April 5, 1949. H. L. McNEILL 2,466,037

FLOTATION PROCESS AND APPARATUS

Filed Dec. 10, 1943 3 Sheets-Sheet 1

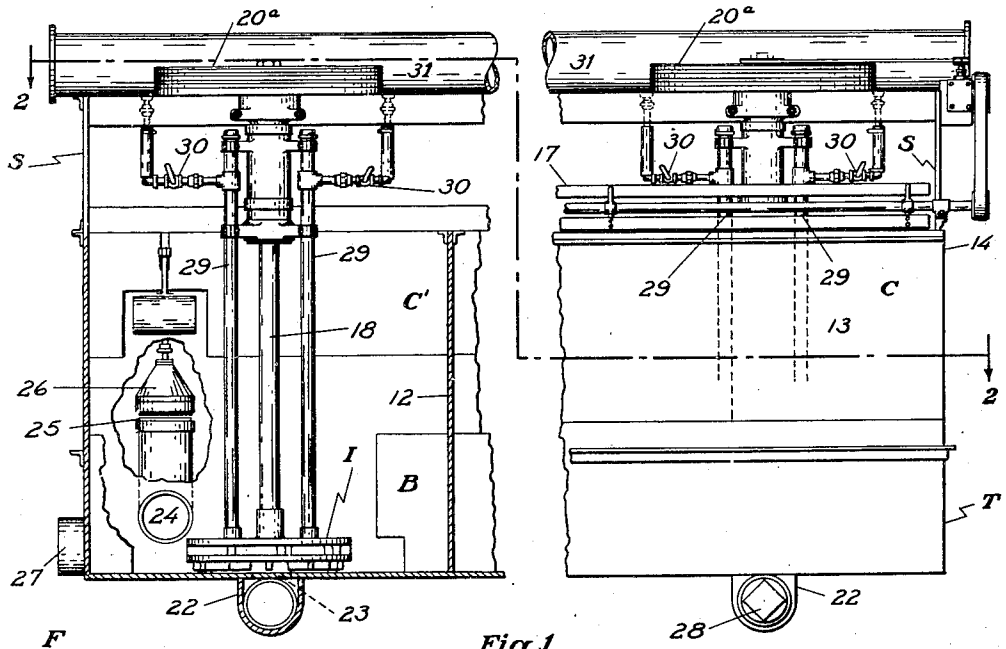


Fig. 1

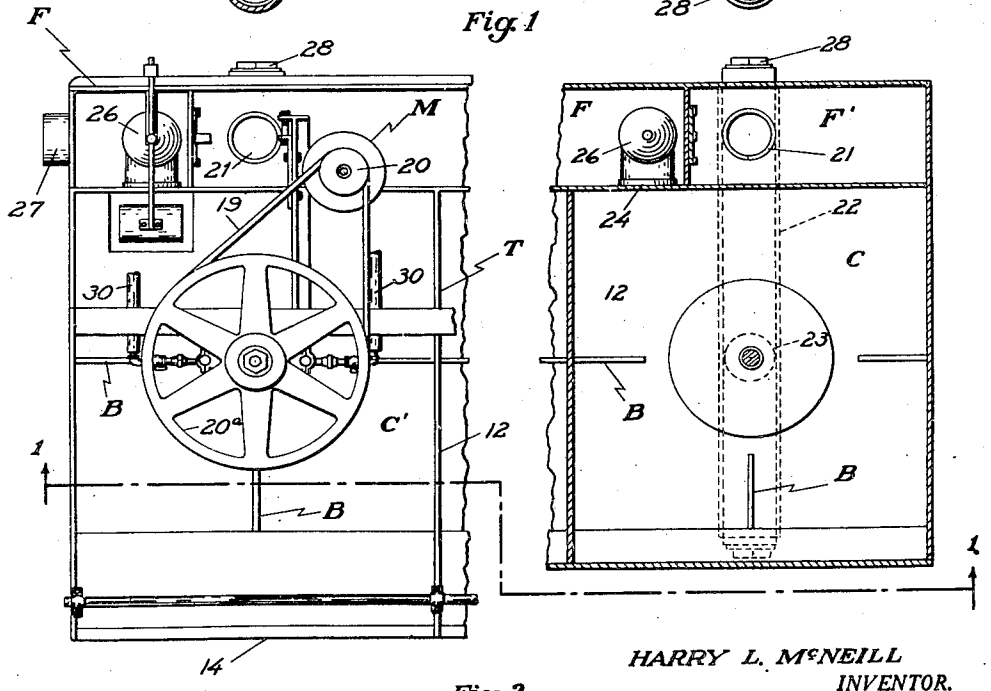


Fig. 2

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FLOTATION PROCESS AND APPARATUS

Filed Dec. 10, 1943 3 Sheets-Sheet 2

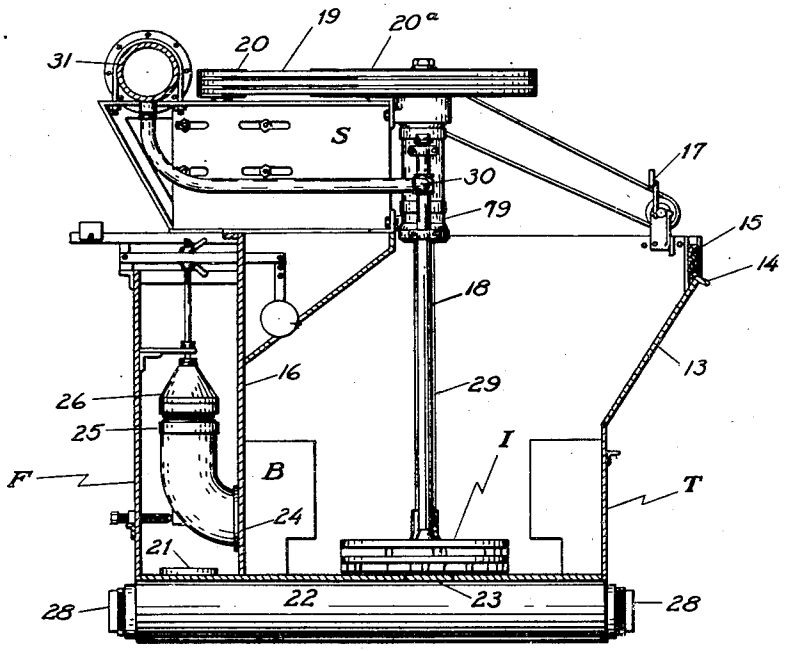


Fig. 3

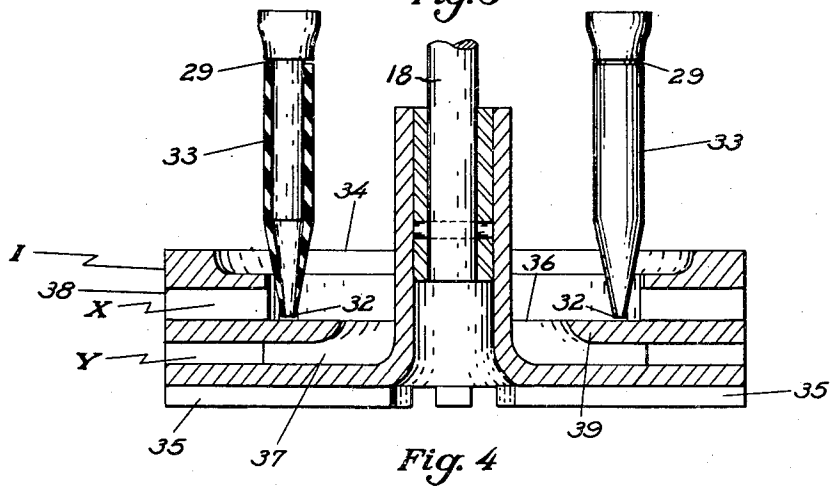


Fig. 4

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FLOTATION PROCESS AND APPARATUS

Filed Dec. 10, 1943 3 Sheets-Sheet 3

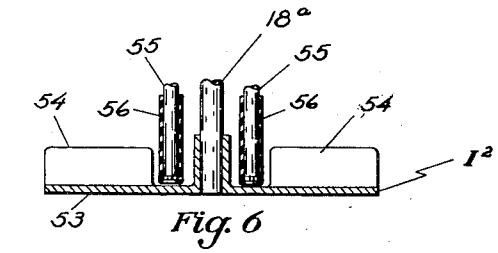


Fig. 6

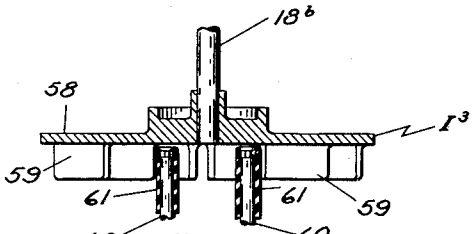


Fig. 7

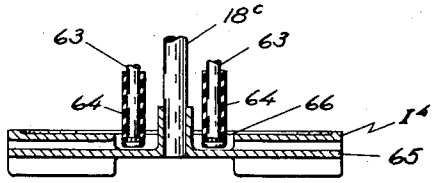


Fig. 8

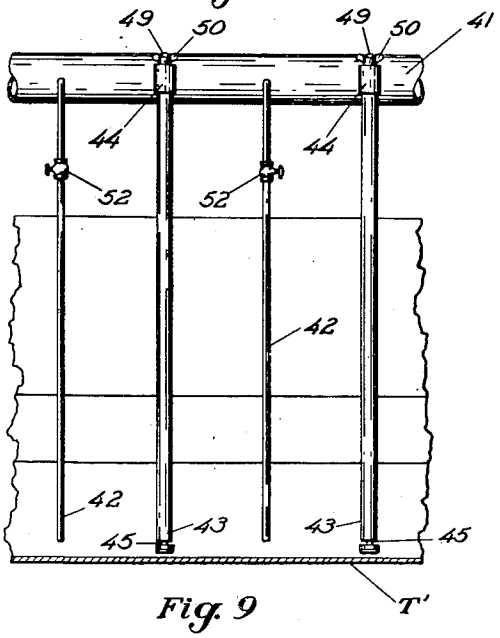


Fig. 9

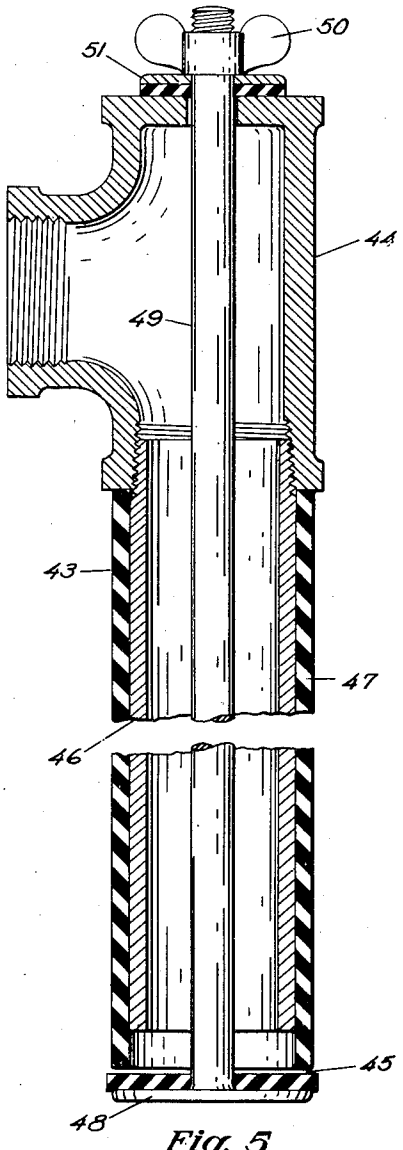


Fig. 5

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Patented Apr. 5, 1949 2,466,037

UNITED STATES PATENT OFFICE

2,466,037

FLOTATION PROCESS AND APPARATUS

Harry L. McNeill, Denver, Colo.

Application December 10, 1943, Serial No. 513,772

13 Claims. (Cl. 261—93)

1

This invention relates to froth flotation methods and apparatus. The present invention is a continuation-in-part of my application Serial No. 343,458 filed July 1, 1940, now Patent No. 2,348,990 patented May 16, 1944, for Aerating apparatus. Features disclosed but not claimed herein have been claimed in the aforesaid application.

In the art of flotation, many different types of machines have been developed. At one end of the range there is the air or pneumatic machine, using about three hundred cubic feet of gas to one cubic foot of pulp treated, while at the other end, there is the machine of the mechanical agitation type which in its agitation of the ore, entrains about ten cubic feet of air for every cubic foot of pulp treated. Intermediate the aforesaid machines, there are numerous other types which combine the features of these machines or variations thereof.

Since both the pneumatic and mechanical machines do the same type of work, it is logical to assume that much of the gas in the form of bubbles in the pneumatic machines does practically no work. It is also a logical assumption that the strictly mechanical machine expends far too much horsepower in order to entrain a relatively small amount of air.

Despite the many variations in the types of froth flotation treatments, there is one condition common to all, namely, without aeration, there is no flotation. This fact emphasizes the importance of air bubbles in the treatment and more particularly the types of bubbles which improve flotation and those which retard it.

In the conventional pneumatic type machine, air is forced under pressure through a tightly woven blanket. Minute bubbles begin to form on the upper side of the blanket. Many of them coalesce before separating from the blanket, and comparatively few remain small. With this type of machine, there is not enough pulp to disperse the large volume of air and coalescence predominates.

Large bubbles have relatively low surface tension. Because of their buoyancy, they cut across the pulp currents in the cell and rise quickly to the surface. Upon reaching atmosphere, they frequently break and drop the mineral entrapments.

Small bubbles, on the other hand, have a much higher surface tension and tend to follow the pulp currents. Because of their low buoyancy, they remain down in the pulp body a much longer time than large bubbles and consequently have

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a longer working interval and more frequent contact with mineral in which to form the attachments before rising to the surface.

It also is obvious that a given quantity of air broken down into small bubbles presents a much larger surface on which the mineral load may be transported.

Heretofore in the art, there has been no control to vary the volume of gas admitted to a flotation cell without also varying the velocity at which such gas is admitted. Through lack of this control, the pneumatic type of machines have wasted tremendous volumes of gas and the mechanical machines have had an unnecessary horsepower consumption.

The present method of introducing gas into the pulp provides a regulation of the velocity at which gas enters the pulp body even though the volume of air be kept constant. Conversely, the velocity of the entering air or gas may be kept constant, although the volume is varied.

In previous practice, low velocity air has been introduced into high velocity impellers, running at approximately 1500 feet per minute, peripheral speed. The violent action of the pulp within the impeller is used to break up the entering air. In contradistinction, the present operation reverses the process and employs a relatively low peripheral speed impeller into which high velocity air is broken up upon delivery thereto, for which reason the impeller is relieved of this work.

In this treatment, the duty of the impeller is to circulate enough pulp to keep the bubbles dispersed and prevent coalescence, for which reason the bubbles delivered into the impeller do not require further reduction in size.

In any flotation problem, the element of time is an important factor. The time required to make a tailing will be reduced if a given quantity of air is broken down to present a large surface to the mineral content in the pulp, while the time necessary to make the same tailing increases when incoming air is not finely divided, as well as requiring more air.

It is an object of the present invention to provide a method of gas discharge, in which substantially all gas delivered to a body of pulp is distributed among the particles of the pulp in dispersed condition and maintained as minute bubbles throughout its travel to the surface.

Another object of the invention is the provision of a method of aeration in association with mechanical agitators, permitting operation of the agitators at low peripheral speeds to attain a de-

sired degree of distribution of gas throughout a body of material treated by such agitators.

A further object of the invention is the provision of an aeration method for use in the froth flotation process, applicable to various types of machines, such as the pneumatic and mechanical agitation types, which permits control of the volume of gas admitted to the treatment zone independently of its velocity and also provides a control of the velocity independent of the volume.

A still further object of the invention is the provision of a method of aeration control, permitting regulation of the volume of gas and its distribution throughout a fluent body under treatment.

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

To clarify understanding of the present invention, the accompanying drawings illustrate a variety of structure embodying the features of the present invention, which will be described as typifying the variety of ways in which the present invention may be practiced.

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

Fig. 1 is a fragmentary side elevation of a multi-cell flotation machine embodying features of the present invention and partially broken away to show interior arrangements of parts;

Fig. 2 is a view of the machine of Fig. 1, partially in section and partially in plan taken from a position approximating the line 2—2, Fig. 1;

Fig. 3 is an end elevation of the machine shown in Fig. 1 and drawn partially in section to illustrate the interior arrangement of parts;

Fig. 4 is a vertical central section through an impeller of the type shown in Fig. 1, showing application of features of the present invention thereto, and drawn to an enlarged scale;

Fig. 5 is a vertical central section through an aerating nozzle of the type illustrated in Fig. 9 and drawn to an enlarged scale;

Fig. 6 is a corresponding section through a modified form of impeller embodying features of the present invention;

Fig. 7 is a corresponding section through another type of impeller;

Fig. 8 is a corresponding section through still another type of impeller; and

Fig. 9 is a fragmentary vertical section through a flotation cell of the pneumatic type, embodying features of the present invention.

Referring first to the form of the invention illustrated in Figs. 1, 2, 3 and 4, a multi-cell flotation machine has been illustrated with two cells C and C′ respectively, comprising the first and last cells of a series and a break shown between said cells to indicate the location of any number of intermediate cells (not illustrated).

The machine comprises a tank T divided at intervals throughout its length by partitions 12 into the aforementioned cells C, C′. The front wall of tank T inclines outwardly as indicated at 13 (Fig. 3) and terminates in a froth overflow lip 14 on which an adjustable weir member 15 is mounted.

The rear wall 16 of tank T inclines inwardly in its upper portion to exert a crowding action on froth forming in the cells C, C′ and this froth is caused to overflow weir 15 and discharge across lip 14 by rotary skimmers or paddles 17. Suitable launders (not shown) may be located under said overflow lip for collection and removal of the discharged froth.

Each cell is provided with an impeller I mounted on a shaft 18 journalled in bearings 79 mounted on superstructure S of the machine. The shafts 18 may be rotated in any convenient manner and preferably are driven through the intermediary of belts 19 and sheaves 20 and 20a by an electric motor M.

Swirl-restraining baffles B may be located in the lower portion of each cell as required. The circulation of pulp through the machine involves the use of a series of flow control compartments F and F″, the former controlling discharge of a given cell and thereby regulating pulp level, and the latter serving as the initial feed delivery compartment of the machine.

Feed to the machine is introduced into said compartment F″ of the first cell C from which is flows through an intake opening 21 of a conduit 22 extending underneath the cell and passes out through an opening 23 (cell C, Fig. 2) directly underneath the impeller I, due to the pumping action of said impeller.

Pulp not carried into the froth concentrate circulates in the cell in a manner hereinafter to be described and then discharges through the intake 24 of an L-conduit, the upper end 25 of which acts as a seat for a float-controlled valve 26. This valve may be adjusted to establish different levels in the cell, and once set serves to maintain the selected level despite feed fluctuations.

Pulp discharging past valve seat 25 flows along compartment F until it reaches the next intake opening 21 of the series, or in the case of the discharge passing out of cell C′, the pulp flows out of the machine through a discharge outlet 27. Preferably, each of the conduits 22 has front and back openings, normally closed by plugs 28, which may be removed for cleaning, or for connection of a suitable return conduit when rougher-cleaner operation is employed.

The construction features thus far described are more or less conventional in machines manufactured by The Stearns-Roger Manufacturing Company, which are classified as mechanical type, sub-aeration machines.

In the machine illustrated in Figs. 1, 2 and 3, the impeller I is of the type shown and claimed in Weinig et al. Patent No. 2,246,560 and the novel features of the present invention have been shown as applied to such an impeller. This involves delivering the aerating gas, preferably compressed air, through one or more supply conduits 29 having valve-controlled connections 30 with a header 31.

Each conduit 29 is arranged to have its outlet 32 in close proximity to an adjoining surface of impeller I, and spaced therefrom a distance not in excess of one-third the diameter of conduit 29. This arrangement provides an annular escape zone for the gas which discharges from outlet 32 in sheet-like form at a velocity greatly in excess of the velocity at which said gas travels through the conduits 29.

Preferably, means are provided for varying the spacing of outlet 32 from impeller I to give selective control of discharge velocity, and as illustrated in Fig. 4, this can be done conveniently by having flexible extension members 33 in the form of sleeves, mounted for lengthwise movement at the lower ends of conduits 29. After an initial setting, these members 33 usually will be

maintained in fixed relation to impeller I, but whenever a change in the aerating action is desired, a slight movement toward or away from the impeller will give the desired effect.

With this understanding of the structural arrangement employed, the operation of the machine of Figs. 1, 2 and 3 in the practice of the present invention will now be described. Cells C and C' plus any intermediate cells of the assembly are filled to the level determined by the initial regulation of float-controlled valves **26**, with pulp continuously fed to compartment F' of cell C and tailings continuously discharged through outlet **27**.

The impeller I of each cell of the series is caused to rotate at a speed substantially less than the usual operating speed of sub-aeration machines. After an initial setting of the sleeves **33** relative to the impellers and after an initial regulation of the gas delivery controls **30**, gas is fed continuously to each impeller at a uniform predetermined velocity.

In this operation, pulp descends into the impeller I through the central top opening **34** after having been given a circulatory movement by the pumping vanes **35** on the bottom surface of the impeller. After entering the impeller, the pump stream divides, with one portion flowing through a second central opening **36** of lesser diameter than opening **34** for subsequent discharge at the periphery of compartment Y under the impelling influence of blades **37**, while the remaining portion travels through compartment X to its peripheral discharge under the impelling influence of blades **38**.

Due to the close spacing of sleeve **33** and the dividing member **39** of impeller I, only a thin passage is provided for the escape of gas from conduits **29** and the rotation of the impeller provides a shearing action on the discharging gas, with the result that it is thrown radially from conduit **21** in sheet-like form and in an extremely fine state of division.

This form of gas discharge does away with large bubble formation and in the subsequent rise of the gas to the surface of the pulp body, the gas bubbles are prevented from coming together in any substantial quantity due to their thorough dispersion through the pulp. To attain this result, it is necessary to employ an initial gas velocity many times higher than the velocity of the liquid currents in the cell, as it is only for a fraction of a second that the light density air can retain a velocity higher than the pulp currents after discharge from the confining body (conduits **29**).

In the practice of the present invention, the gas is discharged at velocities seldom less than 10,000 feet per minute, whereas the pulp currents are almost never more than 2000 feet per minute, and in most instances, do not exceed 1500 feet per minute. This high velocity discharge serves to keep the surfaces bordering the annular discharge passage in an essentially dry condition at all times during operation and because of this, no clogging due to precipitation occurs as it otherwise would tend to do if such surfaces became wet.

Likewise, the high velocity serves to throw the gas a sufficient distance into the pulp body before its high velocity is dissipated to insure thorough intermingling with pulp particles and breaking up of the gaseous body without large bubble formation. Consequently, the aerating action after discharge is comparable to the champagne bottle

action rather than the large bubble formation of present flotation practice.

The presence of substantial quantities of pulp in the zone of gas discharge within the impeller serves to distribute minute bubbles of gas between the solid particles in the pulp. While so dispersed throughout the pulp stream entering compartment X, the minute entrained gas bubbles are moved by the impellent action through the impeller without being brought in contact sufficiently with other gas bubbles to permit any coalescing action.

Also, through the arrangement of valve controls **30** and the adjustment of sleeves **33** as aforesaid, the velocity of gas discharge may be varied for any volume of gas delivered through conduits **29**. With these controls it is possible to regulate volume independently of velocity, or to regulate velocity independently of volume.

That portion of the gas moving centrally of impeller I from the discharge outlets **32** becomes entrained in a similar manner in the pulp stream passing into compartment Y and passes therewith to its peripheral discharge. Due to the arrangement employed, only minor quantities of gas enter compartment Y, whereas large quantities of gas are delivered to the cell through compartment X. As a consequence, compartment X operates in an overloaded condition and compartment Y operates in an underloaded condition with the result that the peripheral mixing described in the aforesaid Weinig patent is attained in this form of aerating mechanism.

Except for these differences in aerating methods, the operation of the machine shown in Figs. 1, 2 and 3 is typical of mechanical type sub-aeration machines. Pulp passes progressively through the cells from first to last, subject to the aforesaid level regulation, and froth is overflowed across the lip **14** of each cell in a continuous action. Individual adjustment of weirs **15** may be made to overflow a selective amount of froth from a given cell, and when desired, froth from one cell may be returned as part of the feed to another cell by removal of a given plug **28** and connection of a conduit with the conduit **22** of such cell.

The constructions illustrated in Figs. 5 and 9 show the adaptation of the present invention to pneumatic flotation machines. In Fig. 9, a tank T' is provided for the treatment of a flotation pulp and a gas header **41** carrying the aerating gas is positioned above the tank while material to be treated therein, such as a mineral pulp, is fed in at one end of the machine and solids of the pulp are maintained in suspension by the agitative action of the process.

To this end, suitable agitating means are provided, here illustrated as pipes **42** having unrestricted discharge outlets adjacent the bottom of tank T'. These pipes or conduits **42** are supplied with gas from header **41** which passes there through at high velocity induced by the gas pressure in the header, and due to the limited capacity of the conduits, the gas discharges into the bottom of the tank in a violent manner.

The resulting agitation serves to keep particles tending to settle in a state of suspension within the liquid body, and the zone of influence of each such agitator is sufficiently large that considerable space may be reserved between successive agitators, here shown as two, in which the quiescent conditions necessary for proper froth flotation may be maintained. Preferably, the gas

discharge of the agitator conduits 42 is controlled by valves 52 permitting regulation of the rate of discharge. Usually an adjustment of outlets 45 will require a corresponding adjustment of valves 52.

At intervals throughout tank T', a series of aerating members 43 are provided, each of which is connected by a suitable fitting 44 with the header 41 for the supply of gas thereto and have at their lower ends a discharge passage 45. The lower extremity of member 43, as best shown in Fig. 5, comprises an inner conduit portion 46 and an external sleeve portion 47, preferably of a resilient character similar to the rubber tubing 33 of Fig. 4.

A plate 48 carried on a rod 49 is held in closely spaced relation to the end of sleeve 47 and defines therewith the annular gas discharge passage 45 aforementioned. The upper end of rod 49 is threaded and a wing nut 50 mounted thereon permits lengthwise adjustment of plate 48 relative to sleeve 47. Preferably, a packing nut 51 is mounted at the upper end of fitting 43 to prevent escape of gas therefrom along rod 49.

When tank T' is filled with pulp to its overflow level and the pulp body is subject to continuous feed and discharge, gas from header 41 is delivered through conduits 43 and caused to escape through outlet 45 into the pulp body. The gas so delivered being under substantial pressure is caused to move through the escape passage 45 at extremely high velocity and in sheet-like form to distribute through the pulp body and particularly between individual particles in the pulp in a finely dispersed condition of the same type as heretofore described with reference to the structure illustrated in Fig. 4. After being so discharged, the gas forms into minute bubbles which rise to the surface without appreciable coalescence, and these bubbles collectively impart the required elevating component on the particles of the constituent material being collected as a froth concentrate.

It will be understood that the discharge passages 45 may be positioned at any desired elevation within the cell. Under some circumstances, it may be desirable to maintain the lower portion of the pulp body in a state of relatively violent agitation and to locate the discharges 45 near the surface of the pulp body for aerating the elevated pulp in a zone of substantial quiescence, depending on the fine bubbles delivered thereto for the elevation and retention of the mineral at the surface.

In such an operation it will be desirable to provide means for volume regulation of the gas, such as by the provision of a valve control similar to the control members 30 shown in Fig. 1, which, in such event, would be located between header 41 and fitting 44. The control of gas volume thus provided together with the regulation of the position of plate 48 will permit gas of any selected volume to be delivered into the cell at a predetermined velocity in the manner previously explained.

The constructions illustrated in Figs. 6, 7 and 8 show the application of the features of the present invention to a variety of different type impellers used in typical mechanical-type flotation machines. For convenience in description, these impellers will be described as substitutes for the impellers I in the machine of Fig. 1, but it will be apparent to persons skilled in the art that the arrangement of parts comprising the aerating means would be just as applicable to any other type of conventional mechanical flotation machine.

The form of impeller I^2 illustrated in Fig. 6 comprises a disk or bottom plate 53 on which a plurality of agitating blades 54 are mounted, usually in radial arrangement. This impeller also is mounted on a rotary shaft 18*a* and the inner ends of the blades 54 terminate at a distance from the center of said impeller. One or more gas conduits 55 extend into the space between shaft 18*a* and blades 54 terminating in close proximity to the plate 53. A sleeve 56 of the type hereinbefore described is mounted on each conduit 55 in this form of invention and is spaced from plate 53 in the manner hereinbefore described. For convenience of illustration, the ends of sleeves 56 have been shown at a considerable distance from plate 53 in proportion to the diameter of conduits 55, but in actual practice the feature of having the spacing a distance not exceeding one-third the diameter of the conduit will be observed.

When the impeller I^2 is employed in the treatment of a fluent material such as a body of pulp being subjected to a froth flotation treatment, it is rotated at relatively high speed and gas is delivered through the conduits 55 at relatively high velocity. This gas discharges through the annular escape zone in sheet-like form and the shearing action previously described results. The finely dispersed gas mixing with pulp entering the space between shaft 18*a* and blades 54 becomes entrained in such pulp stream and moves outwardly along plate 53 under its centrifugal influence, where it is beaten by blades 54 and discharged across the periphery of the impeller.

Fig. 7 illustrates a different type of impeller I^3 in which a top cover plate or disk 58 supports a series of vanes 59 on its undersurface. This form of impeller is shown in Weinig Patent No. 1,998,694 of April 23, 1935 for Impeller, and no claim is made herein for the impeller construction per se.

In this arrangement, gas is delivered to the central space of the impeller through one or more conduits 60 located underneath the impeller and discharging upwardly against the undersurface of disk 58. Pulp or other fluent matter under treatment is drawn inwardly of the impeller by the slicing blades located adjacent the periphery, and upon entering the central space between the blades is mixed with the discharging gas and subsequently this pulp, inclusive of the entrained gas, is thrown outwardly by the pumping action of the radial vanes.

In this form of invention, the close spacing between the discharge outlet and the surface of the impeller plate 58 is again observed, although for clarity of illustration the ends of conduits 60 are shown at a substantial distance from the plate. Gas is discharged in finely divided condition by reason of the close positioning of sleeves 61 relative to plate 58, and the rotation of impeller I^3 serves to provide the necessary shearing action previously described.

In Fig. 8 another form of impeller I^4 has been illustrated, which is similar to the impeller of Fig. 4 with the dividing member (39 Fig. 4) omitted. Because of the widespread dispersion of the gas through the body of pulp treated in the impeller and the maintenance of the minute bubble condition in the treatment zone, the peripheral mixing obtained in the form of impeller illustrated in Fig. 4 is not required. This impeller is mounted on a shaft 18*c* and gas is delivered through supply conduits 63, preferably provided

with resilient sleeve members 64 of the type hereinbefore described. The close spacing arrangement again is employed with relation to the lower plate 65 of said impeller, and the discharged gas is mixed with pulp entering through the central inlet opening 66 of the impeller in the same manner as heretofore described with reference to the other impeller forms.

From the foregoing, it will be observed that in the various types of impellers illustrated the gas discharge action and the mixing of gas with fluent matter is the same or substantially identical. This serves to illustrate the universal application of the present invention to various types of agitators, and the agitators illustrated in Figs. 4 through 8 have been elected as representative of the entire range of such agitators which may be utilized in the practice of the present invention, it being understood that other forms not illustrated, may be similarly adapted for the purposes of the present invention.

The provision of a flexible sleeve, such as the sleeves 33 of Fig. 4, 47 of Fig. 5 and 56 of Fig. 6, provides a conventient means for the selective adjustment required and insures against damage to the agitating mechanism in the event that the rotating surfaces accidentally come in contact with the end of the conduit assembly. However, it is to be understood that other means of adjusting the spacing of the gas discharge outlet are within contemplation of the present invention.

It also has been noted in the practice of the present invention that the thickness of the material defining the annular escape zone is a factor in the efficiency of the operation. Consequently, where desired, the walls of the flexible sleeve may be substantially thicker than indicated in the scale of the present drawings.

With this arrangement, the escaping gas is retained in contact with the rotating impeller face for a relatively long interval and the resulting shearing action is thus accentuated. There are strong indications that a partial vacuum formed behind the pumping vanes in conventional impellers induces coalescence of gas bubbles. It was to avoid such an action that the impeller design shown in Fig. 4 was developed. In this form of impeller, gas is introduced on the pressure side of the impeller and therefore is not subject to partial vacuum conditions of the suction influence.

In certain froth flotation operations, there will be quantities of soluble salts present in the pulp body under treatment, such as calcium sulfate, various alums, carbonates or silicates, and in the treatment a precipitation of such salts occurs filling the gas discharge orifices of the present type of jets or nozzles.

The present invention is particularly suited for use in such a treatment as it provides a self-cleaning orifice, the action of which prevents precipitated matter from entering and closing the outlet passage. This is particularly true when a complete annular passage of the type illustrated is provided, as the force of the discharging gas is sufficient to keep precipitated matter from lodging in such passage.

The control of both velocity and volume of gas by the present aerating method, together with the shearing action provided, result in a discharge of streams of gas in an extremely fine state of division, and because of the radial direction of the discharge movement, the initially separated particles of gas become progressively more distant from one another in the course of their movement, with the result that the solids in the pulp and adhering collector reagent are able to penetrate between portions of such divided gas and effectively prevent coalescence.

Due to this aerating control, the discharge action permits the use of relatively low peripheral speeds where rotary members are employed, and as a consequence, little gas in addition to actual requirements is introduced into the cell. For this reason, the speed of the rotary member is initially calculated and maintained at a standard determined by the suspension requirements of the treatment rather than from the standpoint of the aerating function.

In the preceding description I have referred to the spacing of the nozzle end from the rotary or stationary deflecting member as preferably being at a distance not exceeding one-third the diameter of the conduit. I have found that within these limits the gas is caused to discharge at such high velocity in sheet-like form that no coalescence can be observed, whereas an increase in spacing even slightly beyond the one-third diameter range immediately produces coalescence to an observable degree. Consequently, the gas discharged in accordance with the practice of the present invention remains in an extremely fine state of division throughout its rise to the surface and acts on the reagent and pulp particles to exert an elevating component to the particles being concentrated that carries such particles into the froth formed on the surface of the pulp body.

From the foregoing description, it will be apparent that the present invention may be practiced in a variety of structural arrangements, and changes and modifications may be availed of within the spirit and scope of the hereunto appended claims.

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

1. In froth flotation apparatus, a tank for pulp, means in the tank for agitating matter fed thereto, a tubular conduit extending into the pulp body in the tank and terminating at a distance from said agitating means, a rotary deflector of greater superficial area than the conduit disposed perpendicular to the submerged end of the conduit, means for delivering gas under pressure into said conduit for discharge against said deflector means for varying the volume of gas moving into the conduit per unit of operating time, and means for varying the velocity of said gas at the point of discharge into the tank.

2. In a froth flotation process in which a pulp containing a collector reagent is subjected to aerating influences for the elevation of a pulp constituent to the surface and its collection in a froth formed thereon, the improvement which comprises agitating such a pulp by rotation of a submerged impeller at high speed within the pulp body, directing an aerating gas through a confined zone at right angles to a rotating surface of the impeller and under sufficient pressure to cause said gas to penetrate the pulp body to a substantial distance, and discharging the moving gas stream from said confined zone through an annular escape zone in such close proximity to the surface of the impeller as to cause the gas to travel parallel to said surface in radial sheet-like form for a substantial distance beyond said escape zone.

3. In a froth flotation process in which a pulp containing a collector reagent is subjected to aerating influences for the elevation of a pulp

constituent to the surface and its collection in a froth form thereon, the improvement which comprises agitating such a pulp by rotation of a submerged impeller at high speed within the pulp body, directing an aerating gas through a confined zone at right angles to a rotating surface of the impeller and under sufficient pressure to cause said gas to penetrate the pulp body to a substantial distance, and discharging the moving gas stream from said confined zone through an annular escape zone in such close proximity to the surface of the impeller as to cause the gas to travel parallel to said surface in radial sheet-like form at a velocity greatly in excess of the rate of flow of said gas through said confined zone for a substantial distance beyond said escape zone.

4. In a froth flotation process in which a pulp containing a collector reagent is subjected to aerating influences for the elevation of a pulp constituent to the surface and its collection in a froth formed thereon, the improvement which comprises agitating such a pulp by rotation of a submerged impeller at high speed within the pulp body, directing an aerating gas through a confined zone at right angles to a rotating surface of the impeller and under sufficient pressure to cause said gas to penetrate the pulp body to a substantial distance, discharging the moving gas stream from said confined zone through an annular escape zone in such close proximity to the surface of the impeller as to cause the gas to travel parallel to said surface in radial sheet-like form for a substantial distance beyond said escape zone, and subjecting the radial sheet of gas to centrifugal forces moving in a plane parallel with said sheet-like discharge on at least one side thereof.

5. In a froth flotation process in which a pulp containing a collector reagent is subjected to aerating influences for the elevation of a pulp constituent to the surface and its collection in a froth formed thereon, the improvement which comprises agitating such a pulp by rotation of a submerged impeller at high speed within the pulp body, directing an aerating gas through a confined zone at right angles to a rotating surface of the impeller and under sufficient pressure to cause said gas to penetrate the pulp body to a substantial distance, discharging the moving gas stream from said confined zone through an annular escape zone in such close proximity to the surface of the impeller as to cause the gas to travel parallel to said surface in radial sheet-like form for a substantial distance beyond said escape zone, and subjecting the radial sheet of gas to centrifugal forces moving in a plane parallel with said sheet-like discharge at the top and bottom sides thereof.

6. In a froth flotation process in which a pulp containing a collector reagent is subjected to aerating influences for the elevation of a pulp constituent to the surface and its collection in a froth formed thereon, the improvement which comprises agitating such a pulp by rotation of a submerged impeller at high speed within the pulp body, directing an aerating gas through a confined zone at right angles to a rotating surface of the impeller and under sufficient pressure to cause said gas to penetrate the pulp body to a substantial distance, and discharging the moving gas stream from said confined zone through an annular escape zone in such close proximity to the surface of the impeller as to cause the gas to travel parallel to said surface in radial sheet-like form at a velocity approximating ten thousand feet per minute for a substantial distance beyond said escape zone.

7. In a froth flotation process in which a pulp containing a collector reagent is subjected to aerating influences for the elevation of a pulp constituent to the surface and its collection in a froth formed thereon, the improvement which comprises agitating such a pulp by rotation of a submerged impeller at high speed within the pulp body, directing an aerating gas through a confined zone at right angles to a rotating surface of the impeller and under sufficient pressure to cause said gas to penetrate the pulp body to a substantial distance, discharging the moving gas stream from said confined zone through an annular escape zone in such close proximity to the surface of the impeller as to cause the gas to travel parallel to said surface in radial sheet-like form at a velocity greatly in excess of the rate of flow of said gas through said confined zone for a substantial distance beyond said escape zone, and varying said discharge velocity independently of the volume of said confined zone.

8. In a froth flotation process in which a pulp containing a collector reagent is subjected to aerating influences for the elevation of a pulp constituent to the surface and its collection in a froth formed thereon, the improvement which comprises agitating such a pulp by rotation of a submerged impeller at high speed within the pulp body, directing an aerating gas through a confined zone at right angles to a rotating surface of the impeller and under sufficient pressure to cause said gas to penetrate the pulp body to a substantial distance, discharging the moving gas stream from said confined zone through an annular escape zone in such close proximity to the surface of the impeller as to cause the gas to travel parallel to said surface in radial sheet-like form at a velocity greatly in excess of the rate of flow of said gas through said confined zone for a substantial distance beyond said escape zone, and varying the volume of the discharging sheet of gas independently of its velocity.

9. Froth flotation apparatus, comprising a cell having a discharge outlet for tailings and an overflow for froth, means for delivering pulp into said cell, a rotary, closed-type impeller in the lower portion of the cell having upper and lower discharge compartments and a central opening in its upper surface for admitting plup into the impeller, a conduit having a discharge outlet for delivering gas into the impeller, means for supplying gas under pressure to said conduit, means for varying the volume of gas delivered through said conduit, and means associated with said conduit for moving the discharge outlet toward and away from an inner surface of the impeller.

10. Froth flotation apparatus, comprising a cell having a discharge outlet for tailings and an overflow for froth, means for delivering plup into said cell, a rotary, closed-type impeller in the lower portion of the cell having upper and lower discharge compartments and a central opening in its upper surface for admitting pulp into the impeller, a conduit having a discharge outlet for delivering gas into the impeller, and a flexible sleeve extending into the central opening in the impeller and mounted on the conduit for movement toward and away from an inner surface of said impeller.

11. Froth flotation apparatus, comprising a cell having a discharge outlet for tailings and an

overflow for froth, means for delivering pulp into said cell, a rotary, closed-type impeller in the lower portion of the cell having upper and lower discharge compartments and a central opening in its upper surface for admitting pulp into the impeller, a plurality of conduits for delivering gas into said central opening, each conduit terminating in a lengthwise-movable portion disposed in spaced and proximate relation to an inner surface of the impeller of greater area than the diameter of the conduit at its point of discharge, and means for varying the volume of gas delivered through each said conduit.

12. A multi-cell flotation machine comprising a tank divided into a plurality of cells and having a froth overflow extending along a side of each said cell, a conductive system for delivering pulp from one said cell into the other said cell through a bottom opening therein, a rotary, closed-type impeller overhanging the bottom opening in each cell having upper and lower discharge compartments and a central opening in its upper surface for the intake of pulp, a conduit for delivering a controlled supply of gas from an outside source of pressure supply through the central opening into said impeller, inclusive of a movable member for disposing the discharge end of said conduit at variable and proximate distances from an inner surface of the impeller, and means for controlling the discharge of pulp from each said cell.

13. Froth flotation apparatus comprising a cell having a discharge outlet for tailings and an overflow for froth; means for delivering pulp into said cell; a conduit having a discharge outlet for delivering a gas in finely divided bubble form to the lower portion of said cell, said conduit having a resilient surface on the side toward the end of said conduit, said plate extending transversely to the axis of said conduit and spaced closely adjacent the end of said conduit; means for adjusting said plate toward and away from the end of said conduit; and means for supplying said conduit with a gas under pressure.

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REFERENCES CITED

The following references are of record in the file of this patent:

UNITED STATES PATENTS

Number	Name	Date
374,346	Coats	Dec. 6, 1887
555,515	Knobel et al.	Mar. 3, 1896
615,093	McIntyre	Nov. 29, 1898
1,985,153	Daman	Dec. 18, 1934
2,238,139	Tucker	Apr. 12, 1941
2,246,559	Weinig	June 24, 1941
2,246,560	Weinig	June 24, 1941
2,348,990	McNeill	May 16, 1944

FOREIGN PATENTS

Number	Country	Date
174,379	Great Britain	Jan. 25, 1923
458,583	Great Britain	Dec. 23, 1936
115,255	Germany	Dec. 10, 1900