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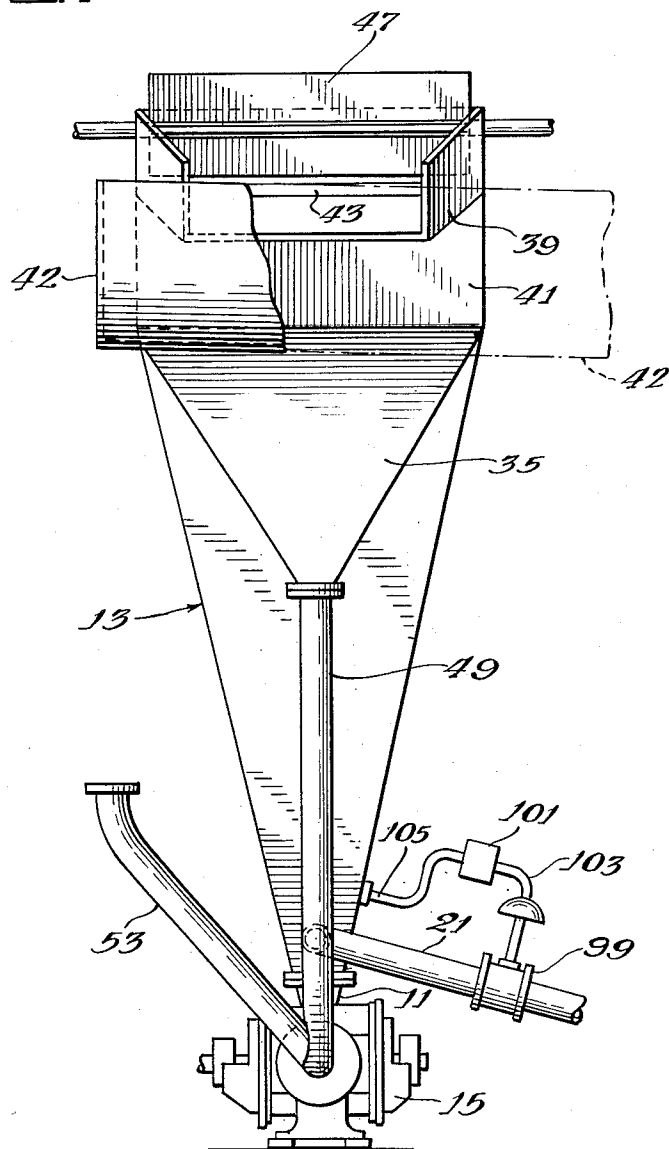
H. U. ZIEMER
FLOTATION APPARATUS

3,012,671

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4 Sheets-Sheet 1

FIG. 1



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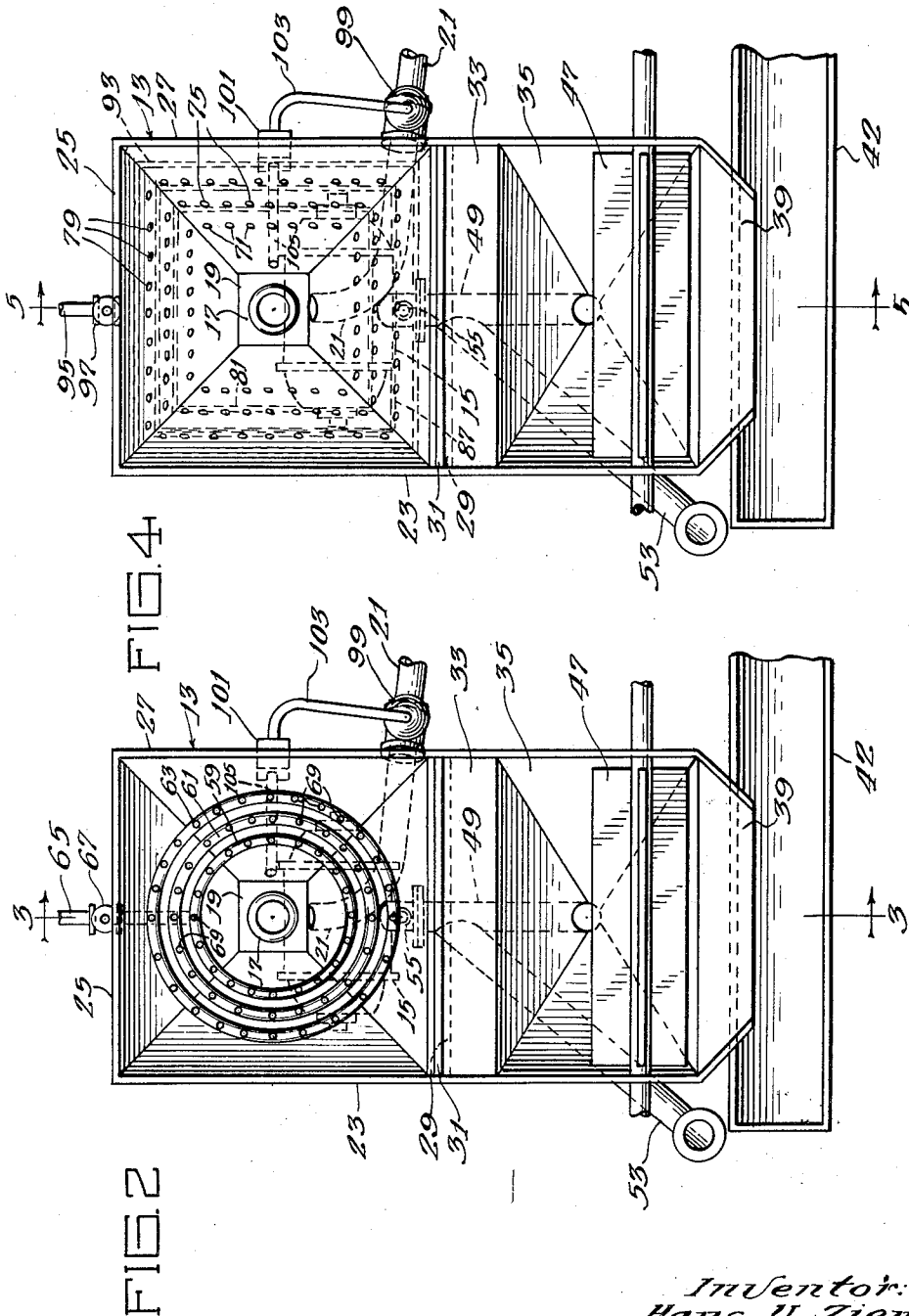
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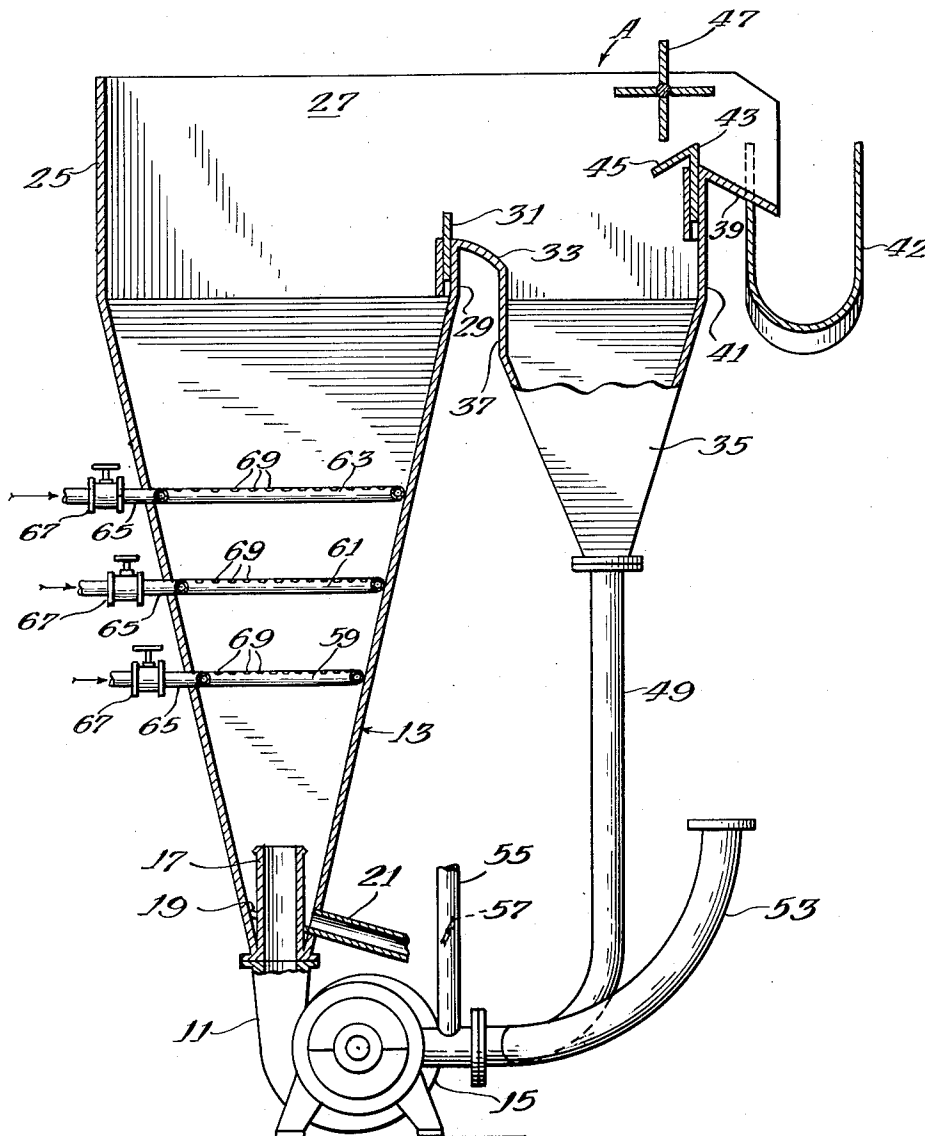
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FIG. 3



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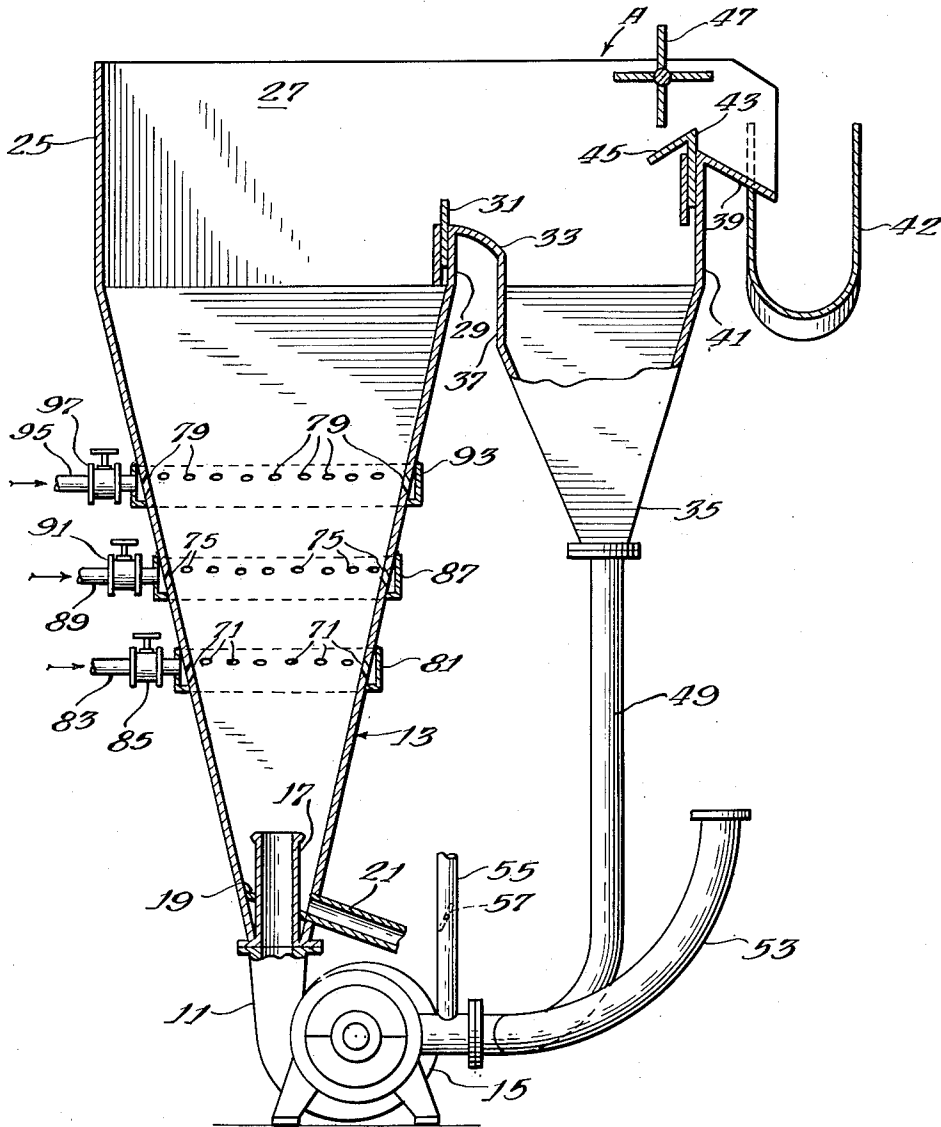
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FIG. 5



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FLOTATION APPARATUS

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The present invention generally relates to the art of beneficiating materials by flotation techniques. More particularly, it relates to a novel apparatus for beneficiating ores and other substances by flotation.

The beneficiation of ores by froth flotation techniques is of great importance to the ore beneficiation art. The flotation process is widely used for treating metallic and non-metallic ores and, in addition, is receiving an ever widening application in other industries.

In many of the prior art flotation machines the mineral feed, which is usually in the form of an aqueous pulp, is introduced horizontally into a flotation cell which is usually constructed substantially in the form of a cylinder or prism. The pulp is agitated and aerated in the flotation cell by a rapidly rotating impeller which rotates on a substantially vertical axis. The mineral-laden air bubbles separate from the other material and pass upwardly to the pulp level of the flotation cell to form a froth which is floated off the top of the cell.

Since the pulp is introduced laterally into such a flotation cell, in which the air bubbles are passing chiefly in an upward direction, it has been difficult because of this difference in the directions of flow to obtain a uniform distribution of air bubbles throughout the cross-section of the cell. It has also been difficult to float mineral particles of relatively large mass in such a flotation cell.

A different type of flotation cell has recently been developed which remedies some of the shortcomings of many of the prior art flotation machines. This new flotation cell is described in detail in copending U.S. patent application Serial No. 754,765, filed August 13, 1958, now U.S. Patent No. 2,922,521, issued January 26, 1960. The apparatus described in the copending patent application includes an inlet conduit for containing a flowing stream of fluid, and a laterally diverging vertical conduit connected to the inflow conduit adjacent the outflow end thereof for receiving the flowing stream of fluid from the inflow conduit. The laterally diverging conduit comprises a part of the flotation cell. A pump is connected in the inflow conduit line for pumping the flotation cell feed through the inflow conduit into the laterally diverging conduit. The present invention is directed to improvements in such flotation apparatus. When using such apparatus, it has been possible, because of air and pump thrust upwardly into the diverging conduit, to effect a higher weight recovery of materials than can be obtained in more conventional flotation cells; for example, such cells as are used in Fagergren and Denver flotation machines. In the flotation apparatus described in application Serial No. 754,765, the aerating air is mixed with the aqueous pulp in the pump and the air-pulp mixture is directed into the flotation cell. It has, however, been difficult to control the quality and quantity of aeration when using such apparatus and the present invention provides an apparatus in which the aeration is readily controlled.

It is, accordingly, an object of the present invention to provide a novel apparatus for beneficiating ores.

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It is a further object of the invention to provide a new flotation apparatus which achieves efficient aeration in the flotation cell.

It is another object of the invention to provide a new flotation machine having a diverging conduit flotation cell with aerating means provided between the diverging walls of the cell.

These and further objects and advantages of the present invention will be apparent from the following description and accompanying drawings which illustrate embodiments of the invention.

In the drawings:

FIGURE 1 is a side elevational view, partially broken, of one form of flotation apparatus embodying certain of the features of the invention;

FIGURE 2 is a plan view of the apparatus illustrated in FIGURE 1;

FIGURE 3 is a sectional view taken substantially along line 3-3 of FIGURE 2;

FIGURE 4 is a plan view of a flotation cell, generally similar to that illustrated in FIGURES 1 to 3, embodying another form of aerating means; and

FIGURE 5 is a sectional view taken substantially along line 5-5 of FIGURE 4.

As will hereinafter appear, the above-stated objects of the invention are accomplished by the provision of aerating means in the diverging conduit system of a flotation cell. The invention makes possible more positive and more effective control of the quality and quantity of aeration in diverging conduit flotation cells than has heretofore been attained.

The apparatus of the present invention is eminently useful for the froth flotation beneficiation of potash ores such as sylvite, sylvinitite, langbeinite, mixed potash ores, etc., phosphate ores, and the like. The apparatus operates efficiently at high throughputs. The apparatus also makes possible the beneficiation of larger ore particles than are usually beneficiated in conventional flotation machines.

In general, the flotation apparatus of this invention comprises an inflow conduit for containing a flowing stream of fluid, a laterally diverging conduit connected to the inflow conduit adjacent the outflow end thereof for receiving the stream of fluid from the inflow conduit, and aerating means between the walls of the diverging conduit. By providing aerating means in the diverging conduit system, more efficient aeration of the pulp is achieved and the quality and quantity of aeration may be readily controlled. It is to be understood that the particular structures illustrated in the drawings are merely illustrative embodiments of the general principles involved.

The apparatus provides a flotation cell having a bottom inlet and an overflow adjacent to the upper end of the flotation cell. Between the inlet and overflow, the flotation cell is defined by a rigid-walled laterally diverging conduit section. The flotation cells, in accordance with the present invention, illustrated in the drawings, are provided with a plurality of aerating means within the diverging walls of the conduit which effect a uniform distribution of air bubbles across the cross section of the cell. The aerating means between the diverging walls of the flotation cell control the quality and quantity of aeration independently of the feed rate and other variables in the flotation operation. The inflow conduit opens centrally or substantially centrally into the flotation cell from below and the pulp-air mixture emerges from the inlet pipe

as a jet stream and rises in the flotation cell. The air-laden mineral particles continue to rise in the cell to the froth level.

Since the jet stream carries the solid entrained particles mainly vertically upwardly in the same direction that the air bubbles are rising, the adherence of the solid particles to the air bubbles is greatly facilitated and at the same time a shaking or shearing of the solid particles from the bubbles is substantially reduced. For this reason, the apparatus enables a reliable flotation of even unusually coarse particles with high efficiency.

The flotation cell is also provided with an outflow conduit connected to a lower portion of the cell through which non-floated material may be withdrawn from the cell. A control valve is connected in the outflow conduit and the control valve is operatively connected to the fluid in the flotation cell.

A flotation apparatus embodying the principles of this invention is illustrated in FIGURES 1, 2, and 3 of the drawings. Another embodiment of the aerating means is illustrated in FIGURES 4 and 5 of the drawings. In both embodiments, many of the pieces of apparatus are the same and corresponding numbers are used. Referring to the drawings, the apparatus illustrated includes an inflow conduit 11 which is connected to the bottom of a rigid walled, laterally diverging conduit or flotation cell 13. The flotation cell 13 is illustrated as an inverted pyramid having a rectangular cross section; however, the diverging conduit may take on other forms such as an inverted cone. The point angle of the cell is preferably from about 20° to about 50°. The cell also preferably has a height from about 1.5 to about 3.5 times the width of the cell. The cell 13 has a substantially vertical axis and the walls thereof diverge laterally with increasing elevation. The inflow conduit 11 is also a discharge conduit of a pump 15. The inflow conduit 11 extends vertically upwardly and has an extension 17 (FIGURES 3 and 5) into the flotation cell. In general, the length of the extension 17 into the flotation cell depends upon the feed rate and the ratio of floated material to non-floated material. For example, when beneficiating different materials at substantially the same inflow conditions, if the ratio changes from 1:2 to 1:4, the extension 17 is preferably of relatively longer length in the latter operation. The flotation cell 13 is provided with an inclined bottom 19 spaced below the outlet opening of the extension 17. The flotation cell 13 also has connected adjacent its lowermost point an outflow conduit 21 through which material may be withdrawn from the flotation cell. In order to efficiently drain the flotation cell when the cell is not in operation, the lower part of the outflow conduit 21 is in substantial alignment with the inclined bottom 19 and is connected into the flotation cell 13 at the lowermost point of the inclined bottom 19.

The flotation cell 13 is provided at the top with vertical walls 23, 25, 27 and 29 which together form a froth box on the flotation cell 13. The upper edge of the inside wall 29 is somewhat lower than the upper edge of the other walls and provides a froth discharge means from the agitation cell 13. An overflow weir 31 is suitably fixed in wall 29 and extends above the upper edge of this wall. The weir 31 is preferably adjustable in height by means not shown. A guide plate 33 is connected to the top edge of the wall 29 and curves downwardly to a funnel 35. The funnel 35, illustrated, is also of rectangular cross section and the upper edge of the inside vertical wall 37 of the funnel is connected to the guide plate 33. The funnel 35 has four vertical walls which form a froth box on the funnel. The inside wall 37 and the outside wall 41 are parallel. The other two parallel walls are extensions of walls 23 and 27 of the flotation cell 13, and, therefore, the same numbers designate these walls. The four vertical walls together form a froth box on the funnel 35.

The wall 41 is somewhat lower than walls 23 and 27 and is provided at its top edge with a chute 39, which receives the discharge froth from the froth box of the funnel

and delivers it to a discharge trough 42. The wall 41 is preferably provided on the inside with a weir 43 which is preferably vertically adjustable by means not illustrated. The top edge of the weir 43 is provided with a downwardly and inwardly inclined plate 45 over which a rotatable paddle wheel 47 is positioned. When in operation, the paddle wheel 47 rotates in the direction shown by the arrow A in FIGURES 3 and 5, which aids in moving the froth out of the funnel and into the discharge trough 42. A recycle conduit 49 connects the bottom of the funnel 35 to a fresh feed inlet conduit 53 which is connected to the suction end of the pump 15. An air inlet conduit 55 is also connected into the fresh feed inlet conduit 53. This conduit 55 has a throttle flap 57 therein for regulating the flow within the conduit 55. Aerating air is introduced into inlet conduit 53 via conduit 55 to aerate the aqueous pulp being drawn into the suction end of the pump 15.

As illustrated in FIGURES 2 and 3, the aerating means provided includes three aerating rings, 59, 61, and 63, positioned within the walls of the diverging conduit flotation cell 13 above the outflow end of the extension 17 and below the overflow from the cell. These rings are vertically spaced within the diverging walls. These aerating means effect efficient aeration of the aqueous pulp in the flotation cell 13. Each of the aerating rings, illustrated, is a circular hollow tube. In order to effect substantially uniform aeration across a horizontal cross section of the flotation cell, the upper ring 63 is of greater diameter than the middle ring 61 and, similarly, the diameter of the middle ring 61 is greater than the diameter of the lower ring 59. The rings are substantially horizontal and the diameter of each ring is preferably such that the outside portion of each ring passes adjacent to the diverging walls; however, the rings may be of smaller diameter. The interior of each of the tubular rings is connected to a source of pressurized air (not illustrated) by a tube 65 which projects through the wall of the cell 13. In order to regulate the quantity of air passing into each of the tubular rings, 59, 61, and 63, a valve 67 is positioned in each of the tubes 65. Each of the aerating rings has a plurality of spaced holes 69 therein which permit the air within the tubular rings to pass into the flotation cell, thereby providing a plurality of aerating points in the cell. The size and number and spacing of the holes or openings 69 may vary with the particular material being processed, the processing conditions, etc. In general, the holes are equally spaced and in the upper part of each tube so as to provide a plurality of upwardly directed jets of air into the cell.

In the embodiments illustrated in FIGURES 4 and 5, the aerating means includes a plurality of holes extending through the walls of the flotation cell. Three sets of holes, 71, 75, and 79, each set being at a different elevation in the cell 13, are provided in the flotation cell so as to achieve substantially uniform aeration across a horizontal cross section of the cell 13. Each set of holes includes a plurality of holes at substantially the same elevation. The lower series of holes 71 are substantially equally spaced and are present in each of the four walls of the flotation cell 13. The middle set of holes 75 is positioned above the lower set 71 and the holes in this middle set are also equally spaced around the four walls of the cell 13. The same is true of the upper set of holes 79. In order to achieve individual control over the amount of aeration being affected by each of the series of holes, each series is separately connected to a source of pressurized air (not shown). Referring to the lower series of holes, 71, a jacket 81 is provided on the exterior of the flotation cell 13 so as to enclose the holes 71. The jacket 81 is continuous and is secured, as by welding, to the exterior of the flotation cell 13 so that air does not leak out between the jacket 81 and the exterior walls of the flotation cell 13. The air chamber provided between the walls of the conduit 13 and the jacket 81 is in fluid communication with a source of pressurized air

(not shown) through pipe 83. A valve 85 is positioned in pipe 83 as to permit the control of the quantity of air being introduced into the flotation cell through the holes 71. In a similar manner, the middle series of holes 75 is in communication with the air chamber formed between the flotation cell 13 and a jacket 87. This air chamber is connected to a source of pressurized air via pipe 89 in which valve 91 is positioned. In a further similar manner, the upper series of holes 79 is connected with the air chamber provided between the walls of the flotation cell 13 and a jacket 93. This air chamber is in fluid communication with a source of pressure air via pipe 95 which has a valve 97 therein.

In the embodiment illustrated in these figures, three series of holes are illustrated at different elevations in the diverging conduit system of the flotation cell. It is to be understood, however, that one, two, three or more of such series of holes may be used. In general, with more aerating holes, a more uniform aeration of the pulp in the flotation cell is achieved. Also in the illustrated embodiment the air supplied to each of the rings 59, 61 or 63, or to the series of holes 71, 75, and 79 is individually controlled. Individual control, while preferred, is not an essential feature.

A control valve 99 (FIG. 1) is positioned in the outflow conduit 21 through which tailings may be withdrawn from the flotation cell 13. It has been determined that the operation of the flotation cell may be efficiently controlled by controlling the rate of tailing withdrawal through the outflow conduit 21. The control valve 99 adjustably controls this rate of withdrawal. The control valve 99 is operatively connected to the fluid in the flotation cell 13. The operation of the flotation cell 13 is preferably controlled by adjusting the rate of tailing withdrawal so as to maintain a substantially constant predetermined pulp density in the flotation cell and preferably in the lower portion of the flotation cell. The control valve 99 is, therefore, preferably operatively connected to the interior of the cell, that is to the fluid in the lower portion of the flotation cell 13, in a manner to obtain a substantially constant predetermined pulp density in the lower portion of the cell 13. The control valve is preferably rubber lined so as to reduce corrosion of the valve. In the illustrated embodiment, the opening or closing of the control valve 99 is controlled by an automatic control device 101 (FIG. 1) which is diagrammatically illustrated in the drawing since such devices are well known and the specific construction of the device 101 forms no part of the invention. The control device 101 is operatively connected to the valve 99 by line 103. The control device 101 is also operatively connected to the material in the lower portion of the flotation cell 13 by line 105. The device 101 receives a signal through line 105 which is proportional to the pulp density in the lower portion of the flotation cell and the control device 101 converts the signal into a form which adjusts the amount of opening of the control valve 99 thereby adjusting the rate of withdrawal of tailing through the outflow conduit 21. The control valve 99 is controlled by the control device 101 in a manner such that when the pulp density in the lower portion of the flotation cell is above the predetermined pulp density which it is desired to maintain, the valve is in a relatively more open position and the rate of withdrawal of pulp through line 21 is greater than when the pulp density is at the predetermined density. Similarly, the control valve 99 is controlled by the control device 101 in a manner such that when the pulp density in the lower portion of the flotation cell is below the predetermined density which it is desired to maintain, the valve 99 is in a more relatively closed position and the rate of withdrawal of pulp through conduit 21 is less than when the pulp density is at the predetermined point.

The description of the invention utilized specific reference to certain construction details; however, it is to be

understood that such details are illustrative only and not by way of limitation. Other modifications and equivalents of the invention will be apparent to those skilled in the art from the foregoing description.

Having now fully described and illustrated the invention, what is desired to be secured and claimed by Letters Patent is set forth in the appended claims.

I claim:

1. Flotation cell apparatus comprising a vertical rigid-walled laterally diverging conduit having a substantially centrally positioned bottom inlet and an overflow adjacent to the upper end, a substantially vertical inflow conduit connected to the bottom inlet of said diverging conduit for introducing a stream of fluid vertically upward into said flotation cell, and aerating means carried by the diverging conduit adjacent the conduit wall and providing a plurality of generally horizontally arranged apertures encircling said stream of fluid, said aerating means being disposed above the outflow end of said inflow conduit and below said overflow to effect a distribution of air bubbles across a horizontal cross section of the cell when the flotation cell is in operation.

2. Flotation cell apparatus comprising a vertical rigid-walled laterally diverging conduit having a substantially centrally positioned bottom inlet and an overflow adjacent to the upper end, a substantially vertical inflow conduit connected to the bottom inlet of said diverging conduit for introducing a stream of fluid vertically upward into said flotation cell, an outflow conduit connected to a lower portion of said flotation cell, and aerating means, carried by the diverging conduit adjacent the conduit wall and providing a plurality of generally horizontally arranged apertures encircling said stream of fluid, said aerating means being disposed above the outflow end of said inflow conduit and below said overflow to effect a substantially uniform distribution of air bubbles across a horizontal cross section of the cell when the flotation cell is in operation.

3. Flotation cell apparatus comprising a vertical rigid-walled laterally diverging conduit having a substantially centrally positioned bottom inlet and an overflow adjacent to the upper end, a substantially vertical inflow conduit connected to the bottom inlet of said diverging conduit for introducing a stream of fluid vertically upward into said flotation cell, an outflow conduit connected to a lower portion of said flotation cell, aerating means carried by the diverging conduit adjacent the conduit walls and providing a plurality of generally horizontally arranged apertures encircling said stream of fluid, said aerating means being disposed above the outflow end of said inflow conduit and below said overflow to effect a distribution of air bubbles across a horizontal cross section of the cell when the flotation cell is in operation, said aerating means including at least one circular tubular member providing said plurality of apertures therein through which air may pass from the interior of said tubular member into said flotation cell, and a conduit connecting the interior of said tubular member with a source of pressured air.

4. Flotation cell apparatus comprising a vertical rigid-walled laterally diverging conduit having a substantially centrally positioned bottom inlet and an overflow adjacent to the upper end, an outflow conduit connected to a lower portion of said flotation cell, a density control valve, said valve being in said outflow conduit operatively connected to the interior of said flotation cell to regulate withdrawal of material from said cell to maintain substantially constant density of pulp within the lower portion of said cell, a substantially vertical inflow conduit connected to the bottom inlet of said diverging conduit for introducing a stream of fluid vertically upward into said flotation cell, and aerating means carried by the diverging conduit adjacent the conduit wall and providing a plurality of spaced generally horizontally arranged apertures encircling said stream of fluid, said aerating

means being disposed above the outflow end of said inflow conduit and below said overflow to effect a substantially uniform distribution of air bubbles across a horizontal cross section of the cell when the flotation cell is in operation.

5. Flotation cell apparatus as recited in claim 4 wherein said aerating means providing a plurality of apertures is formed by a plurality of holes extending through the diverging walls of said diverging conduit and through which air may pass into said flotation cell.

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