation and introduction of wash water from the top of the cell minimize ore particle
10 entrapment in the froth. In column cells, slurry comprises recirculate from the bottom of the cell, pumped into a sparger where bubbles become attached to the particles. The thus formed flotation gas bubble-ore particle agglomerates are the injected back to the
15 flotation cell, where the bubbles rise to the froth layer.

However, column cells are typically restricted to use in cleaner flotation lines or circuits, where the amount of solid material in the slurry is
20 considerably lower than in a typical rougher flotation line or circuit.

Further, feed rate of a column flotation cell, as well as the solid material amount in the slurry to be treated must be lower than in a mechanical flotation
25 cell to prevent settling of particles into the bottom of the flotation cell.

In mechanical flotation cells and in column flotation cells, the formation of flotation gas bubble-ore particle agglomerates for the most part takes place
30 in the pulp within a flotation tank or other liquid-holding vessel. Sufficient time must be provided to allow the agglomerates to rise to the froth layer and to be transported in the froth layer to the overflow launder to be collected as overflow or concentrate in
35 an overflow launder.

To overcome the above problems, so-called pneumatic flotation cells are used, where flotation gas

is introduced in a high-shear device such as a downcomer with slurry infeed, thereby creating finer flotation gas bubbles that are able to entrap also finer particles already during the bubble formation in the downcomer.

5 However, such high-throughput flotation cell requires a vacuum to be created in the downcomer to effectively achieve the required bubble formation rate to entrap the desired particles in the short time slurry infeed resides in the downcomer.

10 Once having exited the downcomer, the flotation gas bubble-particle agglomerates rise immediately towards the froth layer on the top part of the flotation cell, and no further entrapment of particles takes place in the part of the flotation cell
15 downwards from the downcomer outlet. This may lead to significant part of particles comprising a desired material (mineral or coal) to simply drop to the bottom of the flotation tank and ending up in tailings, which reduces the recovery rate of the flotation cell.

20 However, typically the so-called high-throughput flotation cells or pneumatic flotation cells of the Jameson cell type do not include any flow restriction for controlling the pressure within the downcomer after the formation of flotation air bubble-particle agglomerates has taken place. Such control of
25 pressure is advantageous also in view of the pressure at which flotation gas bubbles are formed (effect on bubble size), but also for the adjustment of relative pressure at which they are to be used in the flotation
30 tank. In that way, the coalescence of bubbles may be minimized after their formation. This is especially advantageous, as the rate of entrapment of particles by flotation gas bubbles decreases as the bubble size increases (provided that the air to liquid ratio remains
35 the same).

 In addition, the so-called high-throughput flotation cells may be used in coal liberation

operations, where there typically is a flotation line comprising one or two such flotation cells at the end of the liberation circuit for the recovery of especially fine coal particles. In the liberation circuit, a process water recirculation system circulating water from the end part of the circuit (i.e. from the flotation line and a dewatering circuit) back to the front circuit (beginning of the liberation circuit). Flotation chemicals, especially frothers, typically cause problems in the processes preceding the flotation line. The problems may be alleviated to some extent by minimizing the use of frothers in the flotation line, but if not enough frother is added into the flotation process, the froth formation in downcomers according to state of the art may suffer, which leads to unstable process conditions and especially unstable downcomer operation and froth layer in a flotation cell, which in turn affects the recovery of desired particles negatively, particularly coarse particles.

In prior art downcomers, flotation gas is introduced in a self-aspirating manner under vacuum. There is a very short residence time of flotation air to be entrained into the slurry, so the system is very sensitive to process variations. Frothers need to be constantly added to overcome the effect of restriction to air flowrate needed to maintain or even increase the vacuum inside the downcomer to keep the conditions as constant as possible for bubble-particle engagement, as frothers prevent bubbles from coalescing and rising back into the airspace not filled by slurry inside the downcomer. However, adding an amount of frothers required by the steady utilization of a prior art downcomer creates problems in other parts of the process, particularly in coal operations, as described above. Therefore the solution has been to decrease the frother dosage, which affects the downcomer vacuum, bubble formation, as well as bubble size and surface

area negatively, and decreases recovery of desired particles significantly, making the high-throughput flotation cells known in the prior art inefficient in coal operations.

5 By using a flotation cell according to the present invention, the amount of frother required to optimize the flotation process may be significantly reduced without significantly compromising bubble formation, bubble to particle engagement, stable froth
10 layer formation or the recovery of desired material. At the same time, problems associated with recirculating process water from downstream circuit to front circuit can be alleviated. A downcomer operating under pressure is completely independent of the flotation tank. A
15 better flotation gas flowrate may be reached, and finer bubbles created, and frother usage optimized, as the downcomer operation is not dependent of frother dosage.

 In the solutions known from prior art, problems relate especially to limitations to the amount of
20 flotation gas that can be supplied relative to the amount of liquid flowing through the downcomer, and to the need for relatively high concentrations of frothers or other expensive surface-active agents to produce small bubbles.

25 With the invention presented here, flotation of fine and ultrafine particles comprising for example mineral ore or coal may be improved by reducing the size of the flotation gas bubbles introduced to slurry infeed in a downcomer, by increasing the flotation gas supply
30 rate relative to the flow rate of particles suspended in the slurry, and by increasing the shear intensity or energy dissipation rate either in or adjacent to the downcomer. The probability of finer particles attaching to or being entrapped by smaller flotation gas bubbles
35 is increased, and the recovery rate of desired material such as a mineral or coal, improved. In a flotation cell according to the invention, sufficiently small

flotation gas bubbles, so-called ultra-fine bubbles, may be created to ensure efficient entrapment of fine ore particles. Typically, ultra-fine bubbles may have a bubble size distribution of 0,1 mm to 0,8 mm.

5 At the same time, recovery of coarser particles may be kept at an acceptable level by achieving a high flotation gas fraction in the slurry, by the absence of high turbulence areas in the region below the forth layer. Further, the upwards motion of slurry or pulp
10 within the flotation tank increases the probability of also coarser particles rise towards the froth layer with the flow of slurry.

 By generation of fine flotation gas bubble or ultra-fine bubbles, by bringing them into contact with
15 the particles, and by controlling the flotation gas bubble- particle agglomerates-liquid mixture of slurry, it may be possible to maximize the recovery of hydrophobic particles into the forth layer and into the flotation cell overflow or concentrate, thus increasing
20 the recovery of desired material.

 In this disclosure, the following definitions are used regarding flotation.

 Flotation involves phenomena related to the relative buoyancy of objects. Flotation is a process
25 for separating hydrophobic materials from hydrophilic materials by adding flotation gas, for example air, to the process. Flotation could be made based on natural hydrophobic/hydrophilic difference or based on hydrophobic/hydrophilic differences made by addition of
30 a surfactant or collector chemical. Gas can be added to the feedstock subject of flotation (slurry or pulp) by a number of different ways. Further, frothers or frothing chemicals are typically used to promote the formation of a froth layer from which the desired
35 material is collected.

 Basically, flotation aims at recovering a concentrate of ore particles comprising a valuable

material such as a mineral, or coal. By concentrate herein is meant the part of slurry recovered in overflow led out of a flotation cell. By valuable mineral is meant any mineral, metal or other material of commercial value.

Flotation involves phenomena related to the relative buoyancy of objects. The term flotation includes all flotation techniques. Flotation can be for example froth flotation, dissolved air flotation (DAF) or induced gas flotation. Froth flotation is a process for separating hydrophobic materials from hydrophilic materials by adding gas, for example air, to process. Froth flotation could be made based on natural hydrophilic/hydrophobic difference or based on hydrophilic/hydrophobic differences made by addition of a surfactant or collector chemical.

By a flotation line herein is meant an assembly or arrangement comprising a number of flotation units or flotation cells in which a flotation stage is performed, and which are arranged in fluid connection with each other for allowing either gravity-driven or pumped slurry flow between flotation cells, to form a flotation line. In a flotation line, a number of flotation cells are arranged in fluid connection with each other so that the underflow of each preceding flotation cell is directed to the following or subsequent flotation cell as a infeed until the last flotation cell of the flotation line, from which the underflow is directed out of the line as tailings or reject flow. It is also conceivable that a flotation line may comprise only one flotation stage performed either in one flotation cell or for example in two or more parallel flotation cells.

Slurry is fed through a feed inlet to the first flotation cell of the flotation line for initiating the flotation process. Flotation line may be a part of a larger treatment plant containing one or more flotation

lines, and a number of other process stages for the liberation, cleaning and other treatment of a desired material. Therefore, a number of different pre-treatment and post-treatment devices or arrangements
5 may be in operational connection with the components of the flotation line, as is known to the person skilled in the art.

By a flotation cell is herein meant a tank or vessel in which a step or stage of a flotation process
10 is performed. A flotation cell is typically cylindrical in shape, the shape defined by a sidewall or an outer wall/ walls. The flotation cells regularly have a circular cross-section. The flotation cells may have a polygonal, such as rectangular, square, triangular,
15 hexagonal or pentagonal, or otherwise radially symmetrical cross-section, as well.

By overflow herein is meant the part of the slurry collected into the launder of the flotation cell and thus leaving the flotation cell as concentrate.
20 Overflow may comprise froth, froth and slurry, or in certain cases, only or for the largest part slurry.

By underflow herein is meant the fraction or part of the slurry which is not floated into the surface of the slurry in the flotation process. Underflow is a
25 reject flow or tailings leaving a flotation cell via an outlet which typically is arranged in the lower part of the flotation cell.

By concentrate herein is meant the floated part or fraction of slurry of ore particles comprising a
30 valuable material such as a mineral or coal.

By ultra-fine bubbles herein is meant flotation gas bubbles falling into a size range of 0,1 mm to 0,8 mm, introduced into the slurry in a downcomer.

In contrast, "normal" flotation gas bubbles
35 utilized in froth flotation display a size range of approximately 0,8 to 2 mm. Larger flotation gas bubbles may have a tendency to coalesce into even larger bubbles

during their residence in the mixing zone where collisions between particles and flotation gas bubbles, as well as only between flotation gas bubbles take place. As ultra-fine bubbles are introduced into slurry infeed prior to its feeding into a flotation tank, such coalescence is not likely to happen with ultra-fine bubbles, and their size may remain smaller throughout their residence in the flotation cell, thereby affecting the ability of the ultra-fine bubbles to catch fine particles.

In an embodiment of the flotation cell, the height to diameter ratio is 0,3 to 0,9.

In an embodiment of the flotation cell, the outlet nozzle comprises a throttle for restricting the flow of slurry infeed.

By forcing slurry infeed through a throttle, bubbles that have been formed in the elongated chamber of the downcomer, are further reduced in size as they pass through the outlet nozzle at the throttle.

In an embodiment of the flotation cell, the outlet nozzle is configured to induce a supersonic shockwave into the slurry infeed as it exits the elongated chamber.

A supersonic shockwave is created when the velocity of slurry infeed passing through the outlet nozzle exceeds the speed of sound, i.e. the flow of slurry infeed becomes choked when the ratio of the absolute pressure upstream the outlet nozzle to the absolute pressure downstream of the throttle of the outlet nozzle exceeds a critical value). When the pressure ratio is above the critical value, flow of slurry infeed downstream of the throttle part of the outlet nozzle becomes supersonic and a shock wave is formed). Small flotation gas bubbles in slurry infeed mixture are split into even smaller by being forced through the shock wave, and forced into contact with hydrophobic ore particles in slurry infeed, thus

creating flotation gas bubble-ore particle agglomerates.

In an embodiment of the flotation cell, the downcomer further comprises an impinger configured to
5 contact a flow of slurry infeed from the outlet nozzle and to direct the flow of slurry infeed radially outwards and upwards of the impinger.

In a further embodiment of the flotation cell, the impinger comprises an impingement surface made of
10 wear-resistant material.

The impinger deflects the flow of slurry infeed radially outwards to the flotation tank sidewall and upwards towards the flotation tank upper surface (i.e. to the froth layer). Slurry is highly agitated by the
15 energy of the deflected flow, and forms vortexes in which the size of the bubbles may be further reduced by the shear forces acting upon them. The high-shear conditions favourably also induce high number of contacts between flotation gas bubbles and particles in
20 the slurry within the flotation tank. As the flow of slurry is forced upwards towards the froth layer, turbulence reduces and the flow becomes relatively uniform, which may contribute to the stability of the already formed bubbles, and flotation gas bubble-
25 particle agglomerates, especially those comprising coarser particles.

In an embodiment of the flotation cell, it further comprises a conditioning circuit.

In a further embodiment of the flotation cell, the conditioning circuit comprises a pump tank in fluid
30 communication with the flotation tank, in which pump tank infeed of fresh slurry and a slurry fraction taken from the flotation tank via an outlet are arranged to be combined into slurry infeed.

35 In a further embodiment of the flotation cell, the conditioning circuit further comprises a pump arranged to intake the slurry fraction from the

flotation tank and to forward slurry infeed from the pump tank.

By taking slurry from the bottom of a flotation cell it may be ensured that the finer particles settled to the bottom of the flotation tank may be efficiently reintroduced into the part of the flotation tank where active flotation process takes place, before the finer particles are reported to tailings. Thus the recovery rate of valuable material may be improved as the particles comprising even minimal amounts of valuable material may be collected into the concentrate.

In a further embodiment of the flotation cell, in that the conditioning circuit further comprises a distribution unit arranged to distribute infeed.

In an embodiment of the flotation cell, it comprises 2-24 downcomers, preferably 10-24 downcomers.

In a further embodiment of the flotation cell, the downcomers are arranged concentric to the perimeter of the flotation tank, at a distance from the centre of the flotation tank.

In yet another embodiment of the flotation cell, the downcomers are arranged parallel to the sidewall of the flotation tank, at a distance from the sidewall.

The exact number of downcomers within a flotation cell may depend on the flotation tank size or volume, on the type of material to be collected and other process parameters. By arranging a sufficient number of downcomers into a flotation cell, even distribution of ultra-fine bubbles may be ensured, as well as even mixing effect caused by the shear forces within tank secured.

In an embodiment of the flotation cell, the conical bottom part of the sidewall of the flotation tank has a slant angle of 10-45°, measured in relation to a horizontal of the flotation cell.

By arranging a slant angle to the conical bottom part of the sidewall of the flotation tank, the removal of tailings via the tailings outlet located at the bottom part of the flotation tank may be improved.

5 Further, sanding of the tank bottom may be reduced.

In a further embodiment of the flotation cell, the slant angle is 30-40°.

In a further embodiment of the flotation cell, the slant angle is 15-25°.

10 This kind of construction may be especially beneficial for recovering coal particles suspended in slurry.

In an embodiment of the flotation cell, the height of the vertical wall part of the flotation tank is 1,8 m or lower.

In an embodiment of the flotation cell, the volume of the flotation tank is at least 10 m³.

By arranging a flotation tank to have a sufficient volume the flotation process may be better controlled. The ascent distance to the froth layer on the top part of the flotation tank does not become too large, which may help to ensure that the flotation gas bubble-ore particle agglomerates remain together until the froth layer and particle drop-back may be reduced.

20

25 Further, a suitable bubble rise velocity may be reached to maintain a good concentrate quality.

In an embodiment of the flotation line, the flotation line comprises 1-2 flotation stages wherein the first flotation stage comprises a flotation cell according to the invention described herein.

30 In an embodiment of the flotation line according to the invention, the flotation line comprises two flotation stages, of which at least the first flotation stage comprises a flotation cell according to the invention described herein.

35 In an embodiment of the flotation line, a flotation stage comprises at least two parallel

flotation cells according to the invention described herein.

In an embodiment of the use of the flotation line, frother chemicals are added into a flotation stage
5 in an amount of 12 ppm or less.

Adding as little of a frother or frother chemical, problems associated with recirculating process water comprising frother may be alleviated or even avoided while still maintaining a good level of
10 recovery of a desired material, especially coal.

BRIEF DESCRIPTION OF THE DRAWINGS

The accompanying drawings, which are included to provide a further understanding of the current
15 disclosure and which constitute a part of this specification, illustrate embodiments of the disclosure and together with the description help to explain the principles of the current disclosure. In the drawings:

Fig. 1 is a 3D projection of a flotation cell
20 according to an embodiment of the invention,

Fig. 2 depicts a flotation cell according to an embodiment of the invention, as seen from above,

Fig. 3 is a vertical cross-section of the flotation cell of Fig. 2 along a section A-A, and

25 Fig. 4a-c are schematic drawings of flotation lines according to some embodiments of the invention.

DETAILED DESCRIPTION

Reference will now be made in detail to the
30 embodiments of the present disclosure, an example of which is illustrated in the accompanying drawing.

The description below discloses some embodiments in such a detail that a person skilled in the art is able to utilize the arrangement, plant and
35 method based on the disclosure. Not all steps of the embodiments are discussed in detail, as many of the

steps will be obvious for the person skilled in the art based on this disclosure.

For reasons of simplicity, item numbers will be maintained in the following exemplary embodiments in the case of repeating components.

The enclosed figures 1-3 illustrate a flotation cell 1 in some detail. The figures are not drawn to proportion, and many of the components of the flotation cell 1 are omitted for clarity. Figures 4a-c illustrate in a schematic manner embodiments of the flotation line. The direction of flows of slurry is shown in the figures by arrows.

The flotation cell 1 according to the invention is intended for treating mineral ore particles suspended in slurry and for separating the slurry into an underflow 400 and an overflow 500, the overflow 500 comprising a concentrate of a desired mineral.

The flotation cell 1 comprises a flotation tank 10 that has a centre 11 and a perimeter 12. A sidewall 13 of the flotation tank 10 comprises a vertical wall part 13a and a conical bottom part 13b. The conical bottom part 13b has a vertex 130 facing downwards in relation to the height of the flotation cell 1.

The flotation cell 1 further comprises a launder 2 (not shown in figures 1 and 2, and in figure 3, for the sake of simplicity, only a central launder 2 is shown. It is to be understood that a launder 2 may comprise, alternatively or additionally, a perimeter launder arranged to surround the entire perimeter 12 of the flotation tank 10, as is known in the technical field). The overflow 500 is collected into the launder 2 as it passes over a launder lip 21, from a froth layer formed in the upper part of the flotation tank 10.

The flotation cell has a height h to diameter d ratio h/d of 0,9 or lower. The height h is measured

as the distance between the vertex 130 of the conical bottom part 13b of the sidewall 13, and the launder lip 21. The diameter d is measured as the diameter of the flotation tank 10 at the perimeter 12 of the straight wall part 13a, as can be seen in figure 3, excluding any structures arranged outside the sidewall 13, i.e. collecting launders 2 arranged outside the sidewall 13, such as a perimeter launder. In an embodiment, the height h to diameter d ratio h/d of the flotation tank may be 0,3 to 0,9. The h/d ratio may be, for example 0,45; or 0,5; or 0,7.

The conical bottom part 13b of the sidewall 13 of the flotation tank 10 has a slant angle α of 10° to 45° . In an embodiment, the slant angle α may be 30 to 40° . This kind of arrangement may be especially beneficial if the flotation cell 1 is used in treating slurry comprising mineral ore particle. In an embodiment, the slant angle α may be 15 to 25° . This may be especially beneficial when the flotation cell 1 is used in the recovery of coal, i.e. in flotation of coal particles suspended in slurry.

The height of the vertical wall part 13a may have a height of 1,8 m or lower.

The flotation tank 10 may have a volume of at least 10 m^3 , or at least 20 m^3 . The flotation tank may have a volume ranging from 10 m^3 to 100 m^3 .

In addition, the flotation cell 1 comprises at least one downcomer 4, through which slurry infeed 100 is arranged to be introduced into the flotation tank 11. There may be 1-24 downcomers, or 10-24 downcomers in a flotation cell 1. In an embodiment, there are 16 downcomers 4 (see Fig. 2). In another embodiment, there are 24 downcomers 4. In yet another embodiment, there are 10 downcomers 4. The exact number of downcomers 4 may be chosen according to the specific operation, for example the type of slurry being treated within the flotation cell 1, the volumetric feed flowrate to the

flotation cell 1, the mass throughput feed to the flotation cell 1, or the volume of the flotation tank 10.

In case there are more than one downcomers in a flotation cell 1, the downcomers 4 may be arranged concentric to the perimeter 12 of the flotation tank 10. This is the case when the flotation tank 10 is circular in cross-section. The downcomers 4 may be further arranged so that each downcomer 4 is located at a distance from the centre 11 of the flotation tank 10, the distance being preferably equal for each downcomer 4.

According to an embodiment of the invention, the downcomers 4 may be arranged parallel to the sidewall 13 of the flotation tank 10. This is the case when the flotation tank 10 has a rectangular or square horizontal cross-section. In this embodiment, the downcomers 4 may be further arranged so that each downcomer 4 is located at a distance from the sidewall 13, the distance being preferably equal for each downcomer 4. In other word, the downcomers 4 may be arranged at a straight line within the flotation tank 10.

The downcomer 4 comprises an inlet nozzle 41, intended for feeding slurry infeed 100 into the downcomer 41, more specifically to an elongated chamber 40. An inlet 42 for pressurized flotation gas, such as pressurized air, is arranged in such a way that slurry infeed 100 becomes subjected to the pressurized flotation gas as it is discharged from the inlet nozzle 41. The slurry infeed 100 forms a liquid jet which, as it enters the elongated chamber 40, is mixed with pressurized flotation gas fed through the inlet 42.

Flotation gas is entrained through a turbulent mixing action brought about by the jet, and is dispersed into small bubbles in the slurry infeed 100 as it travels downwards through the elongated chamber 40 to

an outlet nozzle 43 configured to restrict the flow of slurry infeed 100 from the outlet nozzle 43, and further configured to maintain slurry infeed 100 under pressure in the elongated chamber 40.

5 For restricting the flow, the outlet nozzle 43 comprises a throttle such as a throat-like restricting structure. From the outlet nozzle 43, more specifically from the throttle, slurry infeed 100 issues under pressure into the flotation tank 10.

10 As the slurry infeed 100 passes through the outlet nozzle 43, more specifically through the throttle of the outlet nozzle 43, flotation gas bubbles are reduced in size by the pressure changes, and by the high-shear environment downstream of the outlet nozzle
15 43. The velocity of the gas-liquid mixture in the throttle of the outlet nozzle 43 may exceed the speed of sound when the flow becomes a choked flow and flow downstream of the throttle becomes supersonic, and a shockwave forms in the diverging section of the outlet
20 nozzle 43. In other words, the outlet nozzle 43 is configured to induce a supersonic shockwave into slurry infeed 100.

 The flow of slurry infeed 100 becomes choked when the ratio of the absolute pressure upstream the
25 outlet nozzle to the absolute pressure downstream of the throttle of the outlet nozzle 43 exceeds a critical value. When the pressure ratio is above the critical value, flow of slurry infeed 100 downstream of the throttle part of the outlet nozzle 43 becomes supersonic
30 and a shockwave is formed. Small flotation gas bubbles in slurry infeed 100 mixture are split into even smaller by being forced through the shockwave, and forced into contact with hydrophobic ore particles in slurry infeed
100, thus creating flotation gas bubble-ore particle
35 agglomerates.

 The downcomer 4 may further comprise an impinger 44, configured to contact a flow of slurry

infeed 100 from the outlet nozzle 43. Slurry infeed 100 exiting from the outlet nozzle 43 is therefore directed to contact the impinger 44. The impinger 44 is configured to direct the flow of slurry infeed 100 radially outwards and upwards of the impinger 44.

The impinger 44 deflects the flow of slurry infeed 100 radially outwards to the flotation tank sidewall 13 and upwards towards the upper surface (froth layer) of the flotation tank 10. Slurry is highly agitated by the energy of the deflected flow, and forms vortexes in which the size of the bubbles may be further reduced by the shear forces acting upon them. The high-shear conditions favourably also induce high number of contacts between flotation gas bubbles and particles in the slurry within the flotation tank 10. As the flow of slurry is forced upwards towards the froth layer, turbulence reduces and the flow becomes relatively uniform.

The impinger 44 may comprise an impingement surface intended for contacting the flow of slurry infeed 100 exiting the outlet nozzle 43. The impingement surface may be made of wear-resistant material to reduce the need for replacements or maintenance.

The slurry, which in essence is a two-phase gas-liquid mixture, rising out of the impinger 44 enters the upper part of the flotation tank 10, and the flotation gas bubbles rise upwards and separate from the liquid to form a froth layer. The froth rises upwards and discharges over the lip 21 into the launder 2 and out of the flotation cell 1 as overflow 500. The tailings or underflow 400, from which the desired material has substantially been removed, pass out from the flotation tank 10 through an outlet arranged at the bottom part 13b, for example at the vertex 130.

Some of the coarse hydrophobic particles that are carried into the froth may subsequently disengage from flotation gas bubbles and drop back into the

flotation tank 10, as a result of bubble coalescence in the froth. However, the majority of such particles fall back into the flotation tank 10 in such a way and position that they may be captured by bubbles newly entering the flotation tank 10 from the downcomer 4 or downcomers 4, and carried once more into the froth layer.

The flotation cell 1 may also comprise a conditioning circuit (not shown in the figures in its entirety). The conditioning circuit may comprise a pump tank 30, or other such additional vessel, in which pump tank 30 infeed of fresh slurry 200 and a slurry fraction 300 taken from the flotation tank 10 via an outlet are arranged to be combined into slurry infeed 100. Additionally, the conditioning circuit may comprise a pump 31 arranged to intake the slurry fraction 300 from the flotation tank 11, and to forward slurry infeed 100 from the pump tank 30 to the downcomer 4 or downcomers 4.

The slurry fraction 300 may comprise low settling velocity particles such as fine, slow-floating particles. The slurry fraction may be taken from or near the bottom of the flotation tank 10, the bottom defined as the part inside the conical bottom part 13b of the sidewall 13 of the flotation tank 10.

The pump 31 may also be used to forward the slurry infeed 100 into the downcomer 4 or downcomers 4. In order to distribute the slurry infeed 100 evenly into the downcomers 4 (in case the flotation cell 1 comprises a number of downcomers 4), a distribution unit may be utilized.

According to another aspect of the invention, a flotation line 8 is presented in figures 4a-c. The flotation line comprises a flotation stage 81, that is, a process step where flotation for the recovery of a concentrate is performed in a flotation cell. The flotation line 8 may comprise one flotation stage 81,

or a number of flotation stages 81, 82 in series and in fluid connection so that underflow from a first flotation stage 81 is led as infeed to the following flotation stage 82. Although figures 4a-c show only two flotation stages, it is to be understood that there may also be more than two, for example three or four, flotation stages in a flotation line 8.

The flotation line 8 may be preceded by other processes such as grinding, classification, screening, heavy-medium process, coarse particle recovery process, spirals, and other separation processes; and other flotation processes. A number of processes may follow the flotation line 8, such as regrinding, cleaner or other flotation processes, centrifuging, filtering, screening or dewatering. For example in recovery of coal, the flotation line 8 may be preceded by sizing process (typically for finer particles, in a cyclone classification stage) from which the material to be treated by flotation is directed to the flotation line 8. Overflow, i.e. the concentrate of desired material, coal, is then collected led to dewatering (for example in a drum filter).

In the flotation line 8, a first flotation stage 81 may performed in a flotation cell 1 according to the invention, as described above (see Fig. 4a). The flotation line 8 may comprise one to two flotation stages 81, 82, wherein the first flotation stage 81 comprises a flotation cell according to the invention.

In a flotation line 8 comprising two flotation stages 81, 82, both flotation stages may be performed in a flotation cell 1 (Fig. 4b). In an embodiment, a flotation stage 81, 82 may be performed in at least two parallel flotation cells 1 (Fig. 4c). In that case, slurry infeed 100 is divided to both of the flotation cells 1, and underflow 400 from the parallel flotation cells may be combined and led to a following flotation stage 82 as infeed. The following flotation stage 82

may also comprise a flotation cell 1. The following flotation stage 82 may also comprise at least two parallel flotation cells 1.

5 The flotation line 8 according to the invention may be used in recovering coal particles, especially fine or ultrafine coal particles suspended in slurry. Advantageously, by using the flotation line 8 according to the invention, the amount of frother chemicals may be reduced while still accomplishing a
10 good recovery of coal. In an embodiment, frother chemicals may be added into a flotation stage 81 in an amount of 12 ppm or less. The frother chemical or chemicals may be added for example in an amount of approximately 5 ppm; 7,5 ppm; or 10 ppm. The frother
15 chemicals are added into the flotation stage in any suitable manner known to the person skilled in the art.

The invention is herein described in terms applicable to the separation of minerals or coal, in which the mineral ore or coal is either finely crushed,
20 or naturally in a fine particle form, to form a slurry or suspension of particles in water, and the slurry is conditioned with collector and frother chemicals to make the desired mineral or coal species that is to be recovered by flotation hydrophobic or non-wetting,
25 while the non-wetting or hydrophilic species that are to remain in the suspension and are discharged from the flotation vessel as tailings. An example of this is the separation of fine coal particles from the surrounding gangue (ash) in a mining operation.

30 The embodiments described hereinbefore may be used in any combination with each other. Several of the embodiments may be combined together to form a further embodiment. A flotation cell to which the disclosure is related, may comprise at least one of the embodiments
35 described hereinbefore. It is obvious to a person skilled in the art that with the advancement of technology, the basic idea of the invention may be

implemented in various ways. The invention and its embodiments are thus not limited to the examples described above; instead they may vary within the scope of the claims.

CLAIMS

1. A flotation cell (1) for treating particles suspended in slurry and for separating the slurry into an underflow (400) and an overflow (500), the flotation
5 cell comprising
a flotation tank (10) comprising a centre (11), a perimeter (12), and a sidewall (13) with a vertical wall part (13a) and a conical bottom part (13b) comprising a vertex (130);
10 a launder (2) and a launder lip (21) surrounding the perimeter (12) of the tank (11); and
a downcomer (4) through which slurry infeed (100) is arranged to be introduced into the flotation tank (11);
15 wherein the height (h), measured as the distance between the vertex (130) and the launder lip (21) to diameter (d), measured as the diameter of the flotation tank (10) at the perimeter (12) of the straight wall part (13a), ratio (h/d) is 0,9 or lower,
20 characterized in that the downcomer (4) comprises
an inlet nozzle (41) for feeding slurry infeed (100) into the downcomer;
an inlet (42) for pressurized air, the slurry infeed subjected to the pressurized air as it is
25 discharged from the inlet nozzle;
an elongated chamber (40) arranged to receive under pressure the slurry infeed; and
an outlet nozzle (43) configured to restrict the flow of slurry infeed from the outlet nozzle, and
30 to maintain slurry infeed in the elongated chamber under pressure.
2. The flotation cell according to claim 1, characterized in that the height to diameter (h/d)
35 ratio is 0,3 to 0,9.

3. The flotation cell according to claim 1 or 2, characterized in that the outlet nozzle (43) comprises a throttle for restricting the flow of slurry infeed (100).

5

4. The flotation cell according to any one of claims 1 to 3, characterized in that the outlet nozzle (43) is configured to induce a supersonic shockwave into the slurry infeed (100) as it exits the downcomer (4).

10

5. The flotation cell according to any one of claims 1 to 4, characterized in that the downcomer (4) further comprises an impinger (44) configured to contact a flow of slurry infeed from the outlet nozzle (43) and to direct the flow of slurry infeed (100) radially outwards and upwards of the impinger.

15

6. The flotation cell according to claim 5, characterized in that the impinger (44) comprises an impingement surface made of wear-resistant material.

20

7. The flotation cell according to any one of claims 1 to 6, characterized in that it further comprises a conditioning circuit.

25

8. The flotation cell according to claim 7, characterized in that the conditioning circuit comprises a pump tank (30) in fluid communication with the flotation tank (10), in which pump tank infeed of fresh slurry (200) and a slurry fraction (300) taken from the flotation tank (10) via an outlet are arranged to be combined into slurry infeed (100).

30

9. The flotation cell according to claim 7 or 8, characterized in that the conditioning circuit (3) further comprises a pump (31) arranged to intake

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the slurry fraction (300) from the flotation tank (10) and to forward slurry infeed (100) from the pump tank (30).

5 10. The flotation cell according to any one of claims 7 to 9, characterized in that the conditioning circuit (3) further comprises a distribution unit arranged to distribute slurry infeed (100).

10

11. The flotation cell according to any one of claims 1 to 10, characterized in that it comprises 2-24 downcomers (4), preferably 10-24 downcomers.

15 12. The flotation cell according to claim 11, characterized in that the downcomers (4) are arranged concentric to the perimeter (12) of the flotation tank (10) at a distance from the centre (11) of the flotation tank.

20

13. The flotation cell according to claim 11, characterized in that the downcomers (4) are arranged parallel to the sidewall (13) of the flotation tank (10), at a distance from the sidewall.

25

14. The flotation cell according to any one of claims 1 to 13, characterized in that the conical bottom part (13b) of the sidewall (13) of the flotation tank (10) has a slant angle (α) of 10-45°, measured in
30 relation to a horizontal of the flotation cell (1).

15. The flotation cell according to claim 14, characterized in that the slant angle (α) is 30-40°.

35

16. The flotation cell according to claim 15, characterized in that the slant angle (α) is 15-25°.

17. The flotation cell according to any one of claims 1 to 16, characterized in that the height of the vertical wall part (13a) of the flotation tank (10) is 1,8 m or lower.

18. The flotation cell according to any one of claims 1 to 17, characterized in that the volume of the flotation tank (10) is at least 10 m³.

19. A flotation line (8) comprising a flotation stage (81), characterized in that a first flotation stage (81) comprises a flotation cell (1) according to any one of claims 1-18.

20. The flotation line according to claim 19, characterized in that it comprises 1-2 flotation stages (81, 82) wherein the first flotation stage (81) comprises a flotation cell (1) according to any one of claims 1-18.

21. The flotation line according to claim 19 or 20, characterized in that it comprises two flotation stages (81, 82), of which at least the first flotation stage (81) comprises a flotation cell (1) according to any one of claims 1-18.

22. The flotation line according to any one of claims 19 to 21, characterized in that a flotation stage (81, 82) comprises at least two parallel flotation cells (1) according to any one of claims 1-18.

23. Use of a flotation line (8) according to any one of claims 19 to 22 for treating coal particles suspended in slurry.

24. The use according to claim 22, characterized in that frother chemicals are added into

a flotation stage (81, 82) in an amount of 12 ppm or less.

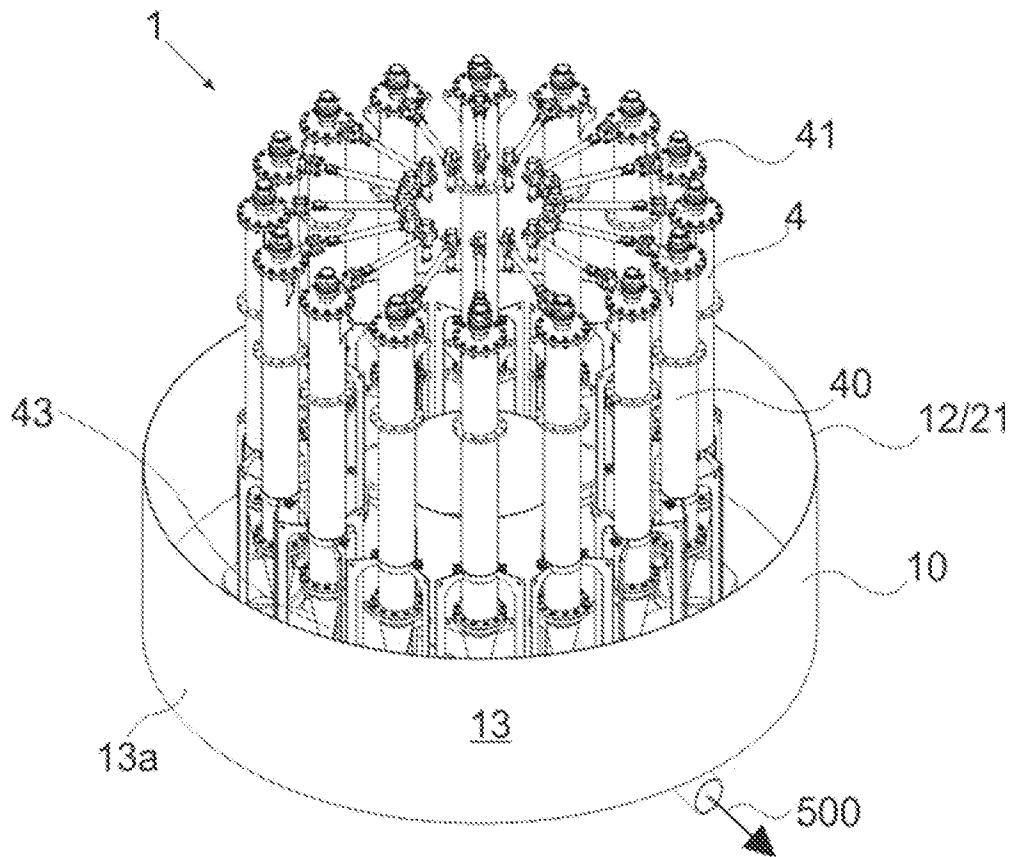


Fig. 1

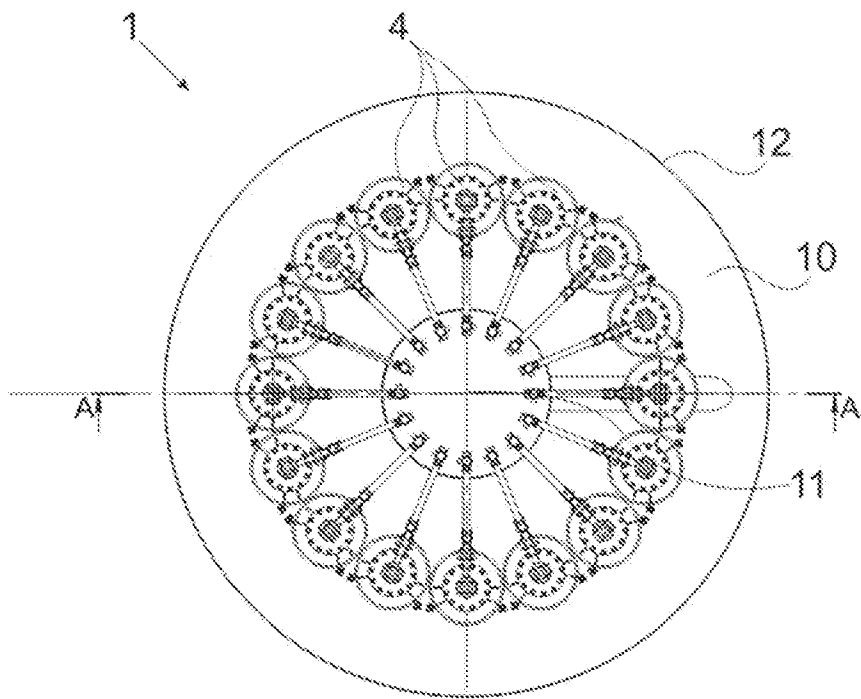


Fig. 2

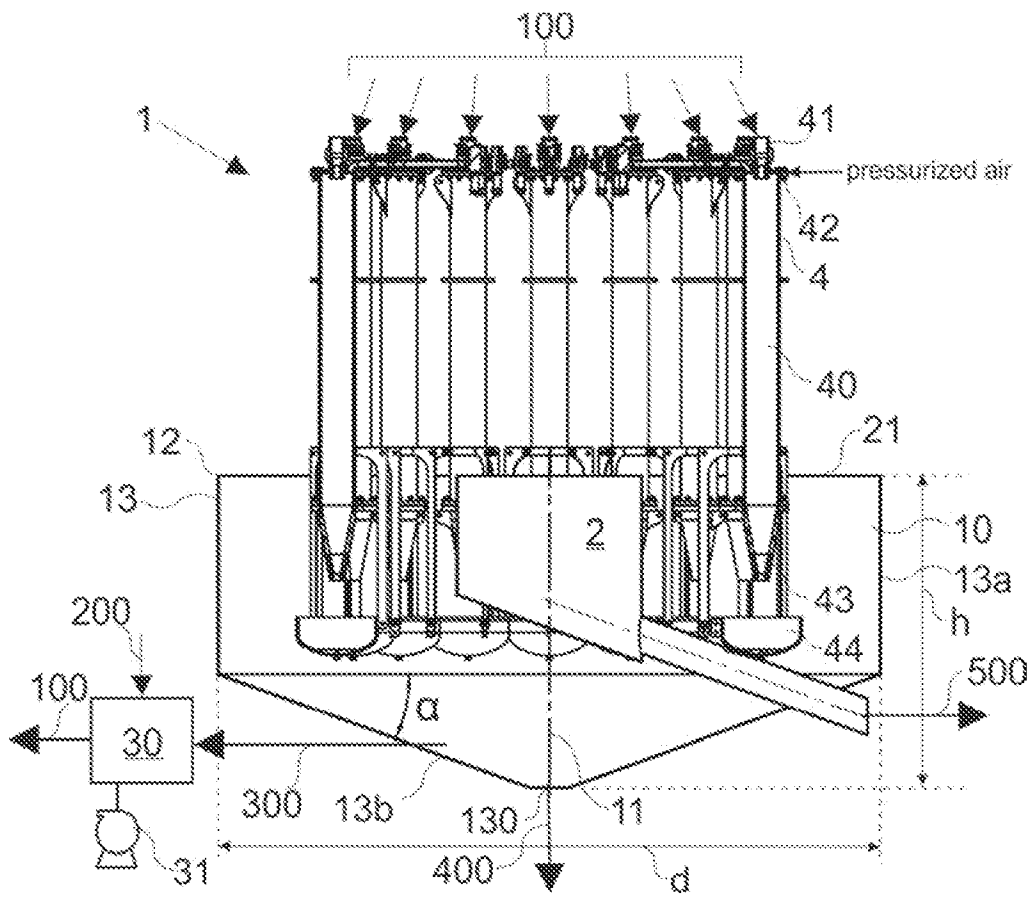


Fig. 3

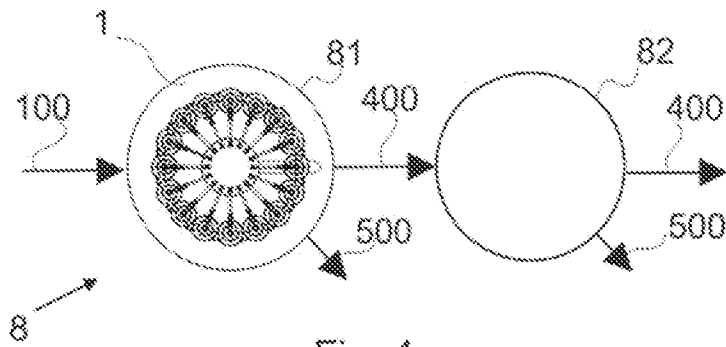


Fig. 4a

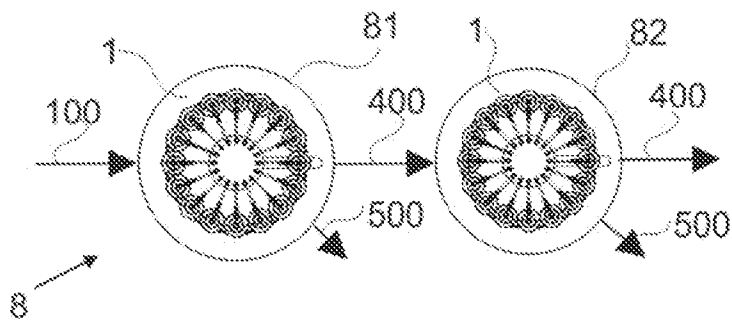


Fig. 4b

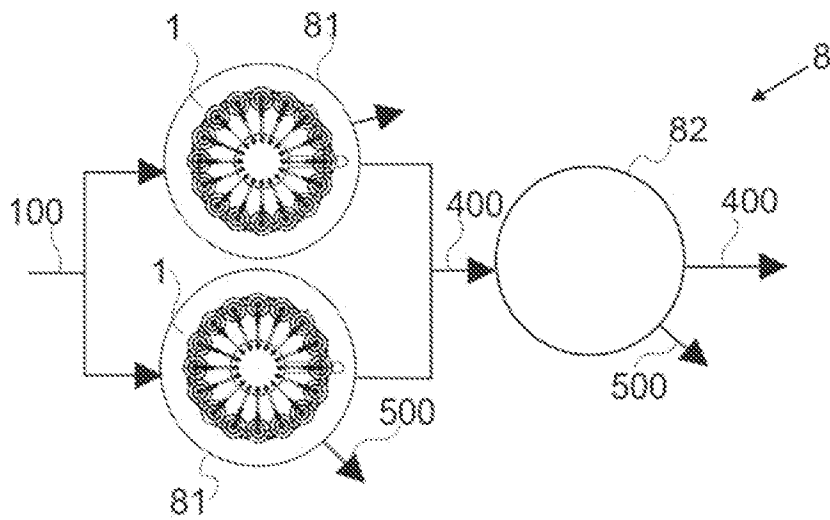


Fig. 4c

INTERNATIONAL SEARCH REPORT

International application No.

PCT/FI2018/050355

A. CLASSIFICATION OF SUBJECT MATTER

See extra sheet

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)

IPC: B03D

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
FI, SE, NO, DK

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

EPODOC, EPO-Internal full-text databases, Full-text translation databases from Asian languages, WPIAP, PRH-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

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X	WO 2006081611 A1 (UNIV NEWCASTLE RES ASS [AU]) 10 August 2006 (10.08.2006) page 12, line 31 – page 15, line 7; page 17, lines 15-23; page 22, line 16 – page 26, line 14; Figures 1, 7-10	1-6, 11-24
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Y	WO 0015343 A1 (JAMESON GRAEME JOHN [AU]) 23 March 2000 (23.03.2000) page 5, lines 21-31; page 6, lines 25-30; page 8, line 17 – page 9, line 13; Figures 1, 12	7-10
Y	WO 2009026612 A1 (XSTRATA TECHNOLOGY PTY LTD [AU]) 05 March 2009 (05.03.2009) page 5, line 31 - page 6, line 23; Figure 1	7-10

☒ Further documents are listed in the continuation of Box C.
☒ See patent family annex.

* Special categories of cited documents:	"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"A" document defining the general state of the art which is not considered to be of particular relevance	"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"E" earlier application or patent but published on or after the international filing date	"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"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)	"&" document member of the same patent family
"O" document referring to an oral disclosure, use, exhibition or other means	
"P" document published prior to the international filing date but later than the priority date claimed	

Date of the actual completion of the international search

16 August 2018 (16.08.2018)

Date of mailing of the international search report

06 September 2018 (06.09.2018)

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INTERNATIONAL SEARCH REPORT

International application No.

PCT/FI2018/050355

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

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T	CN 108273668 A (UNKNOWN) 13 July 2018 (13.07.2018) Figure 1 & abstract [online] EPOQUENET EPODOC & machine translation into English [online] EPOQUENET TXPMTCEA pages 5-6	1-24

INTERNATIONAL SEARCH REPORT

International application No.

PCT/FI2018/050355

CLASSIFICATION OF SUBJECT MATTER

IPC

B03D 1/14 (2006.01)

B03D 103/08 (2006.01)

INTERNATIONAL SEARCH REPORT
Information on Patent Family Members

International application No.
PCT/FI2018/050355

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