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ANVIL MINING CORPORATION LIMITED

METALLURGICAL DEPARTMENT

PRODUCTION OF A COPPER CONCENTRATE FROM THE ANVIL ORE

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In the metallurgical laboratory at Anvil, a copper concentrate has been produced. The technique was dependant on the sulphite ion depression of iron and zinc minerals in the total absense of cyanide ion.

Under the above conditions and with a coarse primary grind, a copper concentrate grading 20.0% Cu, after some cleaning, and a 40% recovery, was obtained. This indicates a gross cash flow of approximately \$1.5 million/annum at current copper prices and 1973 PLAN tonnages.

It has been found extremely difficult to produce a lead/copper concentrate but relatively easy to make a separate copper concentrate.

During plant testing with sodium sulphite, it is recommended that sodium cyanide addition be stopped for a short period of time; in an effort to assess the possibilities of producing a copper concentrate on a plant scale.

PART I — LABORATORY TESTING

During February and March 1972[2] testwork was being carried out on the depression of iron and zinc minerals with sodium sulphite[11]. A portion of this testing was concerned with the effects of (1) firstly reducing the cyanide content and (2) secondly eliminating it entirely from the pulp during grinding, when sulphite was being used as a depressant.

When the first tests were being carried out with no cyanide, the lack of galena floating and some chalcopyrite floating was noted and filed for future reference, as the interest of the moment was centered on the sulphite ion depression of iron and zinc minerals.

Based upon portions of the above mentioned testing, a series of tests were designed and carried out using only sodium sulphite as the iron and zinc mineral depressant and varying the quantities of soda ash that were added to the grind. Soda ash was varied from 0 to 2.5 lbs/ton, with sodium sulphite being held constant at 2.5 lbs/ton.

TABLE I

VARYING SODA ASH IN SULPHITE SYSTEM NO CYANIDE[3] NO FOOT NOTE!

	Grade %			Recovery %		
	Pb	Zn	Cu	Pb	Zn	Cu
STD (0.15# NaCN)	29.2	16.5	0	92.7	82.4	0
2.5 #Na_2SO_3 − Na_2CO_3	34.0	9.2	2.65	85.5	67.4	29.3
2.5 #Na_2SO_3 − Na_2CO_3	31.6	17.9	5.30	85.5	72.9	42.4
2.5 #Na_2SO_3 − Na_2CO_3	41.6	17.0	5.61	85.1	81.1	49.0

Notes:
1. GRADES and RECOVERIES are based on Ro + Scav. Conc.
2. Improving Cu grades and recoveries with increasing soda ash.

TABLE 2

ROUGHER CONCENTRATE GRADES FOR TABLE 1

	Pb%	Zn%	Cu%
STD (0.15 #NaCN)	37.8	42.9	0
2.5 #Na_2SO_3 – 0 #Na_2CO_3	44.2	2.0	2.69
2.5 #Na_2SO_3 – 1.0 #Na_2CO_3	39.2	39.7	5.30
2.5 #Na_2SO_3 – 2.5 #Na_2CO_3	49.1	45.3	5.61

Notes:
1. Tremendous improvement in zinc grades with increasing soda ash.
2. Improvement in copper grades.

The main point to be noted from that report were the greatly improved grades and recoveries obtained in the copper concentrate by increasing soda ash.

A further series of tests were carried out, still investigating the effects of variation in the cyanide/sulphite ratios, and once again a copper concentrate was collected prior to the lead rougher concentrate, extra collector being all that was necessary to levitate the galena. This series also demonstrated for the first time the reduction in the galena recovery in the sulphite system with zero cyanide additions.

TABLE 3A[4]

EFFECT OF REDUCING NaCN (SULPHITE 1.5#)

Test Conditions	Grade % Pb	Grade % Zn	Recovery % Pb	Recovery % Zn
STD	41.3	47.4	88.4	75.8
STD + $SO_3^{=}$ (0.15# NaCN)	53.5	48.4	89.8	74.4
STD + $SO_3^{=}$ (0.05# NaCN)	57.1	46.4	82.3	74.3
STD + $SO_3^{=}$ (0# NaCN)	59.4	48.3	76.2	76.4

TABLE 3B[4]

EFFECT OF REDUCING NaCN (SULPHITE 2.5#)

Test Conditions	Grade % Pb	Grade % Zn	Recovery % Pb	Recovery % Zn
STD	38.9	47.5	92.7	73.5
STD + $SO_3^{=}$ (0.15# NaCN)	39.5	49.1	92.2	75.2
STD + $SO_3^{=}$ (0# NaCN)	48.3	48.9	73.0	72.5

Notes: 1. Grades are primary concentrate only, in both Tables.

2. Tremendous impact on lead recovery of NaCN elimination.

During the above series of tests the very high sensitivity of the chalcopyrite in the Anvil ore to cyanide was demonstrated.

TABLE 4[4]

COPPER DISTRIBUTION

	# NaCN		
Product	0.15	0.05	0
Pb Ro. Conc.	13.0	34.8	47.6
Pb Scav. Conc.	12.8	7.3	3.3
Zn Ro. Conc.	18.0	15.6	13.2
Zn Scav. Conc.	12.4	8.5	7.4
Zn Scav. Tail	40.2	33.8	28.5

Notes: ·· Includes copper in the copper concentrate and in the lead concentrate.

By the end of May 1972, it was thought that sufficient preliminary testing had been carried out and that some idea of cleaned concentrate grade would be necessary in order for management to accertain marketability of the product. The test results were not considered to be, by any means, the ultimate in grade or recovery of copper. Several reasons for this statement maybe advanced.

1. Even locked tests are not truly indicative of mill performance.
2. The amount of copper in the ore (feed average grade Cu = 0.22% or 12.4 grams of chalcopyrite/2000 gms sample) was very small and some dilution of pulps was unavoidable.
3. Only 3 cleaning stages were used in the testing and more maybe necessary.

4. Increased recoveries on a plant scale, are almost certain due to recirculation of cleaner products.

5. Grade would probably be improved as reagents could be added to cleaning stages to depress contaminants (possibility also for reverse flotation with depression of chalcopyrite by cyanide and flotation of contaminants).

TABLE 5

CLEANING OF COPPER CONCENTRATE[5]

	Grade %			Recovery %		
Product	Pb	Zn	Cu	Pb	Zn	Cu
CL Cu. Conc.	13.6	8.8	19.0	1.2	0.7	40.1
3rd CL Tails	15.0	14.6	8.5	0.3	0.13	4.0
2nd CL Tails	17.0	14.8	6.9	0.7	0.6	6.7
1st CL Tails	27.3	10.5	4.2	1.4	0.5	5.1
Cu Scav. Conc.	28.6	12.4	3.3	1.4	0.6	3.9
Cu Ro. Tails	5.0	5.7	0.09	95.0	97.4	40.2
Calc. Heads	5.2	5.7	0.22			

The main direction of testing from this point onwards, was to increase the lead recovery. As has been shown previously, see Table 3A, the results indicated that either sodium cyanide activated galena, which maybe considered unusual, or that the cyanide reacts with a metal ion that acts as a lead depressant and deactivates that ion. A few laboratory tests soon revealed that ferrous or ferric salts in excess would depress the galena, even if cyanide were present. It was, therefore, postulated that the depression mechanism was ferrous or ferric ion. This agreed well with the test results due to the known rapidity and permanence of the ferrous and cyanide ion reaction:

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$$Fe^{++} + 6\ CN^{-} \longrightarrow \left[Fe\ (CN)_6\right]^{\equiv}$$

In an effort to overcome this deleterious effect several approaches were tried. The two most successful being the addition of zinc sulphate to the grind, and the final soluction, increased collector additions.

TABLE 6

GALENA RECOVERY IMPROVEMENT[6]

Test Description	Grade % Pb	Grade % Cu	Recovery % Pb	Recovery % Cu
1) STD – Pb Ro. Conc.	57.0	0.41	80.1	18.7
Pb Scav. Conc.	13.7	0.41	10.8	10.4
Combined Pb Conc.	41.5		90.9	
2) STD + 2.5# Na_2SO_3 (no NaCN)				
Cu Conc.	13.8	6.47	4.4	52.8
Pb Ro. Conc.	53.3	0.31	30.8	4.7
Pb Scav. Conc.	44.6	0.15	45.1	4.0
Combined Pb Conc.	47.8		80.3	
3) As 2) + 2.0 # $ZnSO_4$				
Cu Conc.	15.1	7.2	3.7	52.0
Pb Ro. Conc.	52.7	0.19	73.6	7.9
Pb Scav. Conc.	16.8	0.22	14.2	5.5
Combined Pb Conc.	39.2		91.5	

Note: 1. The vastly improved lead recovery in (3) when compared with (2) and the only difference in techinque being the $ZnSO_4$ addition.

As a result of some completely unrelated testwork, the relationship between the fineness of grind and the recovery of copper into the lead rougher concentrate, was found.

..../8

TABLE 7

COPPER RECOVERY TO GRIND RELATIONSHIP[6]

% −200#	Product	Grade % Cu	Recovery % Cu
53.5	Pb Ro. Conc.	0.69	26.4
64.4	"	0.91	34.4
75.3	"	1.16	43.4
81.5	"	1.48	48.4
88.2	"	1.91	52.6

Note: 1. Dramatic increase in recovery

2. Improvement in grade

The final testing to date was a series of tests using increasing amounts of xanthate collector in an effort to increase lead recovery subsequent to the flotation of a copper concentrate in the sulphite system (see Table 8). Dissappointingly low copper recoveries were obtained in these but this can easily be understood when the grind was only 50% −200# (see Table 7).

TABLE 8

LEAD RECOVERY – #/TON COLLECTOR RELATIONSHIP

Test Conditions	#Z 11	Grade % Pb	Zn	Cu	Recovery % Pb	Zn	Cu
STD	0.06	36.7	31.4	0.71 ··	88.3	75.7	–
STD + Sulphite	0.06	36.9	32.4	5.67	49.0	83.7	29.1
"	0.10	43.3	35.5	7.00	81.4	78.4	38.0
"	0.14	39.7	35.4	5.30	86.5	76.5	32.1
"	0.18	36.9	35.4	5.20	87.5	75.8	31.3

·· Cu in Pb Ro. Conc.

Notes:

1. Lead and zinc combined concentrate grades in std and high xanthate/$SO_3^{=}$

2. Very similar lead and zinc recoveries and a low grade copper concentrate, with 3 x STD amount of collector.

PART II – DEVELOPMENT

At the existing level of testing this Part of the report will be based almost entirely on Part I, Table 5, and educated 'guesstimates'.

The flowsheet developed in Appendix I is extremely simple and wasteful of copper. It is thought that a few comments upon this flowsheet and the test upon which it is based would be appropriate at this time.

As has been demonstrated in Part I, copper recovery is very closely tied to the primary grind, by that is meant copper circuit feed fineness of grind, the finer the grind, the better the recovery. In the cleaning test mentioned above, the grind was only 50% –200# and the normal mill grind is presently 75% –200#. This should, therefore, not only improve the roughing recovery but should also improve the product grade (see Table 7).

It may prove to be necessary to use a reverse flotation techinque to upgrade the copper rougher concentrate, if large amounts of galena continue to float into the final cleaned concentrate. This would probably entail depression of the chalcopyrite with cyanide and flotation of gangu silicates and galena. Under high cyanide conditions it is possible that pyrite and sphalerite may not float and would, therefore, report with the copper concentrate. In view of this fact, it would then be necessary to use the first 2 cleaning stages in a normal manner, and only practice reverse flotation in the 3rd cleaning stage, to remove the galena.

The basic difficulty in laboratory development of a full scale copper flowsheet is the very small amount of copper rougher concentrate produced by one flotation test of 2000 grams of feed. If several

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roughing flotations are carried out in succession to provide sufficient sample for cleaning test, then there is no guarantee that the final rougher concentrate will react in the same fashion metallurgically, as the initial one, due to chances of oxidation upon standing.

A further advantage in the production of a copper concentrate is the knowledge that this would almost certainly improve the zinc 4th cleaner concentrate grade. At the present time, the zinc concentrate runs at approximately 0.5% Cu. Expressed as chalcopyrite this represents 1.5% of the total zinc concentrate. If the zinc circuit feed copper content were reduced by 50%, one would suppose that a 50% reduction in the copper content of the zinc concentrate would follow. Allowing the preceeding premise to be correct, then just reducing the copper content of the feed by 50% would upgrade the zinc by 0.75%.

Based upon 1972 zinc concentrate production and grade at current prices, an increase of $550,000 in pre income tax revenue would have been achieved by the 0.75% upgrading.

Total increase in revenue would therefore, be the copper concentrate value plus the increased zinc concentrate grade revenue. That is

$1,463,285 + $550,000

= $2,013,285/annum

before income tax.

CONCLUSIONS

There is little doubt that a copper concentrate can be profitably produced from the Anvil ore and in addition, increased revenue will be derived from improved zinc concentrate grades, due to the reduction in copper content.

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RECOMMENDATIONS

Further laboratory testing be carried out preferably utilizing a larger sized laboratory cell than at present available, due to small amounts of copper in feed, and cleaning tests carried out to determine optimum proceedures.

A plant test be carried out during a time when sodium sulphite is the subject of plant test, wherein the cyanide is completely shut off for a time and concentrate collected from the 'lead' roughing cells, to ascertain plant feasibility.

APPENDIX I

COPPER CIRCUIT FLOWSHEET

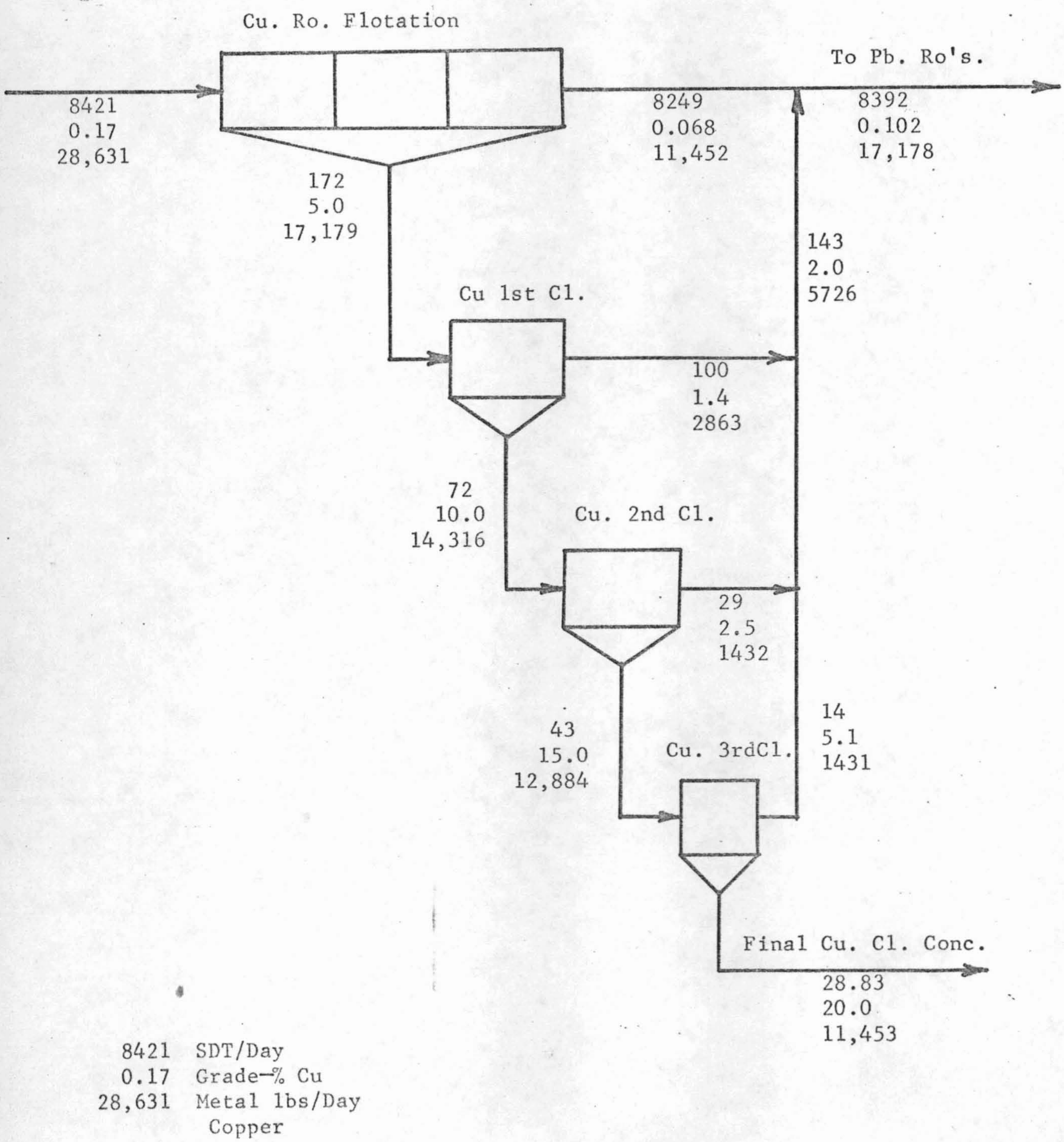

TABLE 5
PART I

.. Basis for flowsheet being the single laboratory cleaning test.

APPENDIX 11

GROSS CASH VALUE

ASSUMPTIONS

1. Copper price 35¢/lb as 20% grade concentrate.
2. Recovery is only 40%.
3. Feed tonnage is daily average for 1973.

Total Cu in Feed:

$$= 0.17 \times 20 \times 8421 \text{ lbs/day}$$

$$= \underline{11{,}453 \text{ lbs}}$$

$\frac{11{,}453}{20} = \frac{4}{80}$ $\frac{45{,}812}{500} = 22.5$ T

POWER

Total Value/Day:

$$= \frac{11{,}453 \times 35}{100} \ \$$$

$$= \$4009/\text{Day}$$

Gross Value/Year:

$$= 4009 \times 365$$

$$= \$1{,}463{,}285/\text{year}$$

APPENDIX III

CELL VOLUMES FOR COPPER CIRCUIT

Copper Roughing

8421 SDT/Day at 50% solids (S.G. 4.5)

100 cu. ft. of pulp contains 2.6 SDT solids.

∴ Total Daily Volume =

$$\frac{8421 \times 100}{2.6} \text{ cu ft}$$

$$= \underline{323{,}900 \text{ cu ft}}$$

∴ Volume/ Min.

$$= \frac{323{,}900}{24 \times 60} \text{ cu ft}$$

$$= \underline{225 \text{ cu ft}}$$

Volume necessary for 4 min retention =

$$225 \times 4 \text{ cu ft}$$

$$= \underline{\underline{900 \text{ cu ft}}}$$

Copper 1st Cleaner

172 SDT/Day, 20% solids (S.G. 4.5)

100 cu ft of pulp contains 0.74 SDT solids

∴ Daily Volume $= \frac{172 \times 100}{0.74}$ cu ft

$$= \underline{23{,}243 \text{ cu ft}}$$

.. Basis – See Appendix I.

Appendix III (Cont'd)

$\therefore$ Volume / Min. $= \dfrac{23,243}{24 \times 60}$ cu ft

$= \underline{16 \text{ cu ft./Min.}}$

Vol. required for 5 mins retension

$= 16 \times 5$

$= \underline{\underline{80 \text{ cu ft.}}}$

Copper 2nd Cleaner

72 SDT/Day, 15% solids, (S.G. 4.5)

100 cu ft. of pulp contains 0.53 SDT solids

$\therefore$ Daily Volume $= \dfrac{72 \times 100}{0.53}$ cu ft

$= \underline{13,585 \text{ cu ft}}$

$\therefore$ Vol / Min $= \dfrac{13,585}{24 \times 60}$ cu ft

$= \underline{9.43 \text{ cu ft/Min}}$

Vol required for 5 mins retention

$= 9.43 \times 5$

$= \underline{\underline{47.2 \text{ cu ft.}}}$

Copper 3rd Cleaner

43 SDT/Day 10% solids (S.G. 4.5)

100 cu ft. of pulp contains 0.34 SDT solids

$\therefore$ Daily Vol $= \dfrac{43 \times 100}{0.34}$ cu ft

$= \underline{12,647 \text{ cu ft.}}$

$\therefore$ Vol/Min $= \dfrac{12,647}{24 \times 60}$ cu ft

$= \underline{8.78 \text{ cu ft/Min}}$

$\therefore$ Vol required for 5 mins retention time

$= 8.78 \times 5$ cu ft

$= \underline{\underline{43.9 \text{ cu ft.}}}$

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