

TR17-184-194

R.638. Examination and concentration tests of tin ore from the St Dizier mine.

Four samples from the St Dizier mine were submitted by Mr P. Verbaan on behalf of Minops Pty Ltd for examination and metallurgical testing. The samples could be roughly divided into three types, massive ore, partially weathered or oxidised material, and one bag of fines. The massive ore was extremely hard and fine-grained. Much magnetite was present with pyrite and some pyrrhotite was observed. Some relatively coarse (pinhead size) cassiterite was noted.

Analyses of the samples included Davis tube tests to determine the amounts of magnetite present, the results of which are given below.

Assays	Sample number				
	714648	713891	713892	720104	720105
	%	%	%	%	%
Sn	1.24	0.60	0.42	1.04	1.32
T.Fe	35.5		41.0		
S.Fe	32.7		33.8		
Insoluble	27.8				
S	6.6		9.6	0.40	0.99
Zn	Trace		<0.1		
Pb	Nil		<0.1		
WO <sub>3</sub>	Nil				
Cu	0.08		0.10	0.06	0.02
As	0.1				
Bi	0.08		<0.1	0.03	0.03
Magnetite	45.8		39.5	44.5	59.5

Note: Insoluble = Insoluble in HCl

Magnetite = Davis tube magnetics after grinding to about 80% -50 µm.

#### SAMPLE DESCRIPTIONS

**Sample 714648.** Chip sample from outcrop containing some weathered material but consisting in the main of massive lump ore. The ore dressing work was confined to this sample.

**Samples 713891 and 713892.** Fine and lump material which was extensively weathered, blasted from surface. Due to this and the low tin content, work was restricted to analyses only, the samples being considered not representative of the ore body and therefore unsuitable for metallurgical testing.

**Samples 720104 and 720105.** Samples from central and eastern parts of ore body respectively, were mostly massive lump ore, but still contained some weathered material. Work on these samples consisted of the assays already shown and determination of the cassiterite grain size.

A significant feature of the analyses is the wide variation in sulphur content, ranging from 0.4-9.6% in the various samples.

#### PRELIMINARY TESTS

##### Quantitative assessment of magnetite content

Davis tube tests were performed on each sample and the results of these are shown in the analyses of the samples.

The Davis tube magnetics from Sample 714648 were assayed with the following result (N1).

Fe	61.4%	Ti	0.03%
S	3.6%	Ni	Nil
Sn	0.27%		

**Cassiterite grain size determinations (N2, N2A, N2B)**

The samples for each test were stage roll crushed to pass a 710 µm screen. The samples tested were 714648, 720104, 720105. The test numbers were N2, N2A and N2B respectively. The grain size determination of each sample is given below.

SnO <sub>2</sub> Grain size µm	Sn distribution					
	714648 - N2		720104 - N2A		720105 - N2B	
	%	% Cum.	%	% Cum.	%	% Cum.
-710+300	7.0	7.0	6.1	6.1	14.0	14.0
+150	13.2	20.2	15.3	21.4	16.4	30.4
+ 75	17.6	37.8	17.7	39.1	15.6	46.0
+ 38	14.7	52.5	10.4	49.5	17.5	63.5
+ 28	11.2	63.7	8.3	57.8	11.5	75.0
+ 20	9.4	73.1	10.1	67.8	8.1	83.1
+ 13	8.4	81.5	7.4	75.2	6.5	89.6
+ 10	13.0	94.5	15.1	90.3	7.0	96.6
- 10	5.5	100.0	9.7	100.0	3.4	100.0

**Magnetic separation of sized fractions (N3)**

A sample of -710 µm roll crushed ore was sized by screening and the individual fractions subjected to wet magnetic separation using a hand magnet with several stages of cleaning in each case.

The objective of this test was to obtain some idea of the release size of cassiterite from magnetite and hence choose a suitable mesh of grind material for subsequent larger scale tests. The results of this test are given below.

Fraction µm	% Weight Overall	Individual Fractions							
		M/A		N					
		% Assays Sn	% Assays Fe	% Distribution Sn	% Distribution Fe	% Assays Sn	% Assays Fe		
-710+355	37.3	1.17	37.9	72.1	94.9	2.08	9.2	27.9	5.1
+250	17.1	0.99	41.0	60.0	94.3	2.35	8.8	40.0	5.7
+150	12.9	0.82	46.1	44.1	91.7	2.27	9.1	55.9	8.3
+106	6.9	0.72	49.6	33.3	89.9	2.31	9.3	66.7	10.1
+ 75	6.0	0.62	49.4	29.7	89.7	2.31	8.9	70.3	10.3
- 75	19.8	0.58	52.0	18.9	79.3	1.74	7.8	81.1	20.7
Head	100.0								

**Flotation of sulphides and magnetic separation of tailings (N5)**

A sample of -710 µm roll crushed ore was stage ball mill ground to pass a 150 µm screen (100# BSS) and subjected to rougher and cleaner flotation. The flotation tailings were magnetically separated (wet) using a hand magnet with five stages of cleaning to keep mechanical entrainment to a minimum.

The objectives of this test were:

- (1) to investigate the response of total ore to sulphide rejection by flotation at a reasonable mesh of grind,
- (2) to ascertain the probable tin loss in magnetic separation for removal of magnetite from the flotation tailings.

The results of this test are given below.

Product	% Wt	% Assays			% Distribution		
		Sn	S	Fe	Sn	S	Fe
F2C	20.0	0.12	19.4	21.4	2.0	61.1	11.0
F2T M/A	3.5	1.30	6.2	47.5	3.7	3.5	4.3
F2T N	8.8	1.50	4.8	14.1	10.9	6.7	3.2
F1C	32.3	0.63	13.4	22.2	16.6	71.3	18.5
F1T M/A	49.8	1.03	2.4	56.8	42.2	19.0	72.9
F1T N	17.9	2.80	3.4	18.5	41.2	9.7	8.6
Head	100.0	1.22	6.3	38.8	100.0	100.0	100.0

The conditions used in this test are as follows:

Rougher Flotation		
Reagent	Usage: kg/t	Conditioning time (min)
Sodium sulphide	0.2	2
Sulphuric acid	to pH 5	
Sodium ethyl xanthate	0.9	3
Potassium amyl xanthate	0.9	
Cresylic acid	4 drops	

Flotation time 10 minutes

Cleaner Flotation		
Reagent	Usage: kg/t	Conditioning time (min)
Calgon	0.5	2
Cresylic acid	2 drops	

Flotation time 10 minutes

#### SUMMARY OF PRELIMINARY TESTING RESULTS

- (1) The Davis tube tests show high magnetite contents in all the samples and magnetic separation will obviously be a major step in any treatment plan.
- (2) The wide variation in sulphide content could have a bearing on the sequence of ore dressing operations required.
- (3) The cassiterite grain size determinations show a fairly extended size range, with some 30% of the cassiterite below 20  $\mu$ m in size in two of the samples (714648 and 720104) tested.

Tin in size ranges below 20  $\mu$ m is not recoverable to any extent by gravity concentration methods. Allowing for some depreciation in grain size during processing, tin recoveries in excess of 60% overall are unlikely on these two types of ore.

The cassiterite in the third sample examined (720105) is considerably coarser, only 17% of the total tin being below 20  $\mu$ m. A somewhat higher

recovery could be expected on this type of ore.

(4) The results of Test N3 show the progressive increase in release of cassiterite and sulphide iron from magnetite, with decreasing size of separation.

It is apparent that grinding to  $-75 \mu\text{m}$  (200#) is necessary to achieve anything approaching total release of cassiterite and sulphides from the magnetite. However, a substantial release of the cassiterite was obtained at coarser sizes, 40% at  $250 \mu\text{m}$ , and 55.9% at  $150 \mu\text{m}$ , being recovered in the non-magnetic product.

(5) Test N5 shows an unsatisfactory sulphide elimination of 61.1% by cleaner flotation of ore ground to  $-150 \mu\text{m}$ , although the tin loss of 2% in the cleaner flotation concentrate (F2C) is remarkably low.

A more meaningful assessment can be obtained by considering the composite rougher flotation concentrate (F1C). In this product 16.6% of the total tin was lost but only 71.3% of the total sulphur was eliminated.

Magnetic separation of the flotation tailings, resulted in extremely high tin losses in the magnetic products.

Interpretation of the test results is difficult, because the presence of certain oxidised sulphides, which are difficult to float, probably influencing flotation efficiency. However, with the supporting evidence from Tests N2 and N3, it is fairly clear that the mesh of grind is the main contributing factor in the lack of selectivity in both the flotation and magnetic separation stages of this test.

#### CONCENTRATION TESTS

On the basis of the information gained from the preliminary tests, the following conclusions, relative to the planning of larger scale concentration tests, were formed.

- (1) The initial separation should be the removal of magnetite which constitutes 40-60% by weight of the samples examined.
- (2) An initial grind to  $-150 \mu\text{m}$  would effect the release of substantial amounts of cassiterite from magnetite.
- (3) Wet magnetic separation followed by grinding to  $-75 \mu\text{m}$  of the magnetics would result in near total release of cassiterite and sulphides from magnetite.
- (4) A further stage of magnetic separation of the  $-75 \mu\text{m}$  rougher magnetics would result in the production of a magnetite concentrate relatively low in tin and sulphur, and a non-magnetic product, free from magnetite, containing most of the tin and sulphur.
- (5) Two methods of tin concentration from the non-magnetic product could now be considered:
  - (a) Production of a sulphide-cassiterite concentrate followed by flotation of sulphides from the rougher concentrate.
  - (b) Flotation of sulphides and gravity concentration of the sulphide free flotation tailing.

The mineral associations in the non-magnetic product remain obscure, but the flotation Test N5 indicates that further grinding would be necessary to allow sulphide rejection by flotation without substantial loss of tin in the sulphide. This would further reduce the average cassiterite grain size

with consequent depreciation in recovery. The better method therefore appeared to be, to make an initial sulphide-cassiterite concentrate without further grinding with the emphasis on recovery rather than grade, followed by an attempt to upgrade the crude concentrate by flotation of sulphides and further grinding and gravity concentration if necessary.

Two tests N6 and N7, of 2 kg each, were carried out on the basis of the considerations outlined above.

#### TEST PROCEDURE

Minus one millimetre roll crushed ore was stage ball mill ground to the indicated sizes.

In Test N6 the initial magnetic separation was performed at -150  $\mu\text{m}$  (100#) with regrinding of rougher magnetics to -75  $\mu\text{m}$  (200#) and re-separation.

In both tests the non-magnetic fractions were combined and sized by hydrosizer to three spigot products and an overflow, which were separately tabled to give a rougher tin concentrate. In Test N7 the overflow was delimed before tabling. This slime product was not treated further.

The four table concentrates were combined for cleaner sulphide flotation, the tailing from which was magnetically separated to yield a final tin concentrate.

In Test N6, the rougher sulphides were ground to -75  $\mu\text{m}$  before cleaner flotation. The magnetics were subjected to cleaner sulphide flotation to produce a final magnetite concentrate.

In Test N7, sizing analyses were made of the non-magnetic products and combined spigot tailings to investigate the tin distribution in these products.

The sizing of the untreated slime was checked by cyclosizing to ensure that no recoverable tin had been lost in this product.

No attempt was made to establish optimum flotation conditions. Generally the reagent combination used in Tests N6 and N7 was similar to that reported for Test N5.

A flow sheet for Test N7 is given in Figure 47.

#### TEST RESULTS

The results of the tests carried out are given in Tables 1 to 5 on the following pages.

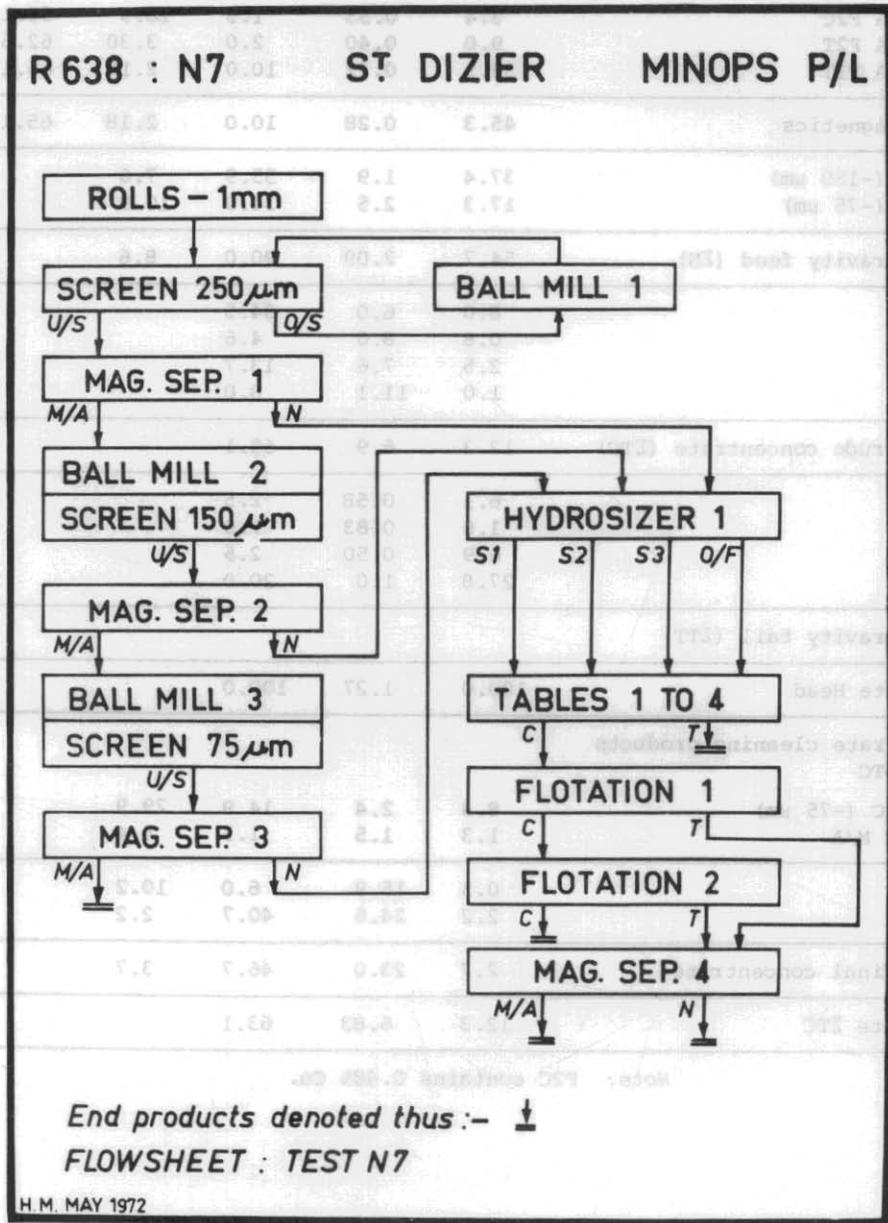


Figure 47.

Table 1. THE RESULTS OF TEST N6

Products	% Wt	% Sn	% Sn Distn	% S	% Fe
M/S2 M/A F2C	3.4	0.55	1.5	16.9	53.1
M/A F2T	9.0	0.40	2.0	3.30	62.6
M/A F1T	32.9	0.22	10.0	2.18	65.1
Total magnetics	45.3	0.28	10.0	2.18	65.1
M/S1 N (-150 μm)	37.4	1.9	55.9	7.6	
M/S2 N (-75 μm)	17.3	2.5	34.0	10.9	
Total gravity feed (ΣN)	54.7	2.09	90.0	8.6	
S1 TC	8.0	6.0	34.5		
S2 TC	0.8	8.0	4.6		
S3 TC	2.5	7.6	13.7		
O/F TC	1.0	11.1	8.0		
Total crude concentrate (ETC)	12.3	6.9	63.1		
S1 TT	6.1	0.58	2.5		
S2 TT	1.6	0.83	1.0		
S3 TT	6.9	0.50	2.5		
O/F TT	27.8	1.0	20.0		
Total gravity tail (ΣTT)					
Composite Head	100.0	1.27	100.0		
Concentrate cleaning products from ETC					
F2C (-75 μm)	8.3	2.4	14.9	29.9	
M/S3 FT M/A	1.3	1.5	1.5	4.4	
F2T N	0.5	15.9	6.0	10.2	
F1T N	2.2	24.6	40.7	2.2	
Total final concentrate	2.7	23.0	46.7	3.7	
Composite ETC	12.3	6.83	63.1		

Note: F2C contains 0.48% Cu.

Table 2. THE RESULTS OF TEST N7

Products	% Wt	% Sn	% Sn Distn	% S	% S
M/S3 M/A F2C	3.6	0.53	1.5	19.4	44.8
M/A F2T	1.8	0.60	0.8	11.0	53.8
M/A F1T	38.0	0.35	10.4	1.4	68.4
Total magnetics	43.4	0.38	12.7		
M/S1 N (-250 $\mu$ m)	45.6	1.97	69.9		
M/S2 N (-150 $\mu$ m)	7.0	1.97	10.8		
M/S3 N (-75 $\mu$ m)	4.0	2.12	6.0		
Total gravity feed ( $\Sigma$ N)	56.6	1.98	87.3		
S1 TC	6.9	7.3	37.6		
S2 TC	2.8	6.7	14.0		
S3 TC	1.5	7.2	8.1		
O/F TC	0.7	6.7	3.5		
Total crude concentrate ( $\Sigma$ TC)	11.9	7.1	63.2		
$\Sigma$ S TT	26.2	0.63	12.2		
O/F TT	10.0	0.77	5.8		
Slime (untreated)	8.5	0.96	6.1		
Total gravity tailing	44.7	0.72	24.1		
Composite Head	100.0	1.33	100.0		
Concentrate cleaning products from $\Sigma$ TC					
F2C	8.7	2.9	19.4	27.7	
M/S4 M/A	1.2	2.5	2.3	2.6	
M/S4 N	2.0	27.0	41.5	3.6	
Composite $\Sigma$ TC					

Note: F2C contains 0.34% Cu.

#### COMMENTS ON RESULTS OF TESTS N6 AND N7

The results from the two tests are practically duplicated down to the stage of production of the low grade rougher tin concentrate.

The Davis tube test, N1, indicates that the magnetite concentrates obtained are as good as can be expected with regard to tin and sulphur contents.

The coarser initial grind in Test N7 has probably occasioned a slightly higher loss of tin to the magnetics than the case in Test N6. However, it has helped to retain the tin in the gravity tailings in a coarser size range, with some probability of further recovery by retreatment of the spigot tailings. The spigot tailings from Test N7 show a tin distribution of 12.2% compared with 6% in Test N6. The sizing analysis of this product shows that 63.5% of the tin is present in size ranges coarser than 53  $\mu$ m and can reasonably be assumed to occur as composite grains. There is a possibility of recovering up to 50% of the tin in this product by regrinding, followed by appropriate sizing and gravity concentration.

Table 3. SIZING ANALYSES, TEST N7

Size fraction SnO <sub>2</sub> diameter µm	M/S1 N (-250 µm)				M/S2 N (-150 µm)				M/S3 (-75 µm)			
	% Wt	% Sn	% Sn	Distn	% Wt	% Sn	% Sn	Distn	% Wt	% Sn	% Sn	Distn
+150	20.3	2.17	22.4									
+100	13.7	2.37	16.5		11.9	1.87	11.3					
+75	13.0	2.27	15.0		14.4	1.92	14.0					
C/S1 +23	11.3	4.56	26.1		14.4	4.41	32.2		23.7	4.02	44.9	
C/S2 +18	6.3	1.82	5.8		7.5	1.82	13.9		11.8	1.82	20.3	
C/S3 +12	6.2	1.72	5.4		7.5			11.8				
C/S4 +8	5.7	1.57	4.5		7.5	1.52	8.7		10.5	1.77	13.2	
C/S5 +6	2.8	1.32	1.9		3.7			5.3				
O/F -6	20.7	(0.23)	2.4		33.1	(1.19)	19.9		36.9	(1.24)	21.6	
Head	100.0	1.97	100.0		100.0	1.97	100.0		100.0	2.12	100.0	

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Table 4. SIZING ANALYSIS OF THE COMBINED SPIGOT TAILINGS

Size fraction µm	% Wt	% Sn	% Sn Distn	% Sn cum. Distn
+210	7.0	0.91	9.7	9.7
+150	21.6	0.70	22.8	32.5
+100	18.5	0.50	14.1	46.6
+75	19.0	0.35	10.1	56.7
+53	12.8	0.35	6.8	63.5
-53	21.1	1.14	36.5	100.0
Head	100.0	0.66	100.0	

Table 5. SIZING ANALYSIS OF THE UNTREATED SLIME

Fraction	% Weight	Fraction	% Weight
C/S1	0.8	C/S4	7.2
C/S2	2.0	C/S5	4.2
C/S3	4.6	O/F	81.2
		Total	100.0

Note: The amount of recoverable tin in this material is negligible.

The high tin loss associated with sulphide flotation encountered in preliminary Test N5 also occurred in the concentrate upgrading stages of Tests N6 and N7. In Test N6, where the rougher sulphides were ground to -75 µm before cleaner flotation, the tin loss was considerably less, 14.9% compared with 19.4% in Test N7. The sulphides were checked for the presence of tin as stannite but only a trace was detected. Some concentration of copper has occurred in this product, the assays are shown in Tables 1 and 2.

The grades of tin concentrates, 23.0 and 27.0% are considered satisfactory at this stage, as no doubt, some siliceous material would enter the low grade sulphide-cassiterite concentrate both as free and composite grains.

Insufficient concentrate has been prepared at this stage to investigate further upgrading, and further tests will be required to show whether re-grinding, sizing and gravity concentration techniques would achieve this without further substantial losses of tin.

#### SUMMARY AND CONCLUSIONS

The test work completed thus far has shown the ore to be quite complex, with cassiterite, sulphides, magnetite and siliceous gangue intimately associated with one another.

The problem of magnetite removal without undue loss of tin can be overcome by progressive grinding and magnetic separation stages. The end products are a -75 µm magnetite concentrate (67-68% S.Fe), which may be saleable, and a relatively coarse (-250 µm) non-magnetic product containing some 90% tin and most of the sulphide minerals.

The most feasible approach to concentration of tin from the non-magnetics appears to be an initial gravity concentration of sized material to a low grade rougher sulphide-cassiterite concentrate.

The test work has established that recovery to this stage (low grade rougher concentrate) would be of the order of 65%. Regrinding and retreatment of middlings and coarse tailings would possibly elevate this recovery figure to 70%. Taking into account the naturally occurring grain size of the cassiterite, these figures are evidently near to the maximum obtainable by gravity concentration methods.

There are obviously some difficulties to be overcome in upgrading the crude concentrates to material which is saleable without considerable penalties due to low grade and impurities. Tin losses could be high in this area and the possibility of cassiterite flotation and/or chemical treatment should be considered.

At this stage of the investigation, with a recovery of 63% obtained in crude concentrate assaying about 7% tin and a possibility of some further recovery from middling and tailing retreatment, it seems reasonable to predict an overall recovery of some 50% in sale grade concentrates.

Further work on the project should consist of confirmation of the results already obtained and a study of the mineral associations in the non-magnetic material. This will give information needed for:

- (1) Investigation of recoveries obtainable by sulphide elimination by flotation ahead of sizing and gravity concentration.
- (2) Devising suitable methods of upgrading the crude concentrates with minimum further losses of tin.