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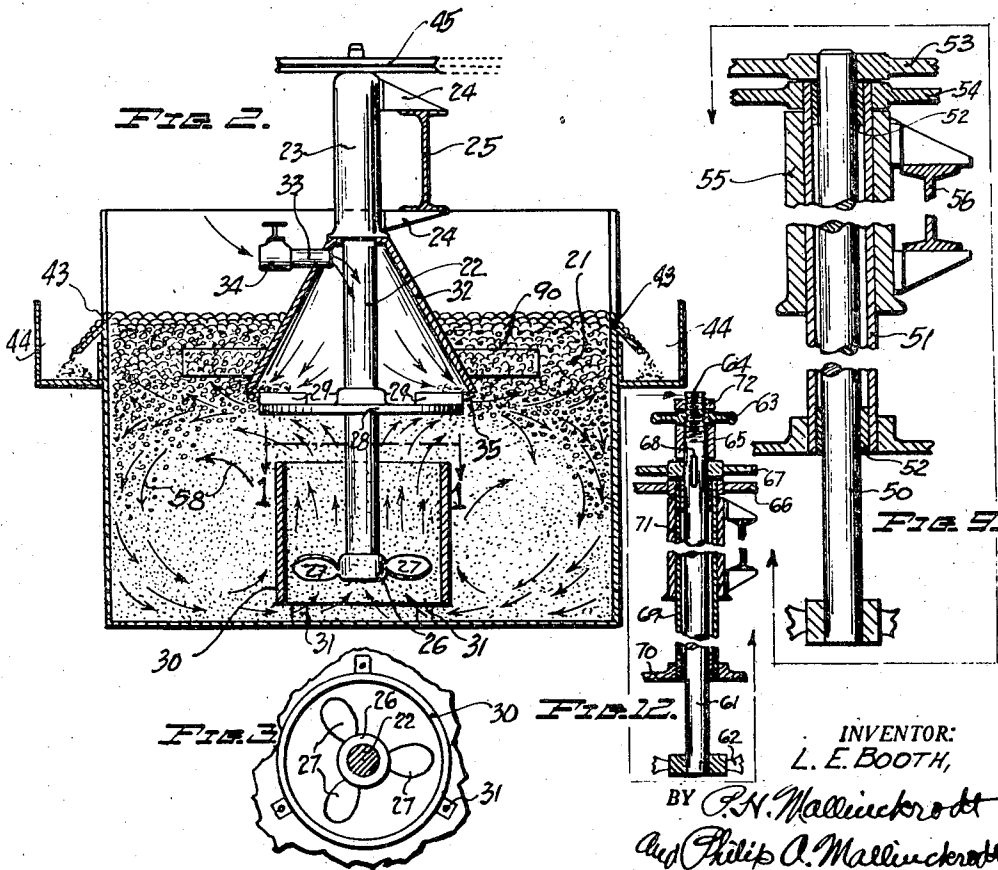
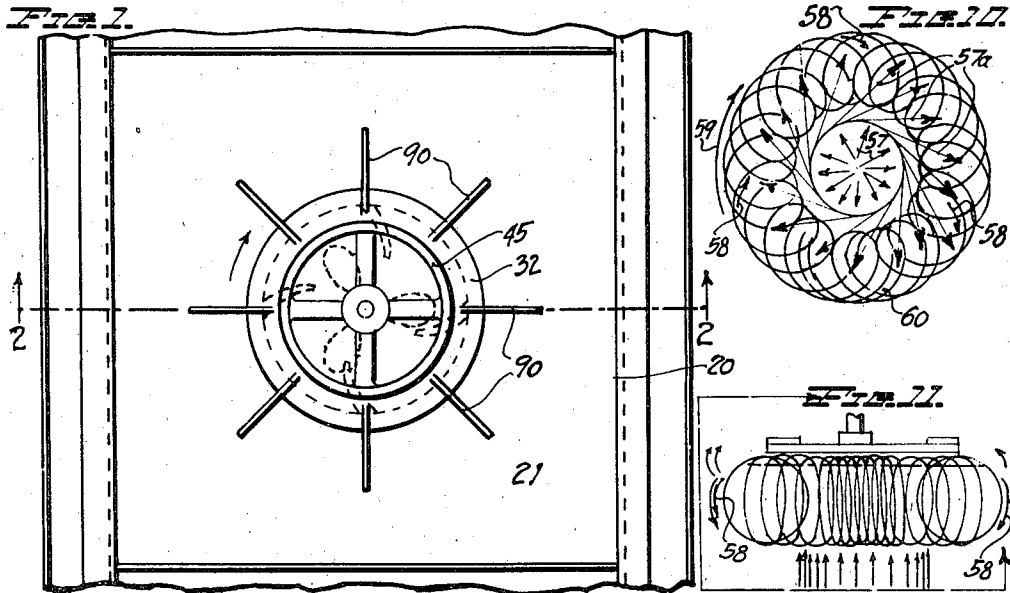
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2,433,592

AERATION METHOD AND MACHINE

Filed May 9, 1945

3 Sheets-Sheet 1



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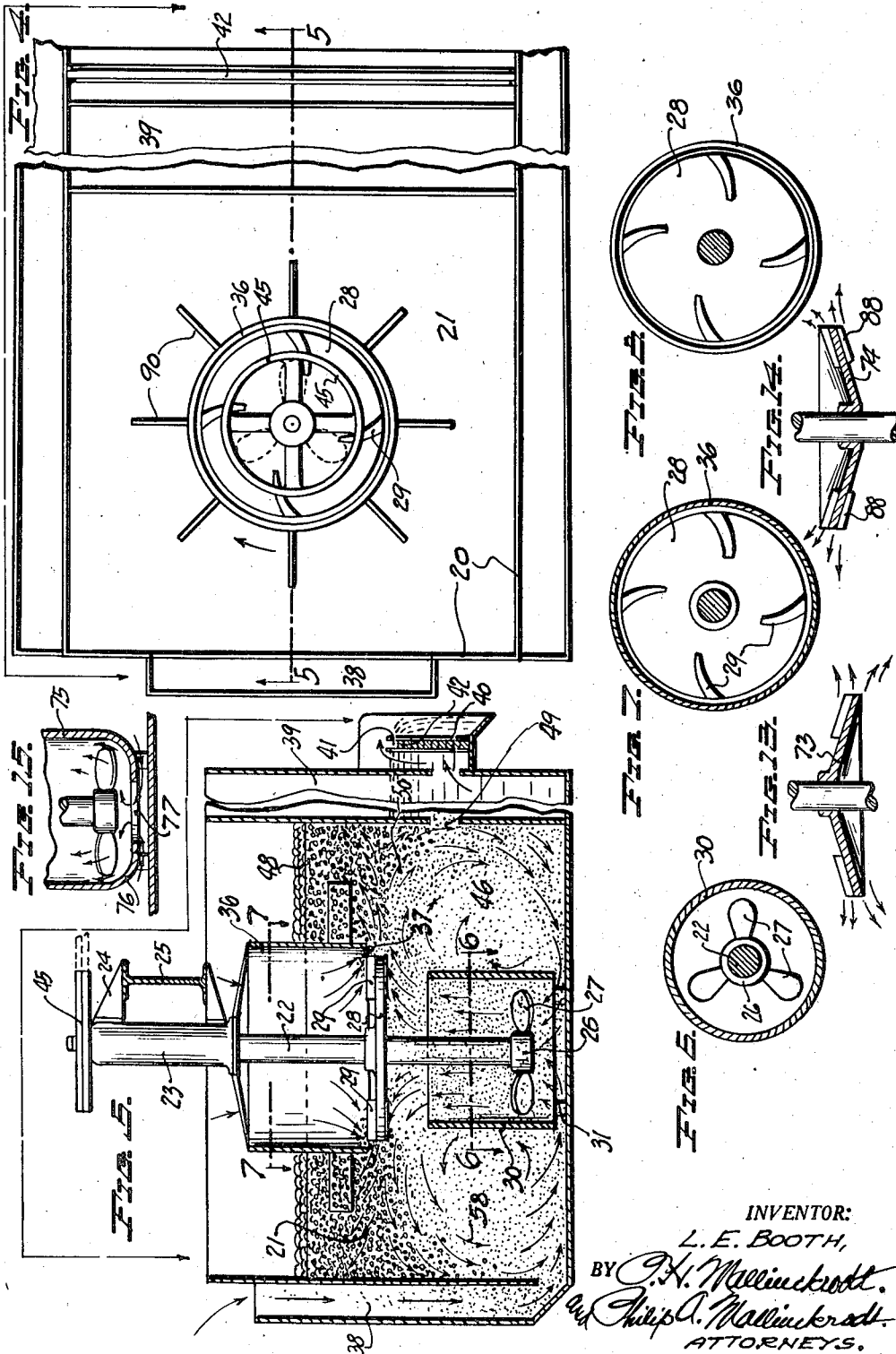
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3 Sheets-Sheet 2



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AERATION METHOD AND MACHINE

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3 Sheets-Sheet 3

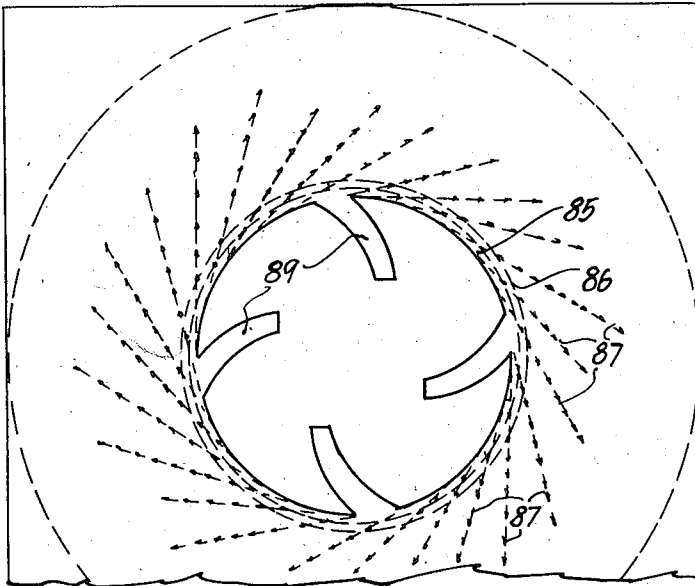


FIG. 16

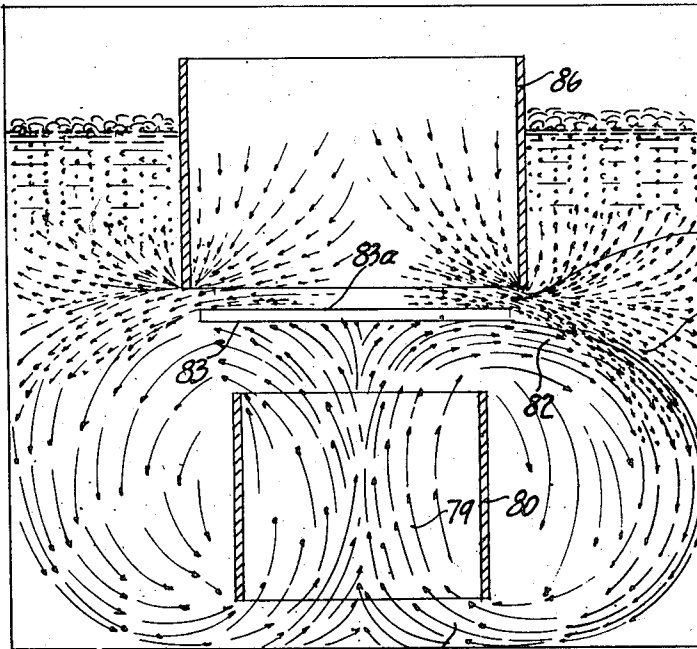


FIG. 17

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UNITED STATES PATENT OFFICE

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AERATION METHOD AND MACHINE

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11 Claims. (Cl. 261-93)

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This invention relates to a novel aeration method and more particularly to such a method and machine wherein the attainment of especially efficient mixing and agitation results are included.

Both the method and the machine find extensive application in the metallurgical art in connection with flotation processes, for which reason the machine is also called a flotation machine. As this is an extensive field of use, the invention will hereinafter be described largely with regard to flotation.

Among the principal objects of the invention may be mentioned those set forth below, namely:

(a) To efficiently subject a metallurgical pulp to mixing, agitating and to aeration at one and the same time.

(b) To provide for maximum economy both in first cost of apparatus and in the subsequent operation thereof.

(c) To provide for considerably greater capacity in a single machine than has heretofore been found possible.

(d) To be simple and rugged in construction.

(e) To have the aeration and agitation zones in such close proximity to each other that one virtually dips into the other to the proper extent efficiently performing each function but not so that the operation in either zone interferes with the practical results to be obtained in the other zone.

(f) To provide for rapid circulation of the pulp and intimate contact between the solid particles and the air bubbles in the aeration zone without interfering with the general efficiency of the operation in either zone.

(g) To keep in suspension to the maximum degree, the coarse solids and those of high specific gravities.

(h) To perform the agitating and mixing functions in virtual absence of air, in other words, a minimum of air.

(i) To reduce the power consumed to a minimum:

(j) To effectively control the flow of air or gas entering the aeration zone.

(k) To minimize surface swirl.

(l) To make possible higher froth columns than has heretofore been practical thus bringing about cleaner final products.

(m) To decrease the wear on operating parts.

(n) To produce copious froths with extremely small quantities of frothing reagents, thus resulting in cleaner products and a minimum cost for frothers.

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(o) To simplify the design of machines of the character usually employed in this art, especially the impellers, which can therefore, be readily constructed of materials most readily obtainable, and at the same time be more suitable for the work under consideration in a particular case.

According to the invention, a radical departure is made from prior practice in that there is a virtual separation of the aeration zone from the mixing, agitation and circulation zones with no confusion or interference between the different zones. This separation while not absolute, is reduced to a practicable minimum.

The agitation zone is advantageously located in the lower portion of a tightly closed housing or container which allows substantially no free air to be drawn into this zone, that is comparatively.

As a result the solid and liquid parts of the pulp are thoroughly agitated and then mixed with each other because of the intensive circulation. The circulating currents of mixed pulp are then caused to meet currents of finely disseminated air particles, these being properly directed into the agitation zone in such a manner as not to interfere with the actual agitation or mixing action. This is effected by causing the aeration zone to merely dip into or overlap the upper portion of the agitation zone, and then to properly control the resulting aerated pulp currents so they will rise through the overlying bubble column and cause the air bubbles to complete their function of carrying the appropriate mineral particles to the surface of the bubble column where the resulting froth is discharged in the usual manner.

In a characteristic construction of the apparatus, two impellers are employed, one being reserved largely for the agitation, and the other, as largely for aeration. These impellers are spaced apart from each other axially, so that each impeller has its individual sphere of action. The lower, or agitation impeller, is preferably of the ship propeller type, that is to say, it has radially disposed helical vanes or blades spaced apart from one another around the axis of rotation, the action of which in operation, is to draw in the pulp from below and propel it along the axis of rotation. This impeller is preferably enclosed by a cylindrical sleeve closely surrounding the periphery of the impeller and spaced apart from the bottom of the circulation compartment.

The aeration impeller which comprises a disc having its plane transverse to the axis of rotation and provided with air impelling elements

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suitably disposed on either one or both sides of the disc, these elements, on the side from which the air enters, being preferably more prominent than those on the opposite side. Suitably disposed above the aeration impeller is a stationary well. In case such well is cylindrical, the top is advantageously open; if conical, the top is advantageously closed so that an air inlet can be provided with suitable control means such as a valve. In the case of either the cylindrical or conical wells, the lower circumferential edge thereof is in close proximity to the circumferential edge of the aeration impeller, but spaced apart therefrom to a carefully determined degree so that any air passing through the well in either case will be properly directed into the pulp circulation zone. The air that enters a well is thrown off substantially radially and tangentially from the impeller and exerts its greatest efficiency because there are substantially no pulp particles to interfere with its operation until the proper time.

In the accompanying drawings, which illustrate several specific embodiments of the invention,

Fig. 1 represents a plan view of a typical construction;

Fig. 2, a vertical transverse section taken on the line 2—2 in Fig. 1;

Fig. 3, a horizontal section taken on the line 3—3 in Fig. 2;

Fig. 4, a plan view of another typical construction, parts being broken away for convenience;

Fig. 5, a vertical, longitudinal section taken on the line 5—5 in Fig. 4;

Fig. 6, a horizontal section taken on the line 6—6 in Fig. 5;

Fig. 7, a horizontal section taken on the line 7—7 in Fig. 5;

Fig. 8, a bottom plan view of the aeration impeller reflected from a mirror plane;

Fig. 9, a fragmentary axial section showing another construction of the driving mechanism for the impellers;

Fig. 10, a diagrammatic representation in plan of the directional motions of the currents generated by the respective impellers;

Fig. 11, a diagrammatic elevation corresponding to Fig. 10;

Fig. 12, a fragmentary axial section showing means for varying the spacing between the impellers, without the necessity of dismantling;

Figs. 13 and 14, axial sections showing alternative constructions of the aeration impeller;

Fig. 15, a fragmentary axial section showing an alternative construction of the agitation well; and

Figs. 16 and 17, conventionalized circulatory diagrams.

Referring to the drawings, Figs. 1 to 3, the numeral 20 indicates a suitably walled, open-top container which with its operative mechanism is frequently referred to as a "flotation cell." The walls of this container enclose a bubble column 21. Within the container 20 is a suitably disposed, substantially vertical shaft 22 which may be supported in any suitable manner, for example, in a bearing 23, the latter being supported by means of brackets 24 on a beam 25 extending across the top of the container structure 20. Rigidly mounted on the shaft 22 is a suitable agitation impeller 26 having for example, the helical blades 27, thus resembling a screw-type ship propeller which, when located in a liquid, causes the liquid to flow axially and upwardly of the shaft 22 somewhat after the manner indicated by

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the arrows. Also rigidly mounted on the shaft 22, but suitably spaced apart upwardly and axially from the impeller 26 is an impeller 28, this impeller being preferably in the form of a disc or a spider lying in a plane transverse to the shaft axis and provided with impelling elements 29, to serve the purpose of aeration.

Surrounding and at least partially enclosing the agitation impeller 26 is a stationary housing or well 30, which in this instance, is circular in form and is supported on the lugs 31.

Above the aeration impeller 28 is a stationary hood or well 32, which in this instance is closed at the top and supported in any suitable manner, for example, by suspending it from the bearing 23. In this instance, the hood has an air inlet 33, controlled for example by a valve 34. The hood or well 32 is open at its bottom and is so positioned with respect to the impeller 28 that a suitable annular space 35 is defined substantially vertically between such rotatable impeller and the circumferential lip at the bottom of the stationary hood or well.

Since both the agitation impeller 26 and the aeration impeller 28 are rigidly mounted on the shaft 22, they will have the same angular velocity when the shaft is rotated, but a limited variation is provided for in the relative peripheral velocities of the two, by making corresponding changes in the diameters of the two.

In the construction shown in Figs. 4 to 8, the general arrangement of the two impellers and their appurtenances, is substantially similar to what has just been described. In the latter construction however, an aeration well 36 takes the place of the conical hood 32 of Fig. 2. The aeration well 36 is preferably circular in form and defines the substantially vertical annular space 37 in Fig. 5 corresponding to the space 35 in Fig. 2. The feed inlet 38, the tailings overflow compartment 39, the tailings outlet 40, and tailings overflow 41 regulated by flashboards 42, as well as the overflow lips 43 and froth launders 44 in Fig. 2, are all of practically the same design in both constructions.

Assuming the shaft 22 to be rotating by means of power derived from any suitable source, such as an electric motor (not shown), belted to the drive pulley 45 so as to rotate the two impellers at the proper peripheral speeds, and assuming that a proper mixture of pulp is flowing in through the inlet 38, the ensuing conditions within the machine are quite accurately illustrated in Figs. 2 and 5. Here the entering pulp is given a vigorous swirling motion by the impeller 26, because of the upwardly directed currents set in motion by the impeller, which serves to circulate, mix, and thoroughly agitate the pulp largely after the manner shown at 46, this zone being at least partially defined as indicated by the curving arrows located below the plane of the aeration impeller 28.

The conditions that occur above the plane of the impeller 28, simultaneously with the agitating, mixing and circulating of the pulp, are indicated more or less accurately by the representation of froth at 48. This froth is the result of the downward suction generated by the aeration impeller which has caused air streams to be drawn through the hood 32 or through the well 36, as the case may be, as indicated by the curved arrows above the plane of the impeller 28. These air streams, after being drawn over the peripheral edge of the aeration impeller, encounter, and are vigorously whipped into, the upper reaches

of the circulating pulp. This results in an upward flow of bubbles somewhat as indicated in Figs. 2 and 5 immediately above the plane of the aeration impeller 28.

The pumping action of the underside of impeller 28 assists in drawing the feed down through the inlet 38, Fig. 5, and at the same time, in causing the overflow of the tailings through the opening 49 and out through the final discharge opening 40.

The operational showing in Figs. 2, 5, 10 and 11 is based on what has been actually observed in a working model of the apparatus of the invention, encased in glass. Attention is directed particularly to the clean cut separation between the swirling mass of pulp and the ensuing discharge of bubbles therefrom in a zone such as that shown at 47, and located somewhat above the tailings opening 49. This zone has largely an annular configuration and surrounds the hood 32 or the well 36. The bubbled froth flows over the discharge lips 43 in the usual manner and is conveyed away from the machine by means of launders 44 as is customary.

In the respective showings of Figs. 2 and 5, any desired differences in peripheral speeds between the aeration impeller and the agitation impeller are limited by the relative diameters of the two as hereinbefore mentioned. This limitation is overcome in the construction shown in Fig. 9, where each impeller is mounted on its own individual shaft. The agitation impeller in this instance is mounted on the shaft 50, while the aeration impeller is mounted on a tubular, or quill-like shaft 51, the latter being axially concentric with the shaft 50. Bushings 52, which may be fast in the quill, serve as bearings on the shaft 50 to facilitate good operation. The shaft 50 has its individual drive pulley 53 and the quill shaft the individual drive pulley 54, each of these drive pulleys deriving its motion from a suitable source (not shown) independently of the other. The quill shaft is mounted to rotate in the bearing 55 which is mounted on the stationary framework 56. Obviously, the construction just described is capable of producing a wide variation in the relative speeds of rotation of the two impellers.

The diagrammatic representation in Fig. 10 serves to illustrate approximately the directional relations existing between the air currents set in motion by the aeration impeller and the pulp currents set in motion by the agitation, mixing and circulation impeller. The directions of the air currents are largely along radial and/or tangential lines as indicated by respective arrows 57 and 57a while the rotational currents set in motion in the pulp are indicated by the arrows 58 and 59. The arrows 58 represent the motion of currents that follow approximately the line of a helix bent around into the shape of an annular ring 60, while the arrow 59 indicates the revolutions, in this instance clockwise, of the annular ring 60 about the rotational axis of the impellers. The arrows 58 are conveniently shown in Figs. 2, 5, 10 and 11, while the arrow 59 appears in Fig. 10.

Viewing the zone of action of the radial and/or tangential arrows 57 and 57a edgewise, it lies in proximity to a plane perpendicular to the axis of rotation, and the currents generated by the aeration impeller originate in proximity to its rotational plane. This diagram suggests how the aeration currents are made to dip into the annular-helical circulation zone of action.

In the construction shown in Fig. 12, the general arrangement is much like that in Fig. 9, with the exception that the shaft 61 which carries the agitation impeller 62 is movable up and down by means of a handwheel nut 63, the latter being threaded on a shank 64 at the upper end of the shaft. The handwheel rests on a stationary supporting member 65, while the shaft 61 is vertically movable through a pulley 67, feathered in a featherway 68 in the shaft.

The hollow shaft or quill 69 carries the aeration impeller 70 and is rotatably disposed in a stationary bearing 71. Obviously, by turning the handwheel nut 63, the shaft 61 with its impeller 62 is raised or lowered as the case may require, thereby varying the distance between the two impellers whenever it is desirable to do this for the purpose of bringing about varying operating conditions between the two impellers. A locknut 72 is provided to hold the handwheel fast after a desired adjustment is made. The quill 69 has its independent pulley 66.

In Figs. 13 and 14, variations in the construction of the aeration impeller are shown typically. In Fig. 13, the impeller 73 has the configuration of a hollow cone, while in Fig. 14 the configuration of the impeller 74 is that of a hollow cone inverted, the purpose of these respective conical constructions being to bring about directional variations in the air currents discharged by the respective impellers.

In Fig. 15 is shown an alternative construction of the agitation well where the well wall 75 is curved inwardly at the bottom thereof as indicated at 76, thus providing a more constricted bottom opening 77.

The novel operational characteristics of the invention, although hereinbefore touched upon, are advantageously emphasized by reference to Fig. 17, where the agitation, mixing and circulation zone of the aqueous pulp is shown as having the configuration of a conventionalized mushroom 78. The stem of the mushroom is represented by the ascending pulp currents 79, at least partially defined by the well 80, the root of the mushroom being indicated at 81 and the head or crown thereof at 82. The head is formed by the brooming out or mushrooming out of the stem pulp currents 79 against the lower impeller plane 83. This mushroom configuration is overspread by the aeration zone which has the configuration of what may be termed an open-umbrella aerial spray 84, resulting from the forcible expulsion of the air through the annular whirling aeration nozzle 85 defined at least partially by the marginal portion of the upper impeller plane 83a and the lower edge of the cylindrical aeration well 86. This open-umbrella-configured spray issuing circumferentially of the impeller plane, in pinwheel fashion reversed, and substantially without lateral obstruction, as illustrated by the arrows 87 in Fig. 16, is directed largely downward so that a considerable portion of the spray dips into the crown of the mushroom configured agitation zone 78, Fig. 17. The open-umbrella-configured spray of finely divided, dynamically moving, air particles becomes intimately and uniformly disseminated throughout the circulating aqueous pulp, continuously and progressively aerating relatively small quantities of the pulp which have first been prepared for such aeration, thereby producing a copious froth in a minimum of time. The air particles are forcibly ejected at just the right location to interrupt and

at least partially merge with the outer portion of the mushroom-crown configured whirling pulp, the degree of the merging being determined as required in particular instances by suitably dimensioning the annular gap between the air-admitting well and the aeration impeller.

By varying the relative proportions of the structural elements involved in bringing forth the novel characteristics just described, almost any desired degree of agitation, mixing and circulating may be attained in producing a dynamic pulp body most susceptible to maximum impregnation with finely diffused air particles, so necessary for effective flotation and other results.

It will now be clear that although on the one hand the primary or major aeration is accomplished by means of the aeration impeller, yet at the same time the agitation impeller assists in diffusing the aeration, while on the other hand, although the primary or major agitation, mixing, and circulation is accomplished by means of the agitation impeller, yet the underside of the aeration impeller assists the agitation very materially by diverting the directional flow initiated by the agitation impeller, and at the same time boosting the energy of this initial flow.

The aeration impeller is susceptible of considerable variation in its construction, for example, the impelling elements 29, Figs. 2, 5 and 7, while shown of involute form similar to that used in centrifugal pumps, can be made in many other appropriate forms, and instead of being located only on the upper face of the impeller, can in any of the constructions be placed on the underside also, as illustrated for example, at 88, Fig. 14. Again, the aeration impeller may be in the form of a solid disk, as at 28 in Fig. 7, or it may be of any well known spider-like form (not shown). Moreover, the impeller disk may have openings therein, such as the ones shown at 89 in Fig. 16, these openings in the present instance, being of involute form to assist in producing the pumping action.

Various features of the invention are summarized as follows.

The arrangement of the impeller means in duplex relation to each other, contributes to maximum economy in both construction and maintenance of the machine of the invention, as well as in its operation.

Since the two impellers are located along a common axis of rotation they can easily be spaced apart from each other to a considerable distance so as to provide the necessary operating room between them.

The lower or agitation impeller can be arranged for downward mixing by reversing its action from that previously described. In downward mixing the surrounding well structure can be omitted.

Stabilizing of the aerated mass counter to surface swirl in the bubble column is effected by means of the blades 90 in Figs. 1, 2, 4 and 5.

The peripheral speeds of the aerating and agitation impellers relative to each other, are important, but can be varied between rather wide limits, an average relation being a peripheral velocity of 1200 feet per minute for the agitation impeller as against a peripheral velocity of 1700 feet per minute for the aeration impeller, the primary purpose being to properly beat atomized air into the circulating pulp stream.

While the conical well 32, Fig. 2, is shown closed at the top, it can be open if desired. Also, while the cylindrical well 36, Fig. 5, is shown open

at the top it can be closed if desired and provided with a valved air inlet similar to the one at 34, Fig. 2.

Obviously, the container structure 20, Figs. 1 and 4, can have any suitable configuration other than rectangular.

Specific details are herein shown and described, but the invention is limited only by the scope of the following claims.

Having fully described my invention what I claim is:

1. An aeration machine, comprising a container for liquid; a pair of impellers rotatably mounted within the said container in mutually spaced relationship along a common substantially vertical axis, the upper of said impellers being of approximate disk formation, and the lower being adapted to cause circulation of liquid along the said common axis toward the said upper impeller; a well disposed above the said upper impeller and adapted to conduct air thereto, said well having an open lower end defined by a circumferential lip which is substantially concentric with and spaced upwardly from the periphery of said upper impeller, thereby defining a laterally open, annular, aerating gap affording communication, without lateral obstruction, of the interior of said well, with the interior of said container.

2. An aeration machine in accordance with claim 1, wherein there is provided means for increasing or decreasing the axial distance between said impellers.

3. An aeration machine in accordance with claim 1 wherein there is provided driving means for the upper impeller and independent driving means for the lower impeller so said impellers may be driven at mutually different speeds.

4. An aeration machine in accordance with claim 1, wherein the lower impeller is surrounded by an open-ended, vertically disposed well spaced apart from the bottom of the container.

5. An aeration machine in accordance with claim 1, wherein the lower impeller is surrounded by an open-ended, vertically disposed agitation well spaced apart from the bottom of the container, and wherein the periphery of the upper impeller overhangs the said agitation well.

6. An aeration machine in accordance with claim 1, wherein the container is a flotation cell, and means are provided for discharging flotation tailings from the said cell at a level between the respective planes of rotation of the upper and lower impellers.

7. An aeration machine in accordance with claim 1, wherein the container is a flotation cell having a bubble column surrounding the aeration well, and cantilever blades extend from the outer wall of said aeration well into said bubble column for stabilizing the contents of said bubble column during operation of the machine.

8. An aeration machine in accordance with claim 1, wherein the upper impeller is provided with pumping formations.

9. A flotation machine, comprising a walled flotation cell adapted to hold flotation pulp; a pair of impellers mounted for rotation within said cell in mutually spaced relationship along a common substantially vertical axis; the upper of said impellers being of approximate disk formation, and the lower being adapted to cause circulation of pulp along the said common axis toward the said upper impeller; an aeration well disposed above the said upper impeller and adapted to conduct air or other gas thereto, said

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well having an open lower end defined by a circumferential lip which is substantially concentric with and spaced upwardly from the periphery of said upper impeller, thereby defining a laterally open, annular aerating gap affording communication, without lateral obstruction, of the interior of said well with the interior of said cell; an open-ended cylindrical wall disposed vertically in said cell and surrounding the lower impeller, said cylindrical wall being spaced apart from the bottom of said cell; froth overflow means laterally of said cell and above said aerating gap, defining a bubble column surrounding said well; pulp inlet means leading into said cell at a low level thereof; and tailings outlet means leading from said cell at a level between the plane of rotation of the said upper impeller and the plane of rotation of said lower impeller.

10. A flotation machine in accordance with claim 9, wherein cantilever blades extend from the outer wall of the aeration well into the bubble column for stabilizing the contents of said bubble column during operation of the machine.

11. A method of froth flotation, comprising maintaining a mixing and circulation zone for a flotation pulp to be aerated; maintaining an aeration zone in limited overlapping adjacency to said mixing and circulation zone; causing the said pulp to be circulated within said mixing and circulating zone and into and through that portion thereof which is in overlapping relationship with said aeration zone; simultaneously introducing air or other gas into said aeration zone and circulating it into and through that

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portion thereof which is in overlapping relationship with said pulp mixing and circulating zone while allowing the said pulp and the air or other gas to intermingle and discharge laterally of the zone of overlap, directly and substantially without interference, whereby the said pulp is progressively aerated in relatively small quantities which have been first prepared for such aeration; removing the froth concentrate at a location or locations of said aeration zone which lie remote from the said overlapping portion thereof; and similarly removing the tailings from said mixing and circulation zone.

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