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Zincore Metals - Summary of Accha Pilot Plant Test Work

Project Report

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SUMMARY OF THE FINDINGS OF THE PILOT PLANT TEST WORK CONDUCTED ON THE SAMPLE FROM THE ACCHA DEPOSIT

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Executive Summary

Following the initial success in the laboratory in the application of high temperature zinc fuming for the recovery of zinc from the Accha ore, a pilot plant campaign was commissioned to meet a number of objectives.

Four sample areas on Accha were identified by the geological team and a 2.5 tonne sample of each was submitted to SGS laboratories in Lima, Peru for crushing, blending and splitting. The samples were then delivered to the plant at Pacasmayo for test work on the pilot scale Waelz kiln.

The pilot plant produces a calcine product and a discard slag that are both collected for analysis and any further test work. Zinc and lead are collected in the calcine product as zinc oxide and lead oxide respectively

The pilot plant campaign is deemed to have been successful in that:

- The results confirm the laboratory findings;
- The pilot plant produced sufficient calcine product for further downstream test work;
- A better understanding of the effect of the operating parameters was developed;
- Design criteria were generated for a future design study;
- A model was developed describing the relationship between the anthracite consumption and the zinc recovery;
- A relationship was developed between the calcine zinc grade and recovery.

Two sets of tests were conducted namely:

- A parameter test programme during which the effect of various parameters on the zinc and lead recovery and grade to the calcine product were determined.
- A continuous test programme where the optimum test conditions identified in the first set of test work was used to determine the variability in the recovery and grade of the zinc and lead in the calcine product.

The results of the continuous test programme yielded an average zinc recovery to the calcine of 92.5% with a the zinc grade of the calcine of 65.5% (+81% zinc oxide). The lead recovery is in excess of 95% and the lead grade in the calcine is circa 7.7% (9.5% lead oxide). A calcine product containing 73.2% zinc and lead metal combined can therefore be

produced or, expressing the zinc and lead as their respective oxides, the calcine product contains 90.5% of zinc oxide and lead oxide.

The results of the continuous run also indicate a strong relationship between the zinc grade and the recovery of zinc to the calcine product. The zinc recovery to the calcine product can reach 95% however this results in a decrease in the zinc grade of the calcine product to circa 59%. Such a relationship is regularly found on mineral processing operations and increasing the recovery of zinc to the calcine product will result in a concomitant decrease in zinc grade in the calcine.

The pilot plant test work has produced in excess of 500 kilograms of calcine product that can be used for further pyrometallurgical and hydrometallurgical test work to establish the cost of further downstream processing.
Concentration of the contaminants chlorine and fluorine at 0.5% and 0.5% respectively was higher than that achieved in the laboratory at 0.13% and 0.17% respectively, indicating that a secondary calcine step may need to be considered.

The author, a professional engineer registered on the international register of professional engineers in accordance with the Washington Accord, has made visits to the various sites in Peru to assess the standard of the work performed. This has included the SGS laboratory where the samples were prepared, the site laboratory that produced the assays during the pilot plant campaign and the pilot plant site. In all cases the standard of work was found to acceptable and of a high standard.

Contents

1. INTRODUCTION

A pilot plant campaign was conducted on sample from the Accha deposit on a Waelz kiln pilot plant owned by Cementos Pacasmayo S.A.A., in Pacasmayo, Peru. This follows on the successful laboratory test work concluded at the Mintek laboratories in South Africa.

The pilot plant campaign consisted of a series of 56 tests to consider the effect of various parameters on the performance of the pilot plant. This was followed by a continuous run over a number of days to determine the variability of the results and generate a grade recovery curve of the calcine product indicating the range of recoveries and grades that could be expected.

Metallicon Process Consulting (Pty) Ltd (Metallicon) was commissioned by Zincore to develop and execute the pilot plant work. This follows on the successful completion of the initial laboratory test work produced by Metallicon at the Mintek research facility in South Africa. Metallicon is a specialist process consulting company that, although based in South Africa, have conducted metallurgical studies throughout the world and have previous experience working on projects in South America.

Metallicon have a long-standing relationship with Hatch, a privately owned international engineering projects company with offices worldwide. In order to provide ongoing support to the pilot plant Hatch was able to provide Metallicon with experienced metallurgical engineers to oversee the pilot operation. The pilot plant was operated by staff from the site under the guidance of Metallicon with the Hatch engineers being the Metallicon site representative..

This report is a summary of the findings of the Accha pilot plant campaign and describes the sample preparation, pilot plant infrastructure and contains findings developed from analysis of the data.

2. OBJECTIVE OF THE PILOT PLANT TESTS

The objectives of the pilot plant test work can be summarised as follows:

- To confirm the findings of the Mintek laboratory test work;
- To study the effect of varying feed grade;
- To study the effect of various operating parameters;
- To generate design criteria for future engineering design;
- To gain a better understanding of the anthracite consumption as this has been identified as a major operating cost;
- To generate sufficient calcine product for downstream test work;
- To determine a relationship between the recovery of Zinc to the calcine and the grade of zinc in the calcine.

3. SUMMARY OF TEST PROCEDURE

3.1 Sample Tested

Samples were sourced with the aid of the geological team and 2.5 tonnes of sample was collected from four sources in the Accha deposit.

The grades of the samples are summarised in the following table.

Ore	Analysis	
	Zinc [%]	Lead [%]
1	5.21	2.10
2	11.80	1.90
3	9.49	1.76
4	20.60	3.87

3.2 Sample Preparation

The four samples were delivered in sealed containers to SGS in Lima, Peru. This SGS laboratory specialises in the preparation, blending, splitting and analysis of samples from various sources.

The sample was crushed to less than 3mm, sampled, assayed and split into 50 kg bags.

The SGS laboratory was inspected by the author and the procedures and standards were found to comply with international best practise. The quality control and sample tracking procedures were particularly well managed.

3.3 Pilot Plant Test Work

The prepared sample was delivered to Pacasmayo where the sample was to be put through a pilot scale Waelz kiln. The operation of the pilot plant is being conducted by local staff from the Bongara zinc plant under the supervision of a Hatch engineer.

A bag of fine sample is mixed with anthracite and formed into pellets. The pelletising is done without the use of binder however one of the parameters that will be considered in the test work programme is whether binder will improve process efficiency by increasing the pellet resistance to breakage.

The drums containing the sample and the pellets are shown in the following photograph.

Figure 1 : Sample drums and pellets feedstock

3.4 Health and Safety

During a visit to the pilot plant it was noted that the operators were equipped with the necessary personal protective equipment. The plant all had all the necessary safety guards, hand rails and kick plates in place.

It must also be noted that the plant was also kept is a very clean state and this is normally a challenge for pilot plant operations.

3.5 Plant Description

A picture of the pilot plant kiln is shown in the picture below.

Figure 2 : Waelz Pilot plant

The pilot plant Waelz kiln is four metres in length with an internal diameter of 0.3 metres. The kiln is fitted with a variable speed drive and the speed of the kiln can be varied from 1.5 to 2.0 revolutions per minute. The kiln is inclined at an angle of approximately 2.4 degrees from the horizontal. The slope of the kiln and the speed of rotation were used to control the residence time of the material in the kiln.

The pilot plant is meant for continuous operation and is fitted with an automatic feeder that is meant to regulate the feed to the kiln. The feeder design was found to accumulate feed sample and it was decided to direct feed the feed sample manually at regular intervals. The average feed rate used during the test work was 15 kilograms per hour. Gas was introduced to the kiln through a regulated gas lance.

Fume generated in the kiln was extracted and the calcine product collected in a system consisting of a cyclone, baghouse and extractor fan. The calcine product collection arrangement is shown in the next photograph. The discard slag product was also collected from the discharge end on the kiln and sent for sample preparation and assay.

Figure 3 : The calcine collection system

The pilot plant is fitted with thermocouples and the necessary equipment was available to be able to record temperatures of the kiln shell and various other items on a routine basis. The routine recording of the temperature in the baghouse is shown in the photograph below.

Figure 4 : Monitoring the temperature in the baghouse

3.6 Parameter Test Work

The first set of test work was done to establish the ideal operating conditions for the different samples. The two samples with the higher grades of respectively 25% and 15% zinc were tested first to establish the effect of various parameters.

Once the effect of the various parameters was understood a series of tests was conducted on an ore blend equivalent to a grade of 10% zinc to confirm the findings observed on the other two samples.

The parameters tested were:

- Plant feed rate;
- Residence time;
- Anthracite ratio;
- Temperature;
- Zinc content;
- Pellet binder.

Each test is run over a day as the residence time of a single test can be up to six hours. Samples are collected at various intervals and only once the plant has reached steady state.

The samples were submitted to the assay laboratory where they were split and assayed. The author inspected the assay laboratory and found that it was operated at a high standard and that the necessary quality control procedures were in place.

3.7 Continuous Pilot Plant Test Procedure

Once the effect of the various parameters was understood the optimum operating conditions were identified for the purpose of conducting a continuous pilot plant campaign.

The objective of the continuous pilot plant campaign was to confirm the design parameters for future engineering design. Furthermore, operating the pilot plant over a long continuous period provided the opportunity to determine the variability in the pilot plant operation and develop a relationship between the recovery of zinc and lead to the calcine product, and the grade and zinc and lead respectively in the calcine product.

It also afforded the team the opportunity of increasing the inventory of high quality calcine product for future metallurgical test work required in defining the downstream processes required to produce a saleable product.

4. RESULTS AND DISCUSSION

4.1 Results of the Parameter test work

4.1.1 Calculation of the Recovery

Metallicon visited the plant in the week of 7 June 2010 and it was apparent that using sample masses for the calculation of recovery was not viable.

For this reason it is recommended that a version of the “two-product formula” is used for the calculation of the zinc recovery. The formula used is widely used on metallurgical operations where the availability of accurate mass flows is not possible. Reference to the use of the “two-product formula” can be found in most metallurgical text books.

The modified expression developed by Metallicon considers the assays for zinc (Zn) and iron (Fe) in the calculation of the zinc recovery, and the use of lead (Pb) and iron (Fe) in the calculation of the lead recovery. As an example the expression used for the zinc recovery is:

$$Recovery\ of\ Zinc = \frac{C_{Zn}}{F_{Zn}} \times \frac{F_{Zn} - \frac{F_{Fe}}{S_{Fe}} S_{Zn}}{C_{Zn} - \frac{C_{Fe}}{S_{Fe}} S_{Zn}}$$

where:

C_{Zn} is the Zn assay in the calcine
F_{Zn} is the Zn assay in the feed
S_{Zn} is the Zn assay in the slag
F_{Fe} is the Fe assay in the feed
S_{Fe} is the Fe assay in the feed

4.1.2 Effect of Anthracite Ratio on Zinc Recovery

The consumption of anthracite is seen as a major cost item in the future operation. For that reason it was imperative that a more robust relationship between ore and anthracite tonnage needs to developed. The results of the sample containing 25% zinc and 15% zinc are plotted against the Anthracite:Ore ratio in the graph below.

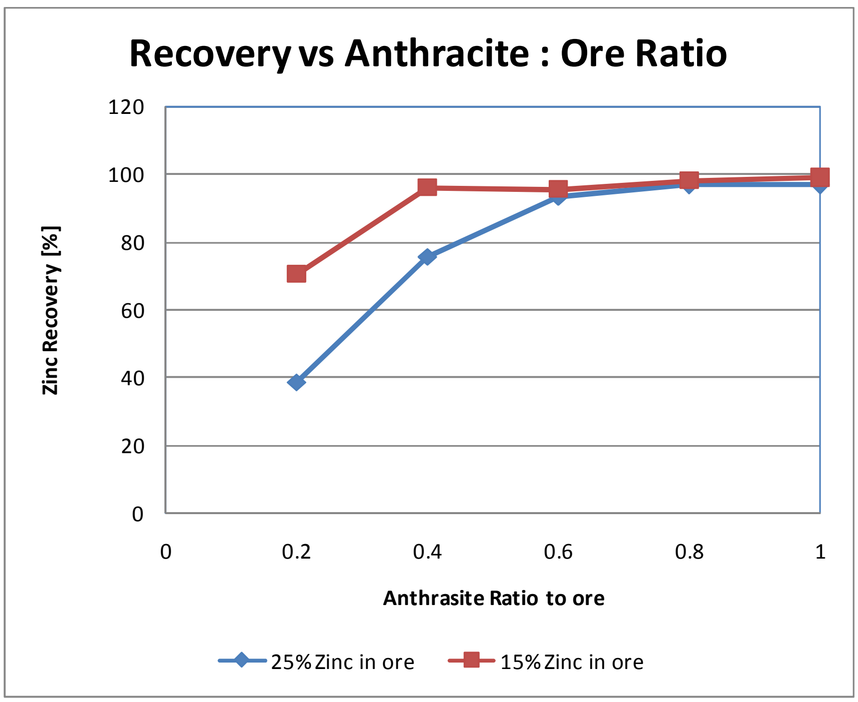


Figure 5 : Plot of zinc recovery versus the ratio of anthracite:ore

The results indicate that there is a relationship between the zinc recovery and the anthracite concentration that tends toward 100% with increasing anthracite consumption. The results also indicate that the sample containing 25% zinc requires significantly more anthracite to achieve recoveries similar to the sample containing 15% zinc. This indicates that the relationship between anthracite and the zinc content in the ore must be considered in any expression developed.

In order to determine whether this relationship could be further refined the zinc recovery was plotted against the anthracite : zinc in ore ratio. The results are plotted in the graph below.

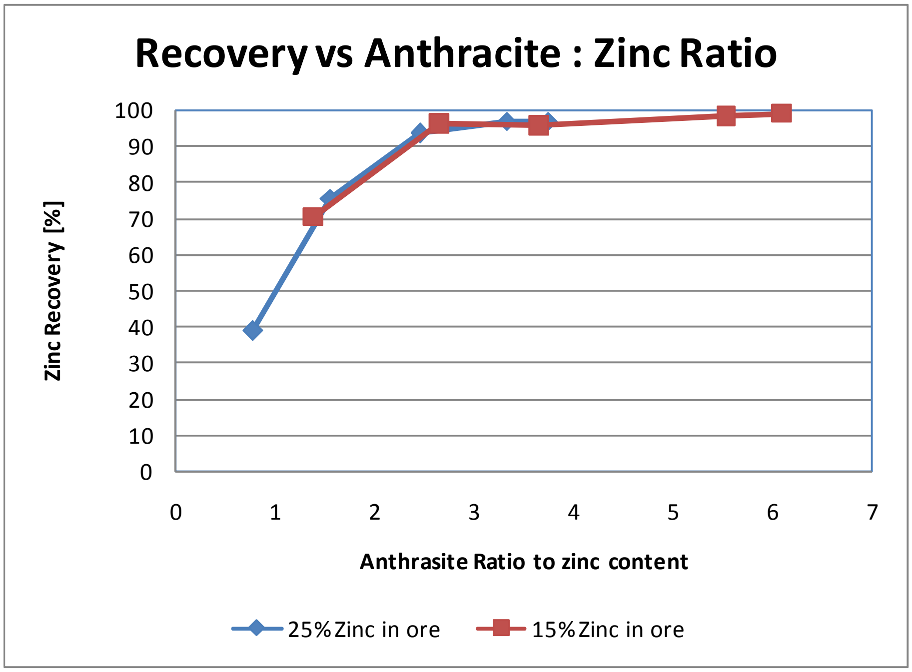


Figure 6 : Plot of zinc recovery versus the ratio of anthracite:zinc in ore

This plot indicates that a distinct relationship exists between the recovery of zinc and the ratio of anthracite to zinc in the ore for the Accha sample. This relationship should enable Zincore to calculate the consumption of anthracite necessary to achieve an optimal recovery.

The results also indicate that the operation of the pilot plant work is reproducible and of an acceptable standard.

The lead (Pb) recoveries were very high and recoveries of up to 100% were obtained in most cases. This was due to the fact that the slag lead content was below detectable limits in most cases. The one instance where the lead recovery dropped to 95% was where the ratio of anthracite to ore was 0.2:1 for the 25% zinc in ore sample.

4.1.3 Development of a Zinc Recovery-Anthracite relationship

Preliminary analysis of the data has shown that the application of an exponential relationship will be able to describe the relationship observed in Figure 7.

An exponential relationship was developed using the results of the parameter test work for the 25%, 15% and 10% samples and the constants solved for using the Solver add-in available in Microsoft Excel.

The analysis of the anthracite at Pacasmayo has indicated that the anthracite has an active content of 85%. The values for the anthracite have been changed accordingly by multiplying the anthracite masses by a factor of 85%.

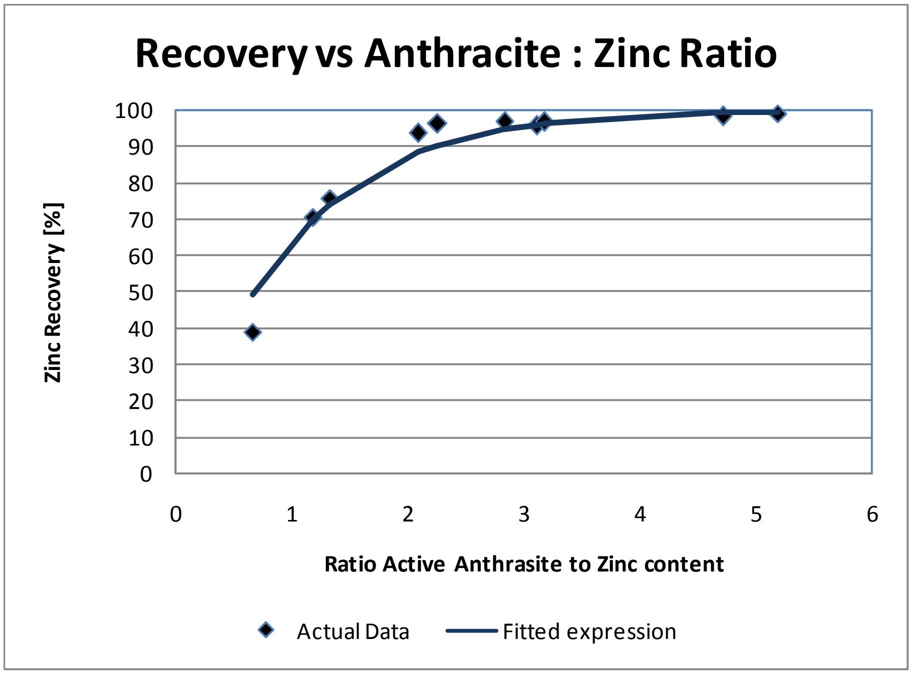


Figure 7 : Plot of zinc recovery versus ratio of active anthracite to zinc content

Although the expression developed will suffice in relating the zinc recovery to the anthracite consumption for the financial model, Metallicon is of the opinion that this empirical expression is the first step to developing a robust model.

The relationship depicted in figure 4 is given below. The expression had a correlation coefficient of 0.983:

$$Zinc\ Recovery = 100 \times \left(1 - \exp\left(-1.02 \times \frac{\%\ Active \frac{Carbon}{100} \times Mass\ anthracite\ [kg]}{Mass\ zinc\ in\ feed\ [kg]}\right)\right)$$

It must be noted that the refractory installed on the pilot kiln is not ideal and that an outside heat source in the form of gas burner was used. The results can be used for determining the cost of anthracite however further work must be done to model/describe the energy balance in the kiln.

The gas lance arrangement is shown in the following photograph.

Figure 8 : Gas lance on slag end of kiln

4.1.4 Optimum Process Parameters

A total of 56 tests were run on the Accha sample in gaining an understanding of the effect of the various parameters.

The test work for the three sample types complimented each other and the results agreed for the various parameters considered. The settings for the various parameters that yielded the best zinc recoveries to the calcine product are tabulated below.

Parameter	Setting
Residence time [hours]	5
Feed rate [kg/hr]	15
Pellet binder required	NO
Anthracite ratio [kg anthracite/kg zinc]	4
Temperature [^{o}C]	1150

4.1.5 Results Achieved in Parameter Test Work

The parameters in discussed in section 3.6 were varied in order to determine the optimum conditions for the recovery of zinc and lead from the Waelz kiln. A test programme was developed and the various parameters were tested on the three samples with the head grades of 10%, 15% and 25% zinc. The best recoveries with the associated zinc grade in the calcine achieved in the parameter test work are tabulated in the following table.

Zinc Feed Grade [%]	Zinc		Lead	
	Recovery [%]	Grade [%]	Recovery [%]	Grade [%]
25%	98.7%	53.68	>99	2.33
15%	96.7%	52.96	>99	4.2
10%	92.1%	52.48	>99	3.4

The major contaminants are chlorine, fluorine and arsenic and the concentrations in the calcine are circa 0.5%, 0.5% and 0.2% respectively. The results are very variable and high values are observed for tests that have poor zinc recoveries i.e. insufficient dilution of contaminants by zinc and lead in the calcine. The results for the chlorine and fluorine were higher than that observed in the laboratory tests of 0.13% and 0.17% respectively. Calcining of the laboratory product yielded very low levels of both chlorine and fluorine at <0.01%.

The fume generated in the kiln can be observed in the following photograph.

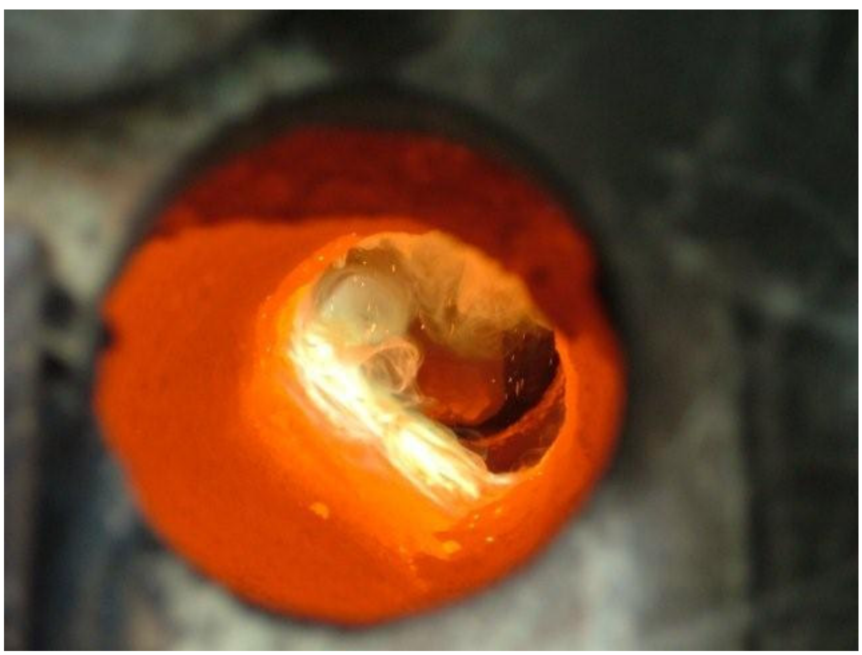


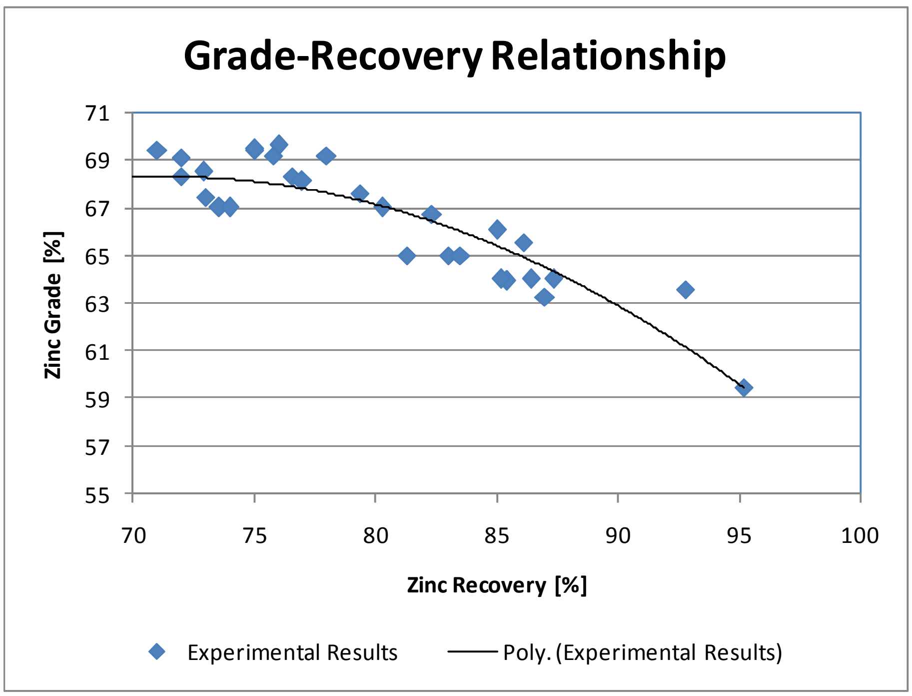
Figure 9 : Fume containing zinc and lead within kiln

4.2 Results of the Continuous Pilot Plant Campaign

In conducting the continuous pilot plant test the pilot plant was operated at the optimum conditions identified and samples were taken every two hours to determine the variability in the results.

The average zinc recovery of the continuous pilot plant campaign was 92.5% at a zinc calcine grade of 65.5%. The average lead recovery to the calcine of the continuous campaign was very high and the lead could not be detected in the slag sample. The recovery is therefore reported as >99% at a lead grade in the calcine product of 7.7%.

The calcine zinc grades and zinc recoveries varied throughout the continuous run. The variability in the results is illustrated in the grade-recovery curve below. This relationship was generated from the assay of the samples taken on a two hourly period.



The above relationship clearly indicates the relationship between calcine grade and recovery.

4.3 Calcine Inventory

The calcine produced during the tests has been collected and properly bagged for future test work. A total of 573 kilograms of calcine material is available.

The grade of the calcine is variable and sufficient mass is available of the different qualities to test the susceptibility of downstream processes to variable calcine grade.

5. CONCLUSIONS

The pilot plant campaign performed on the Accha samples can be regarded as a success and has met the objectives originally specified on commencing the programme.

The test work has confirmed the initial laboratory test work conducted at Mintek with zinc recoveries in excess of 90% and calcine grades in excess of 65% zinc. The lead recoveries surpassed the laboratory recoveries to such an extent that the lead was deemed to be below detectable limits in the slag produced. The lead grade in the calcine was found to be in excess of 7%.

Assuming that the zinc and lead in the calcine occurs as zinc and lead oxide, the concentration of zinc oxide (81%) and lead oxide (9.5%) in the final concentrate is 90.5%.

The concentration of other elements such as chlorine, fluorine and arsenic were found to be 0.66%, 0.71% and 0.17% respectively, that is higher than previously observed in the laboratory. This indicates that a second calcining stage may be required to reduce these high concentrations.

In studying the effect of feed grade on the performance of the kiln, analysis of the results could not identify a robust model relating the zinc recovery to the zinc grade in the feed. The samples containing 10%, 15% and 25% zinc produced very similar results under optimal conditions. The optimal conditions yielded a a calcine zinc grade of circa 52% and a zinc recovery was in excess of 90%.

A better understanding has been gained of the effect of various parameters on the performance of the Waetz kiln. The pilot plant campaign has also produced valuable design data that can be taken forward in the future engineering design study. The refractory installed on the pilot kiln is not ideal and further work may be required to clearly describe the energy balance around the kiln for design purposes.

The anthracite consumption is significantly lower than initially expected and a robust model has been developed describing the anthracite consumption in relation to the zinc content in the ore. For the Accha sample a ratio of 4 kilogram of anthracite is required per kilogram of zinc in the feed.

The pilot plant campaign has produced in excess of 500 kilograms of calcine for further test work. The calcine is of varying grade lending itself to variability test work for the design of downstream processes.

A grade-recovery relationship has been developed during the continuous run that illustrates a commonly observed trend that an increase in the grade of the calcine results in a decrease in the zinc recovery to calcine. The continuous run yielded an average zinc recovery of 92.5% at a calcine grade of 65% zinc (81% zinc oxide). The recovery could be increased to 95% with a decrease in the calcine zinc grade to 59%.

The lead grade in the calcine product for the continuous run was found to average 7.7% (9.5% lead oxide) with a lead recovery in excess of 99% to the calcine product.

Further downstream test work will indicate what the optimal grade-recovery scenario will be for a financial and process related perspective.