

# Fertilizer INTERNATIONAL



**Rice fertilization**

**India market report**

**Innovative froth flotation**

**Phosphate and potash mining**



# Innovations in froth flotation

Newly-developed froth flotation schemes, equipment and reagents are improving selectivity and the grade and recovery of phosphate concentrates

## JESA TECHNOLOGIES

### Two-stage flotation optimises performance

#### Reverse double flotation

Most sedimentary and igneous phosphate ores contain unwanted impurities that need to be removed prior to chemical processing. Froth flotation is currently the most economical beneficiation technique for separation and removal of impurities from phosphates around the world.

Many phosphate reserves beneficiated today are associated with carbonates and silica. Upgrading this type of phosphate ore can be costly and requires many beneficiation processing steps – such as crushing, scrubbing, classification, milling, de-sliming, attrition, direct or reverse flotation, etc. – to produce a phosphate rock concentrate suitable for the production of phosphoric acid.

The separation of carbonate from phosphate has long been recognised as one of the most challenging tasks in phosphate ore beneficiation. This is due to similarities in the physical and chemical properties of phosphate and carbonate minerals. Processing a phosphate ore that contains finely disseminated carbonate, as well as silica impurities, therefore requires a carefully designed flotation scheme. The selection of the correct reagents is also extremely important – to maximize phosphate recovery and ensure reagent consumption is optimised.

#### Single-stage vs two-stage reverse flotation

Single-stage reverse flotation is used to upgrade ore in many current phosphate beneficiation plants. This simultaneously floats carbonate and silica as tail-

ings, leaving the phosphate sink as the final concentrate. Although this type of flowsheet benefits from simplicity, in practice, it can limit phosphate recovery for those ores that contains significant fine material. For these ore types, double reverse flotation is often preferable and recommended because it can improve  $P_2O_5$  recovery, reduce foaming, and lower reagent consumption and cost. In this two-stage process, carbonate is floated first, to remove all fines and slime carbonates from phosphate, followed by a second flotation stage to remove silica and clays.

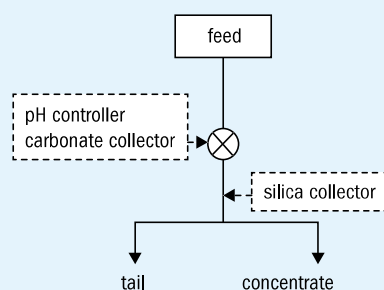
#### Pilot plant tests

Flotation tests were conducted on a North African phosphate ore at JESA's pilot plant, in Lakeland, Florida. The main purpose of the test work was to evaluate flotation performance using two flotation schemes. The first scheme used a single reverse flotation stage to float carbonates and silica together in one step. Whereas, in the second scheme, carbonate and silica were floated separately in two stages.

For both schemes, the ore was firstly scrubbed and classified at 160 microns to generate oversize and undersize products. The +160-micron product was then milled in closed circuit. The -160-micron material obtained from milling was then combined with the sample's original -160-micron undersize. This combined product was then attrition scrubbed and deslimed at 40 microns to generate flotation feed for testing. The resulting -160 + 40 micron feed contained approximately:

- 27 percent  $P_2O_5$
- 7 percent insoluble material
- 1.3 percent MgO.

Fig. 1: Single stage reverse flotation



Source: JESA Technologies

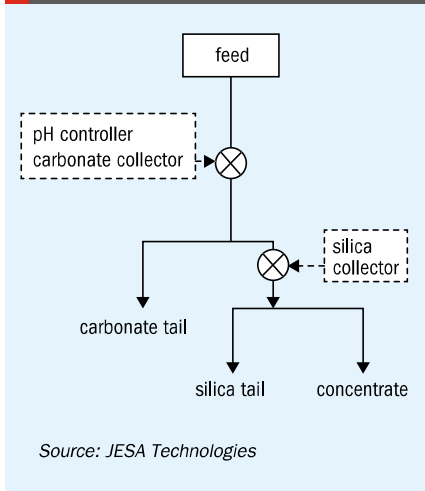
Calcite and dolomite were the main gangue minerals present. Both of these carbonate minerals together with silica needed to be removed from the feed to achieve a target grade of more than 30 percent  $P_2O_5$  in the phosphate concentrate.

Flotation tests were conducted using a Denver D12 laboratory flotation machine. The solids were pulped with Lakeland city tap water at ambient temperature. The feed was conditioned at a slightly acidic pH (less than 5.3) with phosphoric acid.

For single-stage flotation, the carbonate and silica were floated in one step as a tailing product, leaving the phosphate sink as a final concentrate (Figure 1). The slightly acidic feed was conditioned with a carbonate collector (phosphate ester) for two minutes, and a silica collector (amine) for 30 seconds, prior to flotation.

For two-stage flotation, carbonate and silica were floated separately. A fatty acid type carbonate collector was added in the first stage and an amine collector for silica in the second stage (Figure 2). The sink material from the carbonate flotation stage was de-slimed at 40 microns prior to silica flotation.

Fig. 2: Two-stage reverse flotation



Source: JESA Technologies

### Pilot plant results

The flotation results for single- and two-stage reverse flotation are shown in Tables 1 and 2, respectively. These demonstrated that double reverse flotation in two stages separated carbonate and silica from phosphate very effectively. Carbonate flotation is more selective when performed separately from silica flotation – with about 58 percent of the MgO being removed in the carbonate tail compared to 45 percent using one flotation stage. The two-stage flotation scheme also achieved a higher concentrate grade (31.0% P<sub>2</sub>O<sub>5</sub>) and phosphate recovery (91.5%) compared to the one-stage scheme (29.8% and 87%, respectively).

Table 1: Test results for single-stage reverse flotation

Product	Wt. %	Assay, %			Recovery, %		
		P <sub>2</sub> O <sub>5</sub>	Insol.	MgO	P <sub>2</sub> O <sub>5</sub>	Insol.	MgO
Tail	19.5	18.8	14.9	2.9	13	44	45
Concentrate	80.5	29.8	4.7	0.9	87	56	55
Feed	100	27.6	6.7	1.3	100	100	100

Source: JESA Technologies

Table 2: Test results for two-stage reverse flotation

Product	Wt. %	Assay, %			Recovery, %		
		P <sub>2</sub> O <sub>5</sub>	Insol.	MgO	P <sub>2</sub> O <sub>5</sub>	Insol.	MgO
Carbonate tail	10.7	7.7	6.0	6.8	3.0	8.9	58.3
-40 microns	4.8	21	19.3	1.7	3.7	12.9	6.4
Silica tail	3.3	15.5	43.2	1.1	1.9	19.9	3.0
Concentrate	81.2	31.0	5.2	0.5	91.5	58.3	32.3
Feed	100	27.5	7.2	1.3	100	100	100

Source: JESA Technologies

### Summary

Flotation studies on a North African phosphate ore at JESA’s pilot plant in Lakeland, Florida, have demonstrated that separating carbonate and silica in two different stages results in better flotation performance. Overall, the test results show that removing fines and slimes, using a separate carbonate flotation before silica

flotation, improves phosphate recovery, reduces the carbonate content in the final product, as well as minimising problematic foaming.

### Reference

Daoudi, R., 2020. Processing fine phosphate feed with reverse double flotation stages. JESA Technologies. Written for *Fertilizer International* March/April 2020.

## ERIEZ FLOTATION DIVISION

# Column flotation of ultra-fine phosphate ore

Due to decreases in phosphate prices and the development of low-grade, finely liberated phosphate deposits, efforts are being made to maximize global phosphate recovery and grade within existing and prospective phosphate flotation circuits. Such improvements are essential when treating a low-grade ore where processing costs are highest, operating margins are lowest, and a near zero-waste approach is necessary.

### Innovative Eriez Flotation Division (EFD) technology

Column flotation has been successfully adopted as a commercial mineral beneficiation technology due to its proven ability to

improve ore separation performance and meet some of the above challenges. Typically, column flotation cells are capable of producing higher grade concentrates, with lower levels of impurities, compared to other types of flotation machines.

A key characteristic of column flotation cells is their ability to operate effectively while maintaining and washing a deep froth zone. Eriez Flotation Division (EFD) has developed its own proprietary industrial sparging system (Figure 1) for column flotation called the cavitation-tube (cav-tube for short). This improves fine particle recovery and maximizes the generation of bubble surface area.

The cav-tube system operates by recycling a portion of column underflow slurry through one or more specially-designed bub-

ble generators – known as cav-tube spargers – while air is also introduced to the system upstream of the sparger. This two-phase air/slurry mixture is then passed through the cav-tube spargers causing hydrodynamic cavitation to take place. Cavitation ensures maximum collection of particles by promoting two simultaneous mechanisms:

- The generation of tiny ‘picobubbles’ that adhere to the surfaces of hydrophobic minerals
- Intense mixing within the remaining slurry.

### Case study: the Três Estradas project

The Três Estradas greenfield phosphate project is being developed by Aguiá Resources (Aguiá) in the state of Rio

Fig. 1: Typical EFD column flotation cell with cavitation-tube sparging system



Source: EFD



PHOTO: EFD

Column flotation array.

Grande do Sul in southern Brazil. Beneficiation trials with EFD column flotation technology have been an integral part of efforts to develop the project.

Initial bench-scale metallurgical test work on the Três Estradas ore indicated that a substantial portion of the apatite is contained in fine and ultra-fine fractions of the phosphate rock – and that, consequently, losses of apatite using conventional mechanical flotation machines could limit the commercial viability of the project. It was therefore concluded that column flotation should be considered for the Três Estradas project due to its inherent advantages over conventional flotation when treating fine and ultra-fine ores.

Using EFD’s automated multi-stage column flotation circuit, a series of steady-state flotation tests were conducted to determine the flotation response of fresh carbonatite and oxidised carbonatite (sapolite) ore samples provided by Agüia. Nearly one-third of the phosphate content of the fresh carbonatite sample was contained in the minus 25-µm fraction, while one-quarter of the phosphate in the sapolite sample was contained in this fraction. For both samples, this meant recovery and selectivity of ultra-fines during the flotation process was extremely important for maximising the global phosphate recovery and grade. Results obtained for both samples, using a rougher-scavenger-cleaner-cleaner reverse flotation circuit, are discussed below and shown graphically in Figure 2.

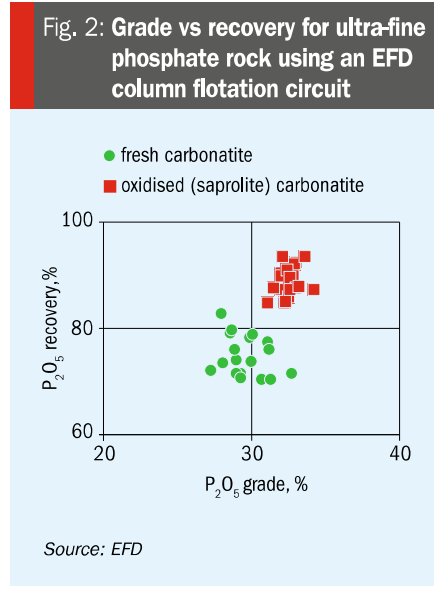
Column flotation results for the fresh carbonatite ore:

- Sample upgraded from 3.6-4.1 percent  $P_2O_5$  to 30-32 percent  $P_2O_5$  – at a  $P_2O_5$  recovery of 71-80 percent.
- Recovery increase of 2-3 percent, at equivalent concentrate grade, compared to results obtained by bench-scale mechanical flotation with five cleaning stages.
- Collector dosage requirement lowered from 600-800 g/t in bench-top mechanical flotation tests to 400-600 g/t in the steady-state column flotation tests.

Results for the oxidised carbonatite ore (sapolite):

- Sample upgraded from 10.0-11.5 percent  $P_2O_5$  to 32-33 percent  $P_2O_5$  – at a  $P_2O_5$  recovery of 85-90 percent.
- Recovery increase of 5 percent, at equivalent concentrate grade, compared to results obtained by bench-scale mechanical flotation results obtained with three cleaning stages.
- Collector dosage requirement lowered from 800-1,200 g/t in bench-top mechanical flotation tests to 450 g/t in the steady-state column flotation tests.

In summary, test work with EFD’s column flotation technology for the flotation of ultra-fine phosphate ores realised a number of distinct benefits. These included a higher degree of selectivity, increased recovery and reduced collector dosage, in comparison to bench-scale mechanical flotation cells. Specifically, column flotation increased phosphate recovery from fresh carbonatite and oxidised carbonatite ore (sapolite) by 2-3 percent and 5 percent, respectively, while collector dosage was reduced by 20-40 percent. At the same time, the required number of cleaning stages to achieve the target concentrate grade was reduced.



Source: EFD

**Reference**

Hobert, A. & Dohm, E., 2020. *Improved flotation recovery and selectivity of an ultra-fine Brazilian phosphate ore using Eriez’ column flotation technology*. Eriez Flotation Division, Written for Fertilizer International March/April 2020.