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THE EFFECT OF THREE TYPES OF COMMINUTION ON GRAVITY CONCENTRATION OF CASSITERITE IN SAMPLES OF TIN ORE FROM SAN JOSÉ, BOLIVIA

by

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MINERAL PROCESSING DIVISION

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THE EFFECT OF THREE TYPES OF COMMINUTION ON GRAVITY CONCENTRATION OF CASSITERITE IN SAMPLES OF TIN ORE FROM SAN JOSÉ, BOLIVIA

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SUMMARY OF RESULTS

No appreciable overall difference was found in the results obtained by concentrating samples of tin ores ground by conventional grinding, dry autogenous grinding, and wet autogenous grinding.

Individual size fractions from the autogenous grinding product appeared to give better results. However, poorer results due to the production of greater amounts of slimes cancelled out this beneficial effect and overall results by autogenous grinding were not appreciably better than conventional grinding results.

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INTRODUCTION

The principal method of concentrating tin from cassiterite-bearing ores throughout the world is gravity concentration. Most of the known tin reserves are now in low grade deposits in which the cassiterite occurs finely disseminated in the gangue rock. Processing of these ores requires finer grinding to liberate the mineral grains with the result that lower tin recoveries are obtained because of the high loss of tin in the slimes.

The mineral cassiterite is said to be very friable and slimes easily if "overground". The ideal method of grinding this type of ore would be one in which the coarser grained cassiterite could be quickly removed from the grinding circuit as soon as it is liberated. Then overgrinding of the freed cassiterite would not occur during the finer grinding required to liberate the fine grained cassiterite. In a conventional ball mill, operating in closed circuit with a drag classifier, the reverse of this is true. The heavier cassiterite grains, which have a weight ratio to the gangue of about 7 to 2.6, will recirculate in this type of grinding circuit until they finally overflow the classifier weir after their particle size has been greatly reduced. The result is a higher loss of cassiterite as slime in the gravity concentration tailing.

The exponents of autogenous grinding claim that much less overgrinding takes place in an autogenous mill. The reason given is that size reduction down to grain size can be readily accomplished autogenously, but not finer, because of the greater energy required to reduce minerals beyond their grain size.

Arrangements for conducting the investigation on this subject were made by Mr. C.C. Huston, President, Prospection Limited, 2001 - 80 Richmond Street West, Toronto, Ontario, with the co-operation of the Mines Branch and Comibol (Mining Corporation of Bolivia).

All the test work at the Mines Branch was done, under the supervision of Mines Branch staff, by Messrs. Roberto Romero and Gorge Reschke, Bolivian engineers, assigned by Comibol for this investigation.

Purpose of Investigation

The investigation was part of a program of technical assistance by Canada to the Bolivian tin industry. The purpose of this investigation was twofold. A new mill is planned to treat an oxide-sulphide tin deposit at San José, Bolivia. Comibol wish to know whether to use dry autogenous grinding, wet autogenous grinding, or conventional grinding in this mill. At the same time the investigation gave the Mines Branch staff an opportunity of broadening its knowledge of comminution and determining if autogenous grinding either wet or dry would liberate cassiterite more efficiently than steel ball milling.

Shipment

Fifteen tons each of two samples of tin ore were received on March 14, 1963, from Bolivia. One sample was described as an oxide ore, the other as a sulphide ore.

At approximately the same time, a similar shipment arrived in Toronto, Ontario, from Bolivia. Prospection Limited arranged for the shipment of the Toronto samples to two independent laboratories for the wet and dry autogenous grinding tests.

Proposed Method of Treatment

The proposed mill for treating these ores will consist of two grinding circuits. The oxide ore is to be ground to minus 14 mesh and the cassiterite recovered by gravity concentration, principally concentrating tables. The sulphide ore, which contains considerable pyrite with some silver and lead minerals as well as cassiterite, is to be ground to minus 65 mesh and a bulk sulphide flotation concentrate removed, containing most of the silver and lead. The flotation tailing will then join the oxide ore for the recovery of the tin.

General Outline of Testing Program

The Mines Branch samples were treated by conventional grinding. The oxide ore was ground to minus 14 mesh and the sulphide ore to minus 60 mesh and a standard flowsheet was worked out for the recovery of the tin from each sample. For bench flotation tests the ore was batch ground in a laboratory grinding mill.

For the comparative testing of the sulphide ore the conventional grinding was done in a small laboratory rod mill on a continuous basis. The mill discharge was screened on a 60 mesh screen and the oversize was returned to the rod mill by hand. In a previous investigation, grinding in this manner gave results similar to those obtained from a pilot plant rod mill in closed circuit with a DSM screen. The resulting pulp was allowed to settle overnight and the supernatant water was decanted off.

Dry autogenous grinding tests were done at Ontario Research Foundation, Rexdale, Ontario, for Aerofall Mills Limited, Toronto, Ontario.

Samples of the oxide ore and the sulphide ore were ground in an Aerofall mill to minus 10 mesh and minus 48 mesh, respectively. Samples of each were then shipped to the Mines Branch for the recovery of tin by the standard flowsheet.

Wet autogenous grinding tests were done at the laboratories of *Allis-Chalmers Manufacturing Company, Milwaukee, Wisconsin, U.S.A. After grinding the oxide ore and the sulphide ore to minus 10 mesh and minus 48 mesh, respectively, by wet autogenous grinding, samples were shipped to the Mines Branch for the tin recovery tests.

Mineralogical Examination

A general mineralogical examination of the two types of ore was done by the mineralogical section of the Mineral Sciences Division, Mines Branch, and has been reported previously in Investigation Reports IR 63-67 and IR 63-72, Mineralogy of a Sulphide Tin-Silver Ore from Bolivia for Prospection Limited and Mineralogy of an Oxide Tin Ore from Bolivia for Prospection Limited, by W. Petruk, Mineral Sciences Division.

DETAILS OF INVESTIGATION

Each sample of ore from each type of grinding was investigated in two ways. Firstly, a screen analysis was made of each grind. Then each size fraction was treated by heavy liquid at a specific gravity of 2.96 and the resulting fractions assayed for tin. This procedure indicated an optimum tailing value which could be obtained from treating each size fraction. Secondly, a sample of each ore from each type of grinding was sized and then concentrated on a laboratory Deister table. In the case of the sulphide ore the sulphides were removed by flotation before sizing.

Sizing before tabling was done by screening for the coarser sizes down to 200 mesh. The minus 200 mesh material was sized hydraulically to produce a -200m + 30μ fraction, a -30μ + 10μ fraction, and -10μ slimes.

All tabling was done on a laboratory Deister table. A sand deck was used for all fractions, except the -30μ + 10μ fraction which was treated on a slime deck.

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*Test Report, Autogenous Grinding, Corporacion Minera de Bolivia, by Allis-Chalmers, June 26, 1963.

A flowsheet of a test done in Bolivia was used as a guide. In the Bolivian test the oxide and sulphide ores were combined before sizing but in this series of tests it was felt that more information could be gained by treating each type of ore separately, although it would be difficult to compare the results with those of the test done in Bolivia. One other change was made from the Bolivian flowsheet. In the Bolivian test the table middling product was retreated on a second table. To follow this procedure would have required a much larger sample than was convenient, so in the Mines Branch tests the middling product was retreated on a superpanner.

TABLE 1

Size Distribution of Ground Products

Sulphide Ore			
Mesh	Conventional Grind	Aerofall Mill Grind*	Allis-Chalmers Grind
35			2.9
48		1.2	2.1
65		8.4	4.9
100	10.7	14.9	6.1
150	14.1	13.4	6.2
200	15.1	10.3	6.8
325	14.9	15.9	7.9
-325	45.2	35.9	63.1
Oxide Ore			
Mesh	Conventional Grind	Aerofall Mill Grind*	Allis-Chalmers Grind
10	-	1.4	6.3
14	16.9	2.9	6.2
20	19.1	-	5.9
28	12.0	15.2	3.3
35	11.1	11.2	4.6
48	7.2	-	3.6
65	6.2	19.3	3.9
100	5.5	9.1	4.4
150	4.2	6.1	5.4
200	3.5	4.8	5.9
325	3.5	7.7	6.2
-325	10.8	22.3	44.3

*Results reported by Ontario Research Foundation.

Heavy-Liquid Separation Studies*

Samples of the ground material from each type of ore and each type of grind were submitted to the Mineralogy Section of the Mineral Sciences Division for heavy-liquid separation and for microscopic studies.

Each sample was sized and each size fraction separated by heavy liquid at a specific gravity of 2.96. The different fractions were weighed, sampled, and assayed for tin. The results of this investigation are shown in Tables 2-7. In addition a microscopic study was made of a portion of each fraction to determine the degree of liberation of cassiterite in each fraction.

The fractions were prepared for a grain count by making polished sections from all the sink fractions and a number of the float fractions. A preliminary examination revealed that the float fractions and the +35 mesh sink fractions did not contain free cassiterite. A grain count was, therefore, made on the -35 mesh sink fractions by counting 200 cassiterite grains in each polished section and classifying the grain as free and not free. The results are given in Tables 8 and 9.

TABLE 2

Sulphide Ore
Conventional Grind Test 1
Heavy-Liquid Separation at 2.96 S.G.

Product		Weight %	Assay % Sn	Distribution % Sn
+100m	Float	2.6	0.18	0.6
	Sink	8.1	1.09	10.2
+150m	Float	6.1	0.17	1.2
	Sink	8.0	1.14	10.6
+200m	Float	7.7	0.18	1.6
	Sink	7.4	1.44	12.5
+325m	Float	7.7	0.18	1.6
	Sink	7.2	1.57	13.2
-325m	Fines	45.2	0.92	48.5
Feed (calcd)		100.0	0.86	100.0

*Mines Branch Internal Report MS-63-27 by W. Petruk, Mineral Sciences Division.

TABLE 3

Sulphide Ore
Aerofall Mill Grind - Classifier Product
Heavy-Liquid Separation at 2.96 S.G.

Product		Weight %	Assay % Sn	Distribution % Sn
+48m	Float	3.2	0.15	0.5
	Sink	0.9	1.70	1.7
+65m	Float	10.2	0.13	1.4
	Sink	4.9	1.73	9.4
+100m	Float	11.7	0.12	1.5
	Sink	8.1	1.69	15.1
+150m	Float	9.3	0.13	1.3
	Sink	8.7	1.68	16.1
+200m	Float	7.0	0.13	1.0
	Sink	7.0	1.75	13.6
+325m	Float	5.5	0.16	1.0
	Sink	5.7	2.03	12.8
-325m	Fines	17.8	1.25	24.6
Feed (calcd)		100.0	0.91	100.0

TABLE 4

Sulphide Ore
Allis-Chalmers Grind
Heavy-Liquid Separation at 2.96 S.G.

Product		Weight %	Assay % Sn	Distribution % Sn
+35m	Float	1.35	0.15	0.3
	Sink	1.51	1.12	2.8
+48m	Float	1.03	0.15	0.3
	Sink	1.08	1.01	1.8
+65m	Float	2.11	0.15	0.5
	Sink	2.82	0.83	3.7
+100m	Float	2.46	0.13	0.5
	Sink	3.60	0.71	4.2
+150m	Float	2.57	0.15	0.7
	Sink	3.62	0.71	4.2
+200m	Float	2.82	0.13	0.7
	Sink	4.01	0.76	4.9
+325m	Float	3.69	0.13	0.8
	Sink	4.26	0.96	6.7
-325m	Fines	63.07	0.66	67.9
Feed (calcd)		100.0	0.61	100.0

TABLE 5

Oxide Ore
Conventional Grind
Heavy-Liquid Separation at 2.96 S.G.

Product		Weight %	Assay % Sn	Distribution % Sn
+14m	Float	14.8	0.19	3.6
	Sink	2.1	6.14	16.6
+20m	Float	16.9	0.17	3.7
	Sink	2.2	6.05	17.1
+28m	Float	10.7	0.17	2.3
	Sink	1.3	6.66	11.2
+35m	Float	9.6	0.14	1.7
	Sink	1.5	5.45	10.6
+48m	Float	6.2	0.14	1.2
	Sink	1.0	4.13	5.3
+65m	Float	5.3	0.12	0.8
	Sink	0.9	4.09	4.8
+100m	Float	4.7	0.13	0.8
	Sink	0.8	3.62	3.7
+150m	Float	3.6	0.11	0.5
	Sink	0.6	3.63	2.8
+200m	Float	3.0	0.10	0.4
	Sink	0.5	3.62	2.3
+325m	Float	3.2	0.14	0.5
	Sink	0.3	6.97	2.7
-325m	Fines	10.8	0.53	7.4
Feed (calcd)		100.0	0.78	100.0

TABLE 6

Oxide Ore
Aerofall Mill Grind - Classifier + Cyclone Product
Heavy-Liquid Separation at 2.96 S.G.

Product		Weight %	Assay % Sn	Distribution % Sn
+14m	Float	7.15	0.29	2.5
	Sink	0.35	8.39	3.4
+20m	Float	10.06	0.22	2.6
	Sink	0.71	6.76	5.7
+28m	Float	10.91	0.21	2.7
	Sink	1.14	6.46	8.8
+35m	Float	8.47	0.20	2.0
	Sink	1.14	7.07	9.5
+48m	Float	7.78	0.17	1.5
	Sink	1.50	5.76	10.2
+65m	Float	7.15	0.16	1.3
	Sink	1.36	5.59	9.0
+100m	Float	6.14	0.13	0.9
	Sink	1.12	5.44	7.2
+150m	Float	5.18	0.12	0.7
	Sink	0.85	4.91	5.0
+200m	Float	5.20	0.11	0.7
	Sink	0.71	5.84	4.9
+325m	Float	5.61	0.16	0.7
	Sink	0.32	6.62	5.1
-325m	Fines	17.15	0.77	15.6
Feed (calcd)		100.00	0.85	100.0

TABLE 7

Oxide Ore
Allis-Chalmers Grind
Heavy-Liquid Separation at 2.96 S.G.

Product		Weight %	Assay % Sn	Distribution % Sn
+10m	Float	5.90	0.32	2.8
	Sink	0.44	5.08	3.3
+14m	Float	5.50	0.25	2.1
	Sink	0.68	5.49	5.6
+20m	Float	5.06	0.21	1.6
	Sink	0.82	4.92	6.0
+28m	Float	2.73	0.22	0.9
	Sink	0.53	5.20	4.2
+35m	Float	3.94	0.19	1.0
	Sink	0.71	5.14	5.4
+48m	Float	2.89	0.16	0.8
	Sink	0.69	3.94	4.1
+65m	Float	3.17	0.15	0.8
	Sink	0.74	3.74	4.2
+100m	Float	3.64	0.13	0.8
	Sink	0.73	3.61	3.9
+150m	Float	4.65	0.11	0.8
	Sink	0.80	3.61	4.4
+200m	Float	5.03	0.11	0.9
	Sink	0.86	3.67	4.8
+325m	Float	5.61	0.14	1.2
	Sink	0.58	5.93	5.1
-325m	Fines	44.30	0.53	35.3
Feed (calcd)		100.00	0.67	100.0

TABLE 8

Percentage of Free Cassiterite in Heavy-Liquid Sink Fractions
Sulphide Ore

Fraction Size (Tyler Mesh)	Conventional Grind	Aerofall Mill Grind	Allis-Chalmers Grind
-35 + 48		0	28
-48 + 65		21	22
-65 + 100	31	25	26
-100 + 150	45	41	44
-150 + 200	47	53	65
-200 + 325	61	58	69

TABLE 9

Percentage of Free Cassiterite in Heavy-Liquid Sink Fractions
Oxide Ore

Fraction Size (Tyler Mesh)	Conventional Grind	Aerofall Mill Grind	Allis-Chalmers Grind
-35 + 48	18	8	8
-48 + 65	23	15	32
-65 + 100	40	39	27
-100 + 150	45	31	35
-150 + 200	46	45	52
-200 + 325	65	56	59

Preliminary Flotation Tests on Sulphide Ore

Before the cassiterite in the sulphide ore could be recovered by gravity concentration, it was necessary to float off the sulphides, as they would have reduced the grade of the tin concentrate. Since the sulphides contained an appreciable amount of silver which would have an economic value, the normal practice was to float off as much as possible of the silver in a lead concentrate, and then float off a pyrite concentrate containing lower silver values.

Several tests were done on a conventionally ground sample to recover the silver in a high grade concentrate, followed by flotation of the pyrite. Due to lack of information on the methods used in similar tests made in Bolivia, it was not possible to make a direct comparison of results, but it is understood that as good results were obtained. Bench flotation tests to recover the silver and pyrite were also done on the samples ground by Aerofall Mills Limited and by Allis-Chalmers but the results were not as good as either the conventional grind or the Bolivian tests.

When larger samples of the ground ore were floated in a No. 7 Denver flotation cell, preparatory to sizing and tabling, the results obtained were not as good as in the bench tests. It was felt that these differences were caused by the lack of control in treating the larger samples.

The best flotation result was obtained after stage grinding a sample of ore to minus 65 mesh. The sample, which had been crushed to minus 10 mesh, was screened on 65 mesh and the oversize was ground for 15 minutes. The ground product was screened again on 65 mesh and the oversize was ground for a second 15 minute period. The resulting pulp had a pH of 6.1 which was raised to 9.1 by the addition of lime. After conditioning successively with sodium cyanide and then with reagent Z-4 and cresylic acid, a primary silver-lead concentrate was floated off. A second stage of conditioning with reagent Z-4 and cresylic acid was followed by a scavenger flotation period. The silver-lead tailing was conditioned with copper sulphate, reagent Z-6, and pine oil, and a pyrite concentrate was floated off. After a second addition of reagent Z-6, additional pyrite was removed by flotation.

Reagents and Conditions

Operation	Reagents - lb/ton			Time, min	pH
Grind (-65m)					6.1
Conditioning	Lime	-	2.2		9.1
	Sodium cyanide	-	0.1	10	
	Reagent Z-4	-	0.1)	20	
	Cresylic acid	-	0.06)		
Ag-Pb flotation				10	
2nd conditioning	Reagent Z-4	-	0.05)	3	
	Cresylic acid	-	0.03)		
Ag-Pb scavenger flotation				5	
Pyrite conditioning	Copper sulphate	-	0.5	5	
	Reagent Z-6	-	0.5		
	Pine oil	-	0.06		
Flotation				7	
2nd conditioning	Reagent Z-6	-	0.25	3	
Flotation				5	

TABLE 10

Results of Flotation Test

Product	Weight %	Assays oz/ton Ag	Assays % Sn	Distribution % Ag	Distribution % Sn
Feed (calcd)	100.0	12.78	0.85	100.0	100.0
No. 1 Ag conc	3.9	260.66	1.41	79.6	6.5
No. 2 Ag conc	1.9	69.88	1.59	10.4	3.5
Pyrite conc	44.8	2.34	0.31	8.2	16.3
Flotation tailing	49.4	0.47	1.27	1.8	73.7

Some preliminary flotation tests were done on the samples ground by Aerofall Mills Limited and by Allis-Chalmers. The results from these bench tests were not as good as had been obtained in previous testwork but there was insufficient time to develop a better flotation procedure. With both of these samples it appeared that oxidation of the sulphides had occurred and this may have decreased the selectivity in flotation. Another factor which might have affected the results was that these samples contained more coarse material. This was particularly true in the case of the Allis-Chalmers sample.

Comparative Tests on Laboratory Tables

(a) Sulphide Ore

Flotation of the sulphides before tabling, in each comparative test, was done in batches but on a larger scale.

Measured volumes of wet pulp were charged to a No. 7 Denver Sub-A cell. The calculated weight was approximately 10,000 grams. Flotation was then done as in the bench test with the exception that single silver-lead concentrates and pyrite concentrates were made. For the Allis-Chalmers ore sample, the same procedure was followed as the pulp was wet. For the Aerofall mill sample, fractions of classifier product and cyclone product were weighed out in proportion to their ratio in the ground product. In some cases attempts were made to clean a portion of one of the products.

TABLE 11

Results of Sulphide Flotation

Product	Weight %	Ag oz/ton	Distribution Ag %
Mines Branch Standard Grind No. 1			
Feed	100.00	12.27	100.0
Silver cleaner conc	1.21	219.76	21.7
" " tailing	5.98	56.57	27.6
Pyrite cleaner conc	1.90	4.70	0.7
" " tailing	1.37	21.99	2.5
Pyrite rougher conc	30.94	11.64	29.3
Flotation tailing*	58.60	3.82	18.2
Allis-Chalmers Grind			
Feed	100.00	11.00	100.0
Silver conc	6.58	103.90	62.2
Pyrite conc	34.45	10.44	32.7
Flotation tailing*	58.97	0.96	5.1
Aerofall Mill Grind			
Feed	100.00	8.29	100.0
Silver cleaner conc	0.55	132.78	8.8
" " tailing	1.01	44.04	5.4
Silver rougher conc	7.30	76.98	67.8
Pyrite cleaner conc	1.31	3.74	0.6
" " tailing	0.15	4.83	0.1
Pyrite rougher conc	27.68	4.18	14.0
Flotation tailing*	62.00	0.28	3.3
Mines Branch Standard Grind No. 2			
Feed	100.00	12.27	100.0
Silver conc	3.34	150.10	40.8
Pyrite conc	40.84	14.38	47.7
Flotation tailing*	55.82	2.54	11.5

*Calculated

The flotation tailing from each type of grind was sized by screening all fractions larger than 200 mesh. The upper size limit in screening was determined by the grind of that particular sample.

The minus 200 mesh material was sized hydraulically, the size range being calculated from the settling velocity of cassiterite. The usual size ranges produced were: -200 mesh + 30 microns, -30 microns + 10 microns, and -10 microns. In one case the first size range was -200 mesh + 20 microns. The -10 micron material was designated as slime and discarded after weighing, sampling, and assaying.

Tabling of the sized fractions was done on a laboratory size Deister table. Usually a concentrate, a middling, and a tailing were made but, in some cases, the middling was eliminated or a second middling fraction was taken. Such changes were made when there was any doubt as to the separation of the different minerals. If results did not appear to be suitable the test was repeated. An attempt was made to do all corresponding tests under identical conditions.

Tabling of the sample given a conventional grind did not produce satisfactory results, even after several attempts, and as it was the first sample tested it was decided to repeat this test after the tests on Aerofall and Allis-Chalmers products. The results of the two tests were designated as Test No. 1 and Test No. 2.

The following tables give the results of the tabling of the sulphide ore with a metallurgical balance of the tin including the flotation products.

TABLE 12

Table Test Sulphide Ore
Conventional Grind No. 1

Product	Weight %	Assay % Sn	Distribution % Sn
Ag cleaner concentrate	1.21	0.72	1.1
" " tailing	5.98	0.60	4.2
Pyrite cleaner conc	1.90	0.17	0.4
" " tailing	1.37	0.78	1.3
Pyrite rougher conc	30.94	0.40	14.5
-60+80m			
Table concentrate	0.17	10.74	2.1
Superpanner conc	0.14	6.82	1.2
" tailing	1.16	1.02	1.4
Table tailing	3.37	0.32	1.3
-80+100m			
Table concentrate	0.17	28.32	5.6
Superpanner conc	0.23	9.43	2.6
" tailing	1.39	1.07	1.8
Table tailing	7.49	0.35	3.0
-100+150m			
Table concentrate	0.06	34.38	2.5
Superpanner conc	0.12	13.00	1.9
" tailing	0.62	1.13	0.8
Table tailing	4.34	0.35	1.7
-150+200m			
Table concentrate	0.07	36.80	3.0
Superpanner conc	0.03	25.47	0.9
" tailing	0.87	1.18	1.2
Table tailing	4.28	0.33	1.6
-200m+20μ			
Table concentrate	0.13	45.90	7.0
Superpanner conc	0.31	25.35	9.2
" tailing	0.74	1.48	1.3
Table tailing	6.48	0.38	2.9
-20μ + 10μ			
Table concentrate	0.79	5.27	4.9
" tailing	3.88	0.35	1.6
-10μ slimes	21.76	0.75	19.0
Feed (calcd)	100.00	0.86	100.0

TABLE 13

Table Test Sulphide Ore
Aerofall Mill Grind

Product	Weight %	Assay % Sn	Distribution % Sn
Ag cleaner concentrate	0.55	0.96	0.56
Ag cleaner tailing	1.01	0.65	0.79
Ag rougher concentrate	7.30	0.76	6.20
Pyrite cleaner conc	1.31	0.34	0.45
Pyrite cleaner tailing	0.15	0.97	0.11
Pyrite rougher conc	27.68	0.41	12.74
-60+80m			
Table concentrate	0.04	29.02	1.35
Superpanner conc	0.10	19.35	2.14
" tailing	2.81	1.14	3.61
Table tailing	8.03	0.21	1.92
-80+100m			
Table concentrate	0.12	42.15	5.75
Superpanner conc	0.04	17.37	0.79
" tailing	0.64	2.52	1.80
Table tailing	7.47	0.25	2.14
-100+150m			
Table concentrate	0.06	43.22	2.93
Superpanner conc	0.03	20.14	0.68
" tailing	0.37	2.04	0.90
Table tailing	4.12	0.21	1.01
-150+200m			
Table concentrate	0.08	57.34	5.19
Superpanner conc	0.04	26.84	1.24
" tailing	0.36	2.58	1.01
Table tailing	4.90	0.20	1.13
-200m + 30μ			
Table concentrate	0.06	67.04	4.51
Superpanner conc	0.10	54.18	6.09
" tailing	0.10	22.20	2.48
Table tailing	0.20	0.45	0.11
-30μ + 10μ			
Table concentrate	0.52	10.90	6.43
" tailing	8.05	0.46	4.17
-10μ slimes	18.76	0.85	17.94
Multiclone product	3.10	0.74	2.59
Sly product	1.90	0.59	1.24
Feed (calcd)	100.00	0.89	100.00

TABLE 14

Table Test Sulphide Ore
Allis-Chalmers Grind

Product	Weight %	Assay % Sn	Distribution % Sn
Ag concentrate	6.58	0.51	5.44
Pyrite concentrate	34.45	0.37	20.32
+35m material	3.06	0.80	3.84
-35+48m			
Table concentrate	0.79	1.36	1.76
" tailing	1.44	0.28	0.64
-48+60m			
Table concentrate	0.33	1.72	0.96
" tailing	0.81	0.29	0.32
-60+80m			
Table concentrate	0.03	13.47	0.64
" midds	0.47	1.91	1.44
" tailing	1.53	0.24	0.64
-80+100m			
Table concentrate	0.02	34.97	1.12
Superpanner conc	0.17	5.11	1.44
" tailing	0.17	2.01	0.48
Table tailing	2.07	0.24	0.80
-100+150m			
Table concentrate	0.01	39.04	0.64
Superpanner conc	0.07	7.25	0.80
" tailing	0.08	2.81	0.32
Table tailing	1.99	0.23	0.64
-150+200m			
Table concentrate	0.07	64.63	0.96
Superpanner conc	0.07	11.15	1.28
" tailing	0.07	2.89	0.32
Table tailing	1.97	0.21	0.64
-200m + 30μ			
Table concentrate	0.05	61.08	4.96
Superpanner conc	0.14	27.20	6.08
" tailing	0.17	8.83	2.40
Table tailing	2.32	0.55	2.08
-30μ + 10μ			
Table concentrate	0.46	8.22	6.08
" tailing	4.59	0.32	2.40
-10μ slimes	36.08	0.53	30.56
Feed (calcd)	100.00	0.63	100.00

TABLE 15

Table Test Sulphide Ore
Conventional Grind No. 2

Product	Weight %	Assay % Sn	Distribution % Sn
Ag concentrate	3.34	1.00	3.72
Pyrite concentrate	40.84	0.43	19.87
+60m material	3.38	1.23	4.74
-60+80m			
Table concentrate	0.05	37.90	2.14
Superpanner conc	0.20	10.20	2.26
" tailing	0.43	4.41	2.14
Table tailing	7.18	0.41	3.27
-80+100m			
Table concentrate	0.06	45.06	3.05
Superpanner conc	0.15	14.27	2.37
" tailing	0.33	5.88	2.14
Table tailing	7.29	0.38	3.16
-100+150m			
Table concentrate	0.04	52.46	2.37
Superpanner conc	0.07	16.93	1.36
" tailing	0.11	7.74	1.02
Table tailing	3.94	0.35	1.58
-150+200m			
Table concentrate	0.06	60.58	4.06
Superpanner conc	0.08	26.43	2.37
" tailing	0.24	5.52	1.47
Table tailing	5.97	0.32	2.14
-200m + 30µ			
Table concentrate	0.09	55.33	5.65
Superpanner conc	0.08	40.81	3.72
" tailing	0.16	5.51	1.02
Table tailing	2.08	0.38	0.90
-30µ + 10µ			
Table concentrate	0.16	25.38	4.63
" tailing	4.90	0.50	2.71
-10µ slimes	18.77	0.76	16.14
Feed (calcd)	100.00	0.88	100.00

The results of tabling the sulphide ore are summarized in the following tables. The table concentrate is obtained by combining the table concentrate with the superpanner concentrate.

TABLE 16

Conventional Grind No. 1

Product	Weight %	Assay % Sn	Distribution % Sn
Feed (calcd)	100.00	0.86	100.0
Sulphide conc	41.40	0.44	21.5
Table conc	2.22	15.76	40.9
Table middling	4.78	1.15	6.5
Table tailing	29.84	0.35	12.1
Slime	21.76	0.75	19.0

TABLE 17

Aerofall Mill Grind

Product	Weight %	Assay % Sn	Distribution % Sn
Feed (calcd)	100.00	0.89	100.00
Sulphide conc	38.00	0.49	20.85
Table conc	1.19	27.65	37.10
Table middling	4.28	2.03	9.80
Table tailing	32.77	0.28	10.48
Slime	18.76	0.85	17.94
Multiclone product	3.10	0.74	2.59
Sly dust collector product	1.90	0.59	1.24

TABLE 18

Allis-Chalmers Grind

Product	Weight %	Assay % Sn	Distribution % Sn
Feed (calcd)	100.00	0.63	100.00
Coarse material	3.06	0.80	3.84
Sulphide conc	41.03	0.39	25.76
Table conc	1.03	14.56	24.00
Table middling	2.08	2.31	7.68
Table tailing	16.72	0.31	8.16
Slime	36.08	0.53	30.56

TABLE 19

Conventional Grind No. 2

Product	Weight %	Assay % Sn	Distribution % Sn
Feed (calcd)	100.00	0.88	100.00
+60m material	3.38	1.23	4.74
Sulphide conc	44.18	0.47	23.59
Table conc	1.04	28.94	33.98
Table middling	1.27	5.43	7.79
Table tailing	31.36	0.39	13.76
Slime	18.77	0.76	16.14

(b) Oxide Ore

The oxide ore was treated in much the same manner as the sulphide ore except there was no flotation step. From investigations done in Bolivia it had been reported that the ore could be treated at minus 14 mesh. The sample prepared at the Mines Branch was done by crushing and screening through 14 mesh. The other samples were ground by Aerofall Mills Limited and Allis-Chalmers.

Sizing was done as with the sulphide ore, screening to 200 mesh and hydraulically sizing the finer material. The minus 10 micron material was again identified as slime and weighed, sampled, and assayed.

In tabling this material it was noticed that in all the fractions coarser than 50 mesh there was no free cassiterite. This made the separation of concentrate and middling fractions very difficult and some variations in procedure were used on these coarser fractions.

TABLE 20

Table Test Oxide Ore
Conventional Grind

Product		Weight %	Assay % Sn	Distribution % Sn
-14+20m	Table concentrate	1.42	8.90	16.1
	No. 1 Table middling	8.11	0.64	6.6
	No. 2 Table middling	4.07	0.28	1.4
	Table tailing	7.20	0.13	1.1
-20+30m	Table concentrate	0.48	18.66	11.4
	No. 1 Table middling	4.19	1.38	7.4
	No. 2 Table middling	4.11	0.43	2.3
	Table tailing	11.54	0.18	2.7
-30+35m	Table concentrate	0.13	18.20	2.9
	No. 1 Table middling	0.64	2.99	2.4
	No. 2 Table middling	2.11	0.52	1.4
	Table tailing	4.75	0.16	1.0
-35+50m	Table concentrate	0.09	26.73	3.2
	No. 1 Table middling	0.32	5.15	2.1
	No. 2 Table middling	2.00	0.68	1.8
	Table tailing	5.43	0.17	1.2
-50+60m	Table concentrate	0.02	21.11	0.6
	No. 1 Table middling	0.04	10.82	0.6
	No. 2 Table middling	1.04	0.88	1.2
	Table tailing	2.18	0.15	0.4
-60+80m	Table concentrate	0.07	20.30	1.7
	Superpanner conc	0.02	8.08	0.3
	" tailing	1.94	0.70	1.8
	Table tailing	1.95	0.13	0.4
-80+100m	Table concentrate	0.11	17.43	2.4
	Superpanner conc	0.01	6.17	0.1
	" tailing	1.50	0.79	1.5
	Table tailing	3.51	0.15	0.6
-100+150m	Table concentrate	0.06	13.56	1.0
	Superpanner conc	0.01	10.02	0.1
	" tailing	0.76	0.50	0.5
	Table tailing	1.32	0.14	0.3
-150+200m	Table concentrate	0.11	13.92	1.9
	Superpanner conc	0.01	18.72	0.1
	" tailing	0.98	0.58	0.8
	Table tailing	2.60	0.18	0.6
-200m + 30μ	Table concentrate	0.17	19.63	4.3
	No. 1 Superpanner conc	0.04	12.06	0.6
	" tail'g	0.09	4.27	0.5
	No. 2 Superpanner conc	0.01	14.46	0.3
	" tail'g	1.66	0.59	1.3
	Table tailing	2.85	0.15	0.5
-30μ + 10μ	Table concentrate	0.35	4.48	2.0
	Superpanner conc	0.01	17.87	0.4
	" tailing	1.58	0.31	0.6
	Table tailing	4.11	0.17	0.9
-10μ	Slime	14.30	0.37	6.7
Feed (calcd)		100.00	0.79	100.0

TABLE 21

Table Test Oxide Ore
Aerofall Mill Grind

Product		Weight %	Assay % Sn	Distribution % Sn
+10m Product		2.69	0.38	1.3
-10+14m	Table concentrate	0.96	2.80	3.5
	" middling	3.34	0.58	2.4
	" tailing	5.86	0.16	1.2
-14+20m	Table concentrate	0.56	5.91	4.2
	" middling	3.22	0.73	3.1
	" tailing	5.39	0.18	1.3
-20+30m	Table concentrate	1.08	6.86	9.5
	" middling	4.48	0.68	3.8
	" tailing	7.61	0.19	1.8
-30+35m	Table concentrate	0.08	26.73	2.7
	" middling	1.69	1.66	3.6
	" tailing	3.21	0.17	0.6
-35+50m	Table concentrate	0.11	31.98	4.5
	" middling	2.13	1.98	5.4
	" tailing	5.35	0.18	1.3
-50+60m	Table concentrate	0.03	33.65	1.3
	" middling	0.57	2.02	1.5
	" tailing	1.56	0.18	0.4
-60+80m	Table concentrate	0.05	32.94	2.0
	Superpanner conc	0.02	23.32	0.6
	" tailing	1.09	1.58	2.2
	Table tailing	3.26	0.17	0.8
-80+100m	Table concentrate	0.11	25.64	3.6
	Superpanner conc	0.01	13.87	0.1
	" tailing	0.95	1.35	1.7
	Table tailing	4.21	0.18	1.0
-100+150m	Table concentrate	0.10	21.46	2.7
	Superpanner conc*		12.37	
	" tailing	0.70	1.19	1.0
	Table tailing	3.36	0.15	0.6
-150+200m	Table concentrate	0.09	22.77	2.6
	Superpanner conc	0.01	10.93	0.1
	" tailing	0.70	1.48	1.3
	Table tailing	3.83	0.15	0.8
-200m + 30μ	Table concentrate	0.03	54.54	2.0
	Superpanner conc	0.19	17.39	4.2
	" tailing	0.51	2.55	1.7
	Table tailing	2.31	0.18	0.5
-30μ + 10μ	Table concentrate	0.32	8.52	3.5
	Superpanner conc	0.04	13.84	0.8
	" tailing	1.88	0.29	0.6
	Table tailing	6.26	0.18	1.4
-10μ	Slime	12.35	0.44	6.9
Multiclone product		5.80	0.41	3.1
Sly dust product		1.90	0.32	0.8
Feed (calcd)		100.00	0.78	100.0

*Too small amount. Can be included with superpanner concentrate from next coarser size.

TABLE 22

Table Test Oxide Ore
Allis-Chalmers Grind

Product		Weight %	Assay % Sn	Distribution % Sn
+10m Product		6.02	0.61	5.52
-10+14m	Table concentrate	0.49	4.66	3.43
	" middling	1.70	1.05	2.69
	" tailing	3.79	0.25	1.34
-14+20m	Table concentrate	0.58	5.13	4.48
	" middling	1.61	1.18	2.84
	" tailing	3.71	0.28	1.49
-20+30m	Table concentrate	0.36	7.68	4.18
	" middling	1.53	1.44	3.28
	" tailing	4.53	0.23	1.49
-30+35m	Table concentrate	0.05	8.42	0.60
	" middling	0.50	2.23	1.64
	" tailing	1.24	0.20	0.30
-35+50m	Table concentrate	0.06	10.10	0.90
	" middling	0.86	2.99	3.88
	" tailing	3.59	0.23	1.19
-50+60m	Table concentrate	0.06	7.34	0.60
	" middling	0.27	2.65	1.04
	" tailing	1.39	0.20	0.45
-60+80m	Table concentrate	0.03	13.08	0.60
	Superpanner conc	0.08	6.51	0.75
	" tailing	0.31	2.83	1.34
	Table tailing	2.64	0.19	0.75
-80+100m	Table concentrate	0.07	11.67	1.19
	Superpanner conc	0.13	5.31	1.04
	" tailing	0.33	2.51	1.19
	Table tailing	4.10	0.18	1.04
-100+150m	Table concentrate	0.02	20.50	0.60
	Superpanner conc	0.10	5.67	0.90
	" tailing	0.42	1.30	0.75
	Table tailing	2.02	0.13	0.45
-150+200m	Table concentrate	0.04	27.47	1.65
	Superpanner conc	0.11	9.74	1.64
	" tailing	0.66	1.41	1.34
	Table tailing	4.98	0.13	0.90
-200m + 30μ	Table concentrate	0.05	59.13	4.48
	Superpanner conc	0.33	10.70	5.22
	" tailing	0.32	2.98	1.49
	Table tailing	3.62	0.25	1.34
-30μ + 10μ	Table concentrate	0.46	7.82	5.37
	Superpanner conc	0.09	11.28	1.49
	" tailing	2.02	0.32	0.90
	Table tailing	9.58	0.20	2.84
-10μ	Slime	36.15	0.37	19.40
Feed (calcd)		100.00	0.67	100.00

Due to variations in procedure and the wide range of products obtained it was difficult to summarize the results of tabling the oxide ore. It was decided to combine the superpanner products as the table middling but, in the case of the conventional grind when two middling products were made on the coarse sizes, the No. 1 middling was combined with the superpanner concentrate and the No. 2 middling was combined with the superpanner tailing.

TABLE 23

Conventional Grind

Product	Weight %	Assay % Sn	Distribution % Sn
Feed (calcd)	100.00	0.79	100.0
Table conc	3.01	12.46	47.6
No. 1 table middling	13.41	1.23	21.0
No. 2 table middling	21.84	0.54	15.0
Table tailing	47.44	0.16	9.7
Slime	14.30	0.37	6.7

TABLE 24

Aerofall Mill Grind

Product	Weight %	Assay % Sn	Distribution % Sn
Feed (calcd)	100.00	0.78	100.0
Coarse product	2.69	0.38	1.3
Table conc	3.52	9.32	42.1
Table middling	21.53	1.24	34.1
Table tailing	52.21	0.17	11.7
Slime	12.35	0.44	6.9
Multiclone product	5.80	0.41	3.1
Sly dust collector product	1.90	0.32	0.8

TABLE 25

Allis-Chalmers Grind

Product	Weight %	Assay % Sn	Distribution % Sn
Feed (calcd)	100.00	0.67	100.0
Coarse product	6.02	0.61	5.5
Table conc	2.27	8.28	28.1
Table middling	11.37	1.97	33.4
Table tailing	45.19	0.20	13.6
Slime	35.15	0.37	19.4

DISCUSSION OF RESULTS

To do comparative tests on different methods of treatment it was necessary to run each test under conditions which were as close to being identical as possible. Every precaution was taken to assure that test conditions were identical. With the exception of the second test of the conventional grind on the sulphide ore, each phase of all of the tests was done by the same person. Although there were considerable differences at times, such as in the grade of concentrate produced, it is felt that the tests were reproduced rather well. Different interpretations of the results can be made depending on the end result desired.

The work was hampered by a lack of previous knowledge of the ores involved. In the case of the oxide ore several attempts were made to table the coarse fractions before it was learned from a mineralogical examination that there was no free cassiterite present.

A flowsheet of the proposed Bolivian operation was available but, as it was for a composite of the two ores, it did not reveal much pertinent information. The procedure followed was one which was considered to be the best for the problem involved. Several assumptions had to be made which might not have been in accord with the desires of the engineers who designed the proposed flowsheet.

Several peculiar results appeared throughout the test work and could not be explained. These were rechecked when possible. It may be that the different types of grinding created conditions different from those encountered in conventional grinding.

The sample submitted from Allis-Chalmers was not prepared properly. It is our understanding that the sample was batch ground and the ground product was not sized properly. There was a considerable amount of coarse oversize present plus a very large amount of slimes. The presence of the slimes meant a considerable loss of tin in that fraction plus a possible lowering of the amount of tin in the feed which might have remained in the mill. In one test on fine material the tailing loss was high, probably due to an extra amount of finely ground tin being present in that fraction.

Due to the variations in grade of table concentrates and super-panner concentrates, especially of the oxide ore, several methods of combining the different products can be used. In the coarser oxide fractions, the material reported as a table concentrate is a true middling product and will have to be reground and retabled to make an acceptable grade of concentrate. In the results reported in these tests the products are named as produced so that the different fractions can be combined as desired.

CONCLUSIONS

From the results of the tests there appears to be little overall difference in the metallurgical results obtained after the different methods of grinding.

On the sulphide ores, some screen fractions of the product from autogenous grinding gave better results than corresponding size fractions from other grinding products. However, the overall recovery was no better as the slime losses were always greater from autogenous grinding.

The results from the oxide ore showed little difference between the different types of grinding. Conventional grinding gave lower tailings in the coarser sizes but this is probably due to the fact that larger quantities of concentrate and middling products were made. In the oxide ore there appeared to be a definite lowering of the tailing value along the length of the table. Dry autogenous grinding produced some fine material which contained low tin values but the overall slime losses were greater than in conventional grinding. It is possible that in more extensive grinding tests better results in grinding could be obtained which would improve the overall recovery. But, as mentioned before, the results from the samples submitted showed no overall improvement.

There appear to be some differences in concentrating characteristics which favour autogenous grinding and which should be investigated more fully.

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GOH:RWB/DV