003466

DISCREPANCY -
MINE AND MILL
JAN/FEB 1991

D. Tenney

C U R R A G H   R E S O U R C E S   I N C.

INTER-OFFICE MEMO

DATE: February 7, 1991

TO: Jim Moore, General Manager

FROM: Gordon Wilson, Chief Metallurgist and
√Dave Tenney, Chief Geologist

SUBJECT: DISCREPANCY - MINE AND MILL

DISCREPANCY - MINE AND MILL JANUARY/FEBRUARY 1991

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1.0 BACKGROUND

On average, the mill head grade - Lead Rougher Concentrate is reported to be 13% lower than the grade predicted from blasthole data. The usual "accepted" discrepancy is around 5%. Since mineral content has a direct impact on expected concentrate production, and revenues, an explanation was sought.

Mining and Metallurgical Personnel met twice as a team, with some graphs and statistics to try to isolate the cause. A problem analysis procedure was followed. Conclusions to the problem January/February are identified, and some clues to the more "usual" difference of 5% are highlighted.

This report is therefore divided into 3 areas:

- The problem analysis procedure
- The Metallurgical graphs and conclusions
- the Mining/Geological graphs and conclusions

2.0 CONCLUSIONS - MAIN

The January/February 13% discrepancy problem is caused by dilution - probably at the East Phase of Faro Pit. A test verifying this will be carried out shortly. Measurements within the mill over 1990 show average error Pb = 2.7% and Zn = 1.4% and cannot explain the normal mill vs. mine 5% discrepancy. Other conclusions, Geological and Metallurgical are upfront in Section 6.0.

The problem analysis procedure highlighted dilution for Lead and Zinc mostly trend together. The assays for Lead and Zinc, trend independently. Four different sampling points confirm this.

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3.0 PROBLEM ANALYSIS DESCRIPTION

The technique used is called "Kepner Tregoe".

(Other Kepner Tregoe tools are Decision Analysis, Potential Problem Analysis, Situation Analysis, Performance System Analysis. All use techniques to keep the logic visible. However, Problem Analysis is the most difficult of the tools, and the most difficult for a non-team member to follow).

Steps are:

a. defining the problem in more detail e.g. both Pb and Zn; Pb only; Zn only; change in waste % Pb content.

b. defining what the problem "is not". A difficult concept and essential step e.g. not Pb alone.

c. developing distinctions between a and b. A large list of distinctions is possible.

d. asking whether the distinctions suggest any changes.

e. developing a list of possible causes from c and d.

f. testing this list against the original problem definition (and the definition of problem "is not"). The list of possible causes is greatly reduced by this step.

g. developing a test/tests to verify which of them caused the problem.

The technique is expected to prevent the team members from "jumping to conclusions" or "jumping to action". With graphs available to Geology and Metallurgy. the steps took 9 hours divided into 2 sessions. An example of a blank standard format sheet is attached. (It is a modification G. Wilson used to teach usage to Flotation Operators. This analysis followed these steps.)

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3.1 Analysis of 13% Discrepancy

STATEMENT OF PROBLEM

Mill Head grade should be 5% lower than blasthole grade
Mill Head grade is 13% lower than blasthole grade

SPECIFIC DETAILS

	Is the Problem	Is Not the Problem
What	Orebody Loss of grade Pb and Zn Blasthole Sampling Mill Feed Assays Apparent Dilution	No logical alternative Zinc only/Lead only Tailings Samples Concentrate Samples Tonnage Flotation Recovery Increase in Grades (Fe and S.G. not known)
Where	Pb Rougher Feed Sampler Blasthole Samples	Tailings Sampler Concentrate Sampler
When First Observed	January 1st. Less Pb dilution 05-25 Jan.	December
When Since Observed	Continuous 24 hours per day Dilution 05-25 Jan.	Intermittent
When in the Operating Cycle	Pb + Zn trend together (Note: Graph details useful here in defining the problem specific details)	Independent
Extent	-13% Pb +/- 15% Zn +/- 11% Nearly always negative	- 5% Not often positive

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Distinctions between "problem is" column and "problem is not" column	Do these distinctions suggest any recent changes
Different sample points	None
Pb and Zn concentration Pb/Zn	Little relative change (detailed on graphs)
Pb and Zn grain size	Not known
Calculation methods	No change
Timing of sampling	No change
Lead and Zinc nugget effect	Changed with changing ore types. Graphs studied
Assays change independently	No change
Dilution trends together	No change
Blasthole results calculated in 5 day blocks	No change
Pb Ro Feed sampler & blasthole both manual	No change. Pb Ro Feed observed
Mining areas and blend	East and South Phase Vangorda
Temperature	Yes fluctuated. Not recorded for this investigation
Viscosity	
Working conditions including daylight	Varies with temperature and month. December also dark
When dilution "positive" only 1 or 2 days	

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TESTING FOR CAUSE

The list of distinctions is taken one by one back through to "specific details" of the problem. Unless it answers fully all of the "problem is" and "problem is not" it drops out as a possible cause of the change. As a consequence the list was greatly reduced to:

Dilution
Nugget Effect

Which Fits Common Sense:-

It was agreed that dilution was most likely. The Nugget Effect was likely to be present in, and change in each orebody, but was less likely to explain the jump to 13%.

Verification:-

The steps recommended by the team were a 3 - 5 day test of 100% Vangorda with dilution effects to be monitored over that period.

Note: In following the problem analysis procedure, the team realized more useful information would have been available should dry solids S.G. be measured at the mill; waste assays were available, and plots of Fe were available. Geological work continued separately to isolate the specific area of the orebody.

4.0 METALLURGICAL INFORMATION

The discrepancy in grades was highlighted early January +/- 8th, late January +/- 27th, and in February. Consequently, statistics were collected over these early periods. Dilution was isolated as a cause in January, and no attempt was made at upgrading the metallurgical statistics gathered for this latest, more rigorous, analysis of continued problems. Graphs of geological and metallurgical information proved to be invaluable tools in the problem analysis.

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4.1 HEAD GRADE SAMPLING

This is an obvious place to start investigating head grade discrepancies. Simple statistics are tabled in "Met Table 1" attached, taken from the following sample points:

Sample	Comment
OSA	X-ray weighted average. Sample is somewhat biased. Calibration is way out of date.
Pb Rougher Feed	The accounting sample, taken from the OSA primary and secondary sampling system. Tertiary Cyclone Overflow Hand cut full stream. Composited over shift. Visually reasonable. Sample integrity depends on the operator.
Secondary Cyclone Overflow	Hand cut grab sample from part of stream only. Intermittent. Visually poor technique.
New Flotation Feed Sample	Automatic. Installed after start of critical period. Needs minor modifications. No statistics collected/used in this analysis.

Statistics Summarized 1/1/91 - 26/1/91

Sampler	Pb Assay % Mean	Pb Assay % Standard Deviation	Zinc Assay % Mean	Zinc Assay % Standard Deviation	Rank Pb	Rank Zn
OSA	2.99	0.19	4.63	0.44	3	3
Pb Ro	2.78	0.31	4.56	0.31	4	4
Tert.	3.14	0.33	4.84	0.33	2	1
Sec.	3.18	0.31	4.80	0.43	1	2

The rank number allocated is an attempt to simplify the statistics. i.e. Rank 1 is the most favourable "for the Mining Department". Rank 4 is the least favourable "for the Mining Department".

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4.1.1 CONCLUSIONS - HEAD GRADE SAMPLERS

a. The OSA was expected to be the odd result as the calibration is out of date. (It is being worked on, as is upgrading sampling to the OSA, as part of the Mill Distributed Control System Project).

b. The OSA standard deviations are at the extremes of the figures calculated.

c. Standard deviations of the others are generally close.

d. The Pb Ro Feed Sample showed the lowest average Pb and Zn.

e. The ranks suggest secondary and tertiary sampling are close.

f. Discounting the OSA, the average assays over the period were %Pb = 3.03, %Zn = 4.73.

g. In the absence of other information, the tertiary cyclone would be the best sample to use. %Pb = 3.16, %Zn = 4.84. Reason: It is the median. It is not the average. Use the median. This is confirmed in any statistics textbook.

h. Added sample points and information add to the confusion. Four samples add to the data, rather than clarifying the data (Now 5 samples with the commissioning of the new flotation feed sample in mid January).

i. Use of one good sample point is best (with a contingency ready on mechanical failure).

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4.2 HEAD GRADE GRAPHS

Information on Met Table 1 Head Grades is presented on 2 graphs as attached, Section 8.0. The graphs add to the information.

Met Graph No.	Assay	Type
1	Pb	Cusum
2	Zn	Cusum

With so many sample points, a normal graph of assay against time, would contain too much information. Instead a graph called a Cusum was used. This type is useful for following trends, as can be seen. Cusum = cumulative sum of the difference. A simple mathematical device = $\sum(A-B)$ where A is the individual assay, and B is the average of the assays taken. When the Cusum trends down, the assays are below average. When the Cusum trends up, the assays are above average. The Cusum is especially valuable in trying to isolate turning points, and periods of correlation.

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4.2.1 CONCLUSION - HEAD GRADE GRAPHS

a. Lead is trending below average until the middle of the month.

b. Lead is trending above average from the middle of the month.

c. All four assay streams follow the same pattern. The samplers are successfully picking up the major lead trends.

d. The OSA shows less variation (confirmed by standard deviation).

e. The zinc trends are independent of the lead trends.

f. Zinc falls early in the month, but rises in a time period where the lead remains constant.

g. Zinc assays are below average in the last 6 days, lead assays are above average.

h. All four assay streams follow the same pattern on zinc. The samplers are successfully picking up the major zinc trends.

i. The samplers at the mill feeds are picking up the trends. "Housekeeping" and investigation are required to choose the best sampler.

j. These 2 graphs have different turning points. The graphs for discrepancies Pb and Zn (geology graphs) show the discrepancies turn at the same time.

It is unlikely that head grade sampling or changes in head grade sampling at the mill causes the discrepancy. (Verified by problem analysis procedures).

4.3 CONCENTRATE PRODUCTION

This is a less obvious place to continue investigating. However, the information attached adds significantly to the discrepancy problem analysis. Met Table 2 lists monthly discrepancies within the plant. Information on this Table is also plotted as follows:

Met Graph	Assay	Type
3	Pb	Time plot. A "normal" graph of the result against time.
4	Pb	Cusum. The same information, translated to show trends.
5	Zn	Time plot. A "normal" graph of the result against time.
6	Zn	Cusum. The same information translated to show trends.

The graphs actually show the concentrate produced compared to the concentrate predicted from the head grades (Pb Rougher Feed). The figure is calculated each month, and is plotted monthly over 1990. It is based on the simple mass balance formula that states:

Minerals entering the plant = minerals leaving plant as concentrate
+ minerals leaving plant as tailings

It is important to note that the graphs indicate how well the mill is measuring itself (heads, concentrates, tailings, tonnage). Skagway stock changes, where applicable, have been added back to show the best estimate of actual production.

4.3.1 CONCLUSIONS - CONCENTRATE PRODUCTION

a. Pb is almost always positive, average 415.5 tonnes. i.e. more concentrate is produced than is predicted from head grades and recoveries.

b. Pb is almost always within 5%. There are 2 major exceptions.

c. Pb is frequently within 3%.

d. The large -ve in September is followed by a large + ve in October. It reflects poor stock estimates only.

e. The Pb positive 415.5 tonnes average equates to 2.7% for the year.

f. Ignoring the 2 "flyers" September and October, standard error = 2.03%.

g. Measurements within the plant probably cannot explain the "normal" 5% difference mining vs. plant.

h. Measurements within the plant probably cannot explain the recent 13% difference mining vs. plant unless there were some recent significant changes.

i. A Pb Concentrate actual tonnage 2.7% higher than predicted means that the mill is underdeclaring head grades (Pb) by a similar proportion, or underdeclaring Pb recovery by a similar proportion. More concentrate is being produced than predicted.

   The more likely is underdeclaring recovery. Reason: - Mine and Mill grades are assayed by similar methods. - Tailings samples are at low grades and (within assay lab) dilution effect or physical effects are more likely.

j. Pb Cusum (Met Graph 4) shows no particular trend. The variation in Pb is almost random (a welcome conclusion).

k. Zn is both +ve and -ve.

l. Zn is almost always within 5%.

m. The large -ve values are followed by large +ve values. This has occurred 3 times (and occurred on Pb once). These reflect poor stock estimates only. This is a significant conclusion. The plant personnel are pressuring themselves when a -ve is reported. The change the following months indicates the true position. Metallurgical accounting is provided good self checking.

n. Zinc graph 5 seems to indicate the average is 0 discrepancy.

o. The actual calculated average is +411.8 tonnes. This equates to 1.4%. Standard error of estimate, as % = 2.8%.

p. Measurements within the plant cannot explain the "normal" 5% difference mining vs plant. Measurements within the plant probably cannot explain the recent 13% difference mining vs plant unless there were some recent significant changes.

q. A Zn Concentrate actual tonnage 1.4% higher than predicted means that the mill is underdeclaring head grades (Zn) by a similar proportion, or underdeclaring Zn recovery by a similar proportion.

The more likely is underdeclaring recovery. Reason: - Mine and mill grades are assayed by similar methods. - Tailings samples are at low grades and (within Assay Lab) dilution effects or physical effects ar more likely.

r. The actual recovery values are important to the Mill. Of more importance however, would be how to increase the recovery.

s. Zn Cusum Met Graph 6 does show a trend - below average to August, and above average since. The trend roughly equates to 1.7% above average in the recent months. No reason for this could be found at this level of investigation. It is not important for this investigation. It would only become important if the trend continues.

t. Relating these graphs to the Ro Feed Sample would indicate that this sample is a fairly good estimate of the incoming head grade. At worst it is low on Pb by an average proportion of 2.7%. At worst it is low on Zn by an average proportion of 1.4%.

u. Met Graphs 3 and 5 can also be called quality control graphs. Quality control graphs can be used as a powerful tool. (ref. Deming, Japanese, Stat. Textbooks). One danger however, is in over-reaction to changes. The action/warning limits must be properly set. It is suggested that a 3 to 5% variance on expected concentrate production is acceptable at this point in time.

v. The best mill head grade sample to use for future accounting purposes cannot be predicted from the work so far undertaken. The Pb Rougher Feed is <u>not</u> a poor sample. It is likely that the New Flotation Feed Sample can be used as a substitute. It presently requires work on the knife cutters, and downpipe, to minimize potential bias in these areas. Proper Courier calibration, and primary sampling will be the ideal combination of accounting sample and contingency sample.

5.0 Geology/Mining

Two potentially major causes of the discrepancy between mill head grade measurements at the lead rougher feed and mill head grades estimated from the blasthole database have been identified as likely:

- External dilution in the pits.
- Nugget effect changes in different orebodies and within the same orebody which ultimately lead to errors in calculations.

5.1 1. External Dilution

If external dilution is the only source of the discrepancy between blasthole grade and mill head grade then lead and zinc grades should be affected equally. That this is substantially correct is illustrated by Graphs A (Monthly cumulative sum apparent dilution for lead and zinc, 1989,1990) and B (Daily cumulative sum apparent dilution lead and zinc, December 1990 and January 1991).

The apparent dilution is calculated as follows:

$$\text{Pb apparent dilution (\%)} = \frac{\text{\% Pb Blasthole calc.} - \text{\% pb in Mill Heads}}{\text{\% Pb in Mill Heads}} * 100$$

which in essence reflects the difference between blasthole predicted mill head grade and actual mill head grade measured at the lead rougher feed. The formula has the same form for zinc. However, as the attached graphs show, the calculated apparent dilutions are not the same, and some other cause must be found to explain this part of the discrepancy (See 2 nugget effect.)

Internal dilution, which is included <u>within</u> the ore blast, is accounted for in blasthole assaying. No effort is made to predict external dilution when forecasting mill feed grade from blasthole grades. Historically in the Faro Pit, the ore dig packets which contained most of the mill feed were a full bench in height and of significant lateral dimensions. This situation tended to mask the small amount of external dilution present limiting it to around 5%. Current mining, however, particularly in the East Phase of the Faro Pit, has been largely in long narrow (One to three blastholes wide) lenses of ore, which might be expected to lead to high rates of external dilution: possibly from 14% to 42% as indicated in the table below. A theoretical estimate of dilution can be made for varying widths of ore dig packet using the attached table. Assumptions:

1. broken/blasted rock at dig face slopes at 63°
2. ore zone is vertical
3. density waste = density ore
4. all waste delimited by dig slope is mucked as ore.

Width of Ore Blast Feet	# of Blastholes (Acess Width)	Volume Ore Cubic Feet	Volume Waste Cubic Feet	Diln. %
24	1	480	200	42
48	2	960	200	21
72	3	1440	200	14
96	4	1920	200	10
120	5	2400	200	8
144	6	2880	200	7
168	7	3360	200	5

Owing to the assumptions the above table represents a worse case scenario.

5.2 2. Nugget Effect

Some mechanism other than external dilution must be found to explain why blasthole lead grades are in general more overstated relative to mill head lead grades than blasthole zinc grades are relative mill head zinc grades. Nugget effect can explain this difference from both the theoretical and observational viewpoints. Semi variograms for lead and zinc at Vangorda are attached showing what appear to be very small nugget effects (Y axis intercept). By contrast the nugget effect at Faro is significant, according to Dagbert (p iii) explaining up to 35% of sample variance. (Rock types 40-70). This suggests that ore sorting and the calculation of grade in dig packets may be prone to greater error at Faro than Vangorda.

5.3 Graphs and Details

Cumulative Sum Apparent Dilution for Lead, Zinc (For years 1989/90 - by Month)

This cumulative sum, as are all those that follow, was plotted using the formula:

Plotted value = (A-B)

where A = value and B = mean of values and includes only the month plotted and those prior to it.

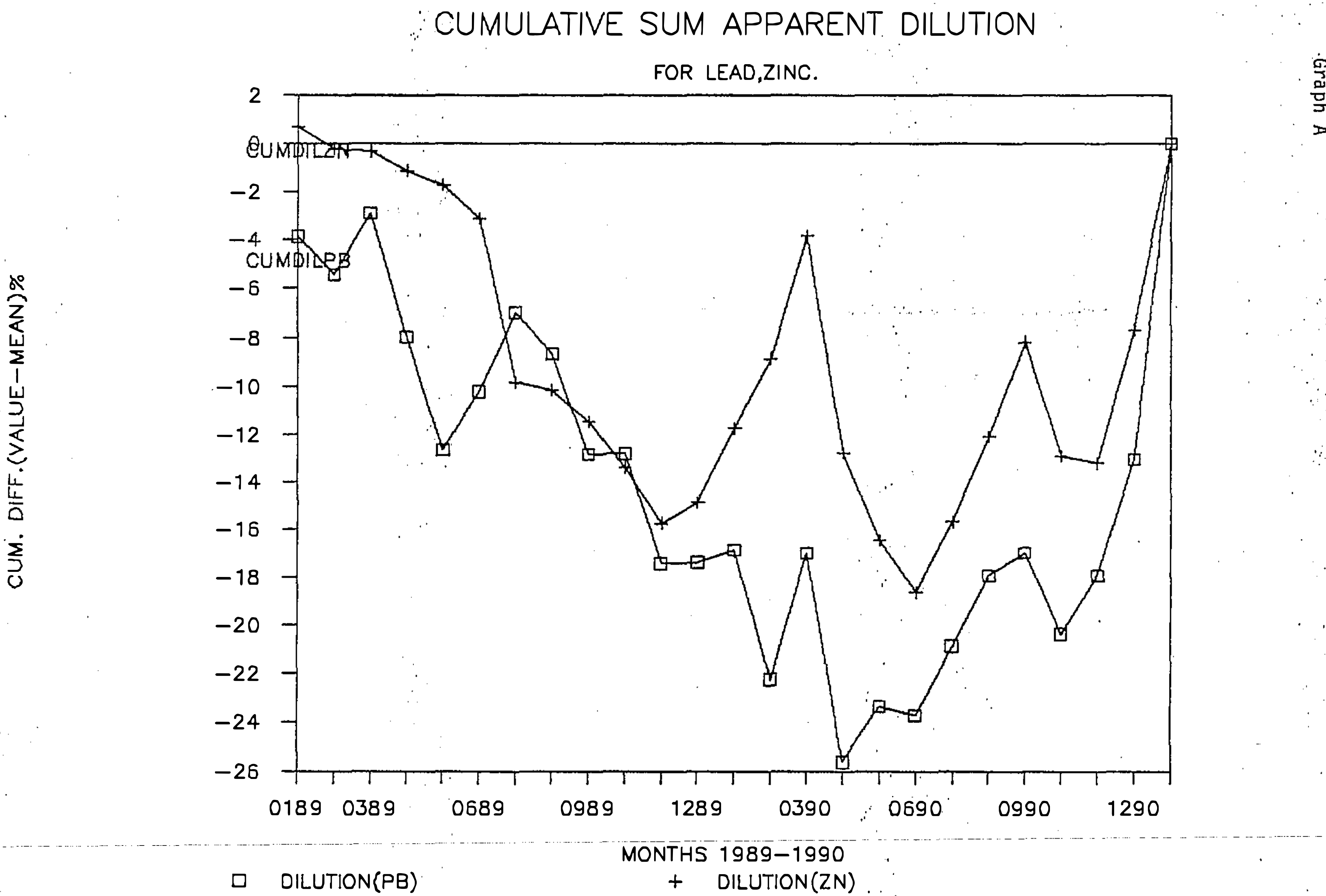
In this case the values represent the relationship between blasthole predicted monthly mill head grades and the actual monthly mill head grade measured at the lead rougher feed in the mill. The cumulative sums are plotted using a monthly apparent external dilution calculated from the blasthole grades (BG), which contains no allowance for external dilution, and the mill head grade (MHG), which does contain external dilution. The following formula was used:

$$\text{Apparent external grade dilution} = \frac{BG - MHG * 100}{MHG}$$

Note: a) Dilution is considered to have zero grade.

b) All references to dilution which follow are to external grade dilution calculated as above.

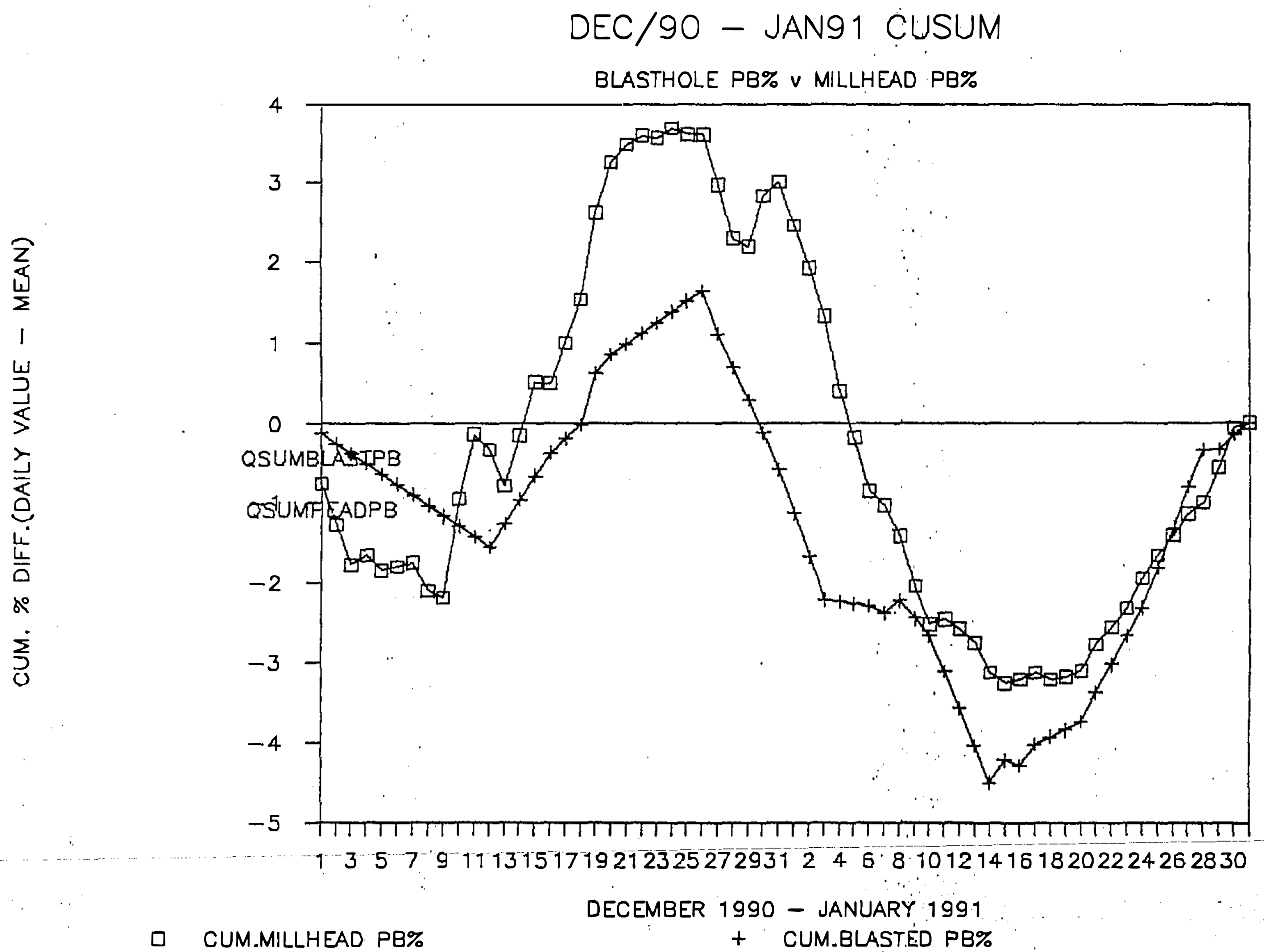
1. Lead and zinc values show a consistent trend most of the time. Over the two year period illustrated.
2. Apparent dilution for lead is generally greater than for zinc (Note a) there are larger positive mill metallurgical balance adjustments for lead than for zinc b) nugget effect for lead in the Faro orebody is higher than for zinc.)
3. There is a common factor affecting apparent dilution for both lead and zinc, giving a common trend in values, but a second factor causing the values (apparent dilution) to be different.



CUMULATIVE SUM APPARENT DILUTION
FOR LEAD,ZINC.
CUM. DIFF.(VALUE−MEAN)%
2
0
−2
−4
−6
−8
−10
−12
−14
−16
−18
−20
−22
−24
−26
CUMDILZN
CUMDILPB
0189
0389
0689
0989
1289
0390
0690
0990
1290
MONTHS 1989−1990
□ DILUTION(PB)
+ DILUTION(ZN)
Graph A

December/90 - January/91 Cusum Blasthole PB% -vs- Mill Head PB%

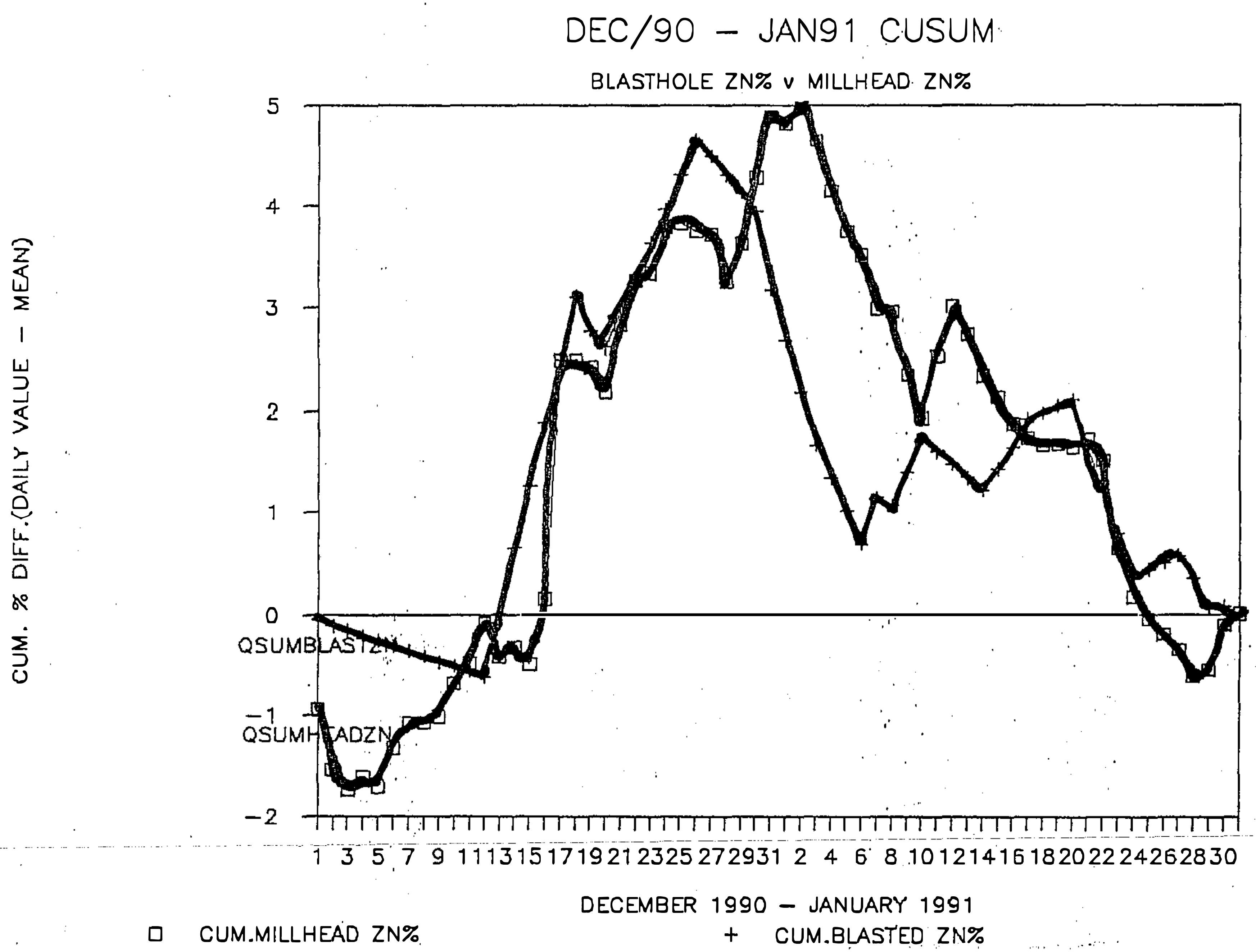
1. Trends for blasthole predicted lead mill head grade and assayed lead mill head grades during Dec/90 and Jan/91 plotted as a cumulative sum.
2. Difference between two curves is directly related to apparent dilution (and part of the difference is no doubt related to actual external dilution).
3. "Apparent Dilution" is used in the following pages to express the difference between blasthole predicted mill head grades and mill head grades determined by assay of samples of lead rougher feed.



DEC/90 – JAN91 CUSUM
BLASTHOLE PB% v MILLHEAD PB%
CUM. % DIFF.(DAILY VALUE – MEAN)
4
3
2
1
0
−2
−3
−4
−5
QSUMBLASTPB
QSUMHEADPB
1 3 5 7 9 11 13 15 17 19 21 23 25 27 29 31 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30
DECEMBER 1990 – JANUARY 1991
□ CUM.MILLHEAD PB%
+ CUM.BLASTED PB%

Dec/90 - Jan/91 Cusum Blasthole ZN % -vs- Mill Head Zn%

Same comments as for lead (see previous page)



DEC/90 - JAN91 CUSUM
BLASTHOLE ZN% v MILLHEAD ZN%
CUM. % DIFF.(DAILY VALUE - MEAN)
5
4
3
2
1
0
-1
-2
QSUMBLASTZN
QSUMHEADZN
1 3 5 7 9 11 13 15 17 19 21 23 25 27 29 31 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30
DECEMBER 1990 - JANUARY 1991
□ CUM.MILLHEAD ZN%
+ CUM.BLASTED ZN%

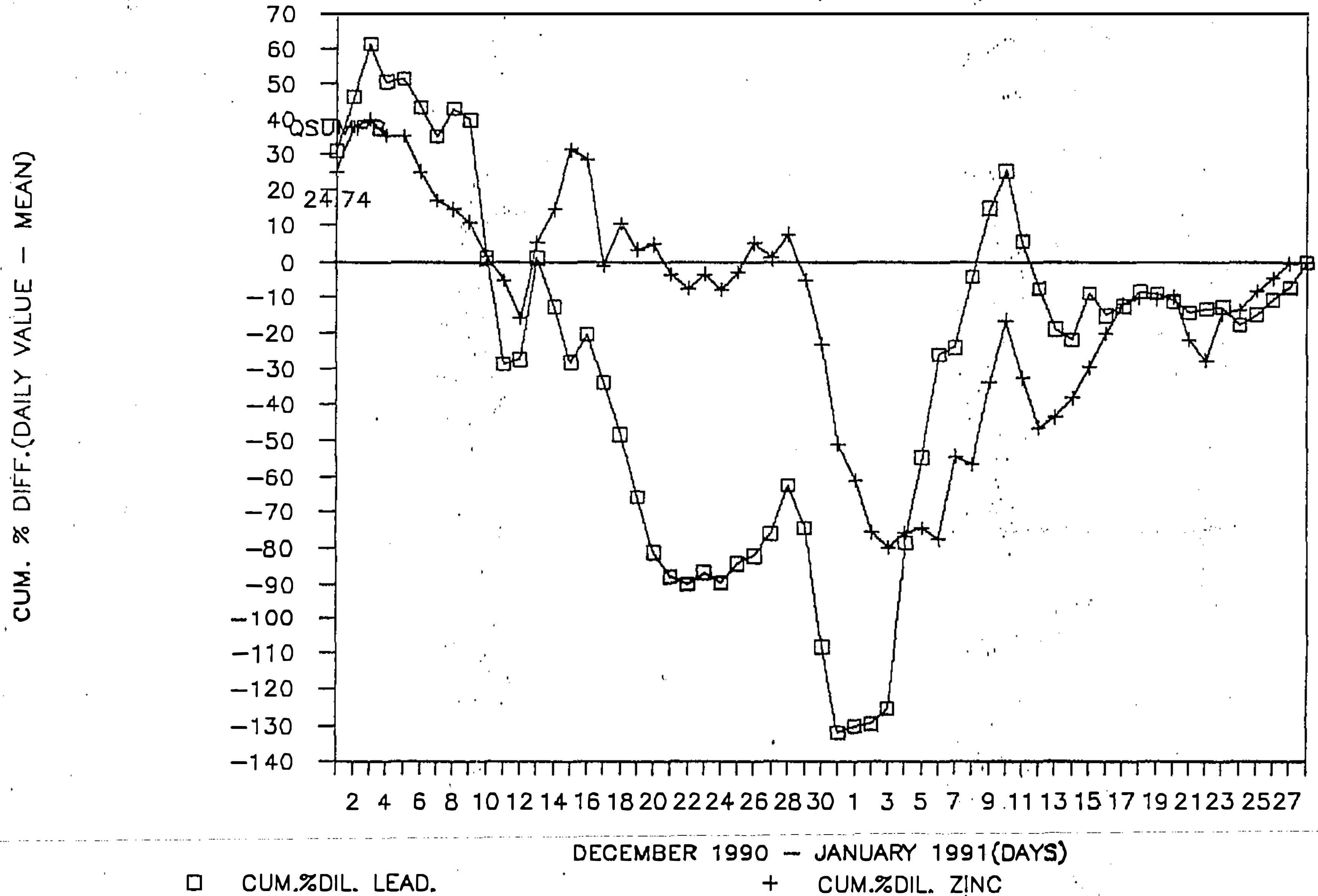
Cumulative apparent Dilution for Pb/Zn Mill Heads Dec/90 and Jan/91

This graph shows two cumulative sums for apparent dilution of lead grade and zinc grade plotted as previously. The time span covered is December 1990 and January 1991, when at times the mill head grade and the blasthole predicted mill head grade were significantly different.

1. As over the two year period described before, the trends for the lead and zinc cumulative sums are generally the same, and their magnitudes different.
2. Conclusions as for the two year period. - two "causes" are in operation, one affecting both lead and zinc apparent grade dilution, and the other affecting primarily one of them.
3. Dilution would affect both lead and zinc grade apparent dilutions and account for the common trend.
4. Overestimation of blasthole block lead grades (or underestimation of zinc grades) would explain the differences.

CUMULATIVE APPARENT DILUTION FOR PB,ZN

MILL HEADS DEC/90 AND JAN/91



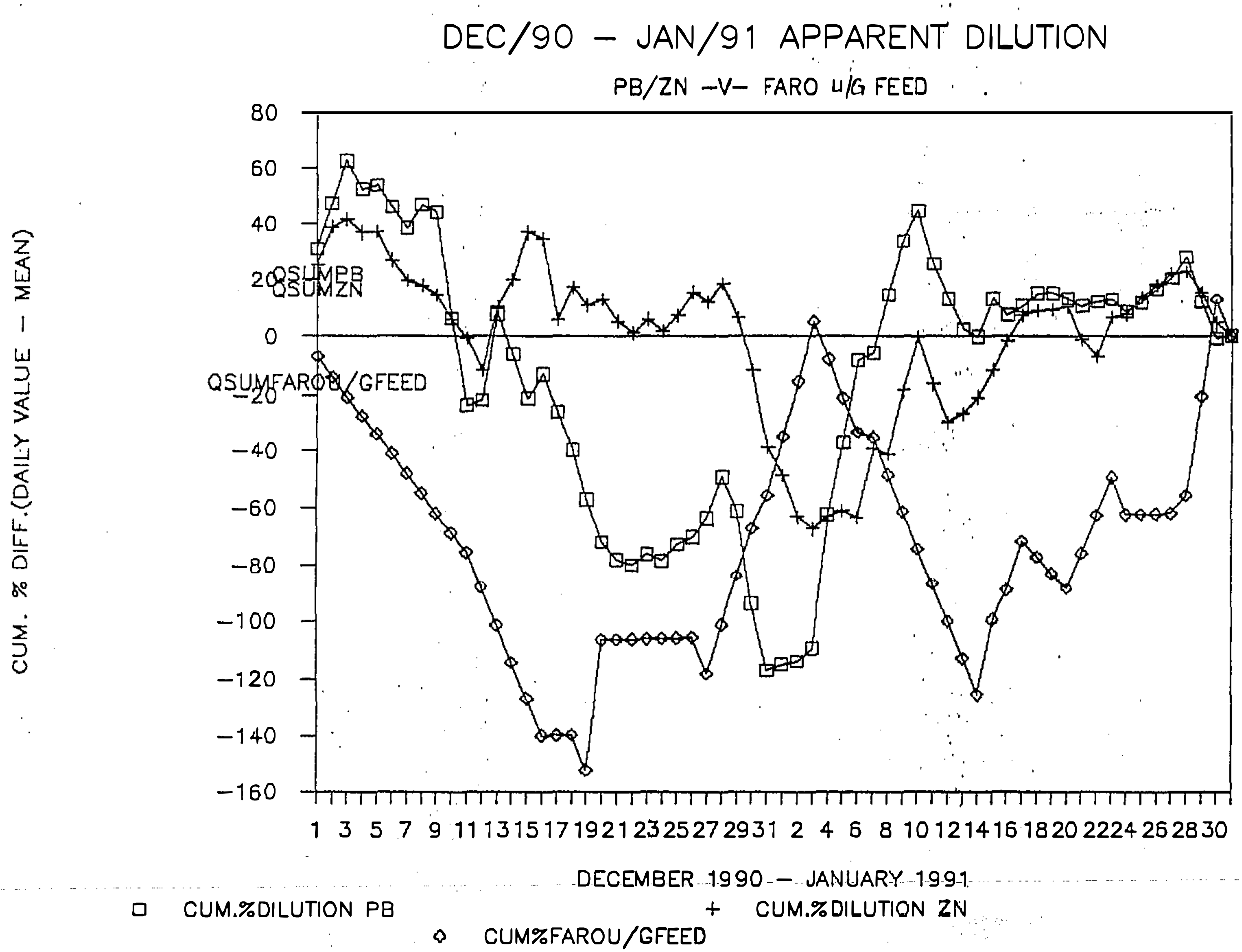
Graph B

B

Dec/90 - Jan/91 Apparent Dilution Pb/Zn -vs- Faro U/G Feed

This graph checks for a relationship between apparent grade dilution in the mill feed and the contained percentage of underground ore. Cumulative sums for apparent lead grade and zinc grade dilution are plotted as before for the period December/90 and January/91 and compared with a cumulative sum for the percentage of Faro underground ore in the mill feed.

1. December 1 - December 31 - apparent grade dilution for lead and zinc is decreasing, however after December 19 the percentage of Faro underground ore in the mill feed is increasing.
2. January 1 - January 10 - apparent dilution is decreasing and Faro underground ore (as a percentage of mill feed) increasing to January 3 then decreasing.
3. January 11 - January 31 - little trend in apparent dilution but proportion of Faro underground ore in mill is increasing.
4. The above suggests Faro underground ore is not the source of changes in apparent grade dilution at the mill head and therefore is not responsible for the discrepancy between blasthole predicted mill head grades and mill head grade measured at the lead rougher feed.



DEC/90 – JAN/91 APPARENT DILUTION
PB/ZN –V– FARO u/G FEED
CUM. % DIFF.(DAILY VALUE – MEAN)
80
60
40
20
0
–20
–40
–60
–80
–100
–120
–140
–160
QSUMPB
QSUMZN
QSUMFAROU/GFEED
1 3 5 7 9 11 13 15 17 19 21 23 25 27 29 31 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30
DECEMBER 1990 – JANUARY 1991
CUM.%DILUTION PB
CUM.%DILUTION ZN
CUM%FAROU/GFEED

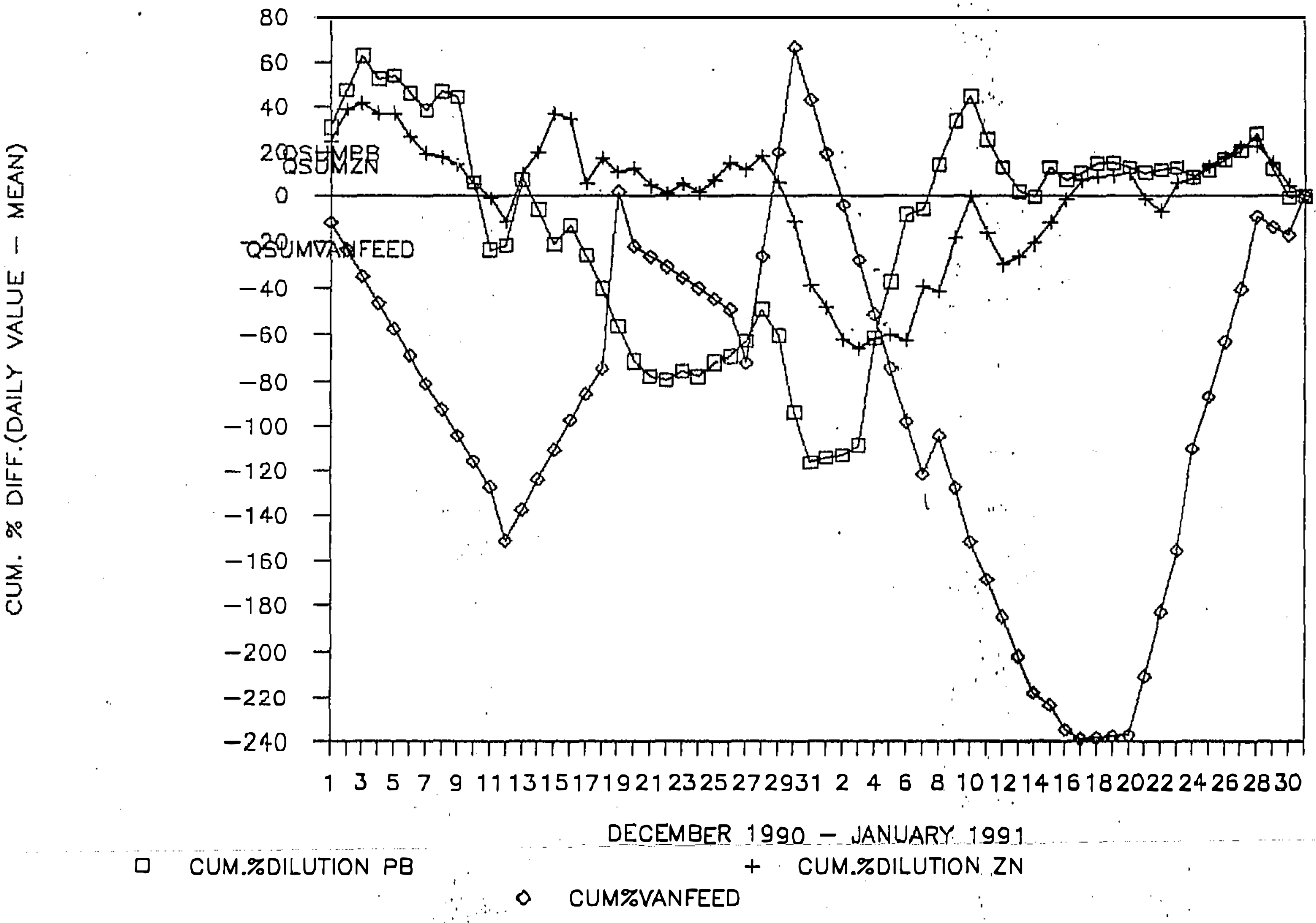
<u>Dec/90 - Jan/91 Cumm Apparent Dilution Pb and Zn -vs- Vangorda Mill Feed (%)</u>

This graph checks for a relationship between the percentage of Vangorda ore in the mill feed and the apparent grade dilution exhibited by lead and zinc at the mill head (lead rougher feed). The graph is constructed in the same way as previously for Faro underground ore.

1. December 1 - December 31 - general trend of <u>falling</u> apparent external grade dilution in combination with generally <u>increasing</u> percentage of Vangorda ore in the mill feed.
2. January 1 - January 10 - <u>increasing</u> apparent external dilution matched against <u>decreasing</u> content of Vangorda ore in the mill feed.
3. January 16 - January 31 - no good trend in apparent grade dilution during period of dropping then rising proportion of Vangorda ore in the mill feed.
4. The above suggests Vangorda ore is not the source of apparent external grade dilution and therefore is not the source of discrepancy between blasthole and mill head grades.

DEC/90 – JAN/91 CUSUM

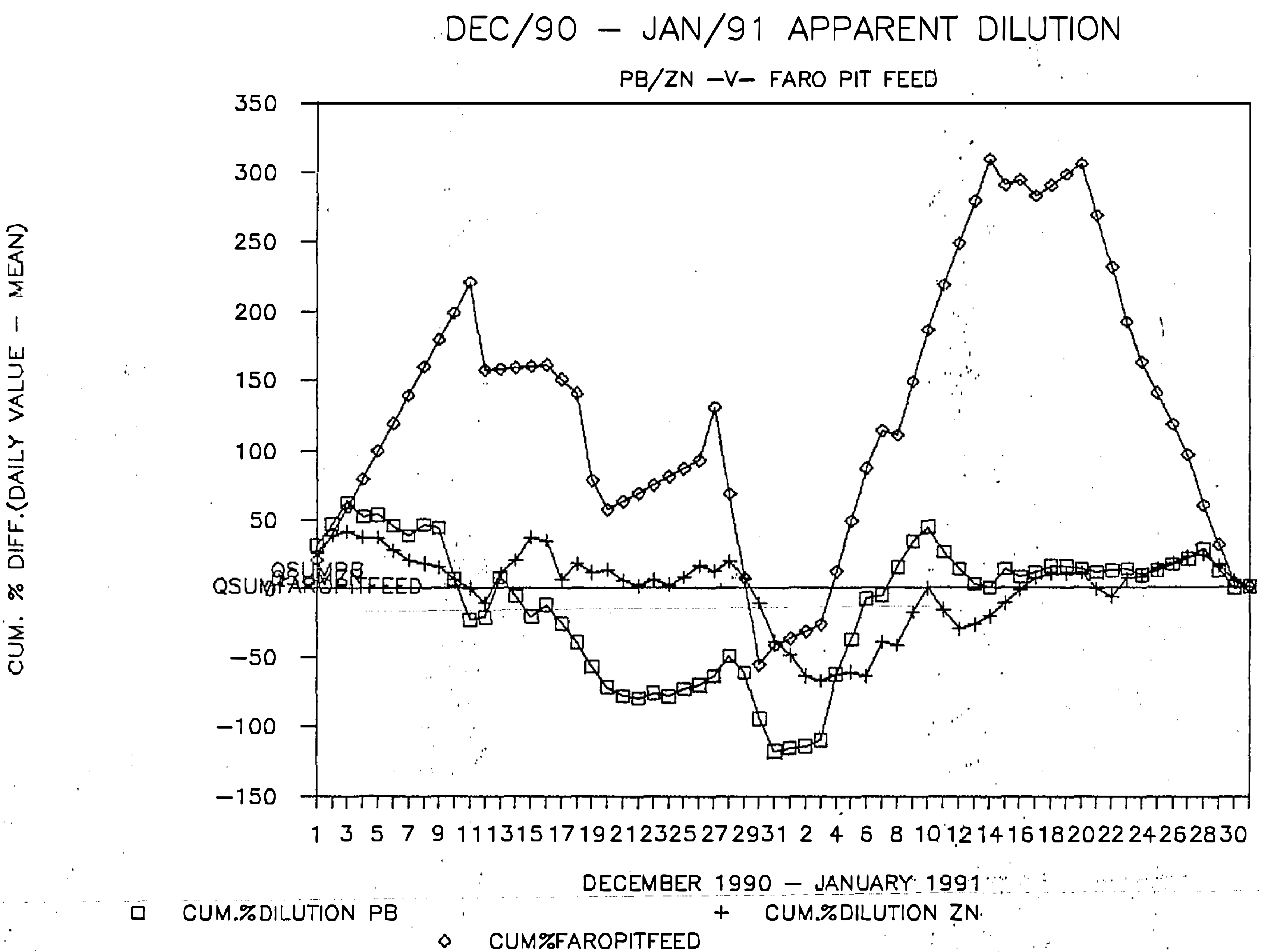
APPARENT DILUTION Pb AND Zn -v- VANGORDA MILL FEED (%)



Dec/90 - Jan/91 Apparent Dilution Pb/Zn - vs - Faro Pit Feed

This graph checks for a relationship between apparent grade dilution and the percentage of Faro Pit ore in the mill feed. It is constructed in the same way as the previous two graphs and covers the period from December 1/90 to January 31/91.

1. December 1 - December 31 - generally decreasing apparent dilution accompanied by generally decreasing content of Faro Pit ore in mill feed.
2. January 1 - January 10 - strongly increased apparent dilution accompanied by strong increases in proportion of Faro Pit ore in mill feed.
3. January 11 - January 31 - decreasing content of Faro Pit ore in mill feed with little change in apparent dilution.
4. Apparent dilution is strongly related to proportion of Faro Pit ore in mill feed for most of December/90 - January/91.

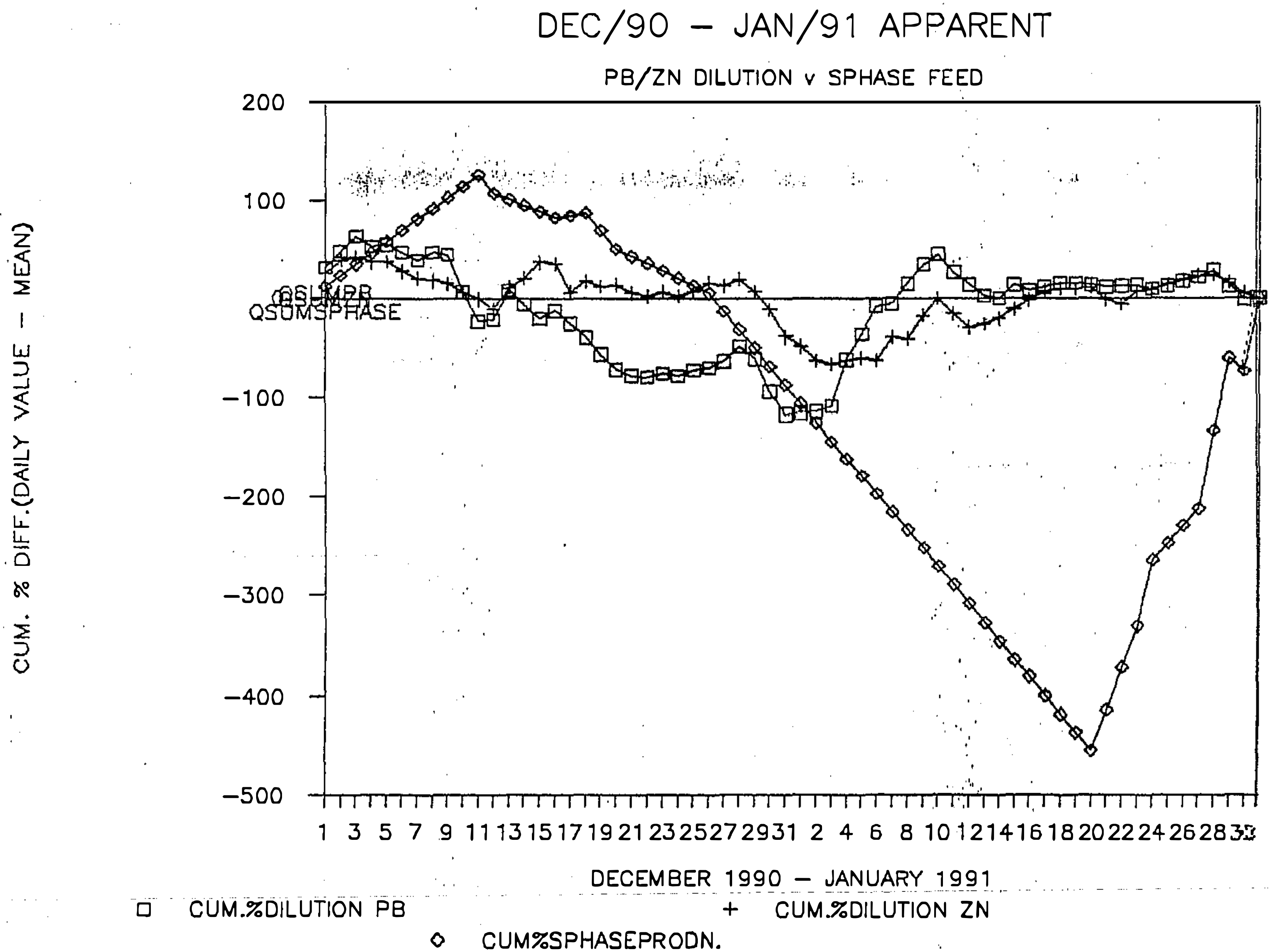


DEC/90 – JAN/91 APPARENT DILUTION
PB/ZN –V– FARO PIT FEED
CUM. % DIFF.(DAILY VALUE – MEAN)
350
300
250
200
150
100
50
QSUMPB
QSUMFAROPITFEED
–50
–100
–150
1 3 5 7 9 11 13 15 17 19 21 23 25 27 29 31 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30
DECEMBER 1990 – JANUARY 1991
CUM.%DILUTION PB
CUM.%DILUTION ZN
CUM%FAROPITFEED

Dec/90 - Jan/91 Apparent Pb/Zn Dilution - vs - S Phase Mill Feed

During December/90 and January/91 Faro Pit mill feed came from two mining areas; the South Phase (3390 Bench) and the East Phase (3550 Bench). This graph relates the proportion of South Phase ore in the mill feed to apparent dilution. The data comes from "mining statistics" (the only place where mining phases are differentiated) so there may be a lag time between in the dates of corresponding inflection points.

1. The proportion of South Phase ore in the mill feed is not related to apparent dilution in anything except perhaps a negative way (See December 1 - 10, January 3 - 10, January 28 - 31).
2. Note that from December 26 to January 20 there was no ore mined from Faro South Phase (straight on graph).
3. South Phase is not responsible for increases in apparent dilution.

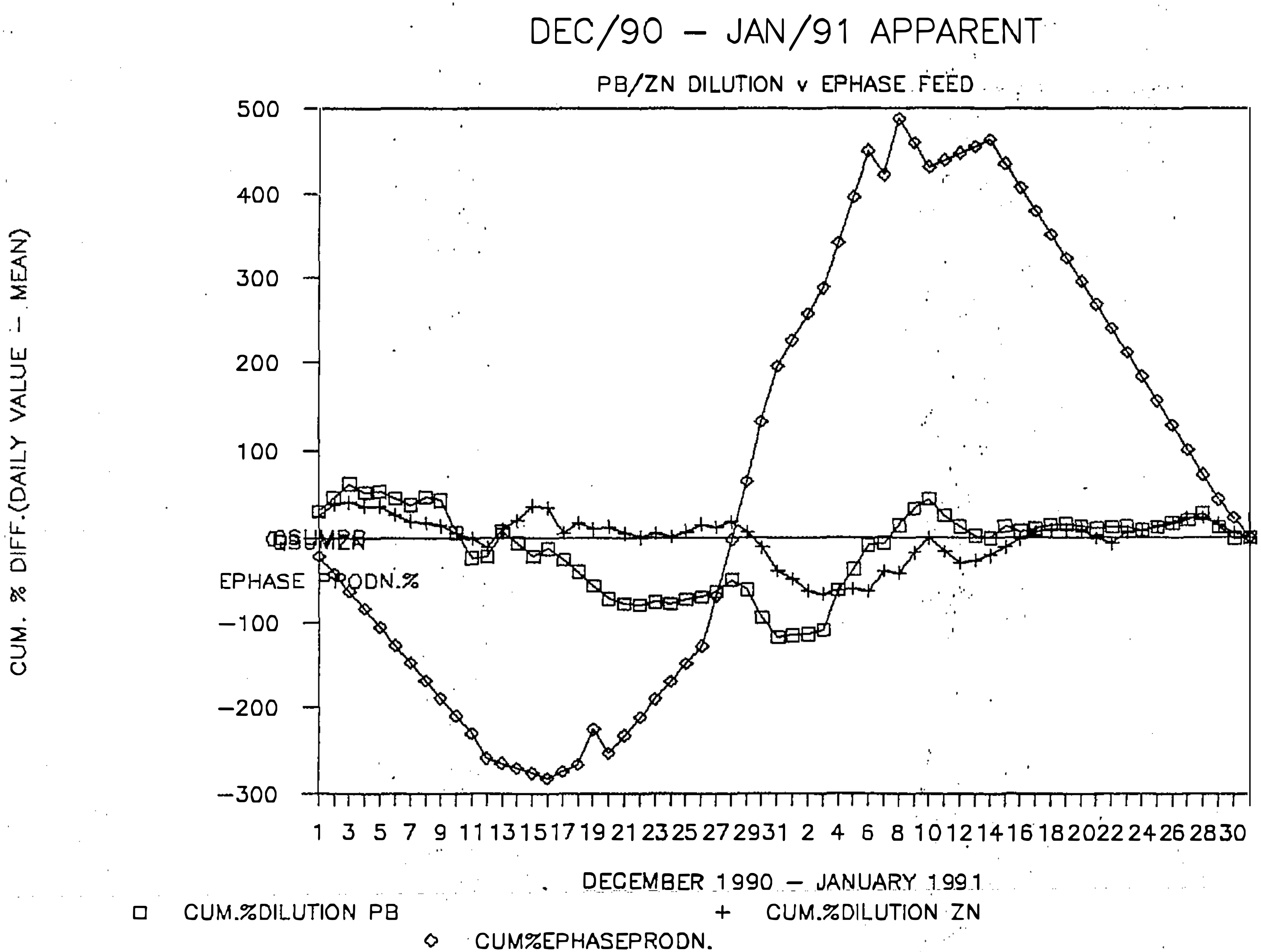


DEC/90 – JAN/91 APPARENT
PB/ZN DILUTION v SPHASE FEED
CUM. % DIFF.(DAILY VALUE – MEAN)
200
100
–100
–200
–300
–400
–500
QSUMPB
QSUMSPHASE
1 3 5 7 9 11 13 15 17 19 21 23 25 27 29 31 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30
DECEMBER 1990 – JANUARY 1991
CUM.%DILUTION PB
CUM.%DILUTION ZN
CUM%SPHASEPRODN.

Dec/90 - Jan/91 Apparent Pb/Zn Dilution - vs - E Phase Feed

This graph shows the proportion of East Phase mining, by day, related to apparent grade dilution for lead and zinc. All graphs are plotted as cumulative sums. The percentage of East Phase ore in the total ore mined was used as a proxy for the proportion of East Phase ore in the mill feed.

1. December 1 - December 31 - generally decreasing apparent dilution with decreasing content of East Phase ore up to December 16, and moderately increasing proportions after that.
2. January 1 - January 10 - strongly increasing amounts of apparent dilution with large increases in the proportion of East Phase ore mined (in mill feed).
3. January 11 - January 31 - decreasing proportion (none) of East Phase ore in mill feed at the same time as level trend in cumulative sum apparent dilution curve. (i.e. "average" apparent dilution).
4. Of the two mining phases in the Faro Pit only mining in one, the East Phase, correlates well with increased in apparent dilution.



DEC/90 – JAN/91 APPARENT
PB/ZN DILUTION v EPHASE FEED
CUM. % DIFF.(DAILY VALUE – MEAN)
500
400
300
200
100
–100
–200
–300
QSUMPB
QSUMZN
EPHASE PRODN.%
1 3 5 7 9 11 13 15 17 19 21 23 25 27 29 31 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30
DECEMBER 1990 – JANUARY 1991
CUM.%DILUTION PB
CUM.%DILUTION ZN
CUM%EPHASEPRODN.

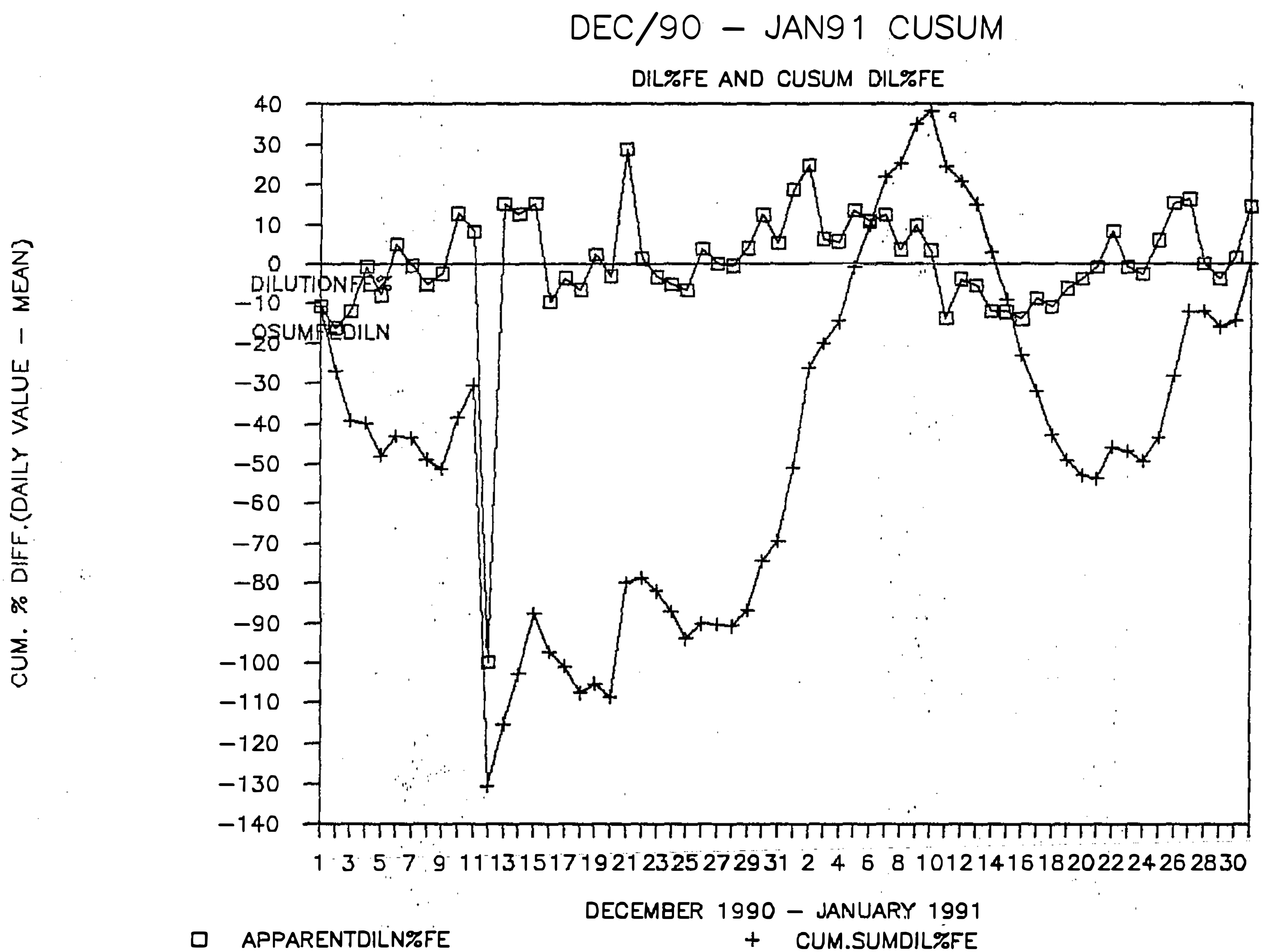
Dec/90 - Jan/91 Cusum Dilution % Fe and Cusum Dilution % Fe

This graph shows the apparent grade dilution calculated from the percentage of iron in blastholes and mill feed along with a cumulative sum for the same data.

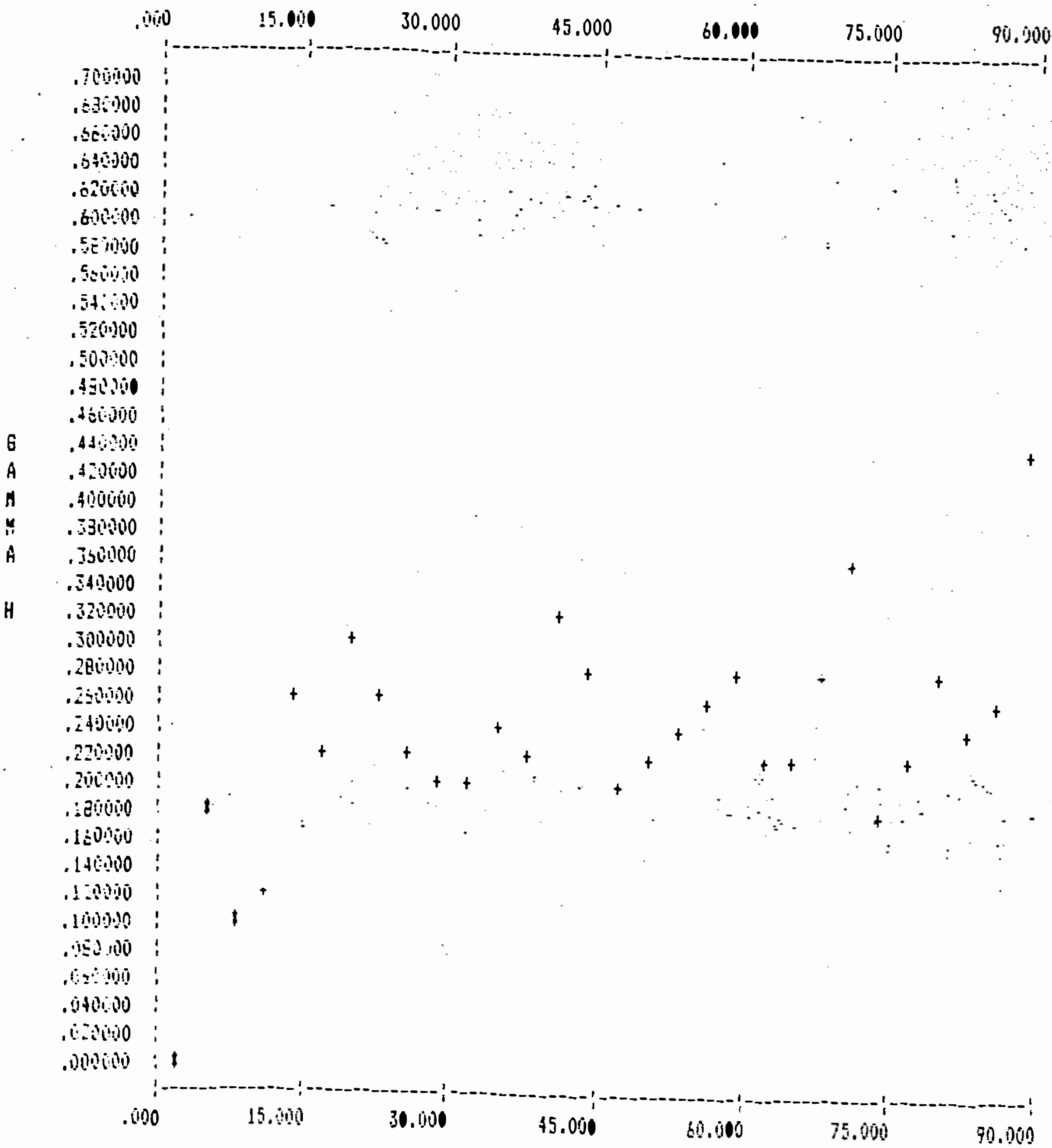
1. A decreasing trend in apparent grade iron dilution is seen from December 1 to December 27.
2. A strong increasing trend in apparent dilution is noted from December 28 to January 10.
3. January 11 - January 31 - decreasing and increasing trends in apparent dilution during period of no new trends in lead and zinc dilution values.

Note: Dilution may be of massive sulphide variety which may contain as much or more iron than the ore.

4. Trend in iron apparent dilution from January 3 - January 10 supports that exhibited by lead and zinc.


DEC/90 – JAN91 CUSUM
DIL%FE AND CUSUM DIL%FE
CUM. % DIFF.(DAILY VALUE – MEAN)
40
30
20
10
0
–10
–20
–30
–40
–50
–60
–70
–80
–90
–100
–110
–120
–130
–140
DILUTIONFE%
CSUMFEDILN
1 3 5 7 9 11 13 15 17 19 21 23 25 27 29 31 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30
DECEMBER 1990 – JANUARY 1991
APPARENTDILN%FE
CUM.SUMDIL%FE

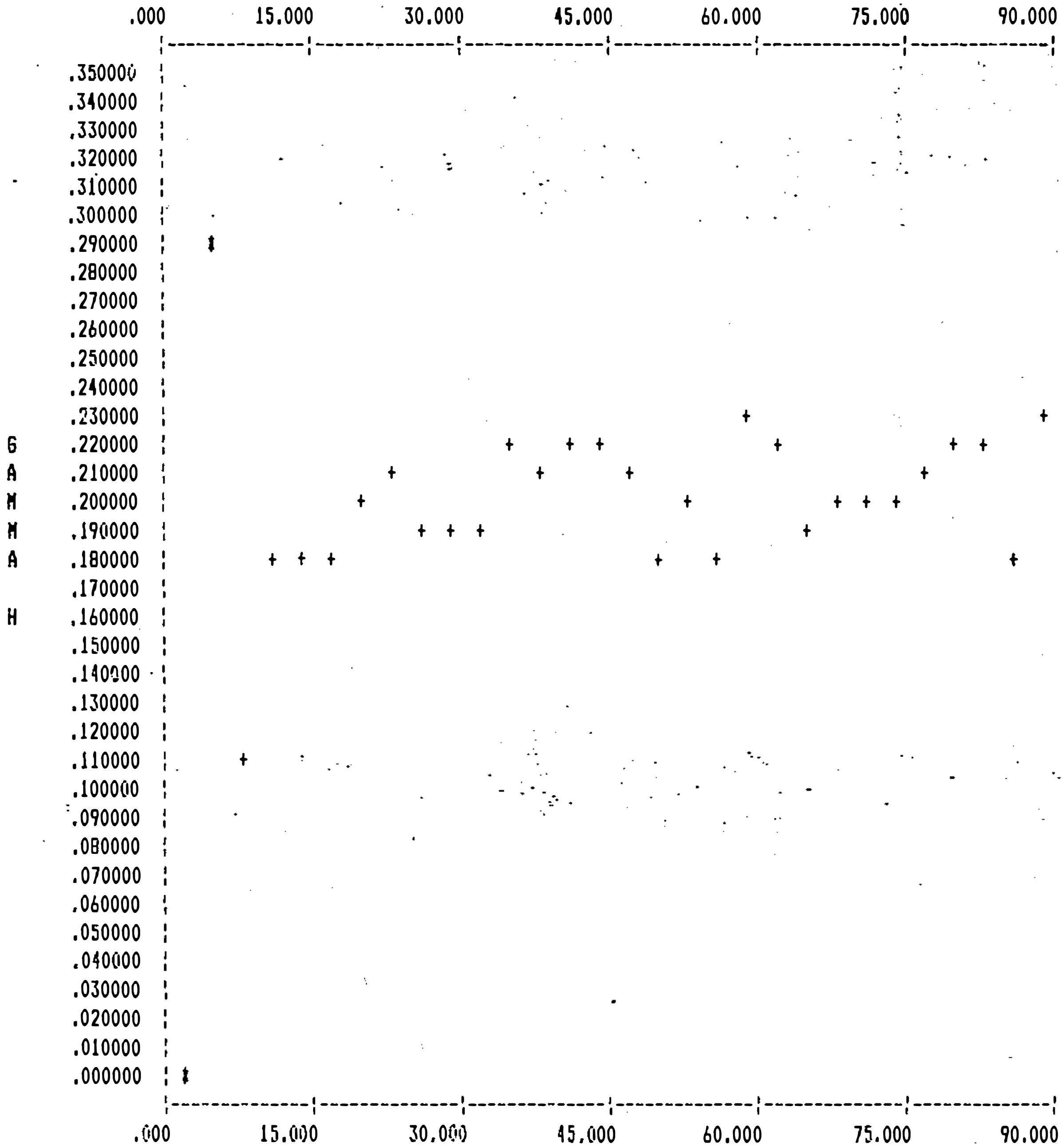
TITLE : MASSIVE SULPHIDE - LEAD
DESCRIPTION : Semi-variogram 3 (SW-NE)
FILENAME : E:\VANGORDA\5080CMP.MEX
DESCRIPTION : MASSIVE SULPHIDE GEOLOGY COMPOSITES



CLASS INTERVAL [3.00]

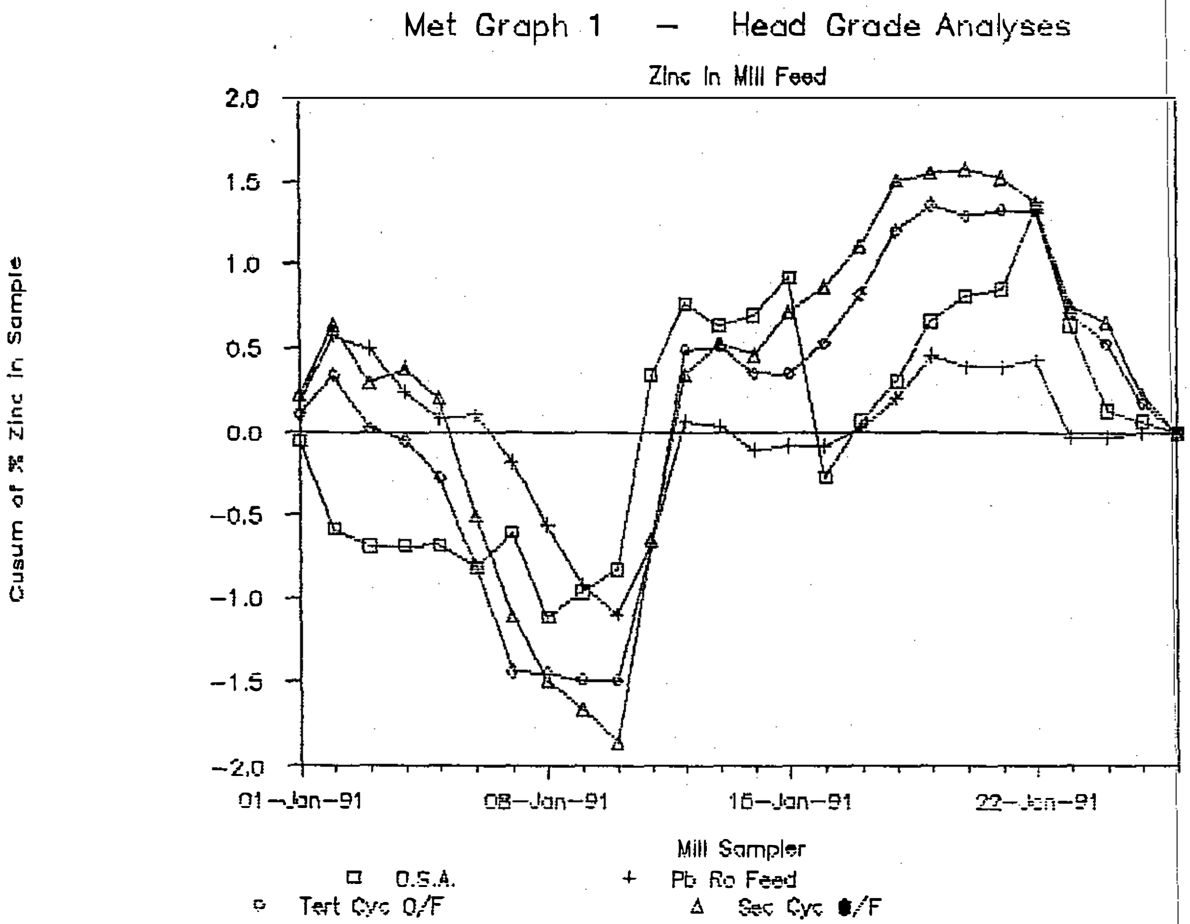
+ INDICATES EXPERIMENTAL SEMI-VARIOGRAM
# INDICATES LESS THAN 5 THRESHOLD PAIRS IN CLASS
x INDICATES SEMI-VARIOGRAM MODEL

TITLE : MASSIVE SULPHIDE - ZINC
DESCRIPTION : Semi-variogram 4 ( )
FILENAME : E:\VANGORDA\50BOZN.MEX
DESCRIPTION : Rock Codes 50-80 %zn

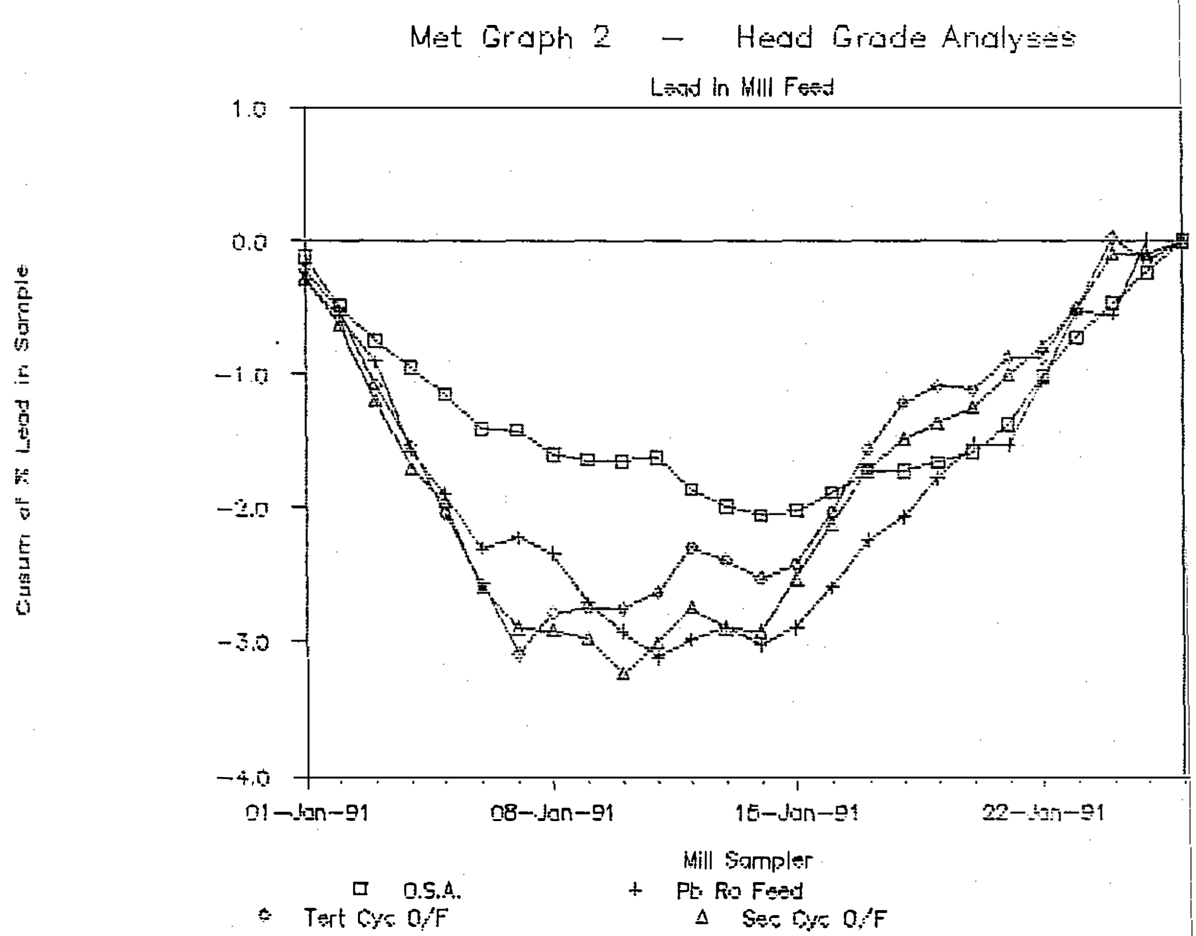


CLASS INTERVAL [3.00]

+ INDICATES EXPERIMENTAL SEMI-VARIOGRAM
! INDICATES LESS THAN 5 THRESHOLD PAIRS IN CLASS
x INDICATES SEMI-VARIOGRAM MODEL

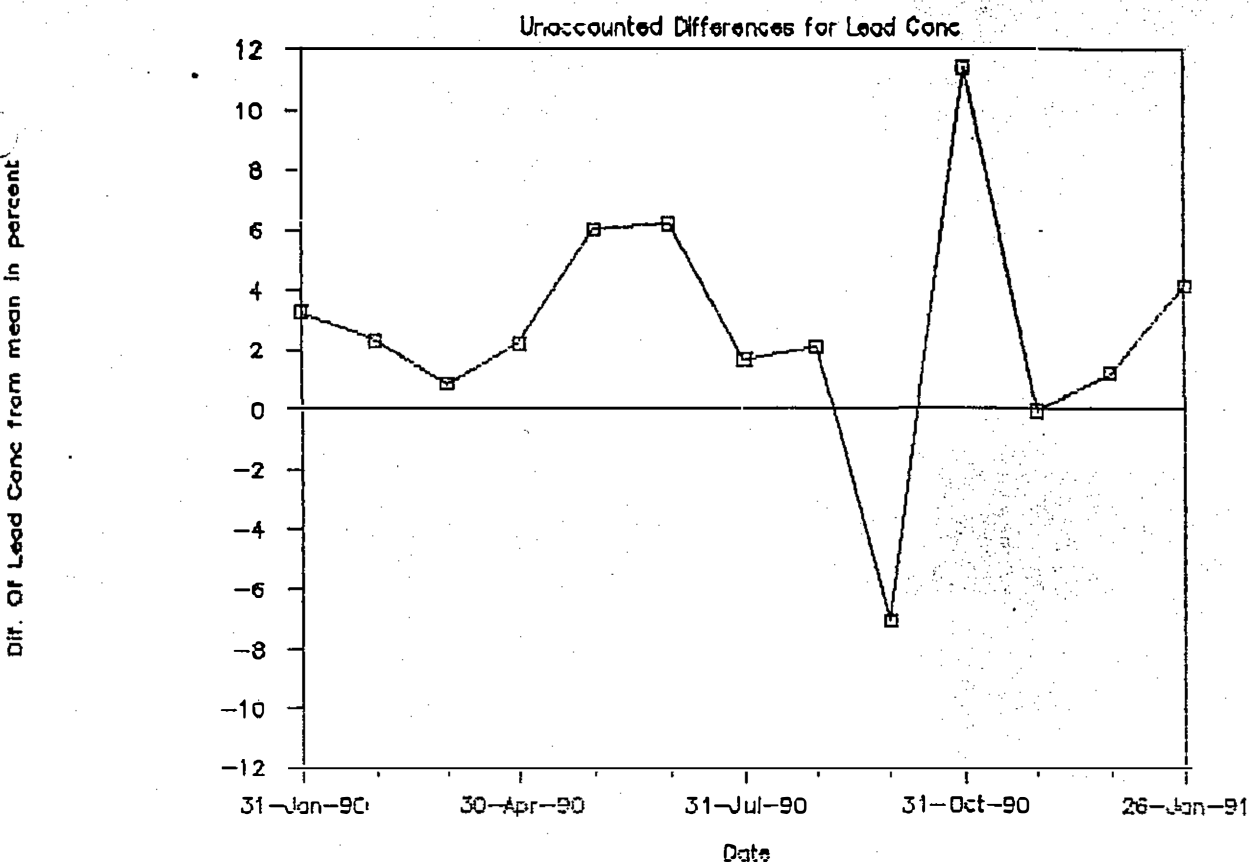


Met Graph 1 — Head Grade Analyses
Zinc In Mill Feed
Cusum of % Zinc in Sample
2.0
1.5
1.0
0.5
0.0
-0.5
-1.0
-1.5
-2.0
01-Jan-91
08-Jan-91
15-Jan-91
22-Jan-91
Mill Sampler
O.S.A.
Pb Ro Feed
Tert Cyc O/F
Sec Cyc O/F

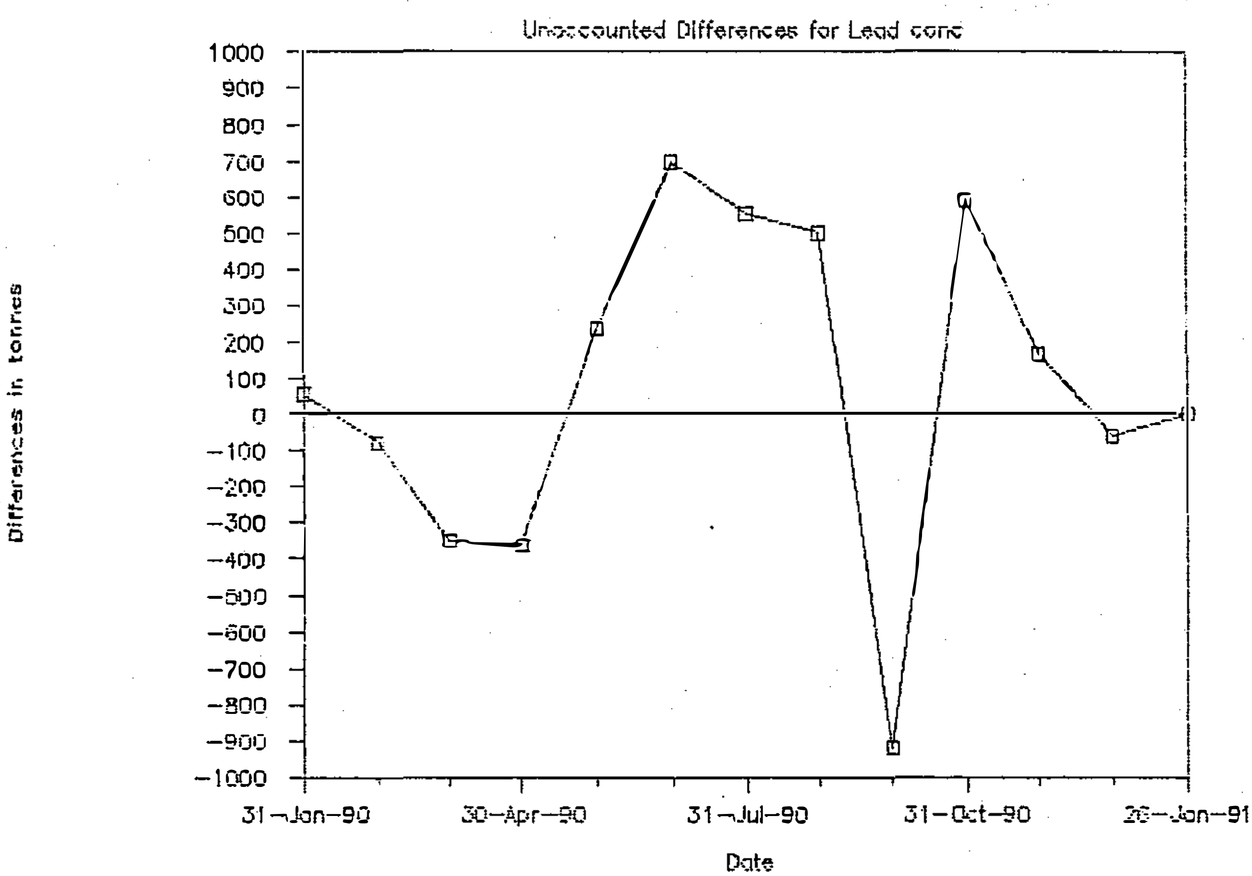


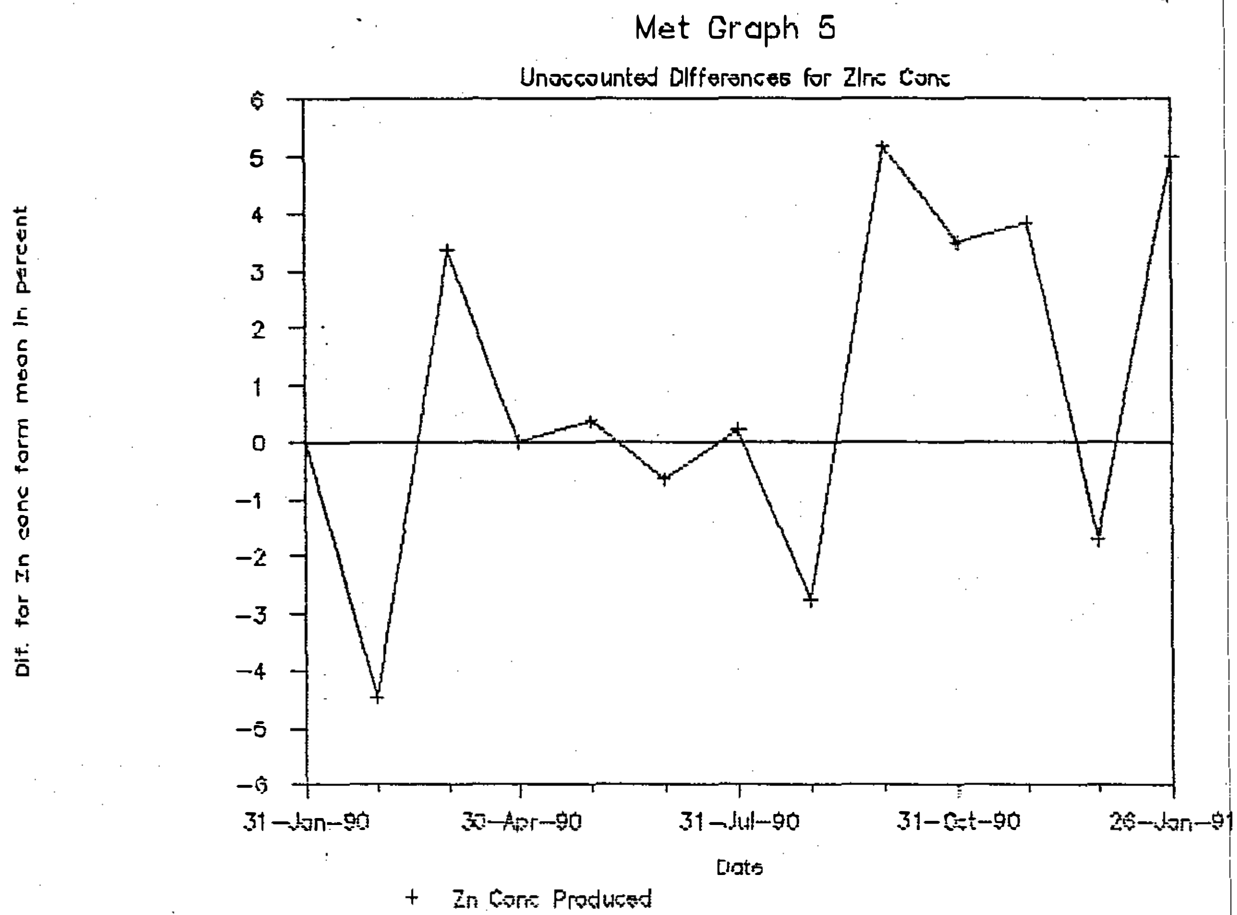
Met Graph 2 — Head Grade Analyses
Lead In Mill Feed
Cusum of % Lead in Sample
1.0
0.0
-1.0
-2.0
-3.0
-4.0
01-Jan-91
08-Jan-91
15-Jan-91
22-Jan-91
Mill Sampler
O.S.A.
Pb Ro Feed
Tert Cyc O/F
Sec Cyc O/F

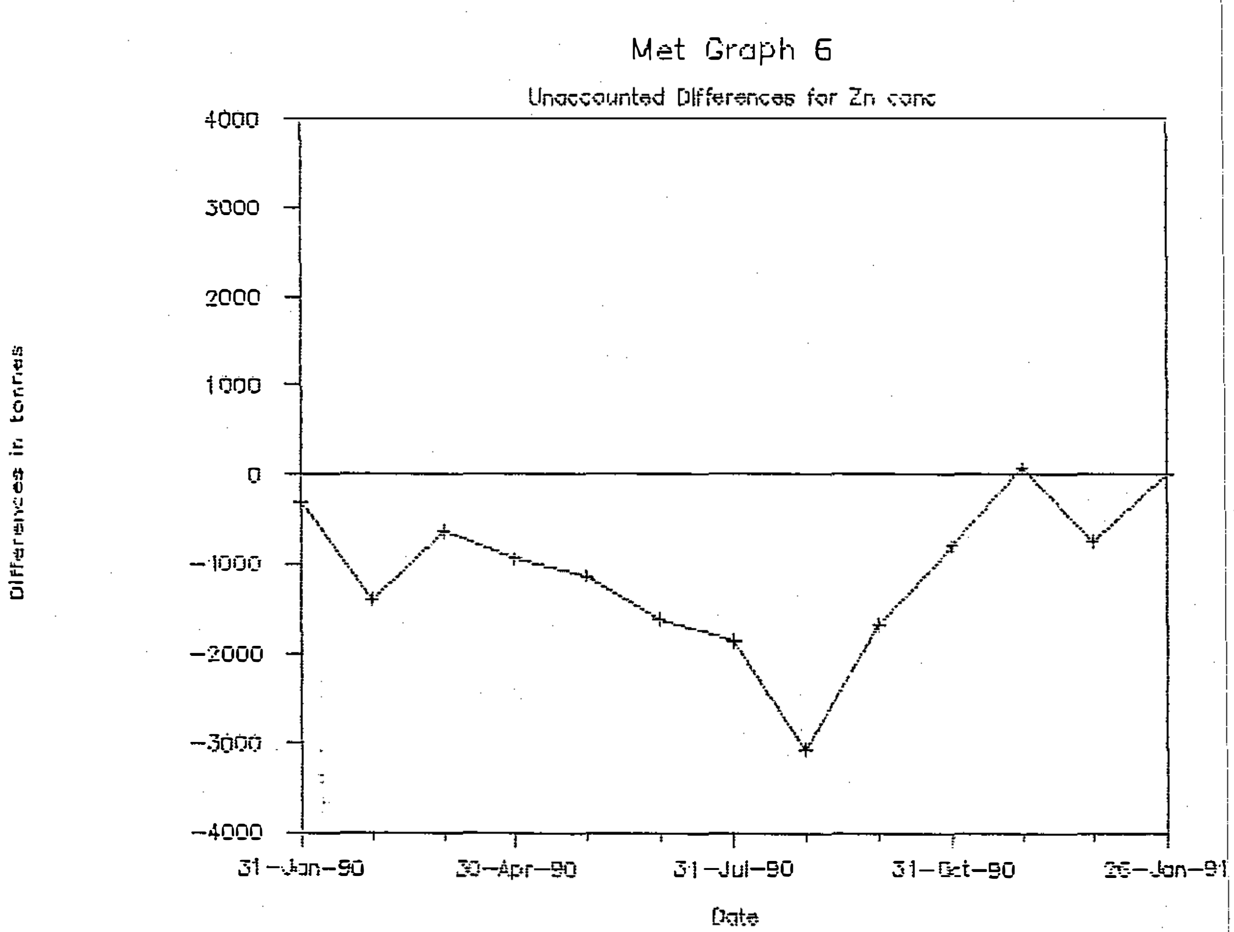
Met Graph 3

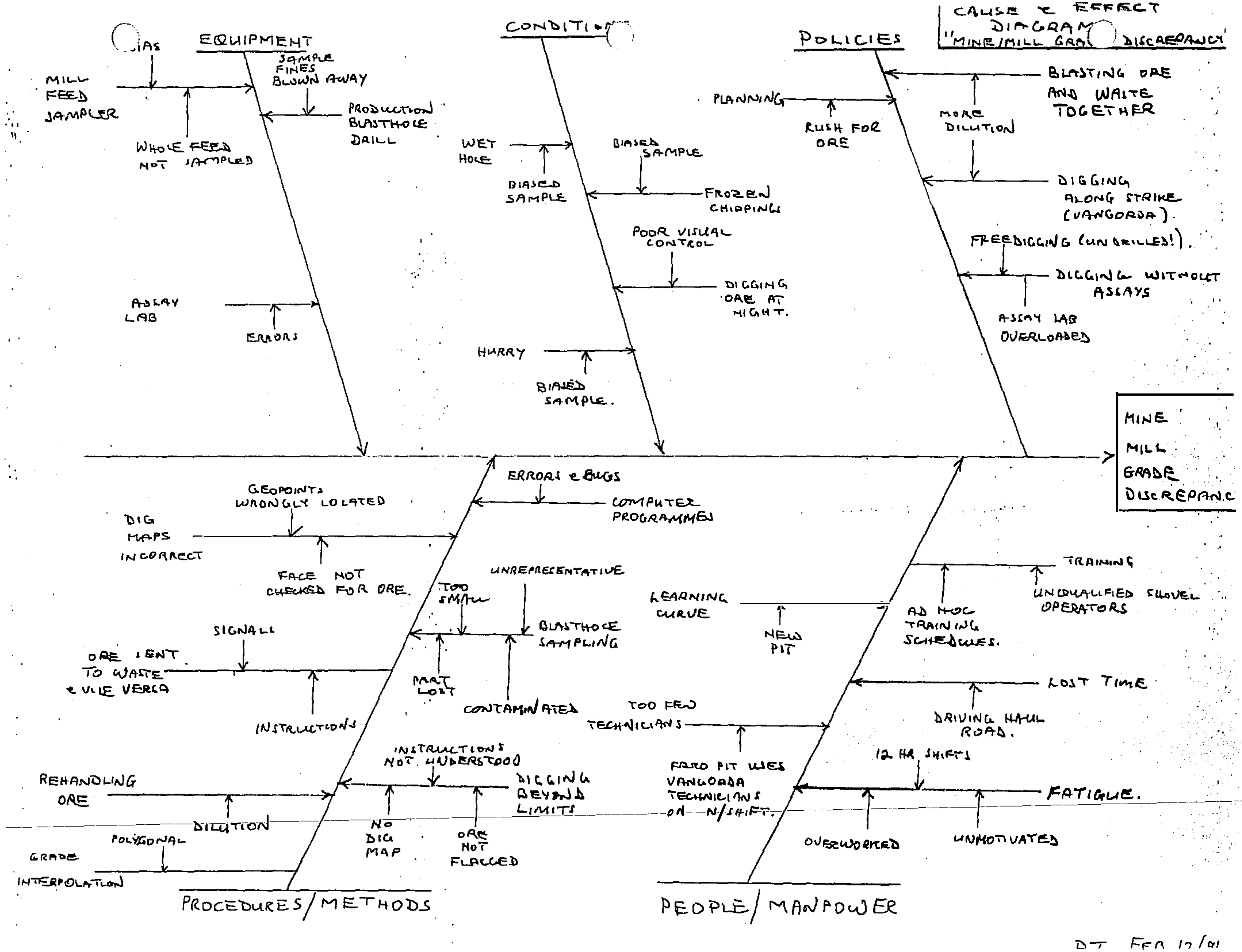


Met Graph 4




Met Graph 5
Unaccounted Differences for Zinc Conc
Dif. for Zn conc form mean in percent
6
5
4
3
2
1
0
−1
−2
−3
−4
−5
−6
31−Jan−90
30−Apr−90
31−Jul−90
31−Oct−90
26−Jan−91
Date
+ Zn Conc Produced


Met Graph 6
Unaccounted Differences for Zn conc
Differences in tonnes
4000
3000
2000
1000
0
−1000
−2000
−3000
−4000
31−Jan−90
30−Apr−90
31−Jul−90
31−Oct−90
26−Jan−91
Date



CAUSE & EFFECT DIAGRAM
"MINE/MILL GRA DISCREPANCY"
EQUIPMENT
MILL FEED SAMPLER
SAMPLE FINES BLOWN AWAY
PRODUCTION BLASTHOLE DRILL
WHOLE FEED NOT SAMPLED
ASSAY LAB
ERRORS
CONDITI
WET HOLE
BIASED SAMPLE
BIASED SAMPLE
FROZEN CHIPPINGS
POOR VISUAL CONTROL
DIGGING ORE AT NIGHT.
HURRY
BIASED SAMPLE.
POLICIES
PLANNING
RUSH FOR ORE
BLASTING ORE AND WASTE TOGETHER
MORE DILUTION
DIGGING ALONG STRIKE (VANGORDA).
FREEDIGGING (UNDRILLED!).
DIGGING WITHOUT ASSAYS
ASSAY LAB OVERLOADED
MINE MILL GRADE DISCREPANC
ERRORS & BUGS
COMPUTER PROGRAMMES
GEOPOINTS WRONGLY LOCATED
DIG MAPS INCORRECT
FACE NOT CHECKED FOR ORE.
TOO SMALL
UNREPRESENTATIVE
BLASTHOLE SAMPLING
PART LOST
CONTAMINATED
SIGNALS
ORE SENT TO WASTE & VICE VERSA
INSTRUCTIONS
INSTRUCTIONS NOT UNDERSTOOD
DIGGING BEYOND LIMITS
NO DIG MAP
ORE NOT FLAGGED
REHANDLING ORE
DILUTION
POLYGONAL GRADE INTERPOLATION
PROCEDURES/METHODS
LEARNING CURVE
NEW PIT
TRAINING
AD HOC TRAINING SCHEDULES.
UNQUALIFIED SHOVEL OPERATORS
LOST TIME
DRIVING HAUL ROAD.
TOO FEW TECHNICIANS
FARO PIT USES VANGORDA TECHNICIANS ON N/SHIFT.
12 HR SHIFTS
FATIGUE.
OVERWORKED
UNMOTIVATED
PEOPLE/MANPOWER
DT FEB 12/91

Mine and Mill Jan/Feb 91

6.0 CONCLUSIONS - DETAILS

6.1 PROBLEM ANALYSIS

a. The January/February problem is caused by dilution. Although the exact dilution source has not been isolated by this analysis, it is most likely from the Faro Pit East Phase.

b. Measurements within the Mill over 1990 show average error Pb = 2.7% relative and Zn = 1.4% relative. These are less than the normally accepted 5% discrepancy. The 5% discrepancy therefore mainly lies elsewhere.

6.2 METALLURGICAL

a. The Mill Metallurgical balance includes a self-check test. This compares predicted concentrate production to estimated concentrate production.

b. The Mill measures its waste product (tailings). The mine do not. Any trend on mine waste would lead to rapid trend identification and should be encouraged. (Absolute values are less important than the trend, where the objective is to monitor dilution.)

c. Mill Feed Samplers all pick up the trends. These statistics indicated the accounting sample - Lead Rougher Feed was a good overall sample over 1990.

d. Pb and Zn Head Grade turning points are independent. Pb and Zn discrepancies Mining and Mill largely trend and change together. This supports the suggestion sampling at the mill is not the problem.

e. The Mill Concentrate Production prediction from Lead Rougher Feed indicate errors of Pb of 2.7% and Zn of 1.4%. It is likely these equate to an underdeclaring of recovery.

6.3 MINING/GEOLOGY

a. External dilution is being caused, and it is likely this comes mainly from Faro East Phase.

b. Nugget Effect changes in different orebodies, and within the same orebody. This ultimately leads to errors in calculations.

7.0 RECOMMENDATIONS

a. A verification test is necessary. It is the usual next/last problem analysis step. e.g. Mining and Milling 100% non-refractory Vangorda For 3-5 days. Watch dilution over that period.

b. It is suggested that the Mining Department try to establish a method of sampling waste left behind. Although actual values would be difficult to obtain, through sampling inaccuracies, any trend is important.

c. Useful tools have been shown - Problem Analysis and Cusums. Trends should be kept daily, Cusums of Pb, Zn, Fe, S.G.

d. Pycnometer for S.G. should be purchased (est. $7500 as used by Lakefield). S.G. and Fe trends will help isolate dilution by massive sulphides or other, when compared to Pb and Zn discrepancy trends. S.G. should be measured on Mill Feed Samples, and is an "indication" of ore mineral content.

e. Work should continue in improving Mill Feed Sampling (minor), and this is likely to be the New Flotation Feed Sampler. OSA Lead Rougher Feed primary sampling and calibration will take somewhat longer - scheduled - 6-8 weeks.

8.0 METALLURGICAL GRAPHS AND TABLES

(Attached)

Met Table 1

Date	O.S.A. Pb	O.S.A. Zn	Pb Rougher Feed Pb	Pb Rougher Feed Zn	Tert. Cyc O/F Pb	Tert. Cyc O/F Zn	Sec. Cyc O/F Pb	Sec. Cyc O/F Zn
01-Jan-91	2.87	4.57	2.49	4.74	2.93	4.95	2.90	5.02
02-Jan-91	2.63	4.10	2.51	4.96	2.84	5.08	2.83	5.21
03-Jan-91	2.73	4.53	2.44	4.48	2.58	4.52	2.60	4.46
04-Jan-91	2.79	4.63	2.12	4.31	2.68	4.77	2.68	4.88
05-Jan-91	2.79	4.63	2.45	4.40	2.64	4.62	2.92	4.62
06-Jan-91	2.74	4.49	2.38	4.58	2.62	4.31	2.54	4.09
07-Jan-91	2.97	4.84	2.86	4.28	2.62	4.21	2.87	4.19
08-Jan-91	2.82	4.12	2.67	4.18	3.45	4.83	3.17	4.42
09-Jan-91	2.95	4.78	2.41	4.20	3.18	4.81	3.12	4.62
10-Jan-91	2.98	4.76	2.57	4.39	3.14	4.84	2.92	4.60
11-Jan-91	3.02	5.80	2.59	4.99	3.26	5.66	3.40	6.01
12-Jan-91	2.76	5.05	2.92	5.29	3.48	6.00	3.44	5.79
13-Jan-91	2.86	4.50	2.87	4.53	3.05	4.86	3.02	4.98
14-Jan-91	2.93	4.69	2.66	4.42	3.01	4.69	3.16	4.73
15-Jan-91	3.02	4.85	2.90	4.59	3.24	4.84	3.57	5.05
16-Jan-91	3.13	3.43	3.09	4.56	3.53	5.02	3.59	4.95
17-Jan-91	3.15	4.97	3.13	4.67	3.62	5.14	3.59	5.04
18-Jan-91	3.00	4.87	2.96	4.74	3.49	5.22	3.40	5.19
19-Jan-91	3.05	4.98	3.07	4.81	3.27	4.99	3.29	4.84
20-Jan-91	3.07	4.78	3.04	4.50	3.12	4.78	3.30	4.82
21-Jan-91	3.20	4.67	2.78	4.56	3.38	4.88	3.43	4.75
22-Jan-91	3.36	5.12	3.26	4.60	3.14	4.84	3.39	4.65
23-Jan-91	3.28	3.92	3.29	4.10	3.52	4.23	3.46	4.18
24-Jan-91	3.25	4.12	2.78	4.56	3.67	4.66	3.59	4.70
25-Jan-91	3.22	4.56	3.33	4.59	2.97	4.49	3.17	4.37
26-Jan-91	3.23	4.56	2.78	4.56	3.29	4.66	3.28	4.56
27-Jan-91								
28-Jan-91								
29-Jan-91								
30-Jan-91								
31-Jan-91								
AVERAGE	2.99	4.63	2.78	4.56	3.14	4.84	3.18	4.80
STD. DEV.	0.19	0.44	0.31	0.26	0.33	0.38	0.31	0.43
Rank Pb	3		4		2		1	
Rank Zn		3		4		1		2

Met Table 2

DATE	Actual Tonnes Pb	Zn	Difference from Actual Pb*	Zn+	Difference from Mean Pb#	Zn**	Cusum Difference Pb	Zn	% Difference Pb	Zn
31-Jan-90	14415	25104	469	1	54	-306	54	-306	3.3	0.0
28-Feb-90	12310	17914	283	-797	-132	-1104	-79	-1409	2.3	-4.4
31-Mar-90	17429	31827	143	1072	-272	765	-351	-644	0.8	3.4
30-Apr-90	18312	31816	403	3	-12	-304	-364	-947	2.2	0.0
31-May-90	16746	31255	1013	115	598	-192	234	-1139	6.0	0.4
30-Jun-90	14106	27766	976	-178	461	-485	694	-1623	6.2	-0.6
31-Jul-90	16803	32198	275	68	-140	-239	554	-1862	1.6	0.2
31-Aug-90	17321	32789	362	-900	-53	-1207	500	-3068	2.1	-2.7
30-Sep-90	14235	32787	-1006	1691	-1421	1384	-921	-1684	-7.1	5.2
31-Oct-90	16875	34171	1927	1196	1512	889	590	-794	11.4	3.5
30-Nov-90	14137	30242	-9	1160	-424	853	166	59	-0.1	3.8
31-Dec-90	15850	29453	190	-505	-225	-812	-60	-752	1.2	-1.7
26-Jan-91	11402	21086	475	1059	60	752	0	0	4.2	5.0
AVERAGE	15380.1	29108.3	415.5	306.5	0	0			3.7	2.4
STD DEV.	2030.0	4727.2	634.1	805.5					4.0	2.9

* Met Graph 3
\+ Met Graph 4
\# Met Graph 5
** Met Graph 6

BREAKDOWN ENQUIRY / PROBLEM ANALYSIS SHEET

1. BREAKDOWN / PROBLEM	WHAT SHOULD HAPPEN WHAT HAS HAPPENED		
2. SPECIFIC DETAILS	What -Unit -Malfunction	A. IS	B. IS NOT
	Where -Geographical -On Unit		
	When -First observed -Since observed -In operating cycle		
	Extent-How many units -How much of each		
3. POSSIBLE CAUSES	What -Unit -Malfunction	A. List distinctions between 2A and 2B	B. List recent System changes
	Where -Geographical -On Unit		
	When -First observed -Since observed -In operating cycle		
	Extent-How many units -How much of each		
4. TEST FOR CAUSE	Which of 3A or 3B explains BOTH the "is" and the "is not" 1. 2. 3.		
5. VERIFY	Which of these fits common sense What steps are to be taken by whom		

COMPILED BY: ____________________ DATE: ____________