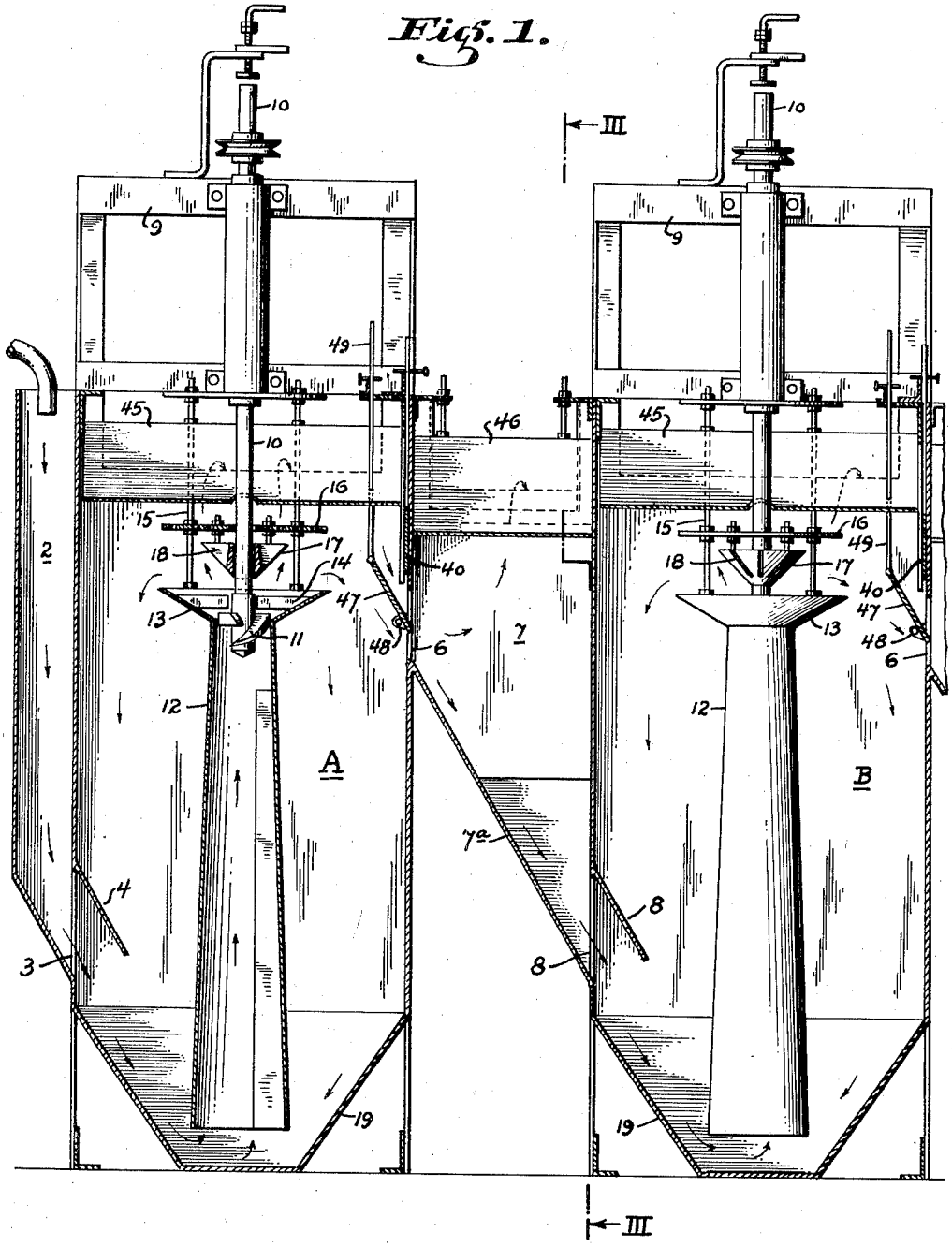
Feb. 28, 1939. L. D. DRAKE 2,148,446

METHOD AND APPARATUS FOR MULTISTAGE FLOTATION

Filed Aug. 17, 1937 3 Sheets-Sheet 1

Fig. 1.



INVENTOR.
Lewis Driver Drake.

BY

Chas. E. Townsend.
ATTORNEY.

Feb. 28, 1939. L. D. DRAKE 2,148,446

METHOD AND APPARATUS FOR MULTISTAGE FLOTATION

Filed Aug. 17, 1937 3 Sheets-Sheet 2

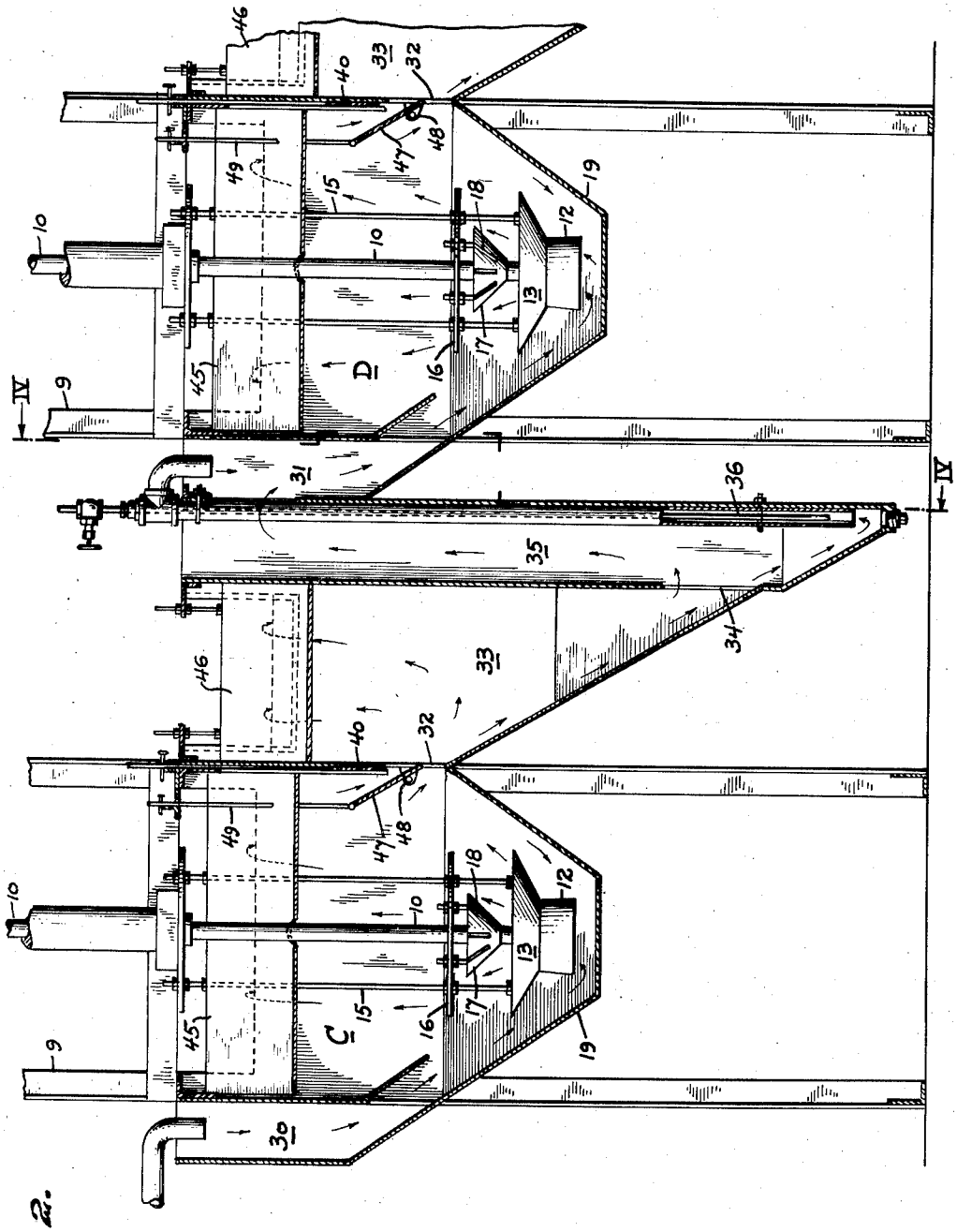


Fig. 2.

INVENTOR.
Lewis Driver Drake.

BY

Chas. E. Townsend.
ATTORNEY

Feb. 28, 1939. L. D. DRAKE 2,148,446

METHOD AND APPARATUS FOR MULTISTAGE FLOTATION

Filed Aug. 17, 1937 3 Sheets-Sheet 3

Fig. 3.

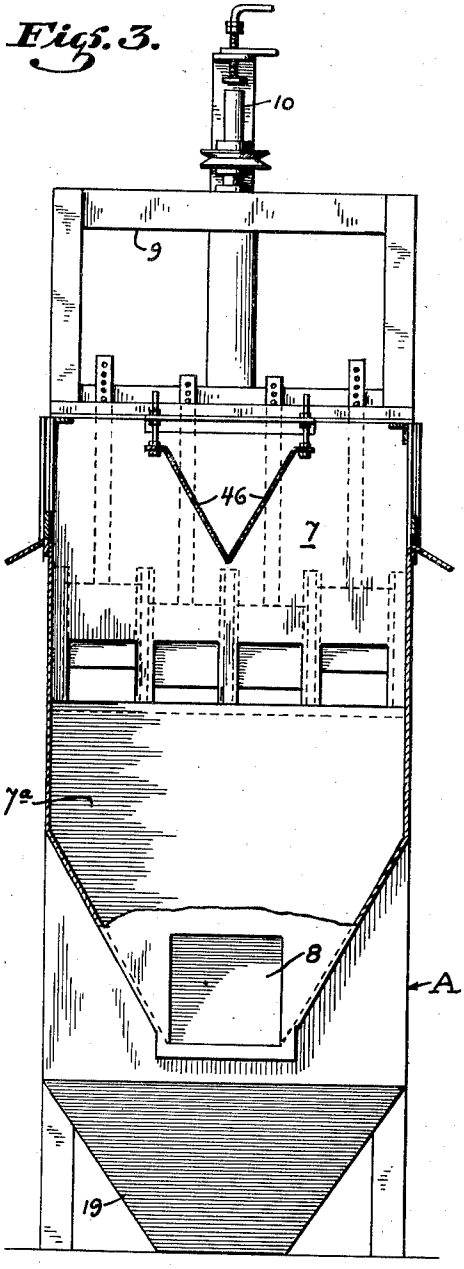
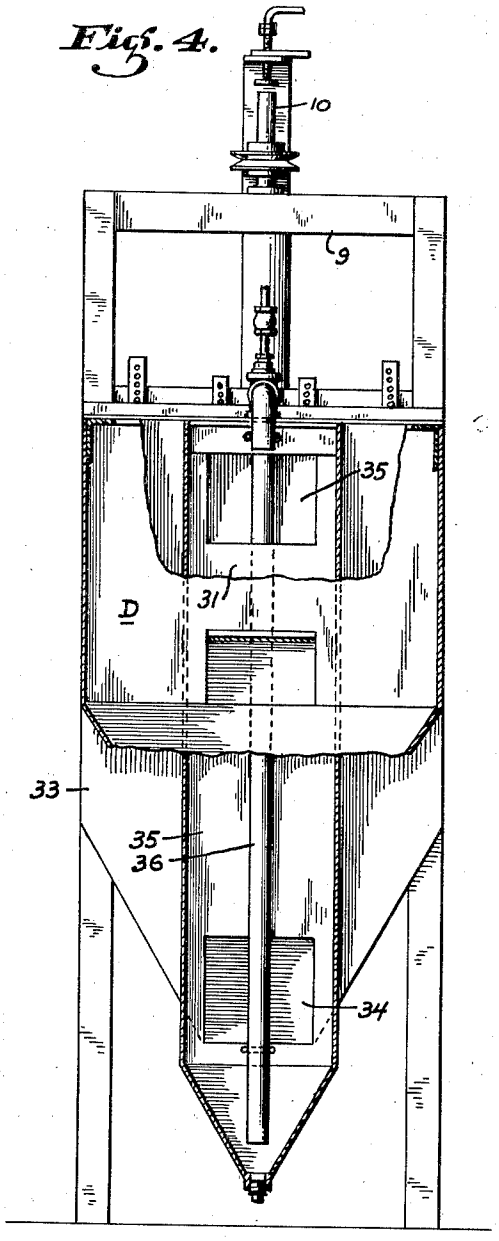


Fig. 4.



INVENTOR.
Lewis Driver Drake.

BY

Chas. E. Townsend.
ATTORNEY.

Patented Feb. 28, 1939 2,148,446

UNITED STATES PATENT OFFICE

2,148,446

METHOD AND APPARATUS FOR MULTI-STAGE FLOTATION

Lewis Driver Drake, Mountain View, Calif.

Application August 17, 1937, Serial No. 159,519

26 Claims. (Cl. 209—164)

This invention relates to a method and apparatus for multi-stage flotation.

In the flotation of certain ores, it has been found that the pulp must be passed through a considerable number of cells in order to insure maximum recovery of concentrates; also that a certain velocity and circulation must be maintained to insure flotability of the bulk of the concentrates and to prevent sanding of the cells. This velocity and circulation or flow carries or holds a certain proportion of the concentrates, such as the very fine particles, attached to bubbles too small to rise through the flow, and it also carries coarse, flaky, or scaly particles having measurable length and width but little thickness, or in other words whose large surface area allows the flow to carry them along in preference to the buoyancy of the attached bubbles. I have discovered that the number of cells usually employed to insure maximum recovery, due to the conditions above mentioned, may be materially reduced and that a greater quantity and higher grade of concentrates may be removed in less time, if the velocity through the cells is changed from a zone of comparatively high velocity and circulation to a zone of low velocity and little or no circulation, and further, that concentrates of different flotability are recoverable in the different zones.

The form of apparatus whereby the pulp may be treated in the manner above described is shown by way of illustration of the accompanying drawings, in which

Fig. 1 is a central vertical section showing two cells in which a comparatively high pulp velocity and circulation is maintained, and an intermediate chamber in which a low pulp velocity and little or no circulation is maintained;

Fig. 2 is a similar section showing a modified form of apparatus;

Fig. 3 is a cross section taken on line III—III of Fig. 1; and

Fig. 4 is a cross section taken on line IV—IV of Fig. 2.

Referring to the drawings in detail, and particularly to Fig. 1, A indicates a vertically disposed tank or container which may be round, square, rectangular or otherwise shaped, in cross section. The pulp to be treated is introduced through the usual feed box 2, and enters the container or tank near the bottom, as shown at 3, a diversion plate 4 being disposed above the inlet to deflect the re-circulated pulp away therefrom. The outlet for the pulp is indicated at 6, and connects with a tank 7 having a chamber formed therein in which a zone of low pulp velocity and little or no circulation is maintained, as will hereinafter be described. This tank is provided with an outlet 8 which connects with a tank or cell of the same construction as that indicated at A. Any number of tanks or cells, together with intermediate tanks or chambers 7 may be employed, and the last tank or cell will be provided with a pulp-level control mechanism, automatic or otherwise, of suitable character.

Disposed above the tank or container indicated at A is an overhead frame 9, and journaled therein is a shaft 10 which may be driven from any suitable source of power. Secured on the lower end of the shaft is an impeller 11 which is disposed on the upper end of an intake tube 12. This tube tapers from end to end as shown, and extends substantially from the bottom of the tank to the impeller. While a tapering tube is shown, and is particularly desirable, a tube of uniform diameter may be used. It is the length of the tube and not the shape that is important. The upper end of the tube is provided with a flaring deflector housing 13 which is provided with radial guide vanes 14. The deflector 13 and the tube 12 may be supported in any suitable manner, such as side tank walls, but in this instance are suspended from the overhead frame by rods 15, said rods also supporting a perforated diffusion plate 16 which in turn supports an upwardly-flaring deflecting cone 17 in which is formed a plurality of radially-disposed slots 18.

In the operation of the apparatus, continuous circulation of the pulp is maintained by the impeller 11. Said impeller and the tube 12 separate or divert the pulp body into two columns, one being a continuous rising central column passing through the tube and the impeller, and the second being a column descending exterior of the tube and which is deflected by a frusto-conically shaped bottom back into the tube for re-circulation. The primary purpose of the frusto-conically shaped bottom indicated at 19 is to direct the pulp with uniform velocity from all directions radially into the lower end of the tube, regardless of the distance between the tube and the cone, and secondly to provide an area of sufficiently high velocity to prevent settling of the pulp on the bottom of the tank, or what is commonly referred to as "sanding". In all instances the tube will extend at least a foot below the impeller, and will increase in length as the depth of the tank increases. The deflector 13 causes diffusion and expansion of the impeller discharge. The cone 17 causes greater de-

flection and diffusion and at the same time, due to the slots provided, insures uniform distribution of the entire rising column beneath the froth surface. Thus it diverts the pulp from the points of overdischarge to the points of underdischarge, in one case feeding a conical discharge evenly into a square tank, and it accomplishes this at a comparatively shallow depth. The perforated plate 16 causes further distribution and diffusion of the pulp at a shallower depth, and smooths out and extends the action of the deflector cone. With a cavitation impeller the greater the submergence of the impeller, the greater the speed necessary to introduce and diffuse a given volume of free air, and the greater the speed, the greater the power; hence shallow depths are desirable for minimum power.

The air introduced to the pulp is supplied by the shaft 10. This is a tubular shaft and a valve disposed at the upper end controls the amount of air that enters. The impeller 11 is of the cavitation type, and draws air from the shaft through an opening formed in the hub and shaft into cavitation pockets formed at the trailing edges of the impeller blades. The air thus introduced is uniformly and thoroughly diffused into the mass of pulp by the revolving blades of the impeller. The pulp discharging from the impeller and deflected and uniformly diffused by the various elements disposed above the same, forms a rising column of pulp and air in which the air is uniformly distributed and diffused. This air in the form of uniformly diffused bubbles is known as the supporting bubble column, and from its bubbles are liberated at the pulp surface as froth and, together with the flotation agents employed, forms the froth or foam which collects and separates the concentrates.

In actual practice, it has been found that the pulp must be passed through a considerable number of cells in order to insure maximum recovery of concentrates, and also that a certain velocity and circulation must be maintained to insure flotability of the bulk of the concentrates and to prevent sanding at the bottom of the cells. As previously stated, this velocity or flow carries or traps and holds a certain proportion of the concentrates, such as the very fine particles attached to bubbles too small to rise through the flow, and it also carries coarser flaky or scaly particles whose surface area allows the flow to carry them along in preference to the buoyancy of the attached bubbles. It is due to this condition that a considerable number of cells are required if maximum recovery of concentrates is to be insured. I have discovered that these finer and flaky particles may be quickly and readily recovered without resorting to a great number of cells, by simply removing them from the zone of high velocity and circulation maintained in the cells to a zone of low velocity and little or no circulation, that is, a velocity and circulation sufficiently low to permit the buoyancy of the attached bubbles to carry the particles, whether fine or flaky, to the surface. In the present instance, I accomplish this by forming an outlet 6 which conducts the flow from the tank A into the tank 7, and from there through the opening 8 into the next cell. By so doing, I reduce the velocity and circulation to such an extent that the bubbles attached to the fine and flaky particles are given an opportunity to rise and collect on the surface where they may be removed by discharging over an overflow lip or by mechanical skimmers or the like, not here shown. Thus the pulp is passed through two zones, one of comparatively high velocity and circulation in the tank A, and one of comparatively low velocity and little or no circulation in the tank 7. An additional cell such as indicated at B, which is identical to the tank A, may be employed, and an additional tank 7 which is not here shown, or the tank B may be provided with a pulp-level control mechanism, automatic or otherwise, from which the pulp is discharged into a tailing launder. The tank 7 will in all instances be provided with a bottom section 7a sufficiently steep to prevent the segregation and retention of the heavier particles in the pulp, the angle being preferably steeper than the angle of repose of any such particles.

The type of cells at A and B in the present drawings form the subject matter of another application filed by me, entitled "Method and apparatus for diffusion control", filed February 1, 1937, Serial No. 123,454. For this reason a brief description of the cells is submitted, as the particular type of cell employed is not the important factor. In Fig. 1, the type of cells employed are of the deep type, usually from six to eight feet or more in depth. In Fig. 2 a shallow type of cell is shown, as indicated at C and D. These cells are provided with the usual inlet feed boxes, such as shown at 30 and 31, and they are provided with the same type of circulating and diffusing mechanism as that shown in Fig. 1, the only difference being that as the cells are shallow, the long tube 12 is eliminated. In Fig. 2, the pulp to be treated enters at 30. It settles towards the bottom of the cell and is picked up by the suction of the impeller and then projected upwardly and as it is directed upwardly it is deflected, distributed and diffused by the same type of mechanism as shown in Fig. 1. A comparatively high velocity and circulation is also there maintained. The cell C is provided with an outlet 32 which delivers all the pulp into a tank 33. This is provided with an outlet 34 which delivers all the pulp to a tank 35, in which is formed a suitable combination of air lift 36 and gravity discharge which delivers the pulp to the feed box 31 of the cell D. After passage through this cell, which is identical to the cell C, it may pass into another tank similar to that shown at 33, or it may be finally discharged to a tailing launder by a suitable form of pulp-level control mechanism, automatic or otherwise, not here disclosed.

Due to the comparatively shallow type of cells C and D employed in the structure shown in Fig. 2, an air lift 36 to lift heavy particles together with gravity flow must be employed to elevate the pulp and all its quick settling particles from the tank or zone 33 of low velocity and circulation to the adjoining cell; in other words, the type of structure shown in Fig. 2 is merely submitted to show that the invention is not limited to an arrangement of cells where gravity flow is maintained through the series of cells, as shown in Fig. 1, but may also be beneficially employed where pulp-elevating means is required between the cells. The important feature is that the pulp is necessarily passed through zones of high and of low velocity and circulation, to permit concentrates of different flotability to rise and collect on the upper surfaces maintained over the different zones. By this method a greater quantity and higher grade of concentrates is recoverable in less time, the number of cells usually required is materially reduced, and first cost and power consumption are materially reduced. It will be understood that each of the cells shown, whether

of the deep or shallow type, will be provided with adjustable froth-discharging lips, and similarly the tanks 7 and 33, and that adjustable flow-controlling and -distributing gates will be disposed between the cells and tanks in which low pulp velocity and low circulation are maintained, a suitable form of gate for use in the structure shown in Fig. 1 being indicated at 40 (see also Fig. 3) and a suitable gate for the structure shown in Fig. 2 being indicated at 40 (see also Fig. 4).

A froth discharger or crowder 45 of the type disclosed in my co-pending application already referred to is mounted in the cells A and B (see Fig. 1) and a similar froth discharger 46 is mounted in the intermediate tank 7. In cell A the pulp is maintained at such high velocity that it is maintained in a substantially unsegregated condition and as such passes through the opening 6 into tank 7. To insure proper diversion of the unsegregated pulp through the opening 6 a diversion plate 47 is employed. This is pivotally secured as at 48 at a point intermediate the upper and lower edges of the opening and the other end of the plate is connected with an adjustable rod 49 whereby the angular position of the plate may be changed to insure proper diversion of the unsegregated pulp.

Location of the diversion plate on the inlet to the tank is determined and varied by the grinding and density of the pulp and will be intermediate the top and bottom of the opening and is so shown and described, and will be determined by the mill operating conditions.

While certain other features of the invention also have been more or less specifically described and illustrated, I wish it understood that changes may be resorted to within the scope of the appended claims, and similarly that the materials and finish of the several parts employed may be such as the judgment of the manufacturer dictates, or varying conditions and uses require.

Having thus described and illustrated my invention, what I claim and desire to secure by Letters Patent is:

1. The combination with a flotation concentration tank having a pulp inlet and a discharge opening and in which the pulp is subjected to such high mechanical agitation velocity that there is a tendency for the less flotable concentrates to be entrained and carried out by the discharging pulp, of a tank with a greater depth than the agitation tank to receive said discharging pulp, said tank slowing the velocity and circulation of the pulp to a point where the less flotable fully-conditioned concentrates are given a chance to rise to a froth-collecting surface and be recovered, a vertically disposed discharge duct extending from the bottom of said tank to the feed inlet of an adjacent flotation concentration tank through which the major portion of the pulp flows by gravity, and an air lift within said duct for elevating quick-settling particles that will not flow with the pulp.

2. In flotation concentration a method of multi-stage removal of concentrates from a pulp which consists in impregnating the pulp with gas bubbles and at the same time mechanically imparting high velocity circulation to the pulp in a first chamber, to cause concentrates to rise to the surface of the pulp in the said first chamber and recovering the same as a first concentrate, and feeding a selected portion of the recirculating pulp from the first chamber into a second separate communicating chamber and controlling the flow into and in the second chamber to create a quiescent zone without further gas impregnation or recirculation producing a float and recovering a second concentrate.

3. In flotation concentration a method of multi-stage removal of concentrates from a pulp which consists in impregnating the pulp with gas bubbles and at the same time mechanically imparting high velocity circulation to the pulp in a first chamber creating a strong supporting bubble column, to cause concentrates to rise to the surface of the pulp in the said first chamber and recovering the same as a first concentrate, feeding a selected portion of the recirculating pulp from the first chamber into a second separate communicating chamber, controlling the flow into the second chamber, and producing a sufficiently lowered pulp velocity and lowered pulp density in the upper portion of the second chamber to create a quiescent zone without further gas impregnation or recirculation to cause concentrates which are fully conditioned and attached to fine bubbles to rise thru the quiescent zone to the surface of the liquid within the second chamber producing a second concentrate.

4. In flotation concentration a method of multi-stage removal of concentrates from a pulp which consists in impregnating the pulp with gas bubbles and at the same time mechanically imparting high velocity circulation to the pulp in a first chamber creating a strong supporting bubble column, to cause concentrates to rise to the surface of the pulp in the said first chamber and recovering the same as a first concentrate, feeding a selected portion of the recirculating pulp from the first chamber into a second separate communicating chamber, controlling the flow into the second chamber and producing a sufficiently lowered pulp velocity and lowered pulp density in the upper portion of the second chamber to create a quiescent zone without further gas impregnation or recirculation to cause concentrates which are fully conditioned and attached to fine bubbles to rise thru the quiescent zone to the surface of the liquid within the second chamber producing a second concentrate, and varying the froth area and the strength of the supporting bubble column in the second chamber to control the recovery of the second concentrate.

5. In flotation concentration a method of multi-stage removal of concentrates from a pulp which consists in impregnating the pulp with gas bubbles and at the same time mechanically imparting high velocity circulation to the pulp in a first chamber, to cause concentrates to rise to the surface of the pulp in the said first chamber and recovering the same as a first concentrate, feeding a selected portion of the recirculating pulp from the first chamber into a second separate communicating chamber, controlling the flow into and in the second chamber and producing in the second chamber a quiescent zone free from recirculation to cause quick settling solids to settle to the bottom of the second chamber and thereby lower the density of the liquid within the upper portion of the second chamber causing fully conditioned concentrates attached to fine bubbles to rise thru the quiescent zone to the surface of the liquid within the second chamber for recovery as a second concentrate.

6. In flotation concentration a method of multi-stage removal of concentrates from a pulp which consists in impregnating the pulp with gas bubbles and at the same time mechanically imparting high velocity circulation to the pulp in a

first chamber, to cause concentrates to rise to the surface of the pulp in the said first chamber and recovering the same as a first concentrate, feeding a selected portion of the recirculating pulp from the first chamber into a second separate communicating chamber, controlling the flow into and in the second chamber and producing in the second chamber a quiescent zone free from recirculation to cause quick settling solids to settle to the bottom of the second chamber and thereby lower the density of the liquid within the upper portion of the second chamber causing fully conditioned concentrates attached to fine bubbles to rise thru the quiescent zone to the surface of the liquid within the second chamber for recovery as a second concentrate and causing the quick settling solids to pass continuously by gravity to a point of discharge at the lower portion of the second tank.

7. In flotation concentration a method of multi-stage removal of concentrates from a pulp which consists in impregnating the pulp with gas bubbles and at the same time mechanically imparting high velocity circulation to the pulp in a first chamber, to cause concentrates to rise to the surface of the pulp in the said first chamber and recovering the same as a first concentrate, flowing the pulp into a second chamber, confining the pricipal pulp flow to a path through and across said second chamber and producing in the second chamber a quiescent zone free from recirculation adjacent said path, producing a second concentrate in said second chamber.

8. A method of concentrating ore pulps by flotation concentration which comprises flowing the pulp to be treated in a body, maintaining the pulp in continuous circulation upwardly in a column of small cross sectional area of the body and downwardly in a column of large area, introducing and uniformly diffusing a gas with the upwardly circulating column of the pulp at a point below but adjacent the upper surface of the pulp, to produce a primary mineral-gathering froth, said body having its major portion extending below the point of gas introduction, and said downwardly circulating portion of the body presenting a cross-sectional area below the point of gas introduction so large, in proportion to the cross-sectional area of the column of vertically circulating pulp, that the velocity of the ascending column will be high and will pick up and recirculate all pulp reaching the bottom of the body, and the velocity of the descending column will be sufficiently low to permit small froth-forming gas bubbles held in the downwardly flowing column to assert their buoyancy and to gather and combine into large enough bubbles to rise through the downwardly flowing column and gather with the primary froth; increasing the velocity of the downwardly flowing column at the bottom of the body to direct all settling pulp to the ascending column to be recirculated, continuously directing incoming pulp to a point adjacent the lower end of the high velocity ascending column and continuously discharging unsegregated pulp at a point higher than the point of delivery of the incoming pulp to the recirculating body of pulp and thereby eliminating coarse particle accumulation in the body, and recovering the combined froth.

9. A method of concentrating ore pulps by flotation concentration which comprises flowing the pulp to be treated in a body maintaining the pulp in continuous circulation upwardly in a column of small cross-sectional area of the body and downwardly in a column of large area, introducing and uniformly diffusing a gas with the upwardly circulating column of the pulp at a point below but adjacent the upper surface of the pulp, to produce a primary mineral-gathering froth, said body having its major portion extending below the point of gas introduction, and said downwardly circulating portion of the body presenting a cross-sectional area below the point of gas introduction so large, in proportion to the cross-sectional area of the column of vertically circulating pulp, that the velocity of the ascending column will be high and will pick up and recirculate all pulp reaching the bottom of the body, and the velocity of the descending column will be sufficiently low to permit small froth-forming gas bubbles held in the downwardly flowing column to assert their buoyancy and to gather and combine into large enough bubbles to rise through the downwardly flowing column and gather with the primary froth; increasing the velocity of the downwardly flowing column at the bottom of the body to direct all settling pulp to the ascending column to be recirculated, continuously directing incoming pulp to a point adjacent the lower end of the high velocity ascending column and recovering the combined froth and continuously discharging unsegregated pulp at a point higher than the point of delivery of the incoming pulp to the recirculating body of pulp into a second body and thereby eliminating coarse particle accumulation in the first body, controlling the flow of said discharged pulp to form a quiescent zone in said second body, the point of entry of the pulp being adjacent but below the quiescent zone's pulp surface, said quiescent zone producing a float, and recovering a second concentrate, and discharging the pulp from the quiescent zone at a point substantially below the point of entry of said unsegregated pulp to the quiescent zone.

10. A method of concentrating ore pulps by flotation concentration which comprises flowing the pulp to be treated in a body maintaining the pulp in continuous circulation upwardly in a column of small cross-sectional area of the body and downwardly in a column of large area, introducing and uniformly diffusing a gas with the upwardly circulating column of the pulp at a point below but adjacent the upper surface of the pulp, to produce a primary mineral-gathering froth, said body having its major portion extending below the point of gas introduction, and said downwardly circulating portion of the body presenting a cross-sectional area below the point of gas introduction so large, in proportion to the cross-sectional area of the column of vertically circulating pulp, that the velocity of the ascending column will be high and will pick up and recirculate all pulp reaching the bottom of the body, and the velocity of the descending column will be sufficiently low to permit small froth-forming gas bubbles held in the downwardly flowing column to assert their buoyancy and to gather and combine into large enough bubbles to rise through the downwardly flowing column and gather with the primary froth; increasing the velocity of the downwardly flowing column at the bottom of the body to direct all settling pulp to the ascending column to be recirculated, continuously directing incoming pulp to a point adjacent the lower end of the high velocity ascending column and recovering the combined froth continuously discharging unsegregated pulp at a point higher than the point of delivery of the incoming pulp to the recirculating body of pulp into a second body and thereby eliminating coarse particle ac-

cumulation in the body, controlling the flow of said discharged pulp to form a quiescent zone in said second body, the point of entry of the pulp being adjacent but below the quiescent zone's pulp surface, said quiescent zone producing a float and recovering of a second concentrate, and discharging the pulp from the quiescent zone at a point substantially below the point of entry of said unsegregated pulp to the quiescent zone and at substantially the height of the point of entry of pulp to the recirculating body.

11. A flotation concentration apparatus including two separate communicating compartments provided with froth weirs, means for flowing the pulp to be treated into the first compartment, means in said first compartment for subjecting the pulp to high velocity circulation and at the same time introducing and diffusing air throughout the pulp to float over the froth weir of the first compartment concentrates which require a strong supporting bubble column, and means for feeding a selected portion of the circulating pulp from the first compartment to the second separate communicating compartment and for controlling the flow into and in the second compartment to create a quiescent zone above the feed in said second compartment for floating a second concentrate over the froth weir of the second compartment without the further agitation or aeration of the pulp.

12. A flotation concentration apparatus including two separate communicating compartments provided with froth weirs, means for flowing the pulp to be treated into the first compartment, means in said first compartment for subjecting the pulp to high velocity circulation and at the same time introducing and diffusing air throughout the pulp to float over the froth weir of the first compartment concentrates which require a strong supporting bubble column, and means for feeding a selected portion of the recirculating pulp from the first compartment to the second separate communicating compartment, and means for reducing the velocity of the flow in and through the second compartment, producing a second concentrate.

13. A flotation concentration apparatus including two separate communicating compartments provided with froth weirs, means for flowing the pulp to be treated into the first compartment, means in said first compartment for subjecting the pulp to high velocity circulation and at the same time introducing and diffusing air throughout the pulp to float over the froth weir of the first compartment concentrates which require a strong supporting bubble column, and means for feeding a selected portion of the recirculating pulp from the first compartment to the second separate communicating compartment and for controlling the flow into and in the second compartment to create a quiescent zone free from recirculation to cause concentrates attached to fine bubbles and having a low buoyancy to rise to the surface of the pulp in the second compartment without opposing downward flow in the upper portion of the second compartment.

14. A flotation concentration apparatus including two separate communicating compartments provided with froth weirs, means for flowing the pulp to be treated into the first compartment, means in said first compartment for subjecting the pulp to high velocity circulation and at the same time introducing and diffusing air throughout the pulp to float over the froth weir of the first compartment concentrates which require a strong supporting bubble column, and means for feeding a selected portion of the recirculating pulp from the first compartment to the second separate communicating compartment and for controlling the flow into and in the second compartment to create a quiescent zone and means for lowering the pulp density in the upper portion of the second compartment sufficiently to cause concentrates attached to fine bubbles and having a low buoyancy to rise to the surface of the pulp in said second compartment and discharge over the weir of the second compartment.

15. A flotation concentration apparatus including two separate communicating compartments provided with froth weirs, means for flowing the pulp to be treated into the first compartment, means in said first compartment for subjecting the pulp to high velocity circulation and at the same time introducing and diffusing air throughout the pulp to float over the froth weir of the first compartment concentrates which require a strong supporting bubble column, and means for feeding a selected portion of the recirculating pulp from the first compartment to the second separate communicating compartment and for controlling the flow into and in the second compartment to create a quiescent zone free from recirculation and for causing quick settling solids to settle out of the upper portion of the second compartment into the lower portion of the same to lower the pulp density in the upper portion of the second compartment.

16. A flotation concentration apparatus including two separate communicating compartments provided with froth weirs, means for flowing the pulp to be treated into the first compartment, means in said first compartment for subjecting the pulp to high velocity circulation and at the same time introducing and diffusing air throughout the pulp to float over the froth weir of the first compartment concentrates which require a strong supporting bubble column, means for feeding a selected portion of the recirculating pulp from the first compartment to the second separate communicating compartment and for controlling the flow into and in the second compartment to create a quiescent zone for floating a second concentrate over the froth weir of the second compartment without the further agitation or aeration of the pulp, and means for varying the froth area and the strength of the supporting bubble column in the second compartment for controlling the second concentrate discharge.

17. A flotation concentration apparatus including two separate communicating compartments provided with froth weirs, means for flowing the pulp to be treated into the first compartment, means in said first compartment for subjecting the pulp to high velocity circulation and at the same time introducing and diffusing air throughout the pulp to float over the froth weir of the first compartment concentrates which require a strong supporting bubble column, means for feeding a selected portion of the recirculating pulp from the first compartment to the second separate communicating compartment and for controlling the flow into and in the second compartment to create a quiescent zone for floating a second concentrate over the froth weir of the second compartment without the further agitation or aeration of the pulp, and means for varying the froth area and the strength of the supporting bubble column in the second compartment to control the discharge of the sec-

ond concentrate comprising a centrally disposed member having an expanded top and a contracted bottom with inclined sides, and means for vertically adjusting said member.

18. A flotation concentration apparatus including two separate communicating compartments provided with froth weirs, means for flowing the pulp to be treated into the first compartment, means in said first compartment for subjecting the pulp to high velocity circulation and at the same time introducing and diffusing air throughout the pulp to float over the froth weir of the first compartment concentrates which require a strong supporting bubble column, and means for feeding a selected portion of the recirculating pulp from the first compartment to the second separate communicating compartment and for controlling the flow into and in the second compartment to create a quiescent zone for floating a second concentrate over the froth weir of the second compartment without the further agitation or aeration of the pulp, said second compartment having an upper inlet and a lower outlet and progressively increasing in depth from the inlet to the outlet sufficiently to pass by gravity quick settling particles from the inlet to the outlet.

19. A flotation concentration apparatus including two separate communicating compartments provided with froth weirs, means for flowing the pulp to be treated into the first compartment, means in said first compartment for subjecting the pulp to high velocity circulation and at the same time introducing and diffusing air throughout the pulp to float over the froth weir of the first compartment concentrates which require a strong supporting bubble column, and means for feeding a selected portion of the recirculating pulp from the first compartment to the second separate communicating compartment and for controlling the flow into and in the second compartment to create a quiescent zone for floating a second concentrate over the froth weir of the second compartment without the further agitation or aeration of the pulp, said means for feeding a selected portion of the circulating pulp from the first compartment to the second compartment comprising a plurality of submerged gates extending across said feeding means at the second compartment inlet for controlling the distribution of incoming pulp to different parts of said second compartment to produce a comparatively uniform froth.

20. In a flotation cell having a feed inlet adjacent its bottom and a submerged discharge outlet elevated with relation to the inlet, means within the cell for maintaining a vertical circulation of substantially all the pulp with a velocity sufficient to maintain the pulp in a substantially unsegregated condition, and a submerged deflector element positioned adjacent the submerged discharged outlet for diverting unsegregated pulp through the outlet.

21. In a flotation cell having a feed inlet adjacent its bottom and a submerged discharge outlet elevated with relation to the inlet, means within the cell for maintaining a vertical circulation of substantially all the pulp with a velocity sufficient to maintain the pulp in a substantially unsegregated condition, and submerged means adjacent the submerged discharge outlet for diverting unsegregated pulp through the outlet, said means comprising an adjustably mounted flat diversion plate disposed on a vertical angle adjacent the submerged outlet.

22. In an apparatus of the character described, having a compartment where quick-settling particles of pulp are allowed to accumulate, means for discharging the bulk of the pulp by gravity flow through a vertical duct, and an air lift cooperating therewith to elevate the segregated quicker-settling particles and some of the pulp from said vertical duct.

23. The combination with a flotation concentration tank having pulp inlet and discharge openings, and in which the pulp is subjected to such high agitation and velocity that there is a tendency for the less flotable concentrates to be entrained and carried out by the discharging pulp after concentrates have been removed from the pulp surface of the first tank, of a second tank to receive said discharging pulp and the less flotable concentrates, a centrally disposed froth crowder expanded at the top and contracted at the bottom, with inclined sides, disposed in said second tank and parallel to the flow of pulp through both tanks, and a concentrate discharge lip in the second tank, said lip being also parallel to the flow of pulp, and means for vertically adjusting the froth crowder to increase or decrease the froth area and thereby vary the strength of the supporting bubble column, to recover a second concentrate.

24. The combination with a flotation concentration tank having pulp inlet and discharge openings and in which the pulp is subjected to such high mechanical agitation and vertical velocity that there is a tendency for the less flotable concentrates to be entrained and carried out by the discharging pulp after concentrates have been removed from the pulp surface of the said tank, of a second tank to receive the bulk of said discharging pulp and less flotable concentrates, said second tank slowing the velocity of the pulp to a point where the less flotable, fully-conditioned concentrates are given a chance to rise to the surface of the pulp and be recovered, a bottom in the second tank having a slope sufficiently steep to prevent solids in the pulp from accumulating thereon, a feed inlet formed in the tank adjacent the upper end of the sloping bottom section, and a discharge outlet adjacent the lower end of the sloping bottom section, said first named tank having an inlet adjacent its bottom and an outlet in the upper portion of the tank, said outlet forming the feed inlet of the second tank and the discharge outlet of said tank being substantially in the same plane as the inlet of the first tank.

25. In a flotation cell having a feed inlet adjacent its bottom and a submerged discharge outlet elevated with relation thereto, means within the cell for maintaining a vertical circulation of substantially all the pulp with a velocity sufficient to maintain all the pulp in a substantially unsegregated condition, and submerged means adjacent the submerged discharge outlet for diverting the quick settling solids in the pulp through the cell faster than the slimes.

26. The combination with a flotation concentration tank having inlet and discharge openings and in which the pulp is subjected to such high mechanical agitation and vertical velocity that there is a tendency for the less flotable concentrates to be entrained and carried out by the discharging pulp after the removal of a concentrate from said tank, of a second tank to receive the bulk of said discharging pulp and less flotable concentrates, said second tank having a froth lip and provided with a steep in-

clined bottom extending from the point of inlet of the pulp downwardly to a discharge outlet, to permit quick settling and removal of the coarse particles in the pulp, to lower the density of the pulp in the second tank above the level of said inlet, said second tank also lowering the velocity of the pulp sufficiently to permit fine air bubbles and concentrates to rise through the less dense portion of the pulp to the surface, adjustable inlet gates to control distribution for producing an even froth, a centrally disposed froth crowder expanded at the top and contracted at the bottom, with inclined sides, for controlling the strength of the bubble column and forcing concentrate over the froth lip of the second tank.

LEWIS DRIVER DRAKE.