April 16, 1968 C. H. WARMAN 3,378,141

FROTH FLOTATION APPARATUS

Filed March 23, 1964 4 Sheets-Sheet 1

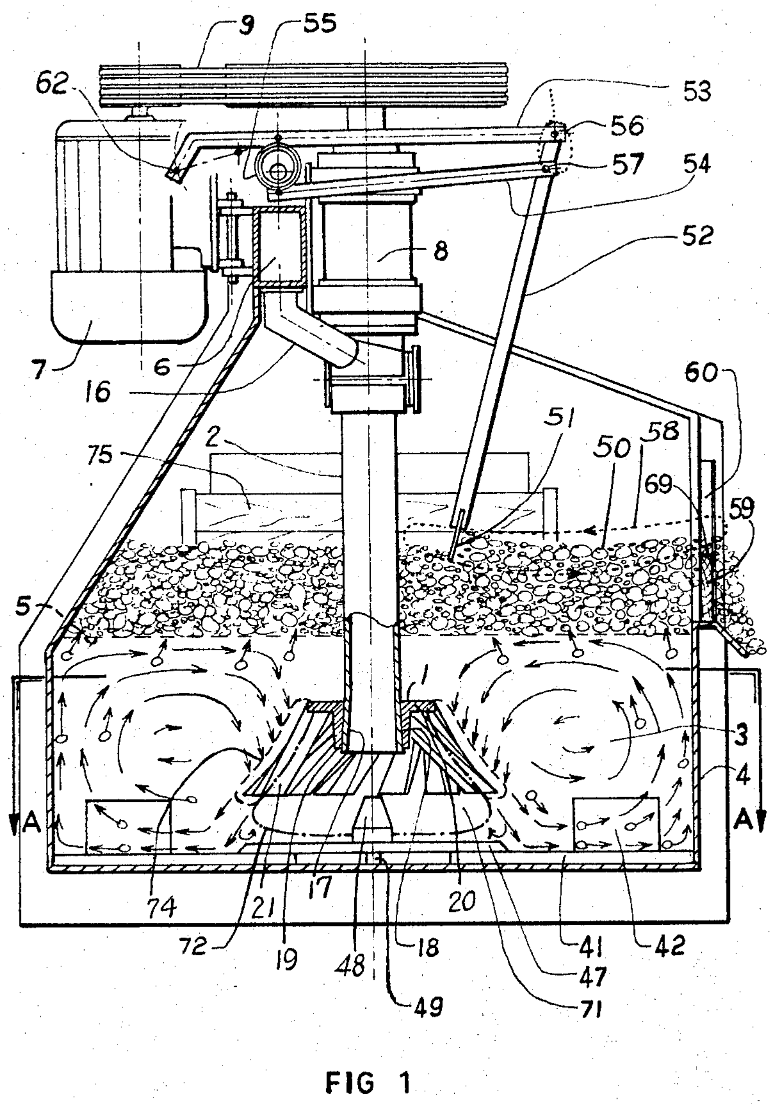


FIG 1

Inventor: Charles Harold Warman

By Wienderoth, Lind and Ponack
attorneys

April 16, 1968 C. H. WARMAN 3,378,141

FROTH FLOTATION APPARATUS

Filed March 23, 1964 4 Sheets-Sheet 2

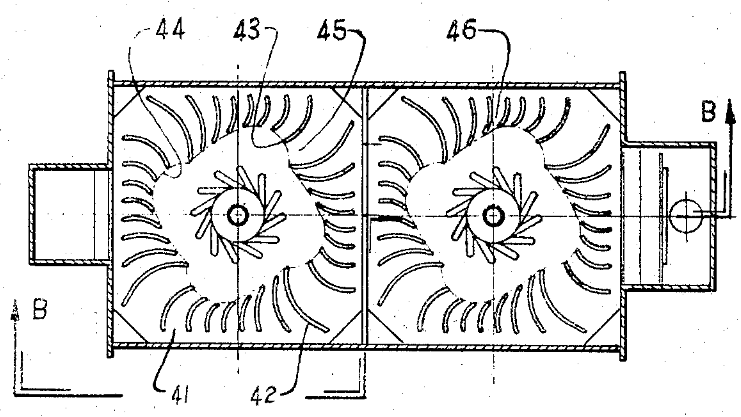


FIG 2

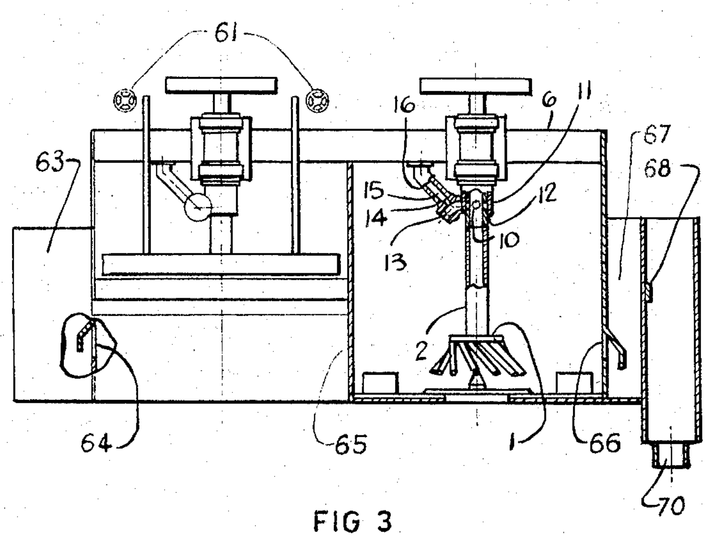


FIG 3

Inventor:
Charles Harold Warman
By Wenderoth, Lind and Ponack
Attorneys

FROTH FLOTATION APPARATUS

Filed March 23, 1964

4 Sheets-Sheet 3

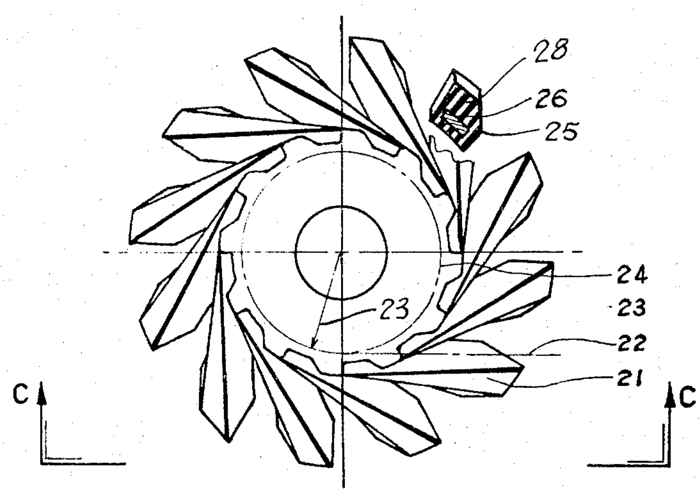


FIG 4

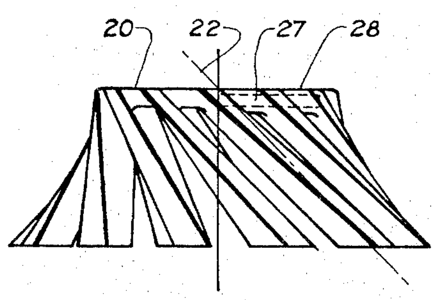


FIG 6

Inventor: Charles Harold Warman

By Wenderoth, Lind and Ponack

Attorneys

FIG. 7

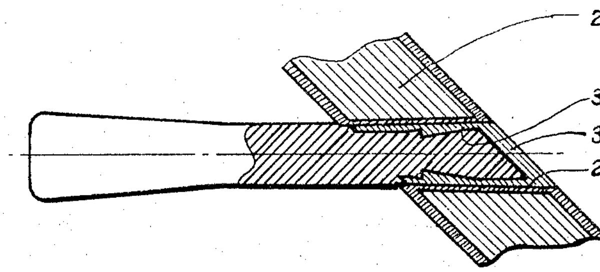


FIG. 8

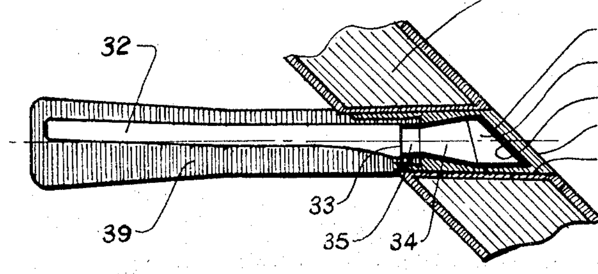
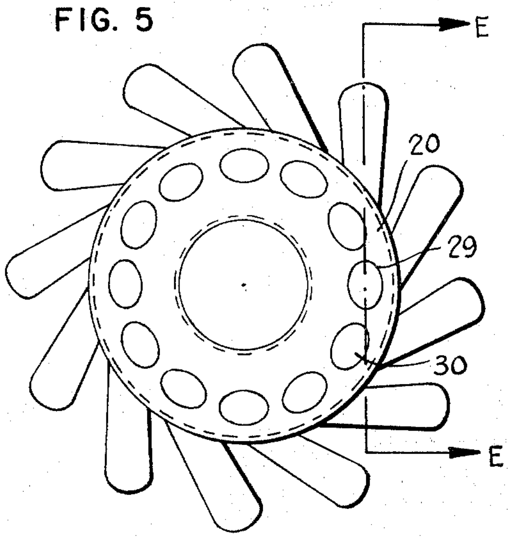


FIG. 5



Inventor: Charles Harold Warman
By Wenderoth, Lind and Ponack
Attorney

United States Patent Office

3,378,141

Patented Apr. 16, 1968

1

3,378,141
FROTH FLOTATION APPARATUS

Charles Harold Warman, Castlecrag, New South Wales, Australia, assignor to Research and Development Pty. Ltd., Perth, Western Australia, Australia, a company of Western Australia

Filed Mar. 23, 1964, Ser. No. 354,026
Claims priority, application Australia, Mar. 28, 1963, 28,944/63
6 Claims. (Cl. 209—169)

This invention relates to flotation concentration processes and aeration and distribution means for performing the like.

Flotation processes are widely used for the concentration of ores and operate by mixing air as bubbles with a pulp in which the ore in a subdivided solid form is maintained in suspension, the pulp having been conditioned in such a manner that a certain component or certain components of the ore adhere and are concentrated in the air-water bubble interfaces and are removed in the froth formed above the pulp by the upward settling of the bubbles, the froth overflowing a weir with or without the assistance of a paddle or scraper.

Other flotation processes are known for concentrating solutions which operate by mixing air as bubbles with the solution which is such that a certain component or certain components of the solution concentrate in the air-water bubble interfaces and can be removed in relatively higher concentration in a froth formed above the solution.

Other processes are in use in which air is required to be mixed with a pulp or solution to dissolve therein and/or perform certain reactions with constituents thereof, the residual gas escaping from the upper surface of the solution or pulp with substantially no formation of froth.

In these processes and the like the efficiency of their operation depends on the effectiveness of the mixing of the air with the pulp or solution and in the case of the flotation process also with the contact achieved between suspended solid particles and air bubbles. Further in the processes in which a froth is removed from above the surface of the pulp or solution, relatively quiescent conditions are required adjacent the surface to allow the bubbles to separate and to minimise entrainment of pulp or solution in the froth and re-entrainment of the froth in the pulp or solution.

Because of the great difference in density between air and the pulp or solution there is considerable difficulty in mixing them and obtaining the necessary contact by dispersion of the mixture throughout the body of pulp or solution since the lower density mixture tends to rise quickly from the mixing zone to the surface of the pulp or solution with liberation of bubbles thereat, the residual mixture of higher density thereafter moving downwards before returning to the mixing zone. One of the chief objects of this invention is to reverse this normal flow pattern by impelling the air-liquid mixture downwardly from the mixing zone thereby increasing the length of the path and the contact of the air bubbles with the pulp or solution before they are liberated at the surface thereof. Further, by impinging the downwardly moving air-liquid mixture from the mixing means against the bottom of the containing vessel or cell in the form of a continuous highly turbulent layer the mixture can be constrained to flow on the bottom of the vessel or cell to the sidewalls thereof before turning upwards towards the surface of the liquid thereby greatly extending the path of the air bubbles and keeping them in extended turbulent contact with the pulp or solution. Another object is to provide relatively quiescent conditions at the surface of the pulp or solution for bubble separation whilst yet employing high energy intensity in the mixing and contacting regions and this objective is attained by impelling the mixture downwardly against the bottom of the vessel or cell as described. A further objective is to enable pulps containing relatively coarse solid particles to be treated, especially in the flotation process. This objective is achieved by the flow characteristics above described, the intense turbulent layer on the bottom of the cell serving to maintain the coarse particles in suspension and facilitate their contact with the air bubbles. Yet another object of the invention is to distribute the air-liquid mixture from the mixing means in as uniform a manner as possible towards the outer limits of the vessel or cell and so enable maximum intensity of mixing and turbulent contact to be employed with the maintenance of a quiescent bubble separating zone above. For this purpose this invention provides a system of curved baffles arranged in a lobed arcuate pattern and attached to the bottom of the vessel or cell.

2

For mixing the air with the pulp or solution this invention provides a rotor mounted for rotation about a substantially vertical axis and provided with inclined surfaces whereby pulp or solution surrounding the rotor is mixed with the air from an axial zone circumferentially delimited and maintained substantially free of liquid by the movement of the inclined surfaces which also serve to impel the resulting air-liquid mixture downwardly. Air is conducted to the axial zone by a passage or passages in or a conduit or conduits attached to the shaft which rotatably supports the rotor.

In one embodiment of the invention the inclined surfaces are provided by inclined rotor bars attached at their upper ends to a disc or boss attached to the vertical shaft supporting the rotor. The axes of the rotor bars may be straight or curved and downwardly the rotor bars may diverge away from the axis of rotation of the rotor. Downwardly the rotor bars may increase in cross-sectional area. Typically the rotor bars are of circular cross-section downwardly increasing in diameter or are any of various blade, vane or elliptical cross-sections of downwardly increasing dimensions and the axes of the bars are straight and downwardly slope in a direction opposite to the direction of rotation of the rotor, the bars being symmetrically disposed with respect to the axis of rotation of the rotor and at a minimum radial distance from the axis adjacent their upper ends where they are attached to the rotor disc or boss. So constructed the rotor is of downwardly increasing outside diameter and its peripheral velocity when rotating likewise increases downwardly causing a downward pumping action on the fluid supplementing the impelling action of the individual inclined bars. The inclination of the bars may vary to suit differing applications but a typical inclination is 45°.

By varying the inclination of the rotor bars to the vertical the characteristics of the rotor performance may be modified. Thus there is for a given rotor construction or geometry an inclination from the vertical at which the downward impelling effect on the liquid is a maximum. A reduction from this inclination decreases the downward impelling effect in absolute terms and also relatively to the rate at which air is mixed, assuming the tip speed of the rotor bars and the pressure of the air relative to that of the liquid surrounding the rotor remain unchanged, and hence the ratio of air to liquid in the mixture leaving the rotor increases. If the inclination is successively reduced from that giving maximum downward impelling effect a point is reached at which the buoyancy of the air-liquid mixture overcomes the downward impelling effect and the mean vertical component of the momentum of the mixture leaving the rotor then changes from downwards to upwards. At this point the rotor would cease to perform in accordance with this invention. If the inclination from the vertical is successively increased from that giving maximum downward impelling effect this effect again diminishes and again a point is reached where the buoyancy of the air-liquid mixture overcomes the downward impelling effect and the means vertical component of the momentum of the mixture leaving the rotor changes from downwards to upwards. The scope and operation of a rotor according to this invention therefore lie between these limiting points.

With a given rotor constructed in acordancec with the invention the power absorbed, air mixing rate and mixture flow rate are functions of the speed of rotation and the pressure of the air relative to that of the liquid surrounding the rotor and it is a feature of this invention to control the power input, air mixing rate and mixture flow rate by varying the rotor speed and/or the pressure of the air relative to that of the liquid surrounding the rotor.

A feature of this invention is the provision of convenient means for detaching and replacing the elements of the rotor that may be subject to wear in operation or for modifying its performance. Thus the rotor bars may be provided at their upper ends with tapered portions upwardly divergent and adapted to fit and be self holding by friction in sockets, or in inserts therein, of complementary shape in the rotor disc or boss. The rotor bars may also be provided with replaceable covers of wear and/or corrosion resisting material. The rotor disc or boss may be provided with a downwardly divergent conical bore adapted to fit and be self holding on a corresponding conical surface on the shaft. So constructed worn parts may be readily removed and replaced and rotor bars of different form, spacing, number and inclination can be fitted to provide various combinations of rotor characteristics to suit a wide range of process requirements.

For removal of the froth from above the surface of the pulp or solution this invention provides a horizontal paddle actuated from above by oscillating arms and hangers to describe a flattened elliptical transverse motion whereby on the lower portion thereof the froth is pushed towards and caused to overflow a horizontal weir by which it is separated from the pulp or solution.

Some specific forms of the invention are illustrated in the accompanying drawings wherein:

FIG. 1 is an axial section of a cell of a flotation machine adapted to perform the process according to the invention;

FIG. 2 is a sectional plan on the line AA of FIG. 1;

FIG. 3 is a sectional elevation on the line BB of FIG. 2;

FIGS. 4 and 5 are plan views of variant forms of rotor;

FIG. 6 is an elevation on the line CC of FIG. 4;

FIG. 7 is a sectional view of a replaceable metal rotor bar; and

FIG. 8 is a sectional view on line EE of FIG. 5.

Like parts are illustrated by like characters throughout the specification and drawings.

As shown in the drawings **1** is a rotor mounted on a hollow vertical shaft **2** for clockwise rotation (as viewed in plan) and submerged in a pulp or solution **3** contained in a cell **4** and having an upper free surface **5** through which the shaft **2** passes. The cell **4** is provided with a longitudinal hollow member **6** which mounts the driving motor **7** and the shaft and bearing assembly **8** which rotatably supports and locates the hollow vertical rotor shaft **2**. A belt and pulley drive **9** of any suitable form is arranged to transmit power from the motor shaft assembly to rotate the rotor at any given predetermined speed.

The upper portion of the hollow rotor shaft **2** is provided with a plurality of holes **10** in the wall thereof through which air may pass from the annular space around the shaft enclosed by the housing **11** attached upwardly to the underside of the bearing assembly **8** and having at its lower end a labyrinth seal **12** disposed with close running clearance around the shaft **2** adjacrent below the holes **10**. The housing **11** incorporates a two-way air control valve **13** which admits air to the housing at a controlled rate either from the atmosphere through the port **14** or via port **15** and piping **16** from the hollow member or manifold **6** which may be supplied with air or other gas at above atmospheric pressure by a fan or other suitable means.

At its lower end the shaft **2** has externally a downwardly divergent conical surface **17** which is self-holding and self-driving in a corresponding conical bore **18** in the boss **19** of the rotor disc **20**. Attached to the disc at their upper ends are the equally spaced rotor bars **21** which, in the form of rotor depicted, are straight and downwardly sloped at 45° in a direction opposite to the direction of rotation of the rotor. As shown in FIGS. 4 and 5 the axes **22** of the bars **21** are at right angles to the radii **23** of minimum length drawn from the axis of rotation of the rotor to the pitch circle **24** of the bar axes within the rotor disc so that downwardly from the rotor disc an envelope of the rotor bars is of increasing diameter.

FIGS. 4 and 6 illustrate rotors in which the rotor bars shaped in cross-section as shown at **25** are integral with the rotor disc **20**. The figures illustrate rubber covered metal construction. In the rubber covered construction illustrated in the figures metal rotor core bars **26** are cast integral with the metal disc reinforcing member **27** and a moulded rubber covering **28** is bonded to and entirely covers the metal reinforcement with rubber thickness so disposed that all parts of the rotor have approximately the same wear life epectancy.

In FIG. 5 are illustrated rotors with detachable rubber covered bars for which the rubber covered metal rotor disc **20** is provided with tapered upwardly divergent sockets **29** adapted to receive tapered inserts or collets **30** constructed in halves and of any suitable material such as a plastic of suitable rigidity and wear resistance outwardly conforming to the sockets **29** and internally shaped to conform with the upper ends of the detachable rotor bars. FIG. 7 illustrates in a section a construction suitable for the attachment to the rotor disc of a replaceable metal rotor bar. The bar illustrated is circular in cross-section and provided with an upwardly divergent conical surface **31** conforming to the inner surface of the split inserts or collets **30**. To attach the bar to the rotor the tapered end **31** of the bar is passed through the socket **29** in the rotor disc from the underside thereof, the half collets **30** placed around the tapered rotor bar end and the assembly so formed then pushed or driven downwardly into the self-holding conical socket **29** in the rotor disc. FIG. 8 illustrates in a section on the line EE of FIG. 5 a construction suitable for the attachment of a rotor bar with a replaceable rubber cover. The bar illustrated is circular in cross-section and comprises a metal core bar **32** downwardly reducing in diameter from a step or shoulder **33** and upwardly increasing in diameter as at **34** from a parallel section **35** adjacent the step **33**. At its upper end the core bar has a cylindrical portion **36** which is truncated by a plane end surface **37** sloping with respect to the bar axis at the angle of inclination thereof so as to lie in a level plane when the bar is in position in the rotor disc **20**. A protective cap **38** of thin rubber or equivalent extensible material is placed over and conforms to the portion of the core bar above the step **33** and a thick slip-on wear resistant cover **39** is placed over the lower portion of the core bar and is provided with an internal step and parallel section conforming to the step **33** and parallel section **35** on the core bar which serve to retain the cover **39** in place when the split collet **40** is placed in position around it and the assembly so formed has been pushed or driven into the self-holding conical socket **29** in the rotor disc.

To suppress the angular momentum or vorticity about the vertical axis of the mixture downwardly leaving the rotor and to direct and distribute it in a substantially uniform manner towards and against the side walls of the cell the removable bottom liner plates **41** thereof are provided with a combination of vertical baffle plates **42** curved in plan and so arranged that the distances of their leading edges **43** from the centre of the cell vary and a curve **44** joining them presents in plan view a four-lobed arcuate figure symmetrical about the centre of the cell. The space between the baffles also varies, being widest as at **45** between those baffles which direct the flow towards the corners of the cell and a minimum as at **46** between those which direct the flow to the mid portions of the cell walls. The plan curvature of the individual baffles is such that at their leading edges the baffles lie substantially in the direction of the flow approaching from the rotor and at their trailing edges their direction is such as to direct the flow leaving them substantially at right angles to the walls of the cell. As shown in the drawings the minimum distance from the centre of the cell of baffle leading edge is substantially greater than the maximum radial dimension of the rotor so that the mixture flow from the rotor impinges and turns outwards on the floor of the cell before entering the baffles. To secure the removable liner plates **41** which carry the baffles a circular clamping plate **47** overlapping the inner edges of the liner plates **41** is downwardly tightened by clamping nut **48** and stud **49** attached to the bottom of the cell.

The vertical location of the rotor with respect to the bottom of the cell is not critical but optimum results are obtained when the clearance between the bottom of the rotor and the bottom of the cell are of the order of one-fourth the bottom outside diameter of the rotor. Likewise the height of the curved baffle plates **42** is not critical, but a minimum height approximately one-fourth the bottom outside diameter of the rotor is desirable. So arranged the top of the baffle plates is at the same elevation as the bottom of the rotor bars.

To assist the overflow of the froth layer **50** from the cell **4** the invention provides when necessary a horizontal froth paddle **51** supported and actuated by hangers **52**, arms **53** and drag links **54** said arms and drag links being so actuated by a rotating eccentric and linkage system **55** that the pinned connections **56** and **57** between the arms **53** and drag links **54** respectively and hangers **52** execute the traces shown in FIG. 1 and the paddle **51** describes in the direction of the arrows the flattened elliptical shaped path indicated by the dotted line **58** and the froth is pushed by the paddle towards and over a slatted weir **59** adjustable as to height by placing slats of varying width in the slots **60** arranged to accommodate them. By means of a handwheel **61** the fulcrum point **62** of the eccentric and linkage system **55** may be changed and the elevation of the paddle path **58** adjusted to suit the height of the froth overflow weir **59**.

The use and operation of the invention may conveniently be described by considering a flotation machine comprising two cells operating in series as depicted in FIGS. 1, 2 and 3 although it will be apparent that any convenient number of cells may be operated as a series bank. Pulp or solution to be processed enters the machine from the feed box **63** and passes successively through the cells via openings **64**, **65** and **66** in the transverse walls thereof to the discharge box **67**. A slatted tail weir **68** adjustable for height by adding or removing slats is provided in the discharge box **67** for controlling the height of the surface of the pulp or solution in the cells **4** at a predetermined level below the froth overflow lip **69** and above the top of the rotor disc **20**. Processed pulp or solution overflowing the tail weir **68** is discharged from the machine through the pipe opening **70** in the bottom of the discharge box **67**. With the rotors turning clockwise in plan at a rotational speed equivalent to a linear speed of 30 to 40 feet per second at the maximum diameter of the rotor bars, an axial zone **71** within and beneath the rotor with boundaries approximately as indicated by the chain dotted line **72** is maintained substantially free of liquid by the outward and downward impelling action of the inclined surfaces **73** of the rotor bars **21**. Around the boundary of the axial air zone **71** and extending into the region of intense turbulence adjacent the surface of revolution generated by the outer limits of the rotor bars **21** lies a mixing zone **74** in which pulp or solution entering downwardly from the upper regions of the cell is mixed with air from the contiguous axial zone **71** and the resulting mixture impelled downwardly and outwardly from the mixing to impinge on the bottom of the cell **4** in an annular area adjacent the periphery of the clamp plate **47**. The mixture flowing outwardly on the bottom of the cell from the area of impingement thereon passes between the baffles **42** and is distributed in substantially a uniform manner at right angles towards and against the sidewalls of the cell thereafter rising towards the upper free surface **5** of the liquid, turning at and adjacent said surface and flowing substantially parallel thereto with separation of bubbles from the mixture to form the froth above, the residual mixture thereafter turning and flowing downwardly to the mixing zone **74**. The path of the mixture flow as above described is shown approximately in FIG. 1 by arrows in the body of the liquid in the cell.

The froth layer **50** which forms above the liquid surface **5** may be flowed between adjacent cells through openings such as **65** for removal from a cell other than that in which it was formed or it may be contained within and removed from the cell of its formation by insertion of the isolating froth boards **75** in the slots provided. Usually the froth is sufficiently mobile to overflow the froth weir **59** without assistance. Viscous or copious froths may require for their removal from the cell the use of paddle mechanism such as herein before described.

In this description of the invention the term "air" is to be understood to mean "air or other gas."

What I claim is:

1. A flotation concentration apparatus comprising a vessel or cell for holding suspension, feed means feeding a suspension into said vessel or cell, discharge means for discharging a non-floated product from said vessel or cell, froth discharge means for discharging a froth product from the vessel or cell, a rotor in said vessel at a level to be submerged in said suspension, a hollow axial shaft on the bottom of which said rotor is mounted with the bottom of the shaft opening into said rotor, gas admitting means feeding gas into said hollow shaft for delivery into the interior of said rotor, rotating means coupled to said hollow axial shaft and rotating said rotor about a substantially vertical axis, said rotor comprising a generally horizontal boss or disc spaced from the bottom of the vessel or cell and supporting a plurality of bars attached thereto at their upper ends in uniform angular relation, symmetrically about said vertical axis, the enveloping peripheral diameter of said bars about said vertical axis diverging downwardly toward the bottom of the vessel or cell, the bars being inclined so that downwardly successive cross sections in horizontal planes of said bars have, with respect to said vertical axis, angular displacements in a direction opposite to the direction of rotation of the rotor, the lower end of the bars being spaced from the bottom of the vessel or cell sufficient to establish and maintain an axial zone free of liquid within and beneath said rotor.

2. A floation concentration apparatus as claimed in claim **1** in which said gas admitting means comprises a housing around the top of said shaft and at least one opening in said shaft within said housing through which the gas is conducted to the hollow shaft.

3. A flotation concentration apparatus as claimed in claim **2** in which said housing encompassing the shaft is sealed to it on either side of said gas admitting opening so as to form a closed annular space around the shaft, and a controllable setting two-way valve in said housing through which gas is transmitted to said annular space at the desired pressure.

4. A flotation concentration apparatus as claimed in claim 1 in which the rotor bars increase in cross-sectional area downwardly.

5. A flotation concentration apparatus as claimed in claim 1 in which the vessel has a substantially square cross-section, and said apparatus further comprises a removable bottom liner plate and a plurality of vertical baffle plates curved in the horizontal direction and attached to said removable bottom liner plate, for distributing the flow in the cell, the distances of the inner ends of the baffle plates from the center of the cell varying so as to produce in plan view a four lobed arcuate pattern, and the space between adjacent baffles also varying, being widest between those baffles which direct the flow towards the corners of the cell.

6. A floation concentration apparatus as claimed in claim 1 in which the rotor disc is readily detachable from the shaft said rotor disc has an axial downwardly divergent conical bore, and said shaft having a corresponding conical surface thereon on which the rotor disc fits and is self-holding.

References Cited

UNITED STATES PATENTS

1,921,220	8/1933	Daman	209—169 X
1,919,970	7/1933	Woods	29—156.8
2,180,120	11/1939	Saltzer	287—124
2,232,388	2/1941	Ingalls, et al.	209—169
2,337,806	12/1943	Fahrenwald	209—169
2,673,724	3/1954	Potts	209—169 X
2,684,233	7/1954	Payne	209—169 X
2,892,543	6/1959	Daman	209—169
2,944,326	7/1960	Stadthaus et al.	29—156.8
3,041,050	6/1962	Nelson et al.	259—107
3,070,229	12/1962	Benozzo	209—169
3,067,988	12/1962	Rodoz	261—93 X

FOREIGN PATENTS

436,041	10/1935	Great Britain.

FRANK W. LUTTER, *Primary Examiner.*

HARRY B. THORNTON, *Examiner.*

L. H. EATHERTON, *Assistant Examiner.*