Oct. 14, 1941. A. C. DAMAN 2,259,243

FLOTATION APPARATUS AND METHOD

Filed Feb. 5, 1938 3 Sheets-Sheet 1

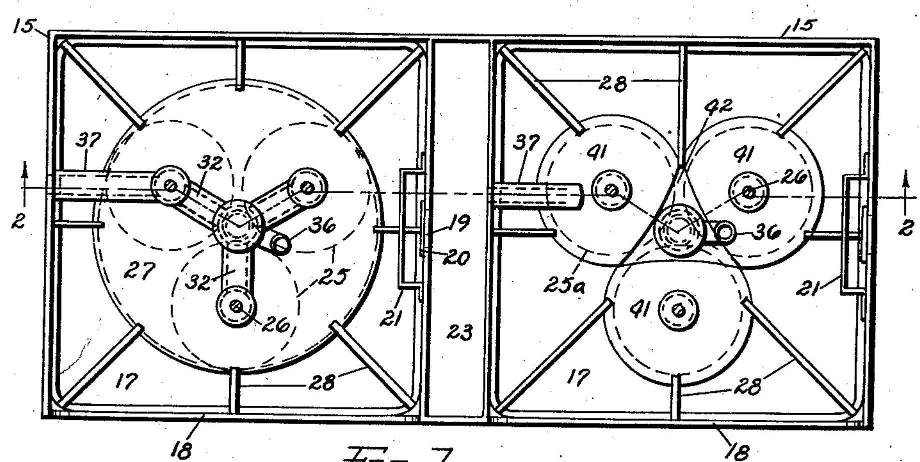

Fig 1

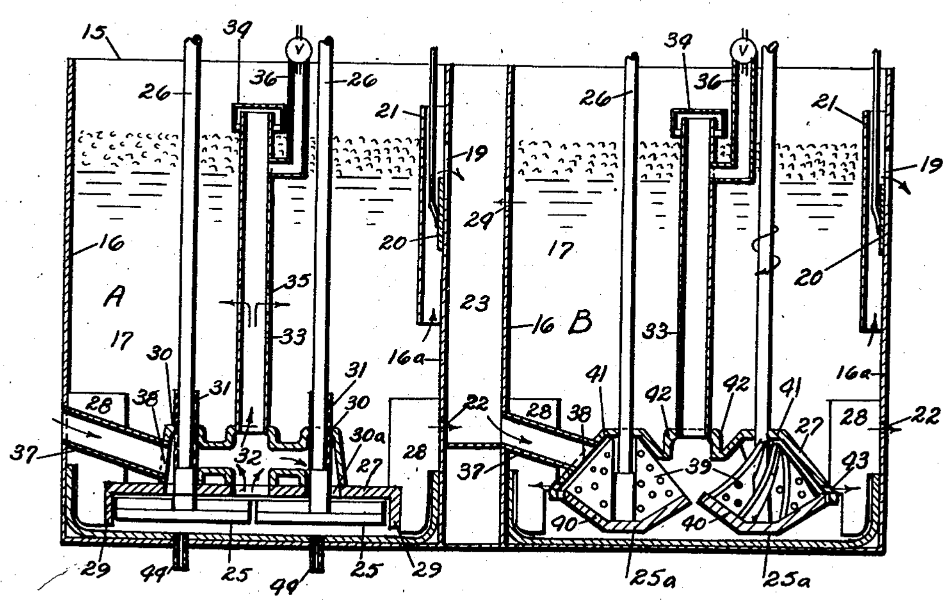

Fig 2

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FLOTATION APPARATUS AND METHOD

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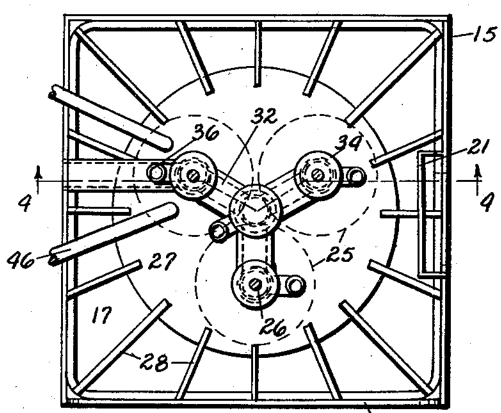

Fig 3

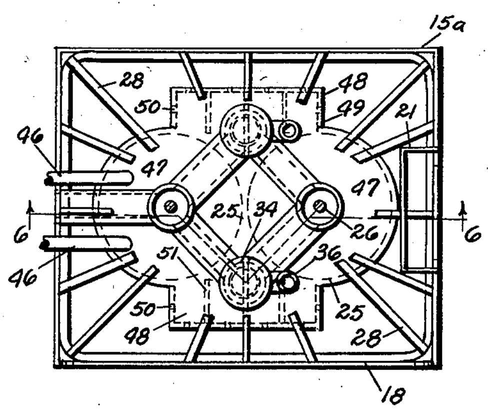

Fig 5

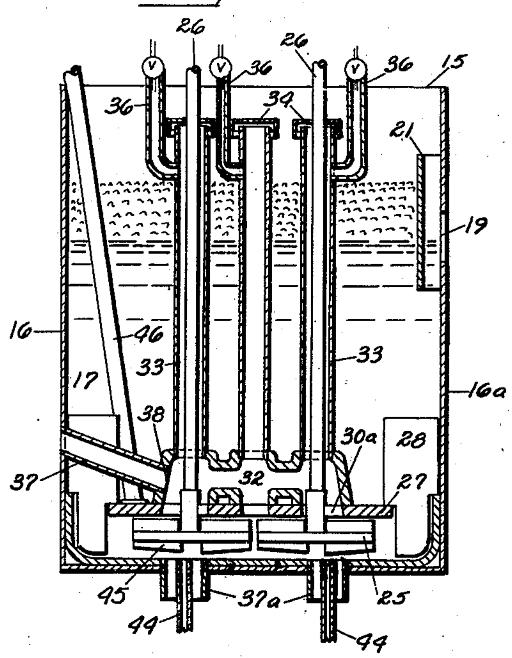

Fig 4

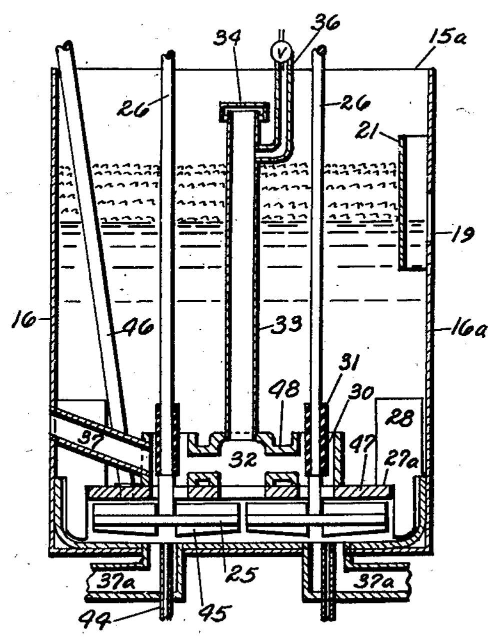

Fig 6

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FLOTATION APPARATUS AND METHOD

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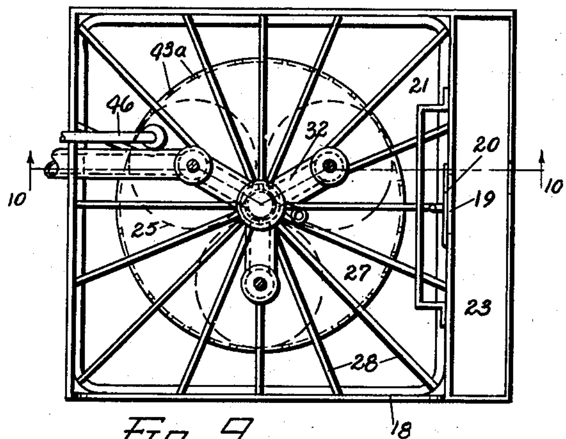

Fig 9

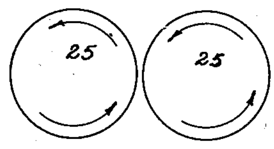

Fig 11

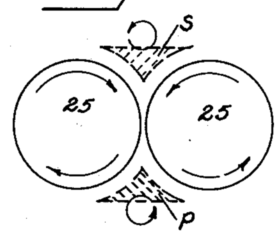

Fig 12

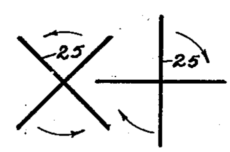

Fig 13

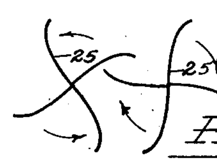

Fig 14

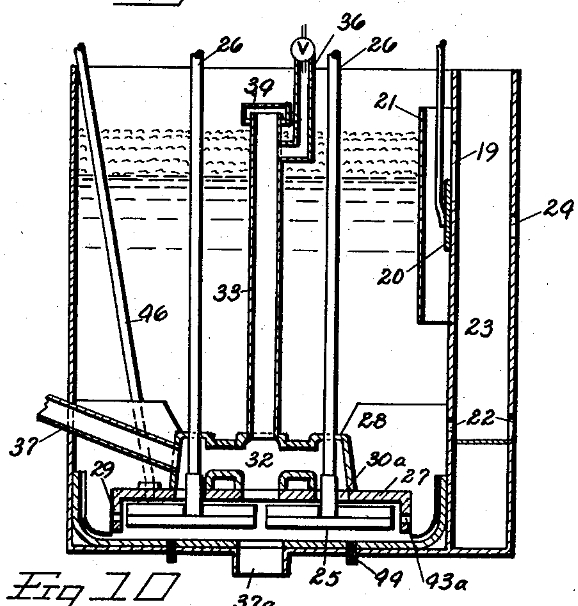

Fig 10

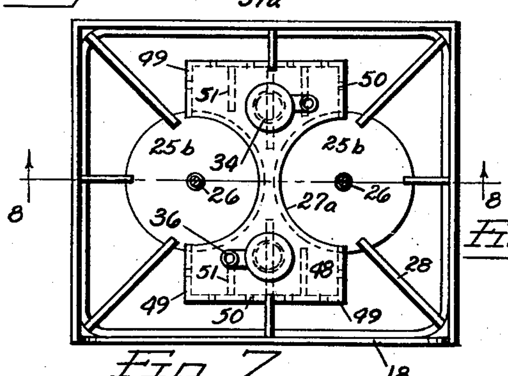

Fig 7

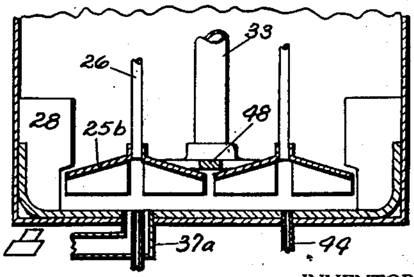

Fig 8

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Patented Oct. 14, 1941 2,259,243

UNITED STATES PATENT OFFICE

2,259,243

FLOTATION APPARATUS AND METHOD

Arthur C. Daman, Denver, Colo., assignor to Mining Process and Patent Company, Denver, Colo., a corporation of Colorado

Application February 5, 1938, Serial No. 188,872

21 Claims. (Cl. 209—165)

This invention relates to apparatus for and methods of froth flotation, and more particularly relates to improvements in agitation and aeration in such a process.

It it a primary object of the invention to induce a relatively widespread diffusion of gas throughout a body of pulp under treatment by a circulatory movement of pulp and gas through a zone of compression before release into the separation zone of the treatment.

Another object of the invention is to provide an intimate intermixture of solids, gas and reagent in a zone of agitation while controlling the discharge of such intermixture from the agitation zone into a zone of separation.

A further object of the invention is the provision of a novel type of agitation in a flotation cell induced by the action of a plurality of impeller elements rotating in opposed relation within a restricted zone.

Still another object is the provision of a novel method of recirculating valuable constituents, suspended in the pulp liquid below the froth body, through the agitation zone of the treatment.

Other objects reside in novel combinations and arrangements of parts, and novel steps and treatments, all of which will appear more fully in the course of the following description.

In the froth flotation process, ore in finely-divided condition is agitated in liquid in the presence of air or other suitable gas, while being subjected to the action of a reagent having a selective affinity for one or more of the mineral constituents. The finely-divided gas bubbles carry the mineral so treated to the surface where it collects in a froth and is removed as a concentrate.

Since the gas is the elevating medium of the process it is important that gas of the treatment be brought in contact with the greatest possible surface of the mineral content. It is likewise important that the reagent be brought in contact with the greatest possible mineral surface. To this end, the mineral and reagent are frequently mixed in advance of the flotation treatment, although in many operations it will be preferred to introduce the reagent directly into the flotation cell.

From the foregoing it is apparent that an intimate intermixture of mineral, gas and reagent in advance of separation is a desideratum, and the present process is designed to attain a high degree of such intermixture by and during the agitative action of the process.

To this end, provision is made for the creation of a zone of compression in the agitation stage, through which mineral and reagent are circulated in the presence of the gas of the treatment. As a result of such compression, large quantities of gas are entered into solution, and because of the agitation a thorough and intimate intermixture of solids and liquid is obtained.

Thereafter, the compressed material is discharged into a zone of separation maintained under atmospheric pressure, and the pressure differential between the zones of separation and compression causes the dissolved and entrapped gases to rise through the liquid of the pulp to the surface.

The mineral to be recovered is surface coated in the compression zone by the gas-reagent liquid and the subsequent pressure release creates a wide diffusion of gas rising as bubbles, many of which form, in surface contact with the mineral, while others during their ascension are in such close association as to exert a sweeping action on substantially all suspended mineral particles in the separation zone, with the result that the flotation reaction attains a high degree of efficiency.

Some of the mineral particles in suspension will be lacking in sufficient contact with the reagent to be carried into the froth, and provision is made for retreatment of this material by recirculating the same through the compression zone where it is again subjected to the intimate intermixture with the gas and reagent.

Because of the widespread diffusion and fine size of the gas bubbles rising through the liquid, the aeration of the present process is relatively gentle, and little, if any, of the mineral being elevated or held in the froth is subjected to any jarring influence sufficient to break the surface tension and permit descent of the mineral.

As a result of the action aforesaid, a high degree of separation will be attained in a relatively short operating interval, thereby increasing the treatment capacity of a machine of a given size.

While the treatment aforesaid may be incorporated in a variety of apparatus, certain essential features will of necessity be incorporated in any such structure, and to illustrate the operation, as well as to give a better understanding of such essential features, reference will be made to the accompanying drawings, in which apparatus adapted for performing the invention has been illustrated.

In the drawings, in the several views of which like parts have been designated similarly,

Figure 1 is a plan view of two cells of a multi-cell flotation machine embodying features of the present invention;

Figure 2 is a section taken approximately on the line 2—2, Figure 1;

Figure 3 is a plan view of another embodiment of a flotation cell of the type illustrated in Figures 1 and 2;

Figure 4 is a section taken approximately on the line 4—4, Figure 3;

Figure 5 is a plan view of a modified type of a flotation cell;

Figure 6 is a section taken approximately on the line 6—6, Figure 5;

Figure 7 is another embodiment of a flotation cell of the type illustrated in Figures 5 and 6;

Figure 8 is a fragmentary section, taken along the line 8—8, Figure 7;

Figure 9 is another embodiment of a flotation cell of the type illustrated in Figures 1 and 2;

Figure 10 is a section taken approximately on the line 10—10, Figure 9;

Figure 11 is a diagrammatic representation of one form of impeller operation employed in a cell of the type illustrated in Figures 5 and 7;

Figure 12 is a diagrammatic representation of another form of impeller operation employed in a cell of the type illustrated in Figures 5 and 7;

Figure 13 is a diagrammatic representation of an arrangement of open-type impellers intended for use in a cell of the type illustrated in Figures 5 and 7; and

Figure 14 is a diagrammatic representation of an arrangement of another type of open impellers intended for use in a cell of the type illustrated in Figures 5 and 7.

Referring first to the apparatus illustrated in Figures 1 and 2, the reference numeral 15 indicates a tank, divided by suitable partitions 16 and 16*a* into a plurality of flotation cells 17. Each cell has one of its sides terminating at its top in a froth overflow lip 18, and while not illustrated, it will be understood that suitable launders are provided below the lips 18 to catch the overflowing froth and conduct it to the next stage of the milling operation.

The walls or partitions 16*a* of each of the cells are slotted as indicated at 19 to provide a weir discharge for such cell, and a suitably mounted gate-member 20 is slidable along the walls 16*a*, to vary the effective elevation of the discharge outlet 19. Preferably such gates are screw-actuated, although any satisfactory means of level regulation may be employed.

An open-ended casing 21 fixed on each wall 16*a* extends from an elevation above the maximum froth level to a point well below the same and defines a discharge passage to the weir overflow, through which tailings are removed from the cell while effectively preventing escape of froth other than across overflow lip 18.

A sand relief hole 22 is provided in each wall 16*a* to permit escape of heavy solids which tend to settle and would otherwise collect on the cell bottom. The walls 16 and 16*a* of adjoining cells are spaced apart to provide a feed passage 23, and the wall 16 is apertured a short distance below the liquid level as indicated at 24 to recirculate a portion of the non-floated solids by discharge into passage 23. This recirculation action will be explained in detail hereinafter, and it will be understood that the openings 24 are usually provided in the walls 16 of each cell of a multi-cell machine other than the first cell.

The structure thus far described is typical of the well-known "Denver 'Sub-A' flotation machines," which illustrates the adaptability of the present invention to conventional constructions.

In the present construction, a plurality of impeller-elements 25 are carried on suitable shafts 26 and disposed at a substantially uniform distance from the bottom of each cell 17, and preferably in proximity thereto. In the form of the invention illustrated in Figures 1 and 2, three impellers are so mounted, with their shafts defining a triangle to position adjoining peripheral surfaces of the impellers in close proximity.

A cover-element 27 supported on baffles 28 in superposed relation to the respective impellers 25 is preferably of disk-shaped contour of a size slightly greater than the combined spheres of rotation of the impellers 25, and has a flanged rim 29 extending lower in the cell than the bottom edges of the impellers 25.

The upper and lower surfaces of the cover-element 27 are suitably apertured as indicated at 30 and 30*a* to admit the respective shafts 26, and if desired, rubber or other erosion-resisting sleeves 31 may be mounted on the shafts 26 where they enter the openings 30 to prevent excessive wear.

Interconnecting passages 32 extend laterally in converging relation from the shaft-enclosing portions of cover-element 27, and the upper surface of element 27 is apertured at the point of convergence to admit a hollow column 33, which extends above the liquid level in the cell and is provided at its upper end with a cap or closure 34, slidable thereon, and acting as a valve to control air passage therethrough.

The column 33, intermediate its ends, is apertured as indicated at 35 in this form of cell, and a valve-controlled branch 36 extends from the column upwardly in the cell above the liquid level.

A feed inlet 37, preferably in the form of a conduit, fitted in an opening 38 in cover-element 27 delivers incoming feed to the impellers 25 in each of the cells 17, the conduit 37 of the first cell of a multi-cell machine, or of a unit cell being connected with a suitable supply conduit for this purpose, while the second and subsequent cells of a multi-cell machine are supplied by the passages 23.

To distinguish the cells 17 in the machine of Figures 1 and 2, the first cell has been designated A, while the letter B has been used to designate the second cell, which letter may be used also to designate any subsequent cells.

In cell B of Figures 1 and 2, a slightly different form of cover-element 27 from that shown in cell A is employed to permit use of a different type of impeller-element. The impellers 25*a* of this cell are formed by a dished plate 40 carrying on its upper surface a plurality of blades 39, either upright or disposed at an inclination to elevate matter acted on during their rotation.

The cover for this type of impeller comprises three conical hoods 41 joined by a triangularly-shaped central portion 42 apertured to admit a column 33 and associated parts, but having no openings corresponding to the openings 35 of cell A. In addition, discharge ports 43 are provided at the peripheries of the hoods 41 adjacent the periphery of the dished surfaces 40. Unrestricted communication between the impellers 25*a* is provided by elimination of the passages 32.

In operation, pulp and reagent are fed into cell

A through the inlet 37, and descend onto the impellers 25. At the same time, air or other gas, under pressure, is admitted through valve-controlled jets 44 into the zone of influence of the impellers 25, and the rotation of the impellers causes violent intermixing of air, reagent and pulp due to impinging the discharge of the several impellers in a common restricted zone under the resulting centrifugal influences.

As a result, a portion of this material rises from the impinging streams and enters the passages 32, being returned thereby to the impellers 25. The annular baffle 29 so restricts the discharge of the impellers that the intermixture aforementioned is compressed, causing large quantities of the gas to dissolve in the liquid. The compression forces the intermixture through the passages 32 into the column 33 where it finally discharges through the openings 35.

The release of pressure on the compressed matter so discharged, permits the dissolved and entrapped gas to rise to the surface in the form of finely diffused bubbles and these bubbles by reason of their intimate association with the mineral constituents of the pulp and the reagent carry the valuable constituents to the surface where they collect in a froth and are moved across the overflow lip 18 in any suitable manner (not shown).

It will be appreciated that the action of the rotary impellers within the compression zone brings gas, pulp and reagent into frequent and intimate association, and by reason of the delayed passage of material from said zone as a result of the restriction of the discharge and the recirculating influences, the intermixture rising in column 35 contains mineral particles effectively coated by the reagent and intimately associated with the gaseous medium by which they will be elevated after the pressure release.

The non-floated solids in cell A discharge over weir 19 or through the sands relief outlet 22, and are subjected to further mixing in the passage 23 due to the cascading action. The material after mixing enters inlet 37 of cell B and passes under the hoods 41 to be acted on by the impellers 25*a*.

This material is then subjected to further mixing with air or other gas. By regulating the position of the cap 34 and the valve in branch 36, the amount of air under pressure admitted to column 33 may be controlled, and this air after passage through the column discharges beneath the hood 42, where it is subjected to the action of impellers 25*a*.

At the same time, additional reagent may be introduced for mixing, and if desired this reagent also may be fed to the mixing zone through branch 36 and column 33, or otherfise. In any event, reagent carried in the pulp from the preceding cell will be present, and the mixing in the agitation zone of cell B also results in an intimate intermixture of air, reagent and mineral.

As illustrated, the blades 39 of the impellers 25*a* may be either upright or inclined, and preferably are apertured to permit a portion of the material acted on to pass through the blades. Because of the dished surface of the impellers an elevating movement is imparted to material so acted upon, and because of the space restriction imposed by the hoods 41 and 42 compression results, again causing large quantities of air to enter into solution.

Material thrown out by the impellers 25*a* passes through the restricted ports 43 and is then free to ascend through the separation zone of the cell. The baffles 28 restrain the agitation in the lower portion of the cell and counteract any vortex tendency.

Due to the combined action of the reagent and the aeration, the valuable constituents are carried to the surface and collected in a froth for subsequent removal across overflow lip 18. The non-floated solids are again discharged from the cell over weir 19 and through outlet 22.

A portion of the mineral is sometimes imperfectly elevated and collects near the surface within the pulp body, requiring treatment with additional reagent to produce the necessary reaction for carrying it into the froth.

This material is recirculated through the opening 24 into passage 23 back to the impellers 25*a*, where it is again subjected to compression and intimate intermixture with entering pulp, air and reagent to give it additional coating. Thereafter, upon discharge it ascends under the influence of the aeration and collects in the froth.

In connection with the foregoing operation, it will be understood that for any given treatment the correct pulp density and gas-reagent ratio will be determined in advance and during treatment according to common practice in the art.

The gas admitted is subject to regulation by control of the valved branch 36 which may be employed for this purpose, or by adjustment of valve 34 or by regulation of valve-controlled jets 44. A certain amount of air will also be entrained by the cascading action of material in passage 23, but since this amount is relatively small, the introduction of air by other means will be necessary to give the desired aeration, and being subject to regulation, such means provide a close quantitative control of gas admission.

Further, the gas-regulating means provide a compression control as the operation of valve 34, and the valve in branch 36 affects the resistance developed below the cover-element 27, and since the compression is a factor of the intermixture, this control in turn defines a degree of the intermixture attained.

Thus it will be understood that the regulations of the operation as herein defined serve to render the apparatus and process amenable to close control at all times and in treatments where proportions are critical the process as performed in apparatus of the character described will attain a high degree of efficiency.

The other forms of three-impeller type cells illustrated herein are similar in essential features to the cells A and B of Figures 1 and 2, and it will be understood that as each of these cells is best suited for particular treatments, a given form will be selected according to treatment requirements, and in some instances certain cells will be of one form while other cells are of a different form, as illustrated in Figures 1 and 2.

The cell illustrated in Figures 3 and 4 is adapted for use either as an A or B cell of a multi-cell machine, and may be used by itself or in association with other forms of cells illustrated herein.

In this form the annular flange 29 on cover-element 27 has been omitted, and each of the shafts 26 is encased in a column 33, provided with a valve-controlled branch 36. The openings 35 are also omitted in the columns 33 and the closure 34 is apertured for passage of the shaft 26 therethrough. The impellers 25 are provided on their lower surface with vanes **45** to suck in material from a feed inlet **37a**, suitably connected with a source of supply (not shown), and also for sweeping the cell bottom to prevent any accumulation of sands thereon.

There is provided also a feed tube **46** extending into the cell from an elevation above the liquid level and terminating in an opening in the cover-element **27**. This tube may be used to supply reagent, gas or even pulp, but is usually employed as a reagent feeder.

The operation of this cell is similar to that hereinbefore described. Material is agitated, mixed and forced upwardly into passages **32** and columns **33**, the resistance therein being regulated by the valved branches **36** and valves **34**. The admission of pulp, gas and reagent is controlled as desired to effect proper mixing and dissolution of gas in the agitation zone.

Inasmuch as there is less restriction to discharge of material by the impellers, it may be preferable to increase the number of baffles **28** in order to avoid undue turbulence in the separation zone. The recirculation opening **24** while not illustrated may be employed in this cell, if desired, in which case, a portion of the solids previously treated would return through inlet **27** and again be subjected to the agitation and compression influences.

The form of cell illustrated in Figures 9 and 10 is generally similar to cell A of Figures 1 and 2. A feed tube **46** is also shown in this form of cell structure, and it will be understood that these tubes may be incorporated wherever desired in the several forms.

Apertures **43a** in the annular baffle or rim **29** permit restricted discharge of matter from the impellers, but because of such restriction an effective compression zone is created beneath cover-element **27**.

In this connection, the passages **32** may be of sufficient cross-sectional area to circulate all the matter elevated by the impellers without restriction, in which case compression will be confined to the lower portion of the agitation compartment.

The free circulation of the intermixture through passages **32** exerts a suction or pumping influence on column **33**, as a result of which large quantities of air will be drawn down, whenever the upper end of the column is left open by proper adjustment of closure **34**.

Therefore, whenever it is desired to eliminate the expense of supplying gas under pressure, aeration can be effected in this manner, and while the feature is illustrated with specific reference to Figure 10, it will be understood that it may be used in the various cell constructions illustrated, so long as the column **33** is not used as a conveying medium for the compressed body.

Further, it should be noted that by extending a portion of each baffle **28** to the cell bottom, any centrifugal movement of the discharged matter is effectively converted into an upward linear movement, further aiding in the diffusion of the ascending gas bubbles rising to the surface.

In operation, the material in the cell of Figure 10 is agitated, compressed, and recirculated in the manner hereinbefore described, and it will be understood that the compressed matter will not rise in column **33** because of the capacity of passages **32** and also because there is less restriction to discharge laterally of impellers **25**.

The controls of gas-admission, reagent and pulp feed and of compression are likewise provided in this cell as will be apparent by reference to Figures 9 and 10. The baffles in this form are shown as extending over the cover **27** (Figure 9) to a greater degree than the baffles illustrated in the other forms.

It will be understood that in any of the three-impeller type cells, all impellers may rotate in the same direction, or one impeller may rotate in a direction opposite to the others.

From the foregoing, it will be apparent that in the various forms of three-impeller type cells described and illustrated, the process performed is essentially the same, and except for slight operating differences and variations in structure to modify the action in minor respects, the arrangement is basically uniform.

In the modified form of the invention illustrated in the other views, the chief distinction resides in the employment of two impellers in place of three to produce an action similar in its basic features to that already described.

Referring first to Figures 5 and 6, the cell **15a** preferably is oblong and provided with a froth overflow lip **18** of the type previously described. A weir overflow **19** is provided in the wall **16a** of this cell and the discharge passage thereto is defined by the open-ended casing **21**. Feed inlets **37** and **37a** deliver pulp to the cell and this pulp may be a previously conditioned pulp mixed with reagent, if desired.

Two rotary impellers **25**, here shown provided with sweeping vanes **45**, are located in the cell on shafts **26** and a cover element **27a** defines a compression zone in association with the impellers **25**. Two columns **33** rise from openings in cover **27a**, above the liquid level and are provided above the froth body with closures **34** and valve-controlled branches **36** of the type hereinbefore described.

The cover-element comprises disk portions **47** above the impellers **25** and an intermediate portion **48** projecting from opposite sides of the disk portions **47**. A flanged rim **49** on the projections of portion **48** provides a closure for the compression zone and a plurality of ports **50** in the rim **49** are provided for the restricted discharge of the mixture from such zone. In addition, baffles **51** are provided inside the closure defined by rim **49** to restrain agitation of material discharged through the ports **50**.

Feed tubes **46** extend into openings in the cover-element **27a** and the openings **30** provided therein to admit the shafts **26** are of a sufficient size to provide recirculation passages therethrough. Erosion-resistant sleeves **31** are carried on shafts **26** at the openings **30**.

The form of the invention illustrated in Figures 7 and 8 differs from the form of Figures 5 and 6 chiefly in the omission of the disk portions **47** of the cover-element **27a**, and the use of covered-type impellers **25b** in place of the impellers **25**.

The operation of a single cell of this type has been diagrammatically illustrated in Figures 11 and 12. In Figure 11, both impellers **25** rotate in the same direction with the result that the confluence of the discharge of the respective impellers results in violent collision, throwing gas, pulp and reagent into intimate intermixture and creating expansive tendencies in the intermixture.

The restriction imposed by the cover **27a** induces a compression of the intermixed body causing the gas to dissolve and giving the mineral an effective surface coating of gas and reagent. The provision of rim 49 and baffles 51 cooperative with the restricted discharge ports 50 aids in this compression and the process as performed in such cells is substantially that previously described.

When one impeller is rotated in a clockwise direction and the other in a counter-clockwise direction as illustrated in Figure 12, the violent impingement is eliminated and a mixing of a different type occurs. The streams travel at their confluence in substantially tangential relation and matter in each is impinged upon matter in the other, while at the same time a vortex is created in the area marked S due to the pumping influence of the impellers, while a high pressure zone develops on the discharge side as indicated at P, in which a high degree of mixing prevails because of the opposed forces imparted thereto by the impellers.

The mixing as aforesaid in zone P creates expansive forces causing much gas to enter into solution and giving an effective surface coating to mineral particles in such zone. In this operation also, the rim 49, ports 50 and baffles 51 cooperate with the hood 48 in restricting such expansive forces to develop the compression zone as aforesaid.

In Figures 13 and 14 another arrangement of impellers for cells of the two-impeller type has been illustrated diagrammatically. The impellers in this instance are the open-type having freely projecting blades and are mounted for rotation with the spheres of rotation of the respective impellers lapping. In order for such an arrangement to be effective one of the impellers rotates in a clockwise direction and another in a counter-clockwise direction.

With such an arrangement, the rotation of the impellers preferably is synchronized to keep the blades of the respective impellers from striking one another. But if for any reason, the movement of one impeller is faster than the other, no damage will be apt to occur because the blades travel in the same direction during engagement. As illustrated, the blades of the impellers in Figure 13 are straight and disposed radially, while the blades of Figure 14 are curved, and radially disposed as well.

Impellers of this type will be operated under hoods of the type hereinbefore described, which divide the cells into intercommunicating agitation and separation compartments, and it will be apparent that a high degree of mixing and an effective compression in the agitation compartment will result from this arrangement.

From the foregoing description, it will be apparent that the process carried on in all the cells illustrated herein is essentially the same, and except for variations in control features and minor phases of the operation, the results attained are substantially uniform.

It should be noted further that the variations in operating detail, while described with reference to a given cell are intended for general application to flotation apparatus and may be incorporated in the several cells, wherever such cells are adapted therefor.

In the operation of the various cells illustrated, a mixture of pulp, reagent and gas is subjected to compression by the agitative action of the impellers, causing gas to enter into solution, and giving an effective surface coating of gas and reagent to the minerals therein.

Frothing is induced by a pressure differential between the separation and compression zones, inducing gas to rise to the surface, carrying with it mineral constituents of the pulp which respond to the flotation reaction. Undue agitation is prevented in the separation zone, and the entrapped minerals are free to pass into the froth without settling occasioned by disturbance of surface tension.

Effective recirculation of valuable constituents not carried or held in the froth, through the compression zone serves to accelerate the flotation reaction in a given quantity of pulp to the end that the time required for completing a given separation is reduced materially over the time required in treating the same material by the methods heretofore in use.

As a consequence, a machine of a given size receives an increased treatment capacity when the features of the present invention are incorporated therein.

Where the expression "flotation reagent" occurs throughout the specification, it is used to designate various types of reagents, such as collectors, frothers, inhibitors, agglomerating agents, dispersing agents, and the like, since the present process deals generally with a flotation separation, rather than a specific treatment.

Changes and modifications may be availed of within the spirit and scope of the invention as defined in the hereunto appended claims.

What I claim and desire to secure by Letters Patent is:

1. In froth flotation apparatus inclusive of a tank, a plurality of impellers disposed for rotation in a horizontal plane in the lower portion of the tank, an element enclosing the impellers and dividing the tank into an upper separation compartment and an agitation compartment therebelow, and means for feeding a pulp, gas and a flotation reagent onto impellers in the agitation compartment, there being communicating enclosed passages, in the enclosing element over the impellers, having a peripheral intake and a central discharge outlet relative to the respective impellers for establishing intercommunication between the respective impellers for the circulation of matter therethrough and there being a discharge passage from the agitation compartment to the separation compartment of less capacity than said pulp feeding means whereby to induce compression of a body of pulp, gas and reagent intermixed by the action of the impellers, prior to its discharge therethrough.

2. In froth flotation apparatus inclusive of a tank, a plurality of impellers disposed for rotation in a horizontal plane in the lower portion of the tank, an element enclosing the impellers and dividing the tank into an upper separation compartment and an agitation compartment therebelow, and means for feeding a pulp, gas and a flotation reagent onto impellers in the agitation compartment, there being communicating enclosed passages, in the enclosing element over the impellers, having a peripheral intake and a central discharge outlet relative to the respective impellers for establishing intercommunication between the respective impellers for the circulation of matter therethrough and there being a discharge passage through said element from the agitation compartment to the separation compartment of less capacity than said pulp feeding means whereby to induce compression of a body of pulp, gas and reagent intermixed by the action of the impellers, prior to its discharge therethrough.

3. In froth flotation apparatus inclusive of a tank, a plurality of impellers disposed for rotation in a horizontal plane in the lower portion of the tank, an element enclosing the impellers and dividing the tank into an upper separation compartment and an agitation compartment therebelow, and valve-controlled means for forcibly feeding a pulp, gas and a flotation reagent onto impellers in the agitation compartment, there being enclosed communicating passages, in the enclosing element over the impellers, having a peripheral intake and a central discharge outlet relative to the respective impellers for establishing intercommunication between the respective impellers for the circulation of matter therethrough and there being a discharge passage from the agitation compartment to the separation compartment of less capacity than said pulp feeding means whereby to induce compression of a body of pulp, gas and reagent intermixed by the action of the impellers, prior to its discharge therethrough.

4. In froth flotation apparatus inclusive of a tank, a plurality of impellers disposed for rotation in a horizontal plane in the lower portion of the tank, an element enclosing the impellers and dividing the tank into an upper separation compartment and an agitation compartment therebelow, and means for feeding a pulp, gas and a flotation reagent onto the impellers in the agitation compartment, there being communicating passages in the enclosing element having a peripheral intake and a central discharge outlet relative to the respective impellers for establishing intercommunication between the respective impellers for the circulation of matter therethrough and of less capacity than said pulp feeding means whereby to induce compression of the intermixture therein.

5. In flotation apparatus inclusive of a tank, a plurality of impellers disposed for rotation in a horizontal plane in the lower portion of the tank, a cover-element overhanging the impellers and dividing the tank into an upper separation compartment and an agitation compartment therebelow, and means for feeding a pulp, gas and a flotation reagent under pressure onto the impellers in the agitation compartment, the cover-element having passages providing a peripheral intake and a discharge outlet centrally of each impeller for establishing intercommunication between the respective impellers for the recirculation of matter therethrough and of less capacity than said pulp feeding means whereby to induce compression of the intermixture therein.

6. In flotation apparatus inclusive of a tank, a plurality of impellers disposed for rotation in a common plane in the lower portion of the tank, a cover-element overhanging the impellers and dividing the tank into an upper separation compartment and an agitation compartment therebelow, means for feeding a pulp, gas and a flotation reagent under pressure onto the impellers in the agitation compartment, the cover-element having passages establishing intercommunication between the respective impellers for the recirculation of matter therethrough and restricted to a degree sufficient to induce compression of the intermixture therein, a hollow column extending from above the separation compartment into a recirculating passage in the cover-element, and a valve controlling ingress and egress of matter at the upper end of the column to thereby regulate the pressure within the column.

7. In a froth flotation process having superposed separation and agitation zones within a flotation cell exposed to the atmosphere, the improvement which comprises feeding pulp, reagent and a gas to a plurality of streams rotating in opposed relation to each other within the agitation zone, compressing the resulting intermixture in a common zone of impingement of the discharges from the respective streams, discharging the compressed intermixture from the agitation zone through a restricted passage circumferentially of the plurality of rotating streams, and moving gas out of the compressed body so discharged directly to the surface of the separation zone throughout the superficial area of the cell.

8. In a froth flotation process having superposed separation and agitation zones within a flotation cell exposed to the atmosphere, the improvement which comprises feeding pulp, reagent and a gas to a plurality of streams rotating disposed in opposed relation to each other within the agitation zone, compressing the resulting intermixture in a common zone of impingement of the discharges from the respective streams, returning portions of the impinging matter centrally of the respective rotating streams for recirculation through the zone of compression, discharging the compressed intermixture from the agitation zone through a restricted passage circumferentially of the plurality of rotating streams, and moving gas out of the compressed body so discharged directly to the surface of the separation zone throughout the superficial area of the cell.

9. In froth flotation apparatus inclusive of a tank, a plurality of impellers disposed for rotation in a horizontal plane in the lower portion of the tank, a cover element overhanging the impellers and dividing the tank into an upper separation compartment and an agitation compartment therebelow, and means for feeding a pulp, gas and a flotation reagent onto the impellers in the agitation compartment, the cover element having passages providing a peripheral intake and a discharge outlet centrally of each impeller for establishing intercommunication between the respective impellers for the recirculation of matter therethrough and of less capacity than said pulp feeding means whereby to induce compression of the intermixture therein, and said cover element being spaced from the tank to provide a restricted passage from the agitation compartment to the separation compartment circumferentially of the plurality of impellers.

10. In froth flotation apparatus inclusive of a tank, a plurality of impellers disposed for rotation in a common plane in the lower portion of the tank, a cover element overhanging the impellers and dividing the tank into an upper separation compartment and an agitation compartment therebelow, means for feeding a pulp, gas and a flotation reagent onto the impellers in the agitation compartment, the cover element having passages providing a peripheral intake and a discharge outlet centrally of each impeller for establishing intercommunication between the respective impellers for the recirculation of matter therethrough and of less caapcity than said pulp feeding means whereby to induce compression of the intermixture therein, and said cover element being spaced from the tank to provide a restricted passage from the agitation compartment to the separation compartment circum-

ferentially of the plurality of impellers, and a plurality of baffles located at intervals about the restricted passage within the separation compartment.

11. In froth flotation apparatus inclusive of a tank, a plurality of impellers disposed for rotation in a common plane in the lower portion of the tank, a cover element overhanging the impellers and dividing the tank into an upper separation compartment and an agitation compartment therebelow, means for feeding a pulp, gas and a flotation reagent onto the impellers in the agitation compartment, the cover element having passages providing a peripheral intake and a discharge outlet centrally of each other for establishing intercommunication between the respective impellers for the recirculation of matter therethrough and of less capacity than said pulp feeding means whereby to induce compression of the intermixture therein, and said cover element being spaced from the tank to provide a restricted passage from the agitation compartment to the separation compartment circumferentially of the plurality of impellers, and a plurality of radially disposed baffles located at intervals about the restricted passage within the separation compartment.

12. The froth flotation process which comprises the treatment of a pulp body in superposed agitation and separation zones, compressing a mixture of pulp, gas and flotation reagent in the agitation zone, releasing a portion of the compressed intermixture into the separation zone at a restricted velocity, moving the portion so released directly to the surface of the quiescent zone exposed to atmosphere in an action in which dissolved gases resume their gaseous state upon entrance into the separation zone, moving another portion of compressed pulp from the agitation zone through a confined zone separate from the separation zone for retreatment at the agitation zone, and removing froth forming at the surface of the pulp body.

13. The froth flotation process which comprises the treatment of a pulp body in superposed agitation and separation zones, compressing a mixture of pulp, gas and flotation reagent in the agitation zone, releasing a portion of the compressed intermixture into the separation zone at a restricted velocity, moving the portion so released directly to the surface of the quiescent zone exposed to atmosphere in an action in which dissolved gases resume their gaseous state upon entrance into the separation zone, restricting another portion of compressed pulp while subject to expansive tendencies, and returning the portion so restricted through a confined zone separate from the separation zone into the agitation zone before release into the separation zone.

14. The froth flotation process which comprises the treatment of a pulp body in superposed agitation and separation zones, compressing a mixture of pulp, gas and flotation reagent in the agitation zone by rotating a plurality of streams in opposed relation within a restricted zone, releasing a portion of the compressed intermixture into the separation zone at a restricted velocity, moving the portion so released directly to the surface of the quiescent zone exposed to atmosphere in an action in which dissolved gases resume their gaseous state upon entrance into the separation zone, moving another portion of compressed pulp from the agitation zone through a confied zone separate from the separation zone for retreatment at the agitation zone, and removing froth forming at the surface of the pulp body.

15. The froth flotation process which comprises the treatment of a pulp body in superposed agitation and separation zones, compressing a mixture of pulp, gas and flotation reagent in the agitation zone by rotating two streams in opposed relation within a restricted zone, releasing a portion of the compressed intermixture into the separation zone at a restricted velocity moving the portion so released directly to the surface of the quiescent zone exposed to atmosphere in an action in which dissolved gases resume their gaseous state upon entrance into the separation zone, moving another portion of compressed pulp from the agitation zone through a confined zone separate from the separation zone for retreatment at the agitation zone, and removing froth forming at the surface of the pulp body.

16. The froth flotation process which comprises the treatment of a pulp body in superposed agitation and separation zones, compressing a mixture of pulp, gas and flotation reagent in the agitation zone by rotating three streams in opposed relation within a restricted zone, releasing a portion of the compressed intermixture into the separation zone at a restricted velocity, moving the portion so released directly to the surface of the quiescent zone exposed to atmosphere in an action in which dissolved gases resume their gaseous state upon entrance into the separation zone, restricting another portion of compressed pulp while subject to expansive tendencies, and returning the portion so restricted through a confined zone separate from the separation zone into the agitation zone before release into the separation zone.

17. The froth flotation process which comprises the treatment of a pulp body in superposed agitation and separation zones, compressing a mixture of pulp, gas and flotation reagent in the agitation zone, releasing a portion of the compressed intermixture into the separation zone at a restricted velocity, moving the portion so released directly to the surface of the quiescent zone exposed to atmosphere in an action in which dissolved gases resume their gaseous state upon entrance into the separation zone, moving another portion of compressed pulp from the agitation zone through a confined zone separate from the separation zone for retreatment at the agitation zone and mixing unfloated mineral from the separation zone with the portion so returning for retreatment, and removing froth forming at the surface of the pulp body.

18. In froth flotation apparatus, a tank divided into superposed agitation and separation compartments, means for feeding a pulp, gas and a flotation reagent into the agitation compartment, a rotary impeller disposed in the pulp in the agitation compartment acting on matter fed thereto for its intermixture, and a closure for the impeller defining the agitation compartment and having a recirculation passage spaced from the feed means with its intake at the periphery of the impeller and with a discharge outlet centrally thereof, said closure cooperating with the tank to provide a passage into the separation compartment of less capacity than said pulp feeding means whereby to induce compression of the intermixture prior to its discharge therethrough.

19. In froth flotation apparatus, a tank divided into superposed agitation and separation compartments, means for feeding a pulp, gas and a flotation reagent into the agitation compartment, a plurality of rotary impellers disposed in the

pulp in the agitation compartment acting on matter fed thereto for its intermixture, and a closure for the impellers defining the agitation compartment and having a recirculation passage spaced from the feed means with its intake at the periphery of the impeller and with a discharge outlet centrally thereof, said closure cooperating with the tank to provide a passage into the separation compartment of less capacity than said pulp feeding means whereby to induce compression of the intermixture prior to its discharge therethrough.

20. In froth flotation apparatus, a tank divided into superposed agitation and separation compartments, means for feeding a pulp, gas and a flotation reagent into the agitation compartment, three rotary impellers disposed in the pulp in the agitation compartment acting on matter fed thereto for its intermixture, and a closure for the impellers defining the agitation compartment and having a recirculation passage spaced from the feed means with its intake at the periphery of the impellers and with a discharge outlet centrally of one of the impellers cooperating with the tank to provide a passage into the separation compartment of less capacity than said pulp feeding means whereby to induce compression of the intermixture prior to its discharge therethrough.

21. In froth flotation apparatus, a tank divided into superposed agitation and separation compartments, means for feeding a pulp, gas and a flotation reagent into the agitation compartment, two rotary impellers disposed in the pulp in the agitation compartment acting on matter fed thereto for its intermixture, and a closure for the impellers defining the agitation compartment and having a recirculation passage spaced from the feed means with its intake at the periphery of the impellers and with a discharge outlet centrally of one of the impellers cooperating with the tank to provide a passage into the separation compartment of less capacity than said pulp feeding means whereby to induce compression of the intermixture prior to its discharge therethrough.

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