EXECUTIVE SUMMARY

Laboratory and Pilot Plant Development Testwork

on Cirque Drill Core and Bulk Samples
submitted by

CURRAGH RESOURCES LTD.

Volume 1 of 3 005031

Project No. L.R. 3889, 4086, 4123

NOTE:

This report refers to the samples as received.

LAKEFIELD RESEARCH
A DIVISION OF FALCONBRIDGE LIMITED
March 13, 1991

PREFACE

This Final Report is submitted in accordance with the contract awarded to Lakefield Research by Curragh Resources to perform laboratory and pilot plant development testwork on Cirque lead zinc ores. The contract was identified as purchase order No. D-124765.

The development work was designed and executed on the basis of previous testwork results carried out by Lakefield Research, Kamloops Research and Assay Laboratory Limited, and Sachtieben Bergban GmbH Laboratories, West Germany, recognizing the degree of difficulty in treatment of the ore. This initial deveiopment testwork was carried out between the years 1978 and 1981.

The Final Report is comprised of 3 volumes:

Volume 1: Executive Summary

Volume 2: Laboratory Development Testwork on Composites and Individual Ore Samples

Volume 3: Pilot Plant and Laboratory Testwork on Pilot Plant Bulk Samples

ABSTRACT

Laboratory bench scale tests were carried out on core samples and bulk sample to develop a commercial flowsheet and reagent scheme for the treatment of the ore. The laboratory development work was carried out on several composites prepared from the drill core samples which represented different ore types.

The pilot plant feed materials were bulk samples from an underground exploration adit, representing two major ore types (i.e. massive sulphide and baritic ores).

When applying the procedure developed in the laboratory, the following metallurgical results were obtained in the pilot plant:

TABLE NO. 1 :
Pilot Plant Metallurgical Results Obtained on Various Composites

Ore Type	Product	Weight %	Assays %, g/t			% Distribution		
			Pb	Zn	Ag	Pb	Zn	Ag
PP Composite 1 ore : Massive Sulphide Baritic:Upper Med = 70 : 20 : 10	Lead Cleaner Conc	3.57	70.8	3.61	180	78.3	1.3	13.2
	Zinc Cleaner Conc	17.40	1.26	55.0	168	6.8	94.7	60.1
	Combined Tailing	79.03	0.61	0.51	16.4	14.9	4.0	26.7
	Feed	100.00	3.23	10.1	62.2	100.0	100.0	100.0
Raise 2	Lead Cleaner Conc	2.60	74.4	5.31	263	69.0	2.2	16.4
	Zinc Cleaner Conc	10.72	2.85	53.3	156	10.9	89.3	40.3
	Combined Tailing	86.68	0.65	0.63	20.7	20.1	8.5	43.2
	Feed	100.00	2.80	6.40	44.2	100.0	100.0	100.0

The Raise 2 ore represents a mining block for initial plant operation.

In spite of the complexity of the ore and fine dissemination of individual minerals, with the application of a special flowsheet and new technology (high intensity conditioning and modified collector) good concentrate grades with satisfactory recoveries were produced.

INTRODUCTION

This Final Report describes the metallurgical resulls obtained in the laboratory and in the pilot plant during the period of June 1990 to March 1991 on different ore samples prepared from drill core and bulk samples from the Cirque deposit.

The test program and scope of the work were discussed with Mr. G. McDonald of Curragh Resources Inc. The laboratory study included development testwork on a composite sample to identify and optimize the treatment process that would produce saleable lead and zinc concentrates with satisfactory recoveries. After development of the treatment process on the composite sample, laboratory tests were carried out on different ore types to determine if the developed procedure was broadly applicable, without significant modiflcation, and also to aid the pilot plant operation.

Pilot plant testwork was carried out on the bulk samples from the underground adit.

LAKEFIELD RESEARCH

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SUMMARY AND CONCLUSIONS

This section contains a summary of the highlights of the detailed results and discussions contained in Volumes 2 and 3.

1. The laboratory development testwork was conducted on a composite sample prepared from the drill core and basically was a mixture of two major ore types (i.e. massive sulphide ore and baritic ore). After development of the treatment process, standard tests were performed on different ore types and mixtures of the ore types and hanging wall material.

2. The bulk samples representing four ore types were used in the pilot plant testwork. Autogenous grinding tests were performed on ore types 4 and 5. Ore type 5 and a composite of ore types 4 and 5 and upper medium ore (i.e. 70:20:10 ratio) were used for flotation testwork. The head grades of the different ore samples used in the laboratory and pilot plant testwork are shown in Tables 2 and 3.

3. The laboratory development testwork was concentrated on development of a flowsheet and reagent scheme that would produce marketable concentrate grades at satisfactory recoveries.

TABLE NO. 2 :
Head Analyses of Laboratory Samples

Element	Assays %, g/t				Hanging Wall
	Composite No. 1	Ore Type 5	Ore Type 4	Ore Type 1	
Lead (Pb), Total	4.25	3.65	2.68	2.64	0.045
Zinc (Zn), Total	11.50	13.70	8.49	6.24	0.13
Lead (Pb), Oxide	-	0.85	0.51	0.42	-
Zinc (Zn), Oxide	-	0.20	0.065	0.044	-
Iron (Fe), Total	16.50	22.20	16.5	3.52	-
Sulphur (S), Total	27.60	36.5	24.0	17.40	-
Barite (Ba)	18.80	10.3	29.8	39.50	-
Carbon (C), Total	-	0.20	0.21	0.17	5.06
Carbon (C), graphitic	-	-	-	-	-
Gold (Au)	<0.02	<0.02	0.07	<0.02	-
Silver (Ag)	65.30	93.3	56.90	37.1	-

Summary - Continued

TABLE NO. 3 :
Head Analyses of Pilot Plant Samples and Composites

Element	Assays %, g/t				
	Ore Type 5	Ore Type 4	PP Comp No. 1*	Upper Medium	Raise 2
Lead (Pb), Total	3.56	-	3.21	2.61	2.79
Zinc (Zn), Total	9.62	-	9.08	8.59	6.65
Lead (Pb), Oxide	0.68	-	0.55	0.41	-
Zinc (Zn), Oxide	0.06	-	0.10	0.09	-
Iron (Fe)	13.60	-	12.70	12.10	9.72
Sulphur (S)	25.20	25.2	23.50	25.60	-
Barite (Ba)	22.10	-	24.10	-	28.5
Carbon (C), Total	0.71	0.49	0.56	0.13	-
Carbon (C), graphitic	0.49	-	0.40	-	-
Gold (Au)	<0.02	<0.02	<0.02	<0.02	-
Silver (Ag)	67.20	52.2	61.3	62.8	-

* blend of 4, 5 and upper medium (70:20:10)

Previous testwork carried out using a conventional flowsheet (Figure 1) and standard reagents (i.e. soda ash-cyanide-xanthate system) gave satisfactory results on baritic ore, but relatively poor results on pyritic ore (Table 4) especially for lead flotation. In order to overcome this problem, a semi-bulk flotation flowsheet has been developed (Figure 2) with introduction of a new depressant (SD200) and modified collector with thiourea (CA830/TH). This treatment process gave significant improvements in the

- lead concentrate grade and recovery,
- zinc recovery
- silver recovery.

TABLE 4 :
Metallurgical Results of Laboratory Testwork Using Sequential Flowsheet with a Conventional Reagent Scheme (LR 2491-1981)

Test No.	Sample	Product	Weight %	Assays %, g/t			% Distribution		
				Pb	Zn	Ag	Pb	Zn	Ag
1	"A" (Baritic ore type)	Pb Cleaner Conc	1.37	59.4	3.57	192.1	70.0	0.8	8.4
		Zn Cleaner Conc	9.57	0.35	56.40	107.5	2.9	89.4	33.2
		Pyrite Cleaner Conc	18.38	1.25	2.57	89.0	19.8	7.8	52.5
		Pyrite Flot'n Tail	70.68	0.12	0.17	2.71	7.3	2.0	6.1
		Head (Calc)	100.00	1.16	6.04	31.19	100.0	100.0	100.0
2	"B" (Massive sulphide)	Pb Cleaner Conc	4.32	45.2	3.86	125.1	66.8	1.5	7.6
		Zn Cleaner Conc	15.97	0.63	58.5	133.8	3.4	83.6	29.9
		Pyrite Cleaner Conc	40.96	1.72	3.81	100.70	24.1	14.0	57.8
		Pyrite Flot'n Tail	38.75	0.43	0.28	8.65	5.7	0.9	4.7
		Head (Calc)	100.00	2.92	11.18	71.37	100.0	100.0	100.0

Summary - Continued

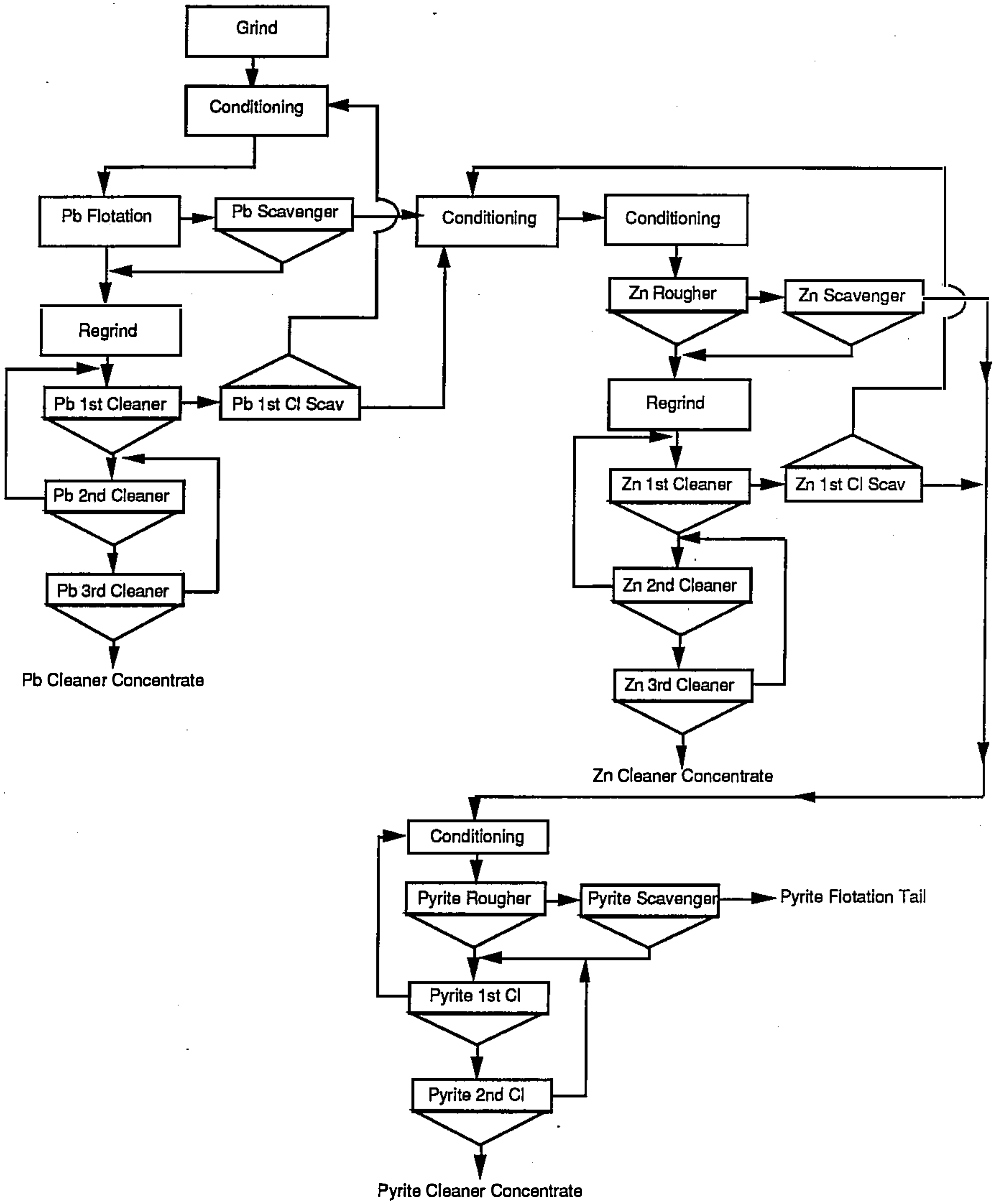

FIGURE 1 : Conventional flowsheet from previous testwork

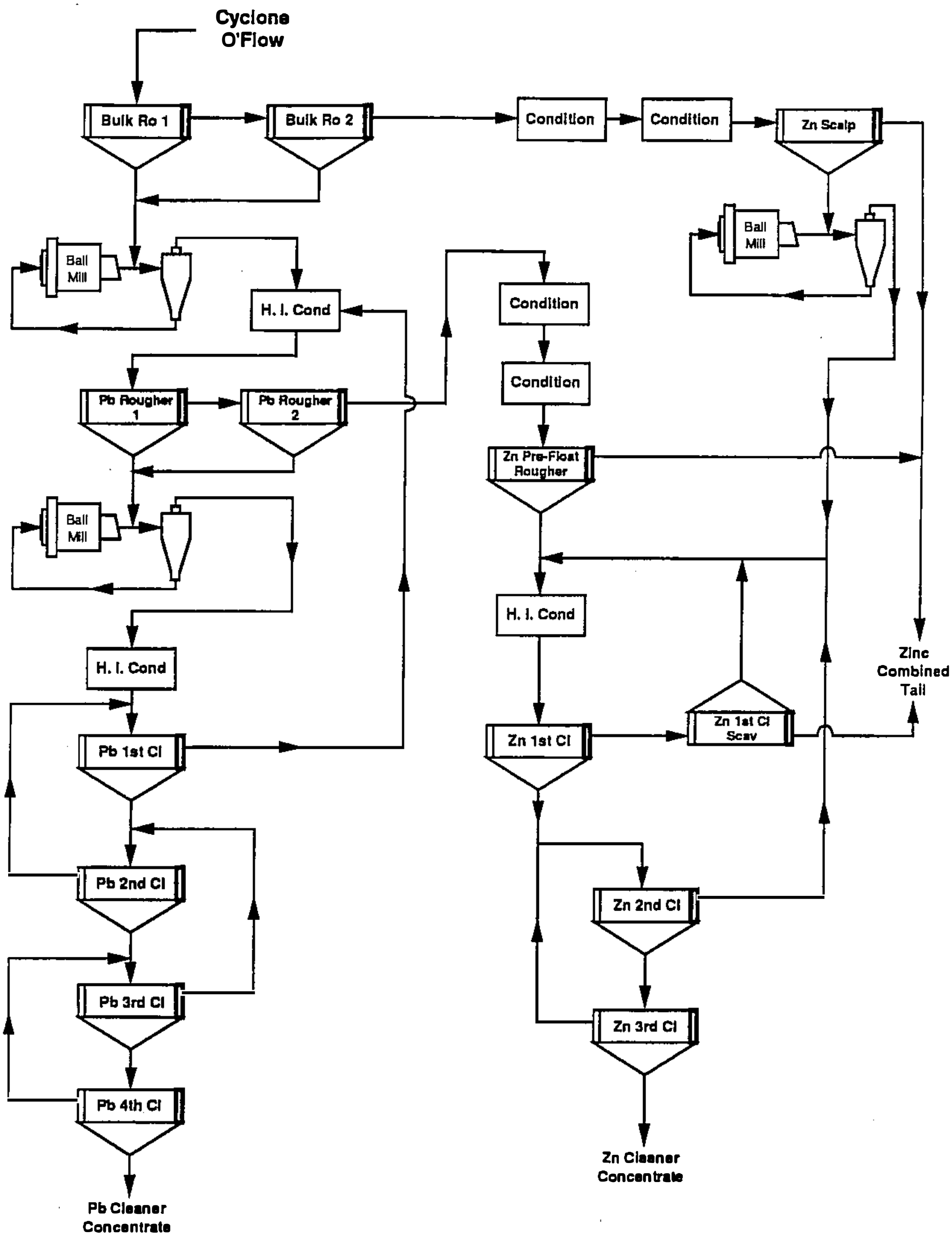

FIGURE 2 : Semi-bulk flowsheet

Summary - Continued

The laboratory results (Table 5) indicated that processing of the Cirque ore using the modified treatment process is technically feasible and would result in satisfactory metallurgical recoveries and high grade concentrates.

TABLE NO. 5 :
Laboratory Metallurgical Results Obtained Using Semi-Bulk Flowsheet

Ore Type	Product	Weight %	Assays %, g/t			% Distribution		
			Pb	Zn	Ag	Pb	Zn	Ag
Composite No. 1	Lead Concentrate	5.5	57.8	2.55	151	79.5	1.3	14.6
	Zinc Concentrate	17.5	0.74	57.4	139	3.2	92.4	41.9
	Combined Tailing	76.9	0.91	0.89	32.7	17.3	6.3	43.5
	Feed	100.0	4.03	10.9	57.9	100.0	100.0	100.0
Pilot Plant Ore Composite No. 1	Lead Concentrate	4.3	60.2	1.81	-	81.0	0.8	-
	Zinc Concentrate	16.7	0.72	54.4	-	3.8	94.3	-
	Combined Tailing	79.0	0.61	0.59	-	15.2	4.9	-
	Feed	100.0	3.18	9.6	-	100.0	100.0	-

4. The flotation conditions for treatment of the Cirque ore are as follows:

(a) a fineness of grind of about 80 % <200 mesh. The work index at a K_{80} of 80 µm was 9.6 for rod mill : ball mill grinding and 7.5 at K_{80} = 85 µm for SAG grinding. A flotation feed of K_{80} = 80 µm is desireable. At this fineness of grind carbonaceous pyrite is relatively coarse and only 20 % of the total lead in the ore is liberated, which is recovered in the form of middlings.

(b) For the lead semi-bulk flotation, soda ash, collectors, xanthate (A317 brand) and CA830/Thiourea mixture (i.e. mercaptobenzothiazole/dithiophosphate collector) are used. The remaining sphalerite is floated in the zinc scalp stage using lime-$CuSO_4$ and collectors A317 xanthate and dialkylthionocarbamate (M2030 brand). The bulk concentrate is reground to K_{80} = 18 µm in the presence of SD200/NaCN mixture and soda ash to pH 9.2-10.0 followed by lead rougher flotation. In this stage, the liberation between lead and zinc is achieved. However, the liberation between lead and pyrite is achieved at about K_{80} of 12 µm. Therefore, the lead rougher concentrate is further reground in the second stage followed by four cleaner stages with closed circuit cleaning. Depressant SD200/NaCN is added in each cleaning stage.

(c) From the lead rougher tailing, the zinc is recovered in a separate zinc prefloat circuit using lime-$CuSO_4$ xanthate and thionocarbamate. Zinc flotation in the scalp and prefloat stages is pH dependent and therefore these two streams are treated separately. The zinc flotation in the prefloat stage requires a pH below 10 while in the zinc scalp optimum pH is 10.8-11.5.

Summary - Continued

(d) The reground zinc scalp concentrate and zinc prefloat concentrate are combined and cleaned 4 times with an open zinc first cleaner stage. Additions of SD200 In the zinc first cleaner and zinc second cleaner improve zinc concentrate grade and reduce lime consumption considerably.

5. Only a few pilot plant variables were examined and these are summarized in Volume No. 3. The detailed evaluation of operating parameters including semi-autogenous grinding followed by flotation was not conducted because sufficient quantitles of the ore were not available.

6. Dewatering characteristics of the pilot plant flotation products were studied by Lakefield Research and equipment manufacturers. Data will be provided in a separate report.

RECOMMENDATIONS

Recommendations In this section are based on the following two premises:

- The Cirque deposit belongs to a class of complex polymetallic sulphide ores in which the composition and hence metallurgical processing characteristics vary considerably. In the laboratory and the pilot plant ores representing at least three different metallurgical types were examined.

- The pilot plant testwork was performed only with conventional grinding. The major parameters that affect metallurgical results, and several relatively new approaches to flowsheet design were not studied in detail in this program.

To provide the engineering data required for optimum mill design and to better define operating parameters, we recommend that further testing should incorporate the following:

- Large scale pilot plant testing should be done using semi-autogenous grinding - flotation to establish the final flowsheet using this grinding system.
- To determine the optimum power spiit between lead rougher and lead first cleaner regrinding. It was Indicated that the fineness of these regrind products determines lead-zinc and lead-pyrite selectivity.
- To better define the utilization of recycle water in various circuits.

DETAILS OF THE TESTWORK

1. Laboratory and Pilot Plant Samples

Laboratory development testwork was conducted on a composite sample and several ore types (i.e. massive sulphide - Type 5, Baritic - Type 4, Upper medium sulphide - Types 4 and 1). Also, testwork was carried out with a mixture of different ore types and hanging wall material.

The pilot plant testwork was carried out on a massive sulphide ore type and the composile of three ore types obtained from an underground exploration adit.

The head analyses of the samples used in the laboratory and pilot plant testwork are shown In Table No. 2 (laboratory samples) and Table No. 3 (pilot plant samples).

2. Mineralogical Characteristics of the Ore

In general, the Cirque deposit consists of complex polymetallic sulphide ore containing lead, zinc, pyrite, barite, quartz, carbonates and clay minerals (sericite, rutile) and carbonaceous shale material.

The sulphide phase minerals are mostly In the form of minute Inclusions, sometimes in extremely fine grains.

Pyrite is predominant in the ore and basically Is present in manifold formation of mostly irregular grains and aggregates, the latter of which are often very unhomogenous due to minute pores.

Galena is mostly found in the form of mobilizations In shrinking and/or kataclastic cracks as well as on grain boundaries and in interstices of adjacent pyrites. The particle size of galena ranges from 10 µm to rarely 50 µm. The fine Intergrowths are due to the replacement of pyrite by galena.

The **sphalerite** contained in the ore forms homogenous aggregates of 20-50 µm which are irregularly bordered by pyrite. In some parts, sphalerite and barite intergrowths are observed. Similar portions of sphalerite are found in Interstices of adjacent formations in coarser pyrite. In this case, the Intergrowths may be within the range of 5-10 µm.

The carbonaceous pyrite and shale material do not contain either galena or sphalerite.

The mineralogical characteristics of the ore Influenced the flowsheet design significantly.

Details of Testwork - Continued

3. Initial Development Testwork (Year 1978-1981)

Extensive laboratory testwork was carried out by Kamloops Research and Assay Laboratory Ltd. and Sachtleben Bergbau GmbH Laboratories (West Germany) in which two hundred batch tests were completed and presented in B progress reports. Preliminary tests were carried out by Lakefield Research, mainly to produce pyrite for silver recovery testwork. During this testwork, a sequential flotation flowsheet was used with a conventional soda ash-cyanide system for lead, and lime-$CuSO_4$ for zinc.

The Sachteleben laboratory was examining a lime-SO_2 scheme employed in the Megan concentrator. From this testwork the following conclusions were made:

- Reasonably good metallurgy was obtained on the baritic ore and the ore type with low pyrite content.
- Poor metallurgy was obtained on massive sulphide ores and the ores containing carbonaceous pyrite.
- The sliver recovery in the combined lead and zinc concentrates did not exceed 35%.

Poor metallurgy was mainly attributed to (a) extremely fine disseminations of galena and pyrite, especially "collomorphous" pyrite and, (b) to the presence of carbonaceous pyrite and carbon in the shale material.

4. Laboratory Development Testwork (1990-1991)

Based on the results described in Sections 2 and 3, laboratory development testwork was designed to overcome the problem of poor lead metallurgy obtained in the precious testwork.

- It was determined that with fine primary grinding (i.e. K_{80} <30 μm) used in the previous testwork, appreciable amounts of carbon were released which resulted in the contamination of the lead concentrate. Moreover, production of ultrafine baritic slimes resulted in slow lead flotation in the rougher and cleaning stages.
- The cyanide was generally not efficient for depression of ultrafine pyrite.

Results obtained using the new laboratory composite and the conventional flowsheet (sequential lead-zinc flotation with Na_2CO_3-NaCN reagent system) gave a lead concentrate grade of 51.5 % Pb at 72.0 % lead recovery. The pyritic ore type (i.e. ore type 5) gave a lead concentrate grade of 44 % Pb at only 50 % recovery in a batch test.

Extensive laboratory testwork was conducted on the laboratory composite using the semi-bulk flowsheet shown in Figure No. 2, in which relatively coarse primary grinding was employed, floating lead and a portion of zinc without depressant additions. This flowsheet, coupled with the introduction of high intensity conditioners designed to improve flotation of fine lead and zinc particles, was highly beneficial in improving lead metallurgical results.

Details of Testwork - Continued

Figure No. 3 shows the lead grade-recovery relationship using sequential lead zinc flotation (Flowsheet Figure 1) and semi-bulk flowsheet (Figure No. 3).

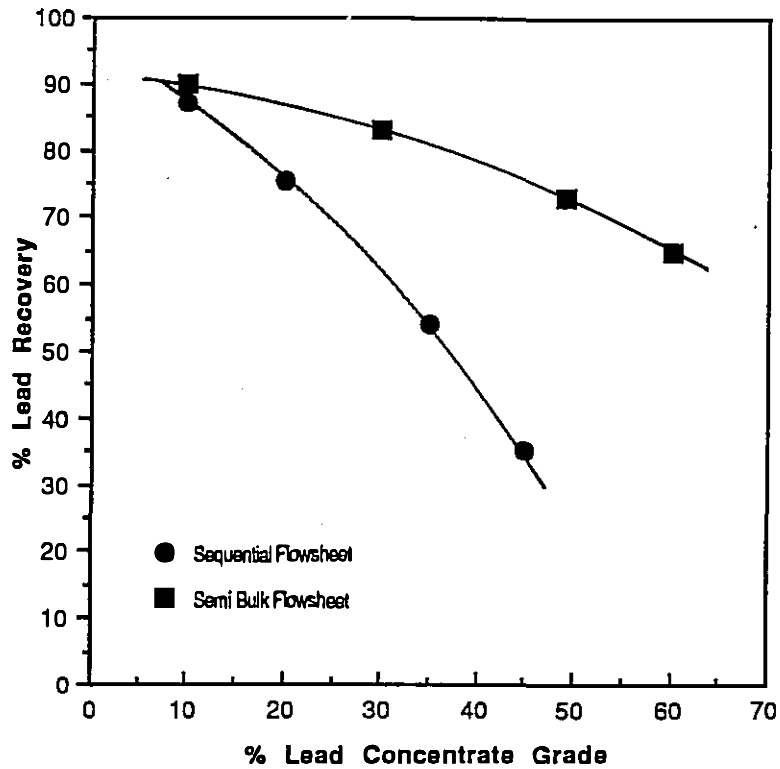

FIGURE NO. 3 : Effect of flowsheet configuration on lead grade-recovery relationship - massive sulphide ore

The lead grade and recovery obtained using the semi-bulk flowsheet were significantly better than those obtained with the sequential flowsheet.

With respect to the reagent scheme, a xanthate collector was used as a primary collector for both lead and zinc with a secondary lead collector (830/thiourea) and Minerec 2030 as a zinc secondary collector.

The pyrite-zinc depression in the lead circuit was achieved using a mixture of Unimin SD200 and cyanide. Lime and Unimin SD200 were used in the zinc circuit.

After development of the basic procedure on the composite sample, standard laboratory tests were conducted on individual ore types prepared from drill core, with and without additions of hanging wall material. Table No. 6 compares the results obtained with the composite and individual ore types.

Details of Testwork - Continued

TABLE NO. 6 :
Laboratory Batch Test Results Obtained on Composite and Individual Ore Types

Test No.	Ore Type	Pb Concentrate					Zn Concentrate				
		Weight %	Assays %		% Dist'n		Weight %	Assays %		% Dist'n	
			Pb	Zn	Pb	Zn		Pb	Zn	Pb	Zn
80	Composite	3.47	70.0	1.35	67.6	0.4	14.91	0.82	58.8	3.4	77.7
85	Ore Type 5*	3.80	62.2	1.82	65.0	0.5	18.40	0.95	51.7	4.7	70.3
88	Ore Type 5 + Hanging Wall 10 %	3.48	60.0	1.93	63.1	0.5	17.30	0.87	53.5	4.6	75.8
91	Ore Type 4	2.67	77.6	1.00	80.0	0.3	12.20	0.58	58.1	2.7	83.5
89	Ore Type 4 + 10% Hanging Wall**	2.53	71.0	1.61	80.1	0.5	11.41	0.61	55.8	3.1	82.9

* massive sulphides
** hanging wall material

In general, similar metallurgical results were obtained on all ore types examined.

5. Pilot Plant Testwork

Pilot plant testwork was performed on bulk ore types and composite samples of ore Types 4 and 5 and Upper Medium ore.

The test program was limited by the amount of ore available for testwork and problems in the initial pilot plant run.

The major objectives of the pilot plant test program were:

a) to reproduce laboratory results
b) to test autogenous grinding method
c) to generate engineering data for feasibility studies and plant design.

5.1. Autogenous Grinding

Although the ore is relatively soft with a work index of less than 8, the application of an autogenous grinding - pebble grinding system is feasible.

The power consumption and work index for the high sulphide ore were as follows:

Power, kWh/tonne :	10.45
Work Index :	7.40

5.2. Conventional Grinding

Conventional rod mill-ball mill grinding was used in the flotation testwork to grind the ore to K_{80} = 85 µm. The power consumption and work index using this grinding system were as follows:

Overall Power :	11.5 kWh/tonne
Overall Work Index :	9.0

Details of Testwork - Continued

5.3. Regrinding

Two stage regrinding of the lead concentrate and regrinding of the zinc scalp concentrate is necessary to produce high grade final concentrates. The fineness of regrind and the estimated power consumption for each regrinding stage are as follows:

Bulk Concentrate Regrind:

Fineness =	K_{80} = 18 µm
Power =	12 kWh/tonne of regrind feed

Lead Concentrate Regrind:

Fineness =	K_{80} = 12 µm
Power =	14 kWh/tonne of regrind feed

Zinc Scalp Concentrate Regrind:

Fineness =	K_{80} = 20 µm
Power =	7.5 kWh/tonne of regrind feed

5.4. High Intensity Conditioning

In both the laboratory and the pilot plant, it was demonstrated that high intensity conditioning is highly important in achieving satisfactory metallurgical results. For plant design, a maximum tank size of 8' x 10' should be used, equipped with 160 HPM and a four-bladed impeller designed for high intensity conditioning. The maximum allowable shaft speed should be used.

5.5. The Final Flowsheet

The final flowsheet developed for treatment of the Cirque ore is shown in Figure No. 4 - Autogenous grinding, Figure 5 - Conventional rod mill-ball mill grinding and Figure 6 - Flotation.

The autogenous grinding flowsheet shown in Figure 4 is the flowsheet proposed by Art McPherson Consulting based on the pilot plant work.

During the autogenous grinding testwork, a relatively high amount of small pebble chips was produced in the pebble mill, which would be detrimental for cyclone classification. The flowsheet, however, does not provide separation and recycle of pebble chips in the pebble mill.

Classified pulp (80-83% <200 mesh) was feed to lead bulk rougher flotation. Two collectors, xanthate (A317 Cyanamid brand) and the mixture of 830/thiourea (CA830 produced by Allied Colloids) were used to recover lead in the semi-bulk concentrate. The semi-bulk concentrates were combined and reground to
K_{80} = 18 µm followed by high intensity conditioning and lead rougher flotation.

Details of Testwork - Continued

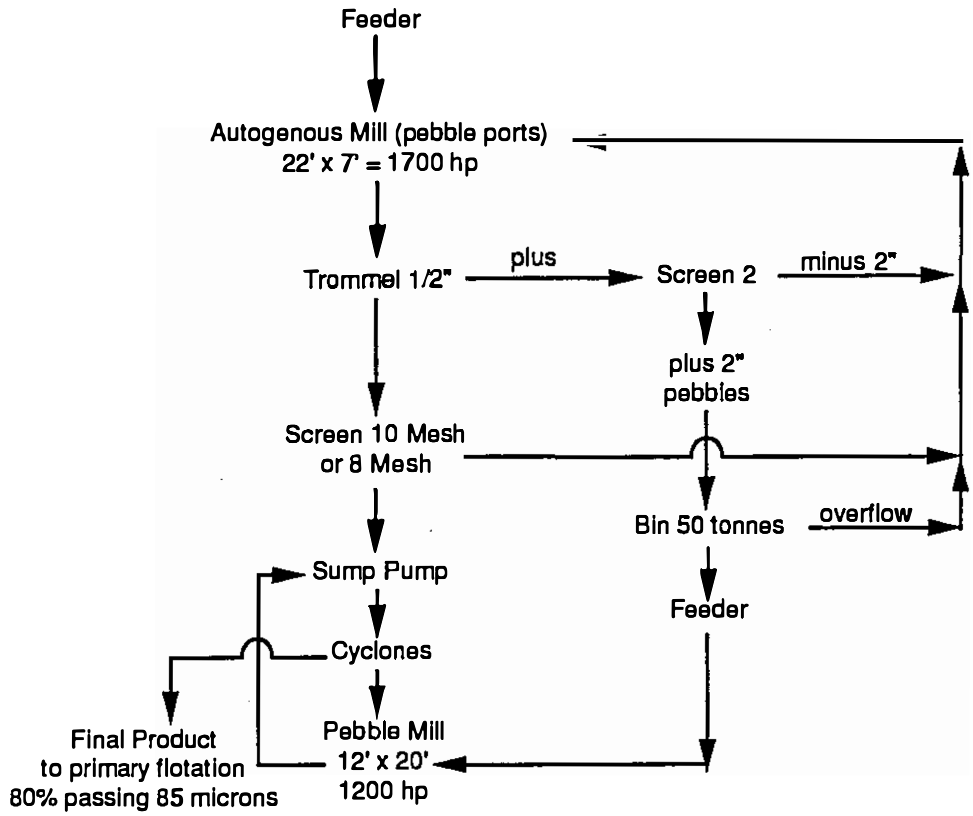

FIGURE NO. 4 : Autogenous grinding flowsheet*

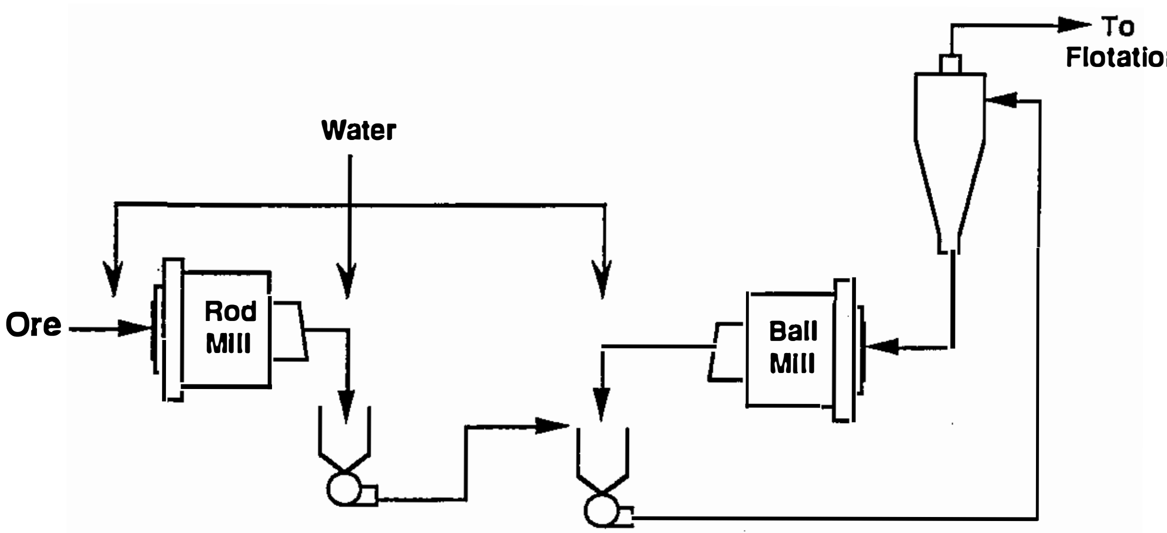

FIGURE NO. 5 : Conventional grinding flowsheet

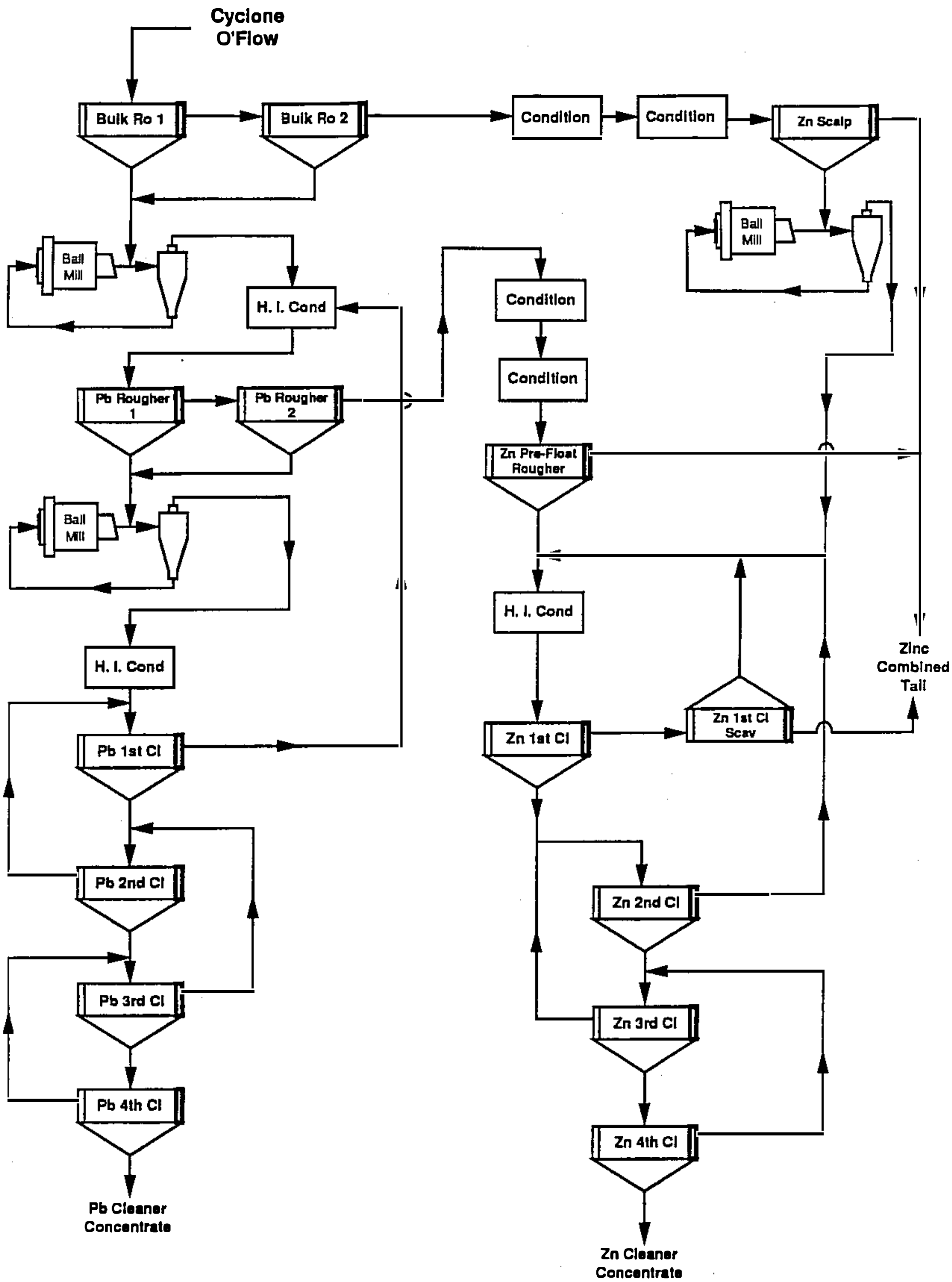

FIGURE NO. 6 : Final semi-bulk flotation flowsheet

Details of Testwork - Continued

The depressant SD200/NaCN mixture was used at pH 9.5 in the regrinding. Collectors used in the lead high intensity conditioning and lead roughers were the same as those used in semi-bulk flotation.

The combined lead rougher concentrates were reground to K_{80} = 12 µm, followed by high intensity conditioning and four cleaning stages. Depressant SD200/NaCN was added to the lead regrind and each cleaner, and collectors were added in high intensity conditioning only.

The semi-bulk flotation tailing was conditioned with lime (pH 11.0-11.5) and $CuSO_4$, followed by zinc scalp flotation with additions of collectors xanthate (A317 brand) and Minerec M2030. The zinc scalp concentrate was reground to K_{80} = 20 µm.

The lead rougher tail was stage conditioned followed by zinc prefloat flotation. The zinc prefloat concentrate was combined with the scalp reground concentrate and subjected to high intensity conditioning in the presence of collector, followed by four cleaner stages with open circuit zinc first cleaning.

The zinc first cleaner tail was scavenged and discarded, and the zinc first cleaner scavenger concentrate was recycled to the high intensity conditioner feed. Lime and Unimin SD200 were used for pyrite depression in the zinc cleaners.

An attempt during the testwork was made to treat the lead tailing and semi-bulk tailing together for zinc recovery, but because of differences in the flotation characteristics of zinc from each stream under similar flotation conditions, these two streams had to be treated separately for maximum zinc recovery.

5.6. Reagent Balance

The laboratory and pilot plant reagent balance for treatment of the Cirque ore are summarized in Tables 7 and 8.

TABLE NO. 7 :
Laboratory Reagent Scheme

Reagent	Additions, g/tonne					
	Semi-bulk	Pb Rougher	Pb Cleaners	Zn Scalp	Zn Prefloat	Zn Cleaners
Modifiers & Depressants						
Na_2CO_3	1500-2500	300	100	-	-	-
$Ca(OH)_2$	-	-	-	600	300	600
$CuSO_4 \times 5\ H_2O$	-	-	-	800	400	-
SD200/NaCN (1:1)	-	300	250	-	-	-
Collectors & Frothers						
A317 (xanthate Cyanamid brand)	70	40	-	-	-	-
CA830/thiourea (80:20)	25	25	-	-	-	-
C7/MIBC (1:1)	20	10	-	-	-	-
A350 (xanthate Cyanamid brand)	-	-	-	60	25	10
M2030	-	-	-	20	10	5
DF250	-	-	-	5	10	5

Details of Testwork - Continued

TABLE NO. 8 :
Pilot Plant Reagent Scheme

Reagent	Additions, g/tonne					
	Semi-bulk	Pb Rougher	Pb Cleaners	Zn Scalp	Zn Prefloat	Zn Cleaners
Modifiers & Depressants						
Na_2CO_3	1900	300	100	-	-	-
$Ca(OH)_2$	-	-	-	1000	200	300
$CuSO_4 \times 5\ H_2O$	-	-	-	500	500	-
SD200/NaCN (1:1)	-	300	300	-	-	-
SD200	-	-	-	-	-	120
Collectors & Frothers						
A317 (xanthate Cyanamid brand)	60	40	10	60	20	10
CA830/thiourea (80:20)	30	20	20	-	-	-
MIBC	20	10	-	-	-	-
DF1012	-	-	-	50	-	10
M2030	-	-	-	15	10	10

A large number of reagents were tested in the laboratory development testwork, to increase intermineral selectivity or recoveries. Special emphasis was placed on improvement in the lead concentrate grade and recovery.

The semi-bulk reagent scheme is relatively simple and includes soda ash and collector addition. The lead recovery in this stage is pH dependant where at pH below 9.5 the selectivity deteriorates. A mixture of cyanide and Unimin SD200 performed well in both laboratory and pilot plant in the lead circuit.

The pilot plant reagent scheme was slightly modified. These modifications included the following:

- Replacement of lead frother C7/MIBC mixture with MIBC, with the objective of reducing the number of reagents.
- In both the lead and zinc circuits, a single xanthate type was used, instead of two xanthates.
- Frother DF250 in the zinc circuit was replaced with DF1012.

Secondary lead collector CA830/thiourea was important for lead flotation especially in the cleaners since this collector provides good selectivity.

The most important parameter in the zinc prefloat during the pilot plant operation was pH value. The fine zinc in this circuit did not float at a pH above 10, and at higher pH the froth was black and unselective. High pH in the cleaners also was detrimental for zinc-pyrite selectivity, because at a high pH the pulp became flocculated and the froth was contaminated with fine pyrite.

To overcome this problem during the pilot plant operation, the pH in the zinc cleaners was reduced and Unimin SD200 was added to depress pyrite. This improved the zinc concentrate grade significantly.

Details of Testwork - Continued

5.7. Overall Metallurgical Results

Table No. 9 shows the overall metallurgical results obtained in the laboratory continuous tests, using the laboratory composite and massive sulphide ore. The overall metallurgical results obtained in the pilot plant are summarized in Table No. 10.

TABLE NO. 9 :
Metallurgical Results Obtained in the Laboratory Continuous Tests

Test No.	Ore Type	Product	Weight %	Assays %, g/t			% Distribution		
				Pb	Zn	Ag	Pb	Zn	Ag
81	Laboratory Composite	Pb Concentrate	5.5	57.8	2.55	152	79.5	1.3	14.6
		Zn Concentrate	17.5	0.74	57.4	139	3.2	92.4	41.9
		Zn Comb Tail	76.9	0.91	0.89	32.7	17.3	6.3	43.5
		Feed	100.0	4.03	10.9	57.9	100.0	100.0	100.0
84	Laboratory Composite	Pb Concentrate	3.9	67.1	2.04	-	70.7	0.7	-
		Zn Concentrate	18.2	1.55	54.9	-	7.6	90.6	-
		Zn Comb Tail	77.8	1.04	1.23	-	21.7	8.7	-
		Feed	100.0	3.73	11.1	-	100.0	100.0	-
96	Ore Type 5 Massive Sulphides	Pb Concentrate	4.8	55.3	2.28	-	72.4	0.8	-
		Zn Concentrate	22.7	1.38	54.1	-	8.5	90.3	-
		Zn Comb Tail	72.5	0.97	1.68	-	19.1	8.9	-
		Feed	100.0	3.68	13.6	-	100.0	100.0	-

TABLE NO. 10 :
Pilot Plant Metallurgical Results

Test No.	Ore Type	Product	Weight %	Assays %, g/t			% Distribution		
				Pb	Zn	Ag	Pb	Zn	Ag
PP15	Bulk Composite 2	Pb Concentrate	2.89	75.3	2.6	196	67.4	0.8	9.5
		Zn Concentrate	16.45	1.75	52.3	175	8.9	89.6	48.1
		Zn Comb Tail	80.66	0.95	1.14	31.5	23.7	9.6	4.2
		Feed	100.0	3.23	9.60	58.7	100.0	100.0	100.0
PP16	Bulk Composite 2	Pb Concentrate	3.57	70.8	3.61	180	78.3	1.3	13.2
		Zn Concentrate	17.40	1.26	55.00	168	6.8	94.7	60.1
		Zn Comb Tail	79.03	0.61	0.51	16.4	14.9	4.0	26.7
		Feed	100.0	3.23	10.1	62.2	100.0	100.0	100.0
PP17	Raise 2	Pb Concentrate	2.60	74.4	5.31	263	69.0	2.2	16.4
		Zn Concentrate	10.72	2.85	53.3	156	10.9	89.3	40.3
		Zn Comb Tail	86.68	0.65	0.63	20.7	20.1	8.5	43.3
		Feed	100.0	2.80	6.40	44.2	100.0	100.0	100.0

Details of Testwork - Continued

The results obtained in both the laboratory and the pilot plant were satisfactory. Direct comparison of laboratory and pilot plant results obtained on the same ore type is made in Table No. 11. The results obtained in both pilot plant and laboratory were similar. During the pilot plant operation, variation in the lead recovery and concentrate grade was evident.

TABLE NO. 11 :
Comparison of Laboratory and Pilot Plant Results - Pilot Plant Composite

Test No.	Test Type	Product	Weight %	Assays %, g/t			% Distribution		
				Pb	Zn	Ag	Pb	Zn	Ag
F-17	Laboratory Continuous	Pb Concentrate	4.3	60.2	1.81	-	81.0	0.6	-
		Zn Concentrate	16.7	0.72	54.4	-	3.8	94.3	-
		Combined Tail	79.0	0.61	0.59	-	15.2	4.9	-
		Feed	100.0	3.18	9.6	-	100.0	100.0	-
PP16	Pilot Plant Continuous	Pb Concentrate	3.57	70.8	3.61	180	78.3	1.3	13.2
		Zn Concentrate	17.40	1.26	55.0	168	6.8	94.7	60.1
		Combined Tail	79.03	0.61	0.51	16.4	14.9	4.0	26.7
		Feed	100.00	3.20	10.1	62.2	100.0	100.0	100.0

From the analyses of the laboratory and pilot plant data, it has been established that there is a strong relationship between lead recovery and concentrate grade (Figure 7) where at high lead concentrate grade (i.e. over 70 %) lead recovery deteriorated.

The overall silver recovery in the combined lead and zinc concentrate is about 60 % Ag.

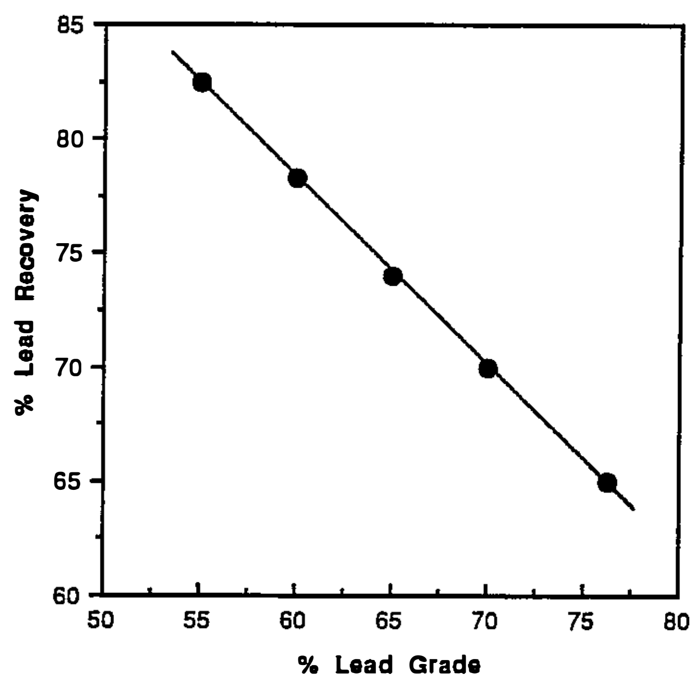

FIGURE NO. 7 : Lead concentrate grades vs recovery - Laboratory and pilot plant data