SUMMARY AND CONCLUSIONS

1. Description of Samples Used in the Laboratory Testwork

A total of 6 different composites were examined during the laboratory testwork. The ore composites were prepared according to mineralogical characteristics and geological setting. Most of the development testwork was carried out on Composite No. 3 and only preliminary tests were performed on Composite No. 5 and the Master Composite. The head analyses of the composites examined in the laboratory testwork are shown in Table No. 2.

TABLE NO. 2 : Head Analyses of Different Laboratory Composites.

Composite	Assays %, g/t												
	Cu	Pb	Zn	Fe	S	Mn	Hg	Au	Ag	C(T)	C(g)	Po	
Comp 1A	0.26	3.95	4.20	26.8	28.5	0.45	0.0018	0.57	49.1	1.47	0.057	11.2	Porous oxide
Comp 1B	0.22	5.75	6.69	28.1	28.9	1.16	0.0049	0.79	77.8	1.71	0.049	17.0	Non porous oxide
Comp 2	0.20	4.75	5.70	24.5	26.8	0.79	0.0036	0.93	64.5	1.67	0.049	12.5	4EG+/-oxide (SE)
Comp 3	0.15	3.96	5.35	21.7	28.2	0.61	0.0043	1.57	64.8	0.20	0.015	10.3	4EG (NW).
Comp 4	0.037	2.20	3.87	7.54	8.83	0.054	0.0023	0.44	31.2	2.20	0.64	12.5	4A4
Comp 5	0.36	0.72	0.89	29.1	26.6	0.58	0.00023	1.60	12.7	1.01	0.060	9.40	4EC
Master	0.22	3.76	4.47	24.2	27.1	0.71	0.0025	0.96	57.9	1.37	0.081	17.2	– all above mixed pro-rata.

The Master composite was prepared from individual composites 1 to 5 and represents 100,000 tons of ore to be tested in the plant towards the end of 1989. The individual composite samples were prepared from 16 drill hole samples from the 1987 Vangorda drilling program.

2. Processing Characteristics of Vangorda Ore

The Vangorda Ore is a complex, massive sulphide ore in which the individual minerals are finely disseminated and the flotation characteristics of both galena and sphalerite vary within the orebody. In addition, the ore contains appreciable amounts of pyrrhotite and secondary copper minerals which interfere with the rate of flotation of galena and sphalerite. Following are the major processing characteristics of the individual ore composites.

(a) **Composite 1A** is the most refractory of the ore types and contains carbonaceous pyrite and secondary copper minerals. The secondary copper minerals were responsible for the extremely poor selectivity between lead and zinc minerals. During the lead rougher flotation, up to 70 % of the total zinc reported in the lead rougher concentrate. In addition, the lead rougher concentrate was heavily contaminated with pyrrhotite resulting in a low lead grade in the cleaner concentrate.

Summary - Continued

b) **Composite 1B** is a high grade lead-zinc ore with high pyrrhotite content. This ore contains less carbonaceous pyrite than Composite 1A. Production of high grade lead and zinc concentrates with respectable recoveries did not represent a significant problem.

c) **Composite No. 2** is the coarsest grained of the composites examined, and gave the highest lead recovery. However, because of the presence of secondary copper minerals, the selectivity between lead and zinc was somewhat reduced, and up to 30 % of the total zinc reported in the lead rougher concentrate.

d) **Composite No. 3** represents the largest portion of the orebody and most of the laboratory development testwork was conducted on this composite. Although good metallurgical results were obtained, it was positively established that Vangorda ore cannot be processed using the plant flowsheet and reagent scheme. The most prominent feature of this ore, using the plant reagent scheme, was slow lead flotation during the lead cleaning and reduced selectivity. With a high dosage of cyanide in the rougher and cleaning and the use of a modified collector, the lead cleaning efficiency improved dramatically.

e) **Composite No. 4** represents graphitic quartzite ore with high amounts of carbon and carbonaceous pyrite. Using the conventional reagent scheme, a low grade lead concentrate was obtained. With the use of an organic base depressant DS20, the lead concentrate grade improved dramatically.

f) **Composite No. 5** is a low-grade ore (i.e. 0.66 % Pb and 0.91 % Zn). In spite of the low head grade, good lead metallurgical results were obtained. This ore made up about 20 % of the Master composite. ← Too much.

g) **Master Composite**. The processing characteristics of the Master Composite were similar to that of Composite No. 2.

3. Development Testwork

3.1. Grindability of the Ore and Primary Grinding Requirements

The grindability of the ore differed within the orebody and the Ball Mill Bond Work indices (Table No. 3) varied between 7.9 and 11.6 metric. The Vangorda ore, however, is somewhat softer than the Faro 3 ore and a slightly finer grind can be expected in the plant than that obtained on Faro 3 ore. The fineness of grind examined in the laboratory on the various composites is shown in Table No. 4. It appeared that a primary grind of about k_{80} = 50 to K_{80} = 40 is the optimum.

Summary - Continued

TABLE NO. 3 : Ball Mill Grindability Test Results

Description	Composite No. 3		Composite No. 2		Composite No. 4		Composite No. 1A		Composite No. 1B	
Work Index (metric)	7.9	7.6	8.9	9.8	11.57	-	9.98	10.9	9.70	-
Screen Size, µm	104	74	104	74.0	104	-	104	74	104	-
Product per revolution	3.07	2.22	2.36	1.85	1.80	-	2.29	1.72	2.33	-
Product K_8O, µm	81	53	78	59.0	81	-	83.0	60	82.0	-
Feed K_8o, µm	890	1800	1230	1230	1150	-	980	980	1000	-

TABLE NO. 4 : Summary of Finenesses of Grind Used in the Laboratory Testwork

Grinding Time minutes	Composite 1A % Pass Cum 270M	Composite 1A % Pass Cum 400M	Composite 1A K8o µm	Composite 1B % Pass Cum 270M	Composite 1B % Pass Cum 400M	Composite 1B K8o µm	Composite 2 % Pass Cum 270M	Composite 2 % Pass Cum 400M	Composite 2 K8o µm	Composite 3 % Pass Cum 270M	Composite 3 % Pass Cum 400M	Composite 3 K8o µm	Composite 4 % Pass Cum 270M	Composite 4 % Pass Cum 400M	Composite 4 K8o µm
20	-	-	-	-	-	-	-	-	-	88.5	-	42.0	-	-	-
30	81.0	-	50.0	83.6	66.5	51.0	84.8	-	46.5	-	-	-	78.1	62.8	58.0
40	89.5	-	40.0	89.1	76.4	41.0	91.8	-	37.0	93.3	-	36.0	84.9	67.2	48.0
50	92.0	-	38.0	92.7	81.4	36.0	95.0	-	33.0	95.7	86.9	31.5	91.2	74.9	41.0
60	96.4	87.0	31.0	-	-	-	-	-	-	97.6	91.3	27.5	-	-	-
70	97.1	-	29.0	-	-	-	-	-	-	99.3	91.3	30.0*	-	-	-

3.2. Lead and Zinc Concentrate Regrind

The grade of both the lead and zinc concentrates was determined by the fineness of regrinding of the corresponding lead and zinc rougher concentrates. A regrind of the total lead rougher and scavenger concentrates would be mandatory in order to maintain a high lead concentrate grade. The present lead regrind flowsheet configuration used in the plant would not be suitable for processing the Vangorda ore.

It should be noted that an improved sharpness of classification in the plant would greatly improve both lead and zinc metallurgy. An estimate of the regrinding requirements for the lead and zinc concentrates is shown below:

(a) Lead Concentrate 90 % <25 µm

(b) Zinc Concentrate 80 % <25 µm.

Summary - Continued

3.3. Summary of Laboratory Development Testwork

3.3.1. Composite 1A

Problems with Composite 1A were experienced in obtaining satisfactory selectivity between lead and zinc minerals. In most of the tests, over 60 % of the zinc reported in the lead rougher concentrate. The major variables examined on Composite 1A included:

a) fineness of primary grind
b) type of zinc depressant
c) regrinding requirements.

The effect of the variables examined on the lead and zinc metallurgical results can be described as follows:

1. The fineness of regrind in the range tested (i.e. K_{80} = 29-50 µm) had no significant effect on lead and zinc rougher concentrate grades and recoveries.

2. The use of an organic based zinc depressant (i.e. LS8) improved lead concentrate grade slightly but at the expense of recovery.

3.3.2. Composite 1B

On this composite, standard roughing tests at different finenesses of grind and cleaning tests using different finenesses of regrind were performed. The results obtained indicated a) an improvement in the lead and precious metal recoveries at a finer primary grind and b) the lead concentrate grade improved significantly with a finer regrind of the lead rougher concentrate.

3.3.3. Composite No. 2

On this composite the fineness of primary grind and regrind and the levels of cyanide addition were examined.

Note that with this composite problems were experienced in obtaining a high grade zinc concentrate. The effects of the variables examined on this composite can be described as follows:

a) a finer primary grind and a finer regrind of the lead concentrate had no effect on lead metallurgical results. A finer regrind of the zinc concentrate, however, improved both zinc concentrate grade and recovery.

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b) Higher cyanide additions to the lead rougher and cleaners did not effect lead metallurgical results.

It appeared that the zinc in this ore type is more finely disseminated than in the other ore types.

Summary - Continued

3.3.4. Composite No. 3

Most of the laboratory development testwork was performed on this composite and the data generated in this testwork served as the basis for metallurgical evaluation of the other composites.

The major variables examined on this ore included:

a) fineness of primary grind
b) fineness of lead and zinc concentrate regrind
c) grinding media
d) level of depressant and collector additions
e) type of collector and pyrrhotite depressant.

The results obtained in this testwork showed the following:

a) The fineness of grind had little or no effect on lead and zinc recoveries, however precious metal recoveries increased with a finer primary grind. Replacing ball mill grinding with rod mill grinding media significantly improved lead rougher recovery.

b) Using the plant reagent scheme, the lead and zinc metallurgical results were satisfactory. However, the upgrading of the corresponding lead and zinc concentrates represented a significant problem, because both lead and zinc dropped during the cleaning operation. Typical results obtained in the lead cleaning are shown in Table No. 5.

TABLE NO. 5 : Lead Cleaning Metallurgical Results Obtained with Plant Collector Metallurgical Results

Test No.	Product	Weight %	Assays %, g/t Pb	Zn	Au	Ag	% Distribution Pb	Zn	Au	Ag
24	Pb Cleaner Conc	3.5	63.6	6.03	12.6	855	57.6	4.1	60.7	52.8
	Pb Rougher Conc	10.7	32.0	9.98	4.78	423	89.9	21.2	71.4	80.8
	Pb Rougher Tail	89.3	0.43	4.45	0.23	12.0	10.1	78.8	28.6	19.2
	Head (Calc)	100.00	3.81	5.04	0.72	559	100.0	100.0	100.0	100.0

Summary - Continued

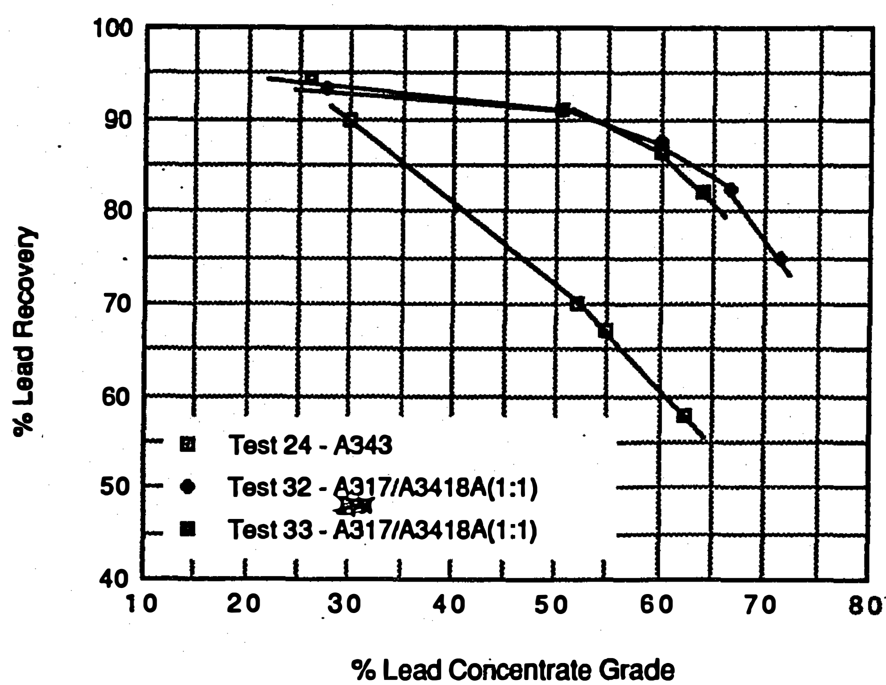
Note that the lead concentrate recovery was dramatically reduced during the cleaning operation . An improvement in the lead cleaning efficiency was realized with the introduction of collector A317:3418A mixture (1:1 ratio). Table No. 6 shows the results obtained with the above collector mixture.

TABLE NO. 6 : Lead Metallurgical Results Obtained with Modified Collector

Test No.	Product	Weight %	Assays, % Pb	Assays, % Zn	% Distribution Pb	% Distribution Zn
32	Pb Cleaner Concentrate	4.81	69.0	4.93	83.1	4.8
	Pb Rougher Concentrate	13.40	27.9	9.74	93.5	26.1
	Pb Rougher Tailing	86.60	0.30	4.27	6.5	73.9
	Head (Calc)	100.00	4.00	5.00	100.0	100.0

Figure No. 1 compares the lead metallurgical results obtained with the standard and with the new collector mixture.

FIGURE NO. 1 : Effect of Collector Type on Lead Cleaning



Summary - Continued

This is the only reagent change which should be transferred to the plant operation before processing Vangorda Ore.

c) The testwork results obtained with different pH's and cyanide levels indicated that higher cyanide additions are required for Vangorda ore than those normally used in the current plant.

d) In the zinc flotation, the most pronounced improvement was achieved in the rate of zinc flotation by introducing high-speed high-power conditioning after the regrind.

In general, satisfactory lead and zinc metallurgical results were obtained with higher depressant additions and changes in the type of collector. High cyanide and soda ash consumptions were mainly attributed to the presence of appreciable amounts of pyrrhotite.

3.3.5. Composite No. 4

The major problem in processing this ore type was in achieving a high lead concentrate grade. The presence of carbon and carbonaceous pyrite was the major reason for the low lead concentrate grade.

The use of an organic based depressant in place of cyanide resulted in a significant improvement in the lead concentrate grade. Table No. 7 compares the lead metallurgical results obtained with cyanide and with organic depressant DS20.

TABLE NO. 7 : Metallurgical Results Obtained with NaCN and DS20 - Composite 4 Ore

Test No.	Depressant Used	Product	Wt %	Assays % Pb	Assays % Zn	% Distribution Pb	% Distribution Zn
66	NaCN	Pb Cleaner Concentrate	2.37	40.9	4.76	46.2	3.0
		Pb 1st Cleaner Conc	4.94	34.0	5.30	80.1	6.9
		Pb Combined Tailing	95.06	0.43	3.69	19.9	93.1
		Head (Calc)	100.00	2.10	3.79	100.0	100.0
77	DS20	Pb Cleaner Concentrate	1.71	57.4	4.74	47.3	2.1
		Pb Rougher Concentrate	15.23	11.6	5.85	84.9	23.2
		Pb Rougher Tailing	84.77	0.37	3.49	15.1	76.8
		Head (Calc)	100.00	2.08	3.85	100.0	100.0

Summary - Continued

3.3.6. Composite No. 5 and Master Composite

Only prelimnary tests were conducted on these two composites. Composite 5 was a low grade ore and was included in the Master Composite (i.e. 20 %). The metallurgical results obtained on these two composites were similar to that obtained on Composite 3.

4. Impurity Analyses of the Lead and Zinc Concentrates

The lead and zinc concentrates from the final locked cycle tests were submitted for impurity analyses. The impurity analyses of the lead concentrate are given in Table No. 8 and the impurity analyses for the zinc concentrate are shown in Table No. 9.

TABLE NO. 8 : Pb Concentrate Impurity Analyses

Element	Comp. 2	Comp. 3	Assays %, g/t Comp. 4	Comp. 1A	Comp. 1B
Iron (Fe)	4.90	4.12	5.86	11.6	5.15
Copper (Cu)	0.40	-	0.27	2.75	0.95
Nickel (Ni)	<0.002	<0.002	0.004	<0.002	<0.002
Lead (Pb)	63.5	66.2	59.0	42.6	64.6
Zinc (Zn)	8.97	7.20	5.19	12.5	7.02
Bismuth (Bi)	<0.002	0.002	<0.002	<0.002	<0.002
Cadmium (Cd)	0.014	0.011	0.008	0.019	0.012
Chromium (Cr)	0.003	0.022	0.003	0.003	0.002
Cobalt (Co)	<0.002	<0.002	0.004	0.005	<0.002
Manganese (Mn)	0.082	0.10	0.037	0.079	0.076
Uranium (U)	<0.001	-	0.005	<0.001	-
Arsenic (As)	0.032	<0.001	0.50	0.031	0.051
Antimony (Sb)	0.14	0.23	0.16	0.12	0.39
Tin (Sn)	<0.001	0.002	<0.001	<0.001	<0.001
Fluorine (F)	0.053	0.093	0.033	0.021	0.038
Chlorine (Cl)	<0.005	-	0.008	0.011	-
Sulphur (S)	18.4	17.8	17.2	25.4	18.0
Carbon Total -	0.20	-	1.78	0.23	-
Silica (SiO_2)	0.76	2.36	6.42	0.56	0.52
Alumina (Al_2O_3)	0.06	0.085	0.61	0.11	0.13
Magnesia (MgO)	-	0.92	0.19	0.14	-
Lime (CaO)	-	0.12	0.17	0.10	-
Sodium (Na_2O)	0.002	-	0.010	0.003	-
Potassium (K_2O)	0.003	-	0.13	0.007	-
Insol	2.79	5.79	7.53	1.26	0.96
Mercury (Hg)	0.0067	0.0050	0.0030	0.0063	0.0068
Gold (Au)	14.0	8.60	5.67	10.3	7.32
Silver (Ag)	684.	813.	651.	490.	739.

Summary - Continued

TABLE NO. 9 : Zn Concentrate Impurity Analyses

Element	Assays %, g/t Comp. 2	Comp. 3	Comp. 4	Comp. 1A	Comp. 1B
Iron (Fe)	7.44	6.72	8.86	8.54	6.56
Copper (Cu)	0.89	-	0.26	0.53	0.23
Nickel (Ni)	<0.002	<0.002	<0.002	<0.002	<0.002
Lead (Pb)	1.15	1.03	0.55	2.64	1.02
Zinc (Zn)	54.2	54.9	53.0	51.2	57.2
Bismuth (Bi)	<0.002	<0.002	<0.002	<0.002	<0.002
Cadmium (Cd)	0.071	0.069	0.062	0.071	0.075
Chromium (Cr)	0.002	0.036	0.003	0.003	0.002
Cobalt (Co)	<0.002	<0.002	0.003	0.002	<0.002
Manganese (Mn)	0.22	0.33	0.11	0.21	0.18
Uranium (U)	<0.001	-	<0.002	<0.001	-
Arsenic (As)	0.004	0.007	0.12	0.021	-
Antimony (Sb)	0.003	0.006	0.005	0.006	-
Tin (Sn)	<0.001	<0.001	<0.001	<0.001	-
Fluorine (F)	0.030	0.11	0.021	0.015	-
Chlorine (Cl)	0.045	-	<0.005	0.009	-
Sulphur (S)	31.3	33.3	32.9	31.1	-
Carbon Total	0.31	-	0.91	0.39	-
Silica (SiO_2)	0.30	0.25	3.15	0.43	0.25
Alumina (Al_2O_3)	0.07	0.034	0.43	0.13	0.07
Magnesia (MgO)	0.13	0.14	0.085	0.14	-
Lime (CaO)	0.34	0.40	0.22	0.39	-
Sodium (Na_2O)	<0.002	-	0.007	0.003	<0.002
Potassium (K_2O)	0.004	-	0.097	0.008	0.003
Insol	1.89	2.00	3.82	1.09	0.87
Mercury (Hg)	0.046	0.028	0.029	0.016	0.033
Gold (Au)	0.59	0.28	0.33	0.57	0.37
Silver (Ag)	40.1	48.5	31.5	65.7	38.2

5. Overall Treatment Process

5.1. Flowsheet

In order to obtain marketable lead and zinc concentrate grades on Vangorda Ore, the current plant flowsheet (Figure 2) should be modified as follows (Figure 3).

(A) Both lead rougher and scavenger concentrates should be reground before cleaning.

(B) The lead first cleaner should be performed in open circuit cleaning with the addition of an extra cleaner scavenger stage.

(C) The zinc first cleaner feed should include a high speed conditioner.