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AUSTRALIAN MINERAL DEVELOPMENT LABORATORIES

REPORT AMDL-200

SOUTH AUSTRALIAN GOVERNMENT
DEPARTMENT OF MINES
PROJECT 1/1/47

MALCOLM CREEK IRON ORE
Beneficiation Tests

by
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Investigated by: Metallurgical Section
Officer in Charge: P.K. Hosking

Issued: July, 1962

L. Wallace Coffer. Director

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CONTENTS

1. INTRODUCTION

A 410 lb sample of iron ore, labelled Malcolm Creek, was received.

It was requested that the investigation should include crushing and sizing tests, Davis-tube tests, Humphreys-spiral tests and any other tests considered advisable.

2. SUMMARY

The sample of ore, consisting of hematite and quartz in the form of large lumps of agglomerated fines, readily disintegrated when lightly crushed.

Flotation tests gave the most satisfactory results. Concentrates containing 65.1 and 61.5 per cent Fe with recoveries of 94.3 and 97.2 per cent respectively were obtained. The reagent cost was less than 2 shillings per ton of ore.

Dry magnetic separation of minus 50-mesh ore, using an induced roll magnetic separator produced a concentrate assaying 62.0 per cent Fe with a recovery of 92.2 per cent. Analysis of this concentrate showed that it contained 0.81 per cent titanium dioxide.

Marketable grade concentrates (60 per cent Fe) were produced in Humphreys-spiral batch tests, but only 30 per cent recovery was obtained because grain-size of the minerals is too fine for effective spiral separation.

Sizing and washing tests gave unsatisfactory results.

Davis-tube tests showed that the ore contained less than 0.1 per cent magnetic iron.

It is recommended that further flotation tests should be conducted on a sample more representative of the orebody.

3. MATERIAL EXAMINED

Six bags labelled, "Malcolm Creek" were received. These samples were reported to be from the dump of the "New Pit" on MC. 3595. They were combined at the sponsor's request to produce a composite sample weighing 410 lb.

The ore consisted of large lumps of agglomerated fines, which readily disintegrated when lightly crushed.

The head sample assayed as follows:

Acid Soluble	Residual[1]	Magnetic[2]
Fe %	Fe %	Fe %
35.9	0.01	<0.1

$<$ Less than.

Results of a mineralogical examination on material lightly crushed to minus 10-mesh are given in Appendix A. Hematite and quartz are the two constituent minerals. Material in the range of minus 10 plus 36-mesh was substantially loose agglomerates which could be broken between the fingers.

A spectrographic analysis of the ore is given in Appendix B.

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1. Per cent Fe in residue from acid digestion.
2. As determined by the Davis-tube (see 5.1).

4. EQUIPMENT USED

(1) Jaw crusher: 8-in. x 5-in.
(2) Roll crusher: 9.5 in. dia. x 6 in. wide
(3) Gyratory screen: 3 ft diameter
(4) Davis-tube magnetic separator
(5) Humphreys-spiral 5-turn closed-circuit test unit
Pitch 13½ in. Model 24A
(6) Stearns laboratory disc, pick-up type, magnetic separator
(7) Carpco laboratory single induced roll magnetic separator
Model No. MA127
(8) Laboratory Fagergren flotation cell (500 g)
(9) BSS Laboratory screens.

5. EXPERIMENTAL PROCEDURE AND RESULTS

Davis-tube tests, heavy-liquid separations, Humphreys spiral tests, dry magnetic separation and flotation tests were conducted.

5.1 Davis-tube Tests

Two Davis-tube tests were made at different coil amperages. Test conditions are shown in Table 1.

TABLE 1: DAVIS TUBE TEST CONDITIONS

Conditions		Test 1.	Test 2.
Coil current:	Amp.	2.0	3.1
Water flowrate:	ml/min	900	900
Tube movement:	str/min	89	89
Tube slope:	degrees	45	45
Feed sizing:	mesh	-52	-52
Feed charge:	g	25	25

Results of the above tests showed that the ore contained less than 0.1 per cent magnetic iron.

5.2 Heavy-liquid Separations

The sizing-analysis of ore crushed to minus 10-mesh is shown in Table 2. Heavy-liquid separations at SG 2.85 were conducted on the sized fractions and results are given in Table 3.

TABLE 2: SIZING ANALYSIS OF MINUS 10-MESH ORE

Fraction Mesh	Weight %	Assay[1] Fe %	Distribution Fe %
- 10 + 18	10.0	28.3	7.7
- 18 + 36	19.9	27.4	14.8
- 36 + 72	23.9	23.5	15.3
- 72 + 100	7.1	30.5	5.9
- 100 + 200	6.6	45.9	8.3
- 200	32.5	54.2	48.0
Feed calc.	100.0	36.7	100.0
Feed assay	-	35.9	-

(1) All Fe assays quoted in this report are acid soluble Fe.

TABLE 3: HEAVY-LIQUID SEPARATIONS

Fraction Mesh		Weight %	Assay Fe %	Distribution Fe %
- 10 + 18	Heavy fraction	87.7	29.5	97.0
	Light "	12.3	6.5	3.0
	Feed calc.	100.0	26.7	100.0
	Feed assay	-	28.3	-
- 18 + 36	Heavy fraction	89.7	29.7	97.6
	Light "	10.3	6.4	2.4
	Feed calc.	100.0	27.3	100.0
	Feed assay	-	27.4	-
- 36 + 72	Heavy fraction	74.5	29.3	93.4
	Light "	25.5	6.0	6.6
	Feed calc.	100.0	23.3	100.0
	Feed assay	-	23.5	-
- 72 + 100	Heavy fraction	62.0	41.9	93.3
	Light "	38.0	4.9	6.7
	Feed calc.	100.0	27.9	100.0
	Feed assay	-	30.5	-
- 100 + 200	Heavy fraction	71.5	58.4	96.6
	Light "	28.5	5.2	3.4
	Feed calc.	100.0	43.2	100.0
	Feed assay	-	45.9	-

5.3 Dry Magnetic Separation Tests

Magnetic separation of ore stage-crushed to minus 18-mesh gave an unsatisfactory rougher concentrate grade and recovery (Test 3 Table 6).

Ore was then stage-crushed to minus 50-mesh and after desliming, two magnetic separation tests were conducted. In Test 4 a Stearns "pick up" magnetic separator was used and in Test 5 a Carpco induced roll machine. In most cases the magentic concentrates were cleaned using the same conditions as for the primary treatment.

The sizing-analysis of the feed is shown in Table 4. Operating conditions for the three tests are given in Table 5 and results in Tables 6, 7 and 8. Results of tests 4 and 5 are also given in Flow-sheets 1 and 2 respectively.

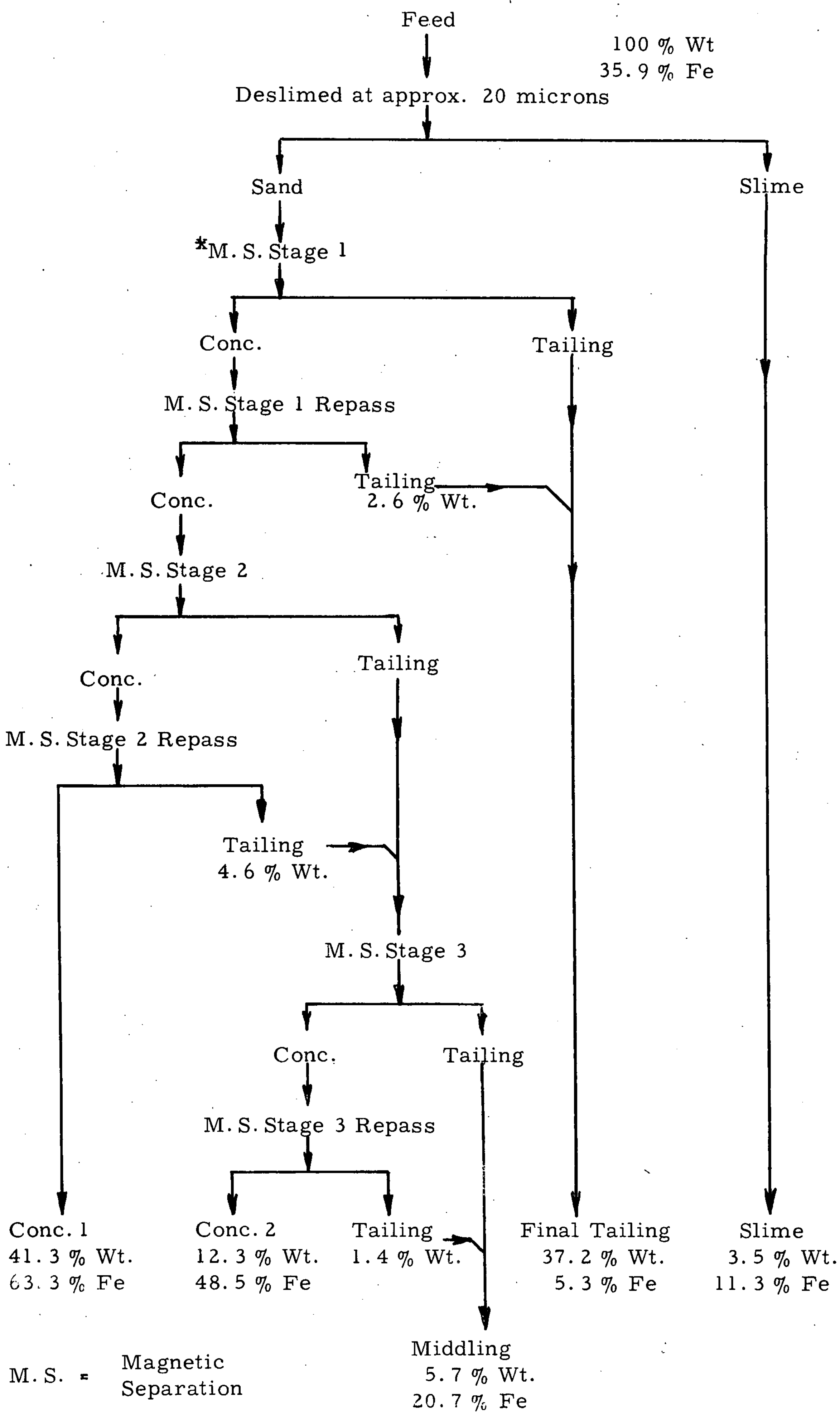
TABLE 4: SIZING-ANALYSIS OF MINUS 50-MESH ORE

Fraction Mesh	Weight %	Assay Fe %	Distribution Fe %
+ 52	2.6	9.7	2.6
- 52 + 72	7.1		
- 72 + 100	16.4	19.9	9.0
- 100 + 150	12.9	27.6	9.8
- 150 + 200	4.7	32.6	4.2
- 200 + 300	8.9	42.2	10.4
- 300	47.4	48.9	64.0
Feed calc.	100.0	36.2	100.0
Feed assay	-	35.9	-

TABLE 5: OPERATING CONDITIONS OF MAGNETIC SEPARATION TESTS

Test No.	Machine Used	Feed Size	Stage No.	Coil Current amps	Pole Gaps inches	Belt Speed ft/min	Roll Speed rpm	Feed Rate lb/in./hr
3.	Stearns "pick up" type	-18	1	1.2	1/8 : 3/16	38	-	2.6
4.	Stearns "pick up" type	-50	1	1.2	1/16 : 1/16	38	-	4.6
			2	0.9	1/8 : 1/8	38	-	-
			3	1.2	1/8 : 1/8	38	-	3.8
5.	Carpco Induced roll type	-50	1	0.2	1/4	-	325	-
			2	0.6	1/4	-	325	-
			3	1.35	1/4	-	340	-

FLOWSHEET 1: MAGNETIC SEPARATION
Stearns "Pick up" type machine



* M.S. = Magnetic Separation

FLOWSHEET 2: MAGNETIC SEPARATION
Carpco induced roll machine

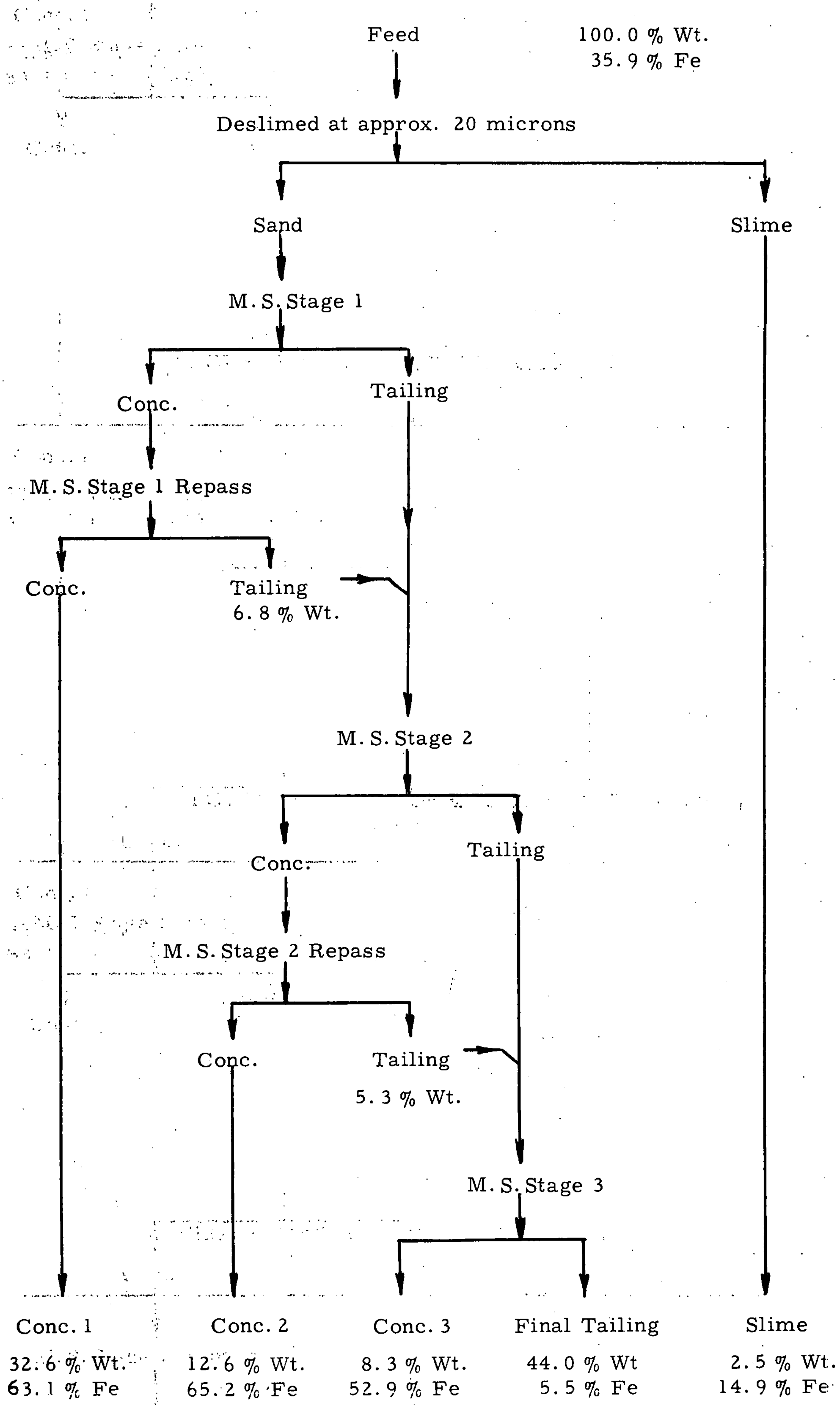


TABLE 6: RESULTS OF MAGNETIC SEPARATION - TEST 3

Product	Weight %	Assay Fe %	Distribution Fe %
Rougher concentrate	63.0	48.3	83.3
Rougher tailing	37.0	16.5	16.7
Feed calc.	100.0	36.5	100.0
Feed assay	-	35.9	-

TABLE 7: RESULTS OF MAGNETIC SEPARATION - TEST 4

Product		Weight		Assay Fe		Distribution Fe	
		%	Cum. %	%	Cum. %	%	Cum. %
Concentrate	1.	41.3	41.3	63.3	63.3	73.3	73.3
"	2.	12.3	53.6	48.5	59.9	16.7	90.0
Middling		5.7	59.3	20.7	56.1	3.4	93.4
Tailing		37.2	96.5	5.3	36.6	5.5	98.9
Slime		3.5	100.0	11.3	35.7	1.1	100.0
Feed calc.		100.0	-	35.7	-	100.0	-
Feed assay		-	-	35.9	-	-	-

TABLE 8: RESULTS OF MAGNETIC SEPARATION - TEST 5

Product		Weight		Assay Fe		Distribution Fe	
		%	Cum. %	%	Cum. %	%	Cum. %
Concentrate	1.	32.6	32.6	63.1	63.1	57.2	57.2
"	2.	12.6	45.2	65.2	63.7	22.8	80.0
"	3.	8.3	53.5	52.9	62.0	12.2	92.2
Tailing		44.0	97.5	5.5	36.5	6.7	98.9
Slime		2.5	100.0	14.9	36.0	1.1	100.0
Feed calc.		100.0	-	36.0	-	100.0	-
Feed assay		-	-	35.9	-	-	-

5.4 Humphreys-Spiral Tests

Two Humphreys-spiral batch tests were carried out by a procedure previously reported[1]. Operating conditions are shown in Table 9,

1. AMDL-177, Mt. Christie Iron Ore Beneficiation Tests, L. Bollen

and results in Tables 10 and 11. Because of high losses of iron in the tailing, a sizing analysis (Table 12) of the tailing from Test 6 was carried out.

TABLE 9: HUMPHREYS-SPIRAL TESTS - OPERATING CONDITIONS

Conditions			Test 6	Test 7
Spiral feed rate	:	gal/min	20	20
Wash water	:	gal/min	4	4
Pulp density of feed	:	% solids	8.3	21
Feed sizing	:	mesh	-18	-50
Spiral feed rate	:	tons/hr	0.47	1.33

TABLE 10: HUMPHREYS-SPIRAL SEPARATION - TEST 6

Fraction	Weight		Assay Fe		Distribution Fe	
	%	Cum. %	%	Cum. %	%	Cum. %
Port 3.	3.7	3.7	65.4	65.4	7.1	7.1
" 4.	3.9	7.6	64.9	65.2	7.3	14.4
" 6.	2.7	10.3	66.7	65.8	5.3	19.7
" 8.	3.1	13.4	64.4	65.5	5.8	25.5
" 10.	5.3	18.7	38.7	58.0	6.1	31.6
" 15.	18.9	37.6	14.7	36.3	8.2	39.8
Tailing	59.2	96.8	33.1	34.3	57.6	97.4
Slime	3.2	100.0	27.2	34.1	2.6	100.0
Feed calc.	100.0	-	34.1	-	100.0	-
Feed assay	-	-	35.9	-	-	-

TABLE 11: HUMPHREYS-SPIRAL SEPARATION - TEST 7

Fraction	Weight		Assay Fe		Distribution Fe	
	%	Cum. %	%	Cum. %	%	Cum. %
Port 3.	4.6	4.6	62.9	62.9	8.2	8.2
" 4.	3.8	8.4	63.4	63.1	6.8	15.0
" 6.	5.1	13.5	56.4	60.5	8.2	23.2
" 8.	3.1	16.6	57.9	60.1	5.1	28.3
" 10.	4.1	20.7	45.5	57.0	5.2	33.5
" 15.	5.6	26.3	36.0	52.5	5.7	39.2
Tailing	69.9	96.2	29.5	35.8	58.5	97.7
Slime	3.8	100.0	21.1	35.2	2.3	100.0
Feed calc.	100.0	-	35.2	-	100.0	-
Feed assay	-	-	35.9	-	-	-

TABLE 12: SIZING-ANALYSIS OF HUMPHREYS SPIRAL TAILING

Fraction Mesh	Weight %	Assay Fe %	Distribution Fe %
+ 36	11.8	4.6	1.6
- 36 + 72	21.3	4.5	2.9
- 72 + 100	3.9		
- 100 + 150	1.9		
- 150 + 200	0.9	11.7	3.0
- 200 + 300	1.7		
- 300	58.5	52.3	92.5
Feed calc.	100.0	33.1	100.0
Feed assay	-	33.1	-

5.5 Flotation Tests

Three preliminary tests were carried out using the following reagent mixture:

Reagent	parts
Pamak 4	1.0
Fuel oil	2.0
Non-ion P100	0.1
Naphthenic acid	0.2

Material for flotation feed was obtained from the minus 50-mesh ore (Refer Table 4). Ore charges weighing 560 g were ground at 60 per cent solids for 5 minutes in a rod mill to produce the sizing shown in Table 13.

TABLE 13: SIZING OF FLOTATION FEED

Fraction Mesh	Weight %
+ 100	0.4
- 100 + 150	6.1
- 150 + 200	7.3
- 200 + 300	16.9
- 300	69.3
	100.0

The ground charges were lightly deslimed and floated using the conditions shown in Table 14. Results are shown in Table 15.

TABLE 14: FLOTATION TEST CONDITIONS

Conditions		Test 8	Test 9	Test 10
Attriting time	: min	30	30	30
Attriting density	: % solids	50	50	50
Reagent addition to attriter	: lb/ton	0.9	1.8	2.7
Temperature of flotation	: °C	25	25	25
Flotation pH	:	natural	natural	natural
Flotation time: roughing	: min	6	6	6
cleaning	: min	4	4	4
Reagent cost, per ton of feed	: pence	7.4	14.8	22.1

TABLE 15: RESULTS OF FLOTATION TESTS

Test No.	Product	Weight %	Assay Fe %	Distribution Fe %
8	Cleaner concentrate	37.8	67.5	70.9
	Cleaner tailing	10.1	51.7	14.5
	Rougher tailing	46.9	10.2	13.3
	Slime	5.2	9.5	1.3
	Feed calc.	100.0	36.0	100.0
9	Cleaner concentrate	52.1	65.1	94.3
	Cleaner tailing	6.3	13.3	2.3
	Rougher tailing	38.4	2.45	2.6
	Slime	3.2	8.6	0.8
	Feed calc.	100.0	36.0	100.0
10	Cleaner concentrate	57.0	61.5	97.2
	Cleaner tailing	8.3	3.6	0.8
	Rougher tailing	29.7	0.90	0.8
	Slime	5.0	8.9	1.2
	Feed calc.	100.0	36.1	100.0
	Feed assay	-	35.9	-

6. DISCUSSION OF RESULTS

The ore consisted of large lumps of agglomerated fines which readily disintegrated when crushed. The constituent minerals were hematite and quartz, the minus 10 plus 36-mesh fraction of ore crushed to minus 10-mesh could be disintegrated by finger pressure.

Results of Davis-tube tests showed that the ore contained less than 0.1 per cent magnetic iron.

The grade of sized fractions increased significantly in the fine fractions in ore crushed to minus 10-mesh. From Table 2 it can be seen that the minus 10 plus 18-mesh fraction and the minus 200-mesh fraction assayed 28.3 per cent and 54.2 per cent Fe respectively. However, direct-washing methods on this ore would not produce a concentrate of acceptable grade and recovery.

From the heavy-liquid splits, Table 3, it can be seen that grades of 41.9 and 58.4 per cent Fe were obtained from the separation of the minus 72 plus 100-mesh and the minus 100 plus 200-mesh fractions respectively. Thus for satisfactory liberation, the ore would need to be crushed to approximately minus 72-mesh.

Dry magnetic separation of the ore crushed to minus 18-mesh gave unsatisfactory results because of insufficient liberation. Separation using the Stearns "pick up" type machine on ore crushed to minus 50-mesh gave a combined concentrate assaying 59.9 per cent Fe with a recovery of 90.0 per cent (Table 7). Using similar material, an induced roll machine gave a combined concentrate assaying 62.0 per cent Fe with a recovery of 92.2 per cent (Table 8). A chemical analysis of this concentrate is given in Appendix C and a spectrographic analysis in Appendix D.

It should be noted that the combined concentrate assayed 0.81 per cent TiO_2 (refer Appendix C).

Humphreys-spiral batch tests conducted on minus 18-mesh (Table 10) and minus 50-mesh (Table 11) feed gave unacceptably low iron recoveries. Spiral feed pulp densities of 8.3 and 21 per cent solids respectively were used. High tailing assays from these tests were caused by the presence of large amounts of hematite too fine to be recovered by the spiral (Table 12).

Preliminary flotation tests, Table 15, gave concentrates of 65.1 and 61.5 per cent Fe with recoveries of 94.3 and 97.2 per cent respectively. The reagent quantities used in these tests were respectively 1.8 and 2.7 lb per ton, and the cost of the reagent is 8.2 pence per pound.

From the results of these preliminary tests, flotation would appear to be the most attractive method of treating this ore. The ore sample was extremely friable and material of this type would require very little crushing and grinding to prepare it for flotation.

A preliminary estimate of the direct operating costs of milling at 2000 tons per day would be in the order of:

	Shillings per Ton of Feed
Crushing and grinding	3.0
Flotation	2.75
Filtration	0.75
Tailing disposal	1.0
Miscellaneous	1.0
	8.5

The cost for additional grinding of concentrate, pelletising and drying is not included, and no allowance has been made for capital depreciation.

7. CONCLUSIONS

The testwork showed that the ore was amenable to concentration by flotation and dry magnetic separation methods. Flotation would appear to be the most attractive treatment method.

Screen sizing, wet classification, wet magnetic separation and Humphreys spiral separations would not produce satisfactory grade concentrates with satisfactory iron recoveries.

8. RECOMMENDATIONS

If exploitation of this material is contemplated, further work on a more representative sample will be necessary to examine the following flotation variables:

1. Grinding time
2. Conditioning time
3. Flotation reagent mixture
4. Use of undeslimed ore

It is also recommenced that a study be made of the mode of occurrence of the titanium.

APPENDIX A

REPORT OF INVESTIGATION

MATERIAL:	Iron ore
LOCALITY:	Malcolm Creek
IDENTIFICATION:	ML171
DATE RECEIVED:	28th February, 1962
INFORMATION REQUIRED:	Mineragraphic

RESULTS

ML171: PS6831 - Minus 10-mesh Head Sample

The two constituents minerals are hematite and quartz. The hematite apparently occurred as bladed crystals in quartz in the original material. Due to the well-crystallized nature of the hematite its liberation has on the whole been very good, even at this size. The gangue occurs as particles up to 0.5 mm across, often with attached hematite on the larger particles. The free hematite grains are angular, and prismatic, due to the fracturing of original bladed crystals. They range from 0.01 mm to 0.15 mm across, with occasional larger groups. Superficial iron-staining of the quartz gangue has occurred.

It is suggested that re-crushing of the coarser material would liberate the hematite in the composites.

Investigated by: H. W. Fander

Officer in Charge, Mineralogy Section: H.W. Fander

APPENDIX B

MALCOLM CREEK HEAD SAMPLE

SPECTROGRAPHIC ANALYSIS

REPORT OF ANALYSIS

Mark			ML170
Major	10	100%	Si, Fe
Minor	1	10%	Al
Heavy trace	0.1	1%	Mg, Ti
Trace	0.01	0.1%	Zr, Zn, B
Faint trace	10	100 ppm	Mn, Ca, Cr, V, Pb, Ni
Very faint trace	1	10 ppm	Mo, Cu, Co.

Other elements not detected at limits quoted in Appendix E, except alkalis and P not sought.

Spectrographic Analysis by: A. B. Timms

Officer in Charge, Analytical Section: T. R. Frost

APPENDIX C

MALCOLM CREEK MAGNETIC CONCENTRATE

CHEMICAL ANALYSIS

REPORT OF ANALYSIS

Mark		ML16
		%
Insoluble		9.6
Silica	SiO_2	8.0
Calcium oxide	CaO	0.085
Magnesium oxide	MgO	0.05
Manganese	Mn	0.002
Titanium oxide	TiO_2	0.81
Phosphorus pentoxide	P_2O_5	0.03
Sulphur	S	0.005
Aluminium oxide	Al_2O_3	1.0

Investigated by: M.R. Hanckel

Officer in Charge, Analytical Section: T.R. Frost

APPENDIX D

MALCOLM CREEK MAGNETIC CONCENTRATE
SPECTROGRAPHIC ANALYSIS

REPORT OF ANALYSIS

Mark			ML16
Major	10	100 %	Fe, Si
Minor	1	10 %	Al
Heavy trace	0.1	1 %	Ca
Trace	0.01	0.1 %	Ti
Faint trace	10	100 ppm	Cu, Zn, B, Ba, Mg
Very faint trace	1	10 ppm	Ni, Cr, V, Zr, Mn, Sr.

Other elements not detected at limits quoted in Appendix E, except alkalis and P not sought.

Spectrographic Analysis by: A. B. Timms

Officer in Charge, Analytical Section: T. R. Frost

APPENDIX E

SPECTROGRAPHIC ANALYSES

Detection-Limit Concentrations of Elements

D.C. Arc Excitation

ELEMENT	%	ppm	ELEMENT	%	ppm
Ag	0.00005	0.5	Na	0.00005	0.5
Al	0.0002	2	Nb	0.003	30
As	0.01	100	Nd	0.001	10
Au	0.001	10	Ni	0.0002	2
B	0.001	10	Os	0.005	50
Ba	0.0002	2	P	0.02	200
Be	0.0005	5	Pb	0.0002	2
Bi	0.0005	5	Pd	0.001	10
Ca	0.0002	2	Pr	0.001	10
Cd	0.001	10	Pt	0.005	50
Ce	0.04	400	Rb	0.0001	1
Co	0.0002	2	Re	0.01	100
Cr	0.0001	1	Rh	0.001	10
Cs	0.0002	2	Ru	0.001	10
Cu	0.00005	0.5	Sb	0.002	20
Dy	0.001	10	Sc	0.0002	2
Er	0.001	10	Si	0.002	20
Eu	0.001	10	Sm	0.05	500
Fe	0.0005	5	Sn	0.001	10
Ga	0.0003	3	Sr	0.0001	1
Gd	0.02	200	Ta	0.01	100
Ge	0.0002	2	Tb	0.001	10
Hf	0.01	100	Te	0.02	200
Hg	0.01	100	Th	0.01	100
Ho	0.001	10	Ti	0.001	10
In	0.0001	1	Tl	0.0001	1
Ir	0.005	50	Tm	0.001	10
K	0.0002	2	U	0.02	200
La	0.001	10	V	0.0005	5
Li	0.0001	1	W	0.005	50
Lu	0.001	10	Y	0.001	10
Mg	0.0002	2	Yb	0.001	10
Mn	0.001	10	Zn	0.0025	25
Mo	0.0005	5	Zr	0.001	10