SOCIETY OF MINING ENGINEERS of AIME

345 EAST 47TH STREET, NEW YORK, N. Y. 10017

PREPRINT NUMBER

71-B-32

26 p

THE PRACTICE OF CASSITERITE FLOTATION IN BOLIVIA

Roberto Romero L.
Head, Minerals Processing Division

Emilio Navarro A.
Senior Engineer

Rolando Torrejon J.
Research Engineer

Cristobal Aguilar M.
Research Engineer

Mining and Metallurgical Research Institute
Oruro, Bolivia

This paper is to be presented at the AIME CENTENNIAL ANNUAL MEETING - New York, New York - February 26 - March 4, 1971.

THE PRACTICE OF CASSITERITE FLOTATION IN BOLIVIA

INTRODUCTION

The dressing of Bolivian tin ores has been done up to the present by classical gravity methods, taking advantage of the high specific gravity of cassiterite compared with that of the accompanying gangue. For this purpose, jigs and shaking tables are used in the treatment of the various size fractions in which the ore is classified. Bolivian ores are mainly of the vein type and, to obtain a reasonable separation, crushing and several stages of grinding are necessary during the process to substantially liberate the cassiterite from the gangue.

Gravity processes for cassiterite are effective for sizes down to 200 mesh. Below this size the efficiency of the gravity methods falls off very rapidly with increasing fineness of the mineral grains. The conventional treatment for this material is desliming followed by tabling on shaking tables. Various other types of machines have been designed for the gravity treatment of these fine particles but they have had limited success.

Bolivian ores contain an appreciable amount of minus 200 mesh material constituted by "primary fines" coming from the mine itself, and "secondary fines" originated during the crushing and grinding necessary for liberation of cassiterite. The difficulty in the treatment of these fine particles is one of the causes why the recovery of tin in concentrates is only of around 50% in the mines owned by Corporación Minera de Bolivia, the State owned enterprise. The average figure for other Bolivian mines is probably less than 50%, hence, there is a strong need to study other means of increasing the recovery, particularly in the fine size range.

Since the 1930's the technical literature contains references to cassiterite flotation systems using various reagents such as oleic acid, tall oil, other fatty acids and soaps, alkyl sulphates and sulphonates, amine compounds, and others as collectors (1-11). In general, the proposed flotation schemes work only under special conditions and have not been applied on an industrial scale. In cases where some success has been obtained, the processes dealt with the production of low grade preconcentrates for pyrometallurgical upgrading (12, 13).

One of the major problems in selective flotation of cassiterite is the presence of metal ions in solution, such as Ca^{+2}, Fe^{+2}, Fe^{+3}. These ions can act as activators for other minerals present in the ore. In this way, for example, quartz and silicates can be floated along with cassiterite, lowering the grade of the tin concentrate. The metal ions in solution can also interfere by reacting with the collector; as a result insoluble compounds are formed leaving insufficient quantity of the surfactant in solution to produce good collection. More recently, new reagents have been developed, such as p-tolyl arsonic acid (14) alkyl phosphonic acids (15, 16) and the alkyl sulfosuccinamates (17) which have shown to be collectors for cassiterite. These reagents, particularly the latter two, have been extensively investigated at the Instituto de Investigaciones Minero-Metalúrgicas in Oruro, Bolivia, with views to their application to the flotation of cassiterite fine ores.

The present paper deals with the results obtained with a reagent commercially known as aerosol-22, an N-octadecyl tetrasodium sulfosuccinamate.

OBJECTIVES OF THE INVESTIGATION

The most important aspects to be studied during the investigation were:

1. The influence of heavy metal ions, Ca^{+2}, Fe^{+2} and Fe^{+3} which are present in the mine waters, or recirculating waters, that are used due to lack of other sources in the concentrating mills.

2. It is known that the presence of very fine particles causes problems such as excesive collector consumption and lack of selectivity due to slime coating. One point to be determined was the minimization of the losses to be incurred in removing the very fine particles.

3. The determination of the conditions under which the collector studied could be successfully employed, and the development of a flowsheet for the treatment by flotation of fine tin-bearing materials.

4. Evaluation of the process to determine whether it could be economically applied on an industrial scale.

MATERIAL EMPLOYED IN THE EXPERIMENTATION

The first stage of work involved vacuum flotation tests with pure cassiterite samples. These samples were obtained from high grade concentrates which were further purified by gravity, flotation and magnetic methods.

Samples for bench tests, continuous tests in laboratory, and pilot plant runs in the field were taken from the feed to the present slime sections and their tailings. Another product tested was an intermediate product from the Machacamarca mill. Here a rough gravity concentrate is first obtained which is then "split" by tabling into a final high grade product and a low grade "middling"; this middling contains a high proportion of the tin in the fine sizes. When it is less than 5% tin it is recirculated to the rough concentration stage where a large part of the fines are lost. When the tin content is over 5% the product is sent to a tin fuming plant. Cassiterite flotation was tried as a means to improve the recovery because trials with other slime materials had already shown good results.

Some typical screen and sedimentation analysis of the materials are given in Tables 1, 2, 3 and 4.

TABLE 1

SLIME GRAVITY TAILINGS, CATAVI MILL

Size	% Weight	Cum. % Wt	% Sn	% Distrib.	Cum. % Distrib.
+100#	0.94	0.94	0.09	0.21	0.21
+150#	3.92	4.86	0.09	0.94	1.15
+200#	7.43	12.29	0.06	1.18	2.33
+270#	7.30	19.59	0.13	2.54	4.87
+325#	4.85	24.44	0.18	2.33	7.20
+ 37µ	4.21	28.65	1.19	13.39	20.59
+ 26µ	4.47	33.12	0.41	4.90	25.49
+ 18µ	8.91	42.03	0.40	9.53	35.02
+ 13µ	14.39	56.42	0.41	15.80	50.82
+ 9µ	25.68	82.10	0.36	24.74	75.56
- 9µ	17.90		0.51	24.44	
	100.00		0.37	100.00	

TABLE 2

SLIME GRAVITY TAILINGS, COLQUIRI MILL

Size	% Weight	Cum. % Wt	% Sn	% Distrib.	Cum. % Distrib.
+100#	6.10	6.10	0.25	2.15	2.15
+150#	5.75	11.85	0.22	1.81	3.96
+200#	13.16	25.01	0.20	3.77	7.73
+270#	17.10	42.11	0.27	6.61	14.34
+ 37μ	10.38	52.49	1.60	23.79	38.13
+ 26μ	15.12	67.61	1.12	24.24	62.37
+ 18μ	5.81	73.42	0.92	7.66	70.03
+ 13μ	8.18	81.60	0.92	10.77	80.80
+ 9μ	4.78	86.38	1.05	7.18	87.98
+ 6μ	2.93	89.31	0.90	3.78	91.76
+ 4μ	1.36	90.67	0.80	1.56	93.32
- 4μ	9.33		0.50	6.68	
	100.00		0.69	100.00	

TABLE 3

FEED TO SLIMES GRAVITY SECTION, POTOSI MILL

Size	% Weight	Cum. % Wt	% Sn	% Distrib.	Cum. % Distrib.
+200#	1.70	1.70	0.30	0.56	0.56
+270#	2.07	3.77	0.25	0.56	1.12
+ 37μ	2.49	6.26	2.55	6.92	8.04
+ 26μ	5.25	11.51	1.40	8.01	16.05
+ 18μ	9.35	20.86	1.40	14.27	30.32

TABLE 3 (cont.)

Size	% Weight	Cum. % Wt	% Sn	% Distrib.	Cum. % Distrib.
+ 13μ	10.61	31.47	1.35	15.62	45.94
+ 9μ	7.48	38.95	1.30	10.60	56.54
+ 6μ	7.15	46.10	1.05	8.19	64.73
+ 4μ	6.76	52.86	0.95	7.00	71.73
− 4μ	47.14		0.55	28.27	
	100.00		0.92	100.00	

TABLE 4

MIDDLINGS FROM SPLITTING OPERATION, MACHACAMARCA MILL

Size	% Weight	Cum. % Wt	% Sn	% Distrib.	Cum. % Distrib.
+100#	16.79	16.79	0.63	8.88	8.88
+150#	21.95	38.74	0.70	12.82	21.70
+200#	20.70	59.44	0.80	13.84	35.54
+270#	16.11	75.55	0.70	9.42	44.96
+ 37μ	3.16	78.71	6.50	17.16	62.12
+ 26μ	2.79	81.50	3.00	7.00	69.12
+ 18μ	6.75	88.25	2.30	12.97	82.09
+ 13μ	3.94	92.19	1.80	5.93	88.02
+ 9μ	2.64	94.83	2.10	4.63	92.65
− 9μ	5.17		1.70	7.35	
	100.00		1.20	100.00	

Mineralogy

The Catavi slime tailings contain abundant quartzitic rock and quartz. Other components of gangue are tourmaline, pyrite, hematite and limonite. Cassiterite is the valuable mineral.

In the Colquiri tailings there are quartzite, slate, sphalerite-marmatite, pyrite, pyrrhotite, siderite, fluorite and cassiterite. The Potosí slimes are composed of gangue rock, quartz, limonite, hematite, pyrite, cassiterite. Other sulphides present in small amounts are arsenopyrite, sphalerite, chalcopyrite, stannite, pyrrhotite. Part of the cassiterite is in the form of "needle tin". Various types of rocks and quartz are the main gangue constituents in the Machacamarca middlings. Other minerals present are pyrite, hematite, limonite, cassiterite a part of which is in the form of needle tin.

The chemicals employed in the investigation were: N-octadecyl tetrasodium sulfosuccinamate, commercial grade known as aerosol-22; sodium isopropyl xanthate, commercial grade; pine oil, Dowfroth 1012, Dowfroth 250, commercial grade; citric acid, sodium silicofluoride, both chemical grade; pH regulators, HCl, H_2SO_4 and KOH, were of chemical grade for vacuum flotation tests, and of commercial grade for other tests. The vacuum flotation tests were done with deionized water. Oruro tap water and mine waters from each location were employed for the bench and pilot plant tests. The following table gives the concentration of metal ions in samples of water employed in the various mills, in mg per liter.

	Catavi	Colquiri	Potosí	Machacamarca
Ca^{2+}	353	405	92	106
Fe^{2+}	148	1590	198	-
Fe^{3+}	19	2	140	0.2
pH	4.5	4.3	4.5	7.1

EXPERIMENTAL METHODS

The vacuum flotation testing was carried out following the procedure indicated by Schuhman and Prakash (18). The object was to define areas of floatability under conditions to be encountered in the field. In the same manner, the effect of certain modifiers such as sodium silicofluoride and citric acid was studied.

Once the vacuum tests had indicated the pH region in which flotation was possible, a series of bench tests were run to determine the best operating conditions. From these a flotation scheme was developed with the following stages:

1. Cycloning of the material to remove the very fine particles, minus 10 microns or less.

2. Sulphide flotation, to remove these minerals which otherwise would float together with the cassiterite. This was a conventional operation with a xanthate and pine oil or other usual frothers.

3. Desliming of the tailings from the sulphide flotation to remove remaining fine particles.

4. Cassiterite rougher flotation at pH 2-3 with aerosol-22. In the case

of charges with cassiterite in coarse sizes (plus 200 mesh) the rougher tailings were sent to a shaking table to recover any coarse cassiterite that did not float.

5. Dewatering of the rougher froth to eliminate excess collector, in cyclones. The overflow returns to stage 3.

6. Cassiterite cleaner flotation at pH 1.5-2.5. The cleaner tailings may go back to stage 3, or to a shaking table for gravity treatment.

In view of the promising results obtained in laboratory, pilot plants with a capacity of 5 tons per day were installed in four mills of Corporación Minera de Bolivia. A typical flowsheet is shown in figure 1. In Machacamarca, a plant of 40 tons per day was assembled for the treatment of the middlings above mentioned in a circuit similar to that shown in figure 1.

RESULTS

Figures 2 and 3 show the vacuum flotation results for pure cassiterite from Colquiri and Potosí under various conditions. In them the metal ions in solution can be seen to reduce the flotation area which is displaced to the acid side.

Tables N° 5, 6 and 7 give the total balance for three pilot plants installed in Catavi, Colquiri and Potosí. Table N° 8 shows the metallurgical balance for the Machacamarca operation.

TABLE 5

TAILINGS FROM GRAVITY SLIME SECTION, CATAVI MILL

	% Weight	% Sn	% Distrib.
Flotation concentrate	0.71	17.04	33.60
Table concentrate	0.15	8.08	3.38
Sulphides	1.78	0.76	3.74
Cyclone O'flow N° 1	30.42	0.33	27.88
Cyclone O'flow N° 2	10.80	0.37	11.11
Table tailings	7.58	0.27	5.70
Flotation tailings	48.56	0.11	14.59
Calculated head	100.00	0.37	100.00

TABLE 6

TAILINGS FROM GRAVITY SLIMES SECTION, COLQUIRI MILL

	% Weight	% Sn	% Distrib.
Flotation concentrate	2.62	15.12	63.27
Sulphides	7.21	0.55	6.32
Cyclone O'flow N° 1	14.28	0.62	14.08
Cyclone O'flow N° 2	2.09	0.67	2.23
Tailings	73.80	0.12	14.10
Calculated head	100.00	0.63	100.00

TABLE 7

FEED TO THE SLIMES GRAVITY SECTION, POTOSI MILL

	% Weight	% Sn	% Distrib.
Flotation concentrate	1.77	20.95	41.18
Cyclone O'flow N° 1	45.44	0.55	27.75
Cyclone O'flow N° 2	20.98	0.80	18.64
Sulphides	5.58	1.30	8.06
Tailings	26.23	0.15	4.37
Calculated head	100.00	0.90	100.00

TABLE 8

MIDDLINGS FROM SPLITTING OPERATION, MACHACAMARCA MILL

	% Weight	% Sn	% Distrib.
Flotation concentrate	2.76	26.72	45.86
Table concentrate	0.37	27.30	6.28
Cyclone O'flow N° 1	7.52	1.79	8.36
Cyclone O'flow N° 2	1.85	1.81	2.09
Sulphides	14.29	0.89	7.69
Table tailings	73.21	0.65	29.72
Calculated head	100.00	1.61	100.00

The reagent consumption was as follows: (in grams per metric ton)

	Colquiri	Machacamarca	Potosí	Catavi
Sodium isopropyl xanthate	30	50	80	190
Copper sulphate	25	-	-	
Dowfroth 1012	-	-	20	
Pine oil	22	100	-	
Dowfroth 250				100
Sulphuric acid	3928	4190	1900	5220
Aerosol 22	440	690	1030	665
Citric acid	-	40	80	100
Na Silicofluoride	-	-	-	497

DISCUSSION

The results presented have shown the possibility of concentrating fine tin-bearing materials by flotation. Although in some cases the concentrates produced are not of high grade they can be commercialized with smelters which treat low grade materials, or can be blended with higher grade products.

Economic calculations along the terms indicated in contracts for sale of tin concentrates to foreign smelters show net profits ranging from $US. 0.50 to $US. 3.00 per ton treated by the process of flotation. Corporación Minera de Bolivia is at present taking steps toward the installation of full scale plants in several of its mills.

Figures 2 and 3 show the effect of the presence of Ca^{+2}, Fe^{+2} and Fe^{+3} on the floatability of pure cassiterite from Colquiri and Potosí with aerosol-22. The flotation area is reduced and a greater concentration of collector is needed. The reduction in flotation area is probably due to precipitation of collector by the metal ions at values of pH above 4 (19). The use of the modifiers, such as citric acid and sodium silicofluoride, widens the flotation area. It has been suggested that these modifiers act as complexing agents for the metal ions in solution. It is worth noting that, in a system free of the mentioned metal ions, the sodium silicofluoride and the citric acid act as depressors for cassiterite.

Taking into consideration the vacuum flotation results the experimental work with mill products was carried out in the pH range 1.5 to 2.5 with the appropriate collector concentration; no major problems were encountered with regard to the presence of the above mentioned metal ions in solution.

The collector does not need conditioning time and can be added directly to the rougher cells. The collector has frothing properties as well, and a separate frother is therefore not needed. However, the froth produced is voluminous and persistent. For this reason pine oil, fuel oil and other reagents were employed to modify the froth and make its handling easier.

The modifiers, citric acid and sodium silicofluoride, were employed only in the cleaner stages to depress mainly quartz, tourmaline and other silicates which float during the rougher stage.

The desliming stages are very important in order to obtain optimum results in the flotation step. Cyclones 2" and 3" were employed for this purpose. The size at which the split should be made was investigated. It has been found that the removal of minus 10 micron (cassiterite) is beneficial to the quality of the froth and to reagent consumption. A split at 6 microns does not cause much problem with the froth but there is an increase in reagent consumption. Since the discarded fines represent a complete loss the importance of a good separation at the finest admissible size cannot be overemphasized. This was particularly true for the Potosí material that contains a large amount of minus 4 micron particles. Figures 4 and 5 show the efficiency curves for the first desliming prior to sulphide flotation for the Colquiri and Potosí operations. These results were obtained using 3" and 2" cyclones respectively, and pressures between 25 and 30 p.s.i.

Tables 9, 10 and 11 give the screen and sedimentation analyses for the feed to cassiterite rough flotation, rougher tailings and final flotation concentrate corresponding to the treatment of Colquiri slime tailings. The weight and tin distributions are typical and apply also to the other slime materials referred to in this paper.

TABLE 9

SCREEN AND SEDIMENTATION ANALYSIS FEED TO CASSITERITE ROUGH FLOTATION

Size	% Wt.	% Cum. Wt.	% Sn	% Distrib.	% Cum. Distrib.
+ 65#	11.70	11.70	0.30	4.46	4.46
+100#	8.08	19.78	0.15	1.56	6.02
+150#	13.66	33.44	0.30	5.28	11.30
+200#	18.60	52.04	0.25	5.99	17.29
+270#	14.46	66.50	0.45	8.39	25.68
+ 37μ	4.70	71.20	3.05	18.49	44.17
+ 26μ	9.79	80.99	1.35	17.03	61.20
+ 18μ	7.07	88.06	2.05	18.70	79.90
+ 13μ	7.21	95.27	1.17	10.87	90.77
+ 9μ	2.80	98.07	1.75	6.33	97.10
+ 6μ	0.94	99.01	1.50	1.82	98.92

TABLE 9 (cont.)

Size	% Wt.	% Cum. Wt.	% Sn	% Distrib.	% Cum. Distrib.
+ 4μ	0.41	99.42	0.90	0.47	99.39
- 4μ	0.58		0.82	0.61	
	100.00		0.78	100.00	

TABLE 10

SCREEN AND SEDIMENTATION ANALYSIS CASSITERITE ROUGHER FLOTATION TAILINGS

Size	% Wt.	% Cum. Wt.	% Sn	% Distrib.	% Cum. Distrib.
+ 65#	12.24	12.24	0.15	15.86	15.86
+100#	6.55	18.79	0.10	5.66	21.52
+150#	14.94	33.73	0.12	15.49	37.01
+200#	18.18	51.91	0.07	10.99	48.00
+270#	7.27	59.18	0.15	9.42	57.42
+ 37μ	3.97	63.15	0.21	7.20	64.62
+ 26μ	14.74	77.89	0.06	7.64	72.26
+ 18μ	11.19	89.08	0.13	12.56	84.82
+ 13μ	6.25	95.33	0.17	9.17	93.99
+ 9μ	2.01	97.34	0.12	2.08	96.07
+ 6μ	0.69	98.03	0.13	0.78	96.85
+ 4μ	0.41	98.44	0.32	1.13	97.98
- 4μ	1.56		0.15	2.02	
	100.00		0.12	100.00	

TABLE 11

SCREEN AND SEDIMENTATION ANALYSIS CASSITERITE CLEANER FLOTATION CONCENTRATE

Size	% Wt.	% Cum. Wt.	% Sn	% Distrib.	% Cum. Distrib.
+100#	1.26	1.26	2.90	0.24	0.24
+150#	1.86	3.12	3.00	0.37	0.61
+200#	3.93	7.05	4.70	1.22	1.83
+270#	3.96	11.01	11.70	3.07	4.90
+ 37μ	13.38	24.39	32.20	28.49	33.39
+ 26μ	17.52	41.91	19.70	22.83	56.22
+ 18μ	25.13	67.04	13.50	22.44	78.66
+ 13μ	21.05	88.09	11.30	15.73	94.39
+ 9μ	8.54	96.63	7.90	4.46	98.85
+ 6μ	1.86	98.49	6.00	0.74	99.59
+ 4μ	0.64	99.13	5.90	0.25	99.84
− 4μ	0.87		2.80	0.16	
	100.00		15.12	100.00	

The plus 200 mesh can really be discarded on account of its low tin content. This will be done in the industrial scale plants. The tin distribution in each size fraction for the three products is depicted in figure 6. It can be seen that the flotation system employed is effective only for sizes below 200 mesh and down to approximately 6 micron. This is exactly the size range where gravity concentration losses efficiency Therefore the combination of gravity plus flotation concentration can increase substantially the recovery in the treatment of Bolivian tin ores.

In order to make a better appraisal of the flotation operations, some figures are given that show gravity concentration results and the effect that cassiterite flotation would have on the recovery of tin at the various mills.

At Catavi, around 800 tons per day are discarded as slime tailings with a tin content of 0.35-0.40%. The treatment of this material by flotation would produce approximately 1.1 tons of fine tin per day. This would be an increase of 8% in present production. The Colquiri mill produces between 350 and 400 tons per day of slime tailings in various parts of the circuit. According to Table 6, 1.4 tons of fine tin can be recovered from these slimes, thus increasing the total recovery from 50% to 60%. The main contaminant in the cassiterite flotation concentrate is siderite which can be easily removed by wet magnetic separation.

In the Potosí mill, the present slimes section, by gravity methods plus sulphide flotation, recovers 26% of the tin contained in the feed to the section, in concentrates with 15.6% Sn. Cassiterite flotation would recover 41% of the tin in concentrates assaying 21% Sn. This would mean an increase of 3.7% in the production of the section of the mill treating sulphide ores.

In the Machacamarca mill, prior to the installation of cassiterite flotation, the "splitting" operation gave concentrates of 30% Sn containing 71% of the total tin recovered. The other 29% of the tin was present in middlings which, if their grade was over 5% Sn were sent to a tin fuming plant; otherwise they were recirculated with consequent heavy losses. However, after the installation of the cassiterite flotation plant, the +5% Sn material could be re-split to give more high-grade concentrates, and the tailings of this operation sent to cassiterite flotation that again produced

30% grade concentrates. In this manner, 96% of the total tin recovered is in concentrates of 30% grade, and only 4% remain as products sent to tin fuming.

Although the results obtained are considered satisfactory there are certain aspects which at present are being investigated at the Instituto de Investigaciones Minero-Metalúrgicas to further improve the efficiency of the processing of tin ores by flotation. These aspects are:

i) The collector is not sufficiently selective and iron oxides, mainly hematite and limonite float together with cassiterite. Studies are being carried out to determine specific depressants for these minerals.

ii) The high acidity of the pulp requires a high acid consumption with the accompanying corrosion problems. Research to establish conditions for flotation in near neutral and alkaline media are under way.

iii) The treatment of the very fine particles , minus 9 micron is also being investigated.

CONCLUSIONS

A flotation system has been developed at the Instituto de Investigaciones Minero-Metalúrgicas in Oruro, Bolivia for the recovery of cassiterite from fine ore materials employing a sulfosuccinamate as collector. Laboratory tests indicated that metal ions in solution such as Ca^{2+}, Fe^{2+} and Fe^{3+} have the effect of displacing the flotation region to the acid range, pH 1.5 to 2.5 increasing the collector consumption.

The system has been tested in pilot plants in the field using mine waters that contain considerable amounts of metal ions in solution. The evaluation of the results has shown that it would be economical is possible to treat slime materials from several mills of the Corporación Minera de Bolivia. In the Machacamarca mill a 40 ton per day flotation plant has been introduced as a part of the circuit for the treatment of fine middlings.

1	FEED BOXES
2	1" CENTRIFUGAL PUMPS
3	2" Ø CYCLONES
4	CONDITIONER TANKS
5	DENVER Nº 8 FLOTATION CELLS
6	DENVER Nº 5 FLOTATION CELLS

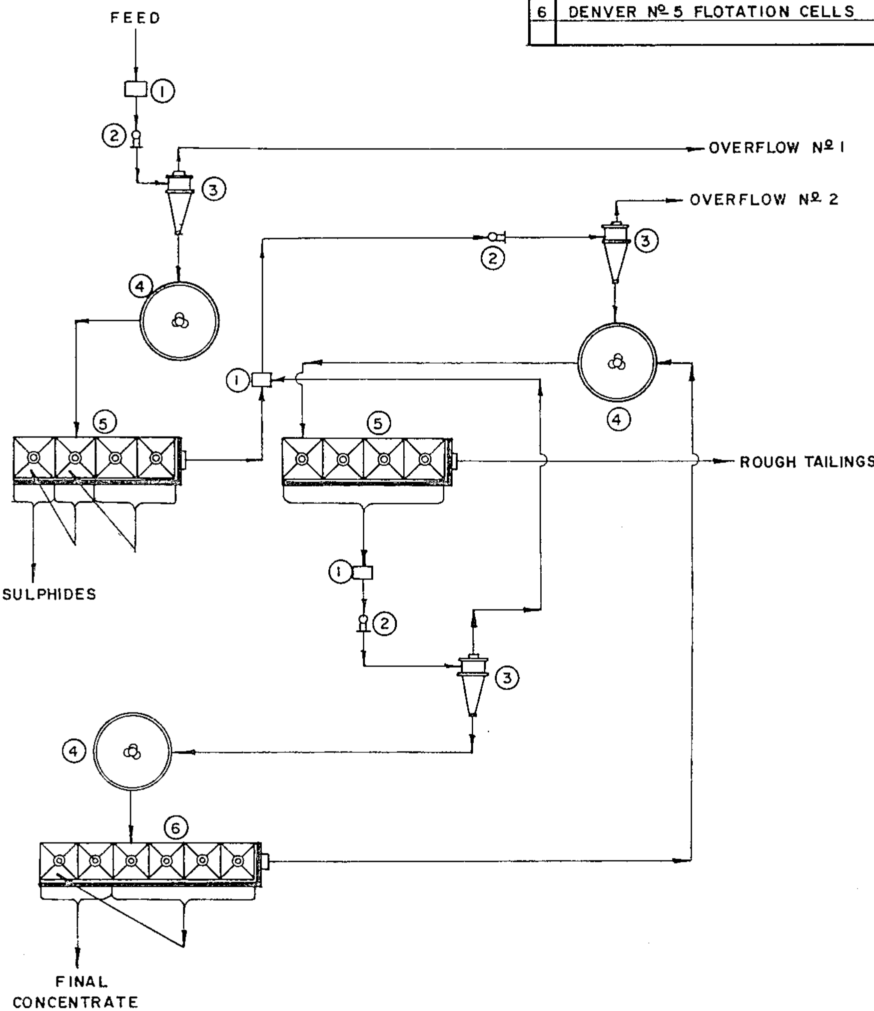

FIGURE 1.– PILOT PLANT FOR CASSITERITE FLOTATION
FLOWSHEET FOR POTOSI SLIMES

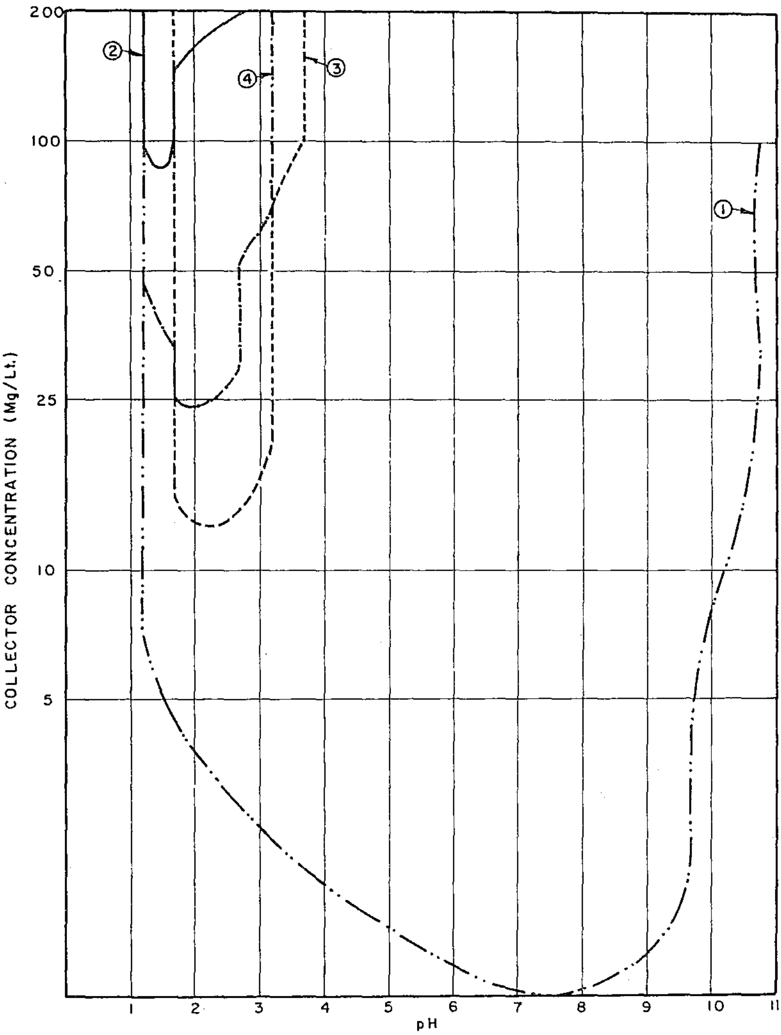

FIGURE 2.– COLQUIRI CASSITERITE FLOTATION WITH AEROSOL 22

1.– NO IONS; 2.– 1600 Grs./Lt. Fe^{2+} + 400 Grs/Lt. Ca^{2+}

3.– 1600 Grs/Lt. Fe^{2+} + 400 Grs/Lt. Ca^{2+} + 100 Grs/Lt. Citric Acid

4.– 1600 Grs/Lt. Fe^{2+} + 400 Grs/Lt. Ca^{2+} + 500 Grs/Lt. Na_2SiF_6

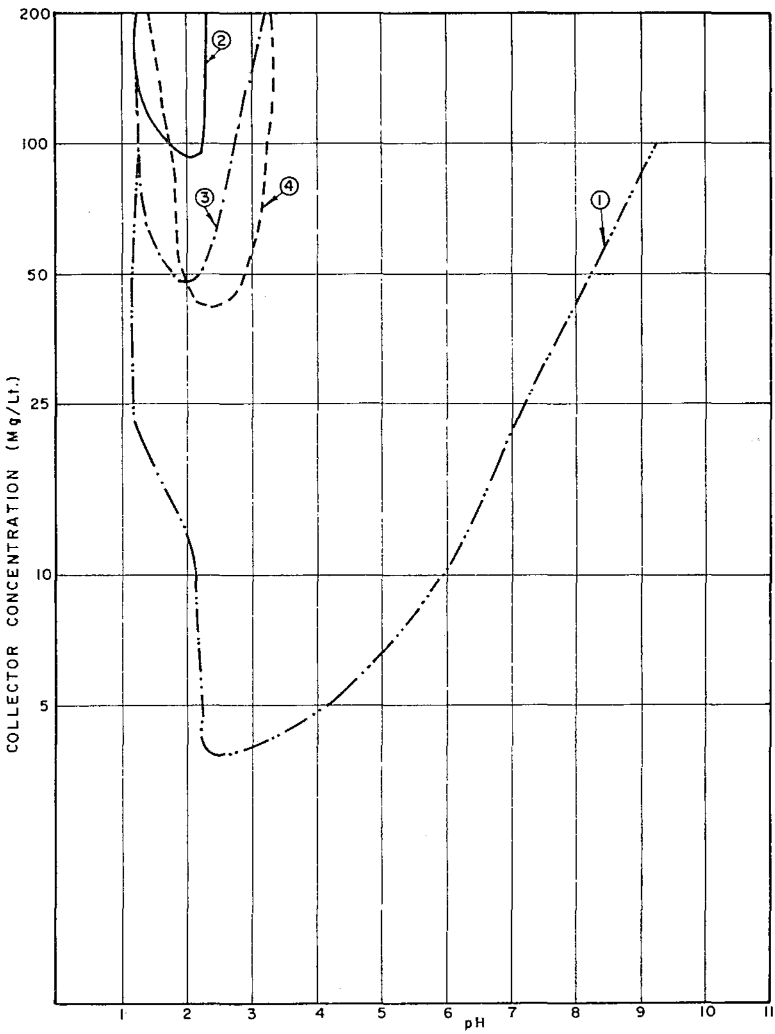

FIGURE 3.- POTOSI CASSITERITE FLOTATION WITH AEROSOL 22

1.- NO IONS; 2.- 100 Grs/Lt. Fe^{2+} + 140 Grs/Lt. Fe^{3+} + 100 Grs/Lt. Ca^{2+}

3.- 100 Grs/Lt. Fe^{2+} + 140 Grs/Lt. Fe^{3+} + 100 Grs/Lt. Ca^{2+} + 500 Grs/Lt. Citric Ac.

4.- 100 Grs/Lt. Fe^{2+} + 140 Grs/Lt. Fe^{3+} + 100 Grs/Lt. Ca^{2+} + 500 Grs/Lt. Na_2SiF_6

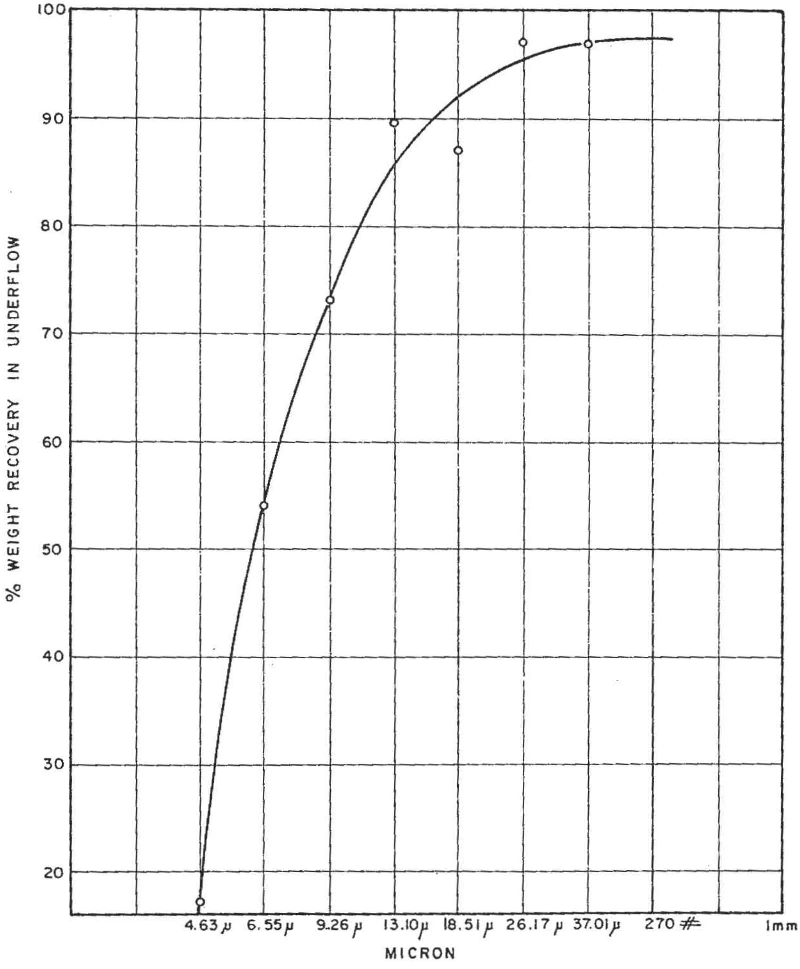

FIGURE 4.— EFFICIENCY CURVE FOR 3" CYCLON
COLQUIRI SLIME TAILINGS

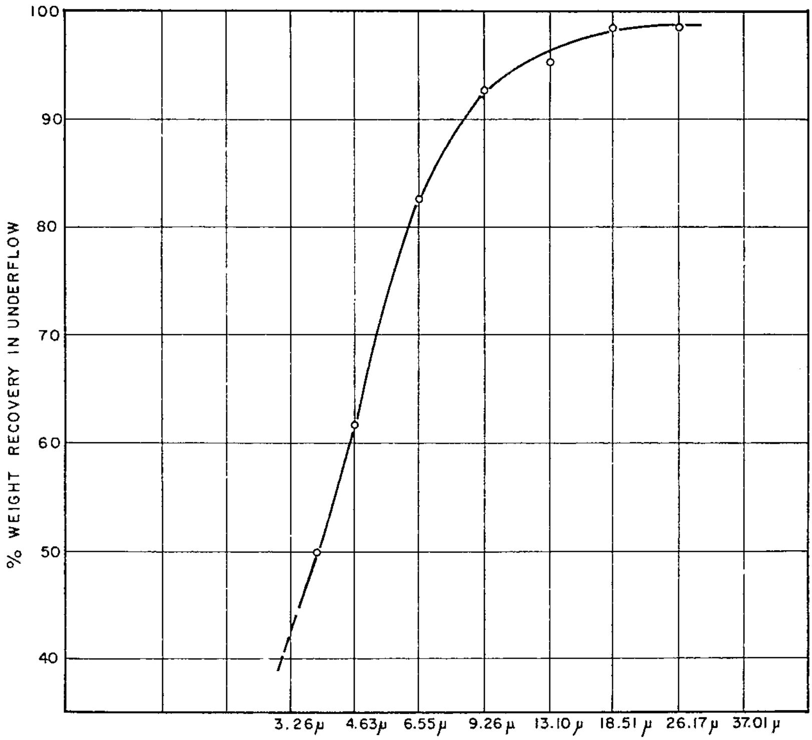

FIGURE 5.- EFFICIENCY CURVE POR 2" CYCLON

POTOSI SLIMES

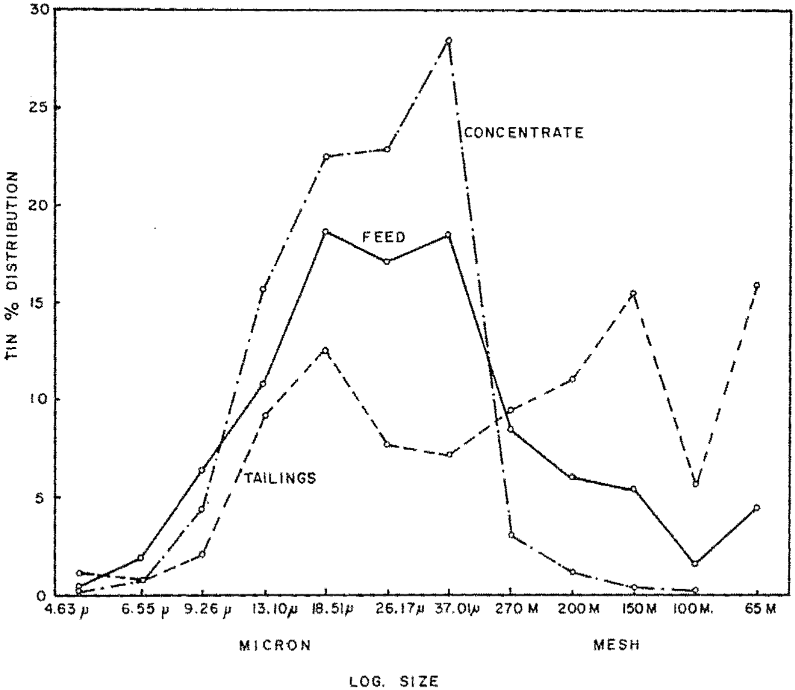

FIGURE 6.- TIN DISTRIBUTION IN PRODUCTS FROM CASSITERITE FLOTATION COLQUIRI ORE