Troublesome levels of carbonate impurities are found in most phosphate deposits across the globe. With rich phosphate ores depleted, carbonates now affect a greater proportion of ore reserves globally than silica and other gangues. The world’s growing demand for food now requires that these high-carbonate phosphate ores be mined not in the future, but today.

Fertilizer producers find carbonate minerals such as dolomite in phosphate ore particularly undesirable because of the magnesium it contains. High magnesium levels in phosphate rock create a multiplicity of problems in downstream fertilizer production, including high phosphoric acid viscosity, acid filtration difficulties and scale buildup on pipework. Separating carbonate minerals from phosphate by flotation can be
It can be easily adopted into a current plant setup. It is more tolerant to changes in ore characteristics, such as Better performance at lower cost. It has no foaming issues.

**Figure 1.** ArrMaz’s two-stage float.

ArrMaz has made significant advances in carbonate rejection, developing robust carbonate and silica collectors under its CustoFloat® and CustAmine® product lines, to benefit carbonate-laden phosphate deposits around the world. Many of these reagent solutions have been applied at full scale commercial plants, while others have been proven to work in pilot-scale flotation and laboratory testing.

The following are three ArrMaz case studies that highlight the flotation results achieved for phosphate deposits in Africa, China and Florida. Each case study demonstrates how collector technology and flowsheet design can be married together and customised to individual ore characteristics, to optimise the rejection of calcite, dolomite, silica and other impurities, and enhance both phosphate grade and recovery.

**Solving Africa’s ore challenges: carbonate and silica**

In Africa, phosphate producers are faced with the challenge of reducing the amount of carbonate, silica and magnesia present in the ore. As lower-cost, simpler-to-beneficiate ores are depleted, producers must mine and process ores that are higher in carbonate, magnesia and silica. In many cases, flotation is the optimum method used to yield the grade required to produce an economically usable product for fertilizer production.

ArrMaz is currently working with major deposits across Africa, and has developed collectors that work stepwise to remove carbonate and silica from Africa phosphate deposits. In this case study, the reagent scheme consists of an anionic collector, CustoFloat M430, and a cationic collector, CustAmine 2048A, combined into a double-reverse flotation flowsheet as shown in Figure 1. This flowsheet was designed to separate fluorapatite (58%) from dolomite (17%), calcite (15%) and silica (6 – 7%) gangue. The feed assay for this ore was 24.5% P₂O₅, 3.8% MgO and 6.1% insoluble material (SiO₂).

Using this flowsheet, economically successful phosphate recovery and grade were achieved, while MgO and insolubles were reduced. Laboratory results proved that good concentrate grades (31.7% P₂O₅) could be achieved with low levels of MgO (0.4%) and insolubles (3.0%) for an excellent overall P₂O₅ recovery (90.6%).

This new reagent scheme for double-reverse flotation delivers the following key benefits:

- Better performance at lower cost
- It can be easily adopted into a current plant setup.
- It is more tolerant to changes in ore characteristics, such as slimy and low-grade feeds
- It has no foaming issues.

ArrMaz laboratory results demonstrated similar benefits when using CustoFloat 714 for dolomite flotation and CustAmine 2060A for silica flotation in additional double-reverse flotation tests on another Africa ore deposit.

**Solving China’s ore challenge: carbonate**

Phosphate deposits in China are old in geological age with low P₂O₅ grade and high levels of finely disseminated impurities (most are siliceous-calcareous with high magnesium content). These impurities complicate the conversion of rock into fertilizer.

ArrMaz developed a new set of collectors specifically to address China’s carbonate issues, achieving notable results for challenging ores from several phosphate mines in China. The CustoFloat 813 series of collectors is ideal for dolomite rejection from phosphate using reverse flotation at acidic pH.

Plant trials of CustoFloat 813B included full scale tests at a beneficiation plant with an output of 1.2 million tpy. The plant benefits a blended ore containing 24.5 – 27.0% P₂O₅ and 3.5 – 4.5% MgO. The quality of phosphate rock concentrate produced by the mine needed to be improved to meet the low magnesium (<0.6% MgO) requirements of the site’s diammonium phosphate (DAP) plant. ArrMaz’s reagent suite solved the problem and improved overall fertilizer production.

The plant flowsheet includes one rougher and two scavenger flotation steps as shown in Figure 2, which yielded a 30% P₂O₅ grade concentrate containing less than 0.5% MgO at an overall recovery rate of 97% and higher.

Overall, all three trials in Hubei, Yunnan and Northern China demonstrated that the CustoFloat 813 series of collectors are highly selective carbonate collectors capable of yielding high P₂O₅ recoveries for variable types of high-MgO feeds.

As they are efficient collectors with a fast flotation rate, the CustoFloat 813 series is capable of yielding high-grade concentrates at a relatively low dosage. These collectors can...
also handle phosphate ores from different and varying sources while delivering excellent flotation performance.

Key benefits of the China Custofloat 813 series of collectors include the following:

- Fast flotation rate.
- Lower dose and cost performance.
- Highly selective carbonate collector for better recovery.

**Solving Florida’s ore challenge: dolomite**

Florida’s phosphate rock output has been steadily decreasing because the easy-to-process, primarily silica-impurity reserves that are low in dolomite have been depleted. As phosphate mining moves towards southern Florida and permits become harder to acquire, lower-grade phosphate rock with higher MgO levels must be processed. These ores typically have lower $P_2O_5$ content and contain more dolomite.

The standard phosphate flotation practice in Florida, the direct-reverse Crago process, is generally unable to handle MgO pebble (-19 mm to +1.19 mm size), which accounts for approximately 20 – 40% of total phosphate resources. Pebble is typically blended with flotation concentrates for phosphoric acid production as long as it’s $P_2O_5$ is 23 – 28% and MgO <1.5%. Most pebble with >1.5% MgO is usually discarded as unusable.

To solve Florida’s dolomitic pebble problem, ArrMaz developed a fine-particle flotation process without de-sliming, which enables higher recovery as shown in Figure 3. The pebble is ground to less than 100 mesh and processed in the following three main steps:

1. Rougher and cleaner float open circuit with depressant, acidic pH modifier, and CustoFloat MP12 collector reagents.
2. Tailings refloat where carbonate tail is removed as a float fraction.
3. Sizing step and silica float (+400 mesh) with CustAmine 1250 collector where the silica tail is removed as a float fraction.

Viable concentrate grades (>31% $P_2O_5$) with low MgO levels (<1%) at high overall $P_2O_5$ recoveries (>86%) have been obtained in the laboratory using this approach. ArrMaz’s Florida dolomitic pebble reagent scheme and flowsheet are able to compensate for the presence of slimes and deliver a significant recovery advantage.

Florida’s dolomitic pebble processing key benefits:

- Better deposit utilisation.
- Eliminate de-sliming step.
- Higher recovery and better grade.

**The key to solving global phosphate processing challenges**

As evidenced by the case studies presented previously, the global challenge of processing troublesome, carbonate-rich phosphate ores can effectively be solved by simultaneously developing an innovative reagent package, a custom flowsheet and a complementary equipment package together from the start. The future of global phosphate processing where reagent formulation, process flowsheet design and equipment selection are developed in unison is already here.
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