Aug. 13, 1935. M. S. HANSEN 2,011,483

FROTH FLOTATION APPARATUS AND PROCESS

Filed Oct. 5, 1932 4 Sheets-Sheet 1

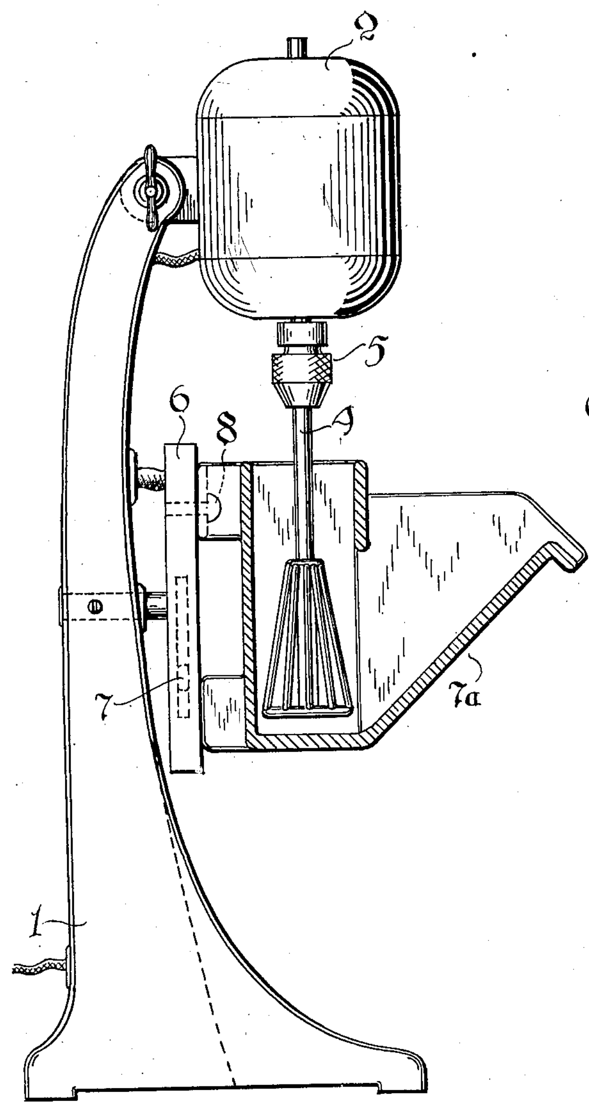

Fig. 1

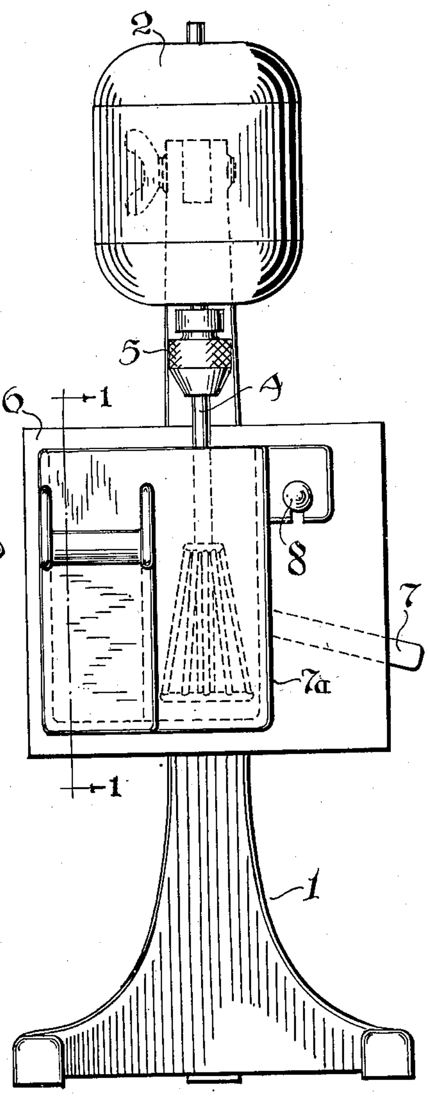

Fig. 2

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FROTH FLOTATION APPARATUS AND PROCESS

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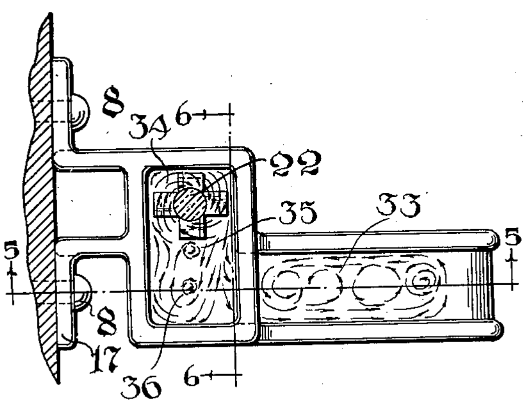

Fig. 4

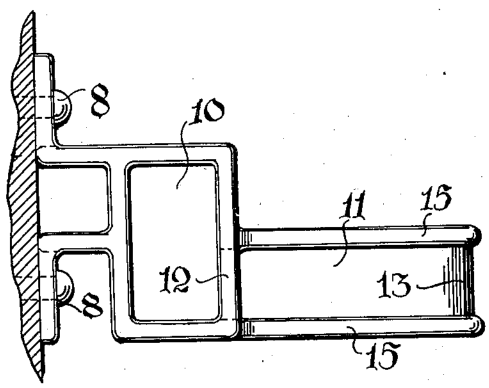

Fig. 3

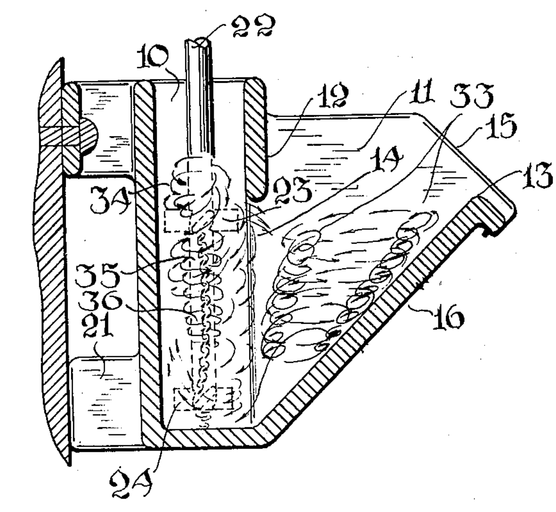

Fig. 5

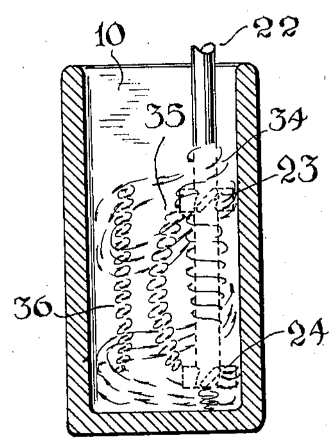

Fig. 6

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FROTH FLOTATION APPARATUS AND PROCESS

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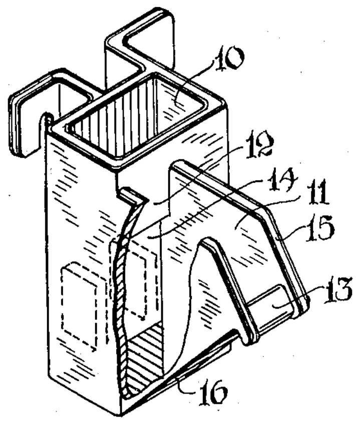

Fig. 7

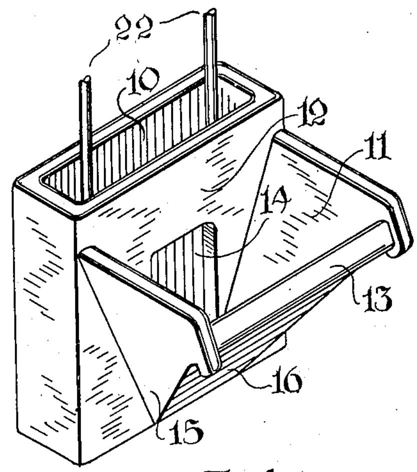

Fig. 8

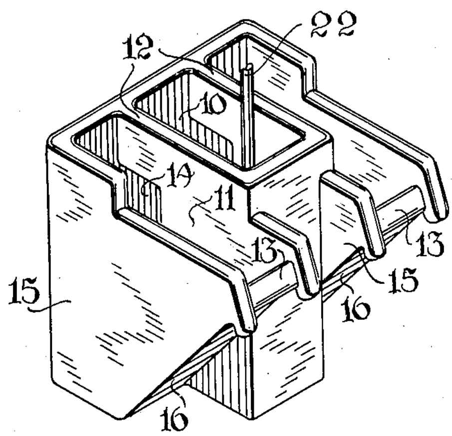

Fig. 9

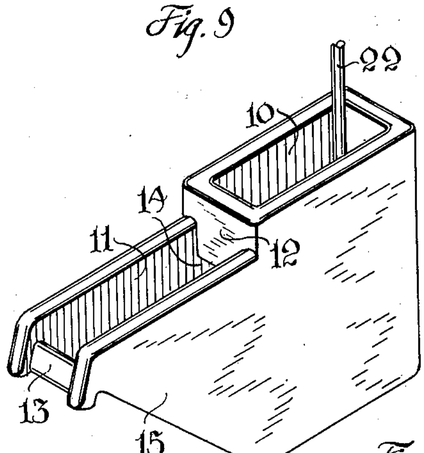

Fig. 10

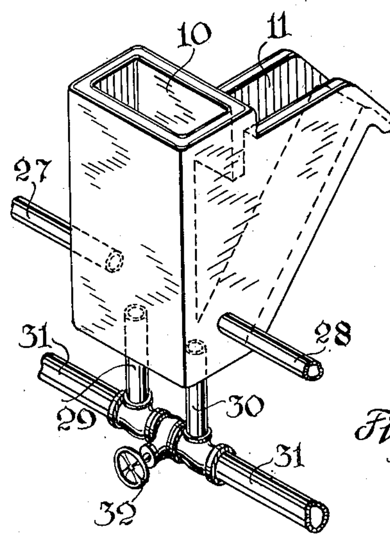

Fig. 11

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FROTH FLOTATION APPARATUS AND PROCESS

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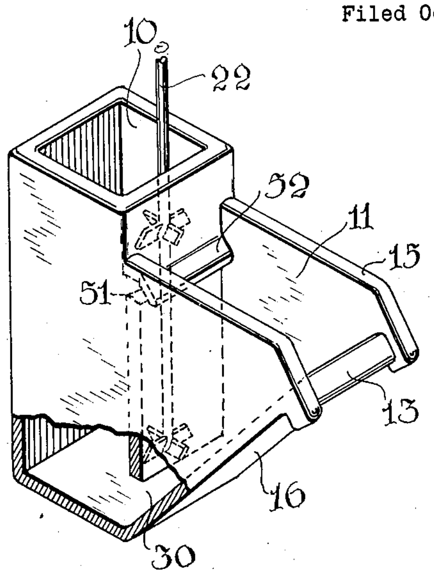

Fig. 12

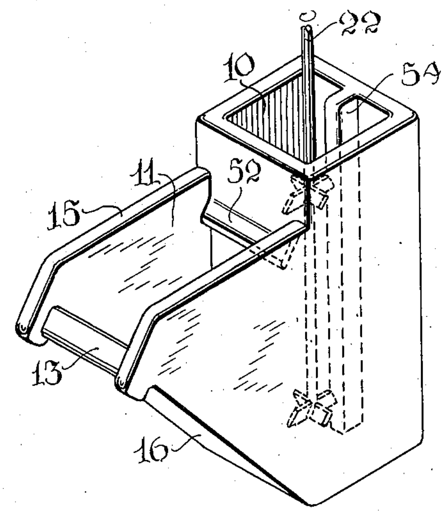

Fig. 14

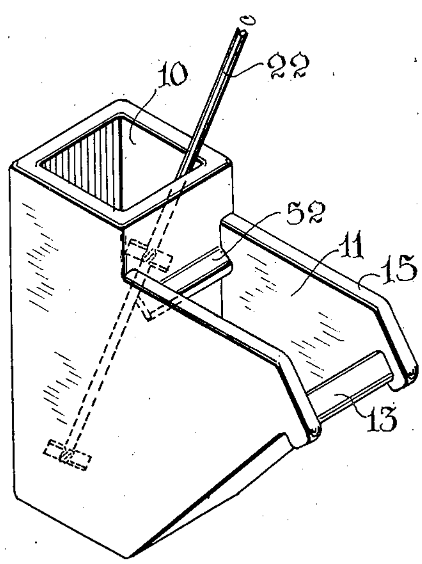

Fig. 13

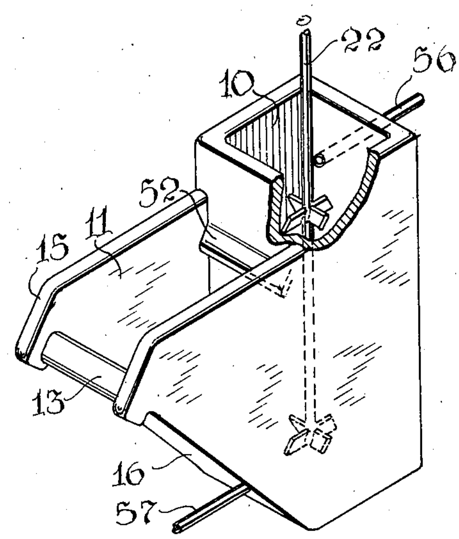

Fig. 15

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Patented Aug. 13, 1935 2,011,483

UNITED STATES PATENT OFFICE

2,011,483

FROTH FLOTATION APPARATUS AND PROCESS

Mahlin S. Hansen, Speedway City, Indianapolis, Ind., assignor to Peter C. Reilly, Indianapolis, Ind.

Application October 5, 1932, Serial No. 636,310

4 Claims. (Cl. 259—107)

This invention relates to improvements in apparatus used in the well known agitation-froth flotation process and also to improvements in that process. More specifically this invention deals with apparatus of novel design and novel orientation of parts and has for its object improved aeration, dispersion and emulsification of air, or equivalent gaseous body, within the flotation circuit.

It is well known that the agitation-froth flotation process depends for its concentrating action upon the selective attachment of the mineral particles to the air bubbles entrained and dispersed in the fluid pulp. The mineral-laden bubbles separate, in the aggregate, as a froth which is easily removed from the circuit for recovery of the mineral it carries. It is further recognized that the efficiency with which this agitation and induction of air into the circuit is accomplished constitutes one of the major factors in determining the economy of the operation.

The agitation-froth flotation cells of the type heretofore used have consisted essentially of two chambers; one, the agitation chamber, in which the impeller operates, for the agitation and aeration of the flotation circuit; the other, the froth settling chamber, for the separation and collection of the mineral-laden froth. These chambers are separated by a vertical wall provided with two vertically spaced, comparatively small openings. An impeller or other agitating means located in the agitation chamber serves to agitate the pulp thereby incorporating air and producing a froth; and, at the same time, to induce circulation of the fluid pulp upwardly through the agitation chamber, outwardly through the upper one of the two openings just mentioned into the settling chamber, downwardly through the settling chamber, and thence through the lower opening into the agitation chamber. There is also a minor pulp circuit, in which the pulp flows downwardly along the walls of the agitating chamber instead of through the separating chamber.

In these prior flotation cells, the agitating and separating chambers had a common vertical plane of symmetry. Both dimensions of the agitating chamber in horizontal cross-section were substantially the same, and the impeller was located centrally therein; so that the vortex produced by rotation of the impeller was substantially symmetrical about the axis of the impeller.

This substantially unvaried design of agitation-froth flotation cell has been, and still is, to a degree, efficiently and economically operated on a gigantic scale for recovery of untold mineral wealth not otherwise available. So far as I am aware, no significant changes in basic design and/or orientation of parts which have contributed in any material way to the efficiency and economy of operation have been suggested or applied prior to the invention of this application.

It is the object of my invention to produce an improved agitation-froth flotation unit and an improved cell and impeller arrangement, and thereby to increase the recovery of mineral obtained, to decrease the cost of the flotation operation, and to render the results obtained with the unit more uniform and dependable and less subject to variations arising from the human factor. More specifically, it is my object to produce a unit in which the agitating and separating chambers are arranged to facilitate the separation of mineral-laden bubbles from the remainder of the pulp and to so shape the agitating chamber, and to so locate the impeller therein, that the incorporation of air in the pulp and the formation of bubbles are speeded and increased. Another object of my invention is to provide an improved form of agitating impeller which will be more effective for its intended purpose, especially when used with my improved cell arrangement, than are impellers of the type used in the past.

In carrying out my invention, I so shape the agitation chamber and so locate the impeller therein as to interrupt the symmetry of the vortex produced, and desirably to produce secondary swirls and vortices in the liquid and thus increase the agitating effect of the impeller and the resulting induction of air bubbles into the pulp. Further, in my improved cell I space the impeller a considerable distance from the wall between the agitating and the settling chamber, and provide relatively free communication between such two chambers, conveniently by the use of a single opening of considerable vertical extent; and thereby get more ready circulation without interfering with the separation of the mineral-laden froth from the liquid in the settling chamber.

The accompanying drawings illustrate my invention: Figs. 1 and 2 are side and front views, respectively, of a laboratory agitation-froth flotation unit including a cell and impeller embodying my invention, the cell in Fig. 1 being shown in vertical cross-section taken on the line 1—1 of Fig. 2; Fig. 3 is a plan of the cell shown in Figs. 1 and 2; Fig. 4 is a view similar to Fig. 3, but showing an impeller in place in the agitating chamber and also illustrating the vortical action induced by operation of the impeller; Figs. 5 and

6 are vertical sections on the lines 5—5 and 6—6 respectively, of Fig. 4; Fig. 7 is an isometric view of the cell illustrated in Figs. 3 to 6; Figs. 8 to 11, inclusive, are isometric views of various different cell-shapes embodying my invention; and Figs. 12 to 15 are isometric views of modified conventional cells showing arrangements by which my invention may be embodied therein.

In the complete assembly shown in Figs. 1 and 2 there is a stand 1 which supports a variable-speed electric motor 2 to the armature shaft of which there is secured the shank 4 of a suitable impeller, as by means of a chuck 5. The stand 1 also supports a rheostat 6 having a control lever 7 by which the speed of the motor may be controlled. A flotation cell 7a, to be described in detail hereinafter, is mounted below the motor 2 conveniently through the medium of slotted feet which receive headed pins 8 projecting outwardly from the face of the rheostat 6.

The cell 7a comprises an agitating chamber 10 and a settling chamber 11. The agitating chamber 10 is of oblong contour in horizontal section, as is clear from Figs. 3 and 4, and the settling chamber 11 is located near one end of one of the longer sides of the agitation chamber and projects outwardly therefrom. A bridge wall 12 with its lower edge at about the normal liquid level separates the settling and agitating chambers, and below the wall the two chambers are in communication with each other through an opening 14 which extends downwardly to the bottom of the chambers. The settling chamber 11 has the usual side walls 15 and an outwardly and upwardly sloping bottom 16 terminating in a lip 13 over which mineral-laden froth discharges.

The impeller shown in Figs. 4 to 6 is of the conventional type and embodies a vertical shaft 22 to which there are affixed an upper set of inclined blades 23 and a lower set of similarly inclined blades 24. This impeller is located near the opposite end of the agitating chamber from the opening 14. This non-central location of the impeller is an important factor of my invention, as will more fully appear hereinafter.

Figs. 8, 9, and 10 illustrate different forms of cells embodying the same general arrangement of agitating and separating chambers and impeller shown in Figs. 4, 5, and 6. In Fig. 8, the agitating chamber 10 is of greater length than that shown in Figs. 4, 5, and 6, the opening 14 is located near the center of one of its side walls, and two impellers are used, one near each end of the agitating chamber. Fig. 9 shows a single agitating chamber associated with two separating chambers located on opposite sides of and parallel to the agitating chamber, the impeller being located in one end of the agitating chamber and the two openings 14, which afford communication respectively with the two settling chambers, being located near the other end. In Fig. 10, the agitating and separating chambers are shown as co-planar, the opening 14 being located in one end wall of the agitating chamber.

Fig. 11 illustrates the type of agitation-froth flotation cell of Figs. 3 to 7, and shows a method of charging and discharging the circuit from the agitation chamber 10 by means of pipe lines 27, 28, 29, 30, and 31 when the cell is used in commercial practice. The pipe lines 27 and 28 may be used as the inlet and outlet of the circuit respectively, while the pipe lines 29, 30, and 31, and valve 32, may be used for circulation of the circuit. When this is done, the valve 32 is closed and the pipe 31 connected in any suitable pulp-circulating circuit whereby the desired circulation is induced in the agitation chamber 10. Likewise the pipe lines 29, 30, and 31, and valve 32 may be used for charging and discharging the circuit from the agitation chamber or they may be used to supply additional air, gases or other liquids to the flotation circuit.

In all the cell-forms so far described, it will be noted that the shape of the agitating chamber is not symmetrical with respect to any axis of symmetry, that the impeller is located in an eccentric position spaced from the opening into the settling chamber, and that such opening is of considerable vertical extent to provide free communication of liquid between the two chambers. The specific rectangular cross-sectional shape of the cells shown is not essential, for other elongated or oblong cross section shapes are suitable. Throughout this specification, I use the word "oblong" in a general sense, to mean any elongated cross sectional shape such as a rectangle or an ellipse or a similar polygon.

The advantages and efficiency of the oblong cell may be obtained in part in the conventional cell by modification of such conventional cell to disturb the symmetry of the vortex produced by the impeller. Some such modifications are shown in Figs. 12 to 15.

In all of Figs. 12 to 15, I have shown a flotation cell of the conventional type, with an agitation chamber 10 square in cross section and a settling chamber 11 with the usual side walls 15 and an outwardly and upwardly sloping bottom 16. The wall between the agitating chamber 10 and the settling chamber 11 terminates short of the bottom of the cell to provide a lower opening 50 providing communication between the two chambers. The upper opening 51 is also provided in this wall at about the normal liquid level, and this opening is provided with an over-hanging lip 52 on the side of the wall toward the settling chamber.

As heretofore used, this conventional cell has been operated with the impeller located substantially on the axis of symmetry of the agitation chamber.

In Fig. 12, I have shown a cell and impeller arrangement modified from this standard practice so that the vertical shaft of the impeller is located near one corner of the agitation chamber 10 rather than at the center of such agitation chamber. The particular corner near which the impeller is located is of less importance than the eccentric location of the impeller, but I have found that good results are obtained with the impeller located near one of the corners formed between the wall separating the two chambers and the side walls.

Another modification involving a change of position of the impeller is shown in Fig. 13. Here, the impeller shaft is disposed diagonally in the agitation chamber 10, so that its axis approaches coincidence with a line connecting one lower corner of the agitation chamber and an opposite upper corner.

In both the modifications shown in Figs. 12 and 13 the swirl produced in the circuit by the impeller will be unsymmetrical with respect to the axis of the impeller, by reason of the unsymmetrical position of the chamber walls with respect to the impeller. With the symmetry of the vortex thus disturbed, the beating effect of the impeller will be greatly increased and a larger number of air bubbles will be entrained in the circuit.

In Fig. 14, I have shown a cell in which this disturbing of the symmetry of the vortex is produced by a vertical baffle **54** projecting from one wall of the agitation chamber **10**, here shown as the back wall.

In Fig. 15, I have shown a cell particularly adapted for use in a flotation operation where several cells are connected in series by pipes so that the pulp is conveyed successively through the different cells, each cell taking out part of the mineral contained in such pulp. In previous arrangements of this sort, care has been taken to introduce the pulp into any particular cell in such a way that it will not disturb the normal symmetry of agitation in that cell. In contrast to this, I introduce the pulp into a particular cell through a pipe **56** which discharges approximately tangentially into the swirl produced by the impeller but in a direction opposite to the direction of travel of the pulp at that point in the swirl, and I discharge this incoming pulp with considerable velocity; so that the incoming pulp and the swirling pulp impact and the normal symmetrical vortex produced by the impeller is destroyed. The out-flowing pulp is desirably withdrawn, as through a pipe **57**, at a point near the bottom of the settling chamber.

In order to make clear the vortical agitating action in a flotation cell arrangement embodying my invention, especially in a cell of oblong cross-section, I have shown in Figs. 4, 5, and 6 the path of movement in the circuit. Owing to the oblong contour of the agitating chamber and to the eccentric location of the impeller, there are produced a plurality of vortices **34**, **35**, and **36**. The vortex **34** is rather closely concentric with the impeller, while the vortices **35** and **36** are eccentrically located with respect to the impeller **22**. The old cross-bladed type of impeller is used here for illustrative purposes because of the lesser degree of agitation it produces and also because of the clearer cut definition of the fundamental effect in the circuit.

The shearing action of the blades occurs at the circular paths traversed by the edges of the blades as the impeller rotates, and, as the vortices **35** and **36** (and also, but to a much lesser extent, the vortex **34**) are eccentric to the axis of the impeller, the impeller blades may therefore be regarded as shearing the pulp on curved paths which are eccentric to a vortex-axis. The impeller shown in Figs. 1 and 2 embodies a plurality of downwardly and outwardly inclined pulp shearing rods and belongs generically to the type of impeller more fully described in my co-pending application Serial No. 680,635, filed July 15, 1933. When such an impeller is used in the process of this application the curved paths along which shearing of the pulp occurs near the bottom of the cell are of greater radius than those near the top of the cell. This results in deepening the vortex and increasing its surface, thus increasing the rate at which air is entrapped in the pulp.

With the impeller located at the opposite end of the agitation chamber from the opening into the settling chamber, any turbulence communicated to the settling chamber through the relatively large opening consists mainly of small eddy currents, and is in no way excessive or detrimental to the separation of the froth.

By contrast, in the conventional type of agitation-froth flotation cell with its impeller centrally located, only a single vortex is formed within the agitation chamber, because of the symmetry of design of the agitation chamber and the central location of the impeller, and this single vortex thus formed is concentric with the axis of rotation of the impeller shaft. The effect of the impeller is largely to circulate the pulp through the two chambers by way of openings that are necessarily restricted to prevent excessive turbulence in the settling chamber.

My agitation-froth flotation apparatus may be made from any suitable materials; for example, wood, glass, brick, concrete, metals and alloys. However, for laboratory use it is preferable to construct the apparatus, and particularly the impeller and flotation cell, of metal such as cast iron or steel, and provided with a surface covering of smooth vitreous enamel on all faces which may come in contact with the flotation circuit; or the entire cell, inside and outside, may be thus coated with vitreous enamel. This prevents the flotation circuit from becoming contaminated and affected by the material of the flotation apparatus, and likewise this same desirable result may be obtained by using glass as the material of construction.

The use of apparatus embodying my invention in the froth-flotation process, and the efficiency of such operation in comparison with the operation of conventional apparatus is illustrated in the following examples:

A series of flotation operations were carried out, (1) with the conventional type cell having its impeller located centrally, (2) with the conventional type cell having its impeller located near one corner—as illustrated in Fig. 15—, (3) with a conventional cell modified by the addition of a baffle, as shown in Fig. 14, and (4) with a new type cell, shaped as shown in Figs. 3 to 6.

The conditions under which these flotation operations were run were kept as nearly constant as possible except as to the amount of frother used. In each case, 50 grams of pure mineral chalcocite was placed in the cell together with 50 cc. of water and 15 cc. of saturated lime water. This mixture was agitated with the impeller for one minute, when the motor was stopped, and the frother, as a water solution (0.5 mg. terpineol per cc. of water), and the collector (di-butyl dithiophosphoric acid in the proportions of 0.07 lb. per ton of mineral) were added, and the mixture was again agitated for one-half minute. Water was then quickly added to bring the liquid up to the level of the lip; and the froth taken for an interval of one minute, and then for an interval of six minutes. The hydrogen ion concentration of the circuit was pH 9.1. The speed of the impeller was maintained constant at 2400 R. P. M. The amount of frother used was varied between the proportions of 0.02 pound per ton of material and 0.20 pound per ton of material, as shown in the following table.

This following table tabulates the total recoveries in percentage of chalcocite (Cu_2S):

Frother lb. per ton of mineral	Conventional cell	Eccentric impeller mounting	Baffle wall	Oblong cell
	% recovery	*% recovery*	*% recovery*	*% recovery*
.02	None.	1.0	----	24.0
.04	None.	22.8	26.0	47.6
.06	12.0	----	----	64.8
.08	27.6	51.4	55.0	84.2
.09	----	----	----	92.0
.10	45.0	----	75.0	----
.12	58.4	87.6	----	96.0
.16	90.0	88.6	----	----
.20	89.0	89.2	----	----

The examination of the foregoing table shows clearly the increase in recovery obtained by modifying the cell and impeller arrangement in accordance with my invention. It is to be noted that while in the conventional type cell with the impeller located centrally the optimum recovery of 90% was obtained with 0.16 lb. of frother per ton of mineral, a substantially equivalent optimum recovery was obtained in a similar cell with the impeller in eccentric position by the use of only about 0.12 lb. of frother per ton of mineral, and with my new oblong cell having its impeller at the end opposite from the opening into the separation chamber, an optimum recovery of 92% was obtained with only 0.085 lb. of frother per ton of mineral.

Further, the three arrangements which embodied my invention showed a much more rapid recovery than the conventional arrangement, and this was especially pronounced in the case of the oblong cell. For example, in the run with 0.12 lb. of frother per ton of mineral, the first minute interval, during which froth was taken from the conventional cell, yielded a recovery of 11.4%, and the subsequent six minute period a recovery of 47.0%; while on the similar run with my oblong cell, the first minute interval yielded 76% recovery and the subsequent six minute interval 20.0% recovery. Further, with 0.20 lb. per frother per ton of mineral, the change of the impeller from a central position to the eccentric position in the conventional cell changed the ratio of recovery between the two periods from 34% for the one minute interval and 55% for the six minute interval to 80% for the one minute interval and 9.2% for the 6 minute interval.

While in this specification and in the drawings, I have discussed and shown apparatus primarily intended for laboratory purposes, it will be obvious that the same principles will be applicable to flotation cells of a commercial size, for these commercial cells differ from the laboratory cells mainly in their size. The principles of operation are substantially the same.

In addition, while the foregoing examples of flotation operations carried out with apparatus involving my invention are limited to the recovery of a single mineral, the particular operations described were given only by way of example; and the principles embodied are applicable to the recovery of other minerals, including both oxidized and non-metallic minerals, as well as to the recovery of many substances which are not minerals at all, such for instance as fibers, both animal and vegetable, starch and gluten, paraffin, various organic materials, etc. In general, my invention is applicable and gives improved results wherever froth flotation finds application; and may also be utilized where only aeration with air or other gas is desired, for example in the oxidation of various sulphate to ferric salts in solution by aeration.

Throughout this specification and in the claims, the term "circuit" has been used in its broad sense, to mean any fluid entity to which aeration or the froth-flotation process is being applied.

I claim as my invention:

1. An agitation-froth flotation apparatus, comprising a cell having agitation and froth-settling chambers, the agitation chamber being oblong in horizontal cross-section, and a vertical-axis rotatable impeller disposed in said agitation chamber nearer one end than the other, said two chambers communicating with each other through an opening near that end of the agitation chamber remote from said impeller.

2. An agitation-froth flotation apparatus, comprising a cell having agitation and froth-settling chambers, the agitation chamber being oblong in horizontal cross-section, and a vertical-axis rotatable impeller disposed in said agitation chamber nearer one end than the other, said two chambers communicating with each other through an opening near that end of the agitation chamber remote from said impeller, said opening extending vertically for approximately the full effective height of said chambers.

3. An agitation-froth flotation unit, comprising a cell having interconnected agitation and settling chambers, a vertical-axis impeller displaced horizontally a material distance from the center of said agitation chamber, and means for supplying a gas to said agitation chamber at a point near the bottom thereof.

4. In a process of separating ingredients of a pulp by froth flotation, the step of swirling a body of the pulp to create a vortex therein while shearing the pulp on curved lines eccentric to the axis of the vortex, said curved lines on which the pulp is sheared being of different elevation, the curvature of the shearing-paths near the bottom of the body of the pulp being of greater radius than those near the top of the body of pulp.

MAHLIN S. HANSEN.