

# THE USE OF COLUMN FLOTATION FOR THE RECOVERY OF ULTRA-FINE PHOSPHATES

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## ABSTRACT

Brazil currently produces around 4.0 Mt per year of phosphate rock, most of which is utilized in the manufacture of phosphate fertilizers. Approximately 80% of the phosphate fertilizers consumed in the country are locally manufactured from phosphate rocks of igneous origin, with low P<sub>2</sub>O<sub>5</sub> grades. Ore from the Araxa, MG, region of Brazil is residual, consisting mainly of apatite, clay minerals, magnetite, barite, hydrated iron minerals, aluminum and iron secondary phosphates, titanium minerals and other minerals.

The ore is processed in four physically distinct processing steps consisting of crushing and grinding, concentration (flotation), high intensity magnetic separation followed by filtration and drying. The naturally occurring fines and the fines generated by grinding are removed in small diameter cyclones prior to being fed to the apatite flotation circuit. This desliming operation, typically carried out at a cut point of about 30 microns, results in the loss of significant quantities of phosphate.

In recent years, the range of recoverable apatite particles has been extended down to 7 - 10 microns through the introduction of column flotation. The high degree of selectivity achieved by this equipment has made it economical to treat material previously considered to be tailings.

This paper discusses the process for recovery of ultra-fines phosphates and provides data for a number of operations who are producing ultra-fine concentrates.

## INTRODUCTION

Column flotation cells were introduced to the market place about thirty ago years as devices capable of producing concentrates that were lower in impurities than those produced by other types of flotation machines. The ability to operate columns with deep froth beds and to wash the froth was the main reasons cited for the improved metallurgical performance. In recent years, many phosphate producers have installed column flotation systems as a means of boosting production whilst reducing operating costs.

## HISTORY

G.M. Callow patented the first pneumatic flotation cell, which used air sparging through a porous bottom and horizontal slurry flow, in 1914. The first countercurrent column flotation device was designed and tested by Town and Flynn in 1919. Cross-current pneumatic flotation machines were widely used in industry in 1920's and 1930's, but were later replaced by the impeller-type flotation devices in mineral processing plants.

Dissolved-air flotation became the main type of flotation for water treatment applications. These substitutions were the result of the absence of effective and reliable air spargers for fine bubble generation and by the lack of automatic control systems on the early columns. During this period, both the poor flotation selectivity and



**FIGURE 1**  
Typical industrial column flotation cell

entrainment of slimes characteristic of impeller-type cells was offset by the use of complex flowsheets using large numbers of cleaner stages and recycle lines. Column flotation devices were re-introduced for mineral processing in the late-1960's in Canada by Boutin and Wheeler (1967) at which time wash water addition to the froth was used to eliminate entrainment of hydrophilic materials to the float product. By the late-1980's column flotation had become a proven industrial technology in the mineral industry. These separators are routinely used on their own or in conjunction with other types of devices within separation circuits.

## DESCRIPTION

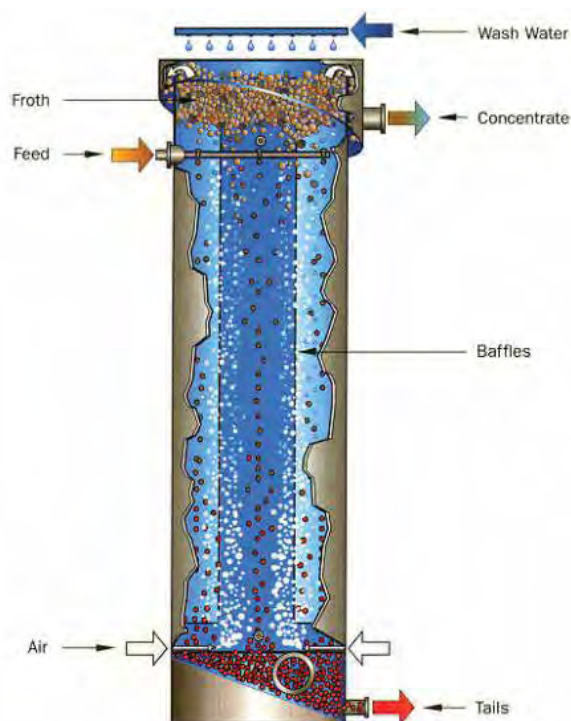
Column cells (Figure 1) are flotation devices that also act as three phase settlers where particles move downwards in a hindered settling environment countercurrent to a swarm of rising air bubbles that are generated by spargers located at the bottom of the cell. Within the vessel there is a distribution of particle residence times dependent on settling velocity that may impact on the flotation of large particles. Impeller devices do not suffer from this effect to the same degree but do require higher energy input to suspend larger particles.

Mechanism of particle/bubble collision in columns is different from intensive mixing devices such as impeller cells. Under the low-intensity mixing caused only by a rising bubble swarm, particle drift from the liquid streamlines is caused mainly by gravity and inertial forces and also by interception, while in mechanical cells, according to many researchers, bubble-particle collision occurs at their relative movement within turbulent vortex or at adjacent vortices. Also, as velocities of both bubble and particle during the attachment are slower under quiescent conditions in a column, the contact time is generally higher. Therefore, probabilities of both collision and adhesion (components of attachment probability) are different than that in mechanical flotation process.

A column can support a deep froth bed and may use wash water (Figure 2) to maintain a downward flow of water in all parts of the vessel. This essentially eliminates the entrainment of hydrophilic particles in the float product when the vessel is used for solid/solid separation. This property, along with the absence of stray flows of feed material to the float product from turbulence, means that column devices are normally superior to impeller type machines for the selective separation of fine particles.

The bubbles used in a column are usually generated within the size range that maximizes interfacial surface flux and collection intensity through the vessel. In mechanical cells bubbles are usually generated by shear action of the impeller; thus, bubble size is dependent on both airflow rate and impeller rotation speed. As such, bubble size cannot be controlled independently of cell turbulence.

The height to diameter ratio of a column is significantly higher than the impeller - type machines. As a result control and consistency of flow is more critical. The column requires much less floor space to operate.



**FIGURE 2**

Description		Mechanical Cells		Column Cells	
		Qty	Cost (\$US)	Qty	Cost (\$US)
Equipment	Flotation Cells	44	\$1,760,000	4	\$380,000
	Compressor	-	-	3	\$24,000
Metal Structure (Fabrication and erection)		200t	\$500,000	65t	\$162,000
Civil Works	Concrete	416 m <sup>3</sup>	\$232,000	240 m <sup>3</sup>	\$133,000
	Foundations	144t		83t	
<b>Total</b>			<b>\$2,492,000</b>		<b>\$915,000</b>

**TABLE 1**  
Investment Requirements: Mechanical Cells Vs.  
Column Cells (Salim, 1996)

Nowadays, the mineral processing engineer has a wide selection of processes and equipment to choose from when designing a new concentrator. For the flotation section there are many different types of machines available including, self-aspirating or forced air impeller-type cells, column cells, pneumatic cells and a variety of specialty or hybrid designs. In many instances, characteristics of the ore will dictate whether or not certain methods can be applied. In other cases, economic considerations and personal preferences of the operators will prevail.

Metallurgical benefits can be derived in a number of ways. In some cases the metallurgical benefits may be obvious. Improved concentrate grades, improved recoveries and reduced reagent consumption are some of the benefits attributed to column cells. In other cases the benefits may be less clear. With some ores, for example, it is possible to recover a portion of the valuable mineral into a high grade concentrate directly at the rougher stage, thereby reducing the size of the subsequent treatment stages.

For new installations, capital equipment and installation costs can be significantly less that for agitated flotation machines. Table 1 compares the costs for an iron ore flotation project utilizing two different types of equipment: mechanically agitated cells and column cells.

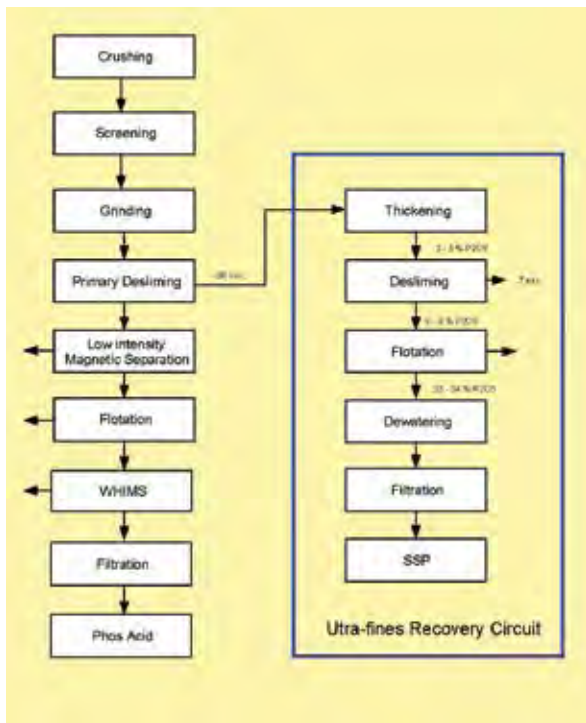
Operating cost savings can be realized from reduced power requirements reduced maintenance costs and in some cases reduced reagent consumption.

- Power costs can be 40 - 50% lower than an equivalent mechanical flotation circuit. Using column flotation it is possible to simplify the process by replacing two to three cleaner stages and associated transfer pumps with a single column producing final concentrate.
- Column cells have very low maintenance requirements and low inventory requirements.
- Reagent savings depend on the nature of the ore being treated and the reagent scheme being utilized. The most significant reductions usually occur with depressants, where it is possible to use wash water to lower impurity levels.

Column flotation has been applied to a wide variety of phosphate ore types ranging from volcanic to sedimentary. Although benefits are seen across the entire particle size range, column cells are particularly well suited to the production of fine and ultra-fine concentrates.



**FIGURE 3**  
Column flotation plants are  
inexpensive and compact



**FIGURE 4**  
Simplified phosphate treatment flowsheet

The Barreiro carbonatite complex located in Araxá, MG, is roughly circular in shape covering an area of approximately 16 km<sup>2</sup>. The major components of the rock formation are carbonatitic and glimmeritic rocks (Braga 1987; Silva 1994).

The deposit is stratified, consisting of the following major layers:

Waste: Overburden / waste rock

Ore: Oxidized ore / micaaceous ore / silico-carbonated ore

Host rock: Carbonatite / glimmerite

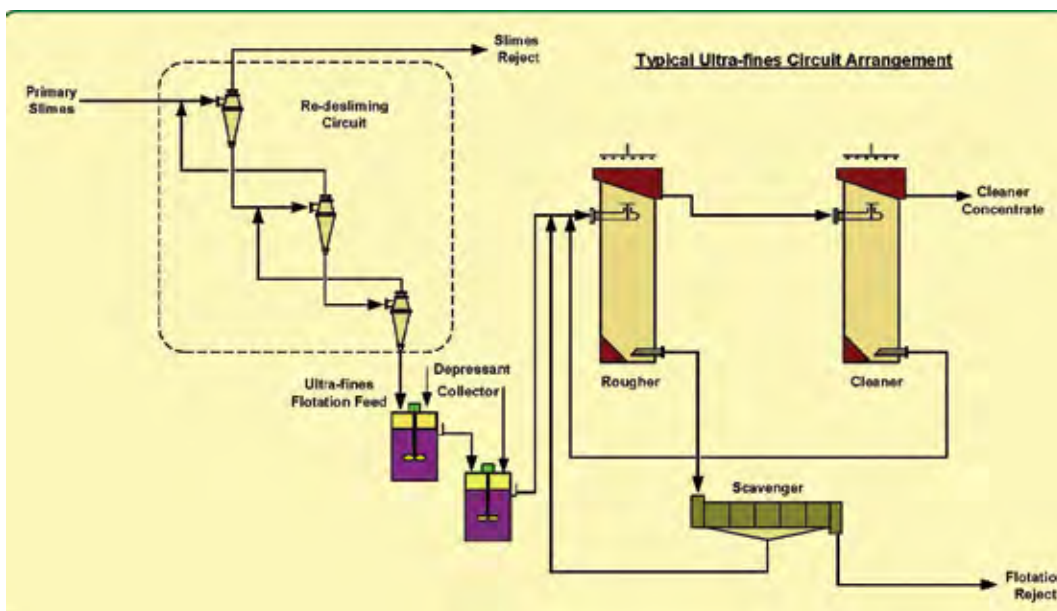
The major source of phosphate is derived from apatite, which comprises approximately 30% of the minerals in the ore zones. The major impurities consist of iron oxides and silicate minerals.

The ore is crushed, screened, and then fed to the concentrator, where it is subjected to grinding (rod and ball mills), classification in hydrocyclones, low intensity magnetic separation, desliming in hydrocyclones and flotation.

Traditionally, the desliming stage is designed to remove particles finer than about 25 – 30 micrometers. The high surface area and high impurity content associated with this particle size class make it difficult to treat by conventional flotation equipment. The removal of these slimes represents a major source of phosphate loss, which could represent 10% – 15% of the total reserves.

The application of column flotation makes it possible to extend the size range of particles that can be treated by flotation to about 5 – 10 microns.

By re-processing the primary slimes (-30 micron) in second stage of hydrocyclones cutting at 5 - 10 microns, followed by treatment in flotation columns, it is possible to obtain an Ultra-fine concentrate ideally suited for the production of Single Super Phosphate (SSP) fertilizers. A simplified treatment flowsheet is shown in Figure 4.



**FIGURE 5**  
Typical circuit arrangement

Stream	Mass Distribution (%)		Analysis	% P <sub>2</sub> O <sub>5</sub> Distribution	
	Circuit	Overall	% P <sub>2</sub> O <sub>5</sub>	Circuit	Overall
Primary Slimes	100.0	10.0	6.0	100.0	10.0
Slimes Reject	60.0	6.0	4.6	46.0	4.6
Ultrafine Flotation Feed	40.0	4.0	8.1	54.0	5.4
Cleaner Concentrate	7.0	0.7	33.5	39.1	3.9
Flotation Tailings	33.0	3.3	2.7	14.9	1.5

**TABLE 2**  
Typical mass balance for Ultra-fines circuit

Following classification, the cyclone underflow is fed to a series of conditioners where the pulp is treated with caustic soda, starch and a collector prior to introduction to the flotation columns. The flotation cells are arranged in a conventional rougher-scavenger-cleaner configuration with intermediate products recycled internally as shown by Figure 5.

Table 2 shows a typical mass balance for an ultra-fines flotation circuit. Assuming that the chemical analysis of the slimes is essentially the same as the feed grade, the loss of phosphate in the slimes is equal to the mass rejection.

Typical values range from 10 to 15% depending on the ore type and cut point of the cyclones. Reclassification using smaller diameter cyclone (to achieve a more precise and finer cut point) followed by flotation can yield an additional 3 – 5 percentage points of P<sub>2</sub>O<sub>5</sub> recovery for a very modest capital investment. The fine particle size minimizes the costs of concentrate regrinding at the fertilizer plant saving additional processing costs.

Faced with difficult ores, and low-grade deposits, the Brazilian phosphate producers have been world leaders in adapting this technology to enhance fine phosphate recovery. Most of the major producers are operating an ultra-fines recovery circuit in their concentrators.