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BENEFICIATION OF ARDLETHAN TIN ORE

(A.M.D.L. Report No.216)

by

P.B. Moffitt

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* of the Australian Mineral Development Laboratories, Adelaide.

Introduction

This research project was sponsored by the Bureau to confirm the results of laboratory tests carried out by various testing organizations, with the object of enhancing the possibility that the deposits would be brought into production on a large scale.

This has since taken place, and the company operating the deposit is Ardlethan Tin N.L.

The report has been included in the Bureau's Record series so that it may enjoy a wider distribution through the Bureau's open file system. The company's concurrence in this wider distribution is much appreciated.

The report has not been altered in any way.

2/1/1

AMDL Report 216
November, 1962

BENEFICIATION OF ARDLETHAN TIN ORE

by

P. B. Moffitt

to

BUREAU OF MINERAL RESOURCES

Investigated by: Metallurgical Section

Officer in Charge: P. K. Hosking

THE AUSTRALIAN MINERAL DEVELOPMENT LABORATORIES

Adelaide South Australia

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1. INTRODUCTION

Beneficiation tests on low-grade tin ores from the Ardlethan area were requested by the Bureau of Mineral Resources, Canberra. Work required included laboratory and small-scale testing of two different ore samples, designated "White Crystal" and "Wild Cherry", to confirm earlier laboratory tests carried out by various testing organisations. The work was to be repeated on a larger sample of combined ore if the preliminary work was successful. In discussion with the sponsor and representatives of Cadwallader, Garretty, Mason and Co., and Aberfoyle Tin N. L., it was agreed that the individual ores should be mixed in equal parts to form the combined ore sample.

Test work was to follow the pattern outlined in CSIRO Investigation No. 394. This involved grinding the ore to minus 18-mesh and sizing into several fractions, tabling of the coarse fractions with the concentrate being further upgraded by magnetic and electrostatic or high tension methods, middlings being reground and retreated as necessary, and fine fractions being treated on a Buckman table. The complexity of the flowsheet prevented continuous pilot-scale treatment, and it was necessary to use batch-testing techniques.

The flowsheet originally proposed for the work is shown in Appendix A to this report. Certain modifications to this flowsheet were found necessary as the treatment of the individual ores proceeded. The flowsheet actually used when testing the individual ores is shown in Appendix B.

Later, further testing was requested to clarify the ultimate distribution of the tin reporting in the middling fractions, and to establish whether it was possible to obtain 60 per cent tin concentrates and find the recovery at this grade.

2. SUMMARY

This report covers investigations into the recovery of tin from Ardlethan ores. The work was carried out in the following stages:

a. Treatment of White Crystal Ore
b. Treatment of Wild Cherry Ore
c. Treatment of mixed (1:1) White Crystal-Wild Cherry Ore
d. Plant-scale tabling treatment of mixed ore.

The first three stages were aimed at developing a flowsheet for treatment, and the fourth stage at establishing the ultimate tin recoveries at market grade, and arriving at equipment specifications. White Crystal and Wild Cherry ores were treated by grinding, sizing, gravity and magnetic methods. The White Crystal ore gave the following results:

	Weight %	Sn %	Distribution Sn %
Concentrate	1.7	18.1	55.9
Middling	9.8	0.93	16.9
Tailing	88.5	0.17	27.2
Feed	100.0	0.54	100.0

The concentrate included a low-grade fraction assaying 6.0 per cent Sn.

Wild Cherry ore gave the following results:

	Weight %	Sn %	Distribution Sn %
Concentrate	1.8	14.5	67.3
Middling	9.0	0.44	10.5
Tailing	89.2	0.09	22.2
Feed	100.0	0.38	100.0

The low grade of the concentrate was again due to the inclusion of a large bulk of fine low-grade concentrate (5.2 per cent tin).

Similar test work was carried out on a larger parcel of a mixture of the two ores. This resulted in the following fractions being produced:

	Weight %	Sn %	Distribution Sn %
Concentrate	1.7	18.7	67.6
Middling	7.6	0.62	10.0
Tailing	90.7	0.12	22.4
Feed	100.0	0.48	100.0

The overall recovery with this ore mixture was better than with either of the two individual ores. This resulted from:

a. a better understanding of the material after the preliminary examinations, and

b. finer grinding to release the tin in the White Crystal ore.

High tension separation tests were carried out on the non-magnetic concentrates to produce high-grade concentrates. This form of separation proved successful in the upgrading of coarse tin concentrates.

Further tin could be recovered from the retreatment of middling fractions. However, it is certain that this gain would be offset by losses resulting from dressing the final concentrate to market grade.

Test work designed to overcome the lack of information on the treatment of middlings was carried out. This consisted of tabling successively finer fractions, with grinding of the middling produced and adding this ground material to the next finer stage. With this treatment and with tabling, magnetic and high tension concentration of the individual table concentrates, the following results were obtained:

	Weight %	Sn %	Distribution Sn %
Concentrate	0.52	60.0	61.9
Middling	1.07	2.3	5.0
Tailing	98.41	0.17	33.1
Feed	100.0	0.50	100.0

It is considered that additional recovery of tin could be obtained by closer sizing of feed and the use of large-scale equipment better suited to the recovery of fine tin than was the laboratory equipment.

A plant is outlined that should be capable of recovering a minimum of 62 per cent of the tin in a concentrate of 60 per cent grade.

Extensions of this test work are suggested:

a. Examination of preliminary concentration of tin in Humphrey spirals to reduce capital cost of plant.

b. The concentration of the fine tin on Buckman tables and the upgrading of these concentrates.

c. Examination of the middling regrinding and the upgrading of these concentrates.

d. Further work on magnetic separation to release entrained and composite particles of cassiterite in the magnetic fractions.

3. MATERIAL EXAMINED

Two ore samples were received on the 10th July, 1961 and were labelled Samples X and Y.

Information received by letter identified these Samples as follows:

Mark	Ore Deposit	Number of Drums	Est. Weight
Y	White Crystal	32	10 tons
X	Wild Cherry	32	10 tons

Lump samples of each ore type were taken and mineralogically examined. The report (Appendix C) indicates the following general composition of the two samples:

White Crystal

Mineral Constituent	Estimated Volume, per cent
Quartz	70
Tourmaline	10
Topaz	10
Cassiterite) Chlorite)	5
Zircon) Opaques)	Trace

Wild Cherry

Mineral Constituent	Estimated Volume, per cent
Sericite	55
Quartz	40
Muscovite	5
Opaques	Trace

3.1 Crushing and Sampling Procedure

The lump ore was crushed to minus $^5/_{32}$ inch in the pilot crushing plant. The major portion of the size reduction was effected in the crushing rolls.

A head sample, representing 12.5 per cent of the total sample, was cut out after crushing. This sample was further reduced by coning and quartering, crushed to minus 18-mesh in the laboratory rolls, and assay samples cut out.

The head assays were as follows:

	Sn %
White Crystal	0.58
(duplicate sample)	0.58
Wild Cherry	0.38
(duplicate sample)	0.38

The remaining minus 18-mesh material from each sample was used in the testing of the individual ores. The $^5/_{32}$-inch material remaining from the original sample was used in the preparation of the sample for test work on the combined ore.

The plant-scale tests were made on ore drawn from bins holding the surplus material from the original crushing.

4. EQUIPMENT USED*

4.1 Pilot Crushing Plant

Jaw crusher	20 x 12 inch
Gyrex crusher	14 inch (setting 1 inch CS)
Rolls crusher	20 in. dia x 14 in. (setting $^1/_4$ inch)
Aerovibe Screen	6 x 3 ft

4.2 Laboratory Crushing Plant

Laboratory rolls	10 x 6 inch
Boulton screen	3 ft dia

4.3 Laboratory Grinding, Sizing and Gravity Equipment

Denver rod mill	1 x 2 ft
3-Spigot hydraulic classifier (similar to a Denver	4 x 4 inch unit)
Hydraulic cyclone	3 in. dia, $12^1/_2$ degree
Dorrco hydrosizer	$7^1/_2$ in. dia
Laboratory Wilfley table	Size 13 - Deck 18 x 40 inch

4.4 Laboratory Magnetic and High Tension Separation Equipment

Magnetic separator	Stearns Pick-up Model Belt width 2.5 inch
High tension separator	Carpco Laboratory Model 6 x 6 inch roll

4.5 Plant-Scale Equipment

Wilfley Table, Model 11D

5. TREATMENT OF WHITE CRYSTAL ORE

5.1 Grinding and Size Classification

The following procedure was common to the three samples tested.

Grinding and size classification was standardized in accordance with the flowsheet shown in Figure 1. This circuit was developed from preliminary work carried out on the White Crystal ore. Minus 18-mesh material was sized in the hydraulic classifier and the overflow treated in a

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* Note: Reference to specific equipment is made to facilitate understanding and does not imply endorsement of such equipment by AMDL.

cyclone to remove granular material. The cyclone overflow was stored for later treatment. The size distribution of the three spigot fractions are shown in Table 1.

When the spigot 1 fraction was tabled directly (for results see Table 2), the high tin loss in the tailing showed that the particle size should be reduced for effective liberation and tin recovery. To accomplish this, the sizing circuit was modified to incorporate the rod mill, as shown in Figure 1.

TABLE 1: WHITE CRYSTAL ORE - SCREEN SIZINGS OF HYDRAULIC CLASSIFIER PRODUCTS

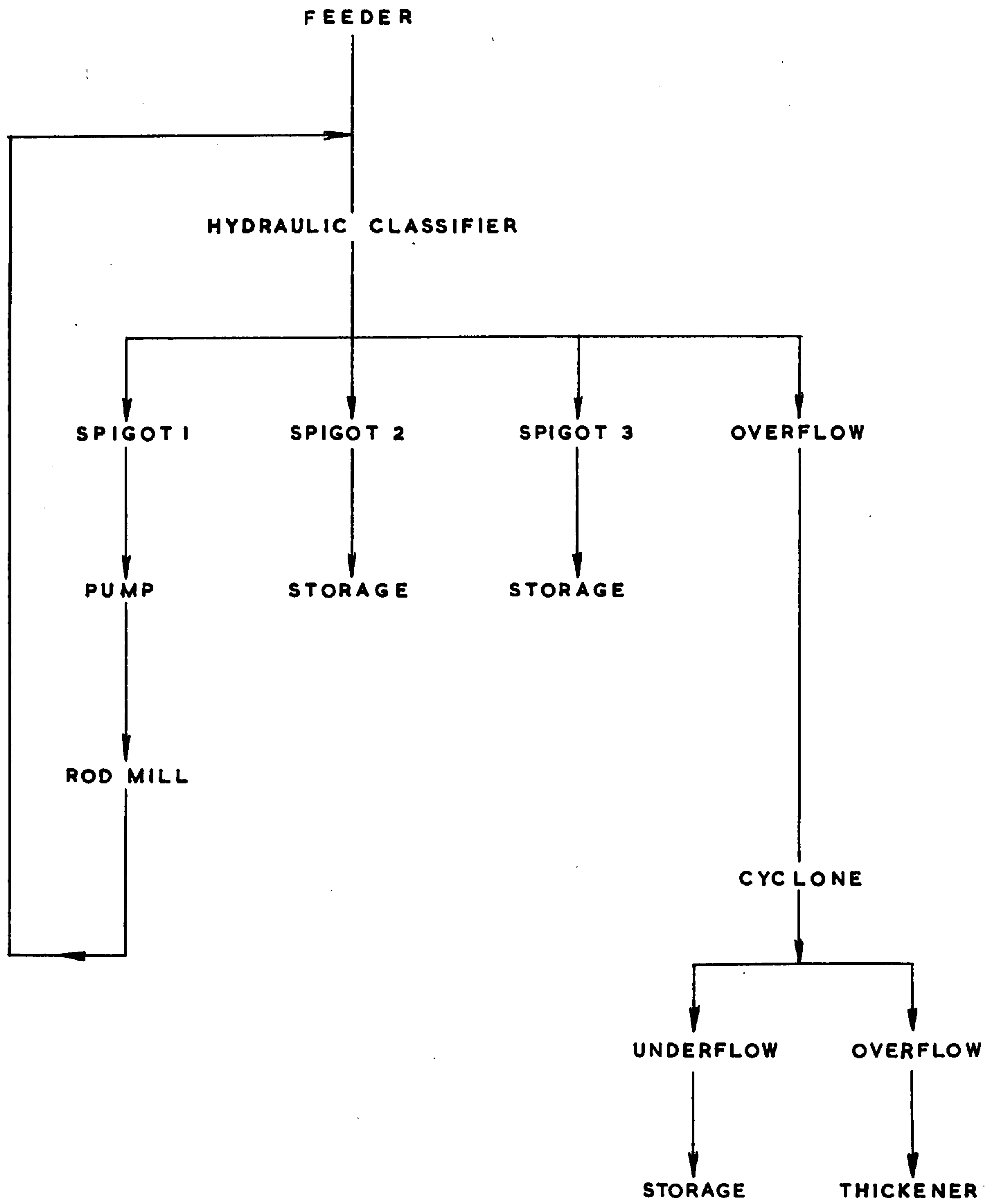
Fraction Mesh*	Spigot 1	Spigot 2	Spigot 3
+ 18	3.7	0.4	-
- 18 + 25	32.4	1.3	-
- 25 + 36	36.9	3.2	0.3
- 36 + 52	22.1	22.5	1.8
- 52 + 72	4.1	52.8	23.2
- 72 + 100	0.3	16.4	38.2
- 100 + 150	(-100) 0.5	(-100) 3.4	24.4
- 150 + 200	-	-	10.6
- 200	-	-	1.5
	100.0	100.0	100.0

* British Standard Screens were used throughout this investigation.

TABLE 2: WHITE CRYSTAL ORE - TABLING OF SPIGOT 1 MATERIAL

Fraction Mesh	Weight %	Sn %	Distribution Sn %
Concentrate	14.7	2.25	56.3
Middling	32.7	0.44	24.5
Tailing	52.6	0.22	19.2
Spigot 1	100.0	0.59	100.0

FIGURE 1: GRINDING AND HYDRAULIC SIZING FLOWSHEET



All fractions of the White Crystal sample, excluding the cyclone overflow, were re-combined and treated in the modified circuit. The granular fractions (Spigots 2 and 3 and cyclone underflow) were then dried, recombined and passed through the classifier and cyclone. This produced four fractions for gravity concentration work. Cyclone overflows were combined.

5.2 Gravity Separation

The sized fractions produced by grinding and classification were each treated on the laboratory Wilfley table to produce concentrates containing as high a recovery as possible, regardless of grade. Middling fractions were held for retreatment after grinding.

Sizings of the hydraulic classifier products and the cyclone underflow are shown in Table 3, with weight and tin distribution results in Table 4.

Results of treatment of the cyclone underflow by tabling are shown in Table 5.

TABLE 3: WHITE CRYSTAL ORE – SCREEN SIZINGS OF FINAL SIZED PRODUCTS

Fraction Mesh		Spigot 1		Spigot 2	Spigot 3	Cyclone Underflow
- 18 + 25		0.8		0.1	-	-
- 25 + 36		6.5		0.3	-	-
- 36 + 52		45.0		8.2	0.3	-
- 52 + 72		40.3		53.2	6.7	0.2
- 72 + 100		5.6		29.1	30.7	2.4
-100 + 150		1.0		7.1	31.7	11.4
-150 + 200	(-150)	0.8	(-150)	2.0	21.7	21.1
-200 + 300		-		-	6.2	19.8
-300		-		-	2.7	45.1
		100.0		100.0	100.0	100.0

TABLE 4: WHITE CRYSTAL ORE - WEIGHT AND TIN DISTRIBUTION IN SIZED PRODUCTS

Fraction	Original Ore		
	Weight %	Sn %	Distribution Sn %
Spigot 1	26.5	0.63	30.73
Spigot 2	17.3	0.55	17.51
Spigot 3	16.5	0.52	15.79
Cyclone underflow	24.3	0.64	28.61
Cyclone overflow	15.4	0.26	7.36
Feed	100.0	0.54	100.00

TABLE 5: WHITE CRYSTAL ORE - RESULTS OF TABLING THE ORIGINAL CYCLONE UNDERFLOW

Fraction	Cyclone Underflow			Original Ore	
	Weight %	Sn %	Distribution Sn %	Weight %	Distribution Sn %
Concentrate	10.3	2.76	45.6	2.5	13.1
Middling	13.5	0.48	10.4	3.3	3.0
Tailing 1	19.0	0.30	9.2	4.6	2.6
" 2	57.2	0.38	34.8	13.9	9.9
Cyclone underflow	100.0	0.62	100.0	24.3	28.6

The high tin losses in the tailing were attributed to the larger range of particle sizes in the table feed. The table products were therefore re-combined and sized in the Dorrco rising current classifier. Water velocity was maintained at 1.0 gallons per minute. This corresponds to a theoretical separation size of 53 microns diameter (300-mesh) for quartz particles and a 28 micron diameter for cassiterite particles. Weights and tin distribution from this separation are shown in Table 6.

The coarse fraction was tabled in a similar manner to the 3 spigot fractions. Results of tabling appear in Table 7.

Concentrates from the four tabling stages were retabled giving the weight and tin distributions shown in Table 8.

TABLE 6: WHITE CRYSTAL ORE - WEIGHT AND TIN DISTRIBUTION IN THE HYDROSIZER SEPARATION OF THE CYCLONE UNDERFLOW

Fraction	Cyclone Underflow			Original Ore	
	Weight %	Sn %	Distribution Sn %	Weight %	Distribution Sn %
Coarse fraction	48.6	0.63	47.8	11.8	13.68
Fine fraction	51.4	0.65	52.2	12.5	14.93
Cyclone underflow	100.0	0.64	100.0	24.3	28.61

TABLE 7: WHITE CRYSTAL ORE - COMBINED SIZE CLASSIFICATION AND PRIMARY TABLING RESULTS

Sized Product	Fraction	Primary Table Tests			Original Ore	
		Weight %	Sn %	Distribution Sn %	Weight %	Distribution Sn %
Spigot 1	Concentrate	9.8	4.84	75.1	2.6	23.07
	Middling	55.8	0.225	19.9	14.8	6.12
	Tailing	34.4	0.091	5.0	9.1	1.54
		100.0	0.63	100.0	26.5	30.73
Spigot 2	Concentrate	13.1	3.08	73.3	2.3	12.84
	Middling	32.2	0.26	15.2	5.6	2.66
	Tailing	54.7	0.116	11.5	9.4	2.01
		100.0	0.55	100.0	17.3	17.51
Spigot 3	Concentrate	10.5	3.46	69.9	1.7	11.04
	Middling	22.2	0.325	13.9	3.7	2.19
	Tailing	67.3	0.125	16.2	11.1	2.56
		100.0	0.52	100.0	16.5	15.79
Cyclone underflow coarse fraction	Concentrate	8.6	5.18	70.7	1.0	9.67
	Middling	12.3	0.77	15.0	1.5	2.05
	Tailing 1	25.5	0.195	7.9	3.0	1.08
	Tailing 2	53.6	0.075	6.4	6.3	0.88
		100.0	0.63	100.0	11.8	13.68
Cyclone underflow	Fine fraction	-	0.65	-	12.5	14.93
Cyclone overflow	-	-	0.26	-	15.4	7.36
Original ore	-	-	0.54	-	100.0	100.00

TABLE 8: WHITE CRYSTAL ORE - RESULTS OF RETABLING GRAVITY CONCENTRATES

Sized Product	Fraction	Primary Table Tests			Original Ore	
		Weight %	Sn %	Distribution Sn %	Weight %	Distribution Sn %
Spigot 1	Concentrate	12.5	30.4	78.1	0.33	18.02
	Middling	67.7	1.51	20.8	1.76	4.80
	Tailing	19.8	0.27	1.1	0.51	0.25
		100.0	4.87	100.0	2.6	23.07
Spigot 2	Concentrate	8.4	27.7	72.0	0.19	9.24
	Middling	53.8	1.45	24.2	1.24	3.11
	Tailing	37.8	0.325	3.8	0.87	0.49
		100.0	3.23	100.0	2.30	12.84
Spigot 3	Concentrate	8.3	26.0	60.5	0.14	6.68
	Middling	65.6	2.01	37.0	1.12	4.08
	Tailing	26.1	0.34	2.5	0.44	0.28
		100.0	3.57	100.0	1.70	11.04
Cyclone underflow (coarse fraction)	Concentrate	16.2	23.2	71.0	0.16	6.88
	Middling	29.4	4.06	22.5	0.29	2.18
	Tailing 1	36.4	0.69	4.7	0.37	0.45
	Tailing 2	18.0	0.51	1.7	0.18	0.16
		100.0	5.30	100.0	1.0	9.67

5.3 Middling Regrind

Fractions for middling treatment are listed in Table 9.

The fractions were combined and after mixing were ground wet in a 1 x 2 inch rod mill. After drying the ground middlings were sized in a Dorrco hydrosizer to produce a nominal size split at 53 microns (for quartz). The fractions produced were designated regrind middling coarse and fine fractions. The coarse fraction was tabled and the concentrate then retabled to produce a high grade tin concentrate. The weights and tin distribution obtained in the hydrosizer separation are shown in Table 10 and the size distribution of the rod-mill discharge and the hydrosizer coarse fractions are shown in Table 11. The results of tabling are shown in Table 12 and 13.

TABLE 9: WHITE CRYSTAL ORE – FRACTIONS SELECTED FOR MIDDLING REGRIND

Sized Product	Fraction	Primary Table Tests			Original Ore	
		Weight %	Sn %	Distribution Sn %	Weight %	Distribution Sn %
Spigot 1	Middling	41.8	0.225	20.2	14.8	6.12
Spigot 2	"	15.8	0.26	8.8	5.6	2.66
Spigot 3	"	10.5	0.325	7.3	3.7	2.19
Cyclone u/f	"	4.2	0.77	7.0	1.5	2.05
(coarse fraction)	Tailing 1	8.5	0.195	3.5	3.0	1.08
Retabled Products						
Spigot 1	Middling	5.0	1.51	16.1	1.76	4.80
	Tailing	1.4	0.27	0.8	0.51	0.25
Spigot 2	Middling	3.5	1.45	10.9	1.24	3.11
	Tailing	2.5	0.325	1.7	0.87	0.49
Spigot 3	Middling	3.2	2.01	13.6	1.12	4.08
	Tailing	1.2	0.34	0.9	0.44	0.28
Cyclone u/f	Middling	0.8	4.06	7.1	0.29	2.18
(coarse	Tailing 1	1.1	0.69	1.5	0.37	0.45
fraction)	Tailing 2	0.5	0.51	0.6	0.18	0.16
Total combined	Middling	100.0	0.47	100.00	35.38	29.90

TABLE 10: WHITE CRYSTAL ORE - WEIGHT AND TIN DISTRIBUTION IN THE HYDROSIZER SEPARATION OF THE GROUND MIDDLING

Fraction	Combined Middling			Original Ore	
	Weight %	Sn %	Distribution Sn %	Weight %	Distribution Sn %
Coarse fraction	81.4	0.445	83.3	28.80	24.90
Fine "	18.6	0.39	16.7	6.58	5.00
Combined middling	100.0	0.44	100.0	35.38	29.90

TABLE 11: WHITE CRYSTAL ORE - SCREEN SIZING OF MIDDLING REGRIND PRODUCTS

Fraction	Rod Mill Discharge Weight %	Rod Mill Discharge Coarse Fraction Weight %
+ 52	1.5	1.8
- 52 + 72	12.8	14.9
- 72 + 100	17.6	20.2
- 100 + 150	21.9	26.6
- 150 + 200	12.3	15.0
- 200 + 300	11.2	13.5
- 300	22.7	8.0
	100.0	100.0

TABLE 12: WHITE CRYSTAL ORE - RESULTS OF TABLING THE COARSE FRACTION OF GROUND MIDDLING

Fraction	Ground-Mid. Coarse Fraction			Original Ore	
	Weight %	Sn %	Distribution Sn %	Weight %	Distribution Sn %
Concentrate	2.7	6.68	38.8	0.78	9.67
Middling	7.3	1.30	20.4	2.10	5.08
Tailing 1	18.1	0.65	25.2	5.21	6.28
" 2	71.9	0.1	15.6	20.71	3.88
	100.0	0.46	100.0	28.80	24.90

TABLE 13: WHITE CRYSTAL ORE - RESULTS OF TABLING PRIMARY CONCENTRATE FROM GROUND MIDDLINGS

Fraction	Primary Concentrate Ground Middling			Original Ore	
	Weight %	Sn %	Distribution Sn %	Weight %	Distribution Sn %
Concentrate	13.5	31.9	64.8	0.11	6.26
Middling	18.6	6.1	16.9	0.14	1.63
Tailing 1	24.1	3.1	11.2	0.19	1.08
" 2	43.8	1.09	7.1	0.34	0.69
	100.0	6.7	100.0	0.78	9.67

5.4 Magnetic Separation of Gravity Concentrates

The table concentrates were treated in a Stearns pick-up type magnetic separator. Four magnetic fractions were made at varying intensities but these were combined before assaying. Results are shown in Table 14.

TABLE 14: WHITE CRYSTAL ORE – RESULTS OF MAGNETIC SEPARATION OF GRAVITY CONCENTRATES

Sized Product	Fraction	Gravity Concentrate Weight %	Sn %	Distribution Sn %	Original Ore Weight %	Distribution Sn %
Spigot 1	Magnetic	8.3	2.06	0.5	0.03	0.09
Concentrate	Non- "	91.7	35.1	99.5	0.30	17.93
		100.0	32.4	100.0	0.33	18.02
Spigot 2	Magnetic	8.0	3.67	1.0	0.02	0.09
Concentrate	Non- "	92.0	30.15	99.0	0.17	9.15
		100.0	28.0	100.0	0.19	9.24
Spigot 3	Magnetic	5.4	5.36	1.2	0.01	0.08
Concentrate	Non- "	94.6	25.5	98.8	0.13	6.60
		100.0	24.4	100.0	0.14	6.68
Cyclone u/f (Coarse fraction)	Magnetic	5.5	4.3	1.1	0.01	0.08
Concentrate	Non- "	94.5	22.5	98.9	0.15	6.80
		100.0	21.5	100.0	0.16	6.88
Regrind mid. (Coarse fraction)	Magnetic	8.5	5.35	1.4	0.01	0.09
Concentrate	Non- "	91.5	34.4	98.6	0.10	6.17
		100.0	31.9	100.0	0.11	6.26

5.5 Buckman Table Treatment

5.5.1 Test Procedure and Results

The feed to the Buckman table consisted of fractions which were too fine to treat on the laboratory Wilfley table. These fractions were combined as shown in Table 15.

Because slime material is detrimental to the recovery of tin on Buckman tables the combined sample was deslimed by sedimentation methods to give the results shown in Table 16. Quartz particles less than 20 microns, and cassiterite particles larger than 10 microns would be rejected.

In the operation of a Buckman table the period of feeding is variable and dependent on the amount of heavies in the ore. Two tests were conducted to establish a suitable feeding time. The conditions for the preliminary tests are given in Table 17. Samples of tailing were taken over the periods indicated in order to determine when feeding should stop and the concentrate should be removed. On the basis of the results given in Table 18 the table was fed for two periods of 5 minutes with concentrate removal after each period. The two rougher concentrates were then combined and cleaned.

The conditions and results of the Buckman table tests are given in Tables 19 and 20.

TABLE 15: WHITE CRYSTAL ORE - FRACTIONS SELECTED FOR TREATMENT ON THE BUCKMAN TABLE

Sized Product	Fraction	Buckman Table Feed			Original Ore	
		Weight %	Sn %	Distribution Sn %	Weight %	Distribution Sn %
Cyclone Overflow	-	44.7	0.26	27.3	15.40	7.36
Cyclone Underflow	Fine	36.2	0.65	55.3	12.50	14.93
Regrind Middling	Fine	19.1	0.39	17.4	6.58	5.00
		100.0	0.43	100.0	34.48	27.29

TABLE 16: WHITE CRYSTAL ORE – SEPARATION OF BUCKMAN TABLE FEED AT 20 MICRONS

Fraction	Combined Fine Fractions			Original Ore	
	Weight %	Sn %	Distribution Sn %	Weight %	Distribution Sn %
+ 20 microns	45.5	0.625	60.6	15.69	16.54
- 20 "	54.5	0.34	39.4	18.79	10.75
	100.0	0.43	100.0	34.48	27.29

TABLE 17: WHITE CRYSTAL ORE – PRELIMINARY BUCKMAN TABLE TEST CONDITIONS

Conditions		Materials Used	
		Cyclone Underflow Fine Fraction	+ 20 Micron Product (a)
Width of table	inches (b)	5.25	5.25
Slope of table	inches/ft	1.75	1.75
Feed pulp density	% solids	15	15
Feed rate	ml/min	1780	1790
" "	gal/ft/min	0.9	0.9
Reagents			
Na_2SiO_3	lb/ton	1.0	1.0
Pine oil	lb/ton	0.3	0.3

(a) Table 16.
(b) Reduced to 3 inches when cleaning.

TABLE 18: WHITE CRYSTAL ORE – PRELIMINARY BUCKMAN TABLE TESTS
Determination of Table Feeding Time

Time Minutes	Assay of Tailing Sn %	
	Test 1	Test 2
0 - 1	0.31	0.195
1 - 2	0.30	0.18
2 - 3	0.305	0.29
3 - 4	0.28	0.315
4 - 5	0.315	0.31
5 - 6) 6 - 7)	0.38	0.335
7 - 8) 8 - 9)	0.405	0.375
Feed Assay	0.65	0.625

TABLE 19: WHITE CRYSTAL ORE – BUCKMAN TABLE OPERATING CONDITIONS

Conditions		Rougher Stage	Cleaner Stage
Width of table	inches	5.25	3
Slope of table	inches/ft	1.75	1.75
Feed pulp density	% solids	15	10.0
Feed rate	ml/min	1780	1020
" "	gal/ft width/min	0.9	0.9
<u>Reagents</u>			
Na_2SiO_3	lb/ton	1.0	1.0

TABLE 20: WHITE CRYSTAL ORE – RESULTS OF BUCKMAN TABLE CONCENTRATION OF THE + 20 MICRON FRACTION

Fraction	Buckman Table Feed + 20 Micron			Original Ore	
	Weight %	Sn %	Distribution Sn %	Weight %	Distribution Sn %
Cleaner concentrate	5.2	6.00	56.1	0.82	9.28
Cleaner tailing	11.3	0.5	10.1	1.77	1.67
Rougher tailing	83.5	0.23	33.8	13.10	5.59
+ 20 microns	100.0	0.56	100.0	15.69	16.54
Rougher concentrate	16.5	2.23	66.2	2.59	10.95

5.5.2 Discussion of Buckman Table Tests

In the test work sodium silicate was used as a dispersant at the rate of 1.0 lb per ton. This was considered necessary because the fractions for the Buckman table tests had been previously dired.

In the preliminary tests (Table 18) pine oil was used to decrease turbulence on the table deck. This was discontinued in latter tests.

The material for the tests was deslimed at nominally 20 microns for quartz (equivalent to 10 microns for cassiterite). Desliming[1,2,3] has been found necessary in plant practice to achieve satisfactory results.

A rougher concentrate was produced assaying 2.23 per cent tin with a recovery of 66.2 per cent (see Table 20). This grade was raised to 6.0 per cent tin by cleaning. The recovery of tin in the Buckman cleaner concentrate was 84.8 per cent of the tin from the rougher concentrate and 9.28 per cent of tin from the total ore sample.

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1. THUNAES, A., and SPEDDEN, H.R., "An Improved Method of Gravity Concentration in the Fine-Size Range", Mining Engineering, 187, 883 (1950).

2. CHASTON, I.R.M., "Gravity Concentration of Fine Cassiterite", Transactions of the Institution of Mining and Metallurgy, 71, Part 4, 215-227, (1961-62).

3. HUTTL, J.B., "Modernised Device Makes Tin Plant Possible", Engineering and Mining Journal, 147, No.5, 85-7, (1946)

5.6 Final Results on Treatment of White Crystal Ore

Final weights and tin distribution of the final concentrate, tailing and middling have been collated and are shown in Tables 21 to 23.

TABLE 21: WHITE CRYSTAL ORE – MATERIAL CLASSED AS CONCENTRATE

Sized Product	Fraction	Original Ore		
		Weight %	Sn %	Distribution Sn %
Spigot 1	Non-magnetic	0.30	35.1	17.93
Spigot 2	- ditto -	0.17	30.2	9.15
Spigot 3	"	0.13	25.5	6.42
Cyclone underflow (coarse fraction)	"	0.15	22.5	6.80
Buckman table	Cleaner concentrate	0.82	6.0	9.28
Regrind middling	Retable concentrate) Non-magnetic)	0.10	34.4	6.17
Combined concentrate		1.67	18.1	55.93

TABLE 22: WHITE CRYSTAL ORE – MATERIAL CLASSED AS TAILING

Sized Product	Fraction	Original Ore		
		Weight %	Sn %	Distribution Sn %
Spigot 1	Table tailing	9.1	0.091	1.54
Spigot 2	- ditto -	9.4	0.116	2.01
Spigot 3	"	11.1	0.125	2.56
Cyclone underflow (coarse fraction)	Table tailing 2.	6.3	0.075	0.88
Buckman table	- 20 micron	18.79	0.34	10.75
	Rougher tailing	13.10	0.225	5.59
Regrind middling	Table tailing 2.	20.71	0.101	3.88
Combined tailing		88.50	0.17	27.21

TABLE 23: WHITE CRYSTAL ORE - MATERIAL CLASSED AS MIDDLING

Sized Product	Fraction	Original Ore		
		Weight %	Sn %	Distribution Sn %
Spigot 1	Magnetic	0.03	2.06	0.09
Spigot 2	"	0.02	3.67	0.09
Spigot 3	"	0.01	5.36	0.08
Cyclone underflow (coarse fraction)	"	0.01	4.3	0.08
Buckman table	Cleaner tailing	1.77	0.495	1.67
Regrind middling	Retable middling	0.14	6.05	1.63
	" tailing 1.	0.19	3.11	1.08
	" " 2.	0.34	1.085	0.69
	Table middling	2.10	1.30	5.08
	" tailing 1.	5.21	0.645	6.28
	Magnetic	0.01	5.35	0.09
Combined middling		9.83	0.93	17.0

5.7 Discussion

Gravity concentration of White Crystal ore crushed to 98 per cent passing 18-mesh gave a recovery of 55.9 per cent of the tin in a fraction which could be classified as concentrate, 27.2 was discarded as a waste fraction, and 16.9 per cent of the tin remained as a middling fraction.

The gravity concentrate produced was of low grade (18.1 per cent tin). Major reason for the low grade of the concentrate is the inclusion of the Buckman table concentrate. In practice this material would be further upgraded on slime tables or vanners to produce much higher grade concentrates. This equipment was not available and no indication of the possible recovery in this operation can be made from the results. It is considered that this fraction can be upgraded sufficiently for it to be included in the final concentrate.

A full size shaking table should allow the production of high grade concentrates from the coarse sized fractions because of better operating conditions. It is expected that market grade concentrates could be produced from material from Spigots 1 to 3 with little loss of tin recovery.

Retreatment of the middling fraction will recover a further amount of tin. However, it is impossible to indicate how much of the tin in the middling will report in the final concentrate.

Tailing material contains very little recoverable tin. Finer grinding of the Spigot 1 - 3 tails would produce some small improvement in tin recovery, but it is doubtful that this latter step could be justified economically.

It is considered that a greater recovery of tin would be obtained with finer grinding. This should cause the bulk of the material to report in Spigot 2 and 3 and the cyclone underflow fractions and lower tailing losses would result.

6. TREATMENT OF WILD CHERRY ORE

Wild Cherry Ore, crushed to minus 18-mesh, was subjected to a grinding, sizing and gravity treatment similar to that described for the White Crystal material.

Grinding and sizing was carried out in the circuit shown in Figure 1. The weights and tin distribution in the sized products are set out in Table 24 and results of screen sizing these fractions are shown in Table 25.

TABLE 24: WILD CHERRY ORE - WEIGHT AND TIN DISTRIBUTION IN SIZED PRODUCTS

Sized Product	Original Ore		
	Weight %	Sn %	Distribution Sn %
Spigot 1	19.2	0.53	26.52
Spigot 2	16.5	0.46	19.77
Spigot 3	18.9	0.40	19.69
Cyclone underflow	32.2	0.34	28.52
Cyclone overflow	13.2	0.16	5.50
Original Ore	100.0	0.38	100.00

TABLE 25: WILD CHERRY ORE - SCREEN SIZINGS OF FINAL SIZED PRODUCTS

Fraction Mesh	Spigot 1.	Spigot 2.	Spigot 3.	Cyclone Underflow
- 18 + 25	1.9	-	-	-
- 25 + 36	15.5	0.6	-	-
- 36 + 52	50.3	11.3	0.3	0.1
- 52 + 72	28.6	55.9	8.6	0.1
- 72 + 100	2.5	27.1	39.3	2.8
-100 + 150	0.5	4.0	30.1	14.0
-150 + 200	(-150) 0.7	0.8	17.3	22.8
-200 + 300	-	(-200) 0.3	3.1	19.1
-300	-	-	1.3	41.1
Sized Product	100.0	100.0	100.0	100.0

6.1 Gravity Separation

Each of the sized products shown in Table 24 was tabled to give a high recovery of tin in the concentrates enabling rejection of a low grade waste fraction. As in the White Crystal Ore work the cyclone underflow did not table successfully and was resized into a coarse and fine fraction. This separation was carried out in the Dorrco hydrosizer at a size separation equivalent to 53 microns diameter for quartz. Results of this separation are shown in Table 26. Results of tabling the various sized fractions are shown in Table 27. Results of tabling the original cyclone underflow are shown in Table 28.

It will be noted that the assay of Spigot 3 tailing 2 (Table 27) is unduly high and quite out of character with the other tailing fraction in the series. The assay was checked and as the weight of the fraction was small and tin content low, it was added to the middling fraction.

Table concentrates were retabled to produce higher grade concentrates and a fraction for middling regrind. Results are shown in Table 29.

TABLE 26: WILD CHERRY ORE - WEIGHT AND TIN DISTRIBUTION FROM HYDROSIZER SEPARATION OF THE CYCLONE UNDERFLOW

Fraction	Cyclone Underflow			Original Ore	
	Weight %	Sn %	Distribution Sn %	Sn %	Distribution Sn %
Coarse	49.2	0.33	47.4	15.84	13.52
Fine	50.8	0.355	52.6	16.36	15.00
Cyclone underflow	100.0	0.34	100.0	32.20	28.52

TABLE 27: WILD CHERRY ORE - RESULTS OF PRIMARY TABLING

Sized Product	Fraction	Sized Product			Original Ore	
		Weight %	Sn %	Distribution Sn %	Weight %	Distribution Sn %
Spigot 1	Concentrate	3.9	9.15	67.7	0.75	17.95
	Middling	53.7	0.24	24.4	10.31	6.47
	Tailing	42.4	0.098	7.9	8.14	2.10
		100.0	0.53	100.0	19.2	26.52
Spigot 2	Concentrate	11.0	3.22	76.4	1.82	15.10
	Middling	35.0	0.17	12.8	5.77	2.53
	Tailing	54.0	0.093	10.8	8.91	2.14
		100.0	0.46	100.0	16.5	19.77
Spigot 3	Concentrate	11.9	2.34	69.8	2.25	13.74
	Middling	35.0	1.25	11.0	6.62	2.17
	Tailing 1	46.0	0.064	7.4	8.69	1.46
	Tailing 2	7.1	0.665	11.8	1.34	2.32
		100.0	0.40	100.0	18.9	19.69
Cyclone underflow coarse fraction	Concentrate	8.4	2.87	73.04	1.34	9.88
	Middling	10.0	0.34	10.21	1.58	1.38
	Tailing 1	26.7	0.085	6.84	4.23	0.92
	Tailing 2	54.9	0.060	9.91	8.69	1.34
		100.0	0.33	100.0	15.84	13.52
Cyclone underflow fine fraction	-	-	0.36	-	16.36	15.00
Cyclone overflow		-	0.16	-	13.2	5.50
Original ore		-	0.38	-	100.0	100.0

TABLE 28: WILD CHERRY ORE - RESULTS OF TABLING ORIGINAL CYCLONE UNDERFLOW

Fraction	Cyclone Underflow			Original Ore	
	Weight %	Sn %	Distribution Sn %	Weight %	Distribution Sn %
Concentrate	15.2	1.20	50.6	4.89	14.43
Middling	10.8	0.26	7.8	3.48	2.22
Tailing 1	16.4	0.18	8.2	5.28	2.34
Tailing 2	57.6	0.21	33.4	18.58	9.53
Cyclone underflow	100.0	0.36	100.0	32.30	28.52

TABLE 29: WILD CHERRY ORE - RESULTS OF RETABLING GRAVITY CONCENTRATE

Sized Product	Fraction	Gravity Concentrate			Original Ore	
		Weight %	Sn %	Distribution Sn %	Weight %	Distribution Sn %
Spigot 1	Concentrate	15.2	52.5	87.5	0.12	15.71
	Middling	56.4	1.93	12.0	0.42	2.15
	Tailing	28.4	0.17	0.5	0.21	0.09
		100.0	9.12	100.0	0.75	17.95
Spigot 2	Concentrate	6.7	37.5	79.7	0.12	12.04
	Middling	49.0	1.12	17.5	0.89	2.64
	Tailing	44.3	0.20	2.8	0.81	0.42
		100.0	3.15	100.0	1.82	15.10
Spigot 3	Concentrate	12.1	13.5	73.4	0.27	10.09
	Middling	43.4	1.13	22.0	0.98	3.02
	Tailing	44.5	0.23	4.6	1.00	0.63
		100.0	2.23	100.0	2.25	13.74
Cyclone underflow (coarse fraction)	Concentrate	22.6	11.3	86.3	0.30	8.53
	Middling	17.5	1.08	6.4	0.24	0.63
	Tailing 1	20.1	0.42	2.9	0.27	0.29
	Tailing 2	39.8	0.33	4.4	0.53	0.43
		100.0	2.96	100.0	1.34	9.88

6.2 Middling Regrind

Fractions for regrinding were the middlings from primary table concentration and all fractions, other than concentrates, in the secondary tabling stage. The fractions selected are listed in Table 30.

After thorough mixing of the fractions, regrinding was carried out in the 1 x 2 ft rod mill at a feed rate of 100 lb per hour. Mill discharge was dried and then separated at nominally 53 microns (quartz) in the Dorrco hydrosizer. Screen sizings of the rod mill discharge and the coarse fraction from the hydrosizer separation are shown in Table 31. Weights and tin distribution in the hydrosizer separation are set out in Table 32.

The coarse fraction was tabled and the concentrate from this operation retabled. Results appear in Tables 33 and 34 respectively.

The mineralogical analysis of the concentrate of Table 34 is shown in Table 35. The large amount of opaque minerals and quartz lowered the grade of this fraction. Magnetic separation will remove the iron oxide minerals (opaques) and retabling of the concentrate would remove the quartz and tourmaline. Some tourmaline will report with the magnetic fraction.

TABLE 30: WILD CHERRY ORE – FRACTIONS SELECTED FOR MIDDLING REGRIND

Sized Product	Fraction	Middling Fractions Weight %	Middling Fractions Sn %	Middling Fractions Distribution Sn %	Original Ore Weight %	Original Ore Distribution Sn %
Spigot 1	Middling	33.3	0.24	25.7	10.31	6.47
Spigot 2	"	18.7	0.17	10.2	5.77	2.53
Spigot 3	"	21.4	0.125	8.6	6.62	2.17
	Tailing 2	4.3	0.665	9.2	1.34	2.32
Cyclone u/f (coarse fraction)	Middling	5.1	0.34	5.5	1.58	1.38
Retable Product						
Spigot 1	Middling	1.3	1.93	8.4	0.42	2.15
	Tailing	0.7	0.17	0.4	0.21	0.09
Spigot 2	Middling	2.9	0.12	10.4	0.89	2.64
	Tailing	2.6	0.20	1.7	0.81	0.42
Spigot 3	Middling	3.2	1.13	11.5	0.98	3.02
	Tailing	3.2	0.27	2.8	1.00	0.63
Cyclone u/f (coarse fraction)	Middling	0.7	1.08	2.6	0.24	0.63
	Tailing 1	0.9	0.42	1.2	0.27	0.29
	Tailing 2	1.7	0.33	1.80	0.53	0.43
Combined Middling		100.0	0.31	100.00	30.97	25.17

TABLE 31: WILD CHERRY ORE - SCREEN SIZING OF MIDDLING REGRIND PRODUCTS

Fraction	Rod Mill Discharge	Rod Mill Discharge Coarse Fraction
+ 52	1.2	1.7
- 52 + 72	7.4	10.4
- 72 + 100	14.9	20.6
- 100 + 150	26.2	35.3
- 150 + 200	12.0	16.4
- 200 + 300	10.6	12.0
- 300	27.7	3.6
	100.0	100.0

TABLE 32: WILD CHERRY ORE - WEIGHT AND TIN DISTRIBUTION IN THE HYDROSIZER SEPARATION OF THE GROUND MIDDLING

Fraction	Combined Middling			Original Ore	
	Weight %	Sn %	Distribution Sn %	Weight %	Distribution Sn %
Coarse	71.4	0.36	84.1	22.11	21.17
Fine	28.6	0.17	15.9	8.86	4.00
Combined middling	100.0	0.31	100.0	30.97	25.17

TABLE 33: WILD CHERRY ORE – RESULTS OF TABLING THE GROUND MIDDLING COARSE FRACTION

Fraction	Ground Mid. Coarse Fraction			Original Ore	
	Weight %	Sn %	Distribution Sn %	Weight %	Distribution Sn %
Concentrate	5.4	4.4	62.6	1.20	13.25
Middling	11.8	0.43	13.4	2.62	2.84
Tailing 1	13.8	0.36	13.1	3.05	2.77
Tailing 2	69.0	0.06	10.9	15.24	2.31
Coarse fraction	100.0	0.38	100.0	22.11	21.17

TABLE 34: WILD CHERRY ORE – RESULT OF TABLING THE GRAVITY CONCENTRATE SHOWN IN TABLE 33

Fraction	Gravity Concentrate			Original Ore	
	Weight %	Sn %	Distribution Sn %	Weight %	Distribution Sn %
Concentrate	25.6	13.3	85.5	0.31	11.33
Middling	31.3	0.93	7.3	0.37	0.97
Tailing 1	35.1	0.74	6.5	0.42	0.86
Tailing 2	8.0	0.34	0.7	0.10	0.09
Gravity Concentrate	100.0	3.98	100.0	1.20	13.25

TABLE 35: WILD CHERRY ORE - MINERALOGICAL EXAMINATION OF GRAVITY CONCENTRATE SHOWN IN TABLE 34

Mineral Constituent	Volume per cent
Topaz	12.0
Tourmaling	18.5
Quartz	19.5
Mica	0.5
Zircon	3.5
Rutile	1.5
Cassiterite	4.5
Opaques (mainly iron oxides)	40.0
Total	100.0

Note: The cassiterite present is mainly fine; a few composite particles of cassiterite-quartz were seen. Cassiterite also occurred as free particles up to 80 microns in diameter.

6.3 Magnetic Separation of Gravity Concentrates

Each gravity concentrate was treated in a Stearns magnetic separator at successively higher intensities to produce 4 magnetic fractions. With the Spigot 3 concentrate each magnetic fraction was assayed. The tin distribution in this test is shown in Table 36.

The magnetic fractions from each of the other gravity concentrates were combined and assayed as bulk concentrates in each case. Results are included in Table 37.

TABLE 36: WILD CHERRY ORE - MAGNETIC SEPARATION OF SPIGOT 3 GRAVITY CONCENTRATE

Fraction	Spigot 3 Gravity Concentrate		
	Weight %	Sn %	Distribution Sn %
1st Magnetic	2.5	1.01	0.2
2nd "	8.1	1.03	0.6
3rd "	8.4	1.32	0.8
4th "	7.5	1.60	0.9
Non magnetic	73.5	18.0	97.5
Spigot 3 concentrate	100.0	13.6	100.0

TABLE 37: WILD CHERRY ORE - RESULTS OF MAGNETIC SEPARATION OF GRAVITY CONCENTRATE

Sized Product	Fraction	Gravity Concentrate			Original Ore	
		Weight %	Sn %	Distribution Sn %	Weight %	Distribution Sn %
Spigot 1	Magnetic	11.5	5.4	1.2	0.01	0.19
Concentrate	Non- "	88.5	59.9	98.8	0.11	15.52
		100.0	53.6	100.0	0.12	15.71
Spigot 2	Magnetic	23.8	3.7	2.3	0.03	0.28
Concentrate	Non- "	76.2	48.2	97.7	0.09	11.76
		100.0	37.6	100.0	0.12	12.04
Spigot 3	Magnetic	26.5	1.3	2.5	0.07	0.25
Concentrate	Non- "	73.5	18.0	97.8	0.20	9.84
		100.0	13.6	100.0	0.27	10.09
Cyclone u/f	Magnetic	32.9	1.3	3.6	0.10	0.31
(coarse frac.)	Non- "	67.1	17.3	96.4	0.20	8.22
		100.0	12.0	100.0	0.30	8.53
Regrind Mid.	Magnetic	41.4	2.0	6.1	0.13	0.69
Retable conc.	Non- "	58.6	21.6	93.9	0.18	10.64
		100.0	13.5	100.0	0.31	11.33

6.4 Buckman Table Treatment

Material not treated on the Wilfley tables was combined as shown in Table 38. This material was deslimed by sedimentation at 20 microns (quartz) and the plus 20-micron fraction treated on a Buckman table. Results of desliming at 20 microns are shown in Table 39.

Buckman table operating conditions were similar to those established for the White Crystal sample. The table was fed for two periods of 5 minutes and a concentrate was removed after each period. This rougher concentrate was then cleaned on a table reduced to 3 inches width.

The Buckman table test conditions and results are given in Tables 40 and 41 respectively.

TABLE 38: WILD CHERRY ORE - FRACTIONS SELECTED FOR TREATMENT ON THE BUCKMAN TABLE

Sized Product	Fraction	Buckman Table Feed			Original Ore	
		Weight %	Sn %	Distribution Sn %	Weight %	Distribution Sn %
Cyclone o/f	-	34.4	0.16	22.4	13.20	5.50
Cyclone u/f	Fine	42.5	0.355	61.6	16.36	15.00
Regrind middling	Fine	23.1	0.17	16.0	8.86	4.00
Buckman table feed		100.0	0.25	100.0	38.42	24.50

TABLE 39: WILD CHERRY ORE - RESULTS OF DESLIMING BUCKMAN TABLE FEED

Fraction	Buckman Table Feed			Original Ore	
	Weight %	Sn %	Distribution Sn %	Weight %	Distribution Sn %
+ 20 microns	51.7	0.35	69.3	19.86	16.98
- 20 "	48.3	0.165	30.7	18.56	7.52
Buckman table feed	100.0	0.26	100.0	38.42	24.50

TABLE 40: WILD CHERRY ORE – BUCKMAN TABLE: OPERATING CONDITIONS

Conditions		Rougher Stage	Cleaner Stage
Width of table	inches	5.25	3
Slope of table	in./ft	1.75	1.75
Feed pulp density	% solids	15	10
Feed rate	ml/min	1760	1020
" "	gal/ft width/min	0.9	0.9
Reagent used: Na_2SiO_3	lb/ton	1	1

TABLE 41: WILD CHERRY ORE – RESULTS OF BUCKMAN TABLE CONCENTRATION

Fraction	+ 20 Micron Fraction			Original Ore	
	Weight %	Sn %	Distribution Sn %	Weight %	Distribution Sn %
Cleaner concentrate	5.0	5.15	66.6	0.99	11.31
Cleaner tailing	10.9	0.26	7.3	2.16	1.24
Rougher tailing	84.1	0.12	26.1	16.71	4.43
+ 20 micron fraction	100.0	0.39	100.0	19.86	16.98
Rougher concentrate	15.9	1.80	73.9	3.15	12.55

6.4.1 Discussion of Buckman Table Test

A rougher concentrate was produced assaying 1.80 per cent tin with a recovery of 73.9 per cent (Table 41). On cleaning the grade was raised to 5.15 per cent tin, with a recovery of 90.1 per cent of the tin in the cleaning stage.

6.5 Final Results on Treatment of Wild Cherry Ore

Tin distribution in the final concentrate, tailing and middling fractions are shown in Tables 42 - 44 respectively.

TABLE 42: WILD CHERRY ORE - MATERIAL CLASSED AS CONCENTRATE

Sized Product	Fraction	Original Ore Weight %	Sn %	Distribution Sn %
Spigot 1	Non-magnetic	0.11	58.7	15.52
Spigot 2	"	0.09	48.2	11.76
Spigot 3	"	0.20	18.0	9.84
Cyclone u/f (coarse fraction)	"	0.20	16.2	8.22
Buckman table	Cleaner concentrate	0.99	5.15	11.31
Regrind middling	Non-magnetic	0.18	21.6	10.64
Concentrate		1.8	14.5	67.3

TABLE 43: WILD CHERRY ORE - MATERIAL CLASSED AS TAILING

Sized Product	Fraction	Original Ore Weight %	Sn %	Distribution Sn %
Spigot 1	Tailing	8.14	0.098	2.10
Spigot 2	"	8.91	0.093	2.14
Spigot 3	"	8.69	0.064	1.46
Cyclone u/f (coarse fraction)	Tailing 1	4.23	0.085	0.92
	Tailing 2	8.69	0.060	1.34
Buckman table	-20 micron	18.56	0.165	7.52
	Rougher tailing	16.71	0.12	4.43
Regrind middling	Table tailing	15.24	0.064	2.31
Tailing		89.2	0.09	22.2

TABLE 44: WILD CHERRY ORE - MATERIAL CLASSED AS MIDDLING

Sized Product	Fraction	Original Ore		
		Weight %	Sn %	Distribution Sn %
Spigot 1	Magnetic	0.01	5.4	0.19
Spigot 2	"	0.03	3.68	0.28
Spigot 3	"	0.07	1.28	0.25
Cyclone u/f (coarse fraction)	"	0.10	1.28	0.31
Buckman table	Cleaner tailing	2.16	0.26	1.24
Regrind middling	Retable middling	0.37	0.93	0.97
	" tailing 1	0.42	0.74	0.86
	" " 2	0.10	0.34	0.09
	Table middling	2.62	0.43	2.84
	Table tailing 1	3.05	0.36	2.77
	Retable concentrate) magnetic)	0.13	1.98	0.69
	Middling	9.0	0.44	10.5

6.6 Discussion

Gravity and magnetic separations gave a tin recovery of 66.8 per cent in a fraction classified as a concentrate. The grade of concentrate was low, 14.5 per cent tin, because of:

a. inclusion of Buckman table concentrate assaying 5.15 per cent tin. This material would be upgraded further by tabling or vanning.

b. inclusion of low grade concentrates obtained by tabling Spigot 3 material and cyclone-underflow coarse-fraction.

The grade of these concentrates would be materially increased by retabling.

Further treatment of these fractions was not possible because of the small weights involved.

Tin lost in the tailing amount to 22.2 per cent of the total and was associated with 89.2 per cent of the feed weight. It is considered that this tin would be extremely difficult to recover. The Buckman table tailing might yield additional tin but this is unlikely. The cassiterite in the slime fraction, minus 10 microns is considered unrecoverable.

A middling fraction containing 10.5 per cent of the tin has not been allocated to either the concentrate or the tailing. There is no evidence from the tests to indicate what would ultimately happen to this material. In general the Wild Cherry ore was easier than the White Crystal ore to concentrate and it is considered that ultimate recovery of some of the middling fraction would be possible.

Iron oxide minerals and tourmaline removed by magnetic separation contain approximately 1-2 per cent tin.

7. TREATMENT OF THE COMBINED ORE

The combined ore comprised equal portions (1:1 by weight) of White Crystal and Wild Cherry Ore. The ore samples at minus $^{5}/_{32}$-inch sizing were mixed thoroughly and then reduced to minus 18-mesh in the laboratory rolls in closed circuit with an 18-mesh screen.

The testing programme for the combined ore was similar to that proved in the previous sections. Some deviations were made, however, to study the tabling of fine material and to examine the high tension separation of the gravity concentrate.

The weight of material treated in this section was 1,394 pounds.

7.1 Size Classification and Tin Distribution

The screen sizings of the material produced in the circuit is shown in Table 45. Weight and tin distribution are given in Table 46.

Cyclone underflow was separated in the hydrosizer at nominally 53 microns (quartz). Screen sizings of the coarse and fine fractions from this separation, together with the sizing of the cyclone underflow as a comparison are shown in Table 47. Tin and weight distributions are shown in Table 48.

TABLE 45: COMBINED ORE - SCREEN SIZING OF SIZED PRODUCTS

Fraction Mesh BSS	Sized Product			
	Spigot 1	Spigot 2	Spigot 3	Cyclone Underflow
- 18 + 25	4.5	0.1	-	-
- 25 + 36	14.9	0.8	-	-
- 36 + 52	34.6	7.2	0.1	0.1
- 52 + 72	38.2	41.4	3.6	0.2
- 72 + 100	6.3	42.5	28.8	0.5
- 100 + 150	1.0	7.3	47.8	11.0
- 150 + 200	(-150) 0.5	0.2	10.7	13.3
- 200 + 300	-	0.1	6.2	23.2
- 300	-	0.4	2.8	51.7
	100.0	100.0	100.0	100.0

TABLE 46: COMBINED ORE - WEIGHT AND TIN DISTRIBUTION IN SIZED PRODUCTS

Fraction	Weight %	Sn %	Distribution Sn %
Spigot 1	12.3	0.715	18.44
Spigot 2	20.0	0.50	20.98
Spigot 3	25.0	0.465	24.40
Cyclone underflow	27.7	0.495	28.77
Cyclone oferflow	15.0	0.235	7.41
Original Ore	100.0	0.48	100.0

TABLE 47: COMBINED ORE - SCREEN SIZINGS OF CYCLONE UNDERFLOW PRODUCTS

Fraction Mesh	Cyclone Underflow		
	Original	Coarse	Fine
+ 72	0.3	0.1	-
- 72 + 100	0.5	0.6	0.1
- 100 + 150	11.0	19.6	0.1
- 150 + 200	13.3	22.6	0.3
- 200 + 300	23.2	34.9	4.8
- 300	51.7	22.2	94.7
Total	100.0	100.0	100.0

TABLE 48: COMBINED ORE - WEIGHT AND TIN DISTRIBUTION IN THE HYDROSIZER SEPARATION OF CYCLONE UNDERFLOW

Fraction	Cyclone Underflow			Original Ore	
	Weight %	Sn %	Distribution Sn %	Weight %	Distribution Sn %
Coarse	55.2	0.51	56.2	15.28	16.16
Fine	44.8	0.49	43.8	12.42	12.61
Cyclone underflow	100.0	0.50	100.0	27.70	28.77

7.2 Tabling of Sized Products

The three products from the hydraulic classifier and the two fractions from the hydrosizer were tabled. The fine fraction from the cyclone underflow material was tabled in order to:

1. determine the efficiency of the laboratory table in recovering fine tin (virtually all less than 28 microns in diameter), and

2. remove as much of the tin as possible as a high grade fraction before passing to the Buckman table.

Results of tabling these fractions are shown in Table 49.

A screen analysis was made of the second tailing from the Spigot 1 fraction to determine the distribution of tin. Results are shown in Table 50.

TABLE 49: COMBINED ORE - DISTRIBUTION OF TIN AFTER PRIMARY TABLING

Sized Product	Fraction	Sized Products Weight %	Sized Products Sn %	Sized Products Distribution Sn %	Original Ore Weight %	Original Ore Distribution Sn %
Spigot 1	Concentrate	4.1	13.6	75.0	0.51	13.82
	Middling	17.3	0.455	10.9	2.12	2.01
	Tailing 1	33.3	0.155	7.2	4.10	1.33
	Tailing 2	45.3	0.11	6.9	5.57	1.28
		100.0	0.74	100.0	12.30	18.44
Spigot 2	Concentrate	7.6	5.30	80.4	1.51	16.87
	Middling	17.0	0.195	6.7	3.40	1.40
	Tailing 1	39.9	0.090	7.2	7.99	1.51
	Tailing 2	35.5	0.080	5.7	7.10	1.20
		100.0	0.50	100.0	20.0	20.98
Spigot 3	Concentrate	9.6	4.08	84.1	2.41	20.54
	Middling	32.6	0.12	8.4	8.16	2.04
	Tailing 1	23.2	0.072	3.6	5.79	0.87
	Tailing 2	34.6	0.053	3.9	8.64	0.95
		100.0	0.47	100.0	25.0	24.40
Cyclone u/f (coarse fraction)	Concentrate	4.9	8.05	72.1	0.75	11.65
	Middling	13.6	0.42	10.4	2.08	1.69
	Tailing 1	28.2	0.16	8.2	4.31	1.33
	Tailing 2	53.3	0.095	9.3	8.14	1.49
		100.0	0.55	100.0	15.28	16.16
Cyclone u/f (fine fraction)	Concentrate	3.7	3.40	25.6	0.46	3.33
	Middling	9.8	0.47	9.3	1.22	1.17
	Tailing 1	18.6	0.34	12.7	2.31	1.60
	Tailing 2	67.9	0.385	52.4	8.43	6.61
		100.0	0.50	100.0	12.42	12.61
Cyclone overflow		-	0.235	-	15.0	7.41
Original Ore		-	0.48	-	100.00	100.00

TABLE 50: COMBINED ORE – TIN DISTRIBUTION IN SPIGOT 1, TAILING 2

Fraction Mesh	Spigot 1 — Tailing 2			Original Ore	
	Weight %	Sn %	Distribution Sn %	Weight %	Distribution Sn %
+ 36	42.4	0.125	47.4	2.36	0.61
- 36 + 52	41.5	0.095	35.2	2.31	0.45
- 52 + 72	14.5	0.090	11.6	0.81	0.15
- 72	1.6	0.405	5.8	0.09	0.07
Spigot 1, Tailing 2	100.0	0.11	100.0	5.57	1.28

7.3 Secondary Tabling

The concentrates produced in the primary tabling tests were cleaned further by retabling. Results are given in Tables 51 and 52.

TABLE 51: COMBINED ORE – RESULTS OF SECONDARY TABLING

Sized Product	Fraction	Primary Gravity Concentrate			Original Ore	
		Weight %	Sn %	Distribution Sn %	Weight %	Distribution Sn %
Spigot 1	Concentrate	17.9	53.5	73.2	0.09	10.12
	Middling	33.1	9.05	22.9	0.17	3.16
	Tailing 1	17.0	2.05	2.7	0.09	0.37
	Tailing 2	32.0	0.50	1.2	0.16	0.17
		100.0	13.6	100.0	0.51	13.82
Spigot 2	Concentrate	10.1	41.4	78.3	0.15	13.20
	Middling	35.7	2.52	16.8	0.54	2.84
	Tailing 1	34.2	0.56	3.6	0.52	0.61
	Tailing 2	20.0	0.35	1.3	0.30	0.22
		100.0	5.35	100.0	1.51	16.87
Spigot 3	Concentrate	12.0	26.0	75.6	0.29	15.52
	Middling	15.6	3.6	13.6	0.37	2.78
	Tailing 1	32.6	0.88	6.9	0.79	1.43
	Tailing 2	39.8	0.41	3.9	0.96	0.81
		100.0	4.14	100.0	2.41	20.54
Cyclone u/f (coarse fraction)	Concentrate	13.0	46.1	73.7	0.10	8.59
	Middling	8.2	9.95	10.1	0.06	1.17
	Tailing 1	27.8	3.05	10.4	0.21	1.22
	Tailing 2	51.0	0.92	5.8	0.38	0.67
		100.0	8.12	100.0	0.75	11.65
Cyclone u/f (fine fraction)	Concentrate	20.6	11.6	63.9	0.10	2.06
	Middling	30.0	2.68	21.6	0.14	0.70
	Tailing 1	49.4	1.09	14.5	0.22	0.47
		100.0	3.73	100.0	0.46	3.23

TABLE 52: COMBINED ORE - RESULTS OF SECONDARY TABLING OF THE CYCLONE UNDERFLOW FINE FRACTION

Fraction	Cyclone U/F Fine Fraction			Original Ore	
	Weight %	Sn %	Distribution Sn %	Weight %	Distribution Sn %
Concentrate	3.7	32.2	31.6	0.02	1.02
Middling	16.9	7.11	32.3	0.08	1.04
Tailing 1	30.0	2.68	21.6	0.14	0.70
Tailing 2	49.4	1.10	14.5	0.22	0.47
Cyclone underflow Fine fraction	100.0	3.73	100.0	0.46	3.23

7.4 Regrinding of Middling Fraction

Middling fractions were selected as in the previous test work, and are listed in Table 53.

Grinding was carried out in the 1 x 2 ft rod mill at 93 lb per hour. This material was passed immediately to the hydrosizer and separated at a nominal size of 53 microns (quartz). Results of this separation are shown in Table 54.

The coarse fraction was tabled and the concentrate retabled. Results are given in Tables 55 and 56.

Mineralogical examination of the middling and tailing 1 from the second tabling stage (Table 56) yielded the results given below:

Mineral Constituents	Volume Per Cent	
	Middling	Tailing 1
Topaz	73.5	75.0
Tourmaline	3.5	5.5
Quartz	1.5	1.0
Mica	0.5	2.0
Zircon	1.5	0.5
Rutile	0.5	-
Cassiterite	2.0	1.0
Opaques (mainly iron oxides)	17.0	15.0
Total	100.0	100.0

Approximately 50 per cent of the cassiterite is composite particles with topaz, tourmaline and mica. The maximum size of the cassiterite particles in these composites is 20 microns in diameter. Average size is approximately 15 microns. Most of these composites are made up of large volumes of gangue mineral with small particles of cassiterite spotting them. Maximum size of the free cassiterite grains is less than 30 microns in diameter.

A small portion of the fine fraction was tabled to test the feasibility of obtaining higher grade concentrates and higher recoveries then when using the Buckman table. Results of this test appear in Table 57. The low percentage of tin recovered in this section indicated that this fraction would be better treated in the Buckman table circuit.

Examination of the retable [illegible], middling and tailing 1 from the coarse fraction indicates that approximately 50 per cent of the cassiterite particles are composite grains with topaz, tourmaline and mica. All cassiterite particles are less than 30 microns in diameter. In composite particles cassiterite is much the minor mineral. The major portion, 75 per cent, of each fraction is topaz with minor amounts of tourmaline, quartz, mica, and zircon. Approximately 15 per cent of each sample consists of opaque minerals, mainly iron oxides. Volume percentages are referred to in each case. Retabling of these fractions would remove most of the topaz and minor minerals. However, it seems that at least fifty per cent of the cassiterite will be lost as composits with these discarded minerals. Regrinding to free composite cassiterite will place the free mineral in the minus 15-micron size-range so the maximum recovery that can be expected of this material is the overall recovery of the Buckman table section.

TABLE 53: COMBINED ORE - FRACTIONS SELECTED FOR MIDDLING REGRIND

Sized Product	Fraction	Middling Fraction			Original Ore	
		Weight %	Sn %	Distribution Sn %	Weight %	Distribution Sn %
Primary Tabling						
Spigot 1	Middling	8.6	0.455	8.2	2.12	2.01
" 2	"	13.8	0.195	5.6	3.40	1.40
" 3	"	33.2	0.120	8.4	3.16	2.04
Cyclone u/f	"	8.5	0.420	7.5	2.08	1.69
(coarse fraction)	Tailing	17.5	0.16	5.9	4.31	1.33
Secondary Tabling						
Spigot 1	Middling	0.7	9.05	12.9	0.17	3.16
	Tailing 1	0.4	2.05	1.6	0.09	0.37
	Tailing 2	0.7	0.50	0.7	0.16	0.17
Spigot 2	Middling	2.2	2.52	11.6	0.54	2.84
	Tailing 1	2.1	0.565	2.5	0.52	0.61
	Tailing 2	1.2	0.35	0.90	0.30	0.22
Spigot 3	Middling	1.5	3.60	11.4	0.37	2.78
	Tailing 1	3.2	0.88	6.0	0.79	1.43
	Tailing 2	3.9	0.42	3.4	0.96	0.81
Cyclone u/f	Middling	0.2	9.95	5.0	0.06	1.17
(coarse	Tailing 1	0.8	3.05	5.4	0.21	1.22
fraction)	Tailing 2	1.5	0.92	3.0	0.38	0.67
Combined middling		100.0	0.48	100.0	24.62	23.92

TABLE 54: COMBINED ORE - WEIGHT AND TIN DISTRIBUTION IN THE HYDROSIZER SEPARATION OF THE GROUND MIDDLING

Fraction	Ground Middling			Original Ore	
	Weight %	Sn %	Distribution Sn %	Weight %	Distribution Sn %
Coarse	56.1	0.59	69.2	13.81	16.56
Fine	43.9	0.335	30.8	10.81	7.36
Ground middling	100.0	0.48	100.0	24.62	23.92

TABLE 55: COMBINED ORE - RESULTS OF TABLING GROUND MIDDLING COARSE FRACTION

Fraction	Ground Middling Coarse Fraction			Original Ore	
	Weight %	Sn %	Distribution Sn %	Weight %	Distribution Sn %
Concentrate	14.4	3.49	82.0	1.99	13.57
Middling	21.6	0.23	8.1	2.98	1.34
Tailing 1.	28.7	0.105	4.9	3.96	0.82
" 2.	35.3	0.087	5.0	4.88	0.83
Coarse fraction	100.0	0.61	100.0	13.81	16.56

TABLE 56: COMBINED ORE - RESULTS OF RE-TABLING THE CONCENTRATE AS SHOWN IN TABLE 55

Fraction	Table Concentrate			Original Ore	
	Weight %	Sn %	Distribution Sn %	Weight %	Distribution Sn %
Concentrate	5.6	38.8	63.7	0.11	8.64
Middling	11.8	3.95	13.5	0.23	1.83
Tailing 1	31.7	1.51	13.9	0.63	1.89
Tailing 2	50.9	0.605	8.9	1.02	1.21
Table concentrate	100.0	3.45	100.0	1.99	13.57

TABLE 57: COMBINED ORE - RESULTS OF TABLING GROUND MIDDLING FINE FRACTION

Fraction	Ground Middling Fine Fraction			Original Ore	
	Weight %	Sn %	Distribution Sn %	Weight %	Distribution Sn %
Concentrate	1.1	4.50	15.2	0.12	1.12
Middling	8.2	0.745	18.8	0.89	1.38
Tailing 1	25.7	0.24	19.0	2.78	1.40
Tailing 2	65.0	0.235	47.0	7.02	3.46
Fine fraction	100.0	0.33	100.0	10.81	7.36

7.5 Magnetic Separation of the Gravity Concentrate

Concentrates obtained from the tabling of the hydraulic classifier spigot products and the coarse fraction of the cyclone underflow were treated in the Stearns magnetic separator. The material was passed through the machine at low intensity and then the non-magnetic fraction repassed at successively higher magnetic intensities. The four fractions produced were combined for tin assay. Results appear in Table 58.

TABLE 58: COMBINED ORE - RESULTS OF MAGNETIC SEPARATION OF GRAVITY CONCENTRATES

Sized Product	Fraction	Gravity Concentrate Weight %	Gravity Concentrate Sn %	Gravity Concentrate Distribution Sn %	Original Ore Weight %	Original Ore Distribution Sn %
Spigot 1	Magnetic	7.2	9.7	1.2	0.01	0.13
	Non- "	92.8	60.3	98.8	0.08	9.99
		100.0	56.6	100.0	0.09	10.12
Spigot 2	Magnetic	9.4	6.8	1.6	0.01	0.21
	Non- "	90.6	43.6	98.4	0.14	12.99
		100.0	40.1	100.0	0.15	13.20
Spigot 3	Magnetic	7.1	3.2	0.9	0.02	0.14
	Non- "	92.9	26.8	99.1	0.27	15.38
		100.0	25.1	100.0	0.29	15.52
Cyclone u/f (coarse fraction)	Magnetic	4.4	3.8	0.4	*0.01	0.03
	Non- "	95.6	45.4	99.6	0.10	8.56
		100.0	43.6	100.0	0.10	8.59
Regrind middling retable concentrate	Magnetic	6.3	4.75	0.8	0.01	0.07
	Non- "	93.7	41.1	99.2	0.10	8.57
		100.0	38.9	100.0	0.11	8.64

* Less than.

7.6 High Tension Separation of Gravity Concentrates

The non-magnetic fractions of the gravity concentrates were subjected to high tension separation in a Carpco roll type separator.

A high grade concentrate was produced and the tailing repassed to produce a second concentrate and a final tailing. Results are shown in Table 59.

TABLE 59: COMBINED ORE - RESULTS OF HIGH TENSION SEPARATION OF NON-MAGNETIC CONCENTRATES

Sized Product	Fraction	Non-Magnetic Concentrate Weight %	Non-Magnetic Concentrate Sn %	Non-Magnetic Concentrate Distribution Sn %	Original Ore Weight %	Original Ore Distribution Sn %
Spigot 1	Concentrate 1	69.3	66.0	76.0	0.055	7.59
	" 2	11.2	70.7	13.1	0.009	1.31
	Tailing	19.5	33.7	10.9	0.016	1.09
		100.0	60.2	100.0	0.080	9.99
Spigot 2	Concentrate 1	24.5	65.0	36.6	0.033	4.76
	" 2	15.5	63.6	22.6	0.023	2.93
	Tailing	60.0	29.6	40.8	0.084	5.30
		100.0	43.5	100.0	0.140	12.99
Spigot 3	Concentrate 1	10.4	61.2	23.0	0.028	3.54
	" 2	9.5	61.0	21.1	0.026	3.24
	Tailing	80.1	19.2	55.9	0.216	8.60
		100.0	27.5	100.0	0.27	15.38
Cyclone u/f (coarse fraction)	Concentrate 1	45.9	60.0	61.3	0.046	5.25
	" 2	6.4	48.9	7.0	0.006	0.60
	Tailing	47.7	29.8	31.7	0.048	2.71
		100.0	44.9	100.0	0.100	8.56
Regrind middling (coarse fraction)	Concentrate 1	43.5	56.7	60.0	0.04	5.15
	" 2	11.2	50.2	13.7	0.01	1.17
	Tailing	45.3	23.9	26.3	0.05	2.25
		100.0	41.1	100.0	0.10	8.57

7.7 Buckman Table Treatment

The fine fractions produced in grinding the ore and middlings were combined (see Table 60), and prepared for treatment on the Buckman table by desliming at 20 microns. The results of this desliming are shown in Table 61. The plus 20-micron fraction was tabled under the conditions shown in Table 62. Results are shown in Table 63.

TABLE 60: COMBINED ORE - FRACTIONS SELECTED FOR TREATMENT ON THE BUCKMAN TABLE

Sized Product	Fraction	Buckman Table Feed			Original Ore	
		Weight %	Sn %	Distribution Sn %	Weight %	Distribution Sn %
Cyclone o/f	-	39.5	0.235	29.4	15.00	7.41
Cyclone u/f	Table Mid.	3.2	0.47	4.8	1.22	1.17
(fine fraction)	" Tail. 1.	6.1	0.34	6.6	2.31	1.60
	- ditto - 2.	22.2	0.385	27.0	8.43	6.61
	Retable tailing	0.6	1.095	2.0	0.22	0.47
Regrind middling	Fine	28.4	0.335	30.2	10.81	7.36
Buckman table feed		100.0	0.32	100.0	37.99	24.62

TABLE 61: COMBINED ORE - RESULTS OF DESLIMING BUCKMAN TABLE FEED AT 20 MICRONS (Quartz)

Fraction	Buckman Table Feed			Original Ore	
	Weight %	Sn %	Distribution Sn %	Weight %	Distribution Sn %
+ 20 microns	50.6	0.367	68.9	19.22	16.96
- 20 "	49.4	0.17	31.1	18.77	7.66
Table feed	100.0	0.27	100.0	37.99	24.62

TABLE 62: COMBINED ORE - BUCKMAN TABLE OPERATING CONDITIONS

Conditions		Rougher Stage	Cleaner Stage
Width of table	inches	5.25	3
Slope of table	in./ft	1.75	1.75
Feed pulp density	% solids	15	10
Feed rate:	ml/min	1820	1020
	gal/ft width/min	0.9	0.9
Reagent used: Na_2SiO_3	lb/ton	1	1

TABLE 63: COMBINED ORE - RESULTS OF BUCKMAN TABLE CONCENTRATION

Fraction	Plus 20-Micron Material			Original Ore	
	Weight %	Sn %	Distribution Sn %	Weight %	Distribution Sn %
Cleaner concentrate	4.9	4.55	59.5	0.94	10.09
Cleaner tailing	13.4	0.40	14.4	2.58	2.44
Rougher tailing	81.7	0.12	26.1	15.70	4.43
+ 20 microns	100.0	0.375	100.0	19.22	16.96
Rougher concentrate	18.3	1.51	73.9	3.52	12.53

A rougher concentrate was produced assaying 1.50 per cent tin with a recovery of 73.8 per cent of the tin present. On cleaning, the grade of the rougher concentrate was raised to 4.55 per cent tin with a recovery of 80.5 per cent in the cleaning stage.

A mineralogical examination of the Buckman table concentration was made. The material was first split in heavy liquids (SG 2.85) producing a heavy fraction containing 44.5 per cent of the total sample. This fraction was then examined to determine the particle size of the cassiterite and the proportion to total free cassiterite particles.

Free cassiterite formed approximately 60 per cent of the total free and composite cassiterite grains. The free cassiterite was between 13 and 45 microns in diameter. The coarse size of the cassiterite grains appears anomalous as coarse cassiterite should have been removed during size separation. Cassiterite in the composite grains had an average diameter of approximately 20 microns. The heavy fraction contained approximately 20 per cent of opaque minerals, mainly iron oxides.

7.8 Final Results on Treatment of the Combined Ore

Final results are grouped in Tables 64, 65 and 66, showing the weight and tin distribution in the final combined concentrate, tailing and middling respectively.

TABLE 64: COMBINED ORE - MATERIAL CLASSED AS CONCENTRATE

Sized Product	Fraction	Original Ore		
		Weight %	Sn %	Distribution Sn %
Spigot 1	Non-magnetic	0.08	60.3	9.99
" 2	- ditto -	0.14	43.6	12.99
" 3	"	0.27	26.8	15.38
Cyclone underflow (coarse fraction)	"	0.10	45.4	8.56
Cyclone underflow (fine fraction)	Retable conc.	0.10	11.6	2.06
Buckman table	Cleaner conc.	0.94	4.55	10.09
Regrind middling	Non-magnetic	0.10	41.2	8.37
Total concentrate		1.7	18.7	67.6

TABLE 65: COMBINED ORE - MATERIAL CLASSED AS TAILING

Sized Product	Fraction	Original Ore Weight %	Original Ore Sn %	Original Ore Distribution Sn %
Spigot 1	Tailing 1	4.10	0.155	1.33
	" 2	5.57	0.11	1.28
Spigot 2	Tailing 1	7.99	0.09	1.51
	" 2	7.10	0.08	1.20
Spigot 3	Tailing 1	5.79	0.072	0.87
	" 2	8.64	0.053	0.95
Cyclone underflow (coarse fraction)	Tailing 2	8.14	0.095	1.49
Buckman table	-20 micron	18.77	0.17	7.66
	Rougher tailing	15.70	0.12	4.43
Regrind middling	Table tailing 1	3.96	0.105	0.82
	" " 2	4.88	0.087	0.83
Total tailing		90.7	0.12	22.4

TABLE 66: COMBINED ORE - MATERIAL CLASSED AS MIDDLING

Sized Product	Fraction	Original Ore		
		Weight %	Sn %	Distribution Sn %
Spigot 1	Magnetic	0.01	9.7	0.[illegible]
" 2	"	0.01	6.8	0.[illegible]
" 3	"	0.02	3.2	0.14
Cyclone underflow (coarse fraction)	"	0.01	5.8	0.03
Cyclone underflow (fine fraction)	Retable middling	0.14	2.68	0.70
Buckman table	Cleaner tailing	2.58	0.40	2.44
Regrind middling	Retable middling	0.23	3.95	1.83
	Retable tailing 1	0.63	1.51	1.89
	- ditto - 2	1.02	0.605	1.21
	Table middling	2.98	0.23	1.34
	Magnetic	0.01	4.75	0.07
Combined middling		7.6	0.62	10.0

8. GENERAL DISCUSSION

The system of gravity concentration and magentic separation gave a concentrate containing 67.6 per cent of the tin present in the original ore. This recovery was contained in a combined concentrate assaying 18.7 per cent tin. The low grade of the concentrate was due to the inclusion of two low-grade fine tin fractions. The laboratory equipment available was not suitable for the treatment of very fine material. It is expected that plant-scale slime tables or vanners would upgrade these fine products to market grade concentrates.

Waste material was contained in a fraction representing 90.7 per cent by weight of the original ore and containing 22.4 per cent of the tin. Very little of the tin in this fraction is considered recoverable, with the exception of tailing from Spigot 1 classifier products.

The middling fraction contains 10.0 per cent of the tin present in the original ore at a grade of 0.62 per cent tin. This tin cannot be allocated to either the concentrate or tailing without locked plant tests. The safest assumption that can be made is that tin recouped from this fraction would make up for losses in bringing the final concentrate to market grade, so giving the overall recovery of approximately 68 per cent of the tin in the combined ore.

It will be noticed that the overall recoveries in the White Crystal ore are much lower than those obtained with the combined ore. This is partly due to the finer crushing and grinding given to the combined ore. This moves a greater portion of the feed into the middle size-ranges so allowing advantage to be taken of the lower grade tailings from these sections. The screen sizings of the crushed and ground material from each ore is shown in Table 67.

TABLE 67: OVERALL SIZING OF WHITE CRYSTAL, WILD CHERRY AND THE COMBINED ORE

Fraction	White Crystal	Wild Cherry	Combined Ore
+ 25	0.2	0.4	0.8
- 25 + 36	1.8	3.1	2.0
- 36 + 52	13.4	11.7	5.8
- 52 + 72	21.0	16.3	13.9
- 72 + 100	12.2	13.2	16.5
- 100 + 150	9.5	10.9	16.5
- 150 + 200	9.3	10.8	6.4
- 200 + 300	5.8	6.8	8.0
- 300	26.8	26.8	30.1
Total	100.0	100.0	100.0

8.1 Crushing and Grinding

Close control is required in grinding to lessen over-grinding of the cassiterite particles. Grinding to 97.5 per cent passing 36-mesh gave good tin recovery.

In practice over-grinding could be reduced by using a DSM screen rather than hydraulic classification for size separation at 36-mesh. This method would remove 52 and 72-mesh cassiterite particles which report with the plus 36-mesh material in the hydraulic classifier.

Treatment of the coarser material is possible, as shown in the preliminary treatment of the White Crystal ore (Table 2). This indicated that approximately 56 per cent of the tin in this fraction could be recovered in 15 per cent of the weight in one tabling stage. Middling and tailing from this test would have to be ground, classified and treated to maintain the necessary recovery. If a coarse recovery technique could be developed upgrading of the tin concentrates would be easier and further investigation of this aspect could be worthwhile.

8.2 Primary and Secondary Tabling

Two-stage tabling produced concentrates which in most cases assayed in excess of 40 per cent tin. However, Spigot 3 material (combined ore) gave only 26 per cent tin. This is attributed to the large amount of concentrate taken and improved operation could increase this grade to that of the other major gravity concentrates. Examination of the high-tension tailing from this fraction indicated that the major portion of the cassiterite particles are free and could be separated from the gangue particles by further tabling.

The fine fraction of the cyclone underflow, when tabled, produced a concentrate assaying 3.4 per cent tin. Retabling of this concentrate produced a secondary concentrate assaying 32.2 per cent tin. The concentrate was combined with the middling to give a total concentrate of 11.6 per cent tin and a recovery of 63.9 per cent of the tin present in the primary table concentrate. The remaining fraction, excluding the first tailing from the retabling of the concentrate, was further treated on the Buckman table.

Tabling of fine concentrate was difficult with the laboratory table; however, it is considered that better recoveries should be possible on a plant size slime table. This section of the work does indicate that tabling to high grades, plus 32 per cent tin, could be accomplished with a portion of the fine material. Desliming of this material at approximately 20 microns (quartz) would allow better table operation and so improve grade.

8.3 Middling Regrind

Tabling of the plus 300-mesh fraction after regrinding of middling fractions produced good grade tin concentrates (38.8 per cent tin). Of the tin present in the middling fraction, 69.2 per cent reported in the plus 300-mesh fraction. Tabling of this fraction and retabling of the concentrate produced recovered 36.2 per cent of the tin in the combined middling fractions in a concentrate of 38.8 per cent tin.

Grain counts on the middling and first tailing from the secondary tabling of the reground middling indicate that the major mineral present was topaz (75 per cent by volume) with 50 per cent of the cassiterite as composite particles with topaz, tourmaline and mica. The remaining 50 per cent of cassiterite is free and is likely to be recovered by retabling; however, regrinding of the composite particles would liberate the tin mineral particles at a very fine size-range, with the usual low recoveries.

Tabling of the fine fraction of the reground middling was not successful. The whole of this material was sent to the Buckman table for treatment.

8.4 High Tension Separation

This form of separation showed that it was capable of producing high grade concentrates. However, recoveries of tin fall off markedly with lowering of feed-grade and decreasing particle size. Tests indicated that concentrates from the three spigot products could be treated successfully by passing the material once to produce a concentrate and then repassing the tailing to produce a second concentrate or middling and a final tailing. Locked tests on larger samples than those available would be required to evaluate this method fully. The cyclone underflow gave a good first concentrate, 60 per cent tin, a 48.9 per cent tin middling and a tailing of 29.8 per cent tin, containing 31.7 per cent of the tin in the separator feed. Examination of the tailing showed the cassiterite particles present to be much smaller than the bulk of the gangue minerals. Gangue minerals were approximately 300-mesh or less in size. Concentrate and middling from this test were much larger in particle size and could be further increased in grade by retreatment in the high tension machine. Without experimental work being carried out on this tailing in a high tension machine designed for treatment of very fine particles, it is suggested that final upgrading of the tailing could best be done on slime tables, vanners or kievs.

In general, screen sizing of the feed to the high tension separator would improve this form of concentration.

8.5 Magnetic Separation

Magnetic separation is required to remove magnetic material which lowers the grade of the concentrates. Wild Cherry Ore gravity concentrates contain large amounts of opaque minerals, mainly iron oxides, which can be removed by magnetic separation. Some tourmaline is also removed. White Crystal Ore contains much less of these minerals, usually resulting in small fractions of higher tin grade than produced from the Wild Cherry Ore. The combined ore has a proportional amount of magnetic material.

Magnetic separation is essential for the final upgrading of the regrind middling concentrate from the Wild Cherry Ore and combined ores.

The magentic fractions contain only a small amount of tin, but are relatively high-grade. Further test work is warranted to examine this separation problem.

In the absence of detailed mineralogical description of this fraction, it seems likely that careful magnetic retreatment would result in a tourmaline-rich tin fraction suitable for regrinding and further gravity concentration.

8.6 Buckman Table Concentration

Feed to this section amounted to 38.0 per cent weight containing 24.6 per cent of the tin present in the original ore. Of this amount, 18.8 per cent weight and 7.7 per cent of the tin is removed as a minus 20-micron (quartz) slime fraction.

The plus 20-micron fraction contained 19.2 per cent of the weight and 17.0 per cent of the tin in the original ore. Treatment on the Buckman table produced a cleaner concentrate containing 59.5 per cent of the tin present in the plus 20-micron fraction. Grade of this concentrate was 4.55 per cent tin and represented 10.1 per cent of the tin and 0.9 per cent weight of the original ore.

No cassiterite particles less than 13 microns in diameter could be found in the Buckman cleaner concentrate. It is assumed that cassiterite finer than 13 microns diameter was not recovered on the Buckman table under the present test conditions.

Cassiterite greater than 13 microns diameter should concentrate on slime tables and vanners with final upgrading in kievs.

8.7 Treatment of the Minus 20-Micron Slime

Cassiterite present in this material is 10 microns or less in diameter. It is unlikely that any of this cassiterite can be collected by economic methods.

8.8 Assay Results

Comparison of the assay results has presented some difficulties. In some cases assay values have been erratic and have not allowed reasonable calculated head grades. This has been due to sampling errors as assay results can be repeated, usually to within 1 per cent of the original value. Most errors occurred in high-grade samples where the small amounts of material available for assay made sampling very difficult. Wherever sufficient sample was available at low grade the sampling of the fraction was satisfactory. To average out these results a system of progressive tin distribution has been used. In each case the tin distribution in the size fractions, and the individual distributions in each separation has been taken as correct.

9. PLANT-SCALE TABLING

9.1 Aim

The aim of this section of the work was:

1. To determine the recovery of tin possible in a concentrate containing 60 per cent or more tin.
2. To determine capacities of plant-size shaking tables when treating sized fractions of Ardlethan tin ore.

9.2 Sample

A grab sample was used in this work, drawn from bins containing the residues of the original 10-ton samples. Equal weights of the White Crystal and Wild Cherry Ores were mixed. This mixed sample was treated as set out in Section 9.3.

9.3 Test Procedure

The original sample (minus $^5/_{32}$ inch) was crushed to pass an 18-mesh screen. This material was then ground to minus 36-mesh and hydraulically sized into four fractions, viz. Spigot 2, Spigot 3, cyclone underflow and cyclone overflow.

The coarsest fraction, Spigot 2, was tabled on a No. 11D Wilfley table to produce a concentrate, middling and tailing. The tailing was rejected as a waste product. (Two middling fractions were formed during treatment, the first being recycled to the head of the table and the second held for regrinding). The middling fraction for regrinding varied between 9 and 16 per cent of the table feed when treating the first three fractions.

The concentrate from this separation was further upgraded on a laboratory-sized Wilfley table. The tailing from this separation was added to the table middling and reground in a 1 x 2 ft rod mill. The ground material was sized, at a nominal 300-mesh quartz particle size, in a Dorrco hydrosizer. Plus 300-mesh material was added to the next size fraction and the minus 300-mesh material to the next fraction but one. In the case of the Spigot 2 fraction, the plus 300-mesh material was added to Spigot 3 and the fine fraction to the cyclone underflow.

Each size fraction was treated in a similar manner. Middlings from the cyclone underflow were reground and added without sizing to the cyclone overflow.

Table concentrate from the cyclone overflow was not retabled on the laboratory Wilfley table. The middling from this section was held as a final middling (Table 69).

The four concentrates produced were treated separately in a magnetic separator (Stearns pick-up type) to reject a magnetic fraction. The magnetic fractions were classed as a final middling (Table 69).

The non-magnetic concentrates were separately screened and the screened fraction treated in a high tension separator. This unit produced high-grade concentrates and low-grade tailings. The tailings were panned by hand to recover any free cassiterite. In some cases grinding was required to liberate locked cassiterite found in the coarser fractions. Concentrates from high tension separation and panning were combined.

Material in the concentrates from the cyclone underflow and overflow finer than 300-mesh was not treated in this manner, as the high tension machine could not effect a suitable separation at this size. However, only the minus 300-mesh fraction from the cyclone overflow required treatment to bring it to market grade. Spot assays of the two minus 300-mesh fractions showed 66.1 and 36.6 per cent tin respectively, and they were added to the final concentrate.

Pan tailings were grouped together as a final middling fraction (Table 69).

The final concentrate was produced by combining, in the proper ratio, the various concentrates from the size fraction.

9.4 Results

The overall results are set out in Table 68. Grades and tin distributions of the components of the middling fraction are shown in Table 69.

TABLE 68: COMBINED ORE TEST RESULTS

Fraction	Weight %	Sn %	Distribution Sn %
Concentrate	0.52	60.0	61.9
Middling	1.07	2.3	5.0
Tailing	98.41	0.17	33.1
Feed	100.00	0.50	100.0

TABLE 69: COMBINED ORE MIDDLING COMPONENTS

Fraction	Weight %	Sn %	Distribution Sn %
Magnetic	0.05	8.0	0.8
Pan tailing	0.13	5.2	1.4
Cyclone overflow - middling	0.89	1.6	2.8
Total middling	1.07	2.3	5.0

The sizings of the three coarse fractions are shown in Table 70, and Wilfley table capacities in Table 71.

TABLE 70: COMBINED ORE - SIZINGS OF FRACTIONS

Fraction Mesh		Spigot 2		Spigot 3	Cyclone Underflow
+ 25		2.5		-	-
- 25 + 36		8.4		0.2	-
- 36 + 52		25.2		1.6	-
- 52 + 72		44.9		17.5	0.2
- 72 + 100		14.6		43.6	3.6
- 100 + 150		3.2		28.2	20.6
- 150 + 200	(-150)	1.2		5.5	13.8
- 200 + 300		-	(-200)	3.4	19.4
- 300		-		-	42.4
		100.0		100.0	100.0

TABLE 71: COMBINED ORE - CAPACITY OF WILFLEY TABLE

Fraction	Weight of Feed %	Tons/24 Hours
Spigot 2	23.5	12.9
Spigot 3	27.5	6.4
Cyclone underflow	36.3	2.3
Cyclone overflow	12.7	5.8*

* Estimate of sand fraction actually treated was 1.9 tons/24 hours. The remaining material was very fine and passed immediately to the tailing as a suspension.

The results of assaying certain fractions obtained in the production of the final concentrate are shown in Table 72. Screen sizings of the various non-magnetic concentrates and the final tin concentrate are given in Table 73.

TABLE 72: COMBINED ORE – TIN CONTENT OF TABLE CONCENTRATE

Size Fraction	Concentrate	Assay Sn %
Spigot 2	Primary table concentrate	29.5
	Secondary - ditto -	59.4
Spigot 3	Primary "	37.0
	Secondary "	59.3
Cyclone underflow	Primary "	29.8
	Secondary "	48.4
Cyclone overflow	Primary "	20.3

TABLE 73: COMBINED ORE – SCREEN SIZINGS OF NON-MAGNETIC FINAL CONCENTRATES

Screen Size	Fraction				
	Spigot 2	Spigot 3	Cyclone Underflow	Cyclone Overflow	Final Concentrate
+ 36	0.3	-	-	-	-
- 36 + 52	0.3	-	-	-	-
- 52 + 72	2.7	0.2	0.3	0.5*	-
- 72 + 100	23.2	2.6	1.3	0.6	3.7
- 100 + 200	62.0	54.7	24.9	41.3	32.0
- 200 + 300	8.9	31.5	26.1	25.3	24.8
- 300	2.6	11.0	47.4	32.3	39.5
	100.0	100.0	100.0	100.0	100.0

* Coarse gangue minerals only.

9.5 Discussion

Results obtained in this stage of the experimental work indicate that the minimum amount of recoverable tin, at 60 per cent grade, is 61.9 per cent of the tin in the mixed ore.

Greater recovery is possible by tabling of more closely-sized fractions. Shaking tables fitted with slime decks and Buckman tables would recover fine tin now lost during treatment of the cyclone fractions. However, no assessment can be made of the amount of additional recovery possible.

Final concentrate grade can be increased with some small loss of tin by the grinding and reconcentration of the plus 150-mesh material in the concentrate. The fine minus 300-mesh material consists mainly of fine mineral particles and should respond to kieving as a final means of concentrate up-grading.

Table capacity figures quoted in Table 71 are low by normal practice. However, the table was well loaded during each test and it was thought unwise to increase the feed rate, as recovery undoubtedly would have suffered. The figures quoted were used to design the treatment plant shown in Figure 4. Therefore, the number of tables quoted in this flowsheet will be the maximum number required.

10. RECOMMENDATIONS FOR TREATMENT PROCEDURES

The flowsheet outlined for treatment of combined ore is based on the experimental work already described. The following assumptions have been made in order to establish equipment requirement.

Daily capacity 1000 tons/day

Operating Time	hr/day	days/week
Crushing	8	5
Concentrating	24	5

It has been assumed that a ¾ yd shovel will be used in mining and the crushing equipment has been selected to match.

The recommended flowsheet is shown in Figures 2, 3 and 4. These show the crushing, grinding and gravity sections respectively. The individual items are numbered and are described in Table 74.

The flowsheet and equipment as outlined should give results comparable with those obtained in Section 11 of this report.

Three variations to the above flowsheet should be considered, these are:

a. installation of a jig in closed circuit with the rod mill (see Figure 5). This should permit removal of tin at the coarsest size possible thus reducing slime losses. The jig concentrate would require further comminution and concentration to achieve market grade.

b. Humphrey spirals are a possible alternative to gravity tables for treating material coarser than 200-mesh.

c. Hydroclassification prior to gravity concentration would be improved by a thickening stage after screening. Cyclone underflow would be ideal feed for hydroclassification. A possible flowsheet is shown in Figure 6.

FIGURE 2: RECOMMENDED TREATMENT PLANT

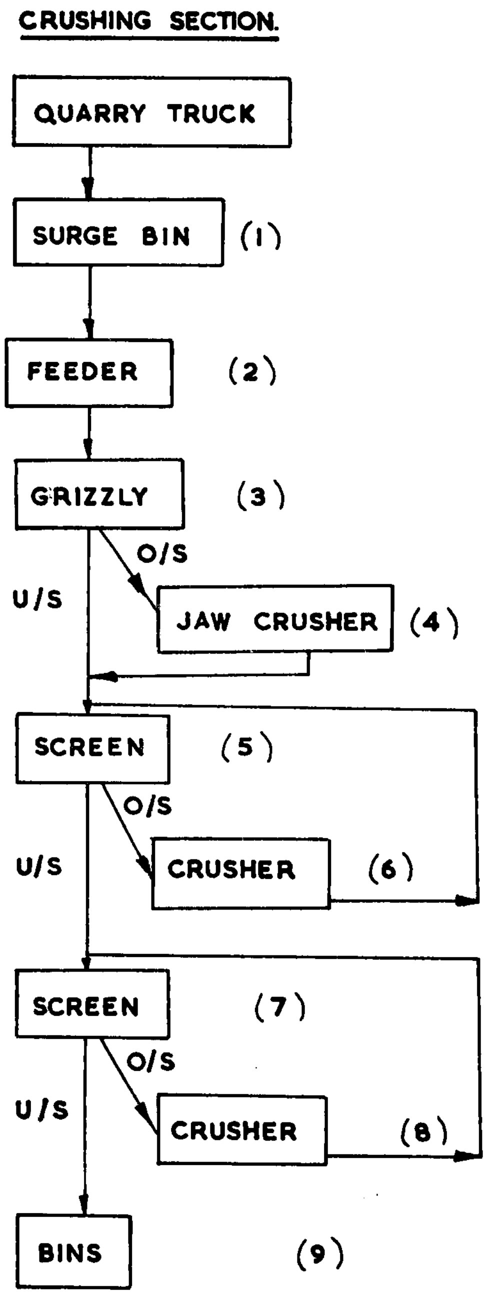

FIGURE 3: RECOMMENDED TREATMENT PLANT

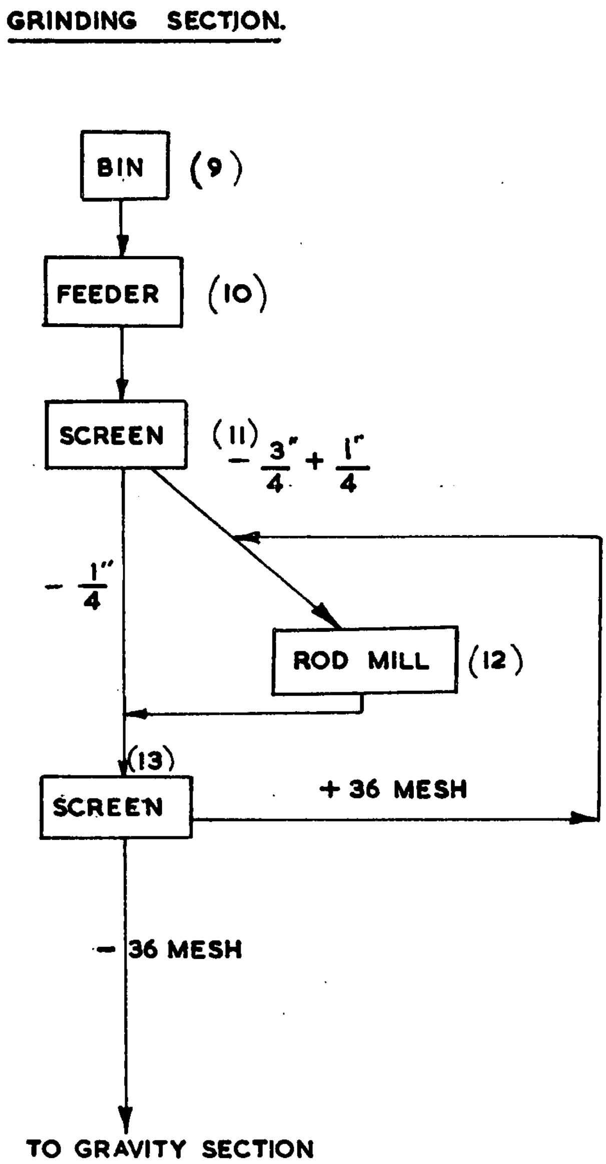

FIGURE 4: RECOMMENDED TREATMENT PLANT
GRAVITY SECTION

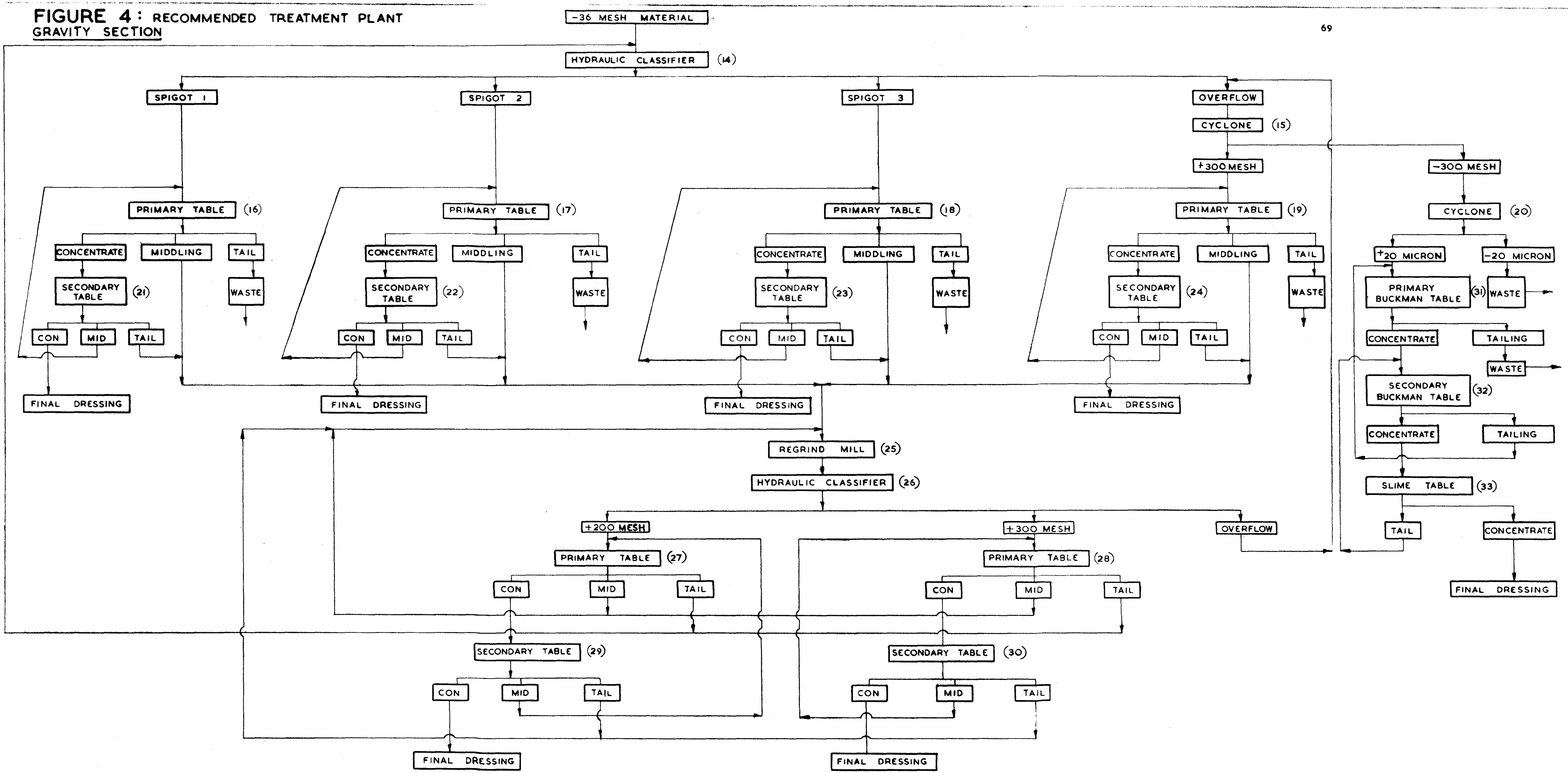

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TABLE 74: DESCRIPTION OF EQUIPMENT

Section	Number	Description
Crushing	1	Surge bin - Capacity of Quarry truck
	2	Feeder - Apron feeder 36 inches wide
	3	Grizzle - Bar grizzly 5 inch spacing
	4	Jaw crusher - 36 x 24 inch unit
	5	Screen - Vibrating screen 2 inch opening 4 x 8 ft screen
	6	Crusher (secondary) - 4 ft standard cone crusher
	7	Screen - Vibrating screen 3/4 inch opening 5 x 10 ft screen
	8	Crusher (tertiary) - Hydrocone 548
	9	2 Bins - 1000 live ton capacity-28, 000 cu ft 1 bin for each ore
Grinding	10	Feeders
	11	Screen - Vibrating screen 1/4 inch opening 2 x 5 ft screen
	12	Rod mill - 8 x 12 ft End peripheral discharge
	13	DSM Screen 0.9 mm spacing - 4 x 3 ft screen
Gravity	14	Hydraulic classifier
	15	Cyclone -
	16	Primary tables - 8 Wilfley tables Sand decks
	17	Primary tables - 20 Wilfley tables Sand decks
	18	Primary tables - 42 Wilfley tables Sand decks
	19	Primary tables - 38 Wilfley tables Slime decks
	20	Cyclone
	21	Secondary table - 1 Wilfley table Sand deck
	22	Secondary table - 1 Wilfley table Sand deck
	23	Secondary table - 1 Wilfley table Sand deck
	24	Secondary table - 1 Wilfley table Slime deck

(Contd.)

TABLE 74: (CONTD.)

Section	Number	Description
Gravity	25	Regrind mill - Grate discharge ball mill
	26	Hydraulic classifier
	27	Primary tables (regrind) - 5 Wilfley tables Sand decks
	28	Primary tables (regrind) - 7 Wilfley tables Slime decks
	29	Secondary table
	30	Secondary table
	31	Buckman primary tables - 8 units of five 6 x 6 ft trays
	32	Secondary Buckman table - 2 units of five 6 x 6 ft trays
	33	Slime tables - 3 Wilfley tables Slime decks

FIGURE 5: PRELIMINARY CONCENTRATION OF TIN BY JIGGING

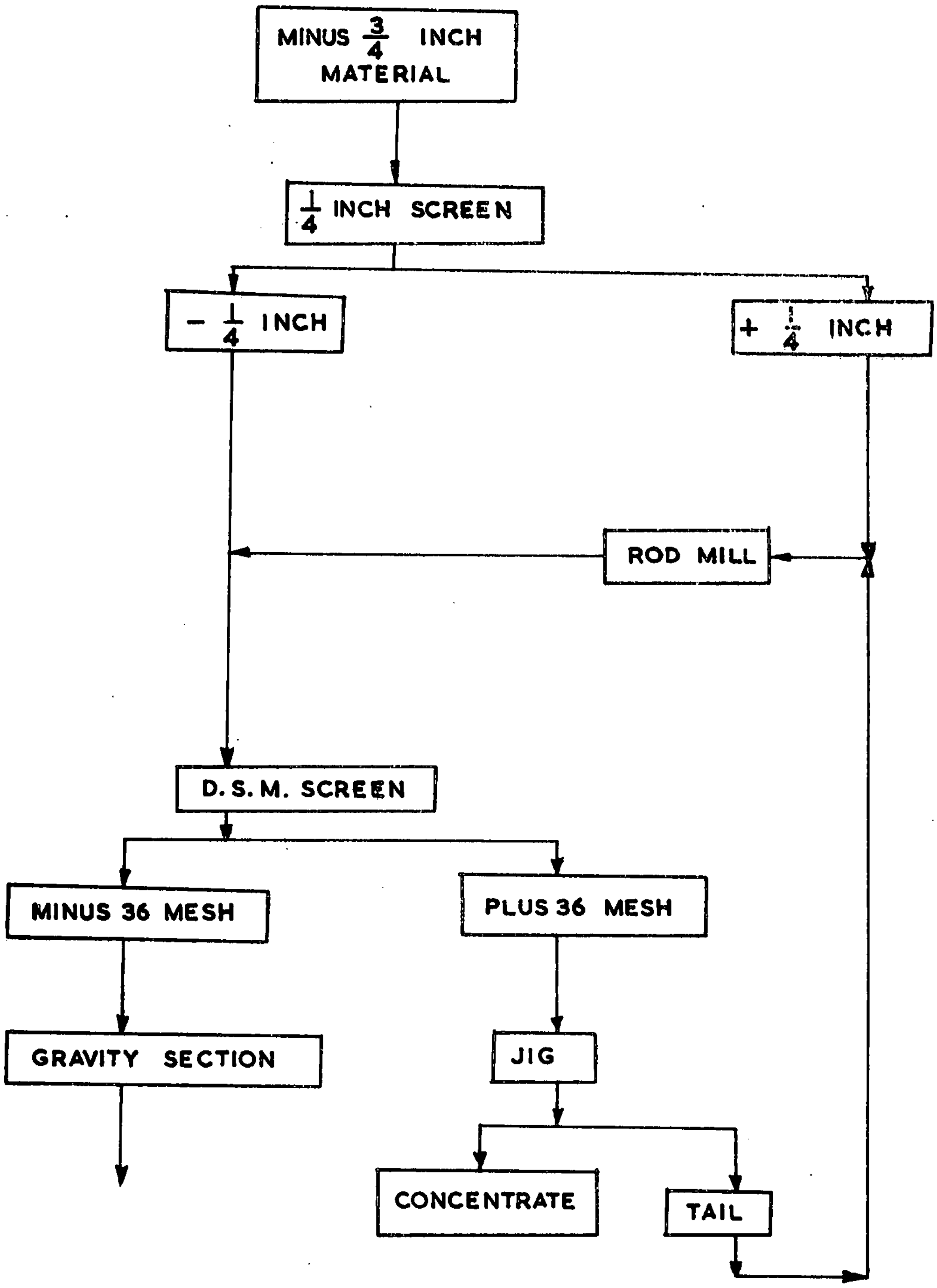
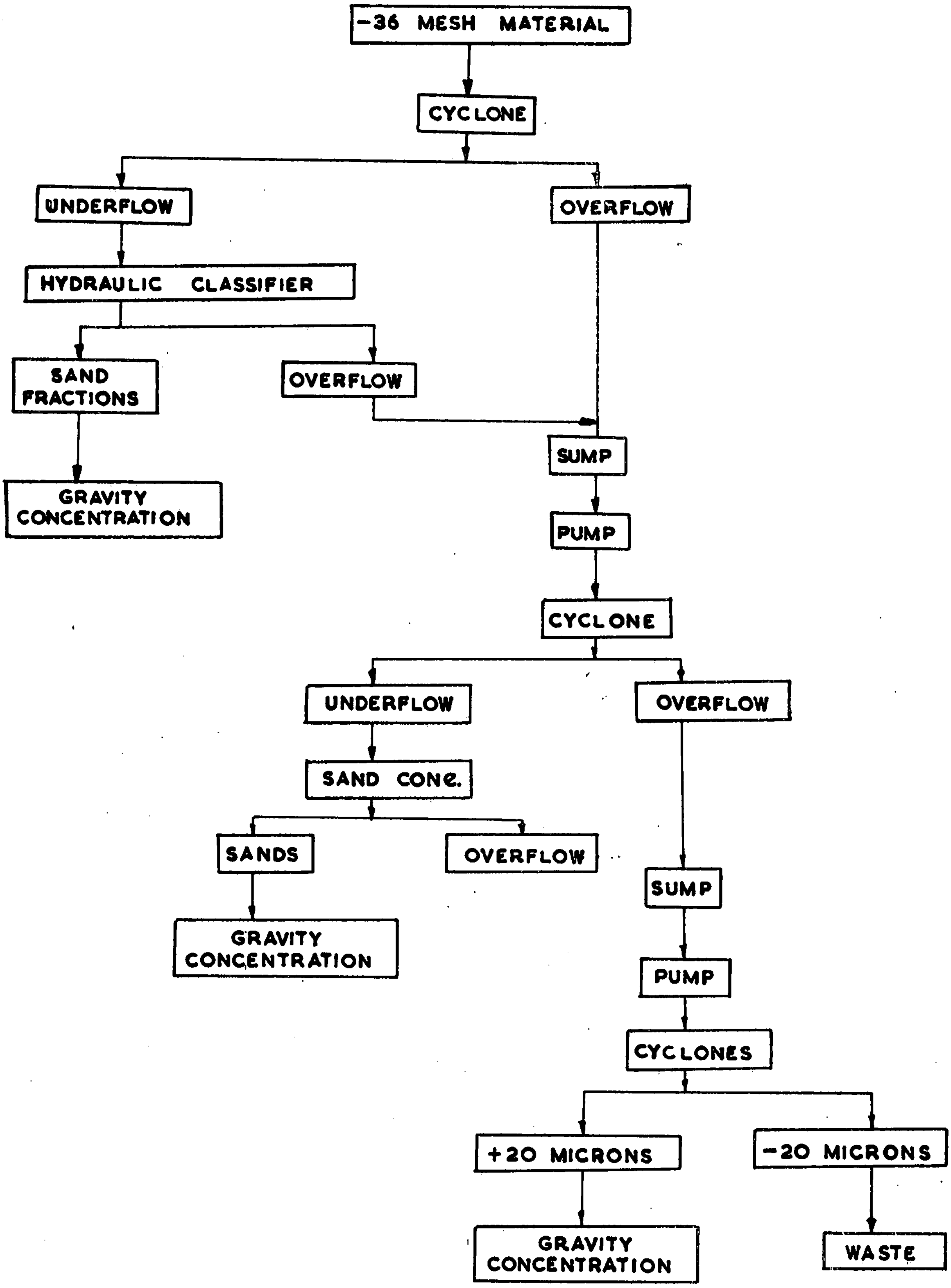
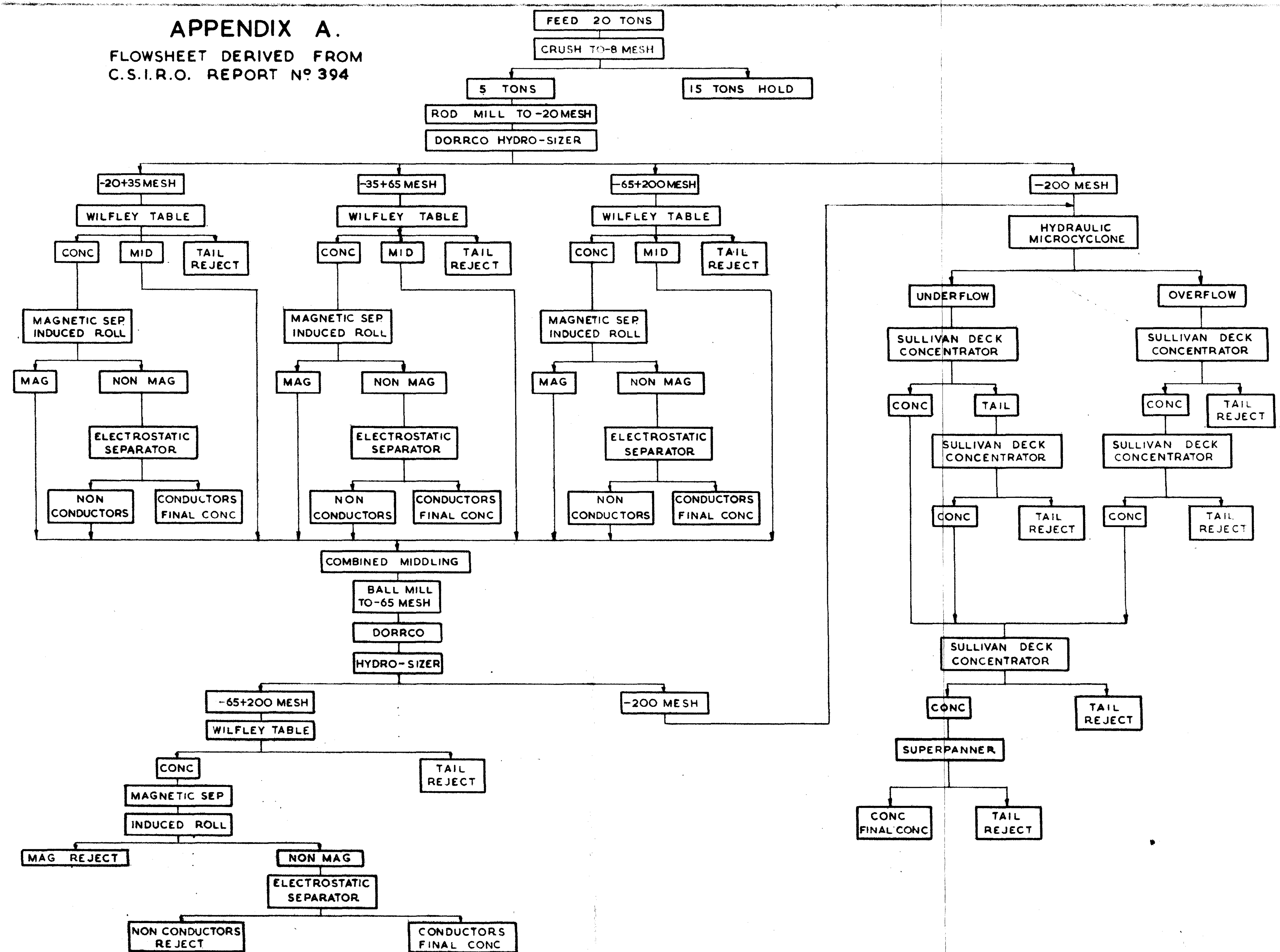


FIGURE 6: PRELIMINARY SIZE CLASSIFICATION BY CYCLONING



APPENDIX A.

FLOWSHEET DERIVED FROM
C.S.I.R.O. REPORT Nº 394



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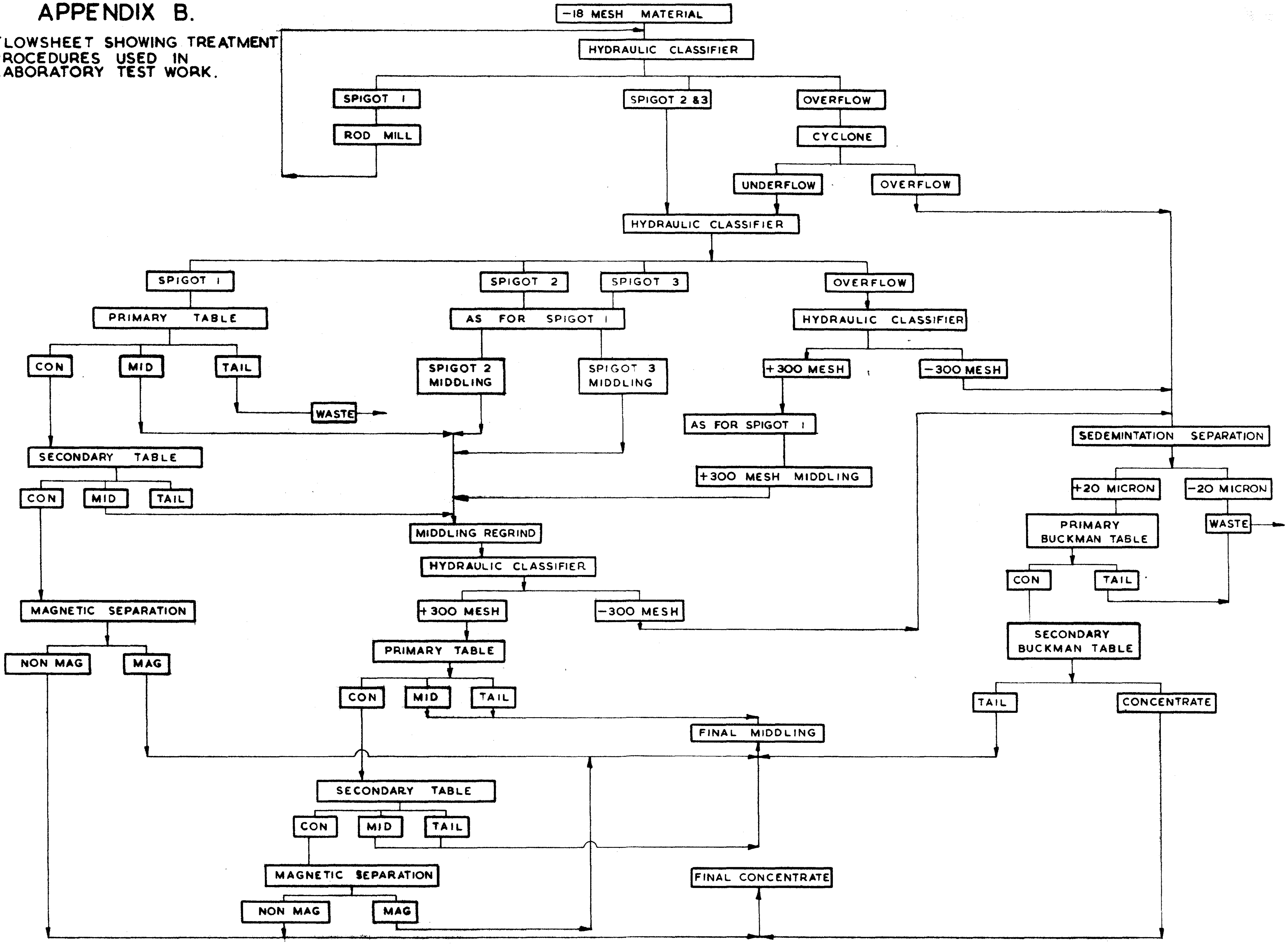
APPENDIX B.

FLOWSHEET SHOWING TREATMENT PROCEDURES USED IN LABORATORY TEST WORK.



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APPENDIX C

MINERALOGICAL EXAMINATION OF HEAD SAMPLES

Results

The bulk samples were examined in thin section and estimated percentages of the major minerals are given below.

Portions of each sample were crushed to minus 100-mesh and concentrates obtained by superpanning. The concentrates were examined mineragraphically to determine the opaque minerals present.

White Crystal

Constituent	Estimated Volume %
Quartz	70
Tourmaline	10
Topaz	10
Cassiterite) Chlorite)	5
Zircon) Opaques)	Trace

Major opaque minerals in the concentrate are cassiterite, goethite and pyrite. Galena, gold, chalcopyrite, sphalerite, and possibly arsenopyrite are rare. Gold has a maximum grain size of 10 microns by 40 microns.

Wild Cherry

Constituent	Estimated Volume %
Sericite	55
Quartz	40
Muscovite	5
Opaques	Trace

Major opaque minerals present in the concentrate are goethite, pyrite, chalcopyrite, and cassiterite. Pyrrhotite, sphalerite, magnetite and gold are rare. The maximum grain size of the gold is 5 microns by 30 microns.

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19/2/62