

## ***ABSTRACT***

The performance of a wet-gravity concentration circuit can be enhanced and the circuit made smaller and less complex by complementing spiral concentrators with a hindered-bed-settling device. The resulting circuit provides producers of industrial minerals a method whereby they can increase profits by improving process efficiency while better accommodating changes in product specification and ore variations. This new wet-gravity process flowsheet has been tested and installed in mineral sand and glass sand operations. The circuit's performance as well as the operational and capital costs will be presented and compared to that of a conventional process circuit.

**HOW TO TEACH AN OLD DOG NEW TRICKS: INCREASING THE  
PROFITABILITY OF INDUSTRIAL MINERAL OPERATIONS USING  
COMPLEMENTARY PROCESSING TECHNIQUES**

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## **INTRODUCTION**

Over its more than 50 year history Carpco, a Division of Outokumpu Technology, has conducted test work designed to improve the separation efficiency of processing circuits for a number of industrial mineral producers. These studies have involved both wet and dry processes have resulted in improved operations, as well as the development or modification of new physical separation equipment.

This presentation focuses on the modification of separation processes, and how the inclusion or rearrangement of standard process equipment can enhance profitability. Presented are data from studies of mineral sand and glass sand process circuits. The studies show how spiral concentrators and a Floatex Density separator can be integrated to complement the separation process and improve the separation efficiency of a process circuit with a reduction in the capital costs of the process equipment.

## **BACKGROUND**

A spiral is a flowing-film concentrator in which the slurried feed material is subject to centrifugal and gravitational forces, (Figure 1). The centrifugal force causes the upper layers of water to flow outward and carry with it particles of lower density and of larger size. The centrifugal force on the bottom-most layer of water is retarded by friction with the surface of the spiral. Consequently the lower layers of water flow sideways toward the spiral's inner edge carrying with it particles of higher density and of smaller relative size. Equilibrium between the centrifugal force outward and the gravitational force downward allows for the separation of particles based on their density and size.

Spirals, because of their versatility and low installation and operational costs, are used in a variety of industrial mineral operations. In these operations it is common to find a large number of spirals used in multiple stages, which are often required to accommodate recirculating streams.

A Floatex Density Separator is a type of hindered-bed classifier. Feed slurry is introduced tangentially through a centralized feedwell that extends into the upper one-third of the tank. Fluidizing (teeter water) is introduced through evenly spaced water distribution pipes over the cross-sectional area at the base of the tank's teeter chamber. As the feed enters the separation zone it expands into a teetered or fluidized bed as a result of the rising current of water, (Figure 2).

The separation takes place in the tank's intermediate zone with the lighter and finer sized particles lifted upwards and exiting the separator from the upper zone while the heavier and coarser particles migrate downward and leave the separator through the lower conical section. The pressure, sensed by a DP cell mounted in the tank's wall, is transmitted to the underflow control valve thereby maintaining a constant height of the teeter bed and a steady discharge of the underflow.

## **Case Study 1. The recovery of ilmenite and other economic heavy minerals from mineral sand deposits**

Recent Carpco studies have focused on improving the performance of wet-gravity circuits used in mineral sand operations. The objectives of these studies were threefold:

- First: Improve the recovery of the economic heavy minerals, namely ilmenite, leucoxene, rutile, and zircon,
- Second: Produce a heavy mineral concentrate that is of equal grade to the concentrate achieved at lower recovery levels,
- Third: Reduce the overall capital and installation equipment costs.

Although the composition of mineral sand deposits varies widely from deposit to deposit, and often within the deposit itself, the wet-gravity circuit is generally comprised of a four-stage spiral circuit, (Figure 3). In this circuit the sand material, after the removal of oversize boulders and undersize clay, is slurried to approximately 30% solids and presented as feed to the rougher spirals. The rougher and the scavenger spiral concentrates are further upgraded using Cleaner and Re-Cleaner spirals. The number of spiral separators in the first three stages, i.e. Rougher, Scavenger and Cleaner, are roughly equal and the number of spirals in the final Re-Cleaner stage is generally reduced by 50%.

The efficiency of the wet-gravity circuit generally varies directly with the heavy mineral content of the feed material. A heavy mineral recovery ranging between 85% and 95% with a concentrate grade of +90% heavy minerals is considered acceptable for most mineral sand wet-gravity operations. As mentioned, these levels are often achieved and/or maintained by varying the amount of re-circulating material.

A common problem in many wet-gravity circuits is the presence of fine silica in the heavy mineral concentrate. Its presence, negatively impacts the downstream electrostatic and magnetic separation processes where its removal is both difficult and expensive. As the wet-mill operators push to improve the concentrate grade by removing the fine silica they trade-off the recovery of coarser ilmenite and other heavy minerals which are transported to the spirals outer rim.

Over the last seven years Floatex Density Separators have been installed at the end of the spiral circuit wet-gravity circuit for the removal of this residual fine silica and other fine particles attritioned from the surface of the heavy mineral. This operation is efficient and results in no practical loss of the economic heavy minerals. This use of a Floatex unit does result in the production of a higher-grade concentrate, but it does not affect heavy mineral recovery and it does not reduce operational costs, (Figure 4).

With the Floatex unit sited higher in the spiral circuit, the higher specific gravity minerals, especially those coarser in size, are immediately captured. The finer sized heavy minerals report to the Floatex overflow along with the coarser minerals of lower specific gravity. The overflow material is then subject to further concentration using spirals where it is easily and efficiently separated, (Figure 5).

Studies conducted at Carpcos show that by moving the Floatex Density Separator higher into the spiral circuit,

- Improves the performance of the wet-gravity circuit,
- Reduces the number of spiral concentrators, and the costs of the associated with installation, operation, and maintenance,
- Provides operators a control mechanism that can be quickly adjusted to accommodate variation in plant feed.

A comparison of the separation results of a Spiral-Floatex flowsheet vs. a Spiral-Only flowsheet show that a Spiral-Floatex combination results in the higher recovery of heavy minerals and a concentrate of higher grade. Importantly these improvements are achieved at lower capital equipment costs (Table 1).

**Table 1. Comparison of separation efficiency and equipment costs of wet-gravity process circuits for a lower-grade mineral sand ore**

	Spirals – Floatex	Spirals – Only
Head Feed Grade (%HM)	3.0	3.0
Concentrate Grade (%HM)	94.6	92.0
HM Recovery (%)	75.4	69.5
TiO <sub>2</sub> Recovery	88.0	N/A
Number of Spirals *	1,050	1,200
Number of Floatex Units *	2	1
Total Equipment Cost (est)*	\$2.7 M	\$3.3 M

\* Circuit capacity 1500 tph

The profitability of the Spiral-Floatex process is readily evident in the nearly 6% increase in the heavy mineral recovery, 2.5% increase in concentrate grade, and lower capital costs for separation equipment. Less evident is the improvement in profitability that will be gained in the improved efficiency of the downstream magnetic and electrostatic separation process operations that will result from the processing of higher-grade material.

When processing a higher grade mineral sand material similar results are found, (Table 2).

**Table 2. Comparison of separation efficiency and equipment costs of wet-gravity process circuits for a higher-grade mineral sand ore**

	Spirals – Floatex	Spirals – Only
Head Feed Grade (%HM)	17.3	17.3
Concentrate Grade (%HM)	92.5	92.5
HM Recovery (%)	95.3	93.3
Number of Spirals *	360	510
Number of Floatex Units *	2	1
Estimated Equipment Costs *	\$1.0 Million	\$1.3 Million

\* Circuit capacity 225 tph

**Case Study 2. Beneficiation of a glass sand**

Glass sand producers like mineral sand producers separate quartz from higher density minerals. They both rely on spirals, magnetic, and electrostatic separation equipment, in their pursuit of a final quality product. The two producers simply differ on their definition of product and gangue material.

Outokumpu Technology – Carpc Division - was recently asked to beneficiate a glass sand material with higher concentrations of iron, titanium, and aluminum, (Table 3).

**Table 3. Comparison of initial glass sand ore material and beneficiated product specification**

	Glass Sand Ore	Glass Sand Product Specification
Fe <sub>2</sub> O <sub>3</sub> (%)	0.035	< 0.01
TiO <sub>2</sub> (%)	0.10	< 0.02
Al <sub>2</sub> O <sub>3</sub> (%)	0.85	< 0.06

Results from the initial analyses showed that the heavy mineral contaminants were all less than 0.6mm in size. Based on this information the run-of-mine material was screened at 0.6mm (30-mesh) and the finer particles were subjected to magnetic separation. It was anticipated that the contaminants would be associated with the iron and they could be efficiently removed with magnetic separation. This logic was valid and the final product was within the stated specifications. However, the concentration of titanium in the final product presented a potential problem, (Table 4).

**Table 4. Comparison of glass sand ore material and product resulting from 2-pass high-intensity magnetic separation**

	Glass Sand Ore	Glass Sand Product Specification	Magnetic-Separation Product
Fe <sub>2</sub> O <sub>3</sub> (%)	0.035	< 0.010	0.007
TiO <sub>2</sub> (%)	0.105	< 0.020	0.023
Al <sub>2</sub> O <sub>3</sub> (%)	0.852	< 0.060	0.031

Results from subsequent test work showed that by incorporating spiral concentrators into the separation process the nonmagnetic titanium and aluminum-bearing particles were removed. Unfortunately, higher capital and operational costs accompany this improvement, as the number of magnetic separators remained the same, and the feed material to the magnetic circuit must be dried.

A process circuit comprised of a Floatex Density Separator and spiral concentrators provided a better solution. This all wet-gravity circuit produced a product equal to that obtained in the spiral-magnetic process, with similar recovery and at less cost, (Table 5).

**Table 5. Comparison of glass sand products resulting from three process circuits, circuit performance and estimated equipment costs**

	Magnetic Separation Product	Spiral and Magnetic Separation Product	Floatex and Spiral Separation Product
Fe <sub>2</sub> O <sub>3</sub> (%)	0.007	0.007	0.007
TiO <sub>2</sub> (%)	0.023	0.014	0.014
Al <sub>2</sub> O <sub>3</sub> (%)	0.031	0.023	0.020
Recovery (%)	94.3	93.1	93.8
* Equip. costs (\$ 000's)	600	720	250

\* Circuit capacity 50 tph  
 Estimated costs include ancillary material handling equipment

## CONCLUSION

Studies of mineral sand and glass sand process circuits show that improvement in separation efficiency can be achieved with the use of complementing process equipment. In most instances these improvements are achieved at lower capital and operational costs.

For mineral sands operations the inclusion of a Floatex separator “into” rather than at the “end of” the spiral circuit results in a higher recovery of the heavy minerals, with a reduction in equipment costs.

For a glass sand operation the final product achieved with magnetic separation was improved with the addition of wet-gravity separation procedures. In addition, an all-wet-gravity process circuit provided a product of equal quality at less cost.

These studies illustrate how costs can be reduced and revenues increased with the inclusion or re-arrangement of standard separation equipment in a process circuit. Not studied were the benefits gained in the downstream drying, material handling, and subsequent separation processes, which, when considered, are certain to add to even more profit to specific operations.