United States Patent

Maxwell

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[54] METHOD OF MINERAL SEPARATION BY FROTH FLOATATION

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Related U.S. Application Data

[63] Continuation-in-part of Ser. No. 735,168, June 7, 1968, abandoned.

[52] **U.S. Cl.**.....**209/164,** 207/168

[51] **Int. Cl.**.....**B03d 1/02,** B03d 1/22

[58] **Field of Search**.....209/166, 167, 108, 162–165 169, 162–165

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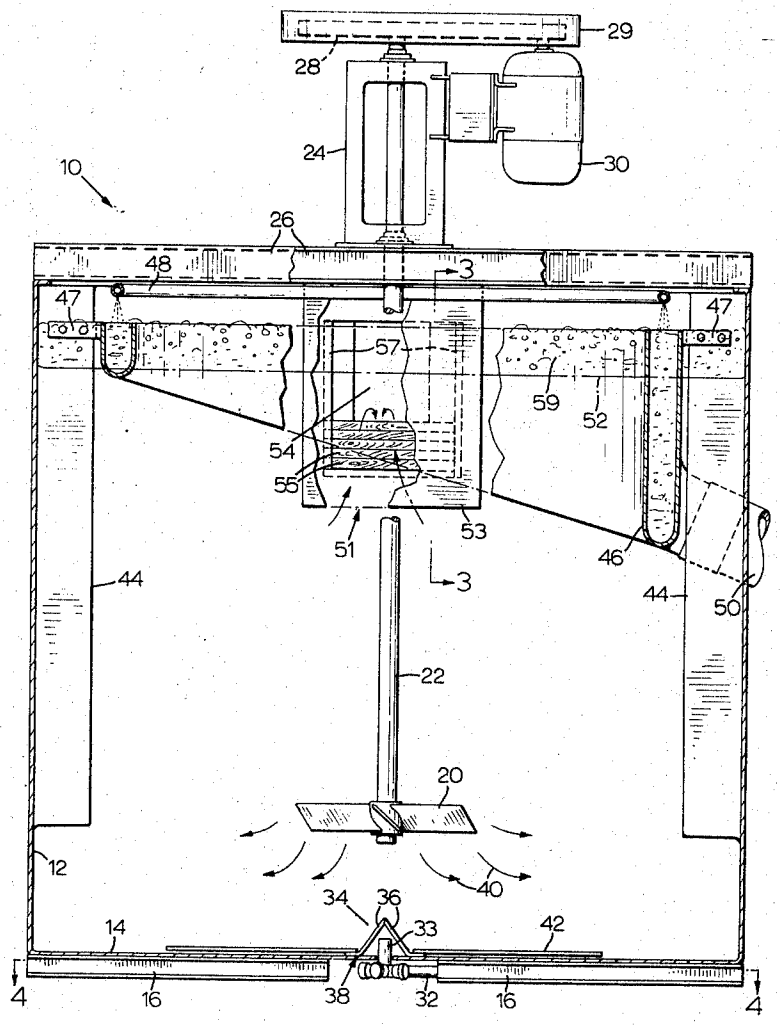
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[57] **ABSTRACT**

A method of mineral separation by froth floatation in which pulp is fed into a cylindrical tank of height approximately equal to its diameter. The pulp is mechanically agitated, and air at low pressure is fed into the bottom of the tank, to keep the tank contents in suspension and to float the desired fraction of the pulp. The feature of the invention is that a low flow of air is used, in the range between 0.05 and 0.30 cubic foot per minute per cubic foot of pulp, and low power mechanical agitation is used, the total consumed power for both the air and the mechanical agitation being between 0.010 and 0.035 horsepower per cubic foot of pulp.

3 Claims, 5 Drawing Figures



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SHEET 1 OF 3

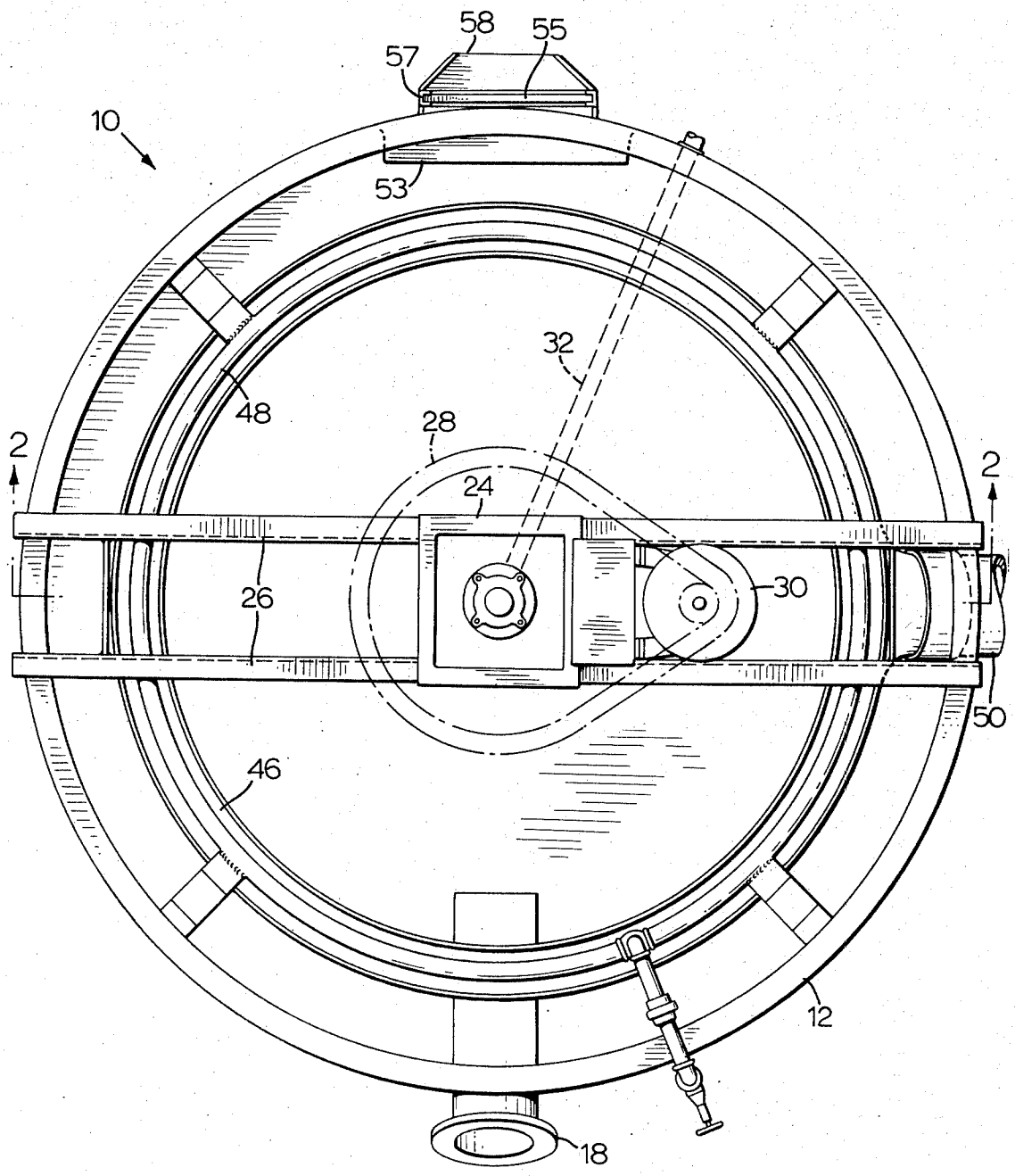


FIG. 1

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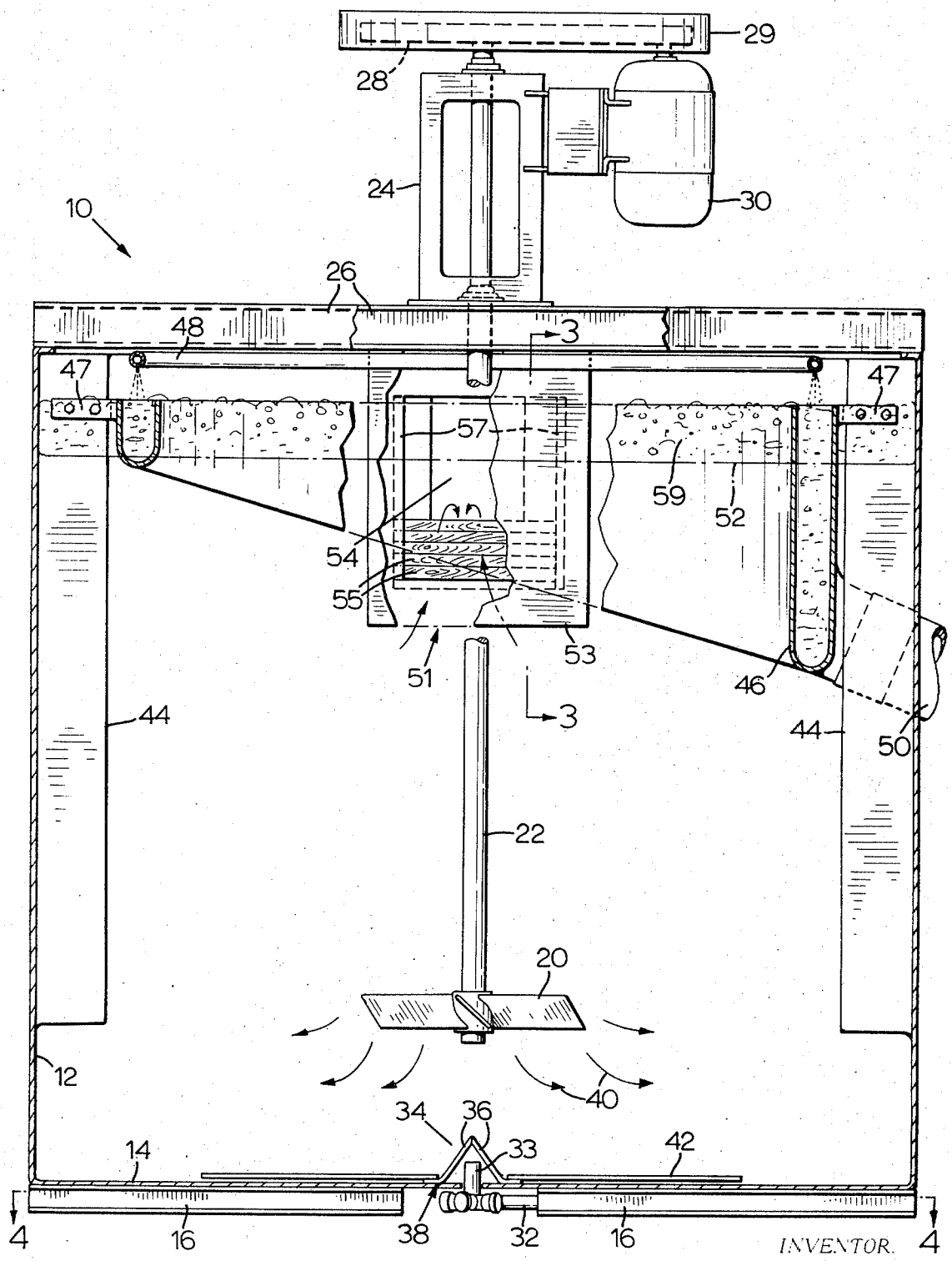


FIG. 2

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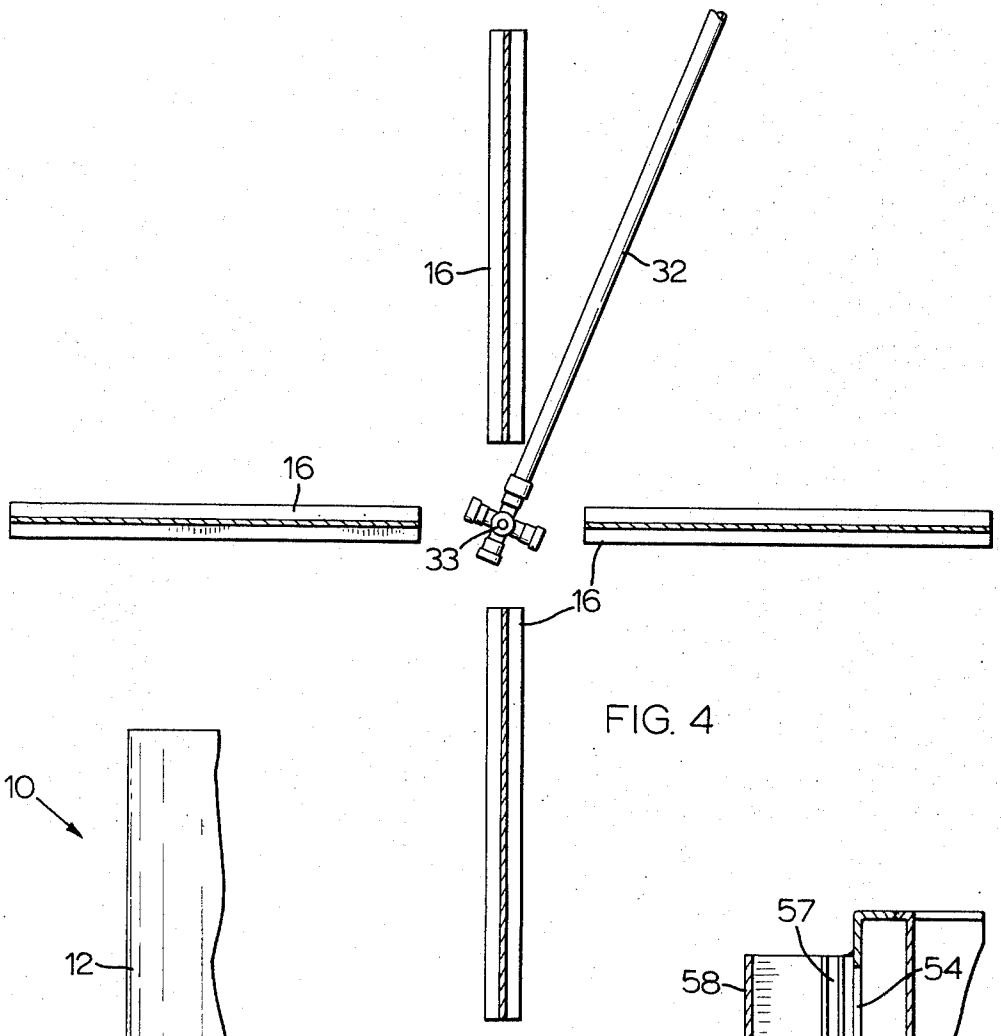


FIG. 4

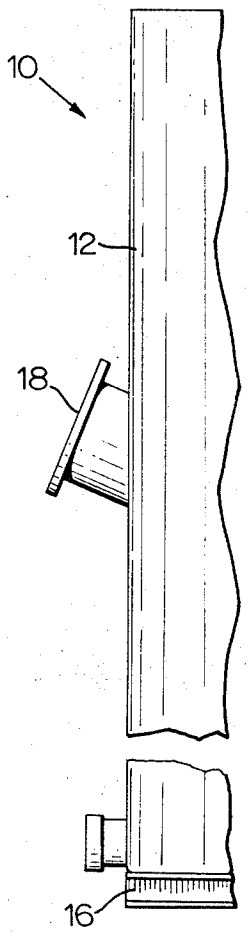


FIG. 5

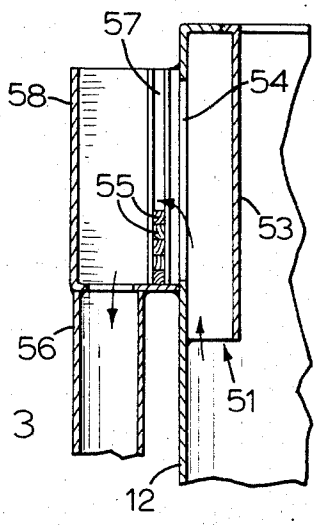


FIG. 3

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METHOD OF MINERAL SEPARATION BY FROTH FLOATATION

This application is a continuation-in-part of my application Ser. No. 735,168 now abandoned filed June 7, 1968 for "Methods of Mineral Separation by Froth Flotation."

This invention relates to an improved process of mineral separation by froth flotation. In particular, it relates to a froth floatation. In particular, it relates to a froth flotation process in which much less power is used than has previously been the practice in processes having a comparable treatment capacity.

At the present time, mineral froth flotation processes are commonly conducted in cells or tanks having rotors or impellers to agitate the pulp mass, and with air introduced either from an external compressor, or from the atmosphere if the impeller can create a vortex or reduced pressure,to float the desired particles to the surface of the tank where they can be collected. It is invariably the practice to employ substantial power intensities in such cells. The power consumption for such cells ranges between 0.08 and 0.25 horsepower (for the mechanical agitation and air combined) per cubic foot of pulp volume, with a common figure being between about 0.11 and 0.15 horsepower per cubic foot.

For example, a typical 200 cubic foot prior art cell has typically required installation of about 25 horsepower (excluding the air blower) and has consumed about 18 horsepower for mechanical agitation, while also consuming about 1½ cubic feet of air per minute per cubic foot of pulp, the air consumption requiring about 5 horsepower.

According to the invention, a low air flow is used, in the range between 0.05 and 0.30 cubic foot of air per minute per cubic foot of pulp, the air being supplied at very low pressure (just sufficient to overcome the static pressure head in the cell). In addition, very low power mechanical agitation us used. The total power consumed, for both air and for mechanical agitation, is between 0.010 and 0.035 horsepower per cubic foot of pulp. Thus, for example, a 300 cubic foot cell according to the invention requires a total horsepower (for both the mechanical agitation and for the air) of about 6.5, while a 2,000 cubic cell requires a total horsepower of about 45, which is only slightly more than double the horsepower required for a 200 foot cell of the prior art. It has been discovered that the pulp can be maintained in suspension, and settling prevented, even at the lower powers mentioned, and that substantial tonnages of material (of the same order of magnitude as in the much higher power) art processes can be processed efficiently.

Further objects and advantages of the invention will appear from the following description, taken with the accompanying drawings, in which

FIG. 1 is a top view of a cell in which the process of the invention may be conducted;

FIG. 2 is a side sectional view along lines 2—2 of FIG. 1, with a baffle plate and part of the froth launder shown in dotted lines;

FIG. 3 is a sectional view along lines 3—3 of FIG. 2, showing a gangue outlet;

FIG. 4 is a sectional view along lines 4—4 of FIG. 2; and

FIG. 5 is a side view of a portion of the cell of FIG. 1, showing a feed inlet.

The flotation cell shown in the drawings includes a tank **10** having a cylindrical sidewall **12** and a circular bottom **14** supported on four beams **16** arranged in the form of a cross. Pulp is fed into the tank through a downwardly slanting inlet pipe **18** located in the sidewall approximately half way between the top and bottom of the tank. The pulp is agitated by an impeller **20** located in the center of the tank, about 10 to 25 percent of the height of the tank from the bottom. The impeller **20** is suspended by a shaft **22** which depends from a bearing box **24** supported over the top of the tank by cross beams **26**. The shaft **22** is driven in conventional manners by belts **28** protected by a guard **29**, the belts being driven by a motor **30**. (A gear drive can be used instead of the belts.)

Air is introduced into the bottom of the tank at a single location directly beneath the impeller, by a pipe **32** and outlet **33**. The air is admitted through a check valve **34** which consists of a pair of rectangular rubber flaps **36** arranged in an upside down V shape and held in a metal box diagrammatically indicated at **38**. The ends of the box are closed by metal plates, not shown, so that the arrangement forms a watertight chamber around the air outlet **33** and prevents the pulp from contacting the outlet. The flaps **36** simply separate when the air pressure at outlet **33** exceeds the pulp pressure head, and at other times the flaps **36** are pressed together by the pressure of the pulp.

The air escaping from the flaps **36** is dispersed through the tank by the impeller **20**, which directs the pulp downwardly and outwardly as indicated by arrows **40** in FIG. **2**. (If desired, an impeller which discharges radially outwardly only can be used.) A rubber surfaced wear plate **42** protects the bottom of the tank from abrasion and can be replaced when it is worn thin. Four vertical baffles **44**, arranged at 90° intervals, extend from the tank walls to prevent swirling of the tank contents.

As the air bubbles rise in the tank, they select the desired particles and float these particles to the surface to form a froth, which is collected by a doughnut shaped froth launder **46**. (If desired, several concentric launders can be used). The launder **46** is supported by four brackets **47** attached to the baffle plates **44**. A water pipe **48** extends above the froth launder and directs a water spray into it to rinse the collected froth down to a froth outlet **50**.

The waste or gangue exits from the tank **10** via an outlet **51** (see FIGS. **2** and **3**) which is located near the top of the tank, but below the surface **52** of the agitated pulp. The outlet **51** is defined by a baffle plate **53** welded to the side of the tank. From the outlet **51**, the gangue flows upwardly through an opening **54** in the side of the tank, and over dam bars **55** to an outlet pipe **56**. The dam bars **55** are set in guides **57** in a box **58** welded to the side of the tank. Depending on the input feed rate, the number of dam bars used will control the level of the pulp in the tank, and the depth of the froth **59**.

The baffle plate **53**, which defines an outlet below the surface of the pulp, serves to prevent froth from being removed with the gangue. The baffle plate **53** also reduces the amount of enriched material near the top of the tank tending to exit with the gangue.

The above described cell is preferably of height approximately equal to its diameter. By height is meant

the distance from the bottom **14** to the top of the tank. The top of the froth launder is normally about 4 to 5 inches below the top of the tank (allowing a slight freeboard), and the top of the pulp is usually about 8 to 10 inches below the top of the froth launder, depending on the dam bars.

The air introduced into the bottom of the tank via pipe **32** is at a pressure just high enough to overcome the pressure head in the tank, so the air bubbles into the tank at very low pressure. The rate of air flow is between 0.05 and 0.30 cubic foot of air per minute per cubic foot of pulp, and in most cases the air flow will be between 0.1 and 0.3 cubic foot per minute per cubic feet of pulp. The total power used to provide the air flow and to operate the impeller **20** is between 0.010 and 0.035 horsepower per cubic foot of pulp (usually between 0.010 and 0.030), of which typically between 0.005 and 0.012 horsepower is used for the air.

By way of example, table I below compares three prior art processes, listed as A, B and C, with the process according to the invention, which is listed as D.

TABLE I

	A	B	C	D
Volume (Ft^3)	62	100	40	100
Motor HP	15	12.5	7.5	2
Brake HP	10	11	6	2
Air Volume (CFM/Ft^3)	??	1.5	1.9	.20
Mechanical (HP/Ft^3)	0.16	0.11	0.15	.020
Air Power (HP/Ft^3)	(incl. above	0.02	0.02	.007
Total Power (HP/Ft^3)	0.16	0.13	0.17	.037
Floor Area (Ft^2/Ft^3)	0.45	0.25	0.40	.25

In the processes of the above table the pulp contained ore having a specific gravity of about 2.7, and the pulp contained about 35 percent by weight of solids. Referring to the table:

The type A method represents a commercially well known machine known for its smaller space requirement. It has been mainly used on pulp volumes of about 60 cubic feet. The structure embodies complex pulp agitating and self induced air flow features.

The type B method represents a very well known widely used form of machine of complex agitating and pulp flow features.

The type C method again employs special baffle and agitation features but is of shallow depth similar to type B.

The type D method of the invention is ordinarily applied to cells of at least 300 cubic feet, and preferably to much larger cells, e.g. up to 2,100 cubic feet and beyond. In a typical 700 cubic foot cell according to the invention, the motor horsepower was 15, the consumed horsepower was 12, the mechanical horsepower per cubic foot of pulp was 0.017, the air flow in cubic feet per minute per cubic foot of pulp was 0.18, the power required to supply the air was 0.007 horsepower per cubic foot of pulp, the total power was 0.024 horsepower per cubic foot of pulp, and the floor area required for each cubic foot of pulp was 0.1 square feet.

By way of further example, table II below lists the installed motor power (and in some cases the consumed motor power), and also the tons per day of ore processed (TPD) for several different size cells according to the invention. The ore processes was in all cases high grade ore; for typical low grade ores, the tons per day per cubic foot of cell may commonly be double the figures given. (Day means 24 hours.)

TABLE II

Dimensions (diameter × height)	Pulp Volume (ft^3)	Consumed Mechanical hp	Air hp	Total consumed hp	TPD	TPD/Ft^3
6′ × 6′	150	3	1.5	4.5	500	3.3
8′ × 6′	300	5	4.0	9.0	600	2.0
10′ × 10′	700	15	4.9	19.9	1200	1.7
14′ × 14′	2000	30	10	40	3000	1.5

of 38 to 40 percent by weight solids, with ore of 2.7 specific gravity (a pulp density of 1.30 of 1.33). The difference in power requirements between the 700 cubic foot cell of table II and the 700 cubic foot cell referred to previously was because the table II cell uses a six bladed impeller, whereas the previously mentioned 700 cubic foot cell used a 4 bladed impeller.

The power figures listed represent a drastic departure from prior art processes. In the past, in flotation processes where it has been desired to maintain the pulp in suspension and float the desired particles to the surface, it has invariably been the practice to use far higher powers. For example, **R. J. Brison and E. H. Gates, writing in the Jan.**, 1970 issue of Mining Congress Journal, list at p. 52, 53 the horsepower required for typical "large" flotation cells as of Sept. 1, 1969. The cells described are typically 200 to 300 cubic feet, the installed motor horsepower for such cells is between 25 and 50, and the air horsepower for such cells is typically between about 2 and 5. The authors also write (at p. **53**) that "the formerly large differences among flotation cells of different manufacturers in power per unit volume have almost disappeared in the new large machines."

Brison and Gates refer in their article to Froth Flotation, 50th Anniversary Issue, an authoritative text published by the American Institute of Mining, Metallurgical, and Petroleum Engineers and edited by D.W. Fuerstenau. Ch. 14 of the text deals with flotation machines and points out at p. 352, that many experts believe that the power intensity (hp per cubic foot of cell volume) is the most important index of machine performance, and that the capacity is roughly proportional to cell power intensity. The text also lists at p. 354 the power intensities for several different kinds and sizes of cells; the listed figures vary between 0.080 and 1.08 horsepower per cubic foot. At p. 358, the text points out produce a uniform suspension of a coarsely ground copper sulphide ore, and that a power density of 0.25 hp per cubic foot was more satisfactory.

Surprisingly, the process of the invention, although it uses one-third or less of the power intensity formerly thought necessary, operates just as efficiently in recovering minerals as the prior art suspension flotation cells. For example table III below compares the efficiency of the present process with that of a typical

prior art process in a comparative run at Opemiska Mines, Quebec, Canada.

TABLE III

SCAVENGER CIRCUIT

DATE	Type D 10×10 Invention Tail % Cu.	TYPE B Mill Tail From Conventional Flotation % Cu.
Aug. 30/67	0.11	0.10
Aug. 31/67	0.11	1.10
Sept. 1/67	0.07	0.12
Sept. 2/67	0.10	0.13
Sept. 3/67	0.10	0.12
Sept. 4/67	0.11	0.13
Sept. 6/67	0.10	0.14
Sept. 7/67	0.13	0.13
Sept. 8/67	0.14	0.14
Sept. 9/67	0.14	0.15
Sept. 10/67	0.12	0.12
Sept. 11/67	0.12	0.13
Sept. 12/67	0.17	0.14
Sept. 13/67	0.11	0.11
Sept. 14/67	0.10	0.12
Sept. 15/67	0.11	0.11
Sept. 16/67	0.12	0.13
Sept. 17/67	0.11	0.11
Sept. 18/67	0.11	0.12

Table III discloses that in typical daily competition between the method D of the invention and existing prior art methods of type B, the results compared favorably. The installation and one year operating cost of type B was 4.8 times the corresponding cost of method D.

The use of very low agitating and air power according to the invention provides in general a substantial saving in capital cost of a flotation plant, particularly where a substantial number of cells is used. The invention also provides in general a substantial saving in operating costs, since the power consumption is less than one-third of that normally used in the past, and since there is less wear of parts at the lower powers used.

The invention also compares favorably with various flotation processes which have been suggested in the past as alternatives to the type of process with which the invention is involved (i.e. processes requiring suspension of the pulp). For example, U.S. Pat. No. 3,455,451 issued July 15, 1969 to P. R. Smith discloses a process in which a froth layer is established by bubbling air through an inclined porous plate, and a feed layer is fed into the froth, so that the desired particles remain floated and the gangue sinks onto the inclined porous plate and then slides off the plate.

The Smith cell requires no power for mechanical agitation, but it still requires a great deal of power because it uses very large quantities of air (and pumping air is generally a less efficient process than pumping a liquid). Specifically, the Smith cell has an average depth of 6 inches above the perforated plate (which is inclined at an angle of 30° or more), and the air flow is given as 0.004 to 0.05 cubic feet per minute per square inch of plate. This is equal to between about 1.33 and 14 cubic feet of air per minute per cubic foot of pulp. More importantly, the Smith cell, which does not operate by keeping all of the pulp in suspension, must be very shallow increased depth confers no benefit), so that it would require enormous floor space to operate commercially, and thus the capital cost of a plant using such cells would be enormous.

Another alternative prior art process is shown in U.S. Pat. No. 2,130,144 issued Sept. 13, 1938 to J. M. McClave. In this process, feed is aerated in a separate tank and is then introduced into a rectangular flotation cell having an inclined bottom. Desired particles float to the surface, while gangue sinks to the bottom and is carried off by an upwardly sloping screw conveyor extending along the bottom. The difficulty with this apparatus is that it will not operate at an acceptable feed rate where substantial quantities of fine particles are present (as is always the case in mineral separation), because it depends on settlement of the gangue, rather than keeping all of the pulp in suspension.

Specifically, in the McClave process, the screw conveyor removes primarily solids, and very little liquid, from the bottom of the tank, so most of the liquid introduced by the feed must rise to the surface of the tank and exit with the desired concentrate. At commercially acceptable feed rates, the rising liquid prevents fine particles from settling, and such fine particles are therefore swept out with the concentrate. The resultant concentrate will therefore be hopelessly contaminated if any substantial quantity of undesired fine particles is present.

In mineral flotation processes to which the present invention is applicable, the ore is usually ground in a crusher, e.g. a ball mill, until the largest particles are no larger than a predetermined size. The crushing process forms many particles much smaller than that size, and typically 20 percent of the solids in the pulp feed may be less than 10 microns in diameter. (1,000 microns equal 1 millimeter). Such fine gangue particles will not readily settle, and therefore it is important where fine gangue particles are present, to employ a process of the type according to the invention, where nothing is allowed to settle to the bottom of the tank but instead the entire pulp mass is kept in suspension and the gangue or waste is removed from a location well above the bottom of the tank.

The process of the invention will normally be used with feeds having a solid content of between 7 and 50 percent, and more usually between 20 and 40 percent. The process will normally be used with metallic ores, although it can be used for other ores (e.g. potash), and the ores when ground will normally contain at least 20 percent by weight of fine particles less than 10 microns in diameter. The process of the invention will of course suspend such fine particles and will float them when desired, and it will also float much larger particles. For example, in a feed consisting primarily of water and particles of a copper sulphide ore (specific gravity, about 2.70), particles as large as about 1,000 microns can be floated. Where the feed consists primarily of brine (having a specific gravity of about 1.24) and the particles to be floated are relatively light, e.g. potash particles (specific gravity, 2.04), much larger particles, up to about 3,400 microns, can be floated.

The process of the invention can be operated at feed rates comparable to those of much higher power prior art processes. The feed rate will of course depend on the total volume of all the cells employed in the circuit and on the retention time needed for the particular

mineral being separated. Some minerals are ore difficult to float than others and therefore require a longer retention time, and in addition, high grade ores are normally given a longer retention time than are low grade ores. The retention time is normally adjusted so that at least 80 percent of the desired mineral content of the pulp is recovered in the complete flotation circuit. Some circuits according to the invention have been operated at 96 to 97 percent overall recovery, processing high grade copper ore.

In order to achieve the above recovery efficiencies, it is found that with cells operated according to the invention, the required retention times are the same as for much higher power cells, i.e. typically between 10 minutes and 1 hour, depending on the type and grade of ore being processed. A common retention time for many ores is between 10 and 20 minutes. This retention time is divided among the cells forming the circuit, so that if the flotation circuit includes three equal size cells (normally a circuit will include at least three cells, to prevent loss of mineral values by short circuiting of the feed, i.e. direct travel of feed from the inlet to the outlet of a cell), then the retention time in each cell will be about one third of the total retention time.

From the total retention time needed, and the total volume of all the cells in the circuit, the tons per day per cubic foot of total cell capacity can be simply derived. If more cells are added, the feed rate can be increased, but since the total cell capacity also increases, the overall TPD per cubic foot remains the same. Typically cells in which the process of the invention is conducted will process at least 0.5 TPD per cubic foot of total cell pulp volume, more usually at least 0.75 TPD, with recovery efficiencies of 80 percent or more, and the tonnages can be much higher, e.g. 5 or 6 TPD per cubic foot of total cell volume, depending on the kind and grade of ore.

The tank **10** may vary in size, as indicated by table II, but it will preferably have a capacity of at least 300 cubic feet of pulp and will commonly have a much larger capacity, e.g. 2,000 cubic feet or more. The size of the tank will however be limited by the mill capacity, since it is not desirable to have the entire flotation operation performed in one tank because of the risk of shortcircuiting the feed, as previously discussed. Usually at least three cells in series will be used in a flotation circuit. In smaller cells such as the 300–1,500 cubic foot capacity, the air flow will commonly not be less than .1 cubic feet per minute per cubic foot of pulp, but in larger cells such as those of 2,000 cubic foot capacity, an air flow of 0.075 cubic feet per minute per cubic foot of pulp was used with excellent results.

The shape and proportions of the tank **10** can be changed but preferably the tank **10** is of substantial height, i.e. of height which is at least a substantial fraction of its minimum lateral dimension, to reduce the amount of floor space needed for the flotation machines. The tank height will not normally be less than about 75 percent of the cell diameter and will not usually exceed the cell diameter. Preferably the tank is cylindrical, and of height approximately equal to its diameter. It is found that conducting the process in such a tank yields particularly good results, while control of the cell (e.g. of the amount of air introduced) is very simple, and the floor area required is much reduced as compared with conventional much shallower cells. It is found that the cylindrical tank used is far superior to a square or rectangular tank, since there are no corners at which "boiling" of the pulp can occur.

It will be appreciated that although there has been described a process in which the mineral portion of the pulp has been floated, the invention is equally applicable to the numerous processes in which the waste or gangue is floated and the mineral portion is removed from below the surface of the pulp.

What is claimed as my invention is:

1. A froth flotation process for a mineral pulp having a first portion to be floated and a second portion to be separated, one of said portions being a desired mineral portion, said process comprising

a. introducing said pulp into a cylindrical tank having a volume of at least **300** cubic feet and having a depth substantially equal to its diameter, said pulp containing between 7 and 50 percent by weight solids, at least 20 percent by weight of said solids being particles having a diameter less than 10 microns,

b. mechanically agitating said pulp by means of an impeller centered in said tank and located at a distance above the bottom of said tank equal to between 10 and 25 percent of the height of said tank, and introducing air into said pulp at a location below said impeller and at a pressure just sufficient to overcome the pressure of the pulp in said tank, to maintain all of the particles of said pulp in suspension and to prevent their settling to the bottom of said tank, while floating at least a part of said first portion, said agitation and aeration being sufficient to float particles of said first portion of up to 1,000 microns diameter,

c. the total power input to said pulp from said impeller and through said air being in the range between 0.010 and 0.035 horsepower per cubic foot of pulp, and the flow of said air being in the range between 0.05 and 0.30 cubic feet per minute per cubic foot of pulp,

d. removing the floated part of said first portion from the surface of said pulp,

e. and removing said second portion at a location substantially above said impeller but below the surface of said pulp,

f. the feed rate of said pulp being at least 0.5 tons per day for each cubic foot of volume of said tank and the recovery of said mineral portion being at least **80** percent.

2. A process according to claim **1** wherein said air is introduced at a single central location directly below said impeller.

3. A process according to claim **1** wherein said tank has a volume of at least 2,000 cubic feet and said total power input is in the range from 0.010 to 0.030 horsepower per cubic foot of pulp in said tank.

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