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Operational Control via Froth Control

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1 Flotation Analogy

To explain flotation in simpler terms the following analogy will be used. A factory (the flotation cell) manufactures a product (collector coated mineral). The product (collector coated mineral) is transported to market (the launder). A truck (the frother) is used to transport the product (collector coated mineral) to the market (the launder). The truck (the frother) transports the product over a road (the froth bed). The truck (the frother) and product (collector coated mineral) are supported by tires (the air).

2 Assumptions

This operating philosophy assumes that the correct collector dosage is present along with the correct particle size distribution, pH conditions, etc. and that the minimum required frother dosage is correct.

3 Collector Addition

The collector addition as used at a flotation plant is based on dosage rate as determined by the amount of mineral value entering the concentrator. Collector is normally added at two points in the concentrator: The primary flotation circuit and staged addition in the rougher scavenger circuit. Surveys have shown that the staged collector addition provides an increase in the kinetics and increases the recovery of the valued mineral in the rougher scavenger circuit.

4 Frother

4.1 Frother Dosage

As explained in the above analogy, frother can be likened to the truck that transports the product (collector coated mineral) to market (the launder). Just as you would not use a truck rated at 15 tonnes to transport a 20 tonne load, you cannot expect to transport coarse minerals to the launder when there is insufficient frother present. Frother dosage must always be at, or above the minimum target. If less frother than the required minimum is used, then coarse mineral particles will not be supported and transported to launder where the mineral is recovered. To the naked eye the froth characteristics, even when insufficient frother is used, will appear to be correct. You cannot see the coarse particles that are not being recovered in the froth. (See Section 4.2 below for an explanation of why this occurs.)

Frother should never be used to control the rate of froth removal from the flotation cell. Some operating philosophies advocate reducing frother if the froth is moving too fast or conversely adding more frother if the froth is moving too slow. Each ore type will have it's own minimum frother dosage required to support the coarse copper in the pulp.

4.2 Frother Mechanism

Frother forms a double membrane as shown in Figure 1 below. Within this double membrane, fine particles of collector coated mineral particles are trapped. The collector causes the particles to become hydrophobic. The particles migrate to the air/pulp interface formed by the frother bubble.

A bubble formed by frother has little strength on it's own. It is the capillary forces between the particles that give the bubble the strength required to support coarse 100 to 212 micron particles. If sufficient frother is not present to form a strong capillary action between the fine mineral particles, then the coarse mineral particles will not be supported, and thus not recovered.

Always use more frother than is required to ensure that the coarse mineral particles will be supported. Remember it is better to use a truck rated at 20 tonnes to transport a 15 load than it is to use a 15 tonne truck for the same duty.

Many plants utilize staged frother addition in the rougher circuit to ensure that sufficient frother is present in the rougher scavenger circuit.

5 Air Volume To Be Used

Just as the tires support the truck and the load, air in a flotation cell supports the froth. If the tires on the truck are under inflated there will be little chance of getting the product to market. In the flotation cell, if too little air is used there will be little chance in getting the collector coated mineral to the launder.

If the tires on the truck are over inflated, then there is a good chance that the tire will rupture. The same is true in the flotation cell: if too much air is used then the cell will boil at the pulp interface, which in turn will cause loss of the collector coated mineral.

When setting up the air, sufficient air must be present to support the load. This is accomplished by setting the air to a point slightly short of the stage where the cell starts to boil.

6 Effect of Percent Solids On Flotation

6.1 Pulp Percent Solids

When discussing percent solids in the flotation circuit one is really talking about the pulp viscosity in the flotation circuit. Pulp viscosity effects the air dispersion and the efficiency of the air in the flotation cell. For each ore type the slurry will have a different pulp viscosity dependant on the percent solids of the slurry. The higher the percent solids, the greater the pulp viscosity. With higher pulp viscosity, greater resistance to air flow will be present.

The following analogy can used:

> If a straw is inserted into a glass of water, air can easily be blown through that glass of water. There will be little resistance to the air passing through the water. The bubbles formed will be

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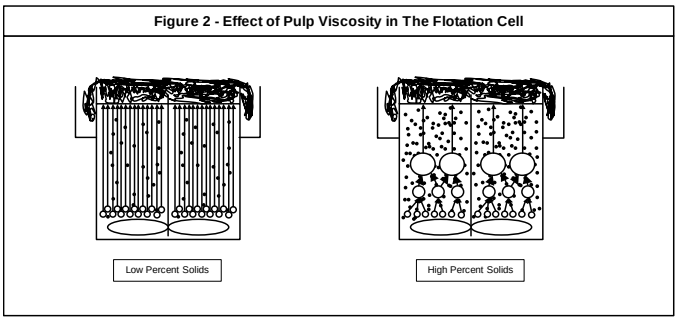
small, evenly dispersed, and move rapidly through the water.

If the water is replaced with honey and an attempt is made to blow air through the straw great resistance to the air flow will present. The bubbles formed will be large, they will not be evenly dispersed, and they will move slowly through the honey.

Figure 2 below demonstrates the difference between a flotation cell running at a low percent solids (low viscosity) compared to a flotation cell running at high percent solids (high viscosity). In the cell at low viscosity, the air exits the mechanism as very small bubbles. The resistance in the pulp is low due to the low viscosity. The air rises rapidly through the pulp colliding with many mineral particles. It moves quickly to the surface to become part of the froth bed.

If the pulp viscosity is too high, as represented by the flotation cell on the right in Figure 2, air again exits the mechanism as very large bubbles. The resistance in the pulp is high due to the high viscosity. The air rises slowly through the pulp colliding with other bubbles and coalesces into larger bubbles. It moves slowly to the surface to become part of the froth bed, sometimes bursting when it reaches the froth bed.

Figure 2 - Effect of Pulp Viscosity in The Flotation Cell



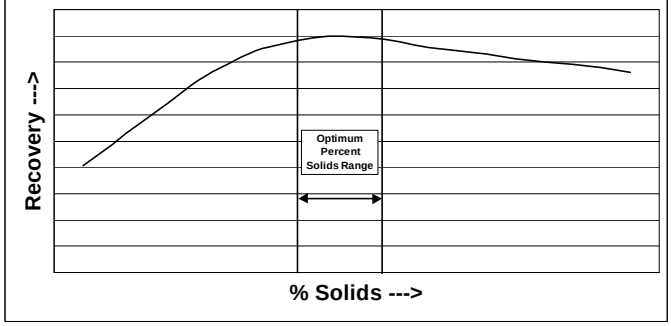
In froth flotation, collector coated minerals are collected on the bubble. The greater the total surface area of bubbles in the cell, the more likelihood of recovering minerals. With viscous pulp there are a small number of large bubbles compared to less viscous pulp where there are many small bubbles. The cell running at lower percent solids, and thus at a reduced pulp viscosity, will produce more bubbles that have a greater surface area than the cell running at high pulp viscosity.

The effect of pulp viscosity (percent solids) on flotation recovery can be seen in Figure 3 below. Figure 3 represents a flotation circuit of fixed volume at a fixed tonnage. In theory, as percent solids is increased (which results in an increase of the residence time) the recovery should continue to increase until the percent solids becomes so high that the pulp will not flow. In practice this does not occur due to the effect of pulp viscosity. Recovery will increase to a maximum point where a trade off between increased residence time and increased pulp viscosity occurs. To the left of the optimum, recovery will be reduced due to a lack of residence time, while to the right of the optimum recovery is reduced due to the effects of pulp viscosity.

As can be seen in Figure 3, to the left of the optimum pulp viscosity the curve is steeper than to the right of the optimum pulp viscosity. Up to the optimum point residence time has a greater effect on flotation than does pulp viscosity.

There is an optimum range of viscosity or percent solids for each ore type that will result in maximum recovery. For hard ores with minimal clay content this optimum viscosity may correspond to percent solids in the range of 38% to 40%. For ores where a high proportion of clay or talc is present the optimum range of solids may be as low as 24% to 28% solids.

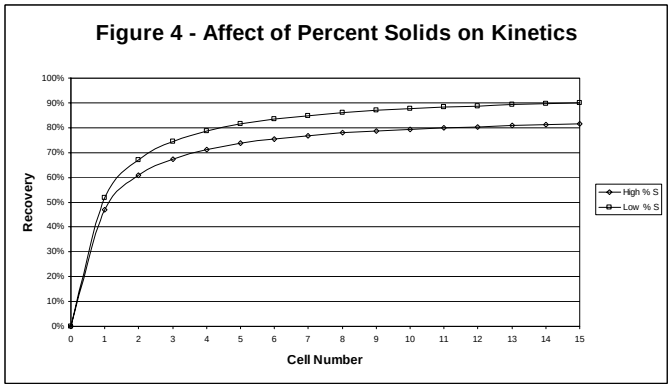
Figure 3 - Affect of Percent Solids On Recovery



6.2 Flotation Kinetics

In a flotation circuit of fixed volume at fixed tonnage, the reduction in recovery due to pulp viscosity is due to a reduction in the flotation kinetics in the circuit (how fast the mineral floats). Graphically this is represented in Figure 4 below.

Figure 4 - Affect of Percent Solids on Kinetics



By operating at the optimum pulp viscosity (percent solids), the kinetics and thus the recovery in the flotation circuit are increased. As can be seen in Figure 4, the most dramatic improvement in recovery is at the head end of the flotation circuit. By improving the recovery up front, there is a greater chance of recovering the remaining copper in the rest of the circuit.

7 Recognising When The Percent Solids (Pulp Viscosity) Is Too High

When the pulp viscosity (percent solids) is too high the following indications will be present (see Figure 5 below):

1. The froth bed will be extremely shallow.

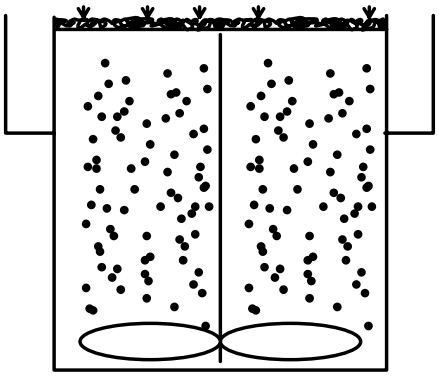
2. The froth bed will be composed of a very heavy, viscous mat.

3. Bubbles will be bursting at the surface of the froth bed as mineral sinks back into the pulp.

4. It will be extremely difficult to maintain a steady overflow of froth to the launder. The froth will appear to pulse over the launder lip as surges lift the level in the cell.

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Figure 5 - Recognising High % Solids



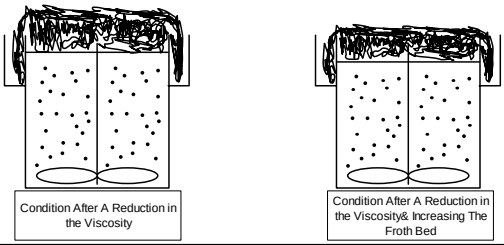
5. If the viscosity is extremely high the froth will appear to curl downwards and sink below the froth bed.

8 Controlling The Froth With Weight Accumulation And Compression Techniques

When the pulp viscosity is lowered to the correct point via a drop in the percent solids, the cell starts to load mineral quickly and the froth will build on the cell and will flow rapidly into the launders, pump boxes, etc.. This can quickly lead to an unstable condition in the flotation circuit.

In order to overcome this condition a method called "Weight Accumulation Compression" is used. With the decrease in pulp viscosity via a reduction in the percent solids, the mineral will float very quickly and accumulate in the froth. By decreasing the pulp level (increasing the froth bed), greater weight of mineral is present in the froth bed. The additional weight of mineral will compress the froth and literally "squeeze" water and air out of the froth compressing the froth into a high percent solids mat. (See Figure 6 below.)

Figure 6 - Froth Accummulation Techniques

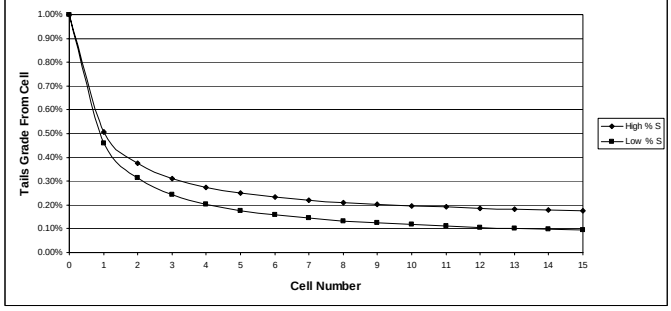


The pulp bed level is set to ensure that a steady flow of mineral laden froth is removed from the cell. This rate of pull will match the rate of accumulation of mineral into the froth and a steady state will be reached in the flotation cell. The volume of froth is then reduced allowing the launder, piping and pumping systems to readily handle the flow rate. As an added benefit the water that is displaced from the froth will tend to wash the froth and remove entrained gangue from the froth, increasing the grade of the concentrate.

9 Froth Depth Settings – Rate of Pull on the Cell

As shown in Figure 7 below, the feed grade to each bank of cells will decrease as you move down the flotation circuit. The rate of decrease will be greater if the proper pulp viscosity is present. At the head of the circuit a "hard" pull is required to recover the accumulated froth. It is of extreme importance in the flotation circuit to recover copper when it is ready to float. Therefore at the head of the circuit shallow froth beds are required.

Figure 7 - Affect of Percent Solids on Tails Grade From Cell



As the feed grade to each subsequent bank of cells decreases, less mineral is present to be recovered. Also, mineral further down the flotation circuit is slower floating than the mineral recovered at the head of the circuit. Therefore the cells must be slowed down in order to let the mineral accumulate in the froth.

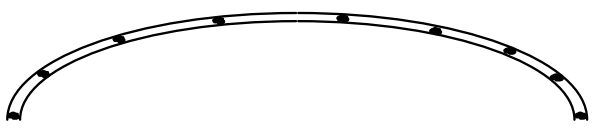
The froth depth profile down the flotation circuit should be shallow at the head of the circuit with gradually deepening froth beds. The froth bed depth will be set to give the proper pull on the cell based on the "Weight Accumulation and Compression" techniques outlined above. A Copper flotation circuit is used as the example.

10 "White Froth"

It is an "Old Wives Tale" that if you pull a white froth in the rougher scavenger cells, recovery is maximised. In reality very little mineral is recovered when pulling a "white froth". The froth is in fact composed mainly of entrained gangue and water.

The reason for this occurrence is based on the fact that there is very little mineral left to be recovered at this point, and the mineral that is present is very slow floating. (The mineral has to be slow floating or else it would have been recovered by this point.). The relative percentage of fine mineral left at the rougher scavenger will be lower than the portion of coarse mineral. The coarse mineral will also have a higher portion of middlings present. Fine mineral particles is required to give strength to the froth. When pulling hard (eg shallow froth beds) the froth bubble will elongate and not be able to collect enough fine mineral to support the coarse mineral in the cells as shown in Figure 8.

Figure 8 - "White Froth"



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11 Air Equalisation (Balancing the Air Flow)

In each bank of flotation cells, the air must be the same for each cell in the bank. If different air flows are present within the bank, then unequal "pulls" will occur from cell to cell. Setting the pulp level or froth bed depth for the bank will result in each cell pulling at a different rate. In order to overcome this problem, each cell in the bank must be balanced by equalising the air flow to each cell.

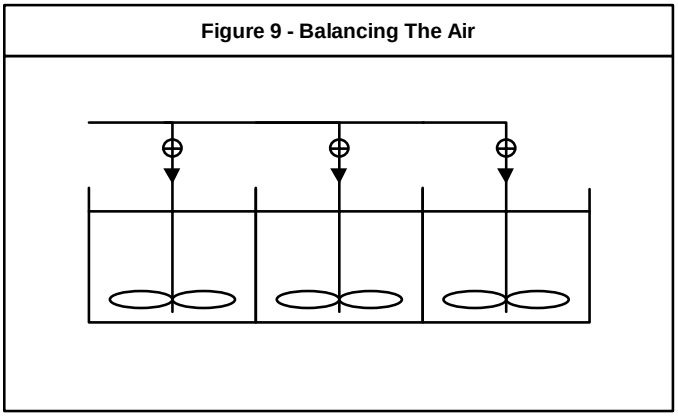
The method is as follows:

1. Set the air to the proper level, in one cell.

2. Adjust the remaining air flows so that each cell is pulling at the same rate. When increasing the air flow it can take several minutes for the air hold up in the cell to arrive at a steady state. Therefore make these adjustments slowly. Decreasing the air flow reaches a steady sate condition much more rapidly.

3. When the cells in the bank are connected to a common air head, as shown in Figure 9, the adjustment of one cell will effect the air flow on the two remaining cells.

Figure 9 - Balancing The Air



4. The air should be balanced at the start of each shift. Minor "tweaks" to the air may be required during the shift to ensure that all of the cells in bank are balanced.

12 Advantages of This Operating Philosophy

This operating philosophy has the following advantages:

1. Maximum desired mineral is recovered at the head end of the circuit. This allows the mineral to be moved to the next stage of the process sooner and thus the mineral will report to final concentrate sooner, passing through fewer stages in the flotation circuit.

2. By maintaining the correct pulp viscosity in the circuit slightly deeper froth beds can be run. The froth that has accumulated on the cell will act as "shock adsorber", and buffer surges to some degree.

3. The same philosophy as described above can be applied to the cleaning circuit.

4. The operator's job becomes much easier. If a change occurs in the flotation circuit, the operator might have to adjust 30 air valves in just one rougher circuit to handle the change. This philosophy relies on the operator possibly adjusting only 12 level set points in a rougher circuit.

5. Higher recoveries will be present in the flotation circuit.

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