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FROTH HEIGHT AND LIQUID SLURRY LEVEL DETERMINATION FOR A FLOATATION CELL

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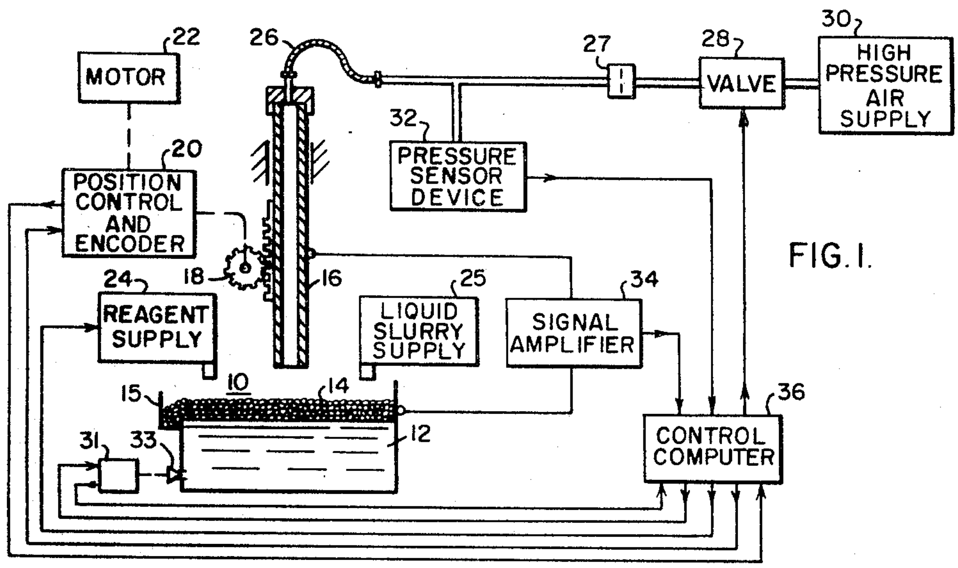

FIG. I.

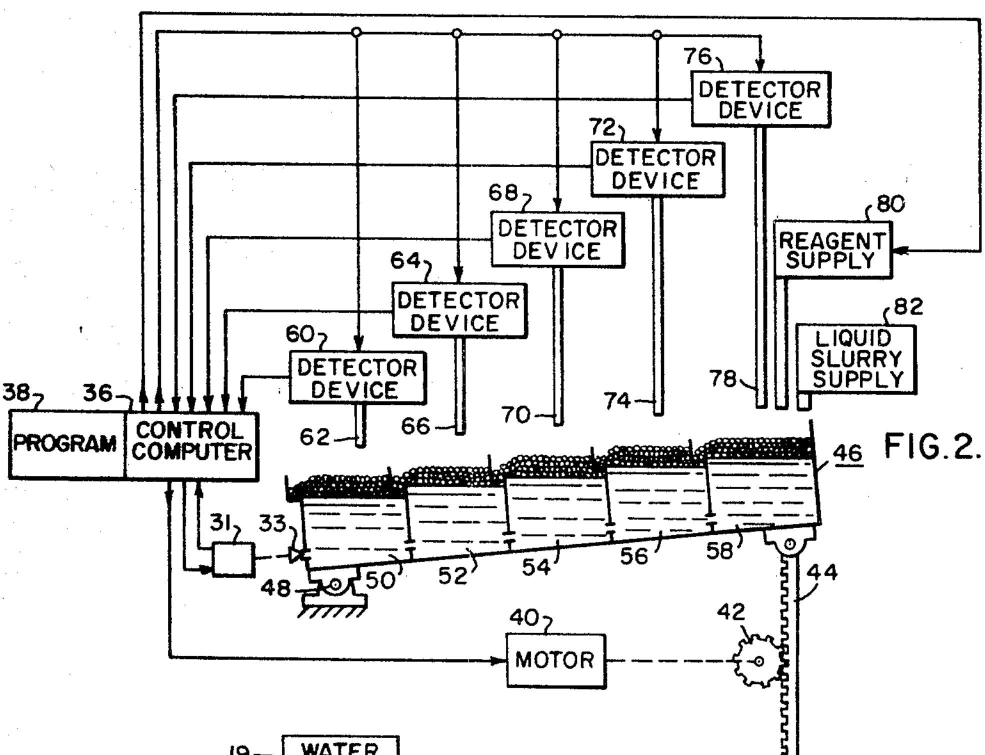

FIG. 2.

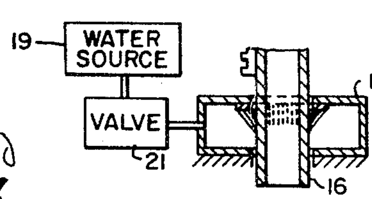

FIG. 3.

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FROTH HEIGHT AND LIQUID SLURRY LEVEL DETERMINATION FOR A FLOATATION CELL

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U.S. Cl. 209—1 10 Claims

ABSTRACT OF THE DISCLOSURE

There is disclosed apparatus for determining the height or depth of the froth material about the liquid slurry contained in a mineral separating floatation cell, and includes the control of the floatation cell including the addition of frothing reagent to one or more cells in relation to the agitation and position of same for providing a desired froth height and liquid slurry level within the one or more cells.

BACKGROUND OF THE INVENTION

In the control of floatation cells utilized in the well known process for the separation of mineral ores through operation of plural and successive floatation cells commonly employed for this purpose, one of the reagents put into this cell is a frothing agent and over the length of the provided plurality of floatation cells there occurs different froth heights, because in the action of the first such cell some of the frothing agent values have been removed and there is less frothing agent later on in succeeding cells. Also, frothing agent has to be added to various of the cells along the length of the plural structure to make sure there is enough froth present in each cell to remove the ore concentrate.

A plural cell structure is in effect a long box, with agitators placed within individual cells along the length of the box. A raw ground ore slurry is fed into the first cell at one end of the box in combination with reagents like cyanide, lead xanthate and pine oil as a frothing agent. Air is entrained due to the action of the provided agitators and a froth is produced containing many bubbles. What is involved here is an adsorption process, where lead xanthate coats the particle sulfides of copper, lead or zinc and so forth which causes them to become attached to the bubbles, which bubbles rise and carry these adsorbed sulfide particles up with them and they discharge out the top of the individual cells. The marketable values of the process are in the ore removed in this manner.

The liquid level of each cell is controlled by a valve at the end of the cell structure, but the froth height at present is not controlled except by manually operated weirs. The liquid is in the form of a slurry, and the liquid level in each cell or more usually at the end of the box structure is measured and regulates an outlet valve to hold the liquid level at such location substantially constant.

The overflow of froth bubbles from each cell is determined by the action of the weir, which is located about one half inch above the controlled liquid level and lets only the froth flow over the side of each cell. In addition, a mechanical paddle or like pusher member is sometimes provided to push the froth toward the weir and over the side of the cell, and then the froth is carried away to another stage of the process.

In the floatation of minerals, various reagents are added to the ore slurry prior to entering the floatation cells. One of these is a frothing agent, and the amount of that agent added should be such as to hold the froth height in the cell substantially constant. Too much froth can

lower the concentrate grade, while too little froth will reduce the recovery rate.

The measurement of this froth height is a desirable step in the closed loop control of this parameter. Up to the present time various capacitance methods have been tried but have met with only partial success.

SUMMARY OF THE PRESENT INVENTION

The present invention describes a control of froth height using the capabilities of a process control computer for the desired operation of the froth height determining apparatus.

A hollow tube probe member is driven with reciprocating or other suitable motion by an electric motor through a sliding block mechanism. The whole unit is mounted in a housing which is electrically insulated from the floatation cell. Connected to the drive shaft is an encoder which is used to establish the position of the probe member. In the tank, an electrode is inserted, with the electrode and the hollow probe being cooperative with a probe signal amplifier. As soon as an electrical circuit is completed between the probe and the tank electrode a signal is supplied to the control computer which then measures probe position.

A control flow of compressed air is piped to the center of the hollow probe in conjunction with a control valve and a pressure sensing switch being provided on the downstream side of the valve. Starting with the probe at the top of its stroke and the solenoid controlled air flow valve being closed, the hollow probe is caused to initially move downward until it touches the froth and in so doing, completes an electrical circuit with the probe amplifier to provide a signal to the control computer. The computer now reads the position of the probe through operation of the encoder and having done this, the computer will energize the air flow controlling solenoid valve to cause air to pass through a restrictive orifice and into the tube. The probe continues to move downward. As soon as the tip of the probe touches the upper surface of the liquid slurry the pressure in the tube will rise causing the pressure switch to sense this air pressure change and to provide a control signal to the computer which again reads the position of the probe through operation of the encoder. By subtraction the computer calculates the froth height, and displays this or uses the value for control of the frothing agent in regard to the flow supply of that frothing agent. The probe is now caused to return to the top of its stroke, and the above cycle is repeated.

It is an object of the present invention to better determine the froth height within a floatation cell and to better control the amount of frothing reagents added to a floatation cell structure, and more specifically, to control the amount of pine oil which is introduced to the floatation cell to improve the control of that particular cell and succeeding cells lower down in the structure in regard to having an adequate height froth in each cell. It is a different object to provide a more accurate measurement of the froth height present within each selected floatation cell for better controlling the amount of frothing agent added to that cell as well as to improve the mineral ore separation function of that cell.

It is also within the scope of the present invention to control the outflow of liquid slurry from the floatation cell structure by a suitable outlet valve, as required to hold substantially stable the level of the slurry within at least the last cell; this is important because each cell has a froth overflow weir for collecting the desired mineral values from the froth layer in each cell, and it is desired that only the fronth and not the liquid slurry within the cell overflows through this weir. In addition, a suitable mechanism is provided to vary the slope of the whole cell structure for the purpose of providing a desired slurry flow relationship through each cell such that the liquid slurry fills up each cell to a level near the overflow weir but does not pass through the overflow weir of each cell.

BRIEF DESCRIPTION OF THE DRAWINGS

FIGURE 1 illustrates one embodiment of the present invention;

FIGURE 2 illustrates an arrangement for sensing the froth height in each of a plurality of succeeding floatation cells in regard to controlling the tilt angle of the cell structure.

FIGURE 3 shows one arrangement for cleaning the movable probe member.

DETAILED DESCRIPTION OF ONE PREFERRED EMBODIMENT

In FIGURE 1 there is shown an individual floatation cell **10**, including a liquid slurry **12** and a layer of froth **14**. A manually adjusted weir **15** is provided to receive overflow froth and drain this froth to a suitable container adjacent the cell **10**. A vertically movable probe member **16** is positioned above the cell **10** and movable through a drive wheel **18** as determined by a position control and encoder **20** operative with a motor **22**. The frothing reagent for the cell **10** is controllably supplied from a reagent supply **24**. The movable probe **16** has at its upper end a flexible air hose coupling **26** operative through an orifice **27** with a flow control valve **28** and a high pressure air supply **30**. A pressure sensor device **32** is connected to sense the air pressure within the probe **16** on the downstream side of the orifice **27** and the valve **28**. A signal amplifier **34** is operative with an electrical circuit connected between the floatation cell **10** operative as one electrode and the movable probe **16**, when the probe comes in contact with the upper surface of the conductive froth **14** for completing an electrical circuit therebetween. At this time the signal amplifier **34** provides an output position indication signal to a control computer **36**. The control computer **36** is connected to the reagent supply **24** for controlling the addition of floatation cell frothing reagent in relation to the supply of liquid slurry to the floatation cell **10**. The control computer **36** is connected to receive a position signal from the position control and encoder **20**, and to provide an output control signal to the position control and encoder **20** for controlling the movement of the probe member **16** through operation of the motor **22** and the drive wheel **18**. The pressure sensor device **32** is connected to provide an air pressure change indicating signal to the control computer **36**, with the orifice **27** being operative to enhance the operation of the pressure sensor device **32** in this respect. The control computer **36** is connected to the valve **28** for controlling the desired open and closed operation of that valve. The output flow of liquid slurry from the cell **10** is determined by a valve control **31** operative with a valve **33** controlled by computer **36** in accordance with liquid level in the cell **10**.

In FIGURE 2 there is shown a control computer **36**, including a stored program **38** within the memory of the control computer **36**, connected to control the operation of a motor **40** operative through a drive wheel **42** and a rack **44** for controlling the angular position of a multiple floatation cell structure **46** about a pivot support **48**. The cell structure **46** includes a plurality of floatation cells **50, 52, 54, 56** and **58**. A froth height the liquid slurry level detector device similar to that illustrated in FIGURE 1, and including a movable probe for providing output signals to indicate the upper surface of the froth level and the upper surface of the liquid slurry within each of the floatation cells is shown in FIGURE 2. More specifically, a detector device **60**, including a movable probe **62** is operative with the floatation cell **50**. A detector device **64** including a movable probe **66** is operative for this purpose with a floatation cell **52**. A detector device **68** including a movable probe **70** is operative for this purpose with the floatation cell **54**. A detector device **72** including a movable probe **74** is operative with the floatation cell **56** for this purpose. A detector device **76** including a movable probe **78** is operative for this purpose with the floatation cell **58**. It should be understood, as an alternative embodiment, that a detector device may be desired for operation only with those cells into which a reagent supply is operative to supply frothing agent, for individually controlling the supply of frothing agent to its particular cell and for combinedly controlling the cell structure position.

Thusly, it is seen that the computer **36** periodically cycles the operation of each of the illustrated detector devices, to determine the respective height of the froth and the respective level of the liquid slurry within each of the floatation cells, for controlling the addition of frothing reagent from at least one reagent supply **80**, with one or more other such supplies being provided as may be desired for responding to the flow of additional liquid slurry from a slurry supply **82**, and for controlling the operation of the motor **40** for determining the liquid slurry throughput flow controlling angular tilt of the cell structure **46**, in accordance with a predetermined and desired froth height for each cell and a predetermined and desired liquid level for each cell in relation to the other respective cells as included in the program **38** stored within the memory of the control computer **36**.

Thusly, it is seen that the froth height of selected ones of the individual floatation cells is measured by a probe apparatus which can be continuously reciprocating and includes a probe position signal transmitter for providing a position indicating signal when an electric circuit is completed through an electrode probe coming into contact with the conductive froth. In addition, the computer **36** receives a signal when the surface of the liquid slurry is sensed upon the probe member coming into contact with the upper surface of the liquid slurry contained within each individual floatation cell. A small signal current will flow when the upper surface of the froth is contacted by the conductive probe member, operating in conjunction with a high impedance electronic sensing relay, a determination can be made when the signal current begins to flow upon the electric circuit being completed through the froth material. When a signal current in this matter is sensed, the position of the probe is measured to indicate the location of the top of the froth. To measure the top surface of the liquid slurry, a pressure change in the provided air flow through the hollow probe is sensed, and which occurs when the end of the probe comes into contact with the upper surface of the liquid. The computer can determine the physical travel difference between the position of the probe when the froth signal current first begins to flow through the froth and the position of the probe member when the air pressure change takes place upon the end of the probe contacting the upper surface of the liquid slurry, and this physical travel difference can provide an indication of the height of the froth layer itself. A suitable control of the amount of frothing agent added to selected ones of the floatation cells, in relation to the desired froth relationships within the whole bank of cells can be made to hold the froth level within such selected floatation cells substantially as desired.

It is generally desirable that the air flow through the hollow probe not be turned on until after the initial signal current flow is sensed through conductivity of the froth layer, in that the air flow might otherwise disturb the froth layer and make it more difficult to determine accurately the upper surface of the froth layer and therefore the height of the froth layer. After the froth upper surface position measurement is completed, the air flow as limited by the restrictive orifice can then be turned on and the probe continued in its movement until the air pressure condition change is sensed due to the end of the probe entering the liquid slurry below the froth.

When the movable probe is withdrawn from a floatation cell, it is desirable to wipe it clean and perhaps flush it with water to insure that the probe is kept free of encrustation and suitably operative for its intended purpose.

It is within the contemplation of the present invention to provide an amplifier which measures and differentiates between two levels of conductivity, with the froth layer being less conductive than the liquid slurry itself and the resulting different conductivity indication signals being used to provide the desired indication of froth height.

It is contemplated that the movable probe can reciprocate at a movement rate in the order of 6 times a minute and travel about 6 to 9 inches. The top of the probe movement stroke is about 2 inches above the upper surface of the froth layer and penetrates the liquid slurry about an inch such that a total travel movement for the probe of about 9 inches is contemplated for the example of a 6 inch froth height. Any wiper device should be positioned low enough to clean the probe as it travels upward and the wash water should be turned on when the probe is in position above the froth layer and can be washed and then turned off after a predetermined time interval such that only a minimum amount of water goes into the cell, which should be no problem to the intended operation of the floatation process.

It is known that the liquid level can change from one end of a plural cell structure to the other. As shown in FIGURE 2, the cell structure can be tilted about a pivot point **48** as needed to provide a desired hydraulic gradient such that each partition has a predetermined opening at the bottom thereof acting as an orifice with a pressure drop across that orifice. The head H_1 on the first cell will be slightly less than the head H_2 across the second cell and so forth.

At the present time the prior art practice is to vary manually the interconnecting gates between individual cells to keep the liquid levels of each cell of a substantially horizontal structure within desirable limits. If instead the entire cell structure is tilted, as shown in FIGURE 2, this would cause the desired pressure gradients to occur, with the velocity drop through the gate in the bottom of each cell equalling the velocity head induced by the slope so the controlled liquid levels would be substantially the same. This should make unnecessary the prior art adjustment of the cell gates for controlling the desired variation in liquid slurry throuhput flow through the cells. Slope adjustment in this regard would be a measure of flow rate, and the computer **36** is operative to monitor the liquid level of each cell and control the adjustment of the tilt angle of the entire structure as required to control the desired liquid level in each cell relative to the other cells as desired. Thusly, by tilting the entire cell structure to stabilize the liquid level of each cell, the computer **36** could determine from the resulting adjusted slope position and its stored program information relating to past activity what was the flow rate of liquid slurry through the cell structure. This control of cell structure angle by the computer simplifies the operation of the cells and gives another measurement parameter which is of value in rationing the proportions of the various added materials and reagents. The output slurry flow control valve can be controlled by the control computer **36**, with its position information being fed back to the computer **36**, by a suitable valve control mechanism **31**.

In the operation of the grinder which supplies the liquid slurry to the floatation cells, if the raw ore becomes harder to grind for some reason this results in less material being supplied to the floatation cells. It was the prior are practice with a cell structure, such as shown in FIGURE 2, to horizontally position the cell structure and then adjust a manual gate in the bottom of each cell for the average liquid slurry flow as monitored by an operator. Then the positions of the froth overflow collecting weirs were manually set and required further adjustment by the operator at frequent intervals, since changes in the slurry flow and froth height required adjustment of the respective cell weirs to keep undesired liquid slurry from overflowing with the desired froth. With the cell structure sloped, as shown in FIGURE 2, a hydraulic gradient is provided to permit control of the liquid slurry within the respective cells in this manner in relation to the slurry flow out of the grinder. For example, an increase in slurry from the liquid slurry supply **82**, which can be the grinder or a container operative with the grinder, can be compensated for by increasing the slope of the cell structure through suitable operation of the motor **40**, to increase the velocity of slurry flow through the cell structure. The froth height and liquid level sensing probes provide signals to the control computer **36** for the purpose of maintaining substantially constant the liquid levels in one or more selected cells in this manner. In addition the supply of frothing reagent is controlled to provide the desired froth height in those selected cells in relation to the provided operation of suitable and well known agitator devices for this purpose. This will optimize the frothing operation in relation to the desired removal of ore values. A supplemental control of liquid level in the cell structure can be maintained by the control computer **36** being operative to control the opening of valve **33** in relation to the sensed flow of liquid slurry from the liquid slurry supply **82**, if desired.

It is within the contemplation of the operation of the FIGURE 2 apparatus, that a froth height and slurry level sensing device be provided for the first and fourth cells, with frothing reagent being added into these same cells, and a slurry liquid level sensing operation being optional for the last cell for the example of a six cell structure, to be correlated with the sensed inflow of liquid slurry into the first cell, or even instead of sensing the slurry inflow into the first cell, for the purpose of controlling the position of the output valve **33**. As a general rule here, a probe should be provided for every cell into which frothing reagent, or some other new material, is added and for any other cell believed to be critical for the operation of the floatation cell structure.

With the infeed flow of liquid slurry from the liquid slurry supply **82** being measured, this permits feed forward control of the frothing reagent addition rate to anticipate the need for same in relation to the infeed of liquid slurry to the cell structure for optimizing the operation of same. Further, the sensed position of the output valve **33** gives a feed forward control parameter in relation to the flow of liquid slurry through the cell structure to anticipate the need for more or less frothing reagent, with the froth height sensing operation then providing a secondary control function over the addition of frothing reagent to particular cells of the cell structure. The sensed position of the output valve **33**, as varied to maintain a substantially constant liquid slurry level in the last cell, might be a less problematical indication of liquid slurry flow through the cell structure than would a flow meter operative with the liquid slurry supply **82**. The slope of the cell structure is then controlled to maintain a substantially constant difference in slurry levels between the respective cells as required for the desired operation of the weirs. We now do not get an undesired lowering of grade of the overflow froth with an increase in the slurry flow rate from the grinder and there is no longer a need to adjust the weirs in relation to the slurry flow rate changes. The control computer **36** can know from stored performance information of the cell structure, what the actual slurry flow rate is as determined by the resulting slope angle of the cell structure.

One reason that the present invention is commercially important can be understood from the practical operation of a floatation cell structure. A typical mill flow is 90 tons/hour. The prior art floatation cells provided optimum operation only at the design slurry flow throughput. The present invention provides slope control in response to variations in the slurry flow due to variation in the ore grinder operation. Flow rates 70 tons/hour to 90 tons/hour or more are common and a 10% variation in such a flow rate does occur. The slope angle adjustment of the cell structure will compensate for this variation to provide improved ore recovery and reduce loss of grade of the concentrate which costs more money in the subsequent smelters.

As shown in FIGURE 3, the probe member **16** can be surrounded by a suitable scraper and washing member **17**, operative with a water source **19** when valve **21** is opened, or other suitable cleaning fluid, for removing any material such as froth or liquid slurry from the probe member **16** by periodic cleaning of same.

While a preferred embodiment of the present invention has been described, it should be understood that various modifications and changes in the arrangement of parts may be made within the scope and spirit of the present invention.

I claim as my invention:

1. In froth condition monitoring apparatus for a liquid slurry containing floatation cell having a froth layer above said slurry, the combination of

probe means movable in position relative to said froth layer such that a first signal is provided upon said probe means sensing a first predetermined surface of said froth layer and a second signal is provided upon said probe means sensing a second predetermined surface of said froth layer, and monitor means operative with said probe means for determining the height of said froth layer in response to said first and second signals.

2. The apparatus of claim **1**, including position sensing means operative with said probe means for providing an indication of the position of said probe means,

with said monitor means being operative with said position sensing means such that the position of said probe means upon the provision of said first signal and the position of said probe means upon the provision of said second signal can be thereby determined and utilized for said determination of said height of the froth layer.

3. The apparatus of claim **1**, including

said probe means being operative in a first manner with the uppermost surface of said froth layer for the provision of said first signal,

and said probe means being operative in a second and different manner with the liquid slurry beneath the lowermost surface of said froth layer for the provision of said second signal.

4. In floatation cell control apparatus operative with a liquid slurry containing floatation cell structure having a froth layer above said slurry, said control apparatus being operative with a source of frothing reagent for determining the depth of said froth layer, the combination of

probe means for sensing the depth of said froth layer and the upper most surface of said liquid slurry,

surface control means operative with said cell structure for controlling the position of said uppermost surface of the liquid slurry,

depth control means operative with said source of frothing reagent for providing a predetermined depth of said froth layer above said liquid slurry within the floatation cell structure.

5. The control apparatus of claim **4**, including

said surface control means including an outlet valve operative with said floatation cell structure for controlling the position of said uppermost surface of the slurry relative to said floatation cell structure and in relation to the inflow of liquid slurry into said floatation cell structure.

6. The control apparatus of claim **4**, including

said floatation cell structure comprising a plurality of individual floatation cells,

and said surface control means being operative to vary the slope of said floatation cell structure in relation to the inflow of liquid slurry into said floatation cell structure.

7. The control apparatus of claim **6**, with said depth control means being responsive to the resulting slope of said cell structure for anticipating the need for frothing reagent in accordance with the slurry flow through said cell structure.

8. The control apparatus of claim **4**, with said surface control means including a slurry flow control valve operative with said floatation cell structure for maintaining the uppermost surface of said liquid slurry in a predetermined position,

said depth control means being responsive to the operation of said control valve for anticipating the need for frothing reagent in accordance with the slurry flow through said cell structure.

9. The method of operating a floatation cell structure supplied with a varying inflow of liquid slurry and having a plurality of individual floatation cells through which the slurry successively passes, and is agitated with a frothing reagent such that a froth layer is formed, with each of said cells having a froth overflow weir, and including the steps of

sensing the depth of the froth layer in selected cells for controlling the provision of frothing reagent to those cells,

controlling the outflow of liquid slurry from said cell structure to provide a substantially constant position for the uppermost surface of the slurry in relation to the overflow weir in at least the last of said cells,

and controlling the angular slope of said cell structure to maintain a predetermined relationship between the respective uppermost surfaces of the liquid slurry in relation to the overflow weir within each of the floatation cells.

10. The method of claim **9**, including controlling the provision of frothing reagent to said cell structure as a function of the slope of said cell structure for anticipating the utilization of frothing reagent for the desired operation of said cell structure.

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