Feb. 18, 1941. C. R. INGALLS ET AL 2,232,388

FROTH FLOTATION APPARATUS

Filed July 19, 1939 5 Sheets-Sheet 1

Fig. 1.

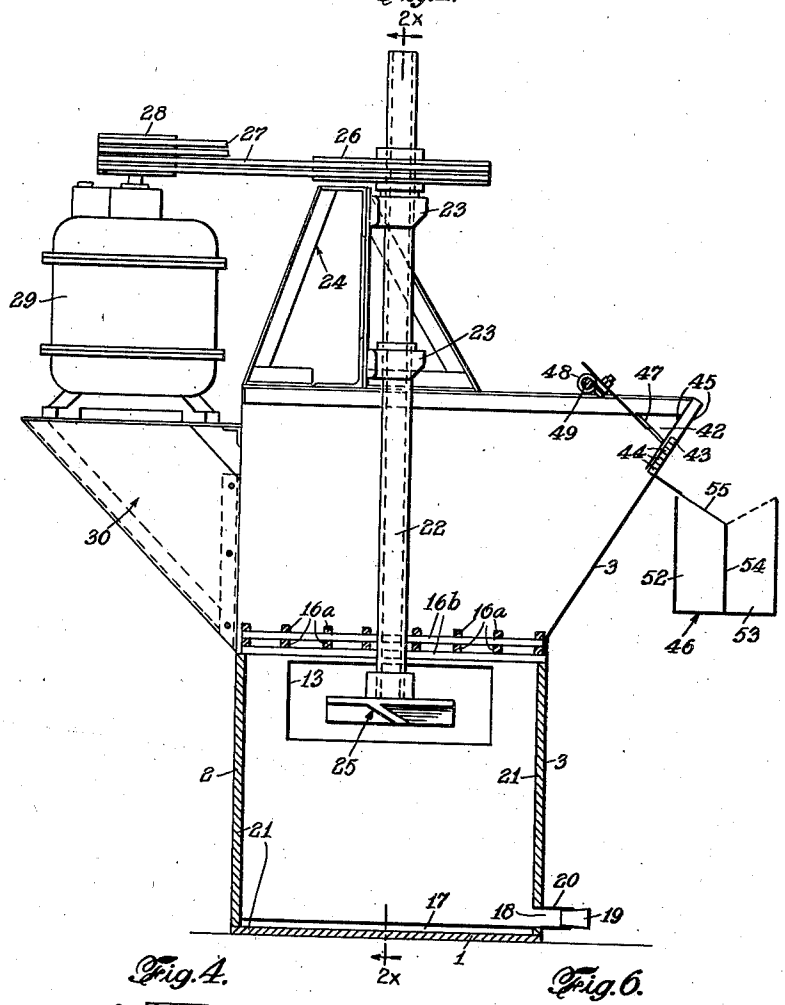


Fig. 4.

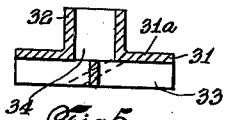


Fig. 5.

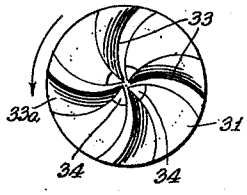


Fig. 6.

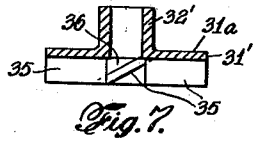
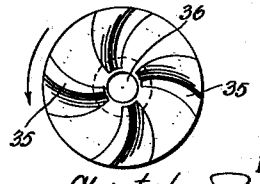


Fig. 7.



INVENTORS
Christopher R. Ingalls
Carl F. Williams
Lawrence L. Mayer
BY Williams Rich & Maxse
ATTORNEYS

Feb. 18, 1941. C. R. INGALLS ET AL 2,232,388

FROTH FLOTATION APPARATUS

Filed July 19, 1939 5 Sheets-Sheet 2

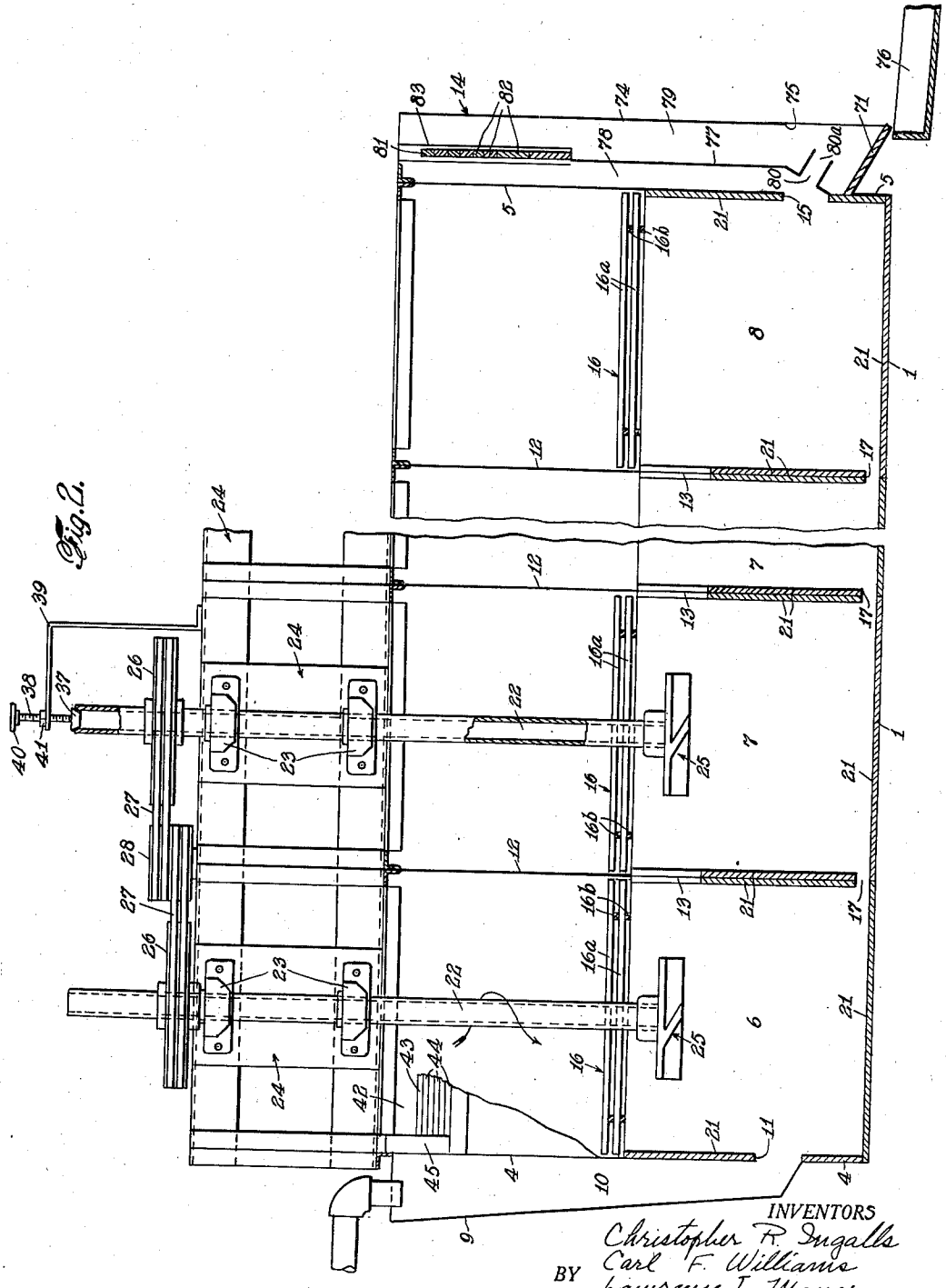


Fig. 2.

INVENTORS
Christopher R. Ingalls
Carl F. Williams
Lawrence L. Mayer
BY Williams, Rich & Morse
ATTORNEYS

Feb. 18, 1941. C. R. INGALLS ET AL 2,232,388

FROTH FLOTATION APPARATUS

Filed July 19, 1939 5 Sheets-Sheet 3

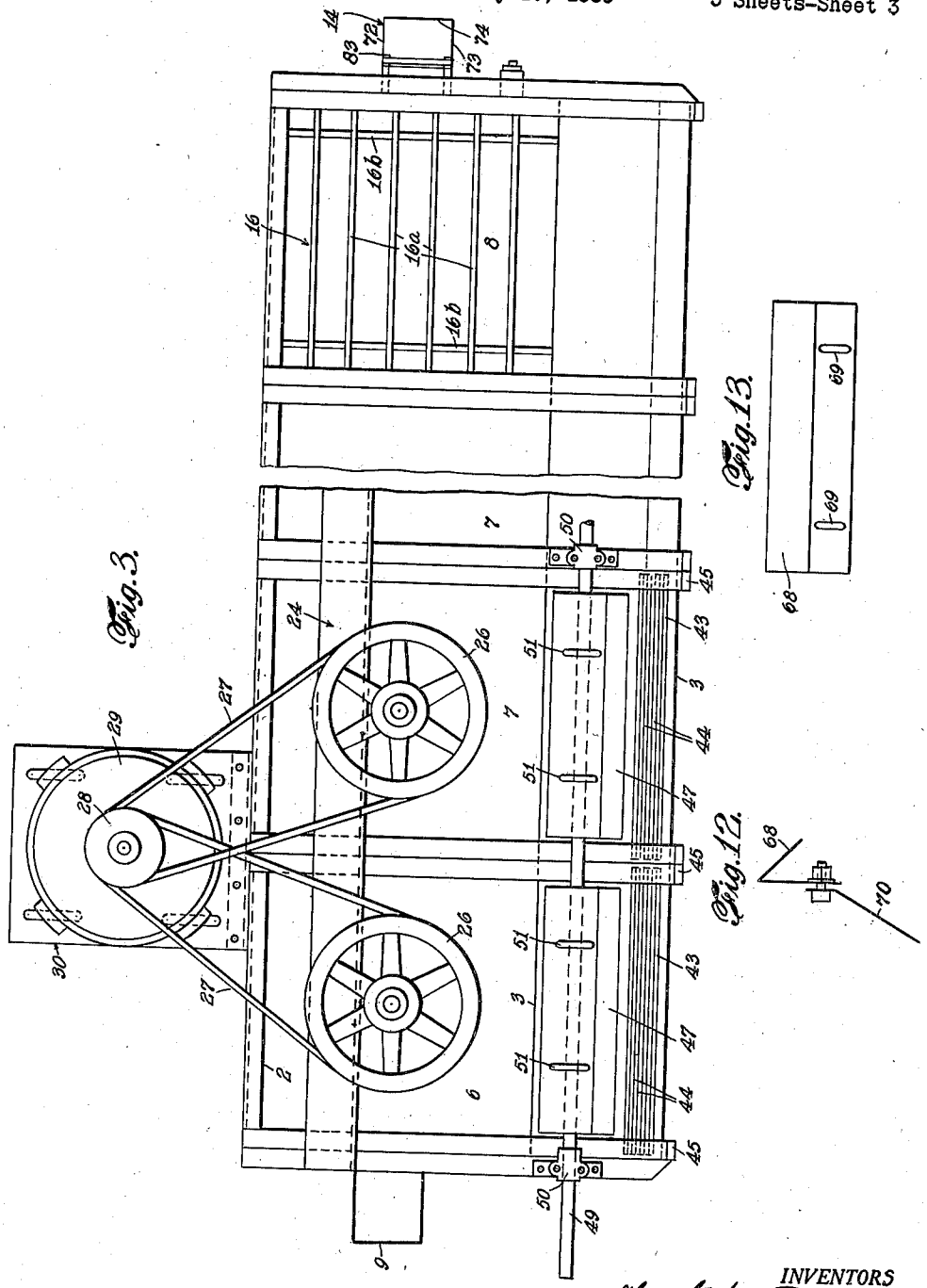


Fig. 3.

Fig. 13.

Fig. 12.

INVENTORS
Christopher R. Ingalls
Carl F. Williams
Lawrence L. Mayer
BY Williams, Rich & Morse
ATTORNEYS

Feb. 18, 1941. C. R. INGALLS ET AL 2,232,388

FROTH FLOTATION APPARATUS

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Fig. 8.

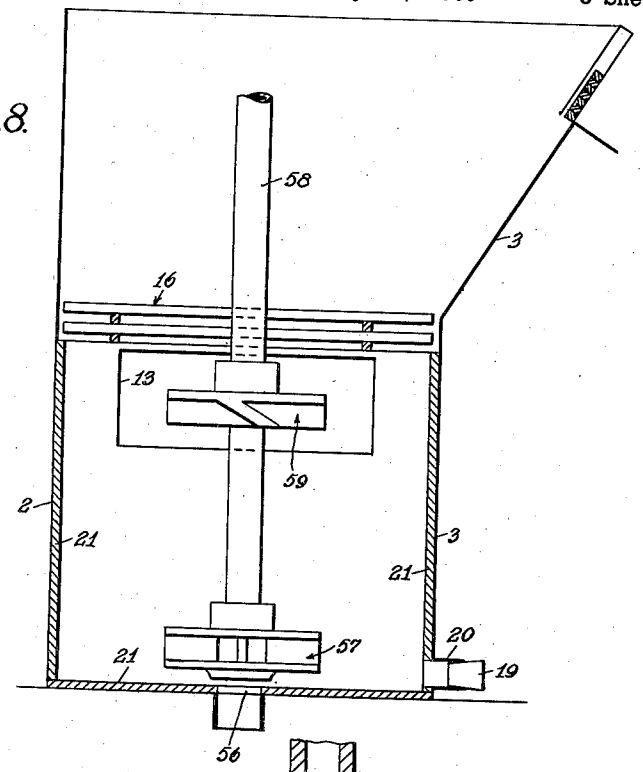
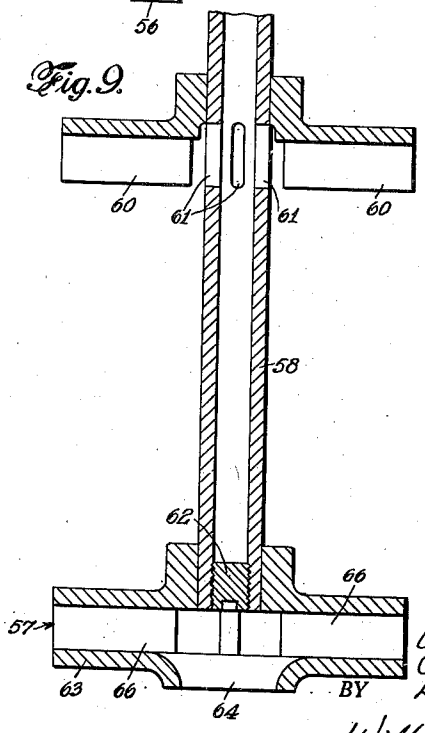


Fig. 9.



INVENTORS
Christopher R. Ingalls
Carl F. Williams
Lawrence L. Mayer

BY
Williams, Rich & Morse
ATTORNEYS

Feb. 18, 1941. C. R. INGALLS ET AL 2,232,388

FROTH FLOTATION APPARATUS

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Fig. 10.

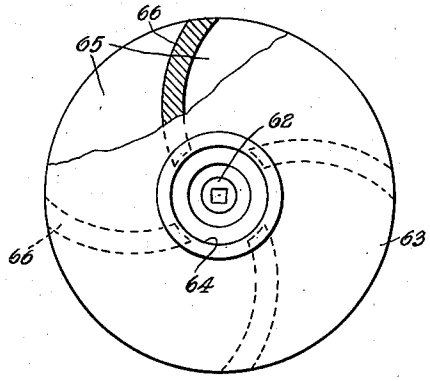
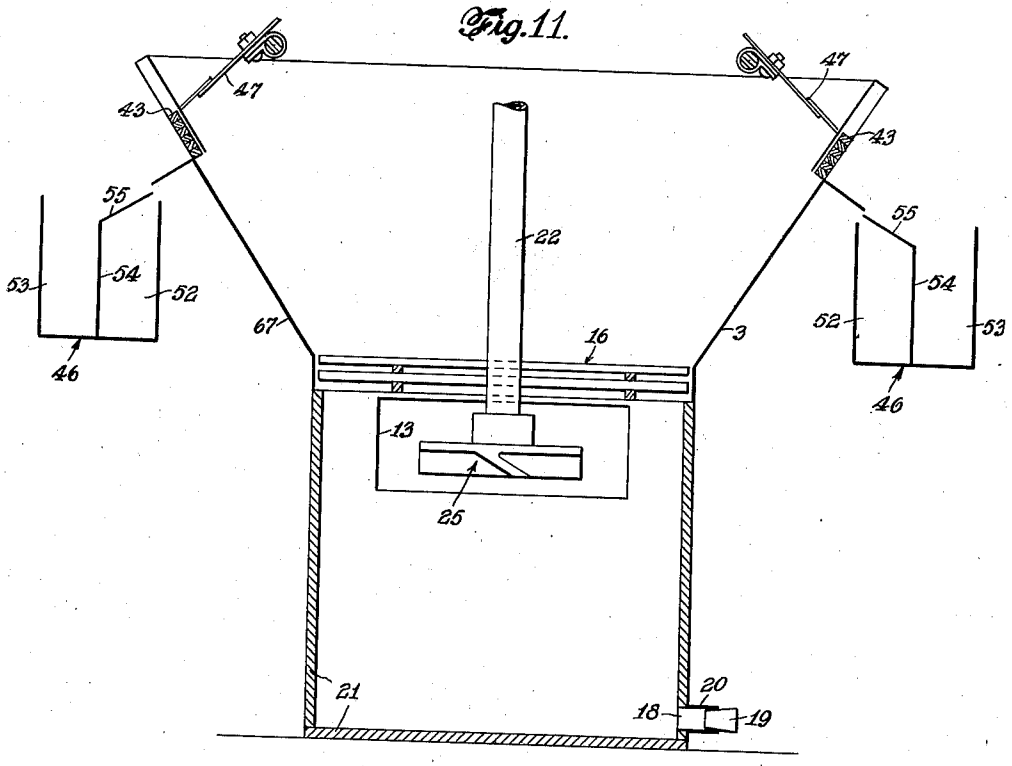


Fig. 11.



INVENTORS
Christopher R. Ingalls
Carl F. Williams
BY Lawrence L. Mayer
Williams Rich & Morse
ATTORNEYS

Patented Feb. 18, 1941 2,232,388

UNITED STATES PATENT OFFICE

2,232,388

FROTH FLOTATION APPARATUS

Christopher R. Ingalls, Alameda, Carl F. Williams, San Mateo, and Lawrence L. Mayer, Palo Alto, Calif., assignors to Minerals Separation North American Corporation, New York, N. Y., a corporation of Maryland

Application July 19, 1939, Serial No. 285,292

8 Claims. (Cl. 209—169)

The present invention relates to apparatus for the flotation concentration of comminuted materials and is herein illustrated and particularly described in a form especially adapted for use in the froth flotation of ores, it being understood that the invention may be usefully applied to the flotation treatment of various other materials including coal and other non-metallic minerals, slimes, trade wastes, sewage, wool grease, sawdust mixtures, starch-gluten mixtures, chemicals of various kinds, etc.

An object of the invention is to provide an apparatus of the character mentioned, which is simple in construction, low in cost of manufacture, and efficient in operation. Another object of the invention is to provide an apparatus of the character mentioned, which requires little attention to maintain its operation at high mechanical and metallurgical efficiencies even under varying mill conditions, which has a low power consumption, and which is not subject to clogging by settling of the solids in the pulp upon failure of the power supply or shutting down for any other reason Still another object of the invention is to provide an apparatus of the character mentioned, which allows easy and rapid passage of unduly coarse or heavy matter, thereby insuring against the possibility of its clogging the apparatus. A further object of the invention is to provide an apparatus of the character mentioned, which is structurally such as to cause the material treated to be thoroughly circulated with the view to effecting its proper conditioning prior to flotation. A still further object of the invention is to provide an apparatus of the character mentioned, which draws in sufficient air for froth flotation, without recourse to such extraneous devices as blowers or fans, and causes the air to be effectively disseminated in the material prior to flotation.

To the above ends, the invention contemplates a flotation apparatus comprising at least one of a series of cells each of which is equipped with a specially constructed impeller located at a substantial distance from the bottom in the vicinity of a baffle dividing the cell into a lower zone of agitation and an upper zone of separation, thus placing the impeller close to the top of the agitation zone instead of in the vicinity of the bottom of said zone and of the whole cell, the impeller being mounted on a hollow spindle which is open to the atmosphere at its upper end and provides a passage for the downward flow of air into the agitation zone. The construction of the impeller is such that a downward thrust or a combined radial and downward thrust is caused to be exerted on the material treated, which is thus effectively circulated in the agitation zone and at the same time is effectively admixed with air drawn downwardly through the spindle by the action of the impeller, the construction of the baffle being such as to permit the material thus conditioned in the agitation zone to rise into the comparatively quiescent upper zone wherein it is subjected to flotation separation. The apparatus comprises any number of such cells connected with one another through suitable openings located in whole or in part below the baffles.

One of the important advantages resulting from the present invention is decreased power consumption due to the fact that the impeller, instead of being located as usual at the bottom of the lower zone of agitation, is located near the top of that zone where air is introduced into the pulp against a lower hydrostatic head than is the case when air is introduced as usual near the bottom of the lower zone of agitation. Another important advantage results from the fact that the impeller is located so high in the zone of agitation that it is not likely to be buried when the solids in the pulp settle in the cell due to stopping of the impeller resulting from power-failure or shut-down. By reason of this last mentioned fact, it is possible, after power-failure or shutdown, to resume operation of the apparatus without digging out or flushing out the settled solids as is often necessary in flotation machines of the prior art characterized by the fact that their impellers are located near the bottom of the zone of agitation. Other advantages of the invention will be obvious to those skilled in the art.

The invention and the objects thereof will be understood from the following description taken in conjunction with the accompanying drawings in which Fig. 1 is a transverse sectional elevation of an apparatus embodying the invention; Fig. 2 is a longitudinal sectional view taken on the line 2×—2× of Fig. 1, certain parts being broken away and other parts omitted; Fig. 3 is a plan view of the apparatus as it appears in Fig. 2; Figs. 4 and 5 are, respectively, a transverse section and a bottom view of our preferred form of impeller; Figs. 6 and 7 are, respectively, a transverse section and a bottom view of a modified form of impeller; Fig. 8 is a transverse sectional view of a modified form of flotation cell; Fig. 9 is an enlarged sectional view of certain details embodied in the modification shown in

Fig. 8, inclusive of its two impellers; Fig. 10 is a bottom view of the lower impeller included in the modification shown in Fig. 8, a portion of the lower disc being broken away; Fig. 11 is a transverse sectional view of another modified form of flotation cell; and Figs. 12 and 13 are, respectively, edge and side elevations of an alternative form of adjustable froth discharge lip.

Referring to Figs. 1 to 3, the apparatus shown therein comprises a trough or box-like vessel having a horizontal bottom wall 1, two side walls 2 and 3, and two end walls 4 and 5, said vessel being divided into a series of connected or communicating pulp-agitating and froth-separating cells 6, 7, and 8. Any number of intermediate cells 7 may be interposed in series between the end cells 6 and 8, but for convenience of description only two such intermediate cells are herein illustrated, one being shown in part and the other in its entirety.

At the feed end of the apparatus, as viewed at the left of either Figs. 2 or 3, is a feed box 9 which is formed in part by the end wall 4 and forms a passage 10 terminating at a lower opening 11 in the end wall 4. The ore pulp is introduced through such passage and opening into the first cell 6. The apparatus is partitioned into the several cells 6 to 8 by means of transverse walls 12 extending crosswise to meet the side walls 2 and 3. Thus, the first cell 6 is bounded by one such partition wall in conjunction with the end wall 4, the side walls 2 and 3, and the bottom wall 1; the intermediate cells 7 are each bounded by two such partition walls in conjunction with the side walls 2 and 3 and the bottom wall 1; and the last cell 8 is bounded by one such partition wall in conjunction with the end wall 5, the side walls 2 and 3, and the bottom wall 1. As shown, the partition walls 12 are provided with comparatively large openings 13, through which the ore pulp may readily pass from one cell to the next. At the discharge end of the apparatus, as viewed at the right of either Figs. 2 or 3, is a tailings discharge and level-regulating unit 14 to be hereinafter more particularly described. The end wall 5 also serves as the front wall of such unit, into which the tailings or residues from the end cell 8 are directed through a lower opening 15 in such wall.

Each of the several cells 6 to 8 is divided by means of a baffle 16 into a lower zone of agitation and aeration and an upper zone of froth formation and separation. These baffles may be of cast iron or steel, or in any other suitable material. Their construction should be such as to permit upward flow of the ore pulp and at the same time confine the swirl of the ore pulp to the lower zone in each cell. Each of the baffles 16 as herein shown comprises a plurality of cross members 16a arranged in layers spaced from one another by longitudinal members 16b, but it is understood that the invention is not limited to this particular form of baffle, any one of various other forms well known in the art being available for use in the apparatus of the invention.

The baffles 16 should be set at a substantial distance from the bottom of the cells, their vertical position being largely determined by the nature of the material to undergo treatment and the efficiency with which the impeller means to be hereinafter described effects circulation in the lower zones of agitation. In the case of light pulps or of high impeller speeds, for example, the baffles 16 may be set so that such zones occupy the greater part of the cells. It is thus apparent that the several cells 6 to 8 may have greater over-all depth than the conventional type of flotation cell. This not only results in increased capacity of the apparatus, but also permits more effective conditioning of the ore pulp prior to flotation. In setting the position of the baffles 16, of course, the distance above them should be sufficient to produce the comparatively quiescent zones needed for the formation and maintenance of the proper depth of froth or float. As shown in the drawings, the baffles 16 are preferably located at a distance from the bottoms of the cells of about one-half of the cell depths, though as explained above this distance may be substantially increased.

The inlet and outlet openings 11 and 15 in the end walls of the apparatus, and the intermediate openings 13 in the partition walls, may be of any suitable shape or size. However, the inlet and outlet openings 11 and 15 should be formed so their entire areas are located below the baffles 16. As to the intermediate openings 13, they should at least in part be formed below the baffles 16, but may extend all the way up to the top of the several cells. If desired, suitable means (not shown) may be associated with the intermediate openings 13 for controlling their effective areas. Also, to facilitate the passage through the apparatus of unduly coarse or heavy matter in the pulp, the partition walls may be spaced at their lower edges from the bottom wall to provide narrow floor openings 17 extending all the way across the apparatus, as best shown in Fig. 1. Other openings 18 may be provided in either one of the side walls of the apparatus for the purpose of drainage, these openings being associated with any suitable closure means, which are herein shown as comprising plugs 19 adapted for insertion into nipples 20.

To guard against the abrasive action of the agitated pulp, each of the respective lower zones of the several cells 6 to 8 may be lined with suitable wear-resisting material 21, such as cast iron or rubber. The upper edges of such lining afford convenient rests for the baffles 16.

Associated with each of the several cells 6 to 8 is a vertical hollow shaft or spindle 22 rotatably supported by bearings 23 carried by an overhead frame 24. The spindles 22 extend through the baffles 16 and carry at their lower ends rotary impellers 25 to be hereinafter more particularly described. Rotation of the spindles 22 may be effected in any suitable manner. As shown, the spindles 22 may be fitted at their upper ends with pulleys 26 connected by belts 27 with the pulleys 28 of a motor 29, which may conveniently be mounted on a side bracket 30.

The impellers 25 are so designed that by their rotary action, downward forces, or both radial and downward forces, are produced on the surrounding pulp, with the result that the latter is caused to be effectively circulated in the lower agitation zones. In this respect, the impellers 25 differ from the impellers of the prior art, whose only forms have been such as to produce simple radial motion or combined upward and radial motion of the treated pulp. The impellers 25 provide communication therethrough from the interior of the hollow spindles 22 so that, by the rotary action of the impellers, air is induced to flow down these spindles into the pulp and thus be effectively admixed with the latter in the lower agitation zones.

Referring particularly to Figs. 4 and 5, the impellers 25 are seen to comprise a disc 31 pro-

vided with a smooth upper surface 31*a*, their attachment to the hollow spindles 22 being effected by any suitable means, which may include an upper hub 32 centrally formed from such upper surface. Formed on the lower side of the disc 31 are the agitating blades 33 which, in our preferred form of impeller illustrated in Figs. 4 and 5, meet at the center of the disc where they are set perpendicularly to its lower side, the central portion of the disc 31 being hollowed out to the inner diameter of the hub 32 to provide a plurality of segmental openings 34 all slightly removed from the disc center for the passage of air into the pulp. From the disc center, the blades 33 extend in curved directions toward the periphery and at the same time become tilted, their inclination at the periphery being such that their lower surfaces 33*a* make an angle of, say, 60 degrees from the vertical. By this form of impeller, as we have found, the induced air as a result of its passage in separate streams through the several openings 34 is most effectively disseminated in the agitated pulp in the respective lower zones of the several cells, aside from which the mixture of agitated pulp and induced air is most effectively circulated and aerated in such zones as a result of its being projected obliquely downwards toward the bottom of the apparatus.

It is understood, of course, that the invention is not limited to the particular form of impeller shown in Figs. 4 and 5. Any other form of impeller may be used which is adapted to exert a downward thrust on the agitated pulp and provides passage of air into such pulp. In the modified form of impeller shown in Figs. 6 and 7, a disc 31' and upper hub 32' are again used, but the blades 35 formed on the lower side of the disc 31' no longer meet at the disc center, the construction of these blades being such that they extend outwardly from points slightly beyond the central opening 36 through the disc 31' and upper hub 32'. A form of cell in which this form of impeller is particularly useful will be hereinafter described.

Like the baffles 16, the impeller should be set at a substantial distance from the bottom of the apparatus. It is our discovery that, as this distance is increased in a cell of given dimensions, the amount of air induced at a given speed tends to increase, while the power required to rotate the impellers decreases simultaneously. Preferably, the impellers should be set just below and close to the baffles 16 and therefore at a considerable distance above the bottom of the cell.

Referring to Fig. 2, the amount of air passing through the spindles 22 may be controlled by a movable plug 37, which may be of metal, felt, or of any other suitable material. A threaded member 38, adjustably supported by a bracket 39 secured to the frame 24, carries the plug 37, a handwheel 40 and a locknut 41 being provided on the member 38 to adjust and lock the plug 37 in any desired position. Any other means, of course, may be used to regulate the air entering the spindles 22.

As best shown in Fig. 1, the side wall 3 of the apparatus slopes outwardly above the baffles 16 and is otherwise formed to provide upper openings 42 for the discharge of the flotation concentrates from the several cells. Associated with the openings 42 are the usual overflow lips 43, the height of which may be controlled by the number of superimposed slats 44 positioned within guide members 45 provided at either side of the openings 42. It will be understood that, inasmuch as the overflow lips 43 may be placed at various horizontal levels, the desired depth of froth may be maintained in each of the several cells. When passing over the lips 43, the flotation concentrates from the several cells may be directed into a collecting launder 46, as shown in Fig. 1.

To facilitate the removal of the flotation concentrates from the several cells, wipers or paddles 47 are provided which are secured to revolving members 48 on a shaft 49, there being one of such wipers or paddles for each of the several cells. As shown in Fig. 3, the shaft 49 is journalled in bearings 50 suitably located on the framework of the apparatus, its rotation being effected by suitable mechanical means (not shown). Since it may be desired to vary the sweep of the wipers or paddles 47, they are provided with elongated openings 51 by means of which they may be adjustably secured to their supporting members 48.

In some cases, it may be desired to separate the concentrate overflow of one cell or group of cells from that of another cell or group of cells. As shown in Fig. 1, the launder 46 may to this end include two collecting compartments or troughs 52 and 53 separated from one another by a common wall 54 equipped with aprons 55 adapted to swing outwardly either into a position (shown in full lines) closing the compartment 52 or into a position (shown in dotted lines) closing the compartment 53, there being one of such aprons for each of the several cells. By properly positioning the several aprons 55, the flotation concentrates from the several cells may thus be collected in part through the trough 52 and in part through the trough 53, which permits returning either of these divided portions of the flotation concentrates to the circuit, if desired.

Material to undergo treatment in flotation apparatus often requires its introduction against hydraulic head, as in the return of middlings toward the feed end of such apparatus. Fig. 8 shows a modified form of cell which may be advantageously employed in such cases. As shown, this cell has a bottom opening 56 through which the ore pulp is introduced by the centrifugal pumping effect of an additional impeller 57. As before, a hollow spindle 58 is employed which is fitted with a down-thrusting impeller 59 below the baffle 16, but in this instance the spindle 58 is made to extend a considerable distance into the agitation zone and carries at its lower end the impeller 57 located close to the cell opening 56. The impeller 59 is similar in construction to the one shown in Figs. 6 and 7. As shown in Fig. 9, it has down-facing blades 60 located in cooperative relation to openings 61 formed through the wall of the spindle 58, which is closed at its lower end by a plug 62, whereby air is entirely induced into the pulp through the openings 61. The lower impeller 57 may take any one of various forms. Referring to Figs. 9 and 10, it may comprise a lower disc 63 shaped so as to provide a central passage 64 for the ore pulp into the spaces 65 between its blades 66, which by their centrifugal pumping effect thus cause the pulp to be effectively introduced from the cell opening 56 into the lower agitation zone of the cell. This form of cell obviously provides for increased circulation and aeration of the pulp in the agitation zone prior to separation in the upper flotation zone.

Referring to Fig. 11, the modified form of cell shown therein merely differs from the cells hereinbefore described in that the upper part is con-

structed in double spitz-kasten form. It is thus seen to include a side wall 67 identical in shape to the side wall 3 and likewise associated with an adjustable discharge lip 43 and a revolving paddle 47, the flotation concentrate being discharged into the two collecting launders 46 on either side of the cell. It is understood, of course, that a number of such cells in series may be used in the same manner as in the apparatus of Figs. 1 to 3.

If desired, the various forms of cells which have been described may be suitably altered to include the metal overflow lip 68 shown in Figs. 12 and 13. As shown, this lip may be formed with elongated openings 69 by means of which it may be adjustably secured to the apparatus wall 70. This form of discharge lip may, of course, also be used on either one or both sides of the apparatus.

Referring to Figs. 2 and 3, the tailings discharge and level-regulating unit 14 is formed by the end wall 5 of the apparatus in conjunction with a bottom wall 71, side walls 72 and 73, and an end wall 74, a lower opening 75 being provided in the end wall 74 for the discharge of the tailings into a collecting launder 76. A transverse wall 77 divides the unit into an upcast compartment 78 and a downcast compartment 79, a lower opening 80 fitted with a conduit 80a being formed in the transverse wall 77 for the discharge of coarse sands from the upcast compartment 78. The transverse wall 77 is associated with a weir 81, the height of which may be controlled by the number of superimposed slats 82 positioned within the side members 83. It will be understood that, inasmuch as the weir lip 81 may be set at various horizontal levels, the desired depth of pulp may be maintained in the apparatus. The tailings from the end cell 8 pass by way of the opening 15 into the upcast compartment 78, flow over the weir 81 into the downcast compartment 79, and are finally discharged by way of the opening 75 into the launder 76; while the solids too coarse or too heavy to rise in the upcast compartment 78 are directly discharged into the launder 76 by way of the conduit 80a and opening 75. Any other means of pulp level regulation, such as float-operated valve or the like, may be employed in the apparatus of the present invention.

As the pulp progresses from left to right through the apparatus as viewed in Figs. 2 and 3, it is obviously successively acted upon in the several cells 6 to 8 so that flotation concentrates are removed from their respect upper zones, while the tailings flow from one cell to the next until finally discharged through the level-regulating unit 14, as above explained.

A particularly advantageous feature of the apparatus of the present invention is the fact that, coincidentally with the agitation of the material under treatment therein, there is set up a circulation of this material with the result that it is thoroughly aerated without the wasteful expenditure of power and without the settling out of solid matter in the bottom of the apparatus.

It is understood that the invention is not limited to any particular number of flotation cells. As few as one only may be employed, which single flotation cell may be associated with the feed box 9 at one end and with the discharge unit 14 at the other, as will readily be understood from the foregoing description.

What is claimed is:

1. In a flotation cell, a baffle located at a distance from the bottom of the cell not substantially less than one-half the depth of the cell and dividing it into a lower zone of agitation and an upper zone of separation, a vertical hollow spindle open at the top to a supply of air or gas and extending through said baffle into the agitation zone, and an impeller mounted on said spindle just below and close to said baffle and constructed to exert a downward thrust on the material treated in the cell, the interior of said spindle communicating with the agitation zone through said impeller.

2. In a flotation cell, a baffle located at a distance from the bottom of the cell not substantially less than one-half the depth of the cell and dividing it into a lower zone of agitation and an upper zone of separation, a vertical hollow spindle open to the atmosphere at its upper end and extending a slight distance through said baffle into the agitation zone, and an impeller mounted on the lower end of said spindle just below and close to said baffle and having down-thrusting blades meeting at its center, the interior of said spindle communicating with the agitation zone by openings formed between said impeller blades.

3. In a flotation cell, a baffle located at a distance from the bottom of the cell not substantially less than one-half the depth of the cell and dividing it into a lower zone of agitation and an upper zone of separation, a vertical hollow spindle open to the atmosphere at its upper end and extending through said baffle into the agitation zone, and an impeller mounted on said spindle just below and close to said baffle and comprising a disc provided with blades on its lower side progressively tilting in curved directions toward its periphery, the interior of said spindle communicating with the agitation zone through said impeller.

4. In a flotation cell, a baffle located at a distance from the bottom of the cell not substantially less than one-half the depth of the cell and dividing it into a lower zone of agitation and an upper zone of separation, a vertical hollow spindle open to the atmosphere at its upper end and extending a slight distance through said baffle into the agitation zone, and an impeller mounted on the lower end of said spindle just below and close to said baffle and comprising a disc provided with blades on its lower side progressively tilting in curved directions from a perpendicular setting at its center to a maximum inclination at its periphery, the interior of said spindle communicating with the agitation zone through openings formed between said impeller blades.

5. A flotation apparatus partitioned into a plurality of cells comprising baffles located at a distance from the bottoms of the cells not substantially less than one-half of the depths of the cells and dividing them into lower zones of agitation and upper zones of separation, vertical hollow spindles open to the atmosphere and extending through said baffles into the agitation zones, and impellers mounted on said spindles just below and close to said baffles and constructed to exert a downward thrust on the material treated in the cells, the hollow interiors of said spindles communicating with the agitation zones through said impellers, said cells communicating with one another through a plurality of openings in the partitions between said cells, the upper openings being close to and just below said baffles and directly in line with said impellers and the other openings being at the bottoms of the cells.

6. A flotation cell comprising a bottom wall provided with an opening for introduction of the

material to be treated in the cell, a baffle located at a substantial distance from said bottom wall and dividing the cell into a lower zone of agitation and an upper zone of separation, a vertical shaft extending through said baffle into the agitation zone, an upper impeller mounted on said shaft below but in the vicinity of said baffle and constructed to exert a downward thrust on the material in the cell, said shaft having a longitudinally extending air passage communicating with the agitation zone through said upper impeller, and a lower impeller mounted on said shaft in the vicinity of said bottom wall opening and constructed to introduce the material to be treated by centrifugal action into the cell.

7. A flotation cell comprising a bottom wall provided with an opening for introduction of the material to be treated in the cell, a baffle located at a substantial distance from said bottom wall and dividing the cell into a lower zone of agitation and an upper zone of separation, a vertical shaft extending through said baffle into the agitation zone, an upper impeller mounted on said shaft below but in the vicinity of said baffle and provided with down-facing blades exerting a downward thrust on the material in the cell, said shaft having a longitudinally extending air passage communicating with the agitation zone by openings located in cooperative relation to said down-facing blades, and a lower impeller mounted on said shaft in the vicinity of said bottom wall opening and constructed to introduce the material to be treated by centrifugal action into the cell.

8. A flotation cell comprising a bottom wall provided with an opening for introduction of the material to be treated in the cell, a baffle located at a substantial distance from said bottom wall and dividing the cell into a lower zone of agitation and an upper zone of separation, a vertical shaft extending through said baffle into the agitation zone, an upper impeller mounted on said shaft below but in the vicinity of said baffle and constructed to exert a downward thrust on the material in the cell, said shaft having a longitudinally extending air passage communicating with the agitation zone through said upper impeller, and a lower impeller mounted on said shaft in the vicinity of said bottom wall opening and constructed to introduce the material to be treated by centrifugal action into the cell, said lower impeller having a centrally apertured lower disc for directing the material to be treated from said bottom wall opening.

CHRISTOPHER R. INGALLS.
CARL F. WILLIAMS.
LAWRENCE L. MAYER.