Nov. 5, 1968 KOICHI NAKAMURA 3,409,130

FLOTATION APPARATUS

Filed Sept. 14, 1967 2 Sheets-Sheet 1

FIG. 1.

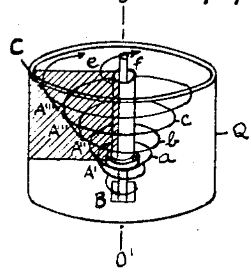


FIG. 2.

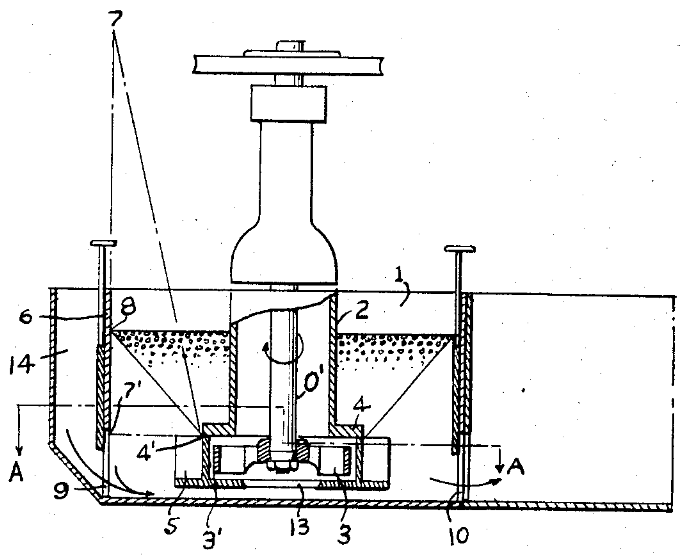


FIG. 4.

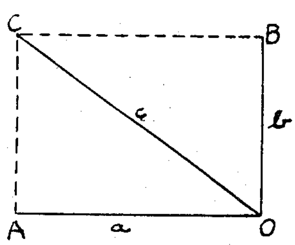
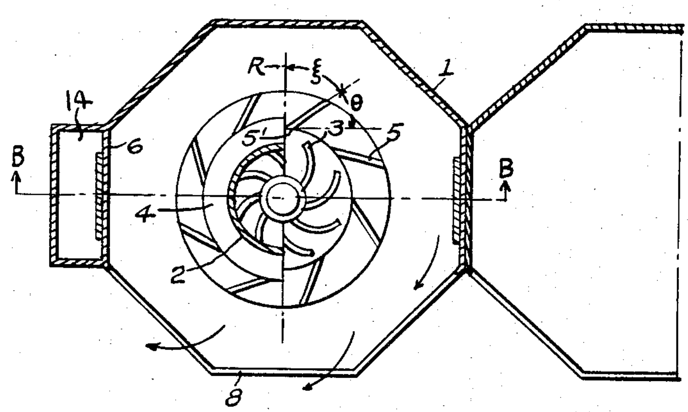


FIG. 3.



INVENTOR.
KOICHI NAKAMURA
BY Otto John Munz
his Atty.

Nov. 5, 1968 | KOICHI NAKAMURA | 3,409,130

FLOTATION APPARATUS

Filed Sept. 14, 1967 | 2 Sheets-Sheet 2

FIG. 5.

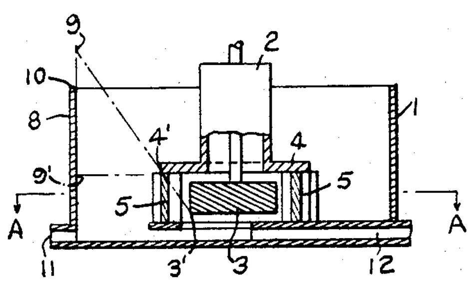


FIG. 7.

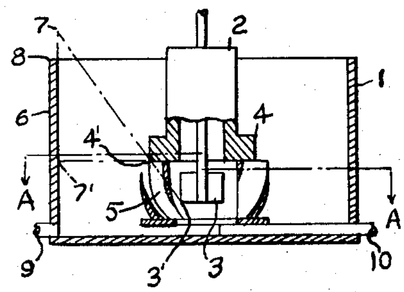


FIG. 6.

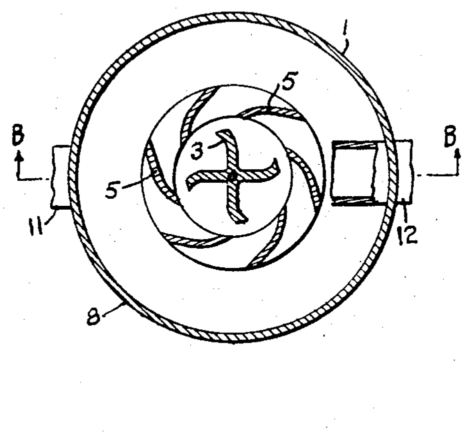
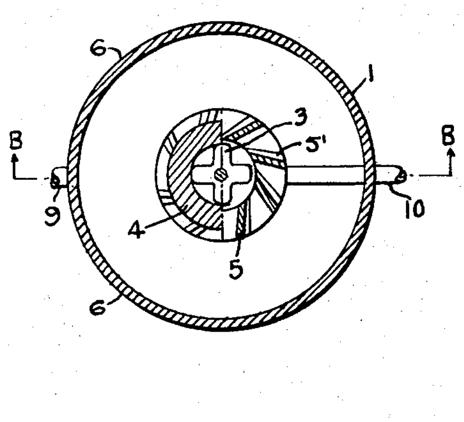


FIG. 8.



INVENTOR.
KOICHI NAKAMURA
BY Otto John Munz
His Atty

United States Patent Office

3,409,130
Patented Nov. 5, 1968

3,409,130

FLOTATION APPARATUS

Koichi Nakamura, 6–28–2 Minamimachi, Kichishoji, Musashino, Tokyo, Japan

Continuation-in-part of application Ser. No. 571,808, Aug. 11, 1966. This application Sept. 14, 1967, Ser. No. 667,691
6 Claims. (Cl. 209—169)

ABSTRACT OF THE DISCLOSURE

Ore separating apparatus including a cell which is filled with ore pulp to be treated and an air-feed pipe extending into the pulp in the center of the cell. A rotor at the bottom of the air-feed pipe mixes air and pulp and forces the mixture outward through a plurality of vanes. The vanes direct the mixture in the initial stages of a locus of minimum length paths to the discharge while producing minimum turbulence in the mixture.

Cross-reference to related application

The present application is a continuation-in-part of copending U.S. patent application Ser. No. 571,808, filed Aug. 11, 1966, now abandoned, and the filing date of its parent, U.S. patent application Ser. No. 244,442, filed Dec. 13, 1962, now abandoned, is hereby claimed for all subject matter claimed herein which in disclosed therein. Application Ser. No. 571,808 is a continuation-in-part of application Ser. No. 244,442.

Background of the invention

This invention relates to flotation apparatus for effecting the flotation of ore pulps in vertical flotation cells.

In flotation cells according to the prior art, it has been the practice to produce as small air bubbles as possible in as large amounts as possible, and to keep these small bubbles in contact with the ore particles being treated over as long periods as possible. Thus, flotation cells of the prior art have been provided with bubble sizing screens for the purpose of making the air bubbles as fine as possible, and also with impellers revolving at high speeds and supplied with an ample supply of air which is fed in such a way as to permit the air bubbles to circulate in the flotation chamber for much longer than the minimum transit time from impeller to discharge.

Flotation apparatus so constructed consumes excessive power to overcome the resistance of the bubble-forming mechanism, and, moreover, many of the bubbles concentrated in the flotation chamber fail to overflow therefrom, but flow back uselessly to the aeration chamber through holes in a flange lying above the impeller, or circulate in a vortex generated by the revolving impeller. Thus, the consumption of power is increased to such an extent by the practices of the prior art that it lowers the efficiency of flotation.

Summary of the invention

Applicant has found that the size of the air bubbles produced in such devices depends on the condition of the pulp, its pH, and the frothers and reagents introduced into the pulp; while the volume of air bubbles depends on the degree of vacuum caused by the centrifugal force of the bubble-forming impeller. Also, in making the present invention it has been discovered that the adhesion of air bubbles and ore particles can be achieved instantaneously, as a result of which the waste solution does not come into contact with the air bubbles. From the above mentioned facts, applicant has confirmed his discovery that the bubbles resulting from the agitation of the pulp by the bubble-forming impeller should, contrary to the practices of the prior art, be expelled from the flotation

cell as rapidly as possible via the shortest possible path, thus improving the efficiency of flotation considerably as compared with that of the prior art.

Therefore, an object of the present invention is to provide an apparatus which is capable of expelling the ore-clad bubbles formed by the agitation of the bubble-forming blade from the overflow lip of the cell in a vertical flotator as soon as possible, via the shortest possible path. In order to accomplish this, it is preferred to carry out the operation of flotation under the following conditions of pulp flow set forth below. Specifically, the present invention provides apparatus for performing the operation of flotation including causing aerated pulp in a container to flow in an ascending spiral flow path with the generatrix thereof ascending obliquely to the upper surface of the container and subsequently causing the aerated pulp to flow substantially horizontally outwardly along a spiral flow path toward the outer edge of the flotator. Such flow path will be called A-type flow hereinafter.

The froth column spreading above the upper part of the generatrix of the A-type pulp flow path and concurrently existing from the flange referred to below, to the surface of the container is called a V-shape froth column, from its shape as shown by the attached drawing. Thus, this V-shape froth column is obsolutely different from the so-called froth blanket in the prior art.

The present invention also contemplates flotation apparatus including a rotor blade supported in a cylinder in a container and adapted to rotate about a fixed vertical axis, this cylinder having a flange with a large external diameter than said blade so that the reverse flow of the V-shape froth column into the vacuum of vortex caused by the rotation of said rotor can be prevented perfectly by said flange. Still further, the present invention provides apparatus for performing the operation of flotation comprising a plurality of vertical guide plates spaced apart at intervals around the circumference of said blade. The relationship between the rotor and guide means is similar to that between the impeller and guide vanes of a turbine pump so that the pulp in the container can flow outwardly in a generally spiral flow path and the horizontal component thereof can advance to the wall of the container. The present invention still further consists in apparatus for performing the operation of flotation including the container having an outlet for the aerated pulp concentrate located between a first limit point defined by the intersection of the extension of the line connecting the outer lower edge of the blade and the outer lower edge of the flange and the line of the side wall of the container or the extension of this line and a second limit point defined by the intersection of a plane containing the lower surface of the flange with the side wall of the container.

The bubbles coming out from between the guide plates tend to move in the direction of a resultant force consisting of two components, i.e., a vertical component due to buoyancy of the bubbles in the moving pulp and a horizontal component of spiral movement of pulp, whereby the V-shape froth column may be generated and then the height of the flotation chamber, i.e., the outlet for concentrates remains within the limits mentioned above.

Thus the present invention consists in an apparatus for causing the aerated pulp in the flotation chamber to ascend along a flow path in the form of an ascending logarithmic spiral, the generatrix of which ascends obliquely to the upper surface of the container, subsequently the flow being outwardly in a spiral flow path toward the upper outer edge of the container; a V-shape froth column lies inwardly of the A-flow pulp path. While controlling the aerated pulp under the above mentioned conditions, the operation of flotation is effected under normal conditions in all other respects and thus it is possible to improve the efficiency of flotation quite remarkably as compared with other processes of flotation of the prior art.

Brief description of the drawings

Now the invention will be explained with reference to the accompanying drawings wherein:

FIGURE 1 illustrates one type of flow of pulp for explaining the method of flotation of the present invention;

FIGURE 2 is a vertical axial sectional view through a preferred type of apparatus, taken on line B—B of FIGURE 3;

FIGURE 3 is a horizontal sectional view taken substantially on line A—A of FIGURE 2;

FIGURE 4 is a diagrammatic view illustrating the generation of a V-shaped froth column;

FIGURE 5 is a vertical axial sectional view of a different form of apparatus, taken on line B—B of FIGURE 6;

FIGURE 6 is a horizontal sectional view substantially on line A—A of FIGURE 5;

FIGURE 7 is an axial sectional view on line B—B of FIGURE 8 showing a further modification; and

FIGURE 8 is a horizontal sectional view on line A—A of FIGURE 7.

Description of the preferred embodiments

FIGURE 1 illustrates the generation of the A-type flow of the aerated pulp which is separated from the center of the bubble-forming blade by centrifugal force and assumes an ascending flow toward the surface of the solution in the form of a logarithmic spiral curve as shown by flow lines *a*, *b*, and *c*, the axis of the spiral being coincident with the axis O, O′ of the container referred to below. The generatrix BC of the flow path ascends obliquely toward the top C of the cell or container and then the flow changes into a spirally-shaped substantially horizontal flow path e–f extending away from the wind cylinder **2** of the apparatus. In this case, the generatrix passes through the vertical series of points A′, A″, and A‴.

FIGURE 4 shows the generation of said V-shape froth column and the height of the container. The bubbles O coming out from the guide plates tend to move in the direction of a resultant force OC consisting of two components, i.e., a vertical component of buoyancy of the bubbles in the moving pulp OB–*b* and a horizontal component of logarithmic spiral movement of ore liquid, OA–*a*, thereby forming a V-shaped froth column COB and the height of the container or outlet for concentrated pulp is reduced to the level of the impeller when $a \doteqdot \infty$ and $b \doteqdot O$, but the height of the container AC–*c* (overflow outlet) becomes large when $a \doteqdot O$ and $b \doteqdot \infty$. According to experiments, it has been proved that both the values *a* and *b* vary between $O \leftrightarrow \infty$, depending on the width of the flange, setting angle θ of the guide plate, distance between the lower end of the flange and the upper end of the impeller, the height of the impeller, distance between impeller and guide plate, relative sizes of diameter of impeller and flotation bath, the distance between the upper surface of the flange and water surface, the kind of impeller, the circumferential speed of the impeller, density of aerated pulp, reagent or concentration of ore liquid.

Consequently, the height AC of the flotation apparatus can be determined experimentally so that its control limit has been defined as described in the specification, with respect to the flange and the impeller.

FIGURES 2 and 3 illustrate an apparatus for performing the above mentioned method of flotation. There is provided a rotary bubble-forming blade **3** carried by a vertical rotatable shaft O′ and a flange **4** having a diameter larger than the rotary blade **3** is also provided at the lower end of an axial air cylinder **2** of a vertical flotator cell **1**.

In this case, the cell **1** may be circular in cross section, but is preferable of a multi-angular shape. A regular octagonal bath may be the best as shown in FIGURE 3 so that the concentrated froth can overflow from the overflow lip **8** in an extremely smooth and automatic flow, thus dispensing with the use of a skimmer for exhausting the froth as is seen in a conventional flotator of the prior art generating a blanket froth. The rotor blade **3** is provided with a plurality of guide plates **5** spaced at intervals around the external circumference thereof.

There is also provided an overflow lip for overflowing the pulp concentrate between a first point **7** defined by the intersection of the extension of the line between points **3′–4′**, connecting the outer circumference **3′** of the lower part of said bubble-forming rotor blade **3** and the lower outer circumference **4′** of said flange **4** and the side wall **6** of the flotator cell or its extension, and a second point **7′** where a horizontal plane containing the lower surface of said flange **4** intersects the side wall **6** of the flotator so that the condition of flow of aerated pulp in the flotator can assume the above mentioned V-type flow.

Reference numeral **10** indicates an outlet for tailings and there is a feed-in hole **9**, the solution communicating with a hopper **14**, for feeding as shown by the arrow. Moreover, it is preferred that the angle between the tangent drawn from the basic point **5′** on the internal circumference of each guide plate **5** in FIGURE 2 and the line of the guide plate **5** itself, namely, the installing angle θ of said guide plate be between 20°–90°.

Due to the fact that each plate **5** makes an angle ζ ($\zeta = 90° - \theta$) with the adjacent radius R, the relation between blade **3** and plates **5** is equal to that between the impeller and guide vanes in a turbine pump. Therefore, the rotation of the pull caused by the rotor blade **3** causes the pulp to be rapidly expelled and the pulp may leave the guide plates **5** in a logarithmic spiral. By using the flotator shown in FIGURE 2 and keeping a constant circumferential speed of said bubble-forming blade but changing the installing angle θ in various ways, the results of flotation have been measured showing the following data.

Type of flow	(1)	(2)	(2)	(2)	(2)	(2)	(1)
Installing angle θ of guide plates, degrees	17	25	30	50	65	90	100
Extraction of metal (percent)	5	60	85	83	45	40	3

1 Bad.
2 Good.

From the results of these experiments, it has been found that the installing angle θ of said guide plates should preferably be selected between 20°–90° and that its optimum value is found best between 25°–60°. Thus it is desirable that each guide plate has the shape of the guide member of a turbine pump. When using an apparatus having this design and selecting suitable operative elements for flotation, the aerated pulp containing mineral particles separates out the minerals from the pulp flowing between the bubble-forming blade **3** and guide plates **5** and flows upwardly in that form of flow shown in FIGURE 1, while the mineral particles are kept in contact therewith but the tailings are not in contact with the air bubbles. Since the gangues cannot be mixed with the air bubbles, they flow toward the base of the flotator cell. In this manner, the concentrated bubbles are directed to the outlet lip **8** and tend to overflow therefrom. On the other hand, the divergent flux toward the base entering at **13** from under the bubble-forming blade **3** will either be refrothed or thrown out from the discharge outlet **10** as tailings in the usual manner. Since the flange **4** prevents the reverse flow of concentrates because of the partial vacuum caused by rotation of said bubble-forming blade **3**, the problems of useless refrothing of the concentrates or depreciating the results of flotation do not exist.

To test the effect of using a round cell flotator in this invention, a large-type apparatus, 1.5 meters in diameter with an installing angle $\Theta=50°$ for the guide plates has been used for comparison with a flotator of conventional type (wherein air bubbles rise vertically upwardly) in the treatment of poor ores of gold and silver while keeping all other conditions of flotation constant, and superior results have been obtained.

As compared with flotators of the prior art, the present flotator can work at a peripheral speed of rotor, ⅗, and for motive power, 1⁄10 of the power required for flotators of the prior art to obtain treated results up to 2 or 3 times as large, while generating air bubbles four times as great as that of the prior flotators.

FIGURES 5 and 6 illustrate an apparatus of another type for carrying out the method of the present invention. There is provided a rotary bubble-forming blade **3** carried by a vertical rotary shaft in a wind cylinder **2** in a vertical flotator cell **1**. Above the upper surface of said rotary blade **3** there is provided on the wind cylinder **2** a flange **4** having an external diameter larger than said rotary blade **3**, and around the circumference of the blade **3** there are spaced at intervals a plurality of flow-regulating members **5** having the form of a guide vane of a turbine pump. The radially innermost portions of these members **5** are specially shaped on both sides to conform to a logarithmic spiral, having a flow-regulating curve. There is also provided an overflow lip **10** at the side wall **8** of the flotator, which lip **10** lies between the point **9** where the extension of the line **3′—4′** connecting the outer circumferential edge **3′** of the lower part of the bubble-forming blade **3** and the lower and outer circumferential edge **4′** of the flange means **4** intersect the second side wall **8** or its extension and the point **9′** where a horizontal plane including the lower surface of said flange **4** intersects the side wall of the flotator so that the condition of the aerated pulp in the flotator can flow in the V-type flow or froth column.

There are also provided an outlet **11** for tailings and an inlet **12** for the solution of flotation. The inner end of each flow-regulating member **5** is a curved surface in order that said inlet for the flow-regulating members **5** may withstand wear and tear caused by hard mineral particles.

When flotation is carried out using this kind of flotator, the majority of curves of the guide plates **5** assume the form of a guide vane so that the flow of pulp by means of revolution of the blade **3** can be regulated in accordance with changes in the pressure of pulp for supply to the chamber of flotation.

Heretofore, improvements in the efficiency of flotation have been regarded as consisting in the formation of fine bubbles in large quantities and therefore, it has been also considered necessary to increase the number of revolutions of the bubble-forming blade by providing some resistant means or other in the flow even at the sacrifice of considerable loss of motive power.

Incidentially, it has been difficult to manufacture a very large flotator in view of the interrelations of the circumferential speed of the bubble-forming blade, its resistance and quantities of bubbles to be formed, and the resistance of some guide means has been unable to eliminate the effect of lowering efficiency. In contrast, according to the present invention, it has been found that the formation of fine bubbles does not result from providing some resistant means in the flow of pulp. For this reason, improvements in the efficiency of flotation can be achieved, without considering the fineness of bubbles, but only by eliminating resistance in the flow of pulp so that the bubble-forming blade can suck in a large amount of air easily. So the resistance to the flow of pulp can be almost eliminated by means of a flotator equipped with said flow-regulating members and a large amount of air sucked in easily and hence it is not only very effective in carrying out the operation of flotation but also it never tends to lower its efficiency. Thus according to this flotator, the flow of pulp separated centrally from the bubble-forming blade can be regulated smoothly by means of the curve of the flow-regulating members and fed to the chamber of flotation therethrough so that the partial vacuum centrally of the bubble-forming blade can be increased without disturbing the power of air suction of the same.

Consequently, it is made possible to suck in a large amount of air easily by using this flotator for flotation purposes. Thus it is very effective in carrying out the operation of flotation, causing the pulp to assume said V-shape froth column by selecting other suitable elements of operation thereby further improving the efficiency of flotation.

FIGURES 7 and 8 illustrate another type of apparatus for carrying out the method of the present invention. In this case, a vertical bending is given to the guide plates **5**. When using this type of apparatus, aerated pulp issuing forth from the bubble-forming blade **3** can assume an obliquely ascending flow toward the outlet for the concentrates of pulp by means of the curved surface of the guide plate **5**, thereby preventing the formation of any ineffective flow other than the V-type flow needed for the purposes of this invention.

In conclusion, each apparatus for carrying out the operation of flotation has such a construction in common that it can produce a flow of said V-type and moreover, the ore-clad bubbles formed by the bubble-forming blade **3** can be delivered out via the shortest possible path without delay, thus offering very high efficiency which has never been achieved by any flotator of the conventional type.

In connection with the foregoing, it will be noted that the air cylinder **2** is imperforate, and that the flange **4** is imperforate and is solidly joined to the air cylinder. Moreover, the diameter of the flange **4** is greater than the diameter of the bubble-forming blade **3**. Therefore, only bubble-forming air can flow downwardly to the bubble-forming means, there being no flow of material from the interior of the flotation cell to the bubble-forming means. Thus maximum bubble-forming is accomplished.

Also the results are obtained not only without flow-resisting means, but also without mechanical guide means to direct the upward V-flow. This is accomplished as a natural result of the relative arrangement of parts **3**, **4** and **5**, particular attention being directed to the fact that the flange **4** projects radially outwardly beyond the member **3**. Radially outward movement of the material is vertically confined until it passes the periphery of the flange **4**, whereupon it is freed to flow upwardly in the V-form described.

What is claimed is:

1. Flotation apparatus comprising:

a cell adapted to contain pulp to be treated;

tubular means for feeding gas to said pulp, said tubular means being vertically disposed substantially centrally of said cell and being imperforate throughout that part of its wall which contacts said pulp;

rotary means disposed in said pulp and beneath the lower end of said tubular means for mixing said gas with said pulp and imparting substantially horizontal motion to the mixture;

flange means sealed to the lower end of said tubular means and extending outwardly from said tubular means above said rotary means and beyond the outer extremity thereof;

and guide means comprising guide plates which project outwardly in the direction of rotation of said rotary means, said guide means disposed outwardly of said rotary means and adapted to guide elemental portions of said mixture over the initial parts of

upwardly spiraling minimum length discharge paths while producing minimum turbulence therein,
the part of said cell through which said discharge paths extend being free of foraminous means.

2. Flotation apparatus as claimed in claim **1** in which said rotary means comprises a bladed rotor.

3. Flotation apparatus as claimed in claim **2** in which said guide plates project beyond said flange means.

4. Flotation apparatus as claimed in claim **2** in which said flange means is imperforate.

5. Flotation apparatus as claimed in claim **2** in which said guide plates are curved to minimize the production of turbulence in said mixture.

6. Flotation apparatus as claimed in claim **2** in which said guide plates are substantially planar.

References Cited

UNITED STATES PATENTS

2,626,052	1/1953	Carbonnier	209—169
2,875,897	3/1959	Booth	209—169
2,892,543	6/1959	Daman	209—169

HARRY B. THORNTON, *Primary Examiner.*

T. R. MILES, *Assistant Examiner.*