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FROTH FLOTATION AND AERATION APPARATUS

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2 Sheets-Sheet 1

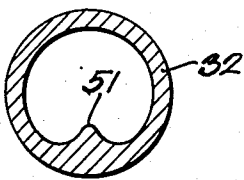
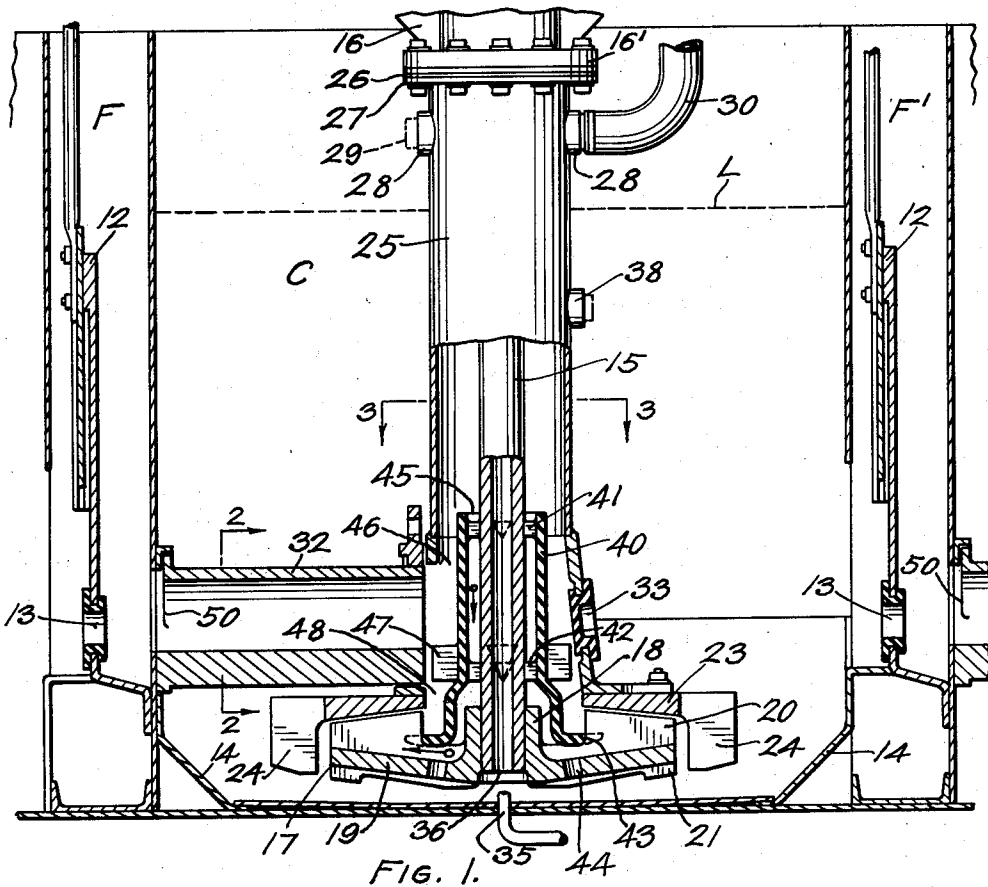


FIG. 2.

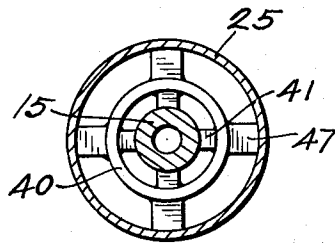


FIG. 3.

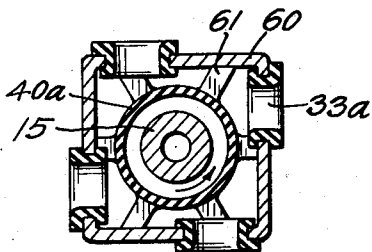


FIG. 6.

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2 Sheets-Sheet 2

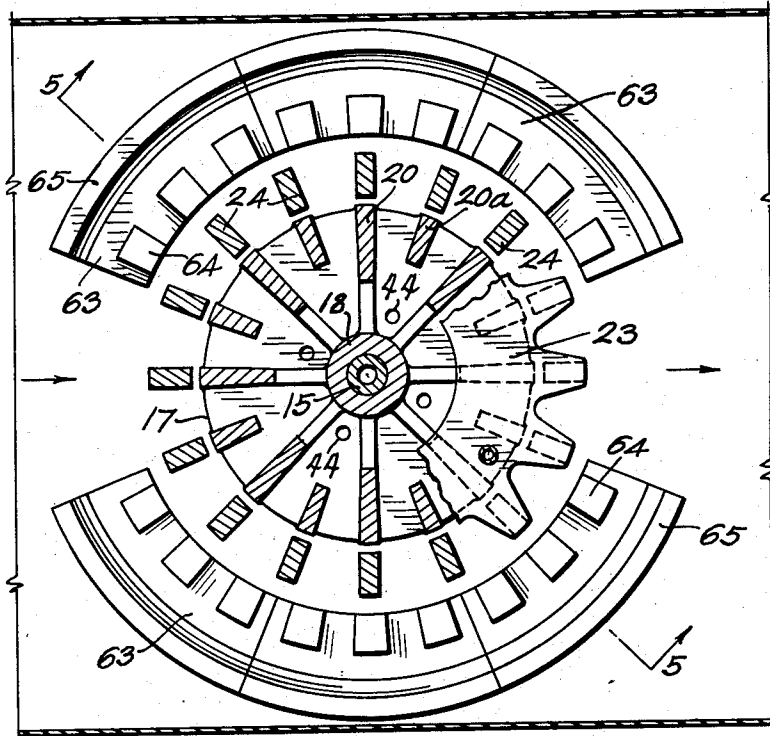


FIG. 4.

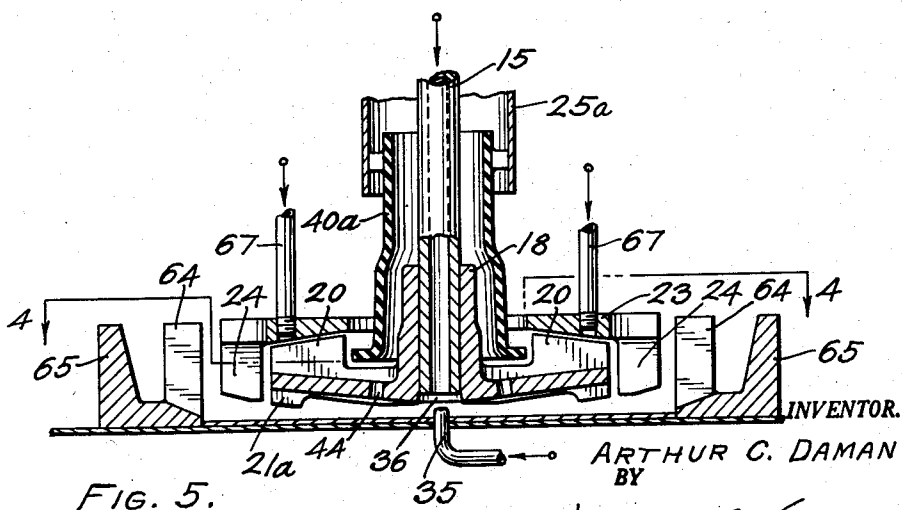


FIG. 5.

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FROTH FLOTATION AND AERATION APPARATUS

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This invention relates to aeration apparatus for flotation processes and more particularly relates to aeration features embodied in a froth flotation cell.

In froth flotation treatments large quantities of air or other aerating gas are introduced into and mixed with the circulating pulp in a flotation cell so as to elevate filmed particles which will carry to the surface and collect in a froth which can be removed as a concentrate by overflow or otherwise. Unless suitably controlled, large bubbles tend to form in such operations which break and release mineral before reaching the froth bed. In addition, large bubbles do not distribute uniformly throughout the pulp body and therefore are not an efficient means for elevating the coated or filmed particles.

It is an object of the present invention to provide simple, durable, and efficient apparatus for dispersing an aerating gas throughout a circulating pulp and for recirculating aerated pulp through its zone of primary mixing.

Another object of this invention is to provide simple, durable and efficient apparatus for controlling the flow of circulating pulp and aerating gas in a mixing zone so as to accelerate the rate and amount of intermixture under centrifugal influence.

Other objects reside in novel details of construction and novel combinations and arrangements of parts as will be more fully described in the course of the following description.

The practice of the present invention will be best understood by reference to the accompanying drawing illustrating typical embodiments and installations. In the drawings, in the several views of which like parts bear similar reference numerals:

Fig. 1 is a vertical section through a single cell of a multi-cell flotation machine utilizing features of this invention;

Fig. 2 is a section taken along the line 2—2, Fig. 1;

Fig. 3 is a section through the hollow column taken along the line 3—3, Fig. 1;

Fig. 4 is a top plan view of a modified impeller and bottom liner arrangement for use in a cell of the type shown in Fig. 1 and corresponding to a developed section taken along the line 4—4, Fig. 5;

Fig. 5 is a fragmentary section taken approximately along the line 5—5, Fig. 4, showing a modified form of pulp distributor and aerating arrangement; and

Fig. 6 is a sectional view of a modification of a pulp distributor housing for use in an aerator of the type shown in Fig. 1 as the interconnecting portion between the hollow column and the cover member.

Referring first to the aeration unit shown in Fig. 1, the cell C represents an intermediate cell of a multi-cell machine of the well known "Denver Sub A" type and receives pulp from a preceding feed compartment F and discharges into a following feed compartment F'. An adjustable weir overflow 12 regulates the liquid level in each feed compartment supplemented by lower passage 13 permitting the circulation of coarse sands from one

2

cell to the next in series. A cove-type bottom liner 14 in the cell assists the sweep of the impeller in directing settled solids into the passages 13.

Circulation of pulp in the cell is induced by an impeller unit including a rotary hollow shaft 15 journaled in bearings 16 and driven by a suitable prime mover (not shown). A rotary impeller member 17 is carried at the lower end of the shaft and in the form shown is the standard "Denver Sub A" impeller having a hub portion 18 fitting the shaft, a dished bottom portion 19, blades 20 spaced from the hub and disposed in radial arrangement on the upper surface, while pumping vanes 21 are provided on the under surface of said impeller.

The impeller is substantially enclosed by a cover member 23 having a series of depending radial blades 24 forming an enclosure for the impeller. A hollow column 25 extends upwardly from cover 23 and connects with the housing of bearing structure 16 to provide a rigid support for cover 23 which has its under surface substantially parallel with and in close proximity to the top surface of blades 20. This spacing may be varied by insertion of one or more spacer rings 26 between the bottom flange 16 of the bearing assembly and the top flange 27 of column 25, and provides for varying the mixing and pumping function of blades 20.

This type of flotation cell is factory-built for use of either atmospheric air or gas under pressure, such as compressed air for example. To this end, a plurality of threaded openings 28 are provided adjacent the upper closed end of column 25. If air under pressure is to be provided, all the openings except one will be closed by suitable plugs 29 and a line 30 connected with a suitable source of gas under pressure (not shown) delivers gas into column 25 and thence through openings (not shown) into the hollow shaft 15. Otherwise, all the plugs 29 are removed permitting substantial intake of atmospheric air through column 25.

Pulp from the feed compartment F enters a tubular feed conduit 32 and flows into the lower end of conduit 25. One or a plurality of openings in the conduit 25, one being shown in Fig. 1 closed with a plug 33, may be used to admit recirculating pulp from the lower portion of cell C into the column 25 for delivery onto impeller 17 and this pulp mixes with the feed through conduit 32 before descent onto the impeller surfaces. One or a plurality of upper openings 38 may admit a recirculating middlings product from the upper portion of the cell for mixing in column 25. Air admitted through openings 28 or discharged by line 30 is drawn through column 25 and through hollow shaft 15 by the pumping action of impeller 17. The bottom of shaft 15 preferably is open ended as indicated at 36 so the descending gas may discharge under the impeller and the pulp moved by the top and bottom surfaces of the impeller is aerated in such movement. Additional aerating gas may be delivered under impeller 17 by a nozzle 35.

The features thus far described, except in the respects hereinafter noted, are more or less standard in the "Denver Sub A" machine. In order to provide a more widespread distribution of the aerating gas throughout the pulp body and a more intense recirculation, a pulp distributor is mounted inside the hollow column 25 adjacent its base. In the form shown in Fig. 1 the distributor comprises a tubular member 40 mounted for conjoint rotation with shaft 15.

In this arrangement, the tubular member is supported by a series of upper pumping vanes 41 and a series of lower pumping vanes 42. The lower end of tubular member 40 widens and terminates in a flanged portion 43 which in this form abuts against or is slotted to fit on the inner end of blades 20. Preferably, the disc or dished portion 19 has a series of openings 44 through which some of

the aerated pulp traveling along the inner passage 45 may be directed underneath the impeller 17 for mixing with other pulp being moved by vanes 21 and finally strikes vanes 24 depending from cover member 23 to receive additional mixing from the resulting shearing effect.

Larger pumping vanes 47 are located on the outer wall of tube 40 within passage 46 adjacent feed conduit 32 and opening 33. These vanes preferably are triangular in section, as are vanes 41 and 42. Pulp descending through passage 46 is subjected to the pumping action of vanes 47 which accelerates its movement through a restriction 48 in the passage before it reaches a zone of expanding area on impeller 17. A similar restriction is placed at the lower end of passage 45 and each stream of pulp passing onto the impeller is activated by the venturi effect of the passage with the result that a high degree of mixing and downward motion is obtained in the converging movement of the streams under centrifugal influence of the impeller.

The operation performed in cell C is as follows: Pulp from a preceding cell overflows weir 12 of compartment F and other pulp enters said compartment through opening 13 at its bottom. Pulp flows from the compartment F into a feed conduit 32, the entrance of which is substantially restricted as indicated at 50 (Fig. 1), and preferably this conduit has a lengthwise ridge 51 as shown in Fig. 2 which divides the flow of pulp into separated streams directed toward the axis of rotation of the impeller in non-radial arrangement. A more effective distribution and better mixing with the aerating gas occurs as a result of this arrangement. The aerating gas is supplied either through a conduit 30 in the manner previously described or through the series of openings 28 in the top of column 25 above the liquid level of the cell which is indicated by the dash line L in Fig. 1. Some of the air enters the hollow shaft through suitable openings aligned with the intake (not shown) while the remainder is drawn downwardly through column 25 under the pumping influence of impeller 19 and its associated structure. When the descending air reaches the top of tubular member 40, it divides with one portion flowing through passage 45 while the remainder travels through passage 46.

Pulp entering through feed conduit 32 and one or more of the recirculating openings 33 mixes with the descending air stream in passage 46 first by entrainment and then by the beating effect of blades 47. If any back pressure develops which causes the level of pulp within column 25 to rise above the top of member 40, the pulp flow will distribute with the air and ultimately pass to the impeller through passages 45 and 46. The lower end of tubular member 40 is shaped with reference to the associated impeller structure so as to provide a venturi effect on pulp flowing through both of the passages prior to its ultimate direction by the extended portion 43. Movement of pulp in said passages is also accelerated to a considerable degree by the series of blades 41, 42 and 47 which due to their shape effect a substantial pumping action in addition to the beating or impact influence exerted on the pulp.

The shaping of the impeller 19 and associated cover 23 direct the separated streams passing over and under extended portion 43 into converging relation, and the blades 20 of the impeller exert a beating effect on the pulp as well as impelling it under centrifugal influence. Preferably the impeller will have bottom openings 44, and gas outlets 36 will be provided at the bottom of shaft 15 to provide a substantial aeration of circulating pulp passing beneath the impeller. This pulp circulation is accelerated by the provision of the vanes 21 on the bottom surface of the impeller. Pulp discharging across the periphery of the impeller encounters the series of depending blades 24 which, due to their radial positioning, exert a shearing effect on the pulp breaking up any large bubble formation which may have occurred and effect-

ing a fine distribution of the aerating gas throughout the body of pulp beyond the blades 24.

Another novel feature of the present development is the housing arrangement shown in Fig. 6. In this modification the housing 60 will have one or more openings, here shown as four, in which port members 33a are fitted. A feed conduit similar to the conduit 32 of Fig. 1 and of a diameter to fit the opening of one port 33a will provide the main pulp feed to the unit while one or more of the remaining openings may be utilized for recirculation of pulp. If too much recirculation is provided by the entire group of openings, one or more of same may be plugged as required.

As shown in Fig. 6, a pulp distributor 40a, similar in shape to the distributor 40 of Fig. 1, is mounted on a spider 61 and supported as a stationary member within housing 60. Other details of this distributor arrangement are shown in Fig. 5 and will be described hereinafter. I have found that with the non-radial port arrangement shown in Fig. 6, a superior mixing action is attained over any radial arrangement of the type heretofore employed in the art. Preferably, this arrangement will provide a flow into the housing directed substantially tangential to the impeller rotation as indicated by the directional arrow in Fig. 6. While best results have been attained from the aforesaid arrangement, I have found that even when the direction of rotation is reversed, the non-radial discharge will provide better mixing than is derived from the radial intake arrangement. The arrangement of Fig. 6 is utilized in the flotation cell whenever it is preferable to have the distributor mounted as a stationary member instead of rotating with the shaft as in Fig. 1.

Fig. 4 illustrates a modified form of bottom cell liner and impeller arrangement which is particularly effective in handling pulps containing a considerable amount of coarse material. In the preferred arrangement, a liner assembly is formed of a plurality of liner segments 63, each of which has an inclined forward surface supporting a series of upstanding projections or vanes 64 arranged at intervals in an arcuate course. Rearwardly of the inclined surface, the segment has a flat portion terminating in an upstanding rim 65, the inner or forward face of which preferably is inclined as shown in Fig. 5. The series of segments are arranged to form a substantially annular liner, the vane and rim portions of which are in the horizontal plane of the impeller, and its associated cover member and the vanes 64 are in proximity to but spaced from the depending vanes 24 of the cover member to provide an additional shearing effect on the pulp moving outwardly from the impeller under centrifugal influence, and following this final shearing, the pulp encounters the inclined rim 65 to provide an elevating component to all of the pulp.

This arrangement serves to throw all solids of the pulp into suspension whether they are of freely settling character or otherwise, and a high degree of mixing and dispersion of gas through the pulp and in contact with the particles results from this control. As shown in Fig. 4, the segmental arrangement permits omission of segments immediately adjacent to the inlet and outlet of the cell with the result that coarse material can be moved rapidly through the cell to its point of ultimate discharge. When more suspension of particles is required, or a longer flotation time, the segments may be arranged in a complete annulus and will thereby create the upcast condition throughout the entire area of the cell.

For some types of operations, it will be desirable to provide even more aeration than can be conveniently handled through the hollow column and hollow shaft. To this end, the cover member 23 may be apertured for connection of pipes 67 Fig. 5 which extend upwardly through the cell and may be connected with the gas header of the machine or provided with an open end above the pulp level of the cell for atmospheric air intake. With

such an arrangement, it is possible to feed reagent through the pipes 67 when additional reagent mixing by the impeller is required.

As shown in Fig. 5, the stationary pulp distributor 40a previously described is mounted on a hollow column 25a and will have a flanged bottom extension which terminates short of the blades 20 but still provides a sufficient direction of the upper and lower pulp streams to function in a manner substantially identical with the distributor 40 of Fig. 1. A special form of bottom vane construction has been shown in Fig. 5 in which a small rib or projection extends from a point adjacent the shaft to a second point near the periphery of the impeller and widens substantially at said second point to provide a vane 21a of substantial vertical extent extending radially from the second point to the periphery. This arrangement produces a pumping effect on pulp adjacent the bottom of the cell and particularly any settled solids of the pulp which throws them outwardly into the stream of material moving toward rim 65 providing substantial contact with the aerating gas and receiving the final elevating effect necessary to carry such solids into suspension.

The structural arrangements hereinbefore described are well suited for use in a novel type of flotation process. I have discovered that when an ore pulp containing a substantial quantity of slime sizes, a substantial portion of which are the valuable constituent of the treatment, is treated by the usual froth flotation procedure, the slime sizes tend to float in volume in the first cells of the series but are greatly impeded in such action by the scouring effect of coarser particles. As a consequence of this activity, a flotation of both the slimes and the coarse sizes is relatively inefficient, and this condition persists even when the pulp is passed progressively through a considerable number of cells in series.

However, by regulating the rate of flow of the respective constituents in a size segregating action, it is possible to first effect a flotation in which the concentrate is predominantly in the slime sizes, following which the slime-depleted pulp is subjected to a treatment in a second group of cells under a control which is directed to the flotation of the coarse sizes and forms a concentrate which is predominantly in the coarse size range. The total concentration attained through this procedure is substantially greater than a conventional treatment of the same ore through a corresponding number of cells.

In order to attain the necessary control, the passages 13 in the first group of cells will be of substantially large diameter to permit a rapid discharge of coarse sizes, and preferably, the bottom liner arrangement shown in Fig. 4 also will be utilized to accelerate the rate of coarse product discharge. At the same time, the overflow weir setting in the this group of cells will be maintained sufficiently high to delay the discharge of suspended solids so that the overall effect of this control is to substantially increase the proportion of coarse solids to slimes in the discharge from each cell. In addition, it will be preferable to run the impeller at slow speed and with substantial gas introduction so that it functions more as an aerator and less as a pump to increase the flotation of the slimes without providing enough circulation and suspension to cause any substantial scouring of the slimes by the coarse fraction.

This action is repeated through a sufficient number of cells to float off a major portion of the valuable constituent in the fine size range and without any substantial flotation of coarse sizes in conjunction therewith. The final pulp discharge from this first group of cells constitutes a feed to a second group of cells, and if additional reagent is required in order to effect the necessary coarse flotation, an intermediate conditioning stage may be provided if desired. In the second group of cells, the discharge passages 13 are of relatively small diameter to accommodate the discharge of only that portion of the pulp which cannot be made to pass over the weir, and pre-

erably the weir will be lowered and the capacity of the cell substantially increased to permit a much longer flotation time. If desired, the impeller may be operated at substantially higher speed to effectively suspend the coarse sizes, and the size or number of the recirculation openings 33 and 38 may be increased to satisfy the pumping requirements of the impeller at such speed. This control will result in a substantial flotation of the valuable constituent in the coarse size range with the result that by the time the succession of treatments is completed, a major portion of the coarse fraction will be concentrated.

If desired, rougher cleaner operations may be employed with the concentrate of the first series of cells fed to a separate cleaner stage for such series, and the concentrate of the second group of cells fed to a separate cleaner stage for that group of cells. In the practice of this process I do not wish to be limited to the structural features hereinbefore disclosed as suited for performing the process. It will be apparent in any arrangement permitting a fast circulation of the coarse fraction through the first group with a controlled circulation of the slime sizes will satisfy the objects of this process. Following said first separation any suitable control to effect the flotation of the major part of the coarse fraction will satisfy the requirements. While I do not wish to be limited to a critical size range, an ore pulp having mixed sizes in the -8, +100 range may be considered as a typical coarse fraction, while the -100 sizes including a substantial portion of -250 mesh will be considered a typical slimes fraction.

The middlings recirculation through the openings 38 may be assisted by mounting a hood or cover on the column 25 in overhanging relation to the openings to avoid any vortex formation and prevent entrainment of mineral-carrying froth which has risen to the surface. The middlings so entering the column will entrain substantial quantities of air and produce a splash mixing effect on meeting the entering feed streams and the recirculating pulp admitted through the openings 33. As a consequence, the pulp streams passing onto the impeller are pre-aerated and receive the final aeration and dispersion effect within the impeller enclosure.

I claim:

1. In aeration apparatus of the type having a rotary shaft carrying an impeller adjacent its lower end, a hollow column extending upwardly from a plane in proximity to the upper surface of said impeller and spaced from said shaft in enclosing relation thereto for delivering an aerated pulp onto the impeller, the improvement which comprises an upright tubular member carried by and rotatable with said shaft in spaced relation to the impeller, said member being disposed between said shaft and said column and defining therewith a plurality of passages for dividing a descending pulp flow onto said impeller in separate streams, there being a restriction in each passage for accelerating pulp flow as it approaches the impeller, and means in each passage mounted for rotation with said shaft for inducing an accelerated flow through the passage and past said restriction.

2. In aeration apparatus of the type having a rotary shaft carrying an impeller adjacent its lower end, a hollow column extending upwardly from a plane in proximity to the upper surface of said impeller and spaced from said shaft in enclosing relation thereto for delivering an aerated pulp onto the impeller, the improvement which comprises an upright tubular member carried by and rotatable with said shaft in spaced relation to the impeller, said member being disposed between said shaft and said column and defining therewith a plurality of passages for dividing a descending pulp flow onto said impeller in separate streams, there being a restriction in each passage for accelerating pulp flow as it approaches the impeller, and means in the innermost passage mounted for rotation with said shaft for inducing

an accelerated flow through said passage and past the restriction.

3. In aeration apparatus of the type having a rotary shaft carrying an impeller adjacent its lower end, a hollow column extending upwardly from a plane in proximity to the upper surface of said impeller and spaced from said shaft in enclosing relation thereto for delivering an aerated pulp onto the impeller, the improvement which comprises an upright tubular member carried by and rotatable with said shaft in spaced relation to the impeller, said member being disposed between said shaft and said column and defining therewith a plurality of passages for dividing a descending pulp flow onto said impeller in separate streams, there being a restriction in each passage for accelerating pulp flow as it approaches the impeller, and a plurality of pumping vanes supported from and rotatable with said shaft in each said passage for inducing an accelerated flow through said passage and past the restriction.

4. In aeration apparatus of the type having a rotary shaft carrying an impeller adjacent its lower end, a hollow column extending upwardly from a plane in proximity to the upper surface of said impeller and spaced from said shaft in enclosing relation thereto for delivering an aerated pulp onto the impeller, the improvement which comprises an upright tubular member carried by and rotatable with said shaft in spaced relation to the impeller, said member being disposed between said shaft and said column and defining therewith a plurality of passages for dividing a descending pulp flow onto said impeller in separate streams, there being a restriction in each passage for accelerating pulp flow as it approaches the impeller, and a plurality of radial pumping vanes supported from and rotatable with said shaft in each said passage for inducing an accelerated flow through said passage and past the restriction.

5. In aeration apparatus of the type having a rotary shaft carrying an impeller adjacent its lower end, a hollow column extending upwardly from a plane in proximity to the upper surface of said impeller and spaced from said shaft in enclosing relation thereto for delivering an aerated pulp onto the impeller, the improvement which comprises an upright tubular member carried by and rotatable with said shaft in spaced relation to the impeller, said member being disposed between said shaft and said column and defining therewith a plurality of passages for dividing a descending pulp flow onto said impeller in separate streams, there being a restriction in each passage for accelerating pulp flow as it approaches the impeller, and a plurality of pumping vanes interconnecting said shaft and the upper end of said tubular member whereby said tubular member rotates with said shaft and said vanes induce an accelerated flow through the passage between said tubular member and said shaft.

6. In aeration apparatus of the type having a rotary shaft carrying an impeller adjacent its lower end, a hollow column extending upwardly from a plane in proximity to the upper surface of said impeller and spaced from said shaft in enclosing relation thereto for delivering an aerated pulp onto the impeller, the improvement which comprises an upright tubular member carried by and rotatable with said shaft in spaced relation to the

impeller, said member being disposed between said shaft and said column and defining therewith a plurality of passages for dividing a descending pulp flow onto said impeller in separate streams, there being a restriction in each passage for accelerating pulp flow as it approaches the impeller, and a plurality of pumping vanes interconnecting said shaft and said tubular member intermediate the ends of said tubular member, a plurality of pumping vanes supported on said tubular member and extending into the passage on the exterior of said tubular member whereby said tubular member rotates with said shaft and said vanes induce an accelerated flow through said passage and past said restriction.

7. In aeration apparatus according to claim 6 in which the pumping vanes on the exterior of said tubular member are substantially larger than the pumping vanes on the interior of said tubular member.

8. In aeration apparatus of the type having a rotary shaft carrying an impeller adjacent its lower end, a hollow column extending upwardly from a plane in proximity to the upper surface of said impeller and spaced from said shaft in enclosing relation thereto for delivering an aerated pulp onto the impeller, the improvement which comprises an upright tubular member carried by and rotatable with said shaft in spaced relation to the impeller, said member being disposed between said shaft and said column and defining therewith a plurality of passages for dividing a descending pulp flow onto said impeller in separate streams, means including a restriction in each passage for accelerating pulp flow as it approaches the impeller, a plurality of pumping vanes supported from and rotatable with said shaft extending into each said passage for inducing an accelerated flow through said passage and past said restriction, and an outwardly directed, annular flange disposed at the lower end of said tubular member for directing said accelerated flow substantially parallel to the top surface of the impeller, there being a plurality of openings in said impeller underneath said flange for directing a portion of said accelerated flow underneath the impeller.

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