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An Investigation of
THE RECOVERY OF LEAD, ZINC AND SILVER
from Faro Tailings
submitted by
ANVIL RANGE MINING CORPORATION
Progress Report No. 1

Project No. L.R. 4964

NOTE:

This report refers to the samples as received.

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Abstract

Metallurgical laboratory testwork was carried out on a sample of Faro Down Valley tailings in order to develop a process for treatment of the tailings upon plant closure and to provide design data for a continuous pilot plant. The lab sample was representatively extracted from about 97 barrels of tailings intended for the pilot plant.

A process was successfully developed to produce separate lead and zinc concentrates or a bulk concentrate. The results of the two locked cycle tests performed are presented in Table No. 1.

Table No. 1 :
Locked Cycle Test Results

Test No.	Bulk Collectors	Product	Weight %	Assays, %/g/t				% Distribution			
				Pb	Zn	Cu	Ag	Pb	Zn	Cu	Ag
64	Flex 31 3418A	Pb Cleaner Conc	0.35	43.8	10.2	3.04	400	20.7	2.8	8.4	10.7
		Pb Separation Tail (Zn Conc)	2.30	9.50	33.0	2.91	133	29.9	59.7	53.6	24.5
		Bulk Cleaner Conc	2.64	14.3	29.9	2.93	174	50.6	62.4	62.0	35.2
		Total Tail	97.36	0.37	0.49	0.049	8.60	49.4	37.6	38.0	64.8
		Head(calc)	100.00	0.73	1.27	0.12	12.9	100.0	100.0	100.0	100.0
66	SIBX M2030	Pb Cleaner Conc	0.30	57.9	4.56	1.45	475	23.4	1.1	-	-
		Pb Separation Tail (Zn Conc)	2.10	9.77	37.9	3.00	131	27.6	63.1	-	-
		Bulk Cleaner Conc	2.40	16.2	33.4	2.79	177	51.0	64.2	-	-
		Total Tail	97.60	0.37	0.46	-	-	49.0	35.8	-	-
		Head(calc)	100.00	0.74	1.26	-	-	100.0	100.0	-	-

The SIBX/M2030 collectors gave better product grades than the Flex 31/3418 combination with slightly higher bulk circuit zinc recovery. Locked cycle recoveries were lower than the projected batch test values.

The process involves grinding of the tailing with a high lime addition, activation with copper sulphate and collector addition (both during high intensity conditioning, HIC), bulk rougher flotation, regrinding with an iron sulphide depressant, HIC of the bulk rougher concentrate and 4 stages of cleaning, with an open 1st cleaner. The bulk concentrate may then be treated to produce separate lead and zinc concentrates.

This report discusses the test details and results.

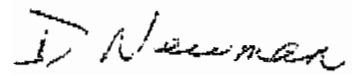
Introduction

Laboratory and pilot plant testwork on existing Faro tailings was requested by Mr. Ken Ball of Anvil Range Mining Corporation and Mr. Godfrey McDonald of Confidential Metallurgical Services on May 17, 1996. Accordingly, Lakefield Research issued a proposal on May 22nd, 1996. Authorization for the work was granted under Anvil Range's purchase order number 00564 on June 5th.

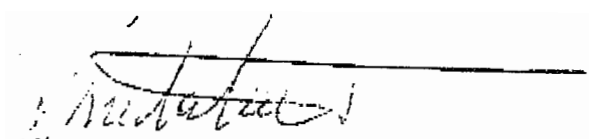
Anvil Range's sample requisition report for the 100 barrels (i.e. shipment 1) of tailings used in the lab testwork, issued on May 6th, 1996, details the collection of the first bulk sample (Appendix 2).

Results of the testwork were issued verbally and in letter reports. Mr. McDonald was present for one of the locked cycle tests.

LAKEFIELD RESEARCH LIMITED



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Summary

1. Description of Samples Used in the Laboratory Testwork

All of the laboratory work was conducted on the main composite collected from 97 of the 100 drums of the 1st shipment. A second oxidized sample was also prepared from the D1-1, D1-2 and F7-1 samples, but was not tested.

The head assays are shown in Table No. 2.

Table No. 2 :
Head Assays of the Main Composite

Element	Assays %, g/t
Lead, Pb	0.81
Zinc, Zn	1.18
Copper, Cu	0.099
Silver, Ag	13.0
Gold, Au	0.23
Iron, Fe	27.3
Sulphur, S	27.1

2. Bulk Rougher Flotation

Most of the tests completed consisted of bulk rougher tests designed to optimize the reagent scheme. The rougher reagents consisted of lime, copper sulphate, a xanthate, a secondary collector (generally a thionocarbamate) and MIBC frother.

The main parameters tested included the following:

- grind fineness
- lime/pH
- high intensity conditioning times
- secondary collector type
- primary and secondary collector addition levels
- CuSO₄ levels
- frother type

The effects of these parameters are summarized in the following discussion:

- Grind fineness from $K_{80} = 78 \mu\text{m}$ to $43 \mu\text{m}$ were examined. The results (Table 3 and Figure 1) showed that grinding was necessary and grinding finer than about $K_{80} = 60 \mu\text{m}$ would not result in further improvement in metallurgical results.

Table No. 3 :
Effect of Grind Size

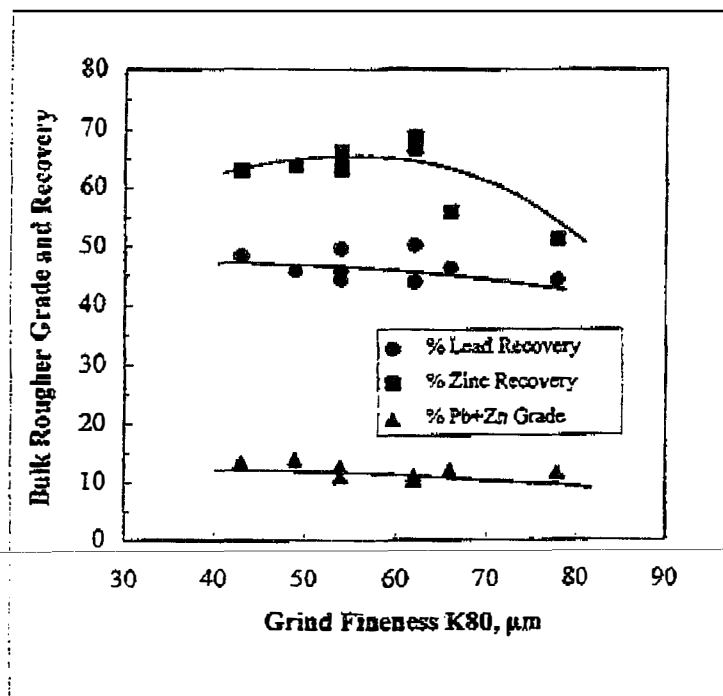
Test No.	Primary Grind		Bulk Rougher Conc					Bulk Rougher Tail				
	Time min	K_{80} μm	Wt %	Assay %		% Dist		Wt %	Assay %		% Dist	
				Pb	Zn	Pb	Zn		Pb	Zn	Pb	Zn
10*	0	78	8.5	3.9	7.85	44.3	51.2	91.5	0.46	0.70	55.7	48.8
11*	5	66	8.9	4.00	8.15	46.4	56.0	91.1	0.45	0.63	53.6	44.0
12*	10	54	9.5	4.00	8.84	49.8	66.4	90.5	0.42	0.47	50.2	33.6
13*	15	49	8.3	4.20	9.90	46.0	63.8	91.7	0.45	0.51	54.0	36.3
14	30	43	8.9	4.2	9.37	48.5	63.0	91.1	0.44	0.54	51.5	37.0
19*	6	62	10.8	3.20	8.15	44.0	66.8	89.2	0.49	0.49	56.0	33.2
23*	10	54	10.5	3.30	7.90	44.5	63.2	89.5	0.48	0.54	55.5	36.8
21**	6	62	12.1	3.20	7.30	50.3	68.7	87.9	0.43	0.46	49.7	31.3
24**	10	54	10.9	3.30	7.79	46.0	65.2	89.1	0.47	0.51	54.0	34.8

*without QHS in grind; higher collector than in Tests 10-14

**without QHS in grind; higher CuSO_4 and collector than in Tests 19 and 23

★QHS in grind; fairly low collector levels

Figure No. 1
Effect of Grinding Size on Bulk Rougher Flotation



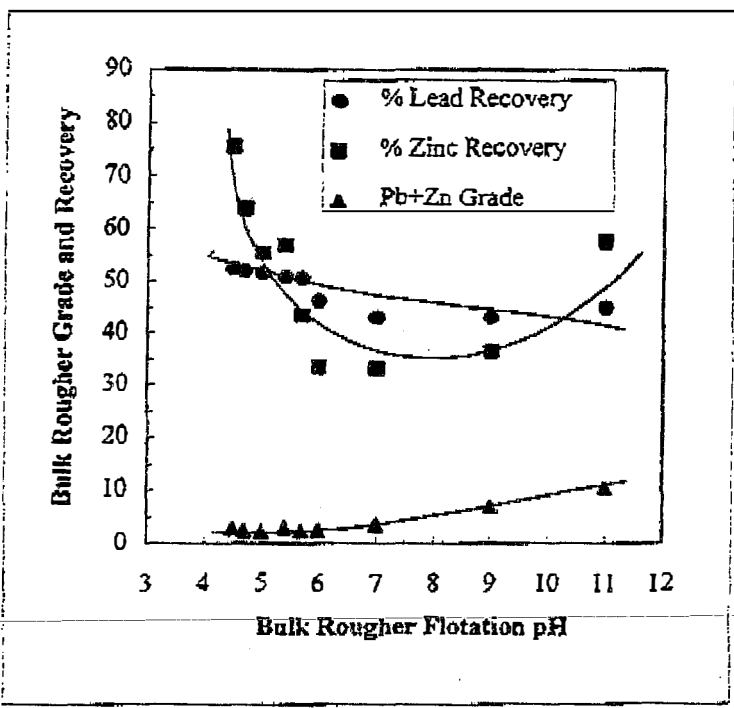
- Flotation pH was an important parameter, as shown in Table No. 4 and Figure No. 2. A lime addition of over 8 kg/t was necessary to provide a reasonable bulk concentrate grade (i.e. >7% Pb+Zn). The optimum pH and lime additions were 11.0 and 10,000 g/t, respectively.

Table No. 4 :
Effect of Lime Level in the Primary Grind

Test No.	Lime g/t	pH	Bulk Rougher Conc				Bulk Rougher Tail					
			Wt %	Assay % Pb	Assay % Zn	% Dist Pb	% Dist Zn	Wt %	Assay % Pb	Assay % Zn	% Dist Pb	% Dist Zn
1*	0	4.5	44.0	1.0	2.00	52.5	75.5	56.0	0.68	0.41	47.5	24.5
2*	1000	4.7	43.4	0.90	1.71	52.0	63.9	56.6	0.66	0.74	48.0	36.1
3*	2000	5.0	42.4	0.90	1.54	51.7	55.4	57.6	0.65	0.91	48.3	44.6
4*	3000	5.4	34.3	1.20	2.00	50.9	56.9	65.7	0.58	0.79	49.1	43.1
5*	4000	5.7	37.3	1.10	1.42	50.7	43.5	62.7	0.61	1.09	49.3	56.5
6*	5000	6.0	30.1	1.20	1.39	46.2	33.5	69.9	0.59	1.19	53.8	66.5
7*	6000	7.0	20.5	1.60	2.07	43.1	33.2	79.5	0.53	1.07	56.9	66.8
8*	8000	9.0	11.4	2.9	4.14	43.1	36.5	88.6	0.49	0.93	56.9	63.5
41**	8000	9.4	29.4	1.60	2.83	62.5	64.8	70.6	0.40	0.64	37.5	35.2
40**	9000	10.6	19.5	2.40	4.80	61.3	74.4	80.5	0.37	0.40	38.7	25.6
9*	10,000	11.0	10.2	3.2	7.24	44.9	57.7	89.8	0.45	0.60	55.1	42.3
22**	10,000	11.0	15.8	2.80	6.22	57.9	76.4	84.2	0.38	0.36	42.1	23.6

*Initial tests with relatively low CuSO₄ and collector
 **Higher CuSO₄ and collectors

Figure No. 2
Effect of pH on Bulk Rougher Flotation



- High intensity conditioning time of the rougher feed was examined (Table 5).

Table No. 5 :
Effect of HIC

Test No.	HIC Time. min		Bulk Rougher Conc				Bulk Rougher Tail					
	Stage 1	Stage 2	Wt %	Assay %		% Dist		Wt %	Assay %		% Dist	
				Pb	Zn	Pb	Zn		Pb	Zn	Pb	Zn
36	1	5	26.08	1.80	3.33	60.5	67.3	73.92	0.41	0.57	39.5	32.7
31*	5	10	15.76	2.8	6.22	57.9	76.4	82.24	0.38	0.36	42.1	23.6
37**	5	10	19.45	2.4	4.74	58.7	71.4	80.55	0.40	0.46	41.3	28.6
32*	5	5	17.92	2.40	4.81	55.5	66.5	82.08	0.42	0.53	44.5	33.5
39**	5	5	25.40	1.90	3.76	64.2	72.7	74.60	0.37	0.48	35.8	27.3
33	10	5	14.74	2.80	6.37	53.8	71.4	85.26	0.41	0.44	46.2	28.6
34	10	10*	15.97	2.8	5.98	57.4	73.0	84.03	0.39	0.42	42.6	27.0
35	10	0*	13.14	3.3	6.94	54.5	71.4	86.86	0.42	0.42	45.5	28.6

*with MIBC

**with DF1012

★Denver cell conditioning only

The highest recoveries were achieved with 5 minutes (for CuSO₄) and 10 minutes (collectors) respectively for stages 1 and 2.

- Secondary collectors were tested. Most tests were carried out with thionocarbamate M2030. This collector proved to provide the highest recoveries while maintaining grade (Table 6).

Table No. 6 :
Effect of Secondary Collector

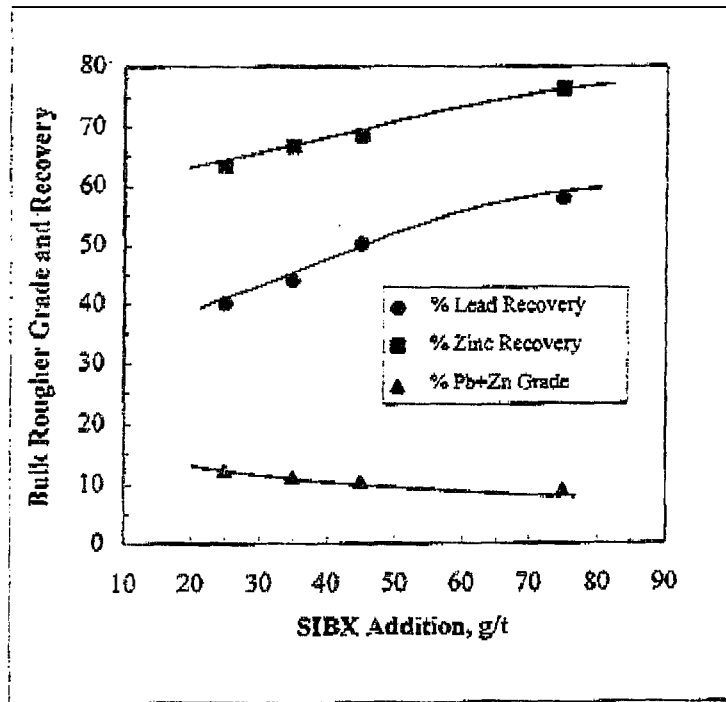
Test No.	Secondary Collector	Bulk Rougher Concentrate					Bulk Rougher Tail				
		Wt %	Assays %		% Dist'n		Wt %	Assays %		% Dist'n	
			Pb	Zn	Pb	Zn		Pb	Zn	Pb	Zn
24	M2030	10.91	3.30	7.79	46.0	65.2	89.09	0.47	0.51	54.0	34.8
26	R208	6.56	3.10	9.81	26.8	48.9	93.44	0.59	0.72	73.2	51.1
27	R3477	8.55	2.60	7.21	29.0	47.0	91.45	0.59	0.76	71.0	53.0
28	S7656	13.82	2.70	6.31	48.2	67.8	86.18	0.47	0.48	51.8	32.2
29	S7251	11.74	2.60	6.47	41.1	59.7	88.26	0.49	0.58	58.9	40.3
30	S6588	12.49	2.90	6.81	47.3	65.6	87.51	0.46	0.51	52.7	34.4

- Collector levels were examined in one test series (Table 7, Figure 3). The 75 g/t SIBX level was adopted as the optimum.

Table No. 7 :
Effect of Collector Level

Test No.	Grind K_{80} μm	SIBX g/t	M2030 g/t	Bulk Rougher Conc					Bulk Rougher Tail				
				Wt %	Assay %		% Dist		Wt %	Assay %		% Dist	
					Pb	Zn	Pb	Zn		Pb	Zn	Pb	Zn
18	62	25	15	9.26	3.41	8.94	40.1	63.3	90.74	0.52	0.53	59.9	36.7
19	62	35	20	10.78	3.20	8.15	44.0	66.8	89.22	0.49	0.49	56.0	33.2
21	62	45	20	12.13	3.20	7.30	50.3	68.7	87.87	0.43	0.46	49.7	31.3
24	54	45	20	10.91	3.30	7.79	46.0	65.2	89.09	0.47	0.51	54.0	34.8
22	62	75	20	15.76	2.8	6.22	57.9	76.4	84.24	0.38	0.36	42.1	23.6
25	54	75	20	12.33	3.10	7.27	49.8	67.6	87.67	0.44	0.49	50.2	32.4

Figure No. 3
Effect of Collector Level on Bulk Flotation

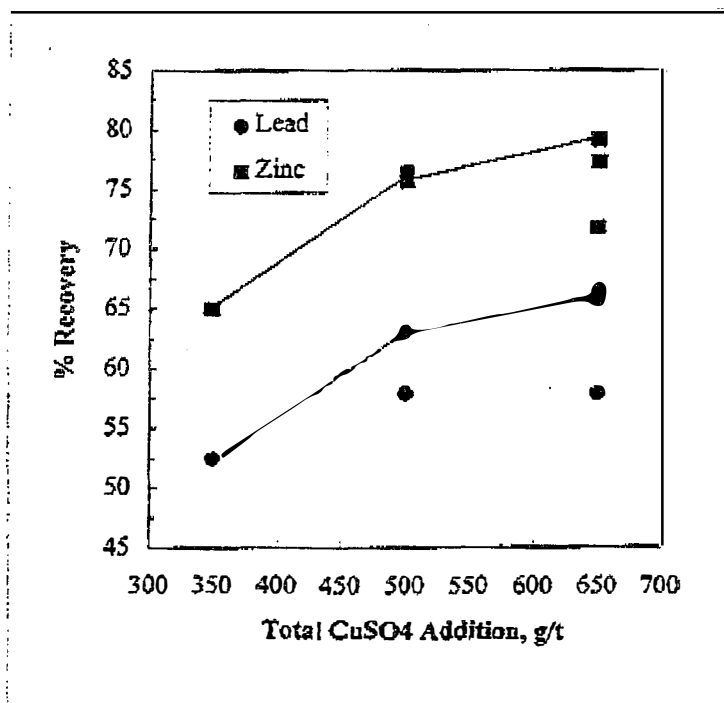


- Copper Sulphate levels and addition points (Table 8, Figure 4) were studied. Improved recoveries were achieved with a 500 g/t addition to the bulk rougher high intensity conditioner. A higher level of 650 g/t provided some increase in recovery but with a loss in selectivity. Stage addition, and especially grinding in the reagent, were not advantageous.

Table No. 8 :
Effect of CuSO_4

Test No.	CuSO_4 , g/t			Bulk Rougher Conc					Bulk Rougher Tail				
	Grind	Ro	Cl	Wt %	Assay %		% Dist		Wt %	Assay %		% Dist	
					Pb	Zn	Pb	Zn		Pb	Zn	Pb	Zn
31	0	350	0	17.76	2.40	4.82	52.5	65.0	82.24	0.46	0.56	47.5	35.0
22	0	500	0	15.76	2.8	6.22	57.9	76.4	84.24	0.38	0.36	42.1	23.6
48	0	650	0	20.49	2.50	4.89	66.5	77.3	79.51	0.32	0.37	33.5	22.7
38	0	500	200	20.22	2.50	4.91	63.0	75.7	79.78	0.37	0.40	37.0	24.3
46	●	500	200	18.78	2.7	5.60	65.8	79.2	81.22	0.32	0.34	34.2	20.8
47	500	0	200	25.42	1.70	3.65	57.9	71.8	74.58	0.43	0.49	42.1	28.2

Figure No. 4
Effect of CuSO_4 on Bulk Rougher Flotation



- MIBC provided more selective flotation than DF1012. Zinc recovery was also higher (Table 9).

Table No. 9 :
Effect of Frother

Test No.	Frother	Bulk Rougher Concentrate					Bulk Rougher Tail				
		Wt %	Assays %		% Dist'n		Wt %	Assays %		% Dist'n	
			Pb	Zn	Pb	Zn		Pb	Zn	Pb	Zn
22	MIBC	15.76	2.80	6.22	57.9	76.4	84.24	0.38	0.36	42.1	23.6
37	DF1012	19.45	2.40	4.74	58.7	71.4	80.55	0.40	0.46	41.3	28.6

3. Bulk Cleaner Flotation

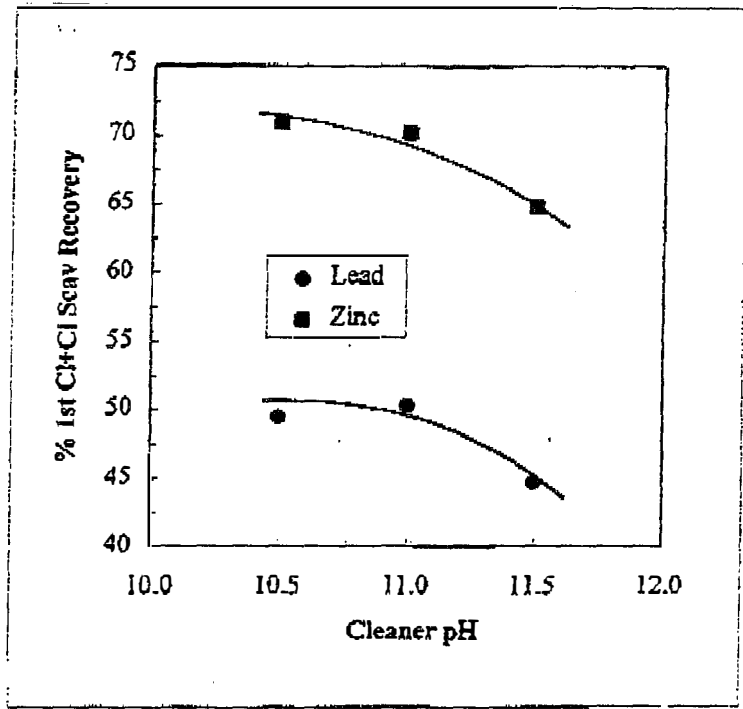
Bulk cleaning was performed with regrinding, HIC and four cleaner stages. Three parameters were tested: pH, regrind fineness and depression of iron sulphides and non-sulphide gangue. Based upon the results of this testwork, the following was concluded:

- A pH of about 10.5 was optimum (Table 10, Figure 5).

Table No. 10 :
Effect of pH

Test No.	pH	Bulk 4th Cleaner Conc					Bulk 1st Cl + Cl Scav Concs					Bulk Cl Scav Tail		Bulk Ro Tail	
		Wt %	Assays %		% Dist'n		Wt %	Assays %		% Dist'n		Assays %		Assays %	
			Pb	Zn	Pb	Zn		Pb	Zn	Pb	Zn	Pb	Zn	Pb	Zn
51	10.5	2.59	12.2	32.8	41.3	66.0	5.34	7.10	17.11	49.5	71.0	0.76	0.72	0.36	0.35
52	11.0	2.45	12.0	33.8	39.6	64.5	5.07	7.40	17.79	50.3	70.2	0.76	0.74	0.33	0.35
45	11.5	2.16	11.6	35.9	34.1	59.8	4.31	7.6	19.51	44.7	64.8	0.76	0.67	0.36	0.44

Figure No. 5
Effect of pH on Cleaner Flotation

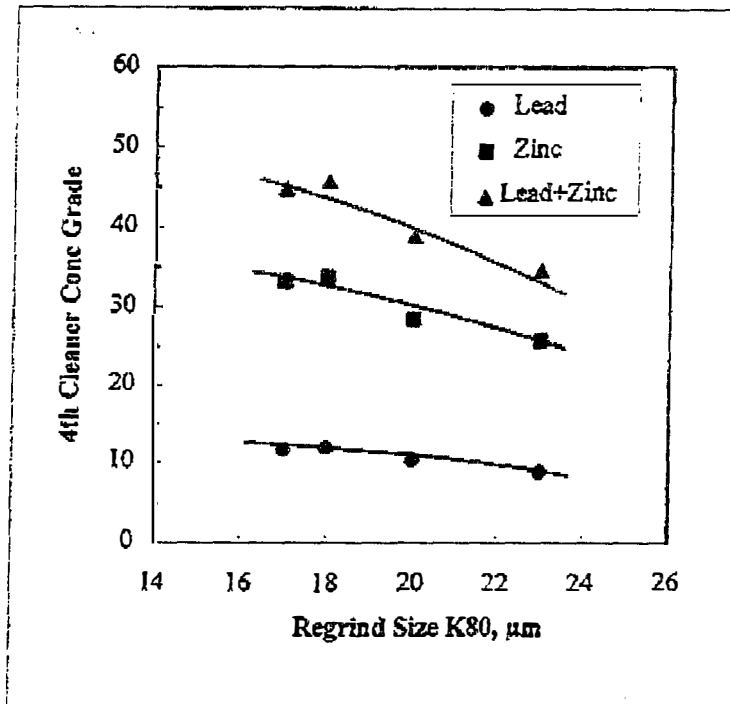


- The product grade was determined by the fineness of the regrind. A K_{80} of 17-18 μm provided a combined grade of 45-48% Pb + Zn (Table 11 and Figure 6).

Table No. 11 :
Effect of Regrinding

Test No.	Regrind		Bulk 4th Cleaner Conc					Bulk 1st Cl + Cl Scav Concs					Bulk Cl Scav Tail		Bulk Ro Tail	
	Time min	K_{80} μm	Wt %	Assays %		% Dist'n		Wt %	Assays %		% Dist'n		Assays %		Assays %	
				Pb	Zn	Pb	Zn		Pb	Zn	Pb	Zn	Pb	Zn	Pb	Zn
54	0	23	2.86	8.93	25.7	35.0	59.1	6.26	5.80	13.71	49.6	69.1	0.69	0.70	0.34	0.36
55	5	20	2.86	10.40	28.5	41.1	64.0	7.06	5.70	13.13	55.5	72.8	0.65	0.65	0.29	0.32
52	10	18	2.45	12.0	33.8	39.6	64.5	5.07	7.40	17.79	50.3	70.2	0.76	0.74	0.39	0.40
56	15	17	2.27	11.70	33.2	35.6	58.7	5.92	6.40	15.10	51.0	69.7	0.69	0.70	0.32	0.35

Figure No. 6
Effect of Regrinding on Bulk Concentrate Upgrading



- The effect of QHS was examined. The results are summarized in Table No. 12. Addition of QHS significantly affected product grades and metal recoveries. (Note that in two other tests, QHS did not appear to affect the metallurgy). QHS was used in the subsequent locked cycle tests.

Table No. 12 :
Effect of QHS Addition

Test No.	QHS Add'n	Bulk 4th Cleaner Conc				Bulk 1st Cl + Cl Scav Concs				Bulk Cl Scav Tail		Bulk Ro Tail			
		Wt %	Assays %		% Dist'n		Wt %	Assays %		Assays %		Assays %			
			Pb	Zn	Pb	Zn		Pb	Zn	Pb	Zn	Pb	Zn	Pb	Zn
62	not added	2.35	9.70	28.9	31.5	54.2	8.27	4.6	10.46	52.9	69.1	0.83	0.81	0.31	0.37
61	regrind	1.86	12.70	36.3	30.6	51.7	5.99	6.8	15.28	52.8	70.2	0.99	0.96	0.34	0.37
60	regrind + cleaners	2.29	12.80	34.1	36.9	58.5	6.16	6.5	14.43	50.7	66.5	1.59	1.52	0.32	0.39

4. Lead-Zinc Separation

Several Pb-Zn separation tests were conducted. The results of these tests were satisfactory, but conditions were not really optimized (Table 13). One test was also completed with Pb-Zn and Cu-Pb separations, but the results were poor.

Table No. 13 :
Pb-Zn Separation Results

Test No.	Bulk Collector	Pb Cleaner Conc					Pb Ro Conc		Pb Ro Tail (Zn Conc)				
		Wt %	Assays %		% Dist		Assays %		Wt %	Assays %		% Dist	
			Pb	Zn	Pb	Zn	Pb	Zn		Pb	Zn	Pb	Zn
58	SIBX M2030	0.23	53.3	7.64	16.6	1.4	27.9	18.08	1.80	6.55	38.1	16.0	54.0
63	Flex 31 3418A	0.09	40.20	10.8	5.0	0.8	23.9	21.18	2.22	10.1	28.8	31.8	51.7
65	SIBX M2030	0.13	32.8	16.2	5.5	1.7	15.0	31.81	1.47	9.87	41.0	18.8	48.5

5. Locked Cycle Flotation

Two locked cycle tests were carried out on the tailings to confirm final product grades and recoveries. The flowsheet shown in Figure No. 7 was used.

The test results, shown in Table No. 14, were fairly good, but in neither test did the total recoveries match the bulk 1st cleaner + cleaner scavenger concentrates recoveries obtained in the respective pre-cycle batch tests (i.e. Tests 63 and 65). Rather, the locked cycle recoveries were 3 to 9% lower. Test 66 results were better than Test 64's. (Note that only one Pb cleaner was employed in Test 64).

Table No. 14 :
Locked Cycle Results

Test No.	Bulk Collectors	Product	Weight %	Assays, %/g/t				% Distribution			
				Pb	Zn	Cu	Ag	Pb	Zn	Cu	Ag
64	Flex 31 3418A	Pb Cleaner Conc	0.35	43.8	10.2	3.04	400	20.7	2.8	8.4	10.7
		Pb Separation Tail (Zn Conc)	2.30	9.50	33.0	2.91	138	29.9	59.7	53.6	24.5
		Bulk Cleaner Conc	2.64	14.3	29.9	2.93	174	50.6	62.4	62.0	35.2
		Total Tail	97.36	0.37	0.49	0.049	8.60	49.4	37.6	38.0	64.8
		Head(calc)	100.00	0.73	1.27	0.12	12.9	100.0	100.0	100.0	100.0
66	SIBX M2030	Pb Cleaner Conc	0.30	57.9	4.56	1.45	475	23.4	1.1	-	-
		Pb Separation Tail (Zn Conc)	2.10	9.77	37.9	3.00	131	27.6	63.1	-	-
		Bulk Cleaner Conc	2.40	16.2	33.4	2.79	177	51.0	64.2	-	-
		Total Tail	97.60	0.37	0.46	-	-	49.0	35.8	-	-
		Head(calc)	100.00	0.74	1.26	-	-	100.0	100.0	-	-

6. Final Metallurgical Conditions and Results

6.1. Reagent Scheme

The final lab reagent scheme is shown in Table No. 15.

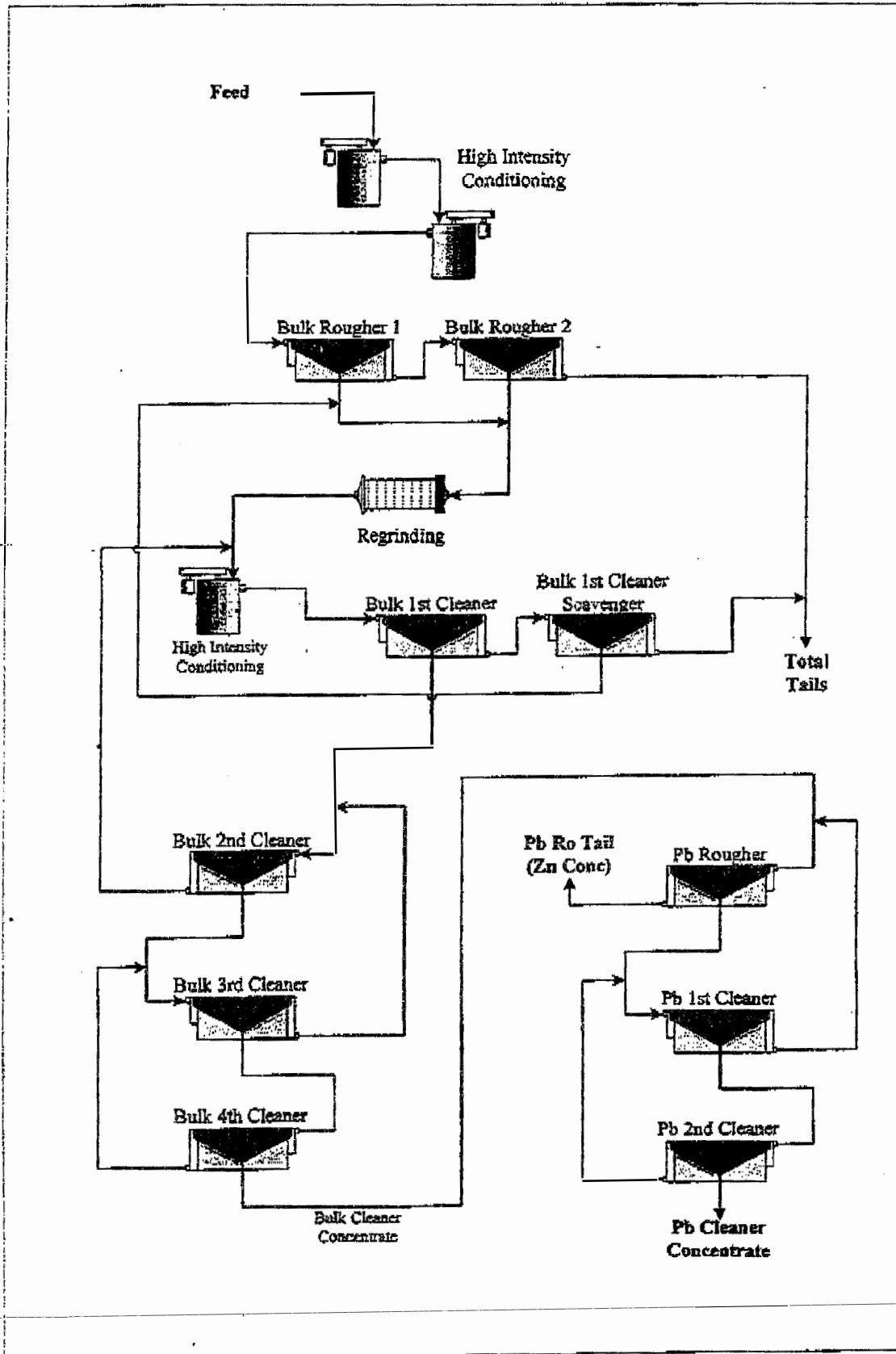
Table No. 15 :
Reagent Scheme

Reagent	Bulk Flotation Circuit		Pb/Zn Separation	
	Grind + Rougher	Cleaners	Pb Rougher	Pb Cleaners
Lime, $\text{Ca}(\text{OH})_2$	10,000	>300	-	-
Cu Sulphate, $\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$	500	80	-	-
QHS	-	135	-	-
Activated Carbon	-	-	100	-
Sodium Carbonate, Na_2CO_3	-	-	750	>30
Sodium Cyanide, NaCN	-	-	150	20
Zinc Sulphate, $\text{ZnSO}_4 \cdot 7\text{H}_2\text{O}$	-	-	500	-
SIBX	90	25	-	-
M2030	27.5	10	-	-
3418A	-	1.5	5	1
MIBC	10	8	-	1

6.2. Flowsheet

The flowsheet used in the locked cycle testwork is shown in Figure No. 7.

Figure No. 7
Locked Cycle Flowsheet



6.3. Metallurgical Results

The best locked cycle metallurgical results are presented in Table No. 16.

Table No. 16 :
Locked Cycle Results

Test No.	Product	Wt %	Assays, %g/t				% Dist'n	
			Pb	Zn	Cu	Ag	Pb	Zn
66	Pb Cleaner Conc	0.30	57.9	4.56	1.45	475	23.4	1.1
	Pb Separation Tail (Zn Conc)	2.10	9.77	37.9	3.00	131	27.6	63.1
	Bulk Cleaner Conc	2.40	16.2	33.4	2.79	177	51.0	64.2
	Bulk 1st Cleaner Scav Tail	5.44	1.53	1.28	-	-	11.2	5.5
	Bulk Rougher Tail	92.15	0.31	0.42	-	-	37.8	30.3
	Total Tail	97.60	0.37	0.46	-	-	49.0	35.8
	Head(calc)	100.00	0.74	1.26	-	-	100.0	100.0

7. Conclusions

1. A process was successfully developed to treat Faro tailings which would produce separate lead and zinc concentrates or a bulk concentrate. The process utilizes common Faro Pb-Zn plant reagents.
2. Optimization of the reagent scheme indicated the following:
 - SIBX and M2030 (xanthate and thionocarbamate respectively) yielded slightly better results than Flex 31 (dithiophosphate modified xanthate) and 3418A (phosphine).
 - Due to oxidation of the tailings in the pond, high lime addition was essential for flotation. Increasing CuSO_4 and collector levels generally yielded higher recoveries.
3. Primary grinding (to K_{80} $\sim 60 \mu\text{m}$), regrinding (to K_{80} $< 20 \mu\text{m}$) and high intensity conditioning were confirmed to be important parts of the flowsheet.
4. The test program generated data for the pilot plant operation.