

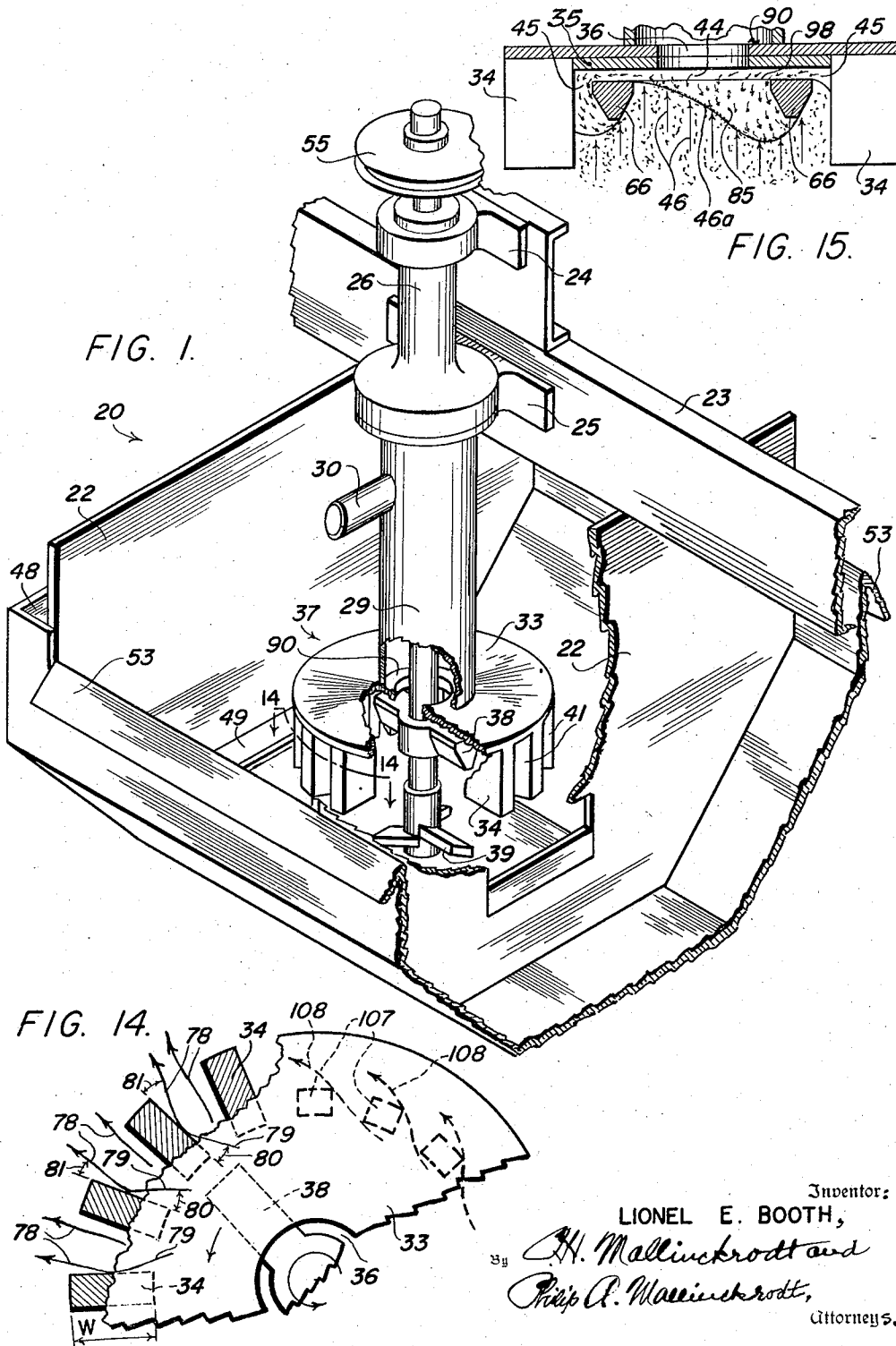
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L. E. BOOTH
FLOTATION MACHINE

2,875,897

Filed June 22, 1953

3 Sheets-Sheet 1



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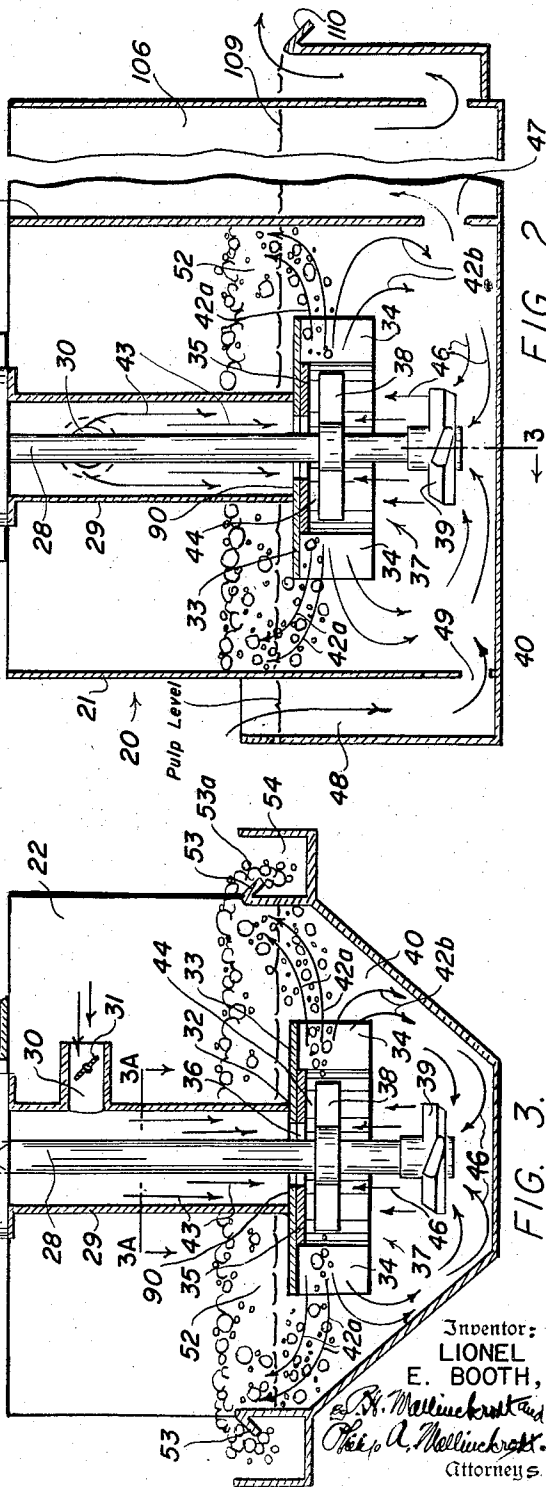
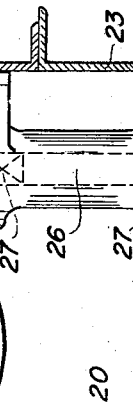
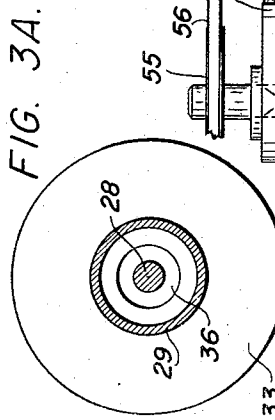
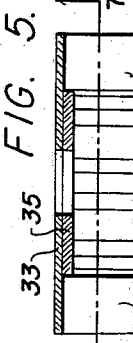
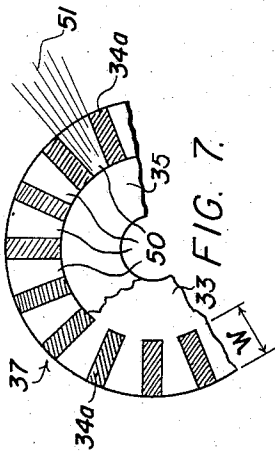
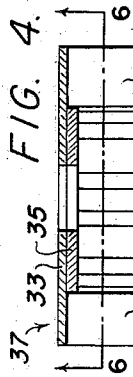
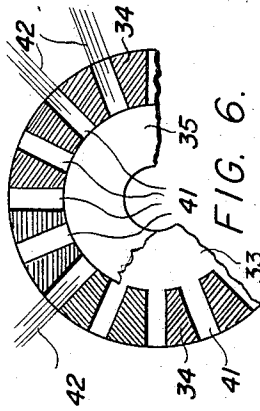
L. E. BOOTH

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FLOTATION MACHINE

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3 Sheets-Sheet 2



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2,875,897

FLOTATION MACHINE

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Application June 22, 1953, Serial No. 363,273

14 Claims. (Cl. 209—169)

This invention relates to the art of flotation and more particularly to aeration methods and machines used in flotation. While the invention is directed largely to a machine for metallurgical flotation, it is not necessarily so restricted.

In general, the invention represents an improvement upon the disclosure set forth in Letters Patent of the United States granted to me on December 30, 1947, and bearing Number 2,433,592. In the machine of the said patent, two superposed and spaced apart impellers are used. The lower impeller functions in an agitating capacity, while the upper impeller functions in an aerating capacity. The specific construction and the operation of the present invention are directed in large part to the aeration impeller and its immediate environment.

A feature of the invention is that the aeration or upper impeller is of the open-arm type and that it rotates within a grid having a plurality of depending vanes spaced around its circumference. The grid is stationary and the number of depending vanes is determined by the diameter of and the peripheral speed at which the impeller operates.

Other features of the invention are that the impeller rotates in relatively close proximity to an annular plate which forms the supporting means of the grid, and that the depth of the vanes depending from the annular plate must be at least great enough to prevent short circuiting of pulp or air below the lower faces of the vanes, that is to say, must be at least great enough to comprehend the upper impeller which rotates within the grid.

Distinctive results achieved by the present invention fundamentally are based upon the unusual open-arm construction of the aeration impeller with the generally V-shaped cross section of its arms and upon the substantially radial general action of air and pulp streams discharged by the impeller through the openings between the vanes of the circular grid. The aforementioned characteristics together with the open and thorough circulation of the pulp through the free space around the lower or agitation impeller effect a smooth, quiescent froth surface with simultaneous maximum aeration and air dissemination. All this is essential for efficient flotation results.

While the present machine retains some of the advantages of the double impeller arrangement of the Booth Patent No. 2,433,592, extensive improvements have been made with respect to the environment of both the upper or aeration impeller and the lower or agitation impeller.

Each arm of the aeration impeller has two mutually opposed oblique surfaces which are instrumental in directing currents of air or gas as well as currents of pulp so as to obtain maximum aeration of the pulp. This impeller rotates within a circumferential grid having radial baffles spaced apart from one another and positioned to rectify the streams of aerated pulp which issue from the im-

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peller. These streams are projected into the surrounding pulp body substantially along planes, the traces of which in the planes of rotation are substantially right lines.

Briefly reiterating the salient features of the foregoing explanation, it may be stated that the characteristically new features of the invention relate to the construction and functioning of the aeration impeller and its environment. The aeration impeller in general is of the open-arm type and is disposed to rotate in a grid having a plurality of depending vanes spaced around its circumference. The vanes advantageously have their support in a substantially plane plate which is located slightly above the upper or significant plane of rotation of the impeller. The arms of the impeller differ markedly from prior practice in that they have an approximately triangular cross-section. One face of the triangular configuration lies in the significant plane of rotation of the impeller, and, in revolving at the proper peripheral velocities, the arms tend to produce vacuums of correspondingly high degrees. The triangular cross-section of the impeller arms in operation causes displacement of pulp and air in a direction away from the upper face of the aeration impeller, which determines and lies substantially in the significant plane of rotation. This action, in the case of a flotation machine, is significant since it establishes virtually a tendency to displace the pulp and air on the lower side of the significant plane. This displacement, because of a downwardly directed force component, results in bringing air deeply into the pulp body.

The free downward flow of the pulp at the aeration impeller is counteracted to an appreciable degree by the centrifugal force which is generated radially along the oblique faces of the impeller arms. Largely because of this centrifugal action, the aerating pulp stream is caused to divide as it leaves the tips of the impeller arms, a portion of the pulp being circulated downwardly into and through the agitation zone below the grid, while the other portion is directed radially outward and tends in transit to be turned upwardly into and through the bubble column.

In further explanation of the increased aerating efficiency of the present machine it is convenient to draw an analogy between the closed impeller of a centrifugal pump and the impeller of the present invention. This analogy will be clarified hereinafter in connection with certain figures of the drawing. In the closed type centrifugal pump the impeller is more efficient because it directs the flow of a fluid radially, and largely prevents any substantial flow or thrust in a direction perpendicular to the plane of rotation. This results in transforming substantially the entire mass-velocity into centrifugal force and as aforesaid, into pulp streams that are directed outwardly along radial lines.

In general, the present aerating mechanism constitutes a closed impeller pump for the following reasons: first, the shape of the aerating impeller is such that it tends to create its vacuum on the lower side of the arms, thus increasing the difficulty of backward flow of air, the air to a large extent being trapped beneath the upper plane of rotation of the impeller after being inducted into the space defined between the upper and lower planes of rotation; and, second, the pulp under pressure along the bottom of an aeration impeller may be said to maintain a dynamically sustained impasse in such a manner that air inducted by the aeration impeller is finally discharged radially. It is, of course, to be realized that a dynamically sustained liquid seal, unlike a solid closure, allows some pulp to penetrate the seal and to enter the space between the upper and lower planes of rotation.

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In comparing the invention with a closed impeller centrifugal pump, it is to be remembered that the outflow from such a pump is usually discharged through a single opening, while in the case of the invention, there are numerous discharge openings formed between the respective vanes of the grid. The agitation impeller, or other means of dynamically sustaining a pressure area, corresponds to the back plate of the centrifugal pump.

In the accompanying drawings which illustrate excellent embodiments of the invention,

Fig. 1 represents in diagrammatic perspective, a single cell of a flotation machine, portions being broken away for convenience in showing the unique features of the interior of the cell of the invention;

Fig. 2, a longitudinal vertical center section corresponding to Fig. 1;

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

Fig. 3a, a horizontal cross-section taken through the drive shaft and its encasing sleeve on the line 3a—3a in Fig. 3;

Fig. 4, an axial section of a grid apart from the machine;

Fig. 5, an axial section of a grid, different from the grid of Fig. 4;

Fig. 6, a horizontal section on the line 6—6 in Fig. 4, viewed from the bottom;

Fig. 7, a cross section similar to Fig. 6, but taken on the line 7—7 in Fig. 5;

Figs. 8 to 13, various forms of the individual impellers, viewed in perspective, apart from the cells in which they are used;

Figs. 8a to 13a, cross-sections of the open arms of the respective impellers illustrated in Figs. 8 to 13, the consecutive arms defining a sectoral space;

Fig. 14, a fragmentary top plan, partly in horizontal cross-section, drawn to an enlarged scale, the section being taken along the line 14—14 in Fig. 1, to illustrate the rectifying action of the radial vanes or baffles, indicated in broken lines, as a matter of present convenience, is a modified form of the vanes;

Fig. 15, a fragmentary vertical section taken along the line 15—15 in Fig. 10, developed, and shown in diagrammatical form, to illustrate a typical operative action of the impeller in place in its grid enclosure;

Fig. 16, a fragmentary diagram illustrating further the action illustrated in Figure 15, the only difference being that in Figure 15 the impeller is assumed to be moving counterclockwise, while in Figure 16 the impeller is moving clockwise; and

Fig. 17, a fragmentary diagram embodying some of the features discussed in connection with Figure 16, but illustrating in addition differences between the action of the present impeller arms in contrast with an ordinary flat blade impeller arm.

Referring to the drawings, the numeral 20, Figs. 1, 2 and 3, indicates an exemplary flotation cell having the longitudinal walls 21 and the transverse walls 22 which intersect each other. It is to be understood that individual flotation cells are usually arranged in batteries, varying considerably in the number of individually contained cells. Extending longitudinally of a battery of cells is a beam 23. Supported on this beam as at 24 and 25, is a housing 26, and journaled at 27 in this housing is an upright drive shaft 28 which extends downwardly into the cell 20. Encasing the depending portion of the shaft 28 is a sleeve 29 which is preferably concentric with the shaft 28. An inlet for air, consisting, in this instance, of a branch conduit 30, is preferably provided with a butterfly valve 31 for controlling the admission of atmospheric air into the interior of sleeve 29, if desired.

Extending across the lower face of the sleeve 29, and fixed thereto, for illustration by welding at 32, is a grid

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plate 33 from which depend a plurality of vanes 34, these vanes being preferably fixed to the plate 33, for example by welding. As a matter of resistance to wear, the plate 33 between the vanes 34 may be shielded by an annular member 35, the latter being advantageously made of rubber or ceramic material. The plate 33 is preferably circular and together with the depending vanes 34 constitutes a grid. Extending through the top of the grid is an aperture 36 through which incoming air from the sleeve 29 is admitted to the interior of the grid, the latter in its assembled form, being shown at 37. Mounted so as to rotate with the shaft 28 is an aerating impeller 38. The top surface of the impeller 38 is closely adjacent the inner plane surface of the grid 37. Spaced downwardly from the aeration impeller 38 is an agitation impeller 39 which may be of any suitable construction that is operative to project pulp from the agitation chamber 40 upwardly into the space below the aerating impeller 38.

When the aerating impeller 38 rotates, it generates centrifugal force which carries the pulp in jets 42, Figs. 2 and 3, through the spaces 41. These jets 42 in their horizontal projection are bounded by mutually parallel lines representing parallel vertical planes, Fig. 6. In the vertical planes, the jets 42 tend to divide into two separate portions, one portion being curved upwardly as indicated by the arrows 42a in Fig. 2, and the other downwardly, as indicated by the arrows 42b. The two moving masses of pulp represented by arrows 42a and 42b, are the result of an internal stress along substantially a horizontal plane. Naturally, the air thrown off in the streams 42a and 42b must be replaced, this being accomplished through the conduit 30 from which the air flows downwardly as indicated by the arrows 43. This downwardly flowing air passes through the aperture 36, thence through the aeration space 44 within the grid 37, before emerging in the jet portions 42a and 42b.

The action of the aeration impeller 38 causes the separation of the pulp into the stream portions 42a and 42b which together pass through the grid spaces at approximately the points 45, Fig. 15, to form aerated pulp jets. Those portions of the aerated pulp jets which do not form or become substantial parts of the froth are re-circulated as shown by the arrows 46. As a matter of fact, the aerated pulp portion 42b is impoverished and contains mineral particles of lesser value than the aerated pulp portion 42a. Therefore, the pulp portion 42b may be regarded as tailings so far as the cell 20 is concerned, and be removed through the opening 47 which leads into one or more subsequent cells 106, Fig. 2, of a given battery.

The pulp feed enters the cell 20 through the inlet passage 48, and thence passes through the aperture 49 into the agitation space surrounding the agitation impeller 39.

In Figures 4 and 6, the grid vanes 34 define passage 41, of which the two mutually opposed faces are parallel to each other, thereby shaping the issuing vanes 42a and 42b accordingly.

In Figs. 5 and 7, the vanes 34a of the grid define passages 50, of which the two mutually opposing faces diverge outwardly, thereby causing the issuing aerating streams to expand into substantially a fan shape 51. The question in any particular case as to which impeller construction is preferred, depends upon local conditions and upon the judgment of the metallurgist.

The froth blanket is indicated at 52 and the discharge lips over which the froth blanket flows, at 53. The discharged froth 53a is carried to any suitable or usual destination, for illustration, through launders 54.

The shaft 28 receives rotative motive power from any suitable source, for example by means of a V-grooved pulley 55 and a corresponding belt 56.

The aerating impeller may have various forms such as are illustrated for example, in Figs. 8 to 13. A dis-

tinctive feature of the impellers is the triangular shape in cross-section of the arms, the vertices of the triangles being preferably stubbed off as indicated for illustration at 89, or truncated as at 89a, Figs. 10, 10A and 11A.

In Fig. 8 the arm 57 of the impeller 58 has in cross-section the general V-shape which may vary from the form 59 to the form 60 in Fig. 8A, depending upon the particular aeration effect desired.

In Fig. 9 the arms 61 of the impeller 62 have a general cross-sectional diamond shape as indicated at 63 in Fig. 9A. This diamond shape may be regarded as formed by two V-shapes joined along their bases, one V-shape being normal and the other inverted.

In Fig. 10 the arms 64 are similar to the arms 57 of Fig. 8, the difference in the impeller 58 of Fig. 8 and the impeller 65 of Fig. 10 being in the number of extended arms. Thus the arms 64 in cross-section may vary from the cross-section 66 to the cross-section 67 in Fig. 10A.

In Fig. 11 the arms 68 of the impeller 69 are similar in cross-section to the arms 57 and 64 respectively, in Fig. 8 and Fig. 10, the difference between the impellers 58, 65 and 69 being in the number of arms employed. The arms 68 may vary in cross-section from the form 70 to form 71 in Fig. 11A.

In Fig. 12 the arms 72 of the impeller 73 have in cross-section the general form 74 in Fig. 12A.

In Fig. 13 the arms 75 and 76 of the impeller 77 are inverted with respect to each other. The impeller in other respects being similar to the impeller 58 in Fig. 8. The cross-sections in Fig. 13A illustrate variations in the arm 75.

A feature of the invention to be particularly observed is that no matter what the shape of an individual impeller and its arms may be, the space between the top of the impeller and the lower face of the grid plate is important in the performance of the impeller.

The rectifying action of the radially wide vanes can be visualized from Fig. 14 where the arrows 78 indicate pulp currents discharged by the impeller to result from first striking the side faces of the vanes 34 along the lines 79. In accordance with well known principles in physics the angle 81 of reflection is equal to the angle 80 of incidence, which means that the jets of pulp leaving the grid are projected along lines which closely approximate radians drawn from the center of impeller. The showing in Fig. 14 makes it clear that the generation of the radians depends largely on the spaces between the vanes as well as on the thickness, width and depth of the vanes themselves.

A considerable number of actual tests shows that the radial width "W" should be sufficiently great so as to cause the jets to issue from the impeller along substantially straight lines. The tests also show that the aeration impeller can have the sectional configuration of the arms varied so as to produce desirable variations in upwardly and downwardly directed force components. Such variations can readily be visualized by observing Figs. 8 to 13. For example, in Fig. 8 supposing the impeller 58 to be rotating counter-clockwise, then the faces 82 would tend to impart a downward component to the jets 78, Fig. 14. In the case of the impeller 62 having the arms 61 of diamond (Fig. 9) shape in cross-section, there would be one set of jets receiving their projective force from the lower faces 83 of the arms 61 while another set of jets having an upward force component, would be discharged from the faces 84. From this can be seen the adaptability of the present invention to produce an almost infinite number of variations which can be fitted to widely divergent requirements.

As a rule, the type of grid shown in Fig. 6 gives good results. A series of operative tests performed in a machine having the general structure illustrated in Fig. 1, with a grid structure similar to that shown in Figs. 4

and 6, showed variations in results obtained under the conditions specified, as follows:

	No. of Baffle Grid Vaness	No. of aerating impeller blades	R. P. M.	Jet injections per minute
Laboratory cell	16	2	3,450	110,400
(A) 6 cu. ft. cell	16	2	735	23,520
(B) 6 cu. ft. cell	24	2	735	35,280
(C) 6 cu. ft. cell	24	3	735	52,920
(D) 6 cu. ft. cell	24	4	735	70,560

The grid used in the foregoing tests consisted of vanes having the width "W," Fig. 7, approximately equal to one-half the radius of the impeller arms.

It was found in operating the flotation cell under "A" conditions, that the aeration was not entirely uniform, there being burps or eruptions in the pulp, causing a deleterious effect in the frothing condition. The number of jet injections into the pulp body under conditions "A" was 23,520 per minute; operating under conditions "B" with 35,280 injections per minute, gave fairly good results; under conditions "C" with 52,920 jet injections per minute, a highly satisfactory result was obtained. The use of a 4-blade aerating impeller did not show as favorable operating conditions as those noted in "B" and "C," probably because of cavitation.

During certain intervals of the experimental period, the machine was operated without the lower or agitation impeller, in order to observe the effect of that omission upon aeration and pulp circulation. Under the conditions of omission of the agitation impeller, the aeration showed a marked decrease, which led to the conclusion that the lower or agitation impeller exercises a more important function than merely causing pulp circulation. It appears evident that the pulp, projected upwardly by the lower impeller, acts as a seal upon the underside of the upper or aeration impeller and by its sealing action increases the efficiency of the aeration impeller. Such a dynamically sustained liquid seal, largely parallels the effect of the back plate in a centrifugal pump.

In the tests reported above, an orifice meter was used to measure the quantity of air injected into the pulp under the different impeller arrangements. It was found that under conditions "B" and "C" from 30 to 35 cu. ft. of air per minute were developed in and disseminated throughout the pulp. This is a greater air volume, with more uniform dissemination in the pulp, than has been attained by other impeller-type flotation machines with which I am familiar, even when such other machines are equipped with auxiliary blowers.

Numerous laboratory tests of a machine of the present type in comparison with other standard flotation machines, have consistently given lower tailings losses, while at the same time, the grades of the respective valuable products have been increased, even to the extent of doubling the latter. A machine equipped with the novel aeration impeller together with proper agitation means operative in conjunction with that impeller provides for vigorous pulp circulation within the body of the machine. The net result is a finely divided product blanket having a smooth top surface, ideal for carrying a heavily mineralized froth across the surface of the bubble column.

In the course of the aforementioned tests it became evident that variations in the specifications of the impellers and the grid vanes, are necessary to obtain the best performance of the various sizes of flotation cells as determined by the volumetric capacities thereof. In some cases the cells showed best performance with the 3-blade aeration impeller. In general, an increase in the cubical contents of a cell requires an aeration impeller of larger diameter, each impeller being provided with from four to eight arms or blades. This means also a corresponding increase in the number of grid

vanes. The important factors to be observed are that the R. P. M. of the impellers, the number of aeration blades and the number of vanes in the grid, multiplied together and taken as a product, should provide from 23,520 to 110,500, or thereabouts aeration jets discharged through the grid, depending on the capacity of a particular flotation cell.

Summarizing the benefits in efficiency obtained by means of the present invention in the aeration and mixing of pulps over and above the best standard equipment at present in use, features set forth below are outstanding. These features are (a) intense agitation and turbulence within the body of an aeration pulp, with a controlled air dissemination which produces a smooth surface, free of turbulence on the pulp body; (b) the production of aeration jets that tend to take paths having major horizontal components, through the pulp, thus keeping the whole surface of the pulp under active aeration conditions, and providing particle-supporting buoyancy to the farthestmost limits of the cell. This is an important feature in overflowing the mineral-laden froths produced in the flotation treatment of ores; (c) a greater volume of disseminated air is maintained throughout the pulp body than is possible in existing equipment, thus providing for increased tonnage treatment per unit of cell volume.

So much for showing the efficiency of the novel pumping action of the impeller in providing improved aeration.

Now, the novel cyclonic action in projecting the high degree of aeration into and disseminating it throughout the pulp, will be described. The method of introducing atmospheric air into the aeration space 44, Fig. 15, is novel in the extreme. After the air passes freely into and through the sleeve 29, Figs. 1 to 3, prior to striking the annular abutment 90, it is forced through the aperture 36, which forms an entry throat or nozzle from where the air is squeezed into and through the restricted space 44 just above the significant plane of rotation of the impeller. This restricted space is of substantially flat, annular, pancake formation. In this restricted pancake space, the incoming air seems to be subjected to a differentially formed vacuum condition which causes a change in the mass velocity of the incoming air that overspreads the aeration impeller 38. The mass velocity is being constantly released in transit, and energetically snapped into and through the fluctuating suction space 85 to meet the turbulent upsurging surface 46a, Fig. 15, of the oncoming pulp 46. This aerated pulp is ejected from the grid in the form of the streams 78, Fig. 14, and is immediately jetted far into the space surrounding the grid. In this surrounding space, the aerated pulp is separated into the two major portions 42a and 42b hereinbefore mentioned, the one portion consisting largely of incipient bubble-forming particles which pass through the stage 42a, Figs. 2 and 3, up, into and through the bubble column, to form the froth blanket 52.

The cross-sections of the impeller arms illustrated in Figs. 8A and 10A to 13A, are hereinbefore termed "triangular." It will be noted that the vertices of these triangular shapes have been stubbed off or truncated. This feature is illustrated in Fig. 16 where the configuration of the impeller cross-section follows closely what is shown in Fig. 8A. In Fig. 16, the broken lines 91 drawn from the points 92 and 93 parallel to the respective oblique faces 94 and 95, define what may be called "wearing pads" between the lines 91 and the faces 94 and 95. The utility of these pads consists in extending the useful life of an impeller arm in working against the abrading action of the flotation pulp. The abrasion causes the original face 94 to be gradually worn down to the line 91. The abrading action tends to be caused by a force component represented by the arrows 96. This force component acting normal to, for example, the surface 94.

Assuming that the impeller in Fig. 16 is moving in

the direction of the arrow 97, clockwise as aforesaid, this tends to create a vacuum at the back of the surface 95 and results in an appreciable stream of air being sucked along and through the significant plane of rotation 98. The stream of air follows the major arrows 99, passing through the surface of rotation 98, and swirls deeply into the pulp as indicated by the minor arrows 86.

In comparison with what has just been described, the action of a usual thin, oblique blade 100, Fig. 17, it will be observed that immediately after the air passes over the cutting edge 105, it follows the arrows 103. Again assuming that the impeller is running clockwise per arrow 102, then the arrows 103 indicate the tendency of the air to be sucked over the upper or leading edge 105 of the oblique upper surface of the blade 100, and thereafter to follow quite closely the paths indicated by the minor arrows 104, which instead of flowing around the impeller are virtually stopped at the line 87, which represents the surface of revolution generated by the bottom or trailing edge of the blade 100.

Reverting to the wearing properties of the present impeller arms, it is convenient in connection with Fig. 16 to explain that not only is the durability of an impeller arm enhanced by the presence of the wearing pads in producing substantially uniform abrasion along an original oblique face, but also, that after a pad is worn off on one side, the direction of revolution can be reversed. This doubles the impeller life because the configuration of the arm cross-section is substantially symmetrical around a center line perpendicular to the significant surface 98. Thus the wearing pad on the opposite side is held in reserve until the direction of revolution is reversed.

It has been found in actual operation that the impeller arms have an optimum vertical dimension or depth which varies for the different sizes or capacities of the machines in which the impellers are used. Such depth varies the bite of the aeration impeller, the result being that the pulp jets thrown radially by the impeller, pass between the grid vanes with a minimum turbulence so as to produce a smooth froth blanket. In a 1000 gram laboratory cell using an aerating impeller two inches in diameter with two arms, this phenomenon was proved to exist. Also, in a 6 cu. ft. cell where the aerating impeller was 9½ inches in diameter with three arms, and again in a 66 cu. ft. cell where the aerating impeller was 20 inches in diameter and had four arms.

It may be noted that the triangular configuration of the impeller arms is advantageously of isosceles formation. The preferred angular relation between the oblique surfaces of the impeller and the pulp level varies from 45 degrees to 60 degrees or thereabouts as indicated in Fig. 8A.

The space 44, in which the transient air is subject to a differential mass velocity, serves actually as an air-distributing medium between the nozzle opening 36 and the space around the impeller and within the sectoral spaces 44a between the arms of the impeller. The top plate 33 with its shield 35 are both preferably annular and imperforate in construction.

An advantageous arrangement of the grid vanes is to make the spaces between the vanes circumferentially along the face of the cylindrical surface which determines the inner termini of the vanes, substantially equal to the thickness of the vanes.

Recapitulation

There is a certain analogy between the operation of a closed impeller centrifugal pump and the pumping action in the present mechanism.

In a centrifugal pump a rotating impeller is completely housed so that displacement occurs radially, thus creating a vacuum and causing flow of liquid from a central inlet to a tangentially disposed outlet.

In the present machine there is a solid casing only on the upper side of the rotating aeration impeller. The

pulp that is forced up from below, seals off the lower side of the aeration impeller much in the same way that a solid housing would do. The rim of the housing in this case is composed of the radial vanes, and the spaces between the vanes represent a multiplicity of outlets rather than the one outlet of a centrifugal pump.

This action, being similar to that of a closed impeller pump, substantially increases the difficulty of backward flow of air. Therefore, the air is more or less trapped beneath the upper plane of rotation, after being inducted into the space defined largely by the conditions created along the upper and lower planes of rotation of the impeller. The upwardly impelled pulp stream from the bottom of the agitation chamber constitutes a seal for the bottom of the impeller. The pulp, under pressure below the aeration impeller, maintains a dynamically sustained impasse in such a manner that the inducted air is expelled in streams directed radially. It is to be realized that a dynamically sustained liquid seal, unlike a solid closure, allows some pulp to enter the space between the upper and lower planes of rotation, thus causing mixing of air and pulp.

The triangular cross-section of the aerating impeller arms tends to produce a vacuum, because of pulp displacement, on the lower side of impeller. This brings air deeper into the pulp than an aeration impeller with blades of usual designs. Usual blades are thin and are set obliquely with respect to the plane of rotation. In operation, such thin blades, because of pulp displacement on the upper faces thereof, effectually stop the inflow of induced air substantially at the upper plane of rotation. It is submitted that this is a partial explanation of the fact that the present machine generates more air, and injects more air into the pulp, than is accomplished by any usually bladed flotation machine, including those machines equipped with auxiliary blowers.

In Fig. 14 the broken lines at 107 serve to indicate what happens if and when the vanes 34 are abbreviated radially. Such abbreviation causes the discharging pulp from the impeller to be projected along paths indicated by the broken arrows 108. It will readily be seen that such a construction defeats the accomplishment of projecting aerating jets radially into the pulp.

The line 109 in Figs. 2 and 3 shows a usual level of the pulp on the top of which is the bubble blanket 53. The level 109 is determined by the overflow lip at 110.

Whereas this invention is here illustrated and described with respect to certain desirable forms thereof, it should be understood that various changes may be made therein without departing from the scope of the claims which follow.

I claim:

1. In a flotation machine, the combination of an aeration assembly comprising an aeration impeller having an upper plane of rotation and a lower plane of rotation mutually spaced apart, said impeller being of open-arm construction defining sectoral spaces between the arms, and said arms having a substantially triangular configuration in cross-section, one side of said triangular configuration being uppermost and determining said upper plane of rotation, the other two sides of said triangular configuration converging to a terminus which establishes the lower plane of rotation; a grid extending around the aeration impeller, said grid having a top plate defining at least partially an air-distributing space immediately above the aeration impeller, and a plurality of vanes depending from the top plate and spaced apart circumferentially from one another, said vanes extending axially below said lower plane of rotation; means for introducing an upwardly directed current of agitated pulp below the grid; an air conduit leading into the air-distributing space; and means defining a bubble column above said top plate, said bubble column being in communication with the spaces between the said vanes.

2. A flotation machine according to claim 1, wherein

the vertices of the triangular cross-section of each of the arms of the impeller are stubbed off to at least partially defined wearing pads extending along the respective converging faces of each of said arms.

3. In a flotation machine, the combination of an aeration assembly comprising an aeration impeller having an upper plane of rotation and a lower plane of rotation mutually spaced apart, said impeller being of open-arm construction defining sectoral spaces between the arms, and said arms having a substantially triangular configuration in cross-section, one side of said triangular configuration being uppermost and determining said upper plane of rotation, the other two sides of said triangular configuration converging to a terminus which establishes the lower plane of rotation; a grid extending around the aeration impeller, said grid having a top plate defining at least partially an air-distributing space immediately above the aeration impeller, and a plurality of vanes depending from the top plate a distance at least great enough to comprehend said aeration impeller and spaced apart circumferentially from one another; means for introducing an upwardly directed current of agitated pulp below the grid; an air conduit leading into the air-distributing space; and means defining a bubble column above said top plate, said bubble column being in communication with the spaces between the said vanes.

4. A flotation machine according to claim 3, wherein the respective depending vanes of the grid have the radial dimension thereof substantially equal to one half the radial length of the respective impeller arms.

5. A flotation machine according to claim 3, wherein the grid top plate is of annular, imperforate construction.

6. A flotation machine according to claim 1, wherein the triangular configuration is of isosceles formation.

7. A flotation machine according to claim 1, wherein the triangular configuration is symmetrical about a perpendicular erected upon a plane of rotation.

8. An aerating assembly according to claim 3, wherein the number of grid vanes, multiplied by the number of impeller arms and the product thereof multiplied by the R. P. M. of the impeller, has a magnitude lying between the numbers 23,520 and 110,500.

9. An agitating and aerating assembly for flotation machines, comprising an elongate air conduit adapted to be substantially vertically positioned in a flotation cell and having an opening adjacent its upper end for inflow of air; a plate extending transversely across and secured to the lower end of said conduit; grid means projecting downwardly from said plate and around the periphery thereof to define an impeller-receiving zone below said conduit; an open-arm type of lateral delivery and down-impulsion impeller mounted for rotation within said zone transversely of said conduit and in closely spaced relationship with the lower face of said plate to define a restricted air space between said impeller and plate; means defining a nozzle orifice through said plate centrally of said impeller, providing passage for air from said conduit into said air space under elevated pressure, the air conduit being imperforate except for said air inflow opening and said nozzle orifice, so as to insure maximum supply of air to said air space under maximum pressure; an updraft impeller rotatably mounted and spaced below the first-mentioned impeller; and means for rotating said impellers, said grid means projecting downwardly from said plate a distance at least great enough to comprehend said lateral delivery impeller.

10. The agitating and aerating assembly of claim 9, wherein the means for rotating the impellers includes an impeller shaft to which said impellers are secured, said impeller shaft passing through the air conduit and the nozzle orifice, axially thereof.

11. The agitating and aerating assembly of claim 10, wherein the plate is of annular formation, defining the

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nozzle orifice at its center, and the grid is provided by a plurality of mutually spaced vanes depending from the outer peripheral margin of the plate and extending radially of said plate.

12. The agitating and aerating assembly of claim 11, 5 wherein the air conduit has a diameter greater than the diameter of the nozzle opening.

13. The agitating and aerating assembly of claim 12, wherein the lateral delivery and down impulsion impeller comprises a plurality of symmetrically spaced arms ex- 10 tending substantially radially from a hub, each arm having an underside of substantially V-formation considered transversely of the length of the arm.

14. The agitating and aerating assembly of claim 13, wherein each of the impeller arms has the vertex of its 15 V-formation stubbed off to at least partially define wear-

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ing pads extending along the converging faces of the arm.

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