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ROBERTSON RESEARCH (AUSTRALIA) PTY. LIMITED

PROJECT NO. 756/9511

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MACQUARIE HARBOUR SULPHIDES:

MINERAL PROCESSING INVESTIGATIONS : JUNE 1975-MAY 1976

by

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Prepared for:

Cities Service International Inc.,
Box 37,
Tulsa, OKLAHOMA.

14th July 1976.

SUMMARY

(1) This report assesses the gravity and flotation testing programmes carried out in Australia on samples from Macquarie Harbour. Testing concentrated on the search for a low cost treatment method capable of producing a commercial sulphide concentrate without grinding of the "ore."

(2) The samples investigated contained 3.75% sulphur (principally as pyrite) and 0.16% copper, with minor amounts of other base metals.

(3) Gravity concentration is capable of producing a commercial sulphide concentrate (approximately 40% S) with good recovery (approximately 80%) but copper recovery is poor (~20%).

(4) Froth flotation will produce a similar or better sulphur grade and recovery, but copper recovery is much better (>50%).

(5) Further improved copper recoveries may be possible in a usable sulphide concentrate, but would involve an increasingly sophisticated plant. The possibilities of flotation in this respect were not fully investigated.

(6) The treatment problems arise from the nature of copper mineralisation, which appears to occur as primary and secondary sulphides, liberated and in composites, as well as a minor amount in slag and oxide form. In marked distinction, almost all the sulphur is present as primary pyrite only.

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1. INTRODUCTION

Australia Cities-Service have rights to a large alluvial deposit containing approximately 5 percent of pyrite and significant base metal values, in Macquarie Harbour, Tasmania. The material is unconsolidated deltaic sands and fines, mostly lying below high water mark, at the mouth of the King River, with more than 50 million tons to dredgable depth. Most of the values will have originated as tailings from mine workings at Mount Lyell, but it is believed that some may be naturally derived detrital material. It also appears that some of the base metals may be present in secondary form after solution transportation.

The basic thinking behind the investigation reported herein, was that it might be possible to produce a pyrite concentrate suitable for acid manufacture by a large-scale low cost dredging and gravity processing operation. It was reasoned that the base metal (and any precious metal) values would be concentrated in the pyrite concentrate and could be economically recovered from the pyrite cinder by leaching or volatilization (e.g. Dowa process), subsequent to burning the pyrite in the acid plant, with the final cinder after removal of copper, zinc and other base metals, being suitable for blast furnace feed. This process is operated commercially in Japan, Germany and the U.S.A.

Processing testwork was undertaken at the following Australian laboratories, with the objective of establishing a viable treatment method:

- Amdel, Adelaide : Lamflo sluice and spirals
- Mineral Deposits, Southport : Reichert cone and spirals
- Robertson Research, Bowral : Flotation testing, mineralogy, etc.

In addition, flotation testwork was undertaken in Canada at the laboratories of Lakefield Research. The testwork at Australian laboratories was coordinated by Mr. R. Butler, chief metallurgist, Robertson Research Australia.

This report summarizes and interprets all the work carried out and results achieved. Fuller details of the work undertaken by Mineral Deposits and Amdel are contained in the following reports:

- AMDEL ME 2072/76 See appendix	March 1976	"Lamflo Sluice and Spiral Beneficiation Tests" - W.G. Rogers.
- MIN. DEPOSITS 15.213.1/1	April 1976	"Cone Concentrator Studies and Circuit Designs on Alluvial Sulphide Ore" - M.S. Cross
- MIN. DEPOSITS 15.213.1/2	May 1976	"Spiral Concentrator Studies and Circuit Designs on Alluvial Sulphide Ore." - M.S. Cross

2. SAMPLES TESTED

The samples tested by the respective laboratories consisted of:

Amdel : 25 x 44 gal drums

Mineral Deposits : Approx. 80 x 44 gal drums from Holes 211-221 (plus 130 other drums)

Lakefield : 1 x 110 pound wet pulp sample

Robertson Research : ex Mineral Deposit Composite

The composition of the various composites reported by the laboratories was:

	Amdel	Min.Dep.	Lakefield	RRA
Size Analysis (cumulative %)				
+300 micron		7.5		14.4
+210 "	31.3	28.7	0.2	
+150 "	56.0	58.0	3.5	78.8
+105 "	77.5	81.3	25.6	
+ 75 "	88.9	91.3	55.3	96.8
Analysis (%)				
Sulphur	3.75	4.12	3.70	3.30
Copper	0.15	0.16	0.13	0.17
Zinc	0.018		0.012	
Cobalt	0.008			
Molybdenum	0.005			

COMMENTS:

The samples tested by Amdel and Mineral Deposits were similar, and said to be representative of the bulk of the available material. In both cases, the material under test varied from time to time as the bulk samples were used drum by drum. The RRA sample was a head sample taken from one particular Mineral Deposits test run.

The Lakefield sample was much finer and presumably typical of a section of the delta further out from the river mouth.

The samples tested at this stage of the programme differed very considerably from those examined in the preliminary stages. This was not unexpected insofar as the earlier samples were either superficial surface pit or random drill hole samples. Initial testing at Lakefield in late 1974 was on very fine slime material, with the following composition:

Sizing	:	14.5 percent retained at 75 micron
Analysis	:	4.8% Sulphur 0.09% Copper

Preliminary testwork at Mineral Deposits in early 1975 was undertaken on very coarse material with the following properties:

Sizing	:	92.0 percent retained at 75 micron
Analysis	:	4.4% Sulphur 0.17% Copper

Generally, however, the results between the different laboratories were consistent, with the coarser fractions tending to show a greater amount of unliberated composite material.

3. MINERALOGY

Mineralogical examination was carried out by Lakefield Research and Robertson Research, on various samples. The following summary details the conclusions which can be drawn from ore microscopy and mineral processing results regarding the nature of the mineralization:

1. The bulk of the sulphur content is present as liberated pyrite - chalcopyrite

   (a) In Lakefield Test 5, 70 percent of the sulphur was recovered as a concentrate assaying 50% S. 95 percent of the concentrate was liberated pyrite, chalcopyrite or pyrite + chalcopyrite composites.

   (b) On the much coarser Mineral Deposits preliminary sample, 90 percent of the sulphur was recovered as a concentrate assaying 15% S. It was estimated microscopically that 30-50 percent of the sulphides were free.

   (c) On the bulk sample tested by Mineral Deposits, composites appeared to account for less than 20 percent of the sulphide present. Most of the composites were coarser size gangue particles with only minor amounts of sulphide, as inclusions.

   (d) On the same bulk sample, RRA achieved by flotation a 93 percent recovery of sulphur at a grade of 32.6% S.

2. Copper is present in several forms: only about 20-25 percent occurs in the form of predominantly liberated pyrite - chalcopyrite (residual primary) mineralization.

   (a) In the original Lakefield sample, minor amounts of chalcocite, covellite, bornite are reported.

   (b) In the preliminary Mineral Deposits gravity testing, only about 50 percent of the copper content reported with 90 percent of the sulphides in the gravity concentrate.

   (c) In the Amdel gravity testwork, the best results gave a recovery of only 24 percent of the copper with 80 percent of the sulphides.

(d) Similarly, in the Mineral Deposits study, copper recovery of about 26 percent was associated with a recovery of 85 percent of the sulphides.

(e) Gravity concentration would be expected to make a substantial recovery of copper occurring as discrete grains of copper mineral above about 20-40 micron size and as inclusions associated with other heavy particles (e.g. pyrite).

3. A greater proportion of the total chalcopyrite content is locked than of the pyrite. This is estimated as about ten percent of the total copper content.

(a) It must be remembered that the deposit is largely the residue from copper and gold winning activities over the years. Whilst there has been some sporadic recovery of pyrite values, in general the ratio of pyrite to chalcopyrite will be considerably greater than that of the original Mt. Lyell mineralization.

(b) It is suggested that the natural ratio of pyrite to chalcopyrite will probably be preserved in the composition of sulphide inclusions. As the natural ratio is approximately 20:1, and gravity concentration losses are only about 10-20 percent, with perhaps 0.70 percent as pyrite inclusions, i.e. 7-10 percent of total pyrite, losses as chalcopyrite inclusions are probably of the order of 0.04 percent, i.e. 0.015 percent Cu.

(c) Mineralogical examination of tailings from tabling and cone tests at Mineral Deposits confirmed the presence of some losses as fine pyrite/chalcopyrite inclusions. The quantity was relatively minor. A greater loss of pyrite occurred as composite coarse (+150 micron) particles, associated with gangue. Such particles tended to be predominantly gangue with minor sulphides. Pyrite, chalcopyrite and chalcocite were reported as occurring in this form, but relative proportions could not be estimated.

4. Only a minor (negligible?) amount of copper is present in the form of oxide copper mineral, or as slag.

(a) Only copper sulphide minerals were observed in mineralogical examinations at Lakefield and Robertson Research.

(b) Only 2-4 percent of the copper present in the RRA samples is soluble in dilute acid at ambient temperature conditions. These conditions would dissolve oxide minerals (chrysocolla only partly) but not copper sulphides.

(c) A very small amount of granulated slag was observed in the coarse size fractions. It constituted a very small fraction of the whole sample (<0.1% perhaps) and therefore could not account for any significant portion of the copper content.

(d) Siderite is present, and constitutes approximately 3 percent of the head. There is no appreciable concentration of copper with the siderite.

5. <u>The remaining "50 plus" percent of copper mineralization appears to be present as secondary sulphide but has not been fully identified. It may occur in several forms.</u>

(a) Secondary minerals, bornite, chalcocite and covellite were identified in the polished sections prepared by Lakefield Research.

(b) Chalcocite was also identified in the polished grain mounts examined by Robertson Research. Approximately twice as much chalcopyrite was present, as chalcocite.

(c) In both cases, the samples examined would have been granular and free of slimes. The finer fractions show a slight concentration of copper, which is presumably present as the sulphide, chalcocite. The Mineral Deposits head sample assaying an average 0.16% Cu, contained 0.20% Cu in the minus 20 micron fraction, but with a fairly uniform copper distribution throughout the size range.

(d) The flotation testwork undertaken by Lakefield and RRA gave much better recovery of copper than gravity concentration for similar sulphide sulphur recovery and grade. This is consistent with the additional flotation recovery of fine chalcocite, and is further supported by the slow flotation of copper (which is characteristic of fine chalcocite).

	Grade		Recovery	
	Cu	S	Cu	S
5 min.	0.79	25.8	54.3	92.3
20 min.	0.64	17.2	85.4	97.8

It seems reasonable to postulate the following genesis for the deposit as it exists:

(1) The deltaic deposit has been formed from material carried down the river, derived by natural weathering and mining operations in the vicinity of Mt. Lyell.

(2) The material brought down from the mining operations will contain pyrite but will generally be depleted in free chalcopyrite particles. Such chalcopyrite as is present will largely be associated with pyrite. Other base metals will also tend to be closely associated with the pyrite.

(3) Some copper (and other base metals) has been introduced as fine slag particles. It is likely that the river waters have tended to be acidic and carry anomalous copper values.

(4) Under the likely conditions existing in the delta, especially below the normal water table (tending to be reducing/ acidic), copper could be precipitated as the secondary minerals, chalcocite, etc., in the form of ultrafine particles or as coatings on other minerals. Zinc is similarly mobile, but cobalt is largely fixed within the pyrite lattice.

(5) Thus there are two distinct sulphide populations:

RESIDUAL PRIMARY SULPHIDES accounting for all the pyrite, and the cobalt content, some of the copper and zinc (most of the sulphur).

SECONDARY SULPHIDES, mostly ultrafine and in process of formation, accounting for a considerable portion of the copper and zinc.

(6) From the foregoing, the following possible distribution of the copper content can be hypothesized:

Chalcopyrite/pyrite, gravity recoverable	-	20-25%
Chalcopyrite/pyrite, as minor constituent (inclusion) irrecoverable by gravity or flotation	-	10%
Oxide copper	-	2-4%
Secondary sulphide copper - fine chalcocite - recoverable by flotation only	-	60%

4. MINERAL PROCESSING TESTWORK

Processing investigations followed two distinct lines of thought, in an attempt to achieve a satisfactory concentration of the sulphides. Preliminary estimates indicated a very clear advantage to large scale gravity processing, using current beach sand technology, if satisfactory recoveries could be achieved. Operating costs (dredging and gravity concentration) of the order of $0.30 per tonne dredged might be achieved, compared with $0.50-0.70 , or even higher, if flotation had to be employed. In addition, capital costs for a gravity plant would probably be considerably lower.

4.1. GRAVITY PROCESSING

Investigations were undertaken by the following laboratories:

- AUSTRALIAN MINERAL DEVELOPMENT LABORATORIES : Beneficiation by Lamflo sluice and spirals.
- MINERAL DEPOSITS : Beneficiation by Reichert cone concentrator and spiral.

In both laboratories, satisfactory concentration of the pyrite could be achieved, but recovery of the copper content was very poor, with no significant upgrading. The results of testwork at each laboratory have been reported in detail elsewhere.

At Amdel, Lamflo sluice concentrators were used to produce a primary (rougher) concentrate which was further upgraded by a Mineral Separator spiral to give a final concentrate. A number of tests were run to evaluate different equipment parameters. In the most promising test, the sulphur recovery was 80 percent, the copper recovery only 24 percent. The details are as follows:

	Grade		Recovery		
	S	Cu	Wt.	S	Cu
Feed	3.42	0.17			
Lamflo sluice Conc.	4.55	0.18	6.93	92.0	74.2
Spiral concentrate	14.6	0.23	19.1	79.7	23.7

More thorough testing to achieve a higher grade concentrate was not carried through because of the obvious difficulty of recovering the copper values in this circuit.

At Mineral Deposits, Reichert cone concentrators were used to achieve a primary bulk separation of the heavy mineral values, with further upgrading of the concentrate by means of spirals. A considerable number of tests were carried out to establish equipment parameters, and to develop a flowsheet for concentrating the pyrite content. In the most satisfactory tests, a final concentrate assaying 43.9% S was achieved, but copper recovery was very poor. From these tests, the predicted performance for a closed cycle operation were:

	Grade		Recovery		
	S	Cu	Wt.	S	Cu
Feed	3	0.16			
Reichert cone conc.	16	0.26	16	85	26
Spiral concentrate	40	0.33	7	80	12

These results serve to confirm the conclusion drawn from the gravity concentration testwork at Amdel, that the pyrite fraction can be satisfactorily concentrated by gravity methods, but that the bulk of the copper content is not recoverable by gravity methods.

The poor recovery of copper confirms the view that only about 25 percent of the copper occurs in close association with the pyrite content, or as free granular sulphide mineral (chalcopyrite). The 75 percent unrecovered must occur either in the fine fraction (below 30-40 micron sizing) not amenable to concentration by gravity sluice, or as a relatively minor component of light granular material, which is rejected by the sluice. Some undoubtedly occurs in this latter form as very minor inclusions (chalcopyrite) in gangue particles, but should not be significantly more than the amount of pyrite occurring in the same mode. It must thus be concluded that the bulk of the copper unrecovered by gravity processing occurs in the fines or possibly as very fine surface coating material on coarser gangue particles.

4.2. FLOTATION

A considerable number of flotation tests have been carried out by Lakefield Research, on two samples. The possibilities of bulk flotation, bulk flotation with middlings regrind, selective copper flotation and various leaching and roasting tests were investigated.

Flotation tests were undertaken in the RRA laboratory as part of the investigation of copper not recovered by the gravity concentration processes. Six tests were completed:

(1) FLOTATION OF SULPHIDES IN SLIMES. This test was undertaken on decanted slimes from the Mineral Deposits test rig. Most of the values would not be recovered by gravity concentration. Flotation recovered 97 percent of the sulphide sulphur and 59 percent of the copper.

(2) FATTY ACID FLOTATION OF SLIMES. This test was undertaken on the tailings from the previous test. The objective was to concentrate the carbonate content (siderite, principally) together with any copper carbonates associated with it. The flotation was unsuccessful in concentrating the copper.

(3) FATTY ACID FLOTATION OF SLIMES. Flotation of the siderite fraction from the decanted slimes resulted in no significant concentration of copper, all products having approximately the same assay.

(4) AMINE FLOTATION. The possibility existed of some of the copper content occurring in intimate association with the illite/mica/chlorite content. Amine flotation to concentrate these minerals resulted in only minor concentration of the copper content. It can be concluded that a small amount of copper occurs in this form. Its recovery would not be economic.

(5) SULPHIDE AND CARBONATE FLOTATION. This flotation was carried out on a representative sample. Using standard flotation technqiues and relatively short flotation times, 54 percent of the copper reported with 92 percent of the sulphides. There was only minor concentration of the copper with the siderite concentrate.

(6) SULPHIDE FLOTATION. This test repeated the conditions of test 5 sulphide float with extended flotation time. The longer float resulted in a recovery of 85 percent of the copper and 97 percent of the sulphur in a concentrate after rejecting 79 percent of the feed.

Fuller details of each of these tests are included in Appendix 1. Some of the tests were designed to provide answers to some of the problems regarding the location of the copper losses. In undertaking sulphide flotation tests, it was considered appropriate to bias the tests towards the practical possibilities of a bulk flotation of unground material, using the simplest reagent combination possible.

The results of the flotation tests show that an acceptable grade of sulphide concentrate with over 50 percent copper recovery is achieved in the simplest possible flotation circuit (short retention time, minimal cleaner flotation and reagent requirement, no grinding). The extension of flotation capacity achieves a greater copper recovery -- 70 or 80% -- depending on retention time allowed, but this would result in dilution of the concentrate and necessitate additional cleaner flotation capacity. (Test 6)

The low copper recovery results from a variety of factors. Some of the copper is present in a form (fine inclusions, slag, etc.) in which it is not amenable to concentration by gravity or flotation processes. A considerable proportion is amenable to flotation, but floats slowly, requiring a long contact time. This is consistent with the presence of fine secondary copper mineral such as chalcocite -- it is an axiom that large particles float faster than the smaller -- though it has been difficult to confirm this by mineralogical examination.

5. CONCLUSIONS

The overall practical conclusions regarding the treatment of Macquarie Harbour sulphides are:

(1) Gravity concentration effectively recovers the pyrite content but not the copper content. It is capable of producing a 40 percent sulphur product accounting for 80 percent of the sulphide, but only about 20 percent of the copper.

(2) A relatively simple flotation procedure works better and is capable of producing a comparable sulphur grade and recovery, with 50 percent recovery of the copper or better.

(3) A product which is satisfactory except possibly in terms of copper recovery can be produced by flotation without grinding, with a single reagent addition, with short retention time (5 minutes' roughing) and using a simple single-stage cleaning circuit.

(4) Improvement in the copper flotation recovery can be achieved by longer flotation, but at the expense of product grade. Additional cleaning stages may improve the grade without excessive loss of copper values, but this possibility has not been thoroughly investigated.

(5) No combination of gravity and flotation processing would appear to offer any advantage over flotation alone.

APPENDIX 1

The following diagrams summarise the conditions and results of the flotation testwork. Each test is shown in the form of a flowsheet identifying successive products.

Results at each stage are given as percent and shown in boxes, using this key:

Weight	Copper Grade	Sulphur Grade
	Copper Recovery	Sulphur Recovery

In some cases a single set of figures only is given. In these instances, only copper values are included.

Reagent quantity and point of addition are all indicated in the following manner:

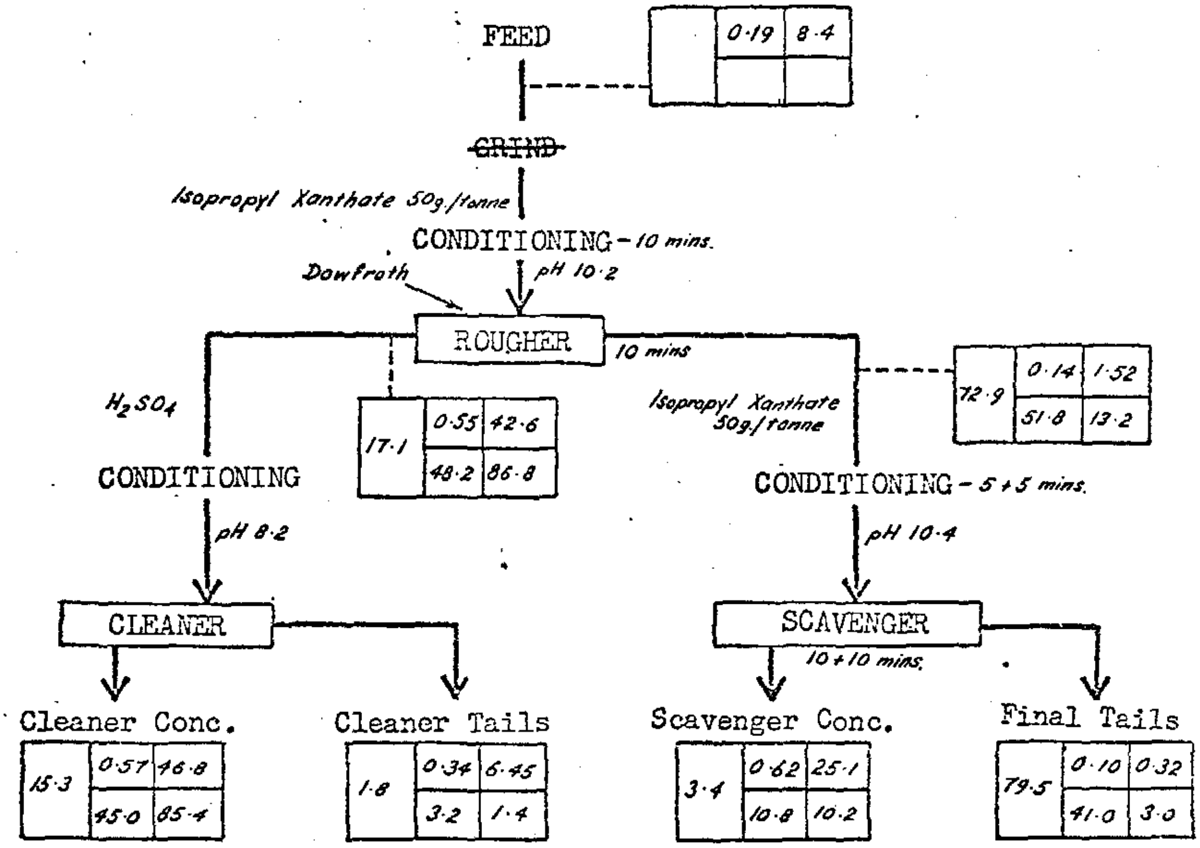
HMP 25 ⟶

which signifies:

Sodium Hexametaphosphate 25 g/t

Frother quantities are not shown, since frother is only added as required to maintain quality of froth.

TEST 9511-1



PURPOSE: To investigate the recovery of fine sulphides, not recovered by the gravity concentrator.

FEED: Reichert cone decanted slimes (N.B. - 8.4% S 0.19% Cu)

GRIND: No grind

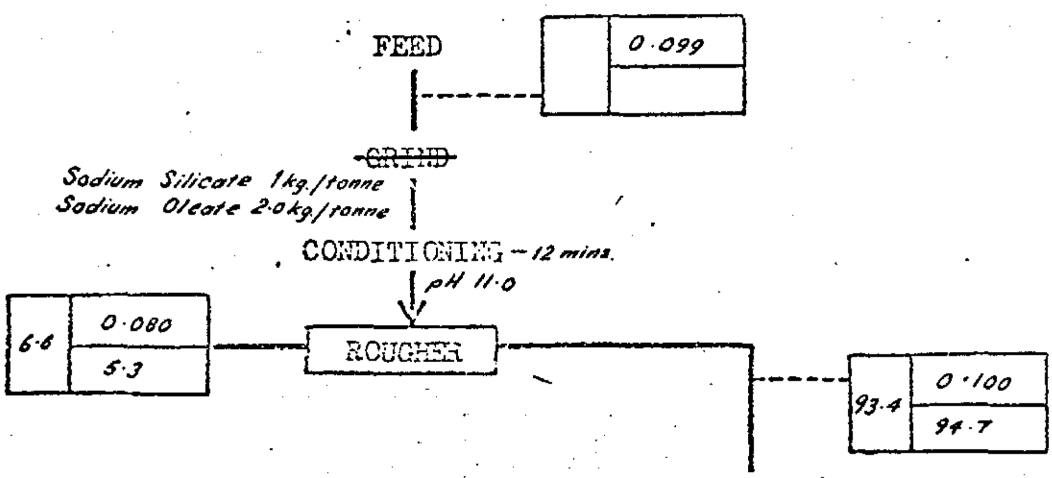
FLOTATION CELL: Denver 500 gm

SPEED: 2500 rpm

PULP DENSITY: 25% solids

COMMENTS: A good recovery of sulphides is achieved in a simple rougher float, with scavenging raising recovery to 97 percent at a combined grade of 39.7% S. The recovery of copper is lower and slower. Of particular significance is that the highest grade of copper is achieved in the scavenger concentrate. This suggests that flotation of the copper sulphides (chalcocite?) is not complete.

TEST 9511-2



PURPOSE: To check the possibility that some of the copper contained in the slime tails after flotation of sulphides may be locked with the siderite/calcite.

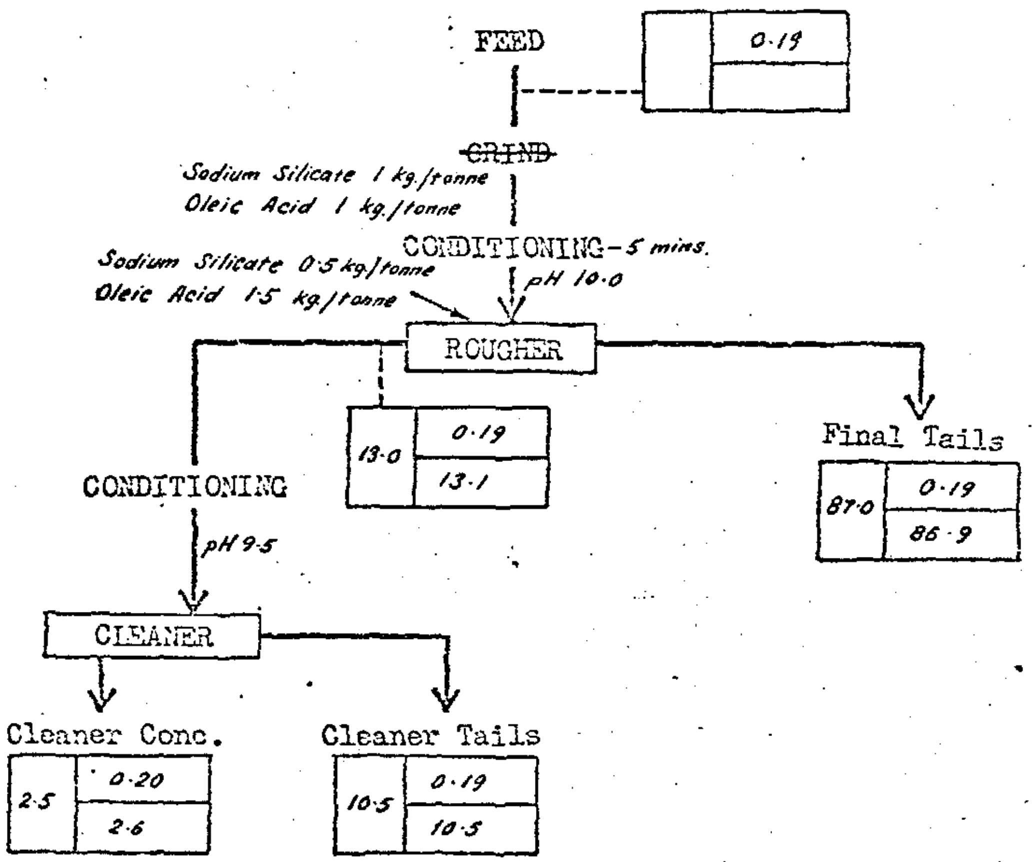
FEED: Tailings from sulphide flotation of slimes (Test 9511-1).

GRIND: No grind.

FLOTATION CELL: Denver 250 gm.

COMMENTS: Although a siderite/calcite concentrate was produced, there is no significant copper content in it.

TEST 9511-3



PURPOSE: To repeat test 2, using slimes decanted from the Reichert cone test as feed.

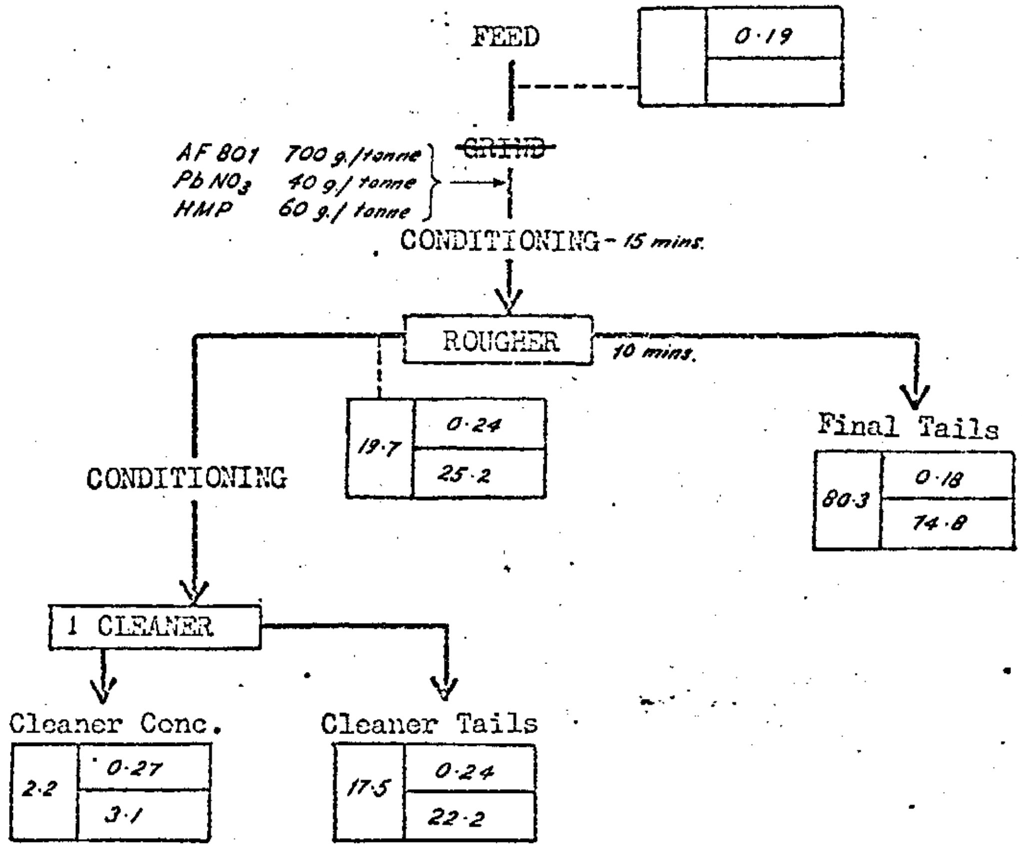
FEED: Reichert cone decanted slimes

GRIND: No grind

FLOTATION CELL: Denver 500 gm

COMMENTS: Again there is no significant concentration of copper with any of the products.

TEST 9511-4



PURPOSE: To determine what portion of the copper lost in slimes was associated with the illite/mica chlorite fraction. An amine reagent was used to selectively float these minerals.

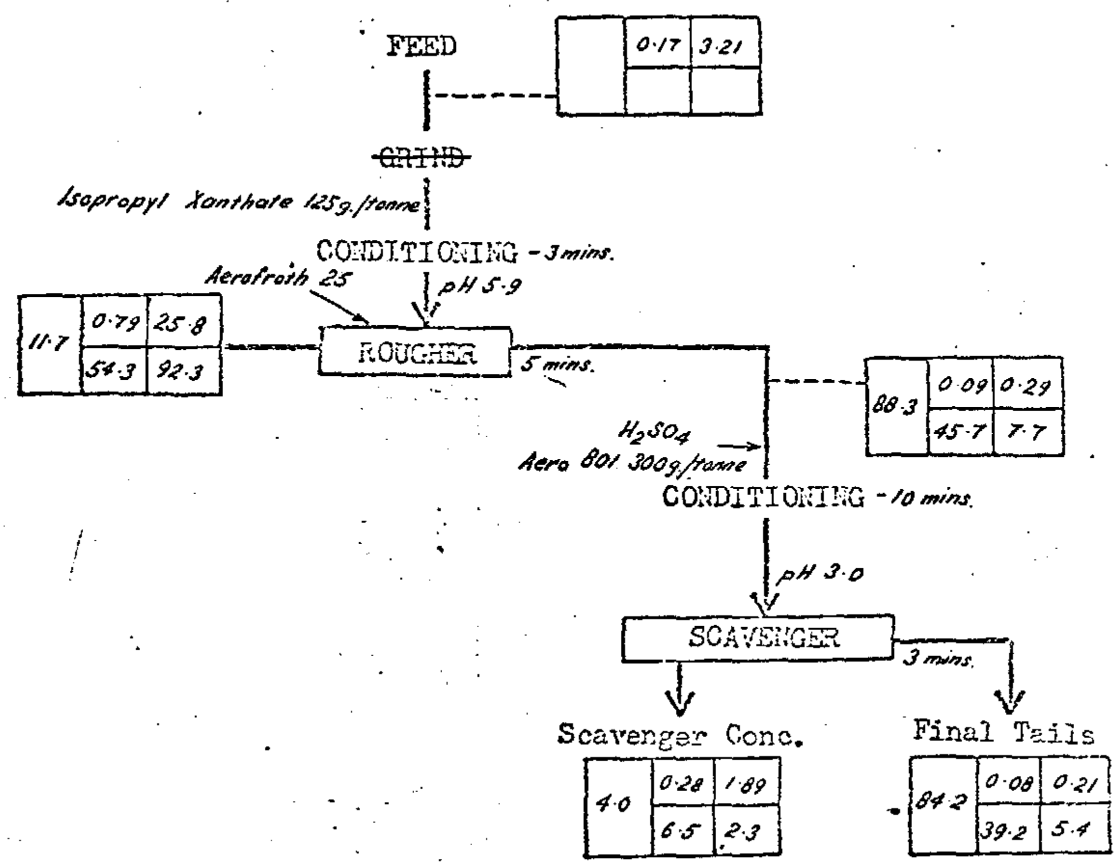
FEED: Reichert cone decanted slimes.

GRIND: No grind

FLOTATION CELL: Denver 250 gm

COMMENTS: There is a minor amount of copper associated with the clay fraction. The copper has probably been adsorbed from solution.

TEST 9511-5



PURPOSE: To float sulphide and copper values from the representative head sample using:

- Xanthate float - to recover sulphides
- Aero 801 float - to recover siderite, calcite etc.

FEED: Representative head sample of material tested at Mineral Deposits.

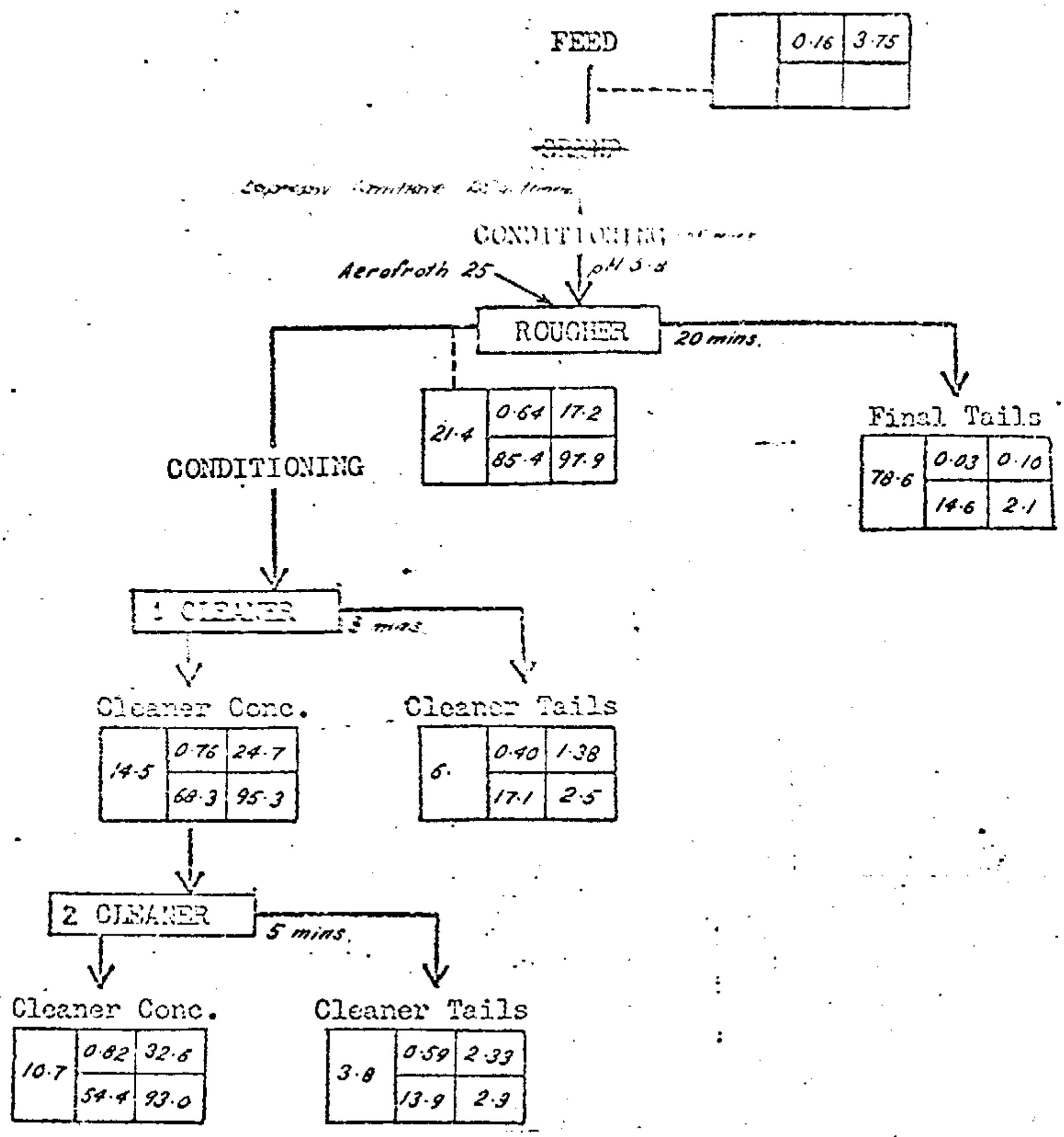
GRIND: No grind.

FLOTATION CELL: Denver 250 gm.

PULP DENSITY: 20% solids.

COMMENTS: In a single flotation step, recovery of copper and grade of sulphides is better than achieved by gravity treatment. Some copper reports with the siderite concentrate, but this may well be sulphides continuing to float (see Test 1) rather than copper-bearing siderite.

TEST 9511-6



PURPOSE: To repeat the sulphide flotation of Test 9511-5, with longer rougher flotation, to permit flotation of fine chalcocite and other copper sulphides which tend to be slow floaters.

FEED: Representative head sample of material tested at Mineral Deposits.

GRIND: No grind.

FLOTATION CELL: Denver 250 gm.

COMMENTS: Rougher flotation time has been quadrupled with marked improvement in copper recovery. This is entirely consistent with presence (and recovery) of fine chalcocite. Although some of this additional copper was dropped on cleaning, it is believed that an improved recovery/grade could be achieved with further testing of the cleaning steps.

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August 30, 1976.

RECEIVED
1 OCT 1976

Mr D.H. Buchholz,
Vice President,
Australia Cities Service Inc.,
5th Floor,
151-153 Macquarie Street,
SYDNEY. NSW 2000

REPORT: ME2072/76

YOUR REFERENCE:	Telex messages dated 8/1/76, 2/2/76
MATERIAL:	Macquarie Harbour Sediment
LOCALITY:	-
IDENTIFICATION	Batch No.1 Composite Sample
DATE RECEIVED:	6/1/76
WORK REQUIRED:	Lamflo sluice and spiral beneficiation tests

Investigation and Report by:	W.G. Rogers
Operations Manager:	R.E. Wilmshurst

R.E. Wilmshurst

for F.R. Hartley
Director.

cc Dr D.D. Jinks
Senior Project Geologist Minerals,
Cities Service International Inc.
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1. INTRODUCTION

Australia Cities Service Inc., are currently carrying out a conceptional study on the feasibility of various beneficiation processes for the treatment of the coarse delta sand deposit from the Macquarie Harbour sediment.

The material in this deposit originated as a result of the deposition of the solids from the tailing pulp discharged into the Macquarie river from the Mount Lyell copper treatment plant. It contains heavy mineral sulphides, mainly pyrite (total sulphur content as much as 3.7%), together with a small amount of the unclaimed copper minerals (at least 0.15% Cu).

The objective is to produce a sulphide concentrate suitable for the manufacture of sulphuric acid and to recover portion of the copper by carrying out an acid leaching stage on the roasted sulphide product.

Results of test work carried out so far indicate treatment probably will require primary gravity concentration stages aimed at rejecting as much of the gangue material as is possible with minimal loss of the sulphide minerals and a secondary flotation stage to assist grade improvement.

Amdel's involvement in this project arose from the availability within Amdel of a Lamflo sluice together with spiral gravity separators. The sponsor was interested in investigating these separators as an alternative primary gravity beneficiation stage for the beneficiation of a composite sample of their coarse delta sand sediment and to compare the separation results obtained, in this case, with those achieved as a result of independent investigation carried out with the Reichert cone.

This report outlines the results of this investigation.

2. MATERIAL EXAMINED

This testwork was carried out with 'Batch No.1' composite sample from the Macquarie Harbour coarse delta sand sediment received 6/1/76 and contained in twenty five 200 litre polythene lined, sealed drums. The material, essentially of minus 710 m with negligible fines, had a net dry weight of 5.5 tonnes. Details of the results of size and assay analyses carried out on a head sample spear sampled from the 25 drums, are included in Tables 1 and 2. The specific gravity of the dry head sample was 2.85.

3. ANCILLARY MATERIAL

The following ragent was used for the purpose of preliminary, assessment of the test results:

Name	Composition	Use
T.B.E. (Heavy liquid)	Tetra bromo ethane	Heavy liquid separation of the heavy minerals in the dry test products at: Sp. gr. 2.95 (Tests 3 to 5) Sp. gr. 2.90 (Tests 7 to 9)

4. EQUIPMENT USED

The following equipment was used in the tests:

- Mineral Separator Spirals (2)
- Denver 1.2 x 1.2 metre conditioning tank (1)
- 2.54 x 3.81 cm Warman 3.7 kW motor fixed speed pumps (2)
- Lamflo Separator (1)
- Automatic Sample Cutters (4)
- Standard Screens (AS 1152 - 1973)

5. EXPERIMENTAL PROCEDURE AND RESULTS

5.1 Sample Preparation

The contents of the twenty five drums were dewatered and the settled solids were spread onto a concrete apron and air dried to 5% moisture. Mixing was accomplished by coning five times with a front-end loader.

Preliminary testing of a 0.5 tonne parcel of the composite sample revealed the presence of plus 1.27 cm stone pebbles which caused blockages to arise in the feed lines. Consequently it was necessary to screen the balance of the composite sample over a 0.635 cm screen to remove the pebble fraction. The weight of pebbles screened from the balance of the bulk composite sample was negligible.

5.2 Preliminary Closed Circuit Lamflo Tests

Preliminary tests with the Lamflow separator were carried out in closed circuit by returning the concentrates (3) and tailing products back to the Denver feed mixing tank charged with approximately 0.5 tonne (dry weight) of the pulped composite sample.

Tests were carried out by varying the cutter slot widths and feed pulp flowrate while maintaining the pulp density and deck slope constant.

Best performance for the Lamflo separator was obtained when using a cutter slot width of 0.635 cm (¼") as this enabled concentrate weight recoveries of the order of 50 to 70% to be obtainable when operating close to the recommended feed rates of 5.6 to 7.8 dry tonnes/hour.

Three tests, Tests 3, 4 and 5 at dry feed rates of 5.49, 6.05 and 6.5 tonnes/hour respectively were carried out when operating at the above cutter slot widths and feed solids concentration of the order of 52% solids weight. The results of these tests were assessed by carrying out T.B.E. heavy liquid separations on the test products. The results are shown in Tables 3 to 5 and graphically illustrated in Figure 1.

5.3 Production of Low Grade Bulk Lamflo Concentrate From Open Circuit Runs (Test 6)

Production of a low grade bulk Lamflo concentrate for spiral cleaning tests was carried out by running approximately 2.0 tonnes of the pulped composite delta sand sediment through the Lamflo separator when run in open circuit. To treat this quantity of the composite sample four 0.5 tonne (approx.) parcels of the sample were run through the separator separately. The average feed rate for these runs was 5.7 dry tonnes per hour at an average pulp solids concentration of 52% solids weight.

The dry solids weight distributions for the bulk concentrate and tailing products were determined by tonnage measurements on the thickened bulk Lamflo concentrate and tailing pulps.

Initial assessment of the results was done by TBE heavy liquid separations on samples of the test products. Final assessment of the Lamflo bulk concentrate and tailing products for Cu, Zn, Co, Mo and Total sulphur. The results are shown in Tables 6 and 7.

5.4 Open Circuit Spiral Cleaning Tests

Spiral cleaning of the bulk Lamflo concentrate was investigated by operating the Denver feed mixing tank in open circuit with a two-stage spiral circuit using a normal rougher/cleaner configuration with the cleaner spiral tailing returning to the rougher unit.

Four Tests, Tests 7, 8, 9 and 10 were carried out by feeding separate batches of the bulk Lamflo concentrate pulp, agitated in the Denver mixing tank, at a pulp solids concentration of approximately 52% solids weight to the rougher spiral feed box where it was diluted to approximately 30% solids weight with fresh make up water. The dry solids feed rates during these tests were within the range of 0.54 to 0.66 tonnes/hour. Wash water was added independently to each spiral at a fixed rate of 3.5 litres/minute.

Variation in the cleaner spiral concentrate weight recovery was accomplished by varying the angle of the cutters at the spiral concentrate ports.

During each test samples were taken of the bulk Lamflo concentrate (rougher spiral feed), rougher spiral tailing and cleaner spiral concentrate. These samples were assayed for Cu, Co, and Total sulphur. The results are shown in Tables 9 to 12.

Preliminary results for the T.B.E. heavy liquid separations carried out on the bulk Lamflo concentrate (rougher spiral feed), cleaner spiral concentrate and rougher spiral tailing are shown in Table 8 and graphicall- illustrated in Figure 1.

6. DISCUSSION OF RESULTS AND CONCLUSIONS

Total sulphur determinations on the Lamflo and spiral test products, were by gravimetric procedures, which were found to be more accurate than the tube furnace method.

The weight recovery results for the spiral tests have been determined from the Total sulphur analyses on the test products as these are considered more reliable than those calculated from the other elements which occur in lower concentrations.

For the spiral tests difficulty was experienced in obtaining mass balances when using the assays for the trace elements Zn and Mo. Therefore these results have not been included. However the indications were that these elements tend to report in the higher weight fractions recovered.

The beneficiation results achieved for the Total sulphur, copper and cobalt when using the Lamflo separator as an initial rougher concentration stage and spiral separators in a cleaning stage are outlined in Figures 2, 3 and 4 respectively. The best results achieved (Test 7) show a concentrate grade of 14.6% T.S. and 0.23% copper for respective recoveries of 79.7 and 23.7% from the original composite sample treated. These results correspond to a weight rejection of 80.9% of the original composite material treated. It is obvious from the test results that effective recovery of the copper constituent will not be possible when employing this type of gravity treatment circuit.

TABLE 1: RESULTS OF SIZE AND ASSAY ANALYSIS

Product (Mesh BSS)	Weight %	Assay					Distribution %				
		%		ppm							
		Cu	Total Sulphur	Zn	Co	Mo	Cu	Total Sulphur	Zn	Co	Mo
Head Sample	100.0	0.15	3.75	185	80	55	100	100	100	100	100
+60	17.0	0.19	0.70	325	25	45	20.9	3.2	25.1	5.2	14.2
-60+85	29.3	0.16	0.88	185	25	45	30.4	6.9	24.7	8.9	24.5
-85+120	22.7	0.14	1.96	200	45	50	20.6	11.9	20.6	12.4	21.0
-120	31.0	0.14	9.40	210	195	70	28.1	78.0	29.6	73.5	40.3
(Calc.) Head	100.0	0.154	3.74	220	82	54	100.0	100.0	100.0	100.0	100.0

TABLE 2: DETAILED SIZING RESULTS

Product		Weight %	
μm	Mesh BSS	Retained	Cumulative Passing
710	22	0.4	99.6
500	30	0.4	99.2
355	44	3.3	95.9
250	60	12.9	83.0
180	85	29.3	53.7
125	120	22.7	31.0
90	170	16.5	14.5
63	240	6.4	8.1
45	350	3.6	4.5
	-350	4.5	
		100.0	

TABLE 3: TBE ASSESSMENT OF RESULTS FOR CLOSED CIRCUIT LAMFLO TEST NO.3
Feed Rate: 5.49 dry tonnes/h (4.9 tons/h)
Feed Density: 53.7% solids weight
Deck Slope: 14°
Slot Width: 0.635 cm
Sp. Gr. TBE: 2.95

Product	Dry Solids Sp. Gr.	Weight %		Wt % Heavy Min		% Heavy Min. Distribution	
		Fract.	Cum.	Fract.	Cum.	Fract.	Cum.
Conc. 1	2.98	27.6	27.6	24.6	24.6	46.7	46.7
2	2.84	29.8	57.4	14.6	19.4	29.9	76.6
3	2.79	14.5	71.9	9.8	17.5	9.9	86.5
Tail	2.77	28.1	100.0	7.0	14.5	13.5	100.0
Feed (calc)	2.85	100.0		14.5		100.0	

TABLE 4: TBE ASSESSMENT OF RESULTS FOR CLOSED CIRCUIT LAMFLO TEST NO.4
Feed Rate: 6.05 dry tonnes/h (5.4 tons/h)
Feed Density: 52.8% solids weight
Deck Slope: 14°
Slot Width: 0.635 cm
Sp. Gr. TBE: 2.95

Product	Dry Solids Sp. Gr.	Weight %		Wt % Heavy Min		% Heavy Min. Distribution	
		Fract.	Cum.	Fract.	Cum.	Fract.	Cum.
Conc 1	2.97	23.3	23.3	25.1	25.1	43.3	43.3
2	2.83	27.3	50.6	15.2	19.8	30.7	74.0
3	2.80	12.7	63.3	10.8	18.0	10.2	84.2
Tail	2.78	36.7	100.0	5.8	13.5	15.8	100.0
Feed (calc)	2.84	100.0		13.5		100.0	

TABLE 5: TBE ASSESSMENT OF RESULTS FOR CLOSED CIRCUIT
LAMFLO TEST NO.5
Feed Rate: 6.5 dry tonnes/h (5.8 tons/h)
Feed Solids Concentration: 52.4% solids weight
Deck Slope: 14°
Slot Width: 0.635 cm
Sp. Gr. TBE: 2.95

Product	Dry Solid Sp. Gr.	Weight %		Wt % Heavy Min		% Heavy Min. Distribution	
		Fract.	Cum.	Fract.	Cum.	Fract.	Cum.
Conc 1	3.02	20.3	20.3	28.4	28.4	40.2	40.2
2	2.87	26.5	46.8	16.1	21.4	29.8	70.0
3	2.83	10.8	57.6	11.5	19.6	8.7	78.7
Tail	2.78	42.4	100.0	7.2	14.3	21.3	100.0
Feed (calc)	2.86	100.0		14.3		100.0	

TABLE 6: TBE ASSESSMENT OF RESULTS FOR OPEN CIRCUIT
LAMFLO TEST NO.6
Feed Rate: 5.7 dry tonnes/h (5.1 tons/h)
Feed Solids Concentration: 52% solids weight
Deck Slope: 14°
Slot Width: 0.635 cm
Sp. Gr. TBE: 2.90

Product	Dry Solids Sp. Gr.	Weight %*	Wt % Heavy Minerals	% Heavy Minerals Distribution
Bulk Conc	2.90	69.2	21.4	87.9
Tail	2.76	30.8	6.6	12.1
Feed (calc)	2.86	100.0	16.8	100.0

* Calculated by carrying out tonnages tests on Lamflo products.

TABLE 7: ASSAY RESULTS FOR OPEN CIRCUIT LAMFLO TEST NO.6

Product	Weight %	Assay					Distribution %				
		%		ppm			Cu	Total Sulphur	Zn	Co	Mo
		Cu	Total Sulphur	Zn	Co	Mo					
Bulk Conc	69.2	0.18	4.55	250	110	50	74.2	92.0	70.1	86.1	73.7
Tail.	30.8	0.14	0.89	240	40	40	25.8	8.0	29.9	13.9	26.3
Feed (calc)	100.0	0.17	3.42	247	88	47	100.0	100.0	100.0	100.0	100.0

TABLE 8: TBE ASSESSMENT OF RESULTS FOR SPIRAL TESTS (TESTS 7 to 9)

Rougher Spiral Feed Concentration: 30% Solids weight
Av Dry Feed Rate: 0.58 tonnes/h
Wash Water Feed Rate: 3.5 litres/min each spiral
No Spiral Stages: 1 Rougher
1 Cleaner, cleaner tail recycled to rougher spiral feed box
Sp. Gr. TBE: 2.90

Test No.	Product	% Weight		% Wt Heavy Mineral	% Recovery Heavy Mineral	
		Feed	Orig. Ore		Feed	Orig. Ore
7	B. Lamflo Conc.	100.0	69.2	19.0	100.0	87.9
	Cl. Sp. Conc	31.0	21.4	52.2	85.1	74.8
	Ro. Sp. Tail	69.0	47.8	4.1	14.9	13.1
8	B. Lamflo Conc.	100.0	69.2	20.0	100.0	87.9
	Cl. Sp. Conc	80.4	55.6	24.4	98.0	86.1
	Ro. Sp. Tail	19.6	13.6	2.0	2.0	1.8
9	B. Lamflo Conc.	100.0	69.2	18.8	100.0	87.9
	Cl. Sp. Conc	46.6	32.2	36.2	89.9	79.0
	Ro. Sp. Tail	53.4	37.0	3.6	10.1	8.9
10	B. Lamflo Conc.	100.0	69.2	18.4	100.0	87.9
	Cl. Sp. Conc	45.1	31.2	37.6	92.2	81.0
	Ro. Sp. Tail	54.9	38.0	2.6	7.8	6.9

TABLE 9: ASSAY RESULTS FOR OPEN CIRCUIT SPIRAL CLEANING TEST NO.7

Product	Weight % (Feed)	Assay % T.S.	Assay % Cu	Assay ppm Co	Distribution % (Feed) T.S.	Distribution % (Feed) Cu	Distribution % (Feed) Co
Spiral Cl. Conc	27.6	14.6	0.23	290	86.6	31.9	76.3
Ro. Spiral Tail	72.4	0.86	0.14	30	13.4	68.1	23.7
Spiral Feed	100.0	4.65	0.16	95	100.0	100.0	100.0

TABLE 10: ASSAY RESULTS FOR OPEN CIRCUIT SPIRAL CLEANING TEST NO.8

Product	Weight % (Feed)	Assay % T.S.	Assay % Cu	Assay ppm Co	Distribution % (Feed) T.S.	Distribution % (Feed) Cu	Distribution % (Feed) Co
Spiral Cl. Conc	86.1	5.10	0.18	115	96.5	52.9	96.6
Ro. Spiral Tail	13.9	1.15	0.16	30	3.5	47.1	3.4
Spiral Feed	100.0	4.55	0.17	105	100.0	100.0	100.0

TABLE 11: ASSAY RESULTS FOR OPEN CIRCUIT SPIRAL CLEANING TEST NO.9

Product	Weight % (Feed)	Assay % T.S.	Assay % Cu	Assay ppm Co	Distribution % (Feed) T.S.	Distribution % (Feed) Cu	Distribution % (Feed) Co
Spiral Cl. Conc	46.5	8.75	0.21	180	90.4	61.8	88.5
Ro. Spiral Tail	53.5	0.81	0.13	25	9.6	38.2	11.5
Spiral Feed	100.0	4.50	0.17	105	100.0	100.0	100.0

TABLE 12: ASSAY RESULTS FOR OPEN CIRCUIT SPIRAL CLEANING TEST No.10

Product	Weight % (Feed)	Assay % T.S.	Assay % Cu	Assay ppm Co	Distribution % (Feed) T.S.	Distribution % (Feed) Cu	Distribution % (Feed) Co
Spiral Cl. Conc	40.5	9.67	0.19	200	89.1	47.5	84.2
Ro. Spiral Tail	59.5	0.81	0.14	25	10.9	52.5	15.8
Spiral Feed	100.0	4.4	0.16	95	100.0	100.0	100.0

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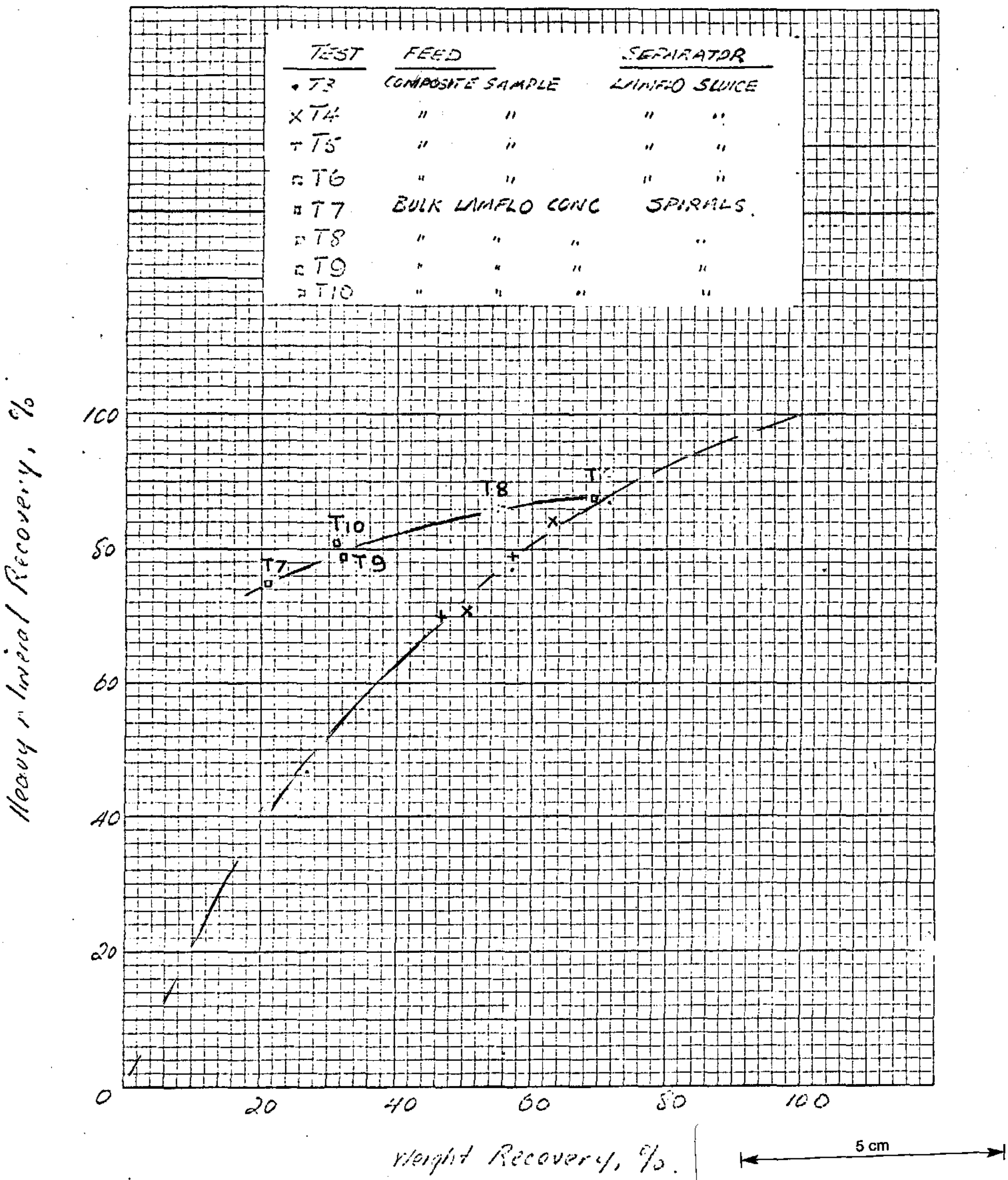

FIG 1. ASSESSMENT OF LAMFLO AND SPIRAL TEST PRODUCTS BY HEAVY LIQUID SEPARATION

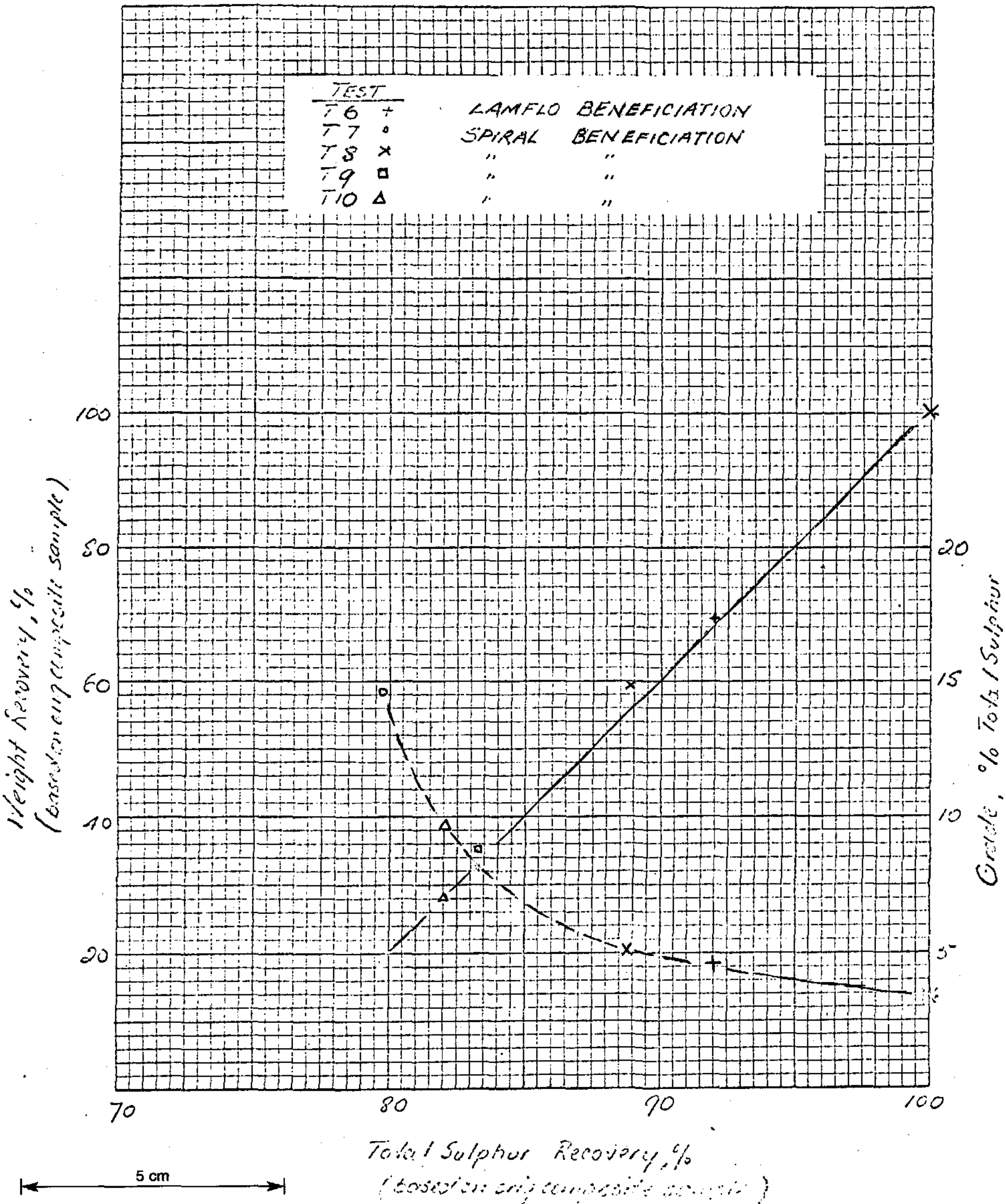

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FIG 2. TOTAL SULPHUR BENEFICIATION OBTAINABLE AS A RESULT OF LAMFLO AND SPIRAL TREATMENT OF COMPOSITE SAMPLE

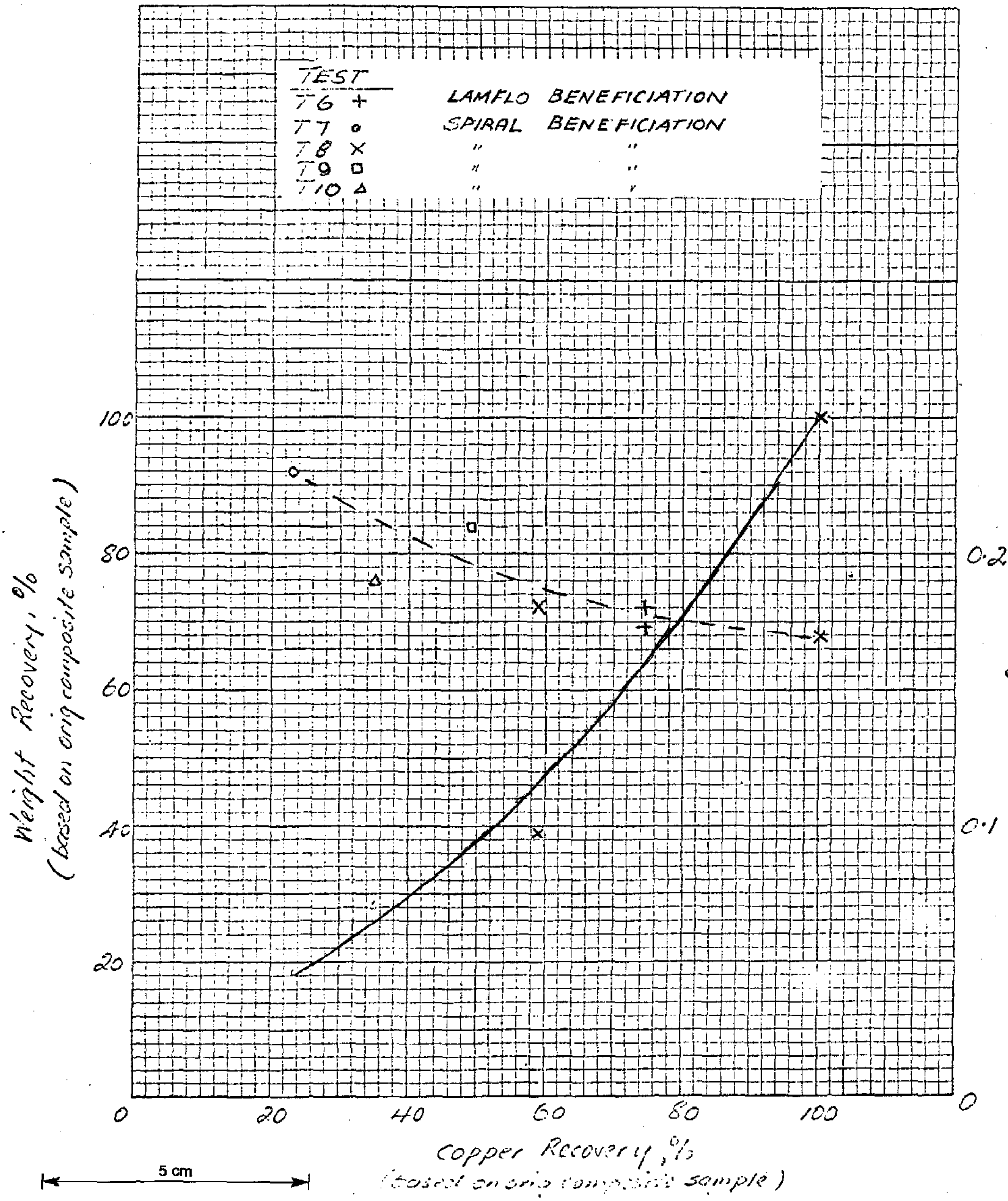

FIG 3. COPPER BENEFICIATION OBTAINABLE AS A RESULT OF LAMFLO AND SPIRAL TREATMENT OF COMPOSITE SAMPLE

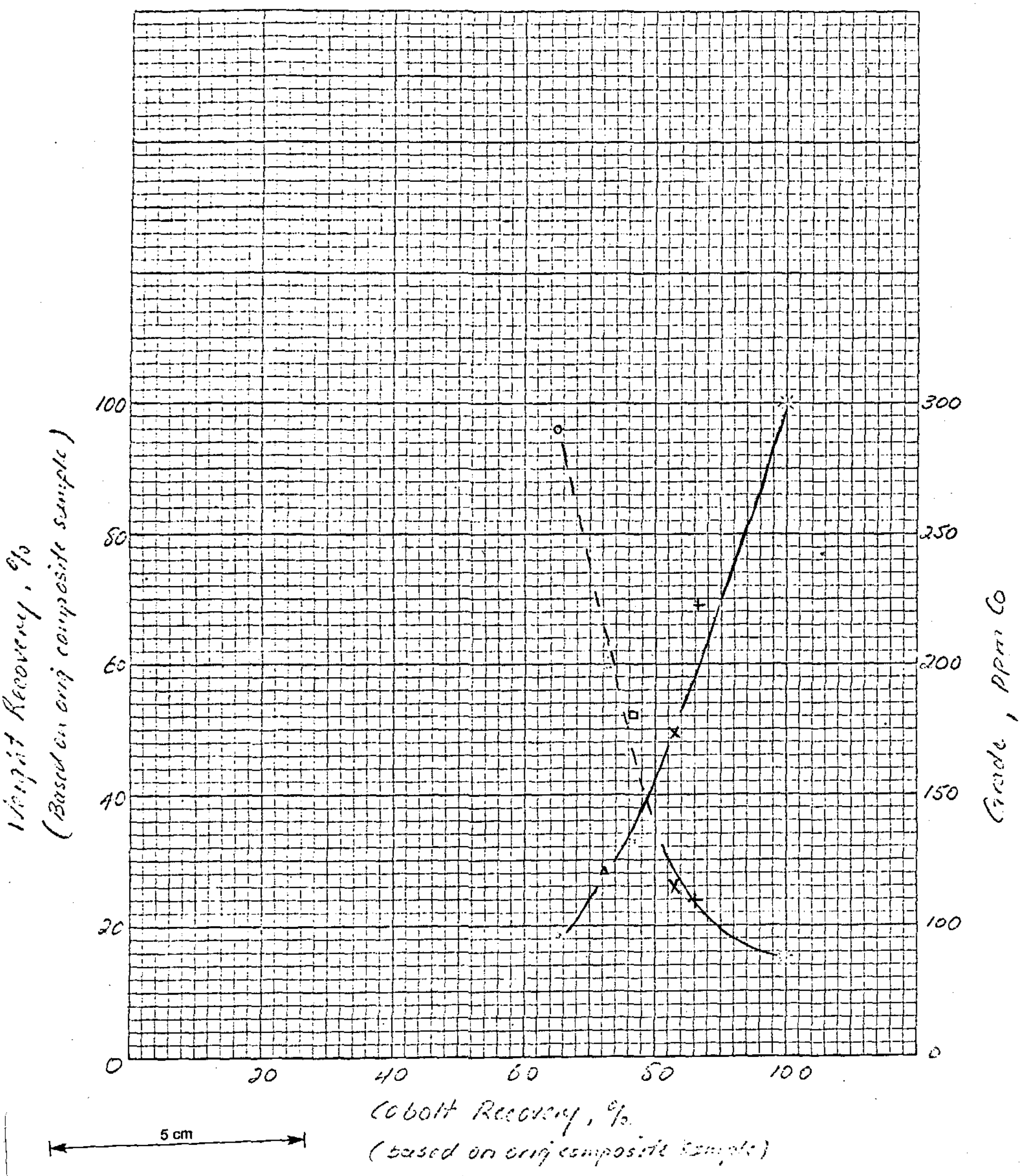

FIG. 4. COBALT BENEFICIATION OBTAINABLE AS A RESULT OF LAMFLO AND SPIRAL TREATMENT OF COMPOSITE SAMPLE

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AUSTRALIA-CITIES SERVICE INC.
MINERALS EXPLORATION DEPARTMENT E.L. 16/73 a2/74

MACQUARIE HARBOUR, TASMANIA
DRILL HOLE LOCATIONS & DEPTH OF MINERALISED SEDIMENTS

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