006511

To: T. Cloutier
From: W. Schieding
Date: 29/01/87
Subject: Headgrade/recovery relationships for lead & zinc.

Confirmation of the original estimates of these relationships has been requested for the Faro Zone 3 feasibility study. These trends were derived from experience, since no valid long-term historical database was available in September, 1986. Since then, 4 months of daily data has become available, which is less disturbed by start-up irregularities. As a result, statistical confirmation of these trends is now possible.

In addition 1981 CAMC monthly data has been used to confirm the trends on a historical basis - earlier data is invalidated by the coarser grind, lower tonnage and simpler ore types prior to the last expansion or by the upset period after the expansion itself. 1982 data is unsuitable by virtue of the large proportion of oxide stockpile being treated.

It should be noted that, while knowledge of these trends could affect the economics of certain sections of the orebody, they will have very little effect on the overall picture, since lower or higher than expected recoveries at low grades will be matched by higher or lower than expected performance at high grades - especially for a nearly linear relationship. What is critical is the mean performance to be expected i.e. the base recovery at the average head grade for a given ore type. This is something that can only be derived by experience with a relatively predictable orebody - and we are short in experience on this orebody and the orebody is short on predictability. If asked to predict lead recoveries from 2E ore on January 13, 63% would have been a reasonable estimate. Two days later, that estimate would realistically be 78%, as the correct treatment route is discovered. Constant review of recoveries to be expected from various oretypes is ~~the~~ required.

Despite the above, four different methods for obtaining the headgrade/recovery relationships are discussed below. They are all based on varying recovery to a constant concentrate grade, which is more realistic given marketing constraints.

(i) <u>25% science/25% common sense/50% experience</u>.

Using experience gained at other operations, and knowing that flotation is a first order rate process, recovery is expected to increase with headgrade when producing a concentrate of constant grade. As the headgrade increases, the concentration ratio decreases, rapidly at first, then more slowly. The ease of removal of valuable mineral (i.e. recovery) will be inversely proportional to the concentration ratio. This leads to a trend which is well-described by multiplication of a base recovery by the log of the headgrade:

$$\text{Recovery} = \underset{\text{(at mean headgrade)}}{\text{Base recovery}} \times (a \times \ln(\text{headgrade}) + K)$$

The second term of the R.H.S. of the equation must equal 1.0 at the mean head grade. By taking logs of the headgrade and matching them to tailings grades expected by experience, factors 'a' and 'K' can then be selected to give the desired curvature and are fine-tuned as historical data is collected.

(ii) <u>50% 'constant tail'/50% 'constant recovery'</u>

Operating plants invariably fall within these two extremes. The headgrade/recovery relationship for a constant tail is defined by the two-product formula (see Appendix I). Once 'c' (concentrate grade) and 't' (tails grade) are fixed, curves can be drawn for lead and zinc. The 'constant recovery' extreme is a straight line on the headgrade/recovery graph. If the mean of the two expressions is chosen as the most likely curve for future Zone 3 ore, curves can be drawn as shown in the graphs. The results are in reasonable agreement with the curves from method (i), if compared at the same base level recovery.

(iii) 1981 CAMC monthly data.

Linear regression of these few data points give the following relationships:

Lead : Recovery = 56·29 + (6·83 x headgrade (%))
Zinc : Recovery = 50·69 + (5.02 x headgrade (%))

Correlation coefficients were 0·82 and 0·66 for lead and zinc respectively, giving confidence levels in the > 95% range. These lines are also plotted on the graphs. As can be expected from a linear approximation of a curve, the gradients are less than those of the curves at low head grades, but exceed those of the curves at high head grades. This leads, of cours to unrealistic numbers at very high grades e.g. 100% lead recovery at a 6·4 % lead head and 100% zinc recovery at a 9·8 % zinc head.

This makes this kind of relationship undesirable for calcula recovery to be expected from smaller zones of high or low grade ore far from the mean headgrades for the orebody. Simple regression also cannot correct for the effect of variations in concentrate grade on the recoveries used in the data base. These are subject to the grade/recovery relationship for the ore (stronger than the headgrade/recovery relationship). This factor, and others which are quantifiable, can be purged from the database by multilinear variable regression analysis - which comes later.

(iv) 1986/1987 Curragh Resources daily data (Oct - Jan).

This data was treated as with the 1981 data, except that there were many more data points (over 100 in all). Oxide ore was removed from the analysis, because of its atypical response and because it should not feature in future Zone 3 ore supply. Because of operational problems and frequent ore changes, the relationships obtained did not have very high correlation coefficients. In terms of degree of confidence in the existence of a trend, however, the large number of data points ensures that the 't'-test is positive at a higher confidence level (> 99%).

Sorting of the data between ore types was not necessary for the zinc trend, but the raw lead data gave no trend whatsoever when treated in bulk (correlation coefficient < 0.05). After the data was batched into successive ore type campaigns of 6 - 15 days duration, individual trends were visible (see Appendix II) for most ore/time periods, but were totally destroyed when combined with periods with very small, negative correlation coefficients. These periods were removed from the analysis and the individual trends composited to obtain overall trends as follows:

Lead : Recovery = 56.29 + (6.83 x headgrade (%))

Zinc : Recovery = 57.80 + (4.35 x headgrade (%))

These trends are also plotted on the graphs. Their gradients agree well with CAMC trends and are good approximations to the curves developed in sections (i) and (ii), but only in the low to medium grade ranges. This is understandable in that they were developed with data which fell only in those ranges - lead grades below 3.8% and zinc grades below 5.5%.

In conclusion, the logarithmic trends originally developed appear to fit the statistical data quite well, and offer greater accuracy at high and low grade extremes. They are also in fair agreement with the '50% constant tail/50% constant recovery' trend which works well at two other base metal concentrators that I'm familiar with. However, their accuracy is of only minor importance compared with the estimates for the base recovery for each ore type at the mean headgrade. I recommend that some sensitivity analysis be performed to assess the impact of ± 3% changes in base recovery for each ore type. If the overall outcome of the feasibility study is significantly affected, more work will have to be done to estimate future performance more accurately e.g. comparison of laboratory versus plant data and generating average laboratory response curves by ore type, which can then be corrected for closed circuit operation. This should be supported by a testwork program on the diamond drill core currently being assayed and typed for ore reserve estimation.

Appendix I: 'Constan tail' and 'constant recovery' trends

Two-product formula $R = 100 \times \frac{c}{f} \frac{(f-t)}{(c-t)}$

where R = recove (%), c = concentrate grade (%), f = feed grade (%) and t = tails grade (%).
For lead, assume c = 60%, f = variable, t = 0.7%
For zinc, assume c = 50%, f = variable, t = 0.7%
and constant 4.5% zinc losses to the lead circuit
Base lead head = 3.0, base zinc head = 4.5%.

Lead Head (%)	Lead Constant tail recovery (%)	Lead Constant recovery (%)	Lead 50% CTR/ 50% CR	Zinc Head (%)	Zinc Constant tail recovery (%)	Zinc Constant recovery (%)	Zinc 50% CTR/ 50% CR
				2.5	69.74	81.79	75.77
1.5	53.96	77.57	65.77	3.0	74.26	81.79	78.03
2.0	65.77	77.57	71.67	3.5	77.48	81.79	79.64
2.5	72.85	77.57	75.21	4.0	79.91	81.79	80.74
3.0	77.57	77.57	77.57	4.5	81.79	81.79	81.79
3.5	80.94	77.57	79.26	5.0	83.30	81.79	82.55
4.0	83.47	77.57	80.52	5.5	84.53	81.79	83.16
4.5	85.44	77.57	81.51	6.0	85.56	81.79	83.68
				6.5	86.43	81.79	84.11

Appendix II - Curragh Resources October 1986 - January 1987

With oxide ore excluded and no sorting of data by ore types, the following trends are obtained:

Pb recovery = 74.55 - (0.43 × headgrade (%)) (Corr. coeff = -0.03)
Zn recovery = 57.80 + (4.3 × headgrade (%)) (Corr. coeff = 0.45)

Given the number of data points involved, the zinc trend is satisfactory as is. However the lead data will have to be sorted by ore type:

Month	Ore type	Intercept	Gradient	Correlation coefficient
October, 1986	2BG	58.45	3.44	0.43
November, 1986	2EF/EH	48.90	8.42	0.42
	2EG/BCD	18.85	16.99	0.08 *
	2EF/EG	51.25	7.75	0.42
December, 1986	2EF/EH	50.24	8.41	0.68
January, 1987	2EG/2G	62.64	3.24	0.22 *
	2A	33.21	-0.08	-0.007 *

The data from three of the sets above have low correlation coefficients, due to circuit problems trending oppositely to headgrade, lower than target concentrate grades etc.
With this data removed, the following average trend is obtained:

Pb recovery = 52.21 + (7.01 × headgrade (%)) Corr. coeff ≃ 0.5