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MAGNETIC BENEFICIATION OF A SOUTHEASTERN QUARTZ SAND

by

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ABSTRACT

An easy to run and inexpensive method is tested and compared with flotation for beneficiation of quartz sand. The process includes scrubbing and desliming of the material and after drying, magnetic separation using permanent magnet belt separators.

The method yields a product that meets with the specifications stated by P. Harben in Industrial Minerals as required by the plate glass manufacturing industry.

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INTRODUCTION

A client contacted MRL and requested testing on their sand from their Southeastern operation. The investigation was required to determine if the material could be beneficiated to yield a glass-grade product. The material had previously been processed by flotation at another University Minerals Laboratory. The process tested produced a low grade product and required magnetic separation and leaching to extract iron mineral contaminants.

The client shipped three samples of their sand product to the Minerals Research Laboratory for flotation for testing. Initial batch flotation performed at the MRL revealed that a process involving attrition scrubbing, desliming and a 3-stage flotation was effective in producing high grade plate-glass sand from three different ore samples. The resulting products in this investigation exceeded the specifications set by a glass manufacturing company for feed to their float glass plant. The customer is a major consumer of high-silica sand.

The encouraging results obtained in the project prompted the client to request an additional project to optimize the flotation process and test the process on eight samples collected from different areas in their mine. The consistent result obtained in this project prompted the client to request a proposal for a pilot plant to be constructed and operated at the Minerals Research Laboratory in Asheville, North Carolina. The pilot plant investigation was to be performed on a 20-ton shipment of the ore to confirm batch studies, provide data for design of a full scale plant and provide bulk samples for custom evaluation.

Although this investigation revealed that a high quality plate glass sand could be produced using flotation, the client requested a follow-up study. In this investigation gravity concentration was to be used to reduce the complexity and cost of beneficiating the sand. After some preliminary test work a flow sheet involving scrubbing and desliming, spiraling, tabling and wet magnetic separation was adopted.

The gravity and magnetic separation investigation yielded a viable product. However, a new project was given to the Minerals Research Laboratory. This time the objective was to study the use of high gradient dry magnetic separation as a substitute for flotation.

OBJECTIVE

To suggest and test an easy to run and inexpensive method to remove iron containing minerals, mica and refractory heavy minerals from the quartz sand. The final quartz product must meet the specifications set by the glass manufacturing industry for container glass.

MINERALOGY

The five principal minerals present in the samples are listed below in order of the descending concentration.

Mineral	Chemical Composition	Breakdown of Oxides	
		Oxide	Wt/ %
Quartz	SiO_2	SiO_2	100.0%
Kaolinite	$Al_2O_3 \cdot 2SiO_2 \cdot 2H_2O$	SiO_2	46.5%
		Al_2O_3	39.5%
		H_2O (LOI)	14.0%
Muscovite	$H_2KAl_3(SiO_4)3$	SiO_2	45.2%
		Al_2O_3	38.5%
		H_2O (LOI)	4.5%
		K_2O	11.8%
Luecoxene	$FeO \cdot TiO_2$	TiO_2	~68%
		FeO	~32%
Staurolite	$FeAl_5Si_2O_{12}(OH)$	Al_2O_3	45% (min)
		Fe_2O_3	18% (max)
		ZrO_2	3% (max)
		TiO_2	5% (max)
		Free Silica	<5%

SAMPLE

Two buckets of material were sent to the Minerals Research Laboratory for dry magnetic separation tests.

Magnetic Susceptibility Distribution

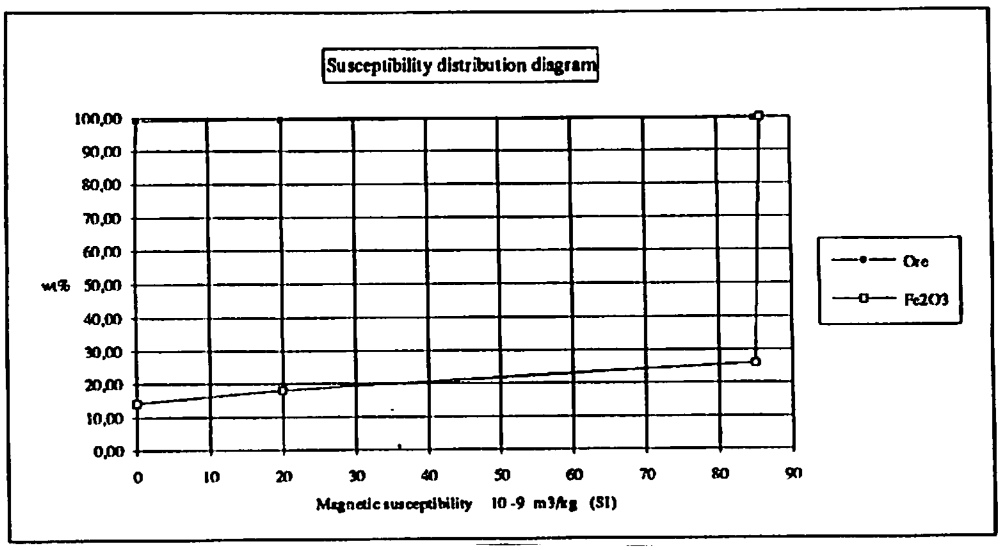


Figure 3. Magnetic susceptibility distribution for the iron content in the Southeastern sample.

The susceptibility distribution suggests that over 75% of the iron contaminants can be removed with very good recovery of quartz. The field required is moderate to high.

EQUIPMENT USED

Permroll

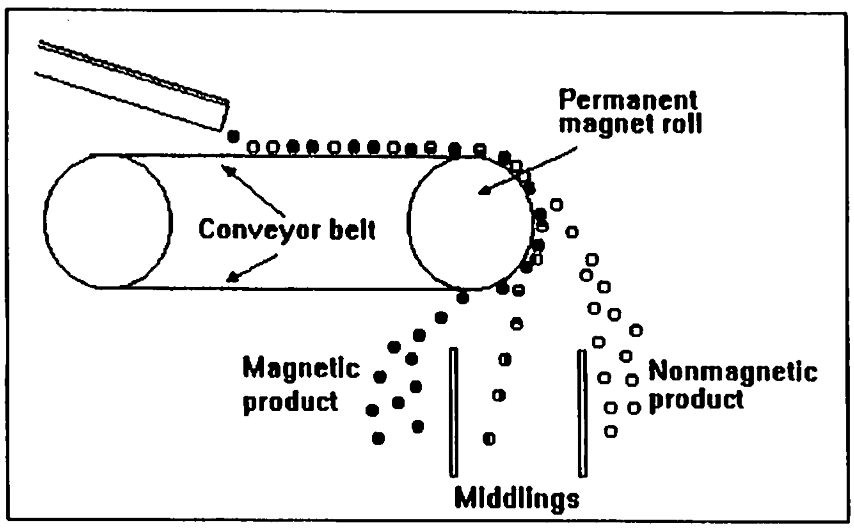
The heart of the Permroll separator is a roll made of relatively thin rare earth cobalt alloy magnet rings, interleaved with mild steel discs (Svoboda 1987). In this way, a very strong magnetic field is created with a high magnetic field gradient. The magnetic force at the surface is of the same magnitude as the best of the conventional induced roll separators. Permanent magnets are able to achieve a 2,3 T (23 kGauss) magnetic induction, and a field gradient of ca 300 T/m (99 kGauss/foot).

Materials to be separated are transported to the magnetic roll by a short, thin and abrasive resistant conveyor belt of either steel or Kevlar. The thickness of the belt is very important for the separation since the magnetic field intensity is reduced by a factor times the squared distance from the magnet surface.

The non-magnetic particles are discharged from the roll surface by gravity and centrifugal forces while the magnetic force retain the magnetized particles. These are released at the point where the belt leaves the magnetic roll. Particle streams are separated by a splitter arrangement into magnetics, middlings and non-magnetics (see figure 4). Often two or three rolls will be used in series to assure high purity of the product.

The Permroll used in this investigation was an Oresorters lab size separator.

Figure 4. Schematic drawing of a band type permanent magnet separator (Permroll).



EXPERIMENTAL LAYOUT OF MAGNETIC SEPARATION PARAMETER TESTS

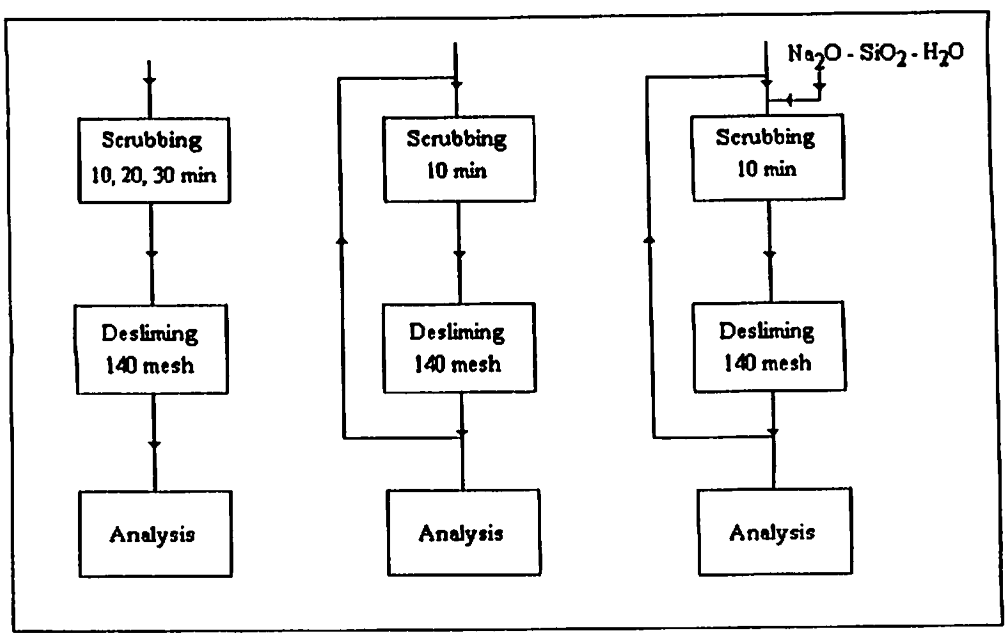
Scrubbing

Since previous work on this material showed that attrition scrubbing was necessary to obtain the desired grade, a thorough scrubbing investigation was undertaken.

The dried sand was fed into an attrition cell. The wt.% solids of the pulp was adjusted by adding water until desired flow characteristics in the cell were reached. Best results in the attrition scrubber were achieved at 70% solids and 950 ft/min (1200 rpm). Subsequent desliming of the scrubbed material at 140 mesh removed the liberated fines, thus reducing the Al_2O_3 and LOI of the product.

The scrubbing tests investigated the effects of scrubbing time and addition of dispersant (sodium silicate).

Figure 5. Scrubbing and desliming test design.

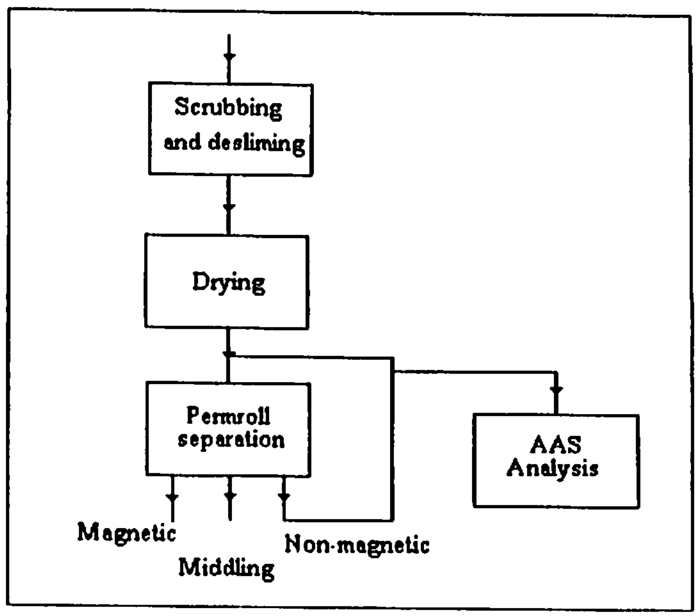


Scrubbing for 10, 20 and 30 minutes were compared to 10 + 10 and 10 + 10 + 10 minutes scrubbing with intermediate desliming. Finally, tests with different concentrations of dispersant (sodium silicate) were done.

Permroll Tests

The scrubbed and deslimed material was dried and fed on the Permroll. The feed rate was adjusted to form a thin layer on the belt. The belt speed was kept at 150 rpm. All three products were weighed and the non-magnetic product was passed a second time over the separator. The final non-magnetic product was assayed by AAS.

Figure 6. Experimental layout for the Permroll tests.



Heavy Liquids

The final non-magnetic product was separated in tetrabromoethane (TBE), the sink product was weighed and minerals were identified by microscopy. All samples were counted in oil of 1.680 refractive index as that value permits easy recognition of kyanite and distinction of that mineral from sillimanite and orthopyroxenes.

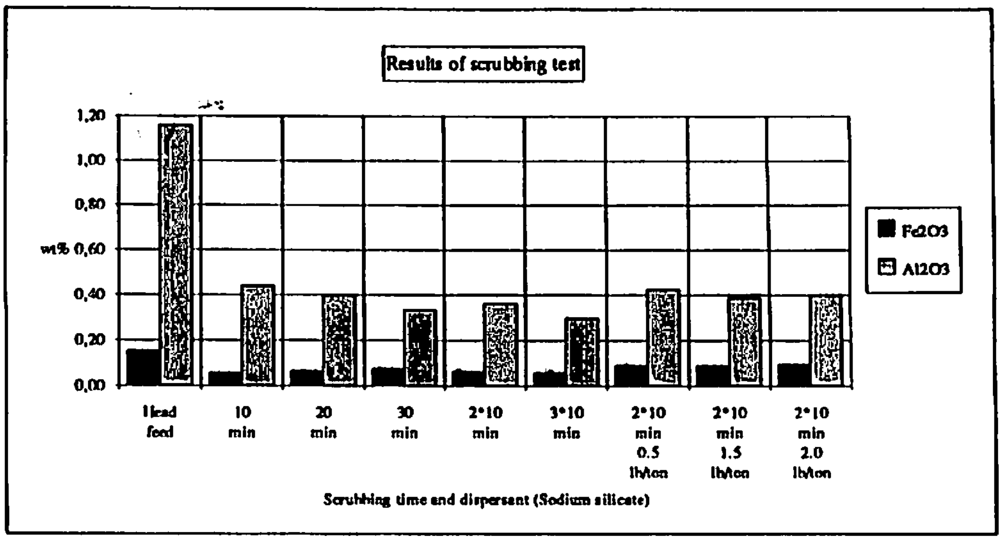
The petrography was done by:

Tom Wilcox
Dept. of Geosciences/Anthropology
Western Carolina University
Cullowhee, NC 28723

RESULTS AND DISCUSSION OF PARAMETER TESTS

Scrubbing and Desliming

Figure 7. Fe_2O_3 and Al_2O_3 in the product after scrubbing.

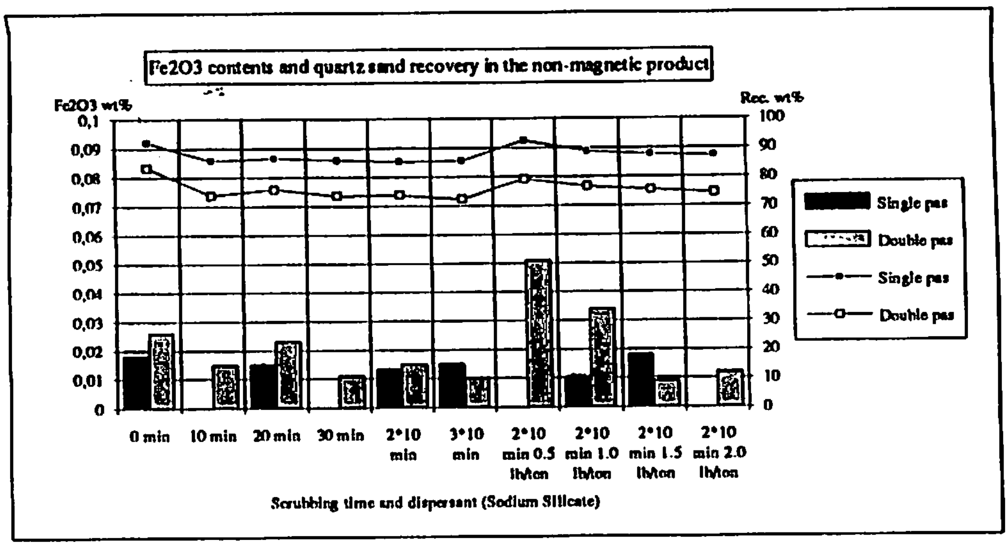


Two stage scrubbing with subsequent desliming proved more efficient than a single stage scrubbing. The liberated fines in a single stage scrubbing act as a lubricant in the pulp reducing the friction between, and thereby the scrubbing effect on the quartz particles. In the double stage tested the fines were removed by the desliming screw. The reduced iron and aluminum contents indicate that much of the aluminum and some of the iron contamination are associated with the semi-weathered feldspar/kaolinite.

Scrubbing with added dispersant did not improve the liberation of the contaminants.

Permroll Separation

Figure 8. Fe_2O_3 content and material recovery to the non-magnetic product after single and double pass over the Permroll.



A single pass over the separator was compared with a double pass. At low feed rates the difference in iron and aluminum concentration was not significant. However, with increasing feed rate the double pass becomes very important since it allows the material in the bed on the belt to restratify, giving magnetic particles a second chance to be attracted by the magnetic field.

The material recovery to the non-magnetic product decreased by approximately 10% with the double pass.

<u>Throughput</u>

Feed rates of 1 ton/h m, 2 ton/h m, 3 ton/h m, 4 ton/h m, and 52 ton/h m were tested (metric ton). It is favorable for the process economy to maximize the through-put on the separator. The investigation showed that the iron concentration in the non-magnetic product was not greatly affected by increased throughput. This indicates that the magnetic field on the roll was sufficient to attract the iron bearing minerals. For this material the aluminum concentration was only slightly affected.

Figure 9. Fe_2O_3 and Al_2O_3 concentration in the non-magnetic product at various throughput on the roll separator.

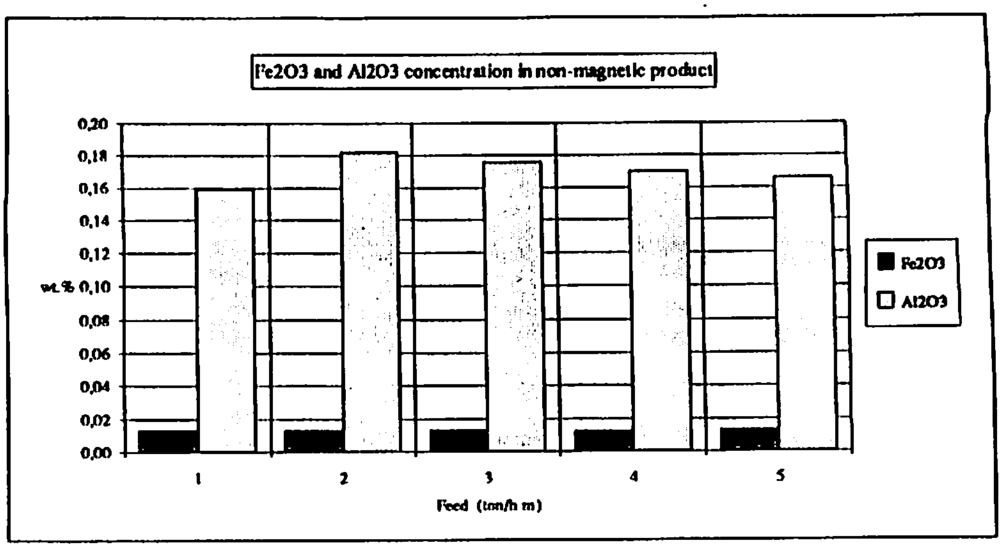


Figure 10. Concentration of heavy minerals in the non-magnetic product after separation.

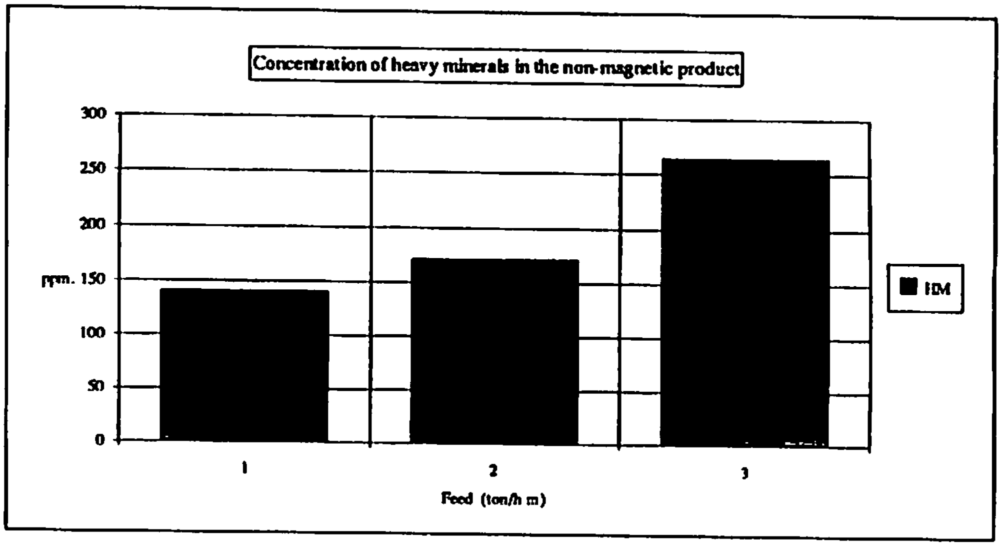


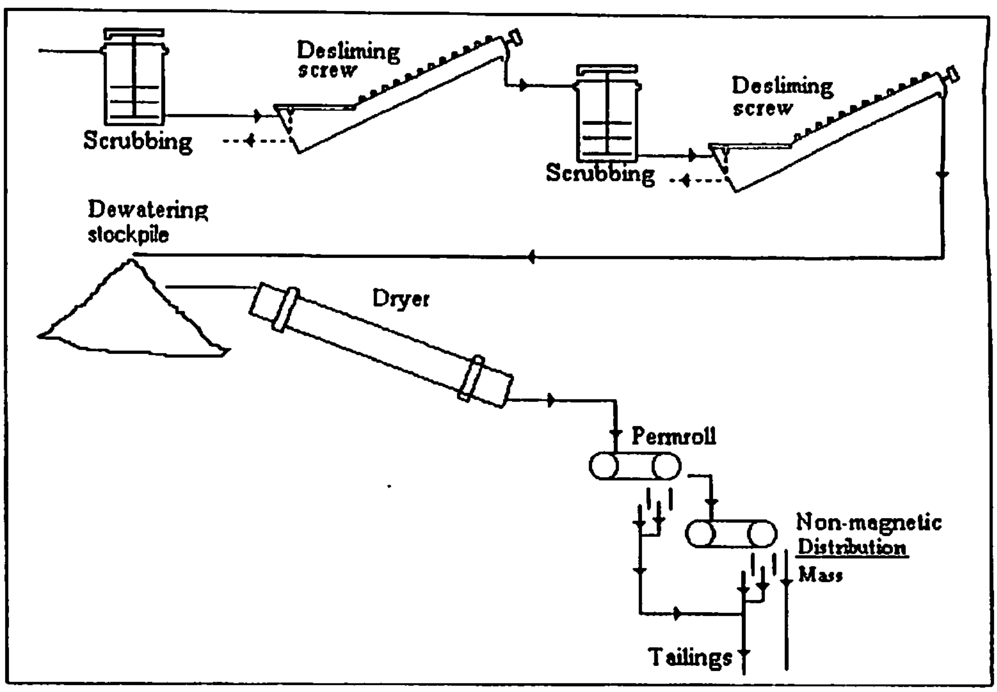
Figure 10. Concentration of heavy minerals in the non-magnetic product after separation.

The amount of heavy minerals in the product, however, increased with the feedrate (Figure 10). The petrographic study showed that the amount of refractory heavy minerals in the product and the amount of particles larger than 60 mesh was low (Appendix A). The composition of the heavy liquid sinks is mainly rutile, tourmaline and unidentified opaques.

Suggested Process Layout

A series of tests to simulate a scalable industrial process were carried out. The test series aimed at improving throughput and recovery of the non-magnetic product. The process flowsheet simulated is shown in Figure 11.

Figure 11. Suggested flowsheet for quartz sand beneficiation.



The suggested flowsheet includes a double stage scrubbing with intermediate desliming in screw-classifiers. The scrubbed and deslimed product is dewatered in cyclones and by natural draining in stock pile. The dewatered quartz sand is dried in a rotary kiln and after cooling fed to the double stage permanent magnet roll separators.

It is important to allow the material sufficient time to cool, since the magnetic field of the permanent magnets in the magnetic roll rapidly decreases with increasing temperature.

<u>Expected Process Results</u>

The process discussed above is expected to yield a marketable product even at 5 tons/h m feed, well within the specs for flat glass quoted by Peter Harben in "Glass raw-materials, Aspects of quality, quantity and prices." <u>Industrial Minerals</u> July 1991 (Appendix B). the iron and aluminum contamination of the product are predicted to be 0.013% Fe_2O_3 and 0.166% Al_2O_3 (Appendix A). The amount of heavy minerals in the test was 425 ppm, 10 ppm +6- mesh. Determination of refractory heavy minerals yielded a total of 38 ppm and 0 ppm +60 mesh.

Heavy minerals were identified as:

Kyanite	3%
Sillinamite	1.5%
Zircon	4.5%
Rutile	21%
Opagues	54%
Tourmaline	10.5%
Other	5.5% (Mainly Quartz; 1.5% Staurolite; and unidentified)

FEASIBILITY

A rough estimate of investment costs and maintenance for a 50 ton/h (metric) are outlined below.

Investments

At a through-put of 50 ton/h the magnetic circuit needs 10 double pass separators with feeders. At present, the double pass separators cost $45.00 each (June 93, Eriez Magnetics). The total process also needs scrubbers, screw classifiers, rotary kiln and conveyer belts.

Operation

The easy to run and simple design of the roll separators allows the entire magnetic circuit to be run by only one person.

Maintenance

The main cost of maintenance is the cost of exchanging belts on the magnetic rolls. It is estimated that the belts need to be replaced every 3-4 months. The eight belt replacements/year on a double pass unit at present cost $230 a piece.

Table 4. Summary of Costs for Running the Magnetic Separator Circuit

	Investment	Maintenance
Separators 10 double pass	450,000	
Replacement belts 80/year		18,400

RECOMMENDATIONS

We recommend that further tests be done at a larger scale to optimize throughput and recovery, in order to reduce the cost per ton of produced concentrate.

REFERENCES

Harben, Peter
Glass raw-materials
Aspects of quality, quantity and prices
Industrial Minerals
July 1991

Industrial Minerals and Rocks
5th Edition
Stanley J. Lefond, Editor
American Institute of Mining, Metallurgical
and Petroleum Engineers, Inc. 1983
ISBN 0-89520-402-9

Svoboda, J.
Magnetic Methods for the Treatment of Minerals
Elsevier, 1987
ISNA 0-444-42811-9

APPENDIX A

APPENDIX A

Physical and chemical analysis of quartz product

Screen Analysis

U.S. Size

Fraction	wt %	Cum. wt %
+30	0.07	100.00
-30 + 40	0.61	99.93
-40 + 50	20.41	99.32
-50 + 70	51.54	78.91
-70 + 100	21.83	27.37
-100 + 140	4.91	5.54
-140	0.63	0.63

Chemical Analysis

Through put: ton / h m*	1	2	3	4	5
Al_2O_3	0,159	0,182	0,238	0,170	0,166
K_2O	0,004	0,009	0,018		
Na_2O	0,002	0,002	0,003		
Fe_2O_3	0,013	0,013	0,014	0,011	0,013
TiO_2	<0,011	0,012	0,016		
LOI	0,075	0,070	0,070		

* ton / h m = metric ton per hour and meter roll length

Heavy Mineral Determination

Through put (metric ton / h m)	1	2	3	4	5
ppm. H.M.*	141	171	264	274	425
ppm. H.M. + 60 mesh	2	3	101	10	10
ppm. R.H.M.**	35	55	95	55	38
ppm. R.H.M. + 60 mesh	0	0	16	0	0

* Part per million heavy minerals

**Part per million refractory heavy minerals

(Determined by petrographic grain count)

APPENDIX B

APPENDIX B EXCERPTS FROM

"GLASS RAW-MATERIALS , ASPECTS OF QUALITY, QUANTITY AND PRICES"
BY
PETER HARBEN, INDUSTRIAL MINERALS, JULY 1991

QUALITY CONSIDERATIONS

Silica sand

Silica sand dominates the raw material feed in all the main types of glass in terms of feed volume. Excluding recycled glass, silica sand consumption runs at around 60% of the volume of flat and container glass produced and can therefor be used as a measure of the glass industry activity. In addition, being such a plentiful and cheap commodity, the silica sand is generally produced, sold and consumed within a very limited geographical area. Glass manufacturers have learned to live with regional differences in quality and price (tables 5 and 6). Consequently silica sand constitutes a regional market.

Within these regional variations, certain minimum standards for glass-grade silica have been established by the consumers. Silica sand used in flat glass requires a high SiO_2 content (a minimum of 99.7-99.8%), mainly because this leaves little room for deleterious materials that colour or weaken the glass. In most cases, however, the actual levels of individual constituents are less important than their variability. The statistical factor "range" is used to define the maximum acceptance variance for a given constituent, that is the difference between the highest and lowest recorded analytical values. The consistency in both the chemistry and the particle size distribution is critical since changes in the chemistry of a single ingredient alters the chemistry of the batch and necessitates reformation. Oversize particles may remain unmelted and create stones and points of weakness in the final glass product. Table 5 summarises some of the control limits and acceptable variances for silica sand as issued by one flat glass producer.

In addition, there is also a limit on the total refractory mineral content of the sand. These are normally chromite and other spinells, corundum, andalusite, kyanite, sillimanite, and zircon. The limit set in this case is 0.200 g cumulative retained on US standard 70 mesh. Similarly, in order to eliminate the possibility of contamination by particles of aluminium, copper, brass, bronze, Monel and stainless steel, the use of products such as copper blasting components, aluminium foil or wire bronze or stainless steel pumps, bronze bracing rods, and stainless steel welding rods in the process system is prohibited. There is also concern over refractory spills if refractory linings are used in the processing of the sand. In terms of sizing, flat glass producers prefer that the bulk of the sand be sized between 40 and 140 mesh, and all must be finer than 16 mesh.

Specifications for silica sand used in container glass are less stringent in absolute value terms, although there is the same need for consistency as described above. The maximum level of alumina and alkali content may be negotiable, but the variation limit is not. Table 6 gives a typical specification for sand used in the manufacture of flint and coloured glass containers. Once again, refractory minerals such as chrome, corundum, zircon, nepheline, etc. must be sufficiently fine to avoid visible stones in the final product.

Chemical	Flat glass Critical limits	Container glass Critical limits
SiO_2	99.5% min.	99.5% min.
Fe_2O_3	0.04% max.	0.03% max.
Al_2O_3	0.30% max.	within $\pm$0.01 %
CaO-MgO		within $\pm$0.1 %
TiO_2	0.1% max.	0.03% max.
ZrO_2		0.01% max.
Na_2O-K_2O		within $\pm$0.1 %
Cr_2O_3	2ppm max.	0.001% max.
Co_3O_4	2ppm max.	
MnO_2	2ppm max.	

Table 5a. Specifications for silica sand used in flat glass

Physical	US Standard Cum.	retained
16 mesh	none	none
20 mesh	0.01% max.	none
30 mesh		4% max.
40 mesh	0.10% max.	25% max.
140 mesh	92.0% min.	5% max.
200 mesh	99.5% min.	

Table 5b. Specifications for silica sand used in flat glass

	Dividing Creek NJ	Wedron IL	Mill Creek OK	Byron CA	Lane Mtn. WA
SiO_2	99.66	99.88	99.75	92.76	99.6
Fe_2O_3	0.025	0.011	0.020	0.127	0.039
Al_2O_3	0.143	0.050	0.100	3.779	0.26

Table 6. Typical specifications of some US silica sands.