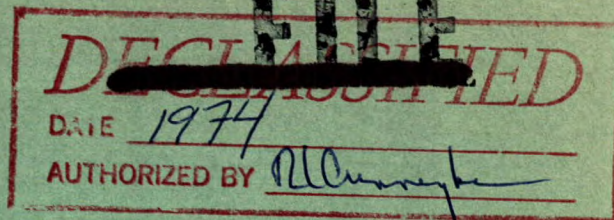


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DEPARTMENT OF MINES AND TECHNICAL SURVEYS

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MINES BRANCH INVESTIGATION REPORT IR 66-38

**BENEFICIATION OF ATHABASCA TAR  
SAND TAILINGS  
(PROJECT MP-IM-6502)**

by

**F.H. HARTMAN**

**MINERAL PROCESSING DIVISION**

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BENEFICIATION OF ATHABASCA TAR SAND TAILINGS  
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SUMMARY OF RESULTS

An attempt was made to produce glass grade sand from tar sand tailings, at the request of Cities Service Athabasca, Inc., whose operations were later assumed by Syncrude Canada Ltd.

Agitation and tabling gave a product analysing 0.08%  $\text{Fe}_2\text{O}_3$ . Magnetic separation and screening of the table product produced a -65 +100 mesh fraction analysing 0.05%  $\text{Fe}_2\text{O}_3$ .

Specialized magnetic, attrition and gravity separation techniques failed to give a sand product analysing less than 0.05%  $\text{Fe}_2\text{O}_3$ . Ultrasonic cleaning lowered the iron content to 0.04%  $\text{Fe}_2\text{O}_3$ .

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## INTRODUCTION

In the fall of 1964, Cities Service Athabasca, Inc., Edmonton, Alberta, approached the Mines Branch with the request that a sample of tar sand tailings be separated into closely sized fractions by gravity separation and/or screening. It was hoped that one or more of these fractions, either "as is" or with further treatment, would produce glass grade sand.

Initially two 50 lb samples were received. A preliminary investigation by the Non-metallic Minerals Section, including attrition, scrubbing, screening, magnetic and electrostatic separation, indicated that the -35 +100 mesh fraction offered the best prospects for beneficiation. Most of the remaining bitumen reported with the +35 mesh. On this basis a 1000 lb sample was obtained for further study. Work on this sample is indicated herein.

During the course of the investigation the operations of Cities Service Athabasca, Inc., were assumed by Syncrude Canada Ltd.

## DESCRIPTION OF SAMPLE

The 1000 lb sample of damp, unwashed tailings was received on March 24, 1965 in three drums.

The sample contained a considerable amount of bitumen, much of it present as blobs or droplets, up to 1/2 in. in diameter. These were viscous enough to allow removal by careful screening. Clay, mica and carbonaceous materials were combined with the sand.

Each drum was sampled and the combined products dried. Screen analyses were run on the material as received, and with the plus 35 mesh (tar fraction) removed. (See Table 1).

TABLE 1

Screen Analysis: Head Sample

Fraction (mesh)	As received	+ 35 mesh removed		
	Wt %	Wt %	Total Fe as Fe <sub>2</sub> O <sub>3</sub>	
			%	Dist %
+ 35	10.4	-	-	-
-35 + 48	1.7	1.9	0.75	5.2
-48 + 65	9.5	10.5	0.28	10.6
-65 + 100	36.1	40.3	0.20	28.9
-100 + 150	30.6	34.1	0.20	23.0
-150 + 200	5.7	6.4	0.32	7.4
-200 + 325	3.3	3.7	0.61	8.1
-325	2.7	3.1	1.51	16.8
Total	100.0	100.0	0.28	100.0

ANALYSIS

The most common undesirable contaminants in high grade glass sand are iron, titanium, zircon and mica.

Total iron (Fe) determinations were used to follow the degree of beneficiation. L. O. I. analysis partly indicated the bitumen content. SiO<sub>2</sub> content was checked.

A semi-quantitative spectrographic analysis was run on one of the better grade products by the Mineral Sciences Division.

Identification of constituents in certain samples was determined by X-ray diffraction in the mineralogical laboratory.

No complete analysis was made of the head sample. This is a long and difficult procedure and would provide little, if any, new information. However, analyses of similar material are available (1), e. g.

Composition of Extracted Abasand Sand (2) (Weight %)

SiO <sub>2</sub>	-	98.4
Al <sub>2</sub> O <sub>3</sub>	-	0.8
Fe <sub>2</sub> O <sub>3</sub>	-	0.1
CaO	-	0.2
MgO	-	0.2
TiO <sub>2</sub>	-	0.1
ZrO <sub>2</sub>	-	trace

Emission Spectra of Sand (Elements - Wt % of Sand) (3)

Si - 50.0  
Mn - 0.005  
Mg - 0.006  
Fe - 0.07  
Al - 1.5  
Ca - 0.015  
Ti - 0.05  
Cu - 0.0025

TEST WORK

The tests are divided into (A) conventional treatment, and (B) specialized treatment. The first covers practical means of upgrading the sand. The second is an attempt to reduce the iron present to its lowest level by mechanical methods.

A. Conventional Treatment

1. Tabling

A number of tabling tests were run on the material as received. It was necessary to use a conditioner or agitator ahead of the table in order to break up the larger particles of bitumen.

Table 2 gives the results of one such test, using a Holman Table. There was a small loss of slimes which is not taken into account.

TABLE 2

Tabling Test 3

Fraction	Wt %	Total Fe as Fe <sub>2</sub> O <sub>3</sub> %
Cut 1	58.6	0.08
Cut 2	15.3	0.20
Cut 3	14.2	0.32
Cut 4	7.3	n. d.
Cut 5	4.6	n. d.
Total	100.0	--

## 2. Magnetic Separation

The effect of this type of separation was checked, using the Jones Wet Magnetic Separator equipped with salient pole plates, and wash water with a head of 3 ft. The material was passed once through the separator set at 25 amps.

Table 3 shows the results of passing material from Cut 1, Tabling Test 3 (Table 2) through the Jones Separator.

Table 4 gives the products obtained when the non-magnetic fraction from the Jones Separation Test 4 (Table 3) is screened.

TABLE 3

### Magnetic Separation

Jones Test	Fraction	Weight %		Analysis			
		Sample	Total	Total Fe as Fe <sub>2</sub> O <sub>3</sub>		SiO <sub>2</sub>	L. O. I.
				%	Dist		
4	Mags	1.3	0.7	1.29	19.6	98.59	0.41
	Non Mags	98.7	57.9	0.07	80.4		
	Total	100.0	58.6	0.08(6)	100.0	-	-

TABLE 4

### Screen Analysis of Non-Magnetic Fraction

Fraction	Weight %		Analysis	
	Sample	Total	Total Fe As Fe <sub>2</sub> O <sub>3</sub>	
			%	Dist
+48 m	1.0	0.6	0.38	5.7
-48+65 m	4.9	2.9	0.06	4.3
-65+100m	42.9	24.8	0.05	31.6
-100+150m	44.2	25.5	0.07	46.2
-150+200m	6.0	3.5	0.10	8.9
-200 m	1.0	0.6	0.22	3.3
Total	100.0	57.9	0.07	100.0

Table 5 gives the results of a test where the material as received was scrubbed, screened into fractions and the tar floated from these with pine oil and discarded; each fraction, except +48 mesh, was then magnetically separated in the Jones Wet Magnetic Separator.

TABLE 5

Magnetic Separation - Screened Fractions

Screen Size	Jones Test 3	Weight %		Total Fe as $\text{Fe}_2\text{O}_3$	
		Fraction	Feed	%	Dist. %
+48 mesh		100.0	4.1	1.75	20.7
-48+65 mesh	Mags	1.4	-	3.86	2.6
	Non mags	98.6	-	0.08	3.8
	Total	100.0	17.1	0.13	6.4
-65+100 mesh	Mags	1.0	-	1.56	2.0
	Non mags	99.0	-	0.06	7.6
	Total	100.0	41.7	0.08	9.6
-100+150 mesh	Mags	1.4	-	2.38	2.1
	Non mags	98.6	-	0.08	4.9
	Total	100.0	22.1	0.11	7.0
-150 mesh		100.0	15.0	1.31	56.3
	Total	-	100.0	0.35	100.0

3. Flotation

A series of tests was run using (1) the material as received with the plus 10 mesh removed, and (2) the non magnetic fraction from a Jones separation. The results were disappointing. Floating most of the sand, or only a small amount, failed to give a low iron product.

B. Specialized Treatment

1. Magnetic Separation

The minus 65, plus 100 mesh non magnetic fraction from Jones Test 3 (Table 5) was run through the Jones Separator again. However; in this case, the wash water was not used and a middlings product collected. In the previous magnetic work described, the middlings had been combined with the non-magnetic portion. Results are given in Table 6.

TABLE 6

Magnetic Separation: -65+100 mesh

Jones Test	Fraction	Weight %	Total Fe as Fe O		L. O. I.	
			%	Dist. %	%	Dist. %
7	Mags	2.3	0.23	8.0	0.98	35.4
	Midds	27.4	0.07	28.8	0.46	19.7
	Non mags	70.3	0.06	63.2	0.41	44.9
	Total	100.0	0.06(7)	100.0	0.64	100.0

The non-magnetics from Jones Test 7 (Table 6) were again run through the Jones Separator, with the wash water off, and using high intensity plates. The latter cuts down the capacity of the equipment but gives a stronger magnetic field. Results are shown in Table 7.

TABLE 7

Magnetic Separation: -65+100 mesh

Jones Test	Fraction	Weight %	Total Fe as Fe <sub>2</sub> O <sub>3</sub>		L. O. I.	
			%	Dist. %	%	Dist. %
8	Mags	21.6	0.20	51.7	0.86	32.7
	Midds	17.6	0.06	12.6	0.55	17.1
	Non mags	60.8	0.05	35.7	0.47	50.2
	Total	100.0	0.08	100.0	0.57	100.0



## 2. Superpanner Separation

The non-magnetic from Jones Test 8 (Table 7) are separated with a Superpanner into four parts. Results are given in Table 8.

TABLE 8

Superpanner Separation: -65+100 mesh

Fraction	Weight %	Total Fe as $\text{Fe}_2\text{O}_3$		L. O. I.	
		%	Dist. %	%	Dist. %
Cut 1	44.5	0.05	42.3	0.41	43.0
2	42.6	0.05	40.5	0.41	41.4
3	9.0	0.07	12.0	0.51	10.9
4	3.9	0.07	5.2	0.51	4.7
Total	100.0	0.05	100.0	0.42	100.0

## 3. Attrition Scrubbing

A sample of the -65+100 mesh non-magnetic fraction from Jones Test 4 (Table 4) was violently scrubbed with water in a Waring Blender run (1) 2 min at low speed and (2) 1 min at high speed. The products were then screened on 100 mesh. Results are shown in Table 9.

TABLE 9

Waring Blender (Attrition Scrubbing): -65+100 mesh

Fraction	Weight %	Total Fe as $\text{Fe}_2\text{O}_3$		L. O. I.	
		%	Dist. %	%	Dist. %
Low Speed +100	81.5	0.05	65.0	0.34	72.3
Low Speed -100	18.5	0.12	35.0	0.58	27.7
Total	100.0	0.06	100.0	0.38	100.0
High Speed +100	78.5	0.05	58.5	0.32	69.2
High Speed -100	21.5	0.13	41.5	0.52	30.8
Total	100.0	0.06 <sup>(7)</sup>	100.0	0.36	100.0

#### 4. Ultrasonic Cleaning

Some of the dried sand, as received but with the +10 mesh bitumen fraction removed, was suspended in a pail in a 2000 w 20 kc. ultrasonic bath for a number of hours. An oily scum came to the surface, and carbon and mica particles floated. This scum broke down and dispersed through the liquid. The water dispersion was decanted and replaced with fresh water 4 to 5 times.

The cleaned product from the above treatment was screened. The -65+100 mesh fraction was placed in a beaker and suspended in the bath. After 6 1/2 hrs cleaning, the material was screened to remove the fines and the coarse material returned to the bath for another 2 hrs. Table 10 gives the analysis of the products. No weight determinations are shown. This is not significant since the object of the work was only to determine how low the iron content could be reduced mechanically.

TABLE 10

##### Ultrasonic Cleaning: Screened Fractions

Ultrasonic Test	Fraction	Total Fe as $\text{Fe}_2\text{O}_3$ %	L. O I %
2	-65+100m		
	Cut 1 - 100m	0.16	0.37
	Cut 2 - 100m	0.12	0.28
	+ 100 m	0.04	0.13

## REMARKS

The first prerequisite of a glass grade sand is purity. In as far as possible the sand should be free from iron and other elements that would introduce an undesirable colour.

Specifications for glass sand are written with reference to the glass to be produced. To facilitate melting it is desirable that the sand contains no grains that will not pass a 20-mesh screen. To prevent dusting none should be finer than 100-mesh. The permissible iron content is lowest for optical glass, where it should not exceed 0.015%  $\text{Fe}_2\text{O}_3$ . For fine tableware, good colour cannot be maintained with  $\text{Fe}_2\text{O}_3$  over 0.04% and lower contents are demanded. As the need for crystal quality diminishes, as in bottles, plate glass, window glass, and finally in amber and green bottles and coloured ware, successively larger amounts of iron are allowed.

Mica, garnet and zircon cause stones, seeds, cords and other defects in glass.

No attempt was made to obtain maximum recovery in any of the tabling tests. The objective was to see whether any glass grade specification material could be produced by conventional commercial means.

Tabling alone eliminated most of the mica, clay and other light constituents. A large amount of the "balled" bitumen was also discarded in the tails. However, it was necessary to break up the large agglomerates of bitumen by conditioning or agitation before feeding them onto the table.

The iron can be reduced to 0.08%  $\text{Fe}_2\text{O}_3$  by one pass over a table (Table 2). However, this iron content is high for a glass sand.

Strong magnetic separation will reduce the iron content to 0.07%  $\text{Fe}_2\text{O}_3$  (Table 3). Screening the product (Table 4) will give a -48+65 mesh fraction with 0.06%  $\text{Fe}_2\text{O}_3$  and a -65+100 mesh fraction analysing 0.05%  $\text{Fe}_2\text{O}_3$ .

Spectrographic analysis\* of the non-magnetic fraction from Jones Test 4, (Table 3) gave the following analysis.

Si	-	P. C.
Al	-	0.13
Mn	-	0.003
Mg	-	0.01
Fe	-	0.04
V	-	0.0004
Ca	-	0.03
Na	-	0.33
Ti	-	0.037

A mineralogical study\*\* of the same material showed that separation in heavy liquid was difficult. Only a small amount of sink was recovered. The float product appeared to be pure quartz. Sink products consisted of mineral assemblages of rutile, pyrite, small amounts of zircon and possibly anatase and garnet.

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\* Mineral Science Division Report No. S. L-65-172

\* Ore Mineralogy Section Report No. MP-IM-6502

Table 5 corroborates that the two fractions most likely to produce a glass sand are the -48 + 65 and the -65 + 100 mesh. Flotation to remove most of the bitumen, screening and magnetic separation did not give as low iron products as tabling and magnetic treatment.

Specialized treatment of the sand emphasized the fact that it is unlikely that gravity and/or magnetic separations can reduce the  $\text{Fe}_2\text{O}_3$  content much lower than that already obtained. In Table 7, where a very strong magnetic field discarded a good deal of material to magnetics and middling products, the iron analysed 0.05%  $\text{Fe}_2\text{O}_3$ . With the Superpanner (Table 8), an extremely fine type of gravity separating device, the lowest iron obtained was 0.05%  $\text{Fe}_2\text{O}_3$ .

Attrition scrubbing (Table 9) showed that a high iron surface coating could be removed. Even with this treatment the iron was 0.05%  $\text{Fe}_2\text{O}_3$ .

Ultrasonic cleaning (Table 10) of the -65 + 100 mesh fraction reduced the iron to 0.04%  $\text{Fe}_2\text{O}_3$ . This type of treatment, under the influence of ultrasonic vibrations, frees the films of the surface mineral formations, removes discrete mineral inclusions and other impurities not only from the surfaces but from microcracks as well. It represents close to the ultimate type of mechanical cleaning presently available.

The problem is therefore one of the removing the gobs of bituminous material and sizing the sand by screening or tabling. The sized fractions can then be upgraded by magnetic separation. Violent agitation or attrition scrubbing should further remove some of the residual high iron coatings on the particles.

## CONCLUSIONS

1. Tar sand tailings with agitation and tabling will give a sand product analysing 0.08%  $\text{Fe}_2\text{O}_3$ .
2. This product when passed through the Jones Wet Magnetic Separator will give a sand analysing 0.07%  $\text{Fe}_2\text{O}_3$ .
3. The screened fractions of the Jones product will give a -65 + 100 mesh portion analysing 0.05%  $\text{Fe}_2\text{O}_3$  and a small -48 + 65 mesh portion analysing 0.06%  $\text{Fe}_2\text{O}_3$ .
4. Tar sand tailings, scrubbed, tar removed by flotation, screened and passed through the Jones Wet Magnetic Separator will give a -65 + 100 mesh fraction analysing 0.06%  $\text{Fe}_2\text{O}_3$ .
5. Flotation does not look promising as a means of beneficiating tar sand tailings to produce a low-iron sand product.
6. Specialized magnetic, attrition, and gravity separation techniques failed to give a sand product analysing less than 0.05%  $\text{Fe}_2\text{O}_3$ .
7. Ultrasonic cleaning lowered the iron content to 0.04%  $\text{Fe}_2\text{O}_3$ .



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