

# **THE ROLE OF PHYSICAL PROCESSING ENHANCING THE QUALITY OF INDUSTRIAL MINERALS**

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14<sup>th</sup> Industrial Minerals International Congress  
Denver, Colorado, USA  
March 26-29, 2000

Ever rising demands of end users in conjunction with lower quality feedstocks has put increasing pressure on industrial mineral suppliers to provide high quality products. The paper will review new developments in mineral processing in the white minerals and mineral sands industries and outline the cost effective role that physical processing plays in the mineral supply chain. Focus will be given to developments in magnetic and electrostatic separation.

## **INTRODUCTION**

Producers of industrial minerals often find that they must meet market demands for higher quality products with lower quality feed materials. This presentation focuses on advances in magnetic separation and the effects of these advances on product quality. Specifically, the results of superconducting magnetic separation test work for the production of brighter kaolin, calcium carbonate and zircon products are presented, as is the reduction of uranium and thorium in an ilmenite product using a permanent rare-earth drum magnetic separator.

Magnetic separation is a recognized and often used procedure in mineral processing. Here the differences in the magnetic properties of a mineral are exploited to segregate more magnetic, generally dark colored, from lesser magnetic, lighter in color, minerals. In the relatively recent past two advances in magnet technology, namely superconducting and rare-earth, have found their way into mineral processing environments. Both technologies combine the more-efficient removal of weakly magnetic minerals with lower processing costs. Superconducting magnetic separators with magnetic field strengths of 50,000 gauss (5 Tesla) are used in wet processing environments primarily for the processing of kaolin. Rare-earth magnets with magnetic field strengths of 20,000 gauss (2 Tesla) are used in dry processing environments and are routinely found in the processing of a variety of industrial minerals.

Outokumpu Technology acquired Carpc Inc. in December 1998. Both organizations have a long and respected history of providing the mineral industry with an array of reliable products and services that assist mineral producers in their quest to meet client specification in a cost-effective manner. Outokumpu Technology – Carpc Division is an integrated company with a complete line of process and separation equipment and engineering services.

### **Beneficiation of Kaolin, Calcium Carbonate and Zircon using Superconducting Magnetic Separation**

#### **Kaolin**

The beneficiation of kaolin from crude ore to finished product relies on a wide variety of processing techniques. Magnetic separation is often used to increase product brightness by removing iron and titanium minerals, e.g. hematite, goethite, and rutile. Conventional high-gradient magnetic separation with a flux density of up to 20,000 gauss (2 Tesla) often does not remove an adequate amount of these paramagnetic minerals particles to improve product quality. High-gradient magnetic separators also have relatively high energy requirements and low per unit capacity. In contrast superconducting magnetic separators have a field intensity of 50,000 gauss (5 Tesla), a unit capacity of up to 100 TPH, and consume only 10-15kW of power. These attributes allow for the more efficient separation of magnetic particles, resulting in a brighter product at a lower cost.

A brief summary of the physical properties of kaolin is provided in **Table 1** with gains in brightness and general performance criteria provided in **Table 2** and **Table 3**, respectively.

**Table 1: Kaolin Product Specification**

	<b>Premium Brightness</b>	<b>Standard Brightness</b>	<b>Filler</b>
TAPPI Brightness, %	89.5 to 92.0	85.5 to 89.0	80.0 to 85.5
Particle Size, % < 2 $\mu$ m	80 to 100.0	80.0 to 97.0	62.0 to 95.0
+325 mesh	0.01	0.01	0.30 to 0.40

**Table 2: Cryofilter Separation Data,  
Brightness Gains for Two Different Kaolin Feed Materials**

<b>Material</b>	<b>Feed Specifications:</b>			<b>Product (Unbleached):</b>	
	<b>Type:</b>	<b>Grade:</b>	<b>% Solids:</b>	<b>Grade (gain)</b>	<b>Production Rate (TPH)</b>
Kaolin	Coating Grade	54 to 84 ISO	23 to 28	67 (13) to 88 (4) ISO	5 to 40
Kaolin	Ceramic	77 ISO	23	81 (4) ISO 80 (3) ISO 79 (2) ISO	5 12 20

**Table 3: Cryofilter Performance**

<b>Parameters</b>	
Energy Consumption	0.1 kW/t
Throughput	up to 100 tph
Brightness Gains	7 points on a feed with 70-75 brightness 5 points on a feed with 80-85 brightness 2 points on a feed with +90 brightness

## Calcium Carbonate

Superconducting magnetic separation for the removal of paramagnetic materials from calcium carbonate is also an area of interest. Here again the objective is to improve product brightness by removing iron-stained particles and weakly magnetic minerals. Certainly the need to achieve this separation at low cost is of importance. **Table 4** summarizes Cryofilter separation performance at different unit capacities.

**Table 4: Cryofilter Test Results – CaCO<sub>3</sub> Feed**

Material	Grade	% Solids	% Gain in grade	Rate T/H
CaCO <sub>3</sub>	> 90 ISO	25	2.5	12
		35	2.3	12
		45	1.8	12
		*55	2.0	20

\* Using larger unit and different bed depth

## Zircon

Zircon, a co-product in mineral sand (titanium) operations is often used as an opacifier for ceramic tiles and sanitaryware. A summary of the general quality of zircon sand concentrates from worldwide sources is presented in **Table 5** and the product specifications for zircon used as an opacifier are presented in **Table 6**.

**Table 5: Major and Trace Elements XRF Analysis of Zircon Sand Concentrates**

	ZrO <sub>2</sub> (% min.) + HfO <sub>2</sub> (% min.)	Fe <sub>2</sub> O <sub>3</sub> (% max.)	TiO <sub>2</sub> (% max.)	Al <sub>2</sub> O <sub>3</sub>	U/Th (ppm max.)
Australia	65.4	0.062	1.065	1.000	500
India	62.5	0.161	0.650	2.967	1500
USA	66.5	0.018	0.083	0.361	220
Brazil	65.8	0.059	0.168	0.930	450

**Table 6: Zircon Opacifier Specification**

Element	ZrO <sub>2</sub> + HfO <sub>2</sub>	Fe <sub>2</sub> O <sub>3</sub>	TiO <sub>2</sub>	Al <sub>2</sub> O <sub>3</sub>	U + Th
Specification	> 66.0 %	< 0.7 %	< 0.2 %	< 1.0%	< 500 ppm

Comparison of the world's zircon supply with opacifier market demands shows that the zircon from locales other than the USA does not meet all market specifications; thus

prompting the need for additional processing. **Table 7** presents the results of two zircon products after superconducting magnetic separation.

**Table 7: Separation of Zircon Concentrate using Carpcryo-Stream Superconducting Magnetic Separator**

	ZrO <sub>2</sub> + HfO <sub>2</sub> (%)	Fe <sub>2</sub> O <sub>3</sub> (%)	TiO <sub>2</sub> (%)	Al <sub>2</sub> O <sub>3</sub> (%)	U + Th (ppm)
Sample A					
Feed	66.21	0.100	0.154	0.292	417
Product	66.30	0.070	0.075	0.201	353
Sample B					
Feed	66.53	0.062	0.105	0.405	178
Product	66.57	0.046	0.049	0.303	174

For both samples, a new dry superconducting magnetic separation procedure was used. The results show that the Fe<sub>2</sub>O<sub>3</sub> specification was met for Sample A and substantially reduced the iron content for Sample B. Also of note is the reduction in TiO<sub>2</sub> for both samples and the U/Th level for Sample A.

The above zircon feed samples are product materials attained after extensive processing. To reach these thresholds different separation equipment and processes were employed. **Table 8** provides general information of a lower grade zircon concentrate and the product that can be achieved using more routine magnetic and other separation procedures.

**Table 8: Analyses of Zircon Concentrate Feed and Products resulting from additional beneficiation**

	ZrO <sub>2</sub>	Fe <sub>2</sub> O <sub>3</sub>	TiO <sub>2</sub>	Al <sub>2</sub> O <sub>3</sub>	P <sub>2</sub> O <sub>5</sub>
Sample	<64.50%	0.30 %	>0.50 %	2.00 %	0.15 %
Product	>66.25%	0.20 %	<0.10 %	<0.60 %	0.10 %

For this particular study the primary objectives were twofold, namely:

Increase the ZrO<sub>2</sub> concentration to at least 66% ZrO<sub>2</sub> and

Reduce the Al<sub>2</sub>O<sub>3</sub> concentration to less than 1% in the product material.

A secondary objective was to improve overall product quality by reducing the concentration of iron, titanium and phosphorus. The removal of phosphorus relates to the separation of the mineral monazite, a primary source of the elements uranium and thorium.

The reduction of aluminum was achieved by attrition scrubbing the zircon concentrate feed and classifying the material using a Floatex Density separator. Attritioning removed

the aluminum-rich clay-like coatings from the individual zircon grains. Treating the scrubbed material in a Floatex Density separator assisted in the removal of sillimanite and other high-specific gravity alumino-silicate minerals, and further classified the scrubbed zircon allowing for its more efficient recovery in subsequent procedures.

Titanium, present in rutile and leucoxene, was removed from the scrubbed and classified zircon feed using high-tension electrostatic separation procedures. This separation process exploits the difference in surface conductivity to achieve the separation of nonconductive zircon from conductive titanium-bearing minerals. Although some iron was removed in each of the above processes high-intensity magnetic separation using an induced-roll separator removed the most significant amounts. Observation of the magnetic products showed the presence of monazite and zircon with dark inclusions; in this instance both minerals are assumed to be iron-bearing.

### **Recovery of Ilmenite and the Removal of Uranium and Thorium from Titanium-bearing concentrates**

Typically a titanium mineral sand processing facility has a wet gravity concentration stage followed by dry electrostatic and magnetic steps to recover and beneficiate an ilmenite product. Feed to the gravity circuit can be as low as 2-5% heavy minerals. This material must be upgraded to a concentrate containing 85-95% heavy mineral prior to its introduction to the dry electrostatic and magnetic separation circuits. Increases in the recovery of ilmenite adds to revenue and reduces subsequent processing costs.

However improvements in heavy mineral recovery and concentration are often accompanied by increases in monazite, a high specific gravity, paramagnetic rare-earth phosphate mineral that contains varying amounts of uranium and thorium. As most pigment producers prefer that the ilmenite feed materials be less than 200 ppm for uranium plus thorium, the removal of monazite is often required to meet market specifications.

Monazite's paramagnetic characteristic allows it to be magnetically segregated from more magnetic ilmenite and less magnetic zircon. **Table 9** compares a ilmenite feed and and product sample. The latter is a result of both gravimetric and magnetic concentration procedures.

**Table 9: Comparison of the Feed and Ilmenite Product Samples**

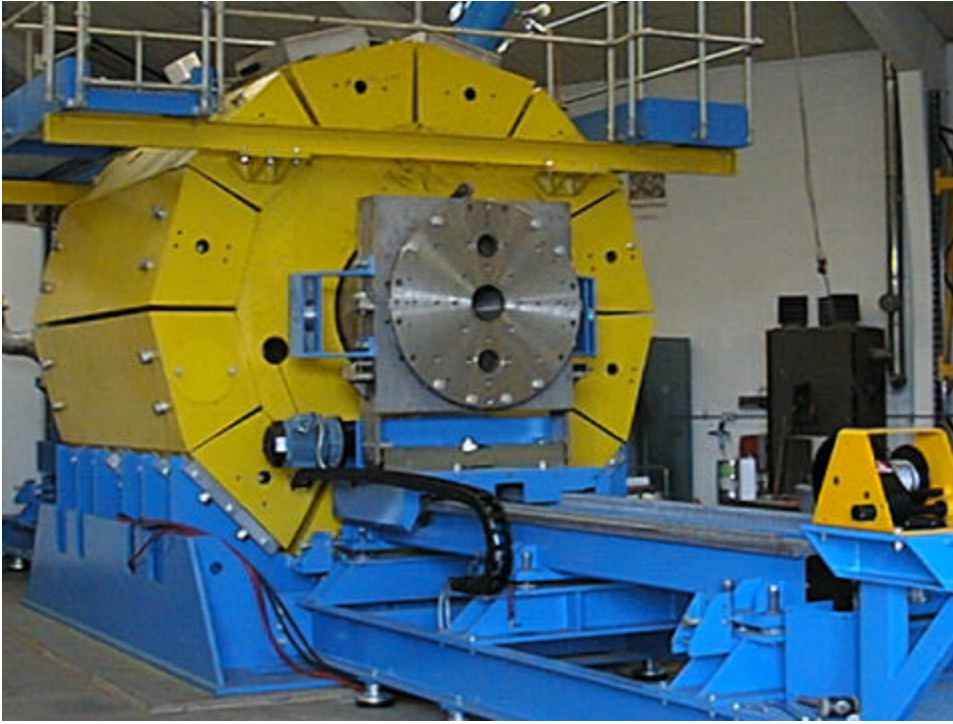
	<b>Feed</b>	<b>Ilmenite Product</b>
TiO <sub>2</sub>	48.0%	61.6%
Fe <sub>2</sub> O <sub>3</sub>	24.9%	34.4%
U	202 ppm	61 ppm
Th	423 ppm	144 ppm

The reduction in the U/Th concentration was largely a result of processing using a rare-earth drum magnetic separator. This unit has an approximate magnetic field strength of 8,000 gauss. This magnetic intensity is of sufficient strength to alter the trajectory of monazite, resulting in its concentration into a middling stream.

## **CONCLUSIONS**

Superconducting magnetic separation can be used to improve the brightness of kaolin, and studies suggest that it can also be used to improve the quality of calcium carbonate and zircon products. In addition, superconducting magnetic separation is a less expensive process and the technology is advancing into dry separation applications.

Advanced magnetic rare-earth drum separators are routinely used to reduce the uranium and thorium levels of ilmenite concentrates to acceptable levels. These separation techniques are often used to complement standard electrostatic and gravimetric processes for the removal of other contaminants.



**Fig 1. A Carpco 5T/1000 magnetic separator in final testing stages**