**ZINCOX RESOURCES PLC**

**JOINT EVALUATION AND EXPLOITATION AGREEMENT**

**in respect of the**

**TSUMEB SLAGS**

**REPORT OF PHASE 1**

April 2002

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**1. General description of the project.**

**1.1 The project.**

The production of a secondary zinc oxide from the lead blast furnace slag stockpiled at Tsumeb. This secondary zinc oxide will contain exotic metals like Germanium, gallium and indium. The zinc oxide will be sold or toll treated by companies equipped to recover zinc and these metals. The value of the exotic metals contained in the slag represents 60% of the zinc value.

**1.2 Feed: Lead slag stockpiled at Tsumeb.**

The Blast furnace stockpiles at Tsumeb have been extensively surveyed and sampled in the past by Tsumeb Corporation to extend the resources. The exercise was competently performed and was confirmed by reference to the plant records.

The lead slag dumps at Tsumeb contain in excess of 1.800.000 tons of material with the average analysis: Zn 9.99%, Pb 2%, Ge: 365 ppm, As: 0.33%, Cu 0.45%. The germanium contained in the slag dumps in Tsumeb is one of the most important germanium reserves, known in the world.

The slag contains also Ga and In, but for these two elements, no systematic analyses have been made. Some bulk samples have been collected and the average of the analysis of these bulk samples is Ga 200 ppm, In 170 ppm. If in the past, Zn and Ge were the most interesting metals to be recovered on an economical point of view, to day Ga is also an interesting metal due to the fact that the world market has increased quite a lot and that the selling price is comparable to the germanium price. Thus, it is necessary to make a precise estimation of the gallium and arsenic grades of the slag. Our project will comprise a new drilling campaign and a precise estimation of the zinc, lead, copper, germanium, gallium and indium of the lead slag dumps.

**1.3 Extraction of metals from lead slag**

Different processes are applied to recover zinc, germanium, lead, indium and gallium from the lead slag. All are based on the same concepts. The slag is molten at+/- 1100°C and a reducing agent, like coal, is added to reduce zinc, germanium lead. indium and gallium. These reduced metals are volatilized from the slag and the vapors produced are re-oxidized with air at the outlet of the oven. Oxidized zinc fumes are collected in bag filters. Hydrometallurgical processes are applied to separate the metals contained in the fumes. In this project, we do not

intend to recover separately the different metals but only to produce the zinc fumes and to sell these zinc fumes to other companies. A typical analysis of the fumes will be the following: Zn 60%, Ge 3,000 ppm, Ga: 1,000 ppm, In 1,000ppm. This typical analysis is based on results obtained in slag fuming plants but not on tests run on Tsumeb slag.

**1.4 Choice of the process**

Two processes will be studied in the pre-feasibility: the Ausmelt and the Primus processes.

**1.4.1 The Ausmelt oven.**

An Ausmelt furnace has been commissioned by Tsumeb Corporation Limited in the 90ties to process lead concentrates from Namibian mines secondary materials from the existing copper smelter. The goal was to replace the existing sinter plant/ blast furnace.

This Ausmelt furnace has never worked properly, and the project was abandoned rapidly.

The two main reasons were: firstly, the corrosion by the slag and the fumes of the fired bricks at the top of the oven and secondly the blocking of the fumes cooling system with accretion of fumes.

Korea Zinc built also in the 90ties an Ausmelt furnace to process lead blast furnace slag and has also encountered the same problems as Tsumeb, but Korea Zinc has developed the process and has made technical improvement. Today, they consider that the process is industrial, and they have created an engineering company to develop the process worldwide.

Industrial tests can be made in their Korean plant to test the process on the Tsumeb slag. It is.

very important to be able to test the treatment of the slag on an industrial scale because until now, the volatilization yield of the exotic elements is not well known on a Ausmelt oven. The recovery yield of those elements will be a determining factor for the economy of the projects.

**1.4.2 The Primus oven.**

Recently, Paul Wurth, an engineering company, has developed with Arbed, a European steel producer, a process to treat the EAFD (electric arc furnace dust). EAFD is a secondary material from steel produced on electrical arc furnaces. This material contains mostly iron.

and zinc.

The Primus oven is a vertical multi-hearths furnace. The slag blended with coal is progressively reduced in the different hearths of the furnace. The zinc compounds are reduced, and zinc is volatilized. The zinc vapors containing also the rare elements are re-oxidized at the outlet of the furnace and collected in bag filters. The iron compounds, mainly iron oxides, are also reduced to metallic iron. The clinker collected at the bottom of the oven is molten in an electric arc furnace where molten slag and cast iron are produced.

Paul Wurth has tested several slags containing zinc and has obtained very good yields of zinc.

volatilization. Production of cast iron is not a must in the project. The decision to produce cast iron will depend on the iron grade of the feed and on the local price of cast iron.

In the multi-hearth furnace, the material is kept in a solid form. One of the problems of the Ausmelt furnace, the corrosion with the molten slag of the fired bricks is, in this way, not encountered. The blocking of the fumes cooling system with accretion of fumes has also been observed in the Primus oven, but Paul Wurth has been able to solve the problem by choosing the adequate cooling temperature profile.

Paul Wurth has two pilot furnaces: a discontinuous oven with only one earth and an industrial

oven of small capacity (+/-50 tpd) but working continuously. In this way, it will be possible to obtain precise recovery yields for all the metals and particularly for the exotic metals.

**2. Market of the zinc oxides fumes**

The zinc oxide produced will be sold or toll treated by companies able to recover zinc and the rare metals. Today there is no existing company equipped to recover or to enhance the value of all the interesting elements contained in the zinc oxide fumes. Existing companies can recover zinc, indium and germanium but not gallium. The concept we intend to apply to recover also gallium will be that the Joint Venture (ZincOx- Ongopolo) remains the owner of the residue obtained after the recovery of zinc, germanium and indium and sell this residue to a company, which will be equipped to enhance the value of the gallium.

**2.1 Germanium.**

Germanium is produced largely as a by-product of zinc refining. Two zinc mines, located in USA, Gordonville in Tennessee and Red Dog located in Alaska, are the most important sources of germanium.

The underground mine located in Tennessee is a marginal zinc mine due to the low zinc grade of the ore. The ore contains 3.1% of zinc, 15 to 25 ppm of Germanium and 25 to 30 ppm of gallium. The mine has been operating for more than 25 years at an extraction rate of 1,700,000 tons of ore per year. It represents between 25 and 35 tons of Germanium per year, 25% of the to day consumption of Germanium. The ore after concentration by floatation is treated in the Clarksville smelter where the germanium and gallium are concentrated in a residue containing 0.6% of germanium. This residue is sold to Umicore and treated in Olen in Belgium. Umicore produced in final products 60 tons of germanium per year.

The second important source of germanium is the Reddog owned by Teck Cominco and located in Alaska. Reddog is the most important zinc mine in the world. The germanium grade is lower than the germanium grade of the Gordonville ore. The ore after concentration is sold to different smelters around the world and a lot of smelters not equipped are not recovering the Germanium. One of the reasons is that the smelters are treating the Reddog concentrates blended with other concentrate to diminish the germanium grade of the feed because traces of germanium in the electrolyte will increase significantly the energy required to produce zinc. Probably, only Cominco in its Trail smelter is recovering germanium from the Reddog concentrate and from other concentrates (Sullivan in the past, Pend d'Oreille in the future). The quantity of Germanium recovered is not published. Competitors of Teck Cominco estimate the quantity recovered between 10 and 15 tons per year.

New production of germanium has appeared recently in China and in Russia. The Germanium is recovered from zinc ore but also from coal ashes in these countries. The quantities produced are not well known and in China the production is erratic. Plants are stopped if the Germanium price is too low.

Germanium is currently used for fiber optics, polymerization catalysts, semiconductors, infrared optics. Fiber-optic systems constituted the major end-use of Germanium, accounting for about 44% of the market, polymerization catalysts accounted for 22%, infrared optics 11% electrical /solar applications for 17%.

The world consumption is estimated today at 120 tons per year, twice the consumption of the last 90ties and the increase of annual consumption is around 5%.

The electronic grade of "six nines'' priced between USD650 and USDl,700 with an average.

price for the last five-year ofUSDl,000. Today the price USD650 is depressed.

The major final product producers of germanium are Umicore in Belgium (50% of the world production), Eagle Picher in USA, and Metal Europe in Europe. Recently Teck Cominco bought a German company specialized in the production of Germanium dioxide used as a polymerization catalyst and such has become an important final germanium producer.

In Japan, Sumitomo is developing its market in final products.

**2.2 Gallium.**

Gallium is frequently derived from bauxite ore. It is extracted from sodium aluminate solution produced in the Bayer process. The most important source of gallium is the Australian bauxite. During years, Rhone Poulenc with the help of Pechiney have controlled the market of the recovery of gallium from these Australian bauxites but recently Rhone Poulenc has sold its interests in the gallium business to another French company. France remains following the USA statistics the first source of metal for the American market. This metal (four nine) has to be refined to produce extra high pure metal used in the different compounds produced.

There are no precise figures of world production. In 2000, world primary production was estimated to be about 100 metric tons per year. Following other sources, the Japanese market of gallium was 170 metric tons in 2000. Recently, the world's largest gallium metal producer, GEO Specialty Chemicals Inc, has built a new facility that has quadrupled GEO's virgin gallium capacity to over 130 tons per year. In 2001, Sumitomo has also announced that a joint venture will be created in China with a local partner to produce 50tpy of refined gallium. The increase in gallium consumption has been higher than 10% during the last five­ year period. Today the market is depressed but some gallium producers expect a shortage of gallium, particularly in the second half of 2002.

Gallium arsenide and Gallium nitride are important compounds used in advanced semiconductors and other electronic applications. About 44% of the gallium consumed in USA is used in the opto-electronic devices, which include light-emitting diodes (LEDs), laser diodes, photodetectors and solar cells. Semiconductors and their implementations in integrated circuits represent 51% of the demand.

The electronic grade of"seven nines" priced progressively from USD425 in 1996 to USD640 in 2000. In 2001, high variations of the gallium price have been observed. In July, the allium 99.99% from Chinese origin has raised up to USD2,100 on the Japanese market. Today the price of the same quality has dropped to USD 550.

**2.3 Indium.**

Recovered almost as a by-product of the zinc industry, but some indium is also recovered from the lead and the copper industries. They are more producers of indium than of Germanium and of gallium. The most important producer of indium metal are also producers of germanium: in Europe: Umicore and Metal Europe, in Canada: Teck Cominco.

While the first major commercial application for the metal was dental alloys, today indium is used chiefly for thin-film coatings in electro-luminescent lamps and liquid-crystal displays.

Solders and alloys are also important applications. Indium semiconductor compounds are also used in photovoltaic devices, infrared detectors, high speed transistors and certain applications.

The estimated distribution of applications in the USA in 1997 was about the same as in 1996, with coatings accounting for 45% of the uses; solders and alloys, 35%, electrical components and semiconductors, 15%.

While for Germanium and gallium a very high purity (level of impurities: ppb) is required for all the applications, a large portion of the indium uses does not require such a high purity: coatings, solders and alloys. Thus, there is still an important market for an indium metal specification of 99.99%.

The production has been estimated at 220 tons in 2000. The increase in indium consumption has been higher than 5% during the last five-year period. After 3 years of relative stability (USD300-USD 370 per kilogram, Indium 99.97%), the price of indium dropped in 2000. Expanding LCD manufacture was more than matched by adequate supply and greater efficiency in processing. Despite a strong increase in LCD production, the ready availability of low-priced indium from China forces world prices down. The long-range outlook for the indium market remains promising despite current market term fluctuations.

**2.4. Conclusions.**

Even if the consumptions and the prices of Germanium, gallium and indium have diminished in 2001 and probably in 2002, all the important producers questioned believe that futures of the uses of these three metals remain very positive and that the annual consumption growth will exceed 5%. They believe that the market will recover in 2003.

The economic sources of these metals are limited. Due to the fact that these rare metals are by products of the production of other common metals, the available quantity of rare metals depends on the consumption of these common metals.

**3. Market for the zinc oxide fumes**

If the quantity of slag that we intend to retreat is 100,000 tons. Based on the KZ Engineering data and on the average grade of the slag, 12,300 tons of zinc fumes will be produced. The content of the fumes will be Zn 58%, Pb 16%, Ge 3,000ppm, Ga 1,000ppm and in 1,000ppm.

The quantity of Germanium contained in the fumes 36,900 kg represents approximately 25%.

of the germanium market. It means that the market will have difficulties absorbing that quantity immediately and that other production will disappear or stop. Based on an annual increase of 5% of the consumption and on an 80% of germanium yield, the market will need 5 years to absorb this quantity.

**3.1. Existing processes and plants to recover the metals contained in the zinc fumes.**

All the processes are based on the recovery of zinc and secondary to produce different residues or purified products containing the rare metals separately or together.

Zinc can be recovered by an electrolytic process or by a thermic process. The electrolytic process will give higher rare metals recoveries than the thermic process.

**3.2 Contacted companies.**

**3.2.1 Umicore, Belgium.**

Umicore is recovering the germanium (30 tons) contained in the residues produced in the Clarksville plant in Tennessee (USA). The plant is located in Olen in Belgium. This residue contained also gallium (40 tons) but in the 90ties, this rare metal was not recovered. Today Umicore is very discreet on this point but probably they are producing a concentrate of gallium sold to other companies producing final products of gallium.

Umicore also producing indium and can be interested in the indium contained in the fumes. Umicore has studied in the past the recovery of the zinc and the rare metals contained in the fumes that Tsumeb Company intended to produce in the past.

They are interested in the fumes, but they will be obliged to invest to treat these fumes. They are doing a study to define the investment and the operating costs to process the totality of the zinc fumes we intend to produce in Tsumeb. They promise to submit a budgetary offer by the end of April. To confirm their offer, they need to obtain a representative sample of the fumes to run some tests.

Umicore is interested in fumes for several reasons. The future of their main source of the Germanium, the Gordonville mine, is not absolutely secured. Umicore has an expansive strategy and wants to increase their market share. They believe that the market will grow in the future. They want also to assure their clients that they will always be able to deliver the final products and that they will never have a lack of feed. Recently, Umicore has invested in a recycling plant of germanium scraps in Belgium and in the production of germanium chloride in USA.

**3.2.2. Metal Europe, France.**

Metal Europe is recovering rare metals: germanium, gallium and indium in their ISF plant located in Noyelles Godault in France. The ISF furnace produces zinc and lead simultaneously. The rare metals are volatilized with the zinc and condensed in the zinc metal condensed on the top of the furnace. The rare metals are concentrated in the metallic residue obtained during the purification of the zinc by distillation.

The rare metals are extracted from the metallic residue with a hydrometallurgy process. Metal Europe is producing final products in a German plant of the three rare metals: germanium, gallium and indium.

Zinc fumes produced in Tsumeb interest them, but they do not want to submit a budgetary offer without having received a representative sample. The reasons are not very clear. They are treating this type of material in their Noyelles Godault plant. They have also mentioned that they could not be competitive compared with other potential buyers. In any case, we have to contact them again when representative samples are available.

**3.2.3 Eagle Picher, USA.**

Eagle Picher was in the past an important zinc producer in USA Eagle Picher was the first producer of electronic Germanium just after the Second World War. Today, they are producing final products of germanium, gallium and indium of ultra-high purity and compounds for semiconductors and telecommunications. They are the second producers of final products of Germanium after Umicore.

They would consider purchasing a portion of the production of fumes that include germanium, gallium and indium. Following Eagle Picher, there are several important upcoming uses for these materials, as well as the current markets and with a revived world economy over the next years the demand should be substantial.

As for all the firms contacted, Eagle Picher wants to receive a representative sample of the fumes to submit a budgetary offer. Requests have been made to Eagle Picher to obtain a budgetary offer without the delivery of a sample explaining them that we intend to produce zinc fumes in the second stage of the study but that we need to obtain a budgetary offer to value the profitability of the project before running an industrial tests.

**3.2.4 Sumitomo, Japan.**

Sumitomo is a newcomer in the market of the rare metals. They want to fill the lack of Japanese producer while Japan is one of the most important consumers of compound for the electronics, semiconductors and telecommunications.

Sumitomo has recently created a joint venture in China to produce very high purity gallium metals. They intend to produce 40,000 kg of high pure gallium per year. We do not know the process applied by Sumitomo to recover zinc, lead and the rare metals.

Sumitomo has directly contacted us to find out if materials will be available. They could be interested in the total production. Again, they are asking a representative sample to be able to submit a budgetary offer but like Umicore they agree to prepare this offer taking into account fumes analysis based on the average grade of the slag and on the KZ Engineering pre-feasibility assumptions. The offer has to be transmitted in April.

**3.2.5 Meldform Metals, United Kingdom**.

Meldform Metals has been interested in the past to establish a Joint Working relationship with Ongopolo to run pilot plant tests. Recently they sold their German subsidiary (Melform Germanium Ag) to Teck Cominco. Meform Germanium is specialized in the production of germanium dioxide used as polymerization catalysts.

Meldform metals are not more interested in purchasing fumes having no more interests in the

germanium, gallium and indium business.

**3.2.6 Teck Cominco, Canada.**

Teck Cominco is involved in the germanium and indium business, and they are producing germanium and indium metals in Trail Canada. They are producing zinc fumes like we intend to produce in Tsumeb but in an existing slag fuming oven and not in an Ausmelt furnace.

The fumes are leached to recover zinc, and germanium is extracted by solvent extraction from the zinc liquor. The Germanium is re extracted from the organic phase and precipitated with soda as germanium hydroxide. The germanium hydroxide is purified and transformed to obtain the different compounds. It is also possible to extract the gallium and the indium separately from the zinc solution. No information is available concerning the flow sheet used to recover these elements in Trail.

Trail is surely the best adapted plant to treat the fumes produced in Tsumeb and the investment required will be negligible.

Contacts have been taken with the manager of the germanium business unit but until now, we have not obtained answers.

**3.2.7 China**

A company located in Daojiao Dongguan is processing differently by products to recover germanium and indium. We have contacted them to offer them the fumes we intend to produce. Again, they are asking for representative samples of the fumes. We have decided to wait until samples are available to contact them again. Indeed, the contact in English is difficult and we need to prepare documents in Chinese or to have discussions in Chinese.

**3.2.8 Russia**

A Russian company, Germanium State Company, has been recently created in Russia. The main activity of the company is to produce compounds in Germanium and gallium for the end users of rare metals. Several feeds are treated, scraps coming from the end users but also residues or concentrate coming from the non-ferrous industry and particularly from the zinc industry. Contacts have been taken with this company but without success until now.

**3.2.9 USA**.

Contacts have been taken also with Atomergic Chemetals, a company producing compounds in rare metals. They are not interested in the fumes. They are only reprocessing scrap from the end users and not primary materials.

**3.2.10. GAA, France.**

Contacts have been taken with the important French producer of gallium metal. The feed is essentially gallium concentrates coming from the Australian aluminum business. This company is not interested intreating the zinc fumes. They could be interested in a gallium concentrate where the only metal to be recovered will be gallium. They naturally want samples of the gallium concentrate.

**3.2.11 Pasminco, USA**.

As has been mentioned before, Pasminco is exploiting the Gordonsville mines and the Clarksville zinc smelter in Tennessee USA. The Gordonsville mines contain germanium and gallium. These two rare metals are recovered with high yields in a leaching residue produced in the zinc smelter. This residue is sold to Umicore in Belgium that produce rare metals.

The Ongopolo zinc fumes could be treated in the Clarksville plant with the same flow sheet as the Gordonville concentrate. The roasting stage will not be necessary, but the leaching stage will be the same: the zinc will be leached, and the three rare metals will be concentrated in the leaching residue. This residue can be sold to different companies like Umicore, Eagle Picher but also Metal Europe could be interested in recovering the rare metals simultaneously with the lead contained in the residue.

Until now, we have not contacted Pasminco because the company has financial difficulties and is managed by administrators. These administrators have decided to sell the United State assets of Pasminco, and the assets have to be sold before we can have contact with the new owners.

**3.3. Conclusions.**

It will be very difficult to obtain a precise idea of the value of the fumes at this step of the study. The main reason is that we cannot provide representative samples to the direct potential purchasers of the fumes. Another reason is also that we are not able to define with the potential purchasers of the fumes the characteristics of intermediate concentrates (gallium concentrate as an example) that will be delivered to other companies interested in processing metals that the first purchasers would not be interested to produce or recovering.

The results of this first enquiry are, however, positive. Three of the most important companies in the zinc and germanium business are interested to sign long term contract with the joint venture for buying the totality or a portion of the production even if they consider that the quantity of germanium is very important and can have in the first years of production a serious impact on the germanium price. The level of the price of Germanium metal is not so

important for the producers of Germanium compounds because the germanium metal price can always be reflected in the final products. The selling price of some final products could be ten times higher than the metal price of germanium. They are looking essentially for stable and secure feed.

**4. Bulk sample for pilot tests.**

The contents in rare metals: germanium, gallium and indium and the volatilization yields will have a very bad impact on the profitability of the project.

In the first stage of the study, the figure collected annually in the past by Tsumeb Corporation will be used as reserve estimation and for the average essays of the slag. The gallium and indium have not been analyzed during the production years but later some representative samples have been taken and analyzed for Gallium and indium. Gallium and indium found on these samples will be used for the economical evaluation.

20 samples of25 kg have been collected close to the surface of the slag damp to obtain a new representative sample of the slag damp. This sample will be used to run tests on the Paul Wurth oven in Luxemburg.

Unfortunately, the analyses found for germanium in CTP were very low in the order of 50ppm. A sample of the 20 sent, has been sent back to Ongopolo to be analyzed, and the same sample has been sent also to Louvain University and to Umicore to analyze the germanium.

Germanium analyses

CTP 50ppm

Louvain University 55 ppm

Umicore 90ppm

Ongopolo 155 ppm

The variation of the analyses is too high. It is well known that it is difficult to analyze germanium in slag but we have to review the analyses and obtain coherent analyses from several laboratories. The low level of the germanium analyses found can be explained by the fact that the samples have been taken close to the surface of the slag deposit and the germanium grade in the last years of the production period of slag was lower than in the preceding year: 220ppm in 82 and only 140ppm in 83.

A new sample of slag has been taken by Ongopolo deeper in the slag deposit. The germanium content found by Ongopolo is higher. Several analytical samples will be sent to several laboratories to study the variation of the analyses. It is only when we are sure of the accuracy of the analysis that we will review the program of the reserve estimation. Zinc, gallium and indium will also be analyzed by the different laboratories.

**5.Mission of KZ Engineering in Tsumeb.**

A mission of two engineers ofKZ Engineering has been sent to Tsumeb to study the possibilities of recovering some equipment of the existing Ausmelt oven to treat 100,000 tons of slag per year. KZ Engineering has to provide a pre feasibility based on the final conclusions drawn at the end of the mission.

The first Ausmelt furnace built at Onsan in 1992 was a slag fumer for treating slag from a QSL lead plant. The first oven was similar to the Ausmelt oven built in Tsumeb. But Korea Zinc has been obliged to introduce different modifications in the process to obtain good zinc volatilization but also in different construction concepts.

To day, the slag fumer installations in Onsan are running continuously and two ovens are operating in series. The construction of the ovens has been totally modified and a shell steam boiler has been built on the top of the oven. The results are that there is no more corrosion of the refractory no important accretion and some energy can be recovered from the steam produced.

After all these modifications, the availability of the Onsan plant has grown from 47% to 90%. KZ Engineering has also experienced a process with one oven or with two ovens in series.

Particularly when the products loaded have to be remelted, it is difficult to obtain good volatilization yields in one oven. All the installations operating in Onsan will have two ovens in series.

Also after the visit of the site with the engineers of Ongopolo, we have decided that the pre feasibility and the estimation for the investments and for the operating costs will be based on a new plant The localization of the new plant has been chosen by the Ongopolo engineers.

Some equipment of the existing Ausmelt plant could be recovered for the new plant but it will be determined during the detail-engineering period.

**6. Pre Feasibility study.**

**6.1 Process design.**

The process design characteristics described in the pre feasibility study takes into account the local available products like coal, fuel oil , fluids and the local climatic data.

A mass balance has been established taking into account the slag and the coal analysis. The volatilization yields are based on the results obtained in Onsan on lead slag containing zinc but also low quantities of rare metals. KZ Engineering did not give volatilization yield for gallium because there is no gallium in the slag treated in Onsan. In volatilization tests

made in the past on Tsumeb slag, a volatilization yield of 50% has been obtained. We have taken this figure for the economical valuation of the project.

An oil lance was used for the previous Ausmelt operation and an evaluation has been made to

compare the two systems: oil and coal. The coal system requires a quite high investment cost ( coal grinding and supply system on pulverized coal under an inert atmosphere) but the lower coal price compared with the oil price will pay back the increase of investment in two years..

The volatilization yields estimations are the following:

Zn Pb As Ge In

1st oven 50% 70% 80% 70% 50%

2nd oven 50% 70% 50% 80% 50%

Total 75% 92% 90% 94% 75%

12,034 tons of fumes will be produced annually by the two ovens and the average analysis of the fumes (1st oven and 2nd ovens) will be the following:

Zinc 59.23%

Lead 16.68%

Arsenic 2.26%

Germanium 2,929ppm

Indium 1,059ppm

One important modification of the project has been the production of steam of the two ovens. The total production will be 20t/h. The characteristics of the steam are similar to the characteristics of the steam produced in Onsan but these characteristics are not suitable for the existing turbine in the Ongopolo plant. KZ engineering has to study the modification of the steam production system to obtain a steam having the adequate characteristics.

**6.2 Capital cost Estimate.**

KZ Engineering describes in their pre feasibility study the methodology used to determine the investment costs. As it is mentioned in the pre feasibility document, some investments are not comprised in the budget established by KZ Engineering.

**6.2.1. Production of oxygen and nitrogen.**

This equipment is not comprised in the budgetary offer of Z Engineering. Ongopolo has asked Afrox, his supplier of oxygen to submit an offer for the delivery of the two gases in the quantity and the quality required for the project. On the other hand, ZincOx has asked Air Liquide to submit a budgetary offer for the delivery of an installation able to deliver the necessary quantities of oxygen and nitrogen.

The two offers have been compared. The first conclusions are that the energy required by the Air Liquide plant will be the half of the energy that Afrox will charge. Afrox will also charge a monthly rental. If you compare the monthly rental of Afrox with the investment costs of the Air Liquide plant, the Air Liquide plant will be repaid in 3 years. The offer of Air Liquide is definitely more interesting than the Afrox offer. Air Liquide has been questioned to know if the company will be interested in the delivery of gas instead of the delivery of an installation. Their South African subsidiaries will submit an offer for delivering gas.

In our economical valuation, we will consider the Afrox offer to establish the operating costs.

**6.2.2. Energy production**

The battery limits of the steam production are the inlet of hot water at 105°C and the steam at the outlet of the boiler. Several equipment have to be added to be able to produce energy.

As it has been mentioned earlier, KZ Engineering has to study the production of steam having the same characteristics as the steam produced at Ongopolo. So it will be possible to use the existing turbine to produce energy.

To obtain the total investment required, we have to add as investment: a demineralized station, a turbo generator with his peripherique, and a cooling system to extract calories from the condenser of steam. We will suppose that a new turbine has to be built as first approach.

**6.2.3. Cooling of the oven and the air compressors**.

600 m3/hour are required to cool the ovens and the air compressors. Demineralized water is used to cool the copper finger coolers.

The inlet pumps for cooling water are not foreseen in the budget of KZ Engineering and also the cooling system of this water. The temperature of these 600 m3/h of water will raise from 35 to 50°C. I suppose that an evaporation cooling tower will be used to cool this water.

**6.2.4. Feed of slag.**

The feed system from the slag storage area to the two slag hoppers has to be added to the investment of the slag handling area.

**6.2.5. Feed of coal.**

The screening of the coal and the feed system have also to be added to the investment of the coal crushing area.

**6.2.6. Handling and packaging of the fumes.**

Two bins of 25 tons each, with their handling equipment will collect the fumes from the filter bags of the two ovens. The fumes will be packed in big bags. The big bags will be transported to the warehouse by a forklift and also with forklift from the warehouse to the trucks or the railway wagons.

**6.2.7. Total Capital Cost Estimate.**

Some amounts have to be added to the investment estimate of KZ Engineering.

All the engineering costs, erection costs and EPCM costs have been integrated in the following amounts. A contingency amount of I0% has been taken on the total costs.

The assessments are based on USA bases. It is sure that these investments can be lowered if the equipment is coming from South Africa or Namibia. Some existing equipment’s will be probably recovered.

Production of oxygen and nitrogen

Air Liquide unit 4,158 ,000 USD

Energy production

Steam Turbine 2,400 kW 1,050,000 USD

Water treatment

Demineralized unit 20 m3/h 220,000USD

Water cooling

Cooling tower 820 m3/h 225,000 USD

Slag handling

One shift per day 371,000USD

Coal Handling

One shift per day 339,000USD

Fumes handling and packaging

Two shift per day 265,000USD

KZ Engineering total capital cost estimate 32,900,000 USD

Total investment with the production of02 and N2 39,528,000USD

Total Investment without the production of02 and N2 35,370,000USD

**6.3 Operating costs**

Based on the pre feasibility study of K.Z Engineering and on information coming essentially from Ongopolo, operating costs estimation has been made. Some items of the KZ Engineering studies have been modified or introduced.

**6.3.1 Labor.**

Personnel has been increased to take into account the handling of the different products: slag, coal and fumes. Two chemists and two administrative persons have also been added. The two administrative persons have also to organize the transport of the fumes to buyers of the fumes. The total amount of personal is 25 persons.

**6.3.2 Oxygen and nitrogen.**

Two solutions have been studied the first one is to by oxygen and nitrogen to a company Afrox. The company will charge a monthly rental and a energy bill function of the quantity of oxygen and nitrogen consumed. The second is to by oxygen and nitrogen plant. The joint venture will have to support the energy consumption and the operating costs of the oxygen and nitrogen plant.

The comparison have been made of the two possibilities. Due to the important difference of the investment costs and of the operating costs, the profitability have been establish for the both cases.

The operating costs drop from 70USD per ton of slag with the Afrox solution to 46USD per ton of slag with the Air Liquide solution. The savings per year are USD 2,400,000 .

**6.3.3 Energy recovery**

The energy recovery has been based on the KZ Engineering figures of the production of saturated steam and on a new turbine generator. The figures could be modified with the study made by KZ Engineering to use the existing turbine with superheated steam. The recovery of energy has been estimated ofUSD 452,000 per year.

**6.2.4 Operating costs**

Table 1

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Item Rate | Annual rate | **N$** per Unit | Annual Amount **N$** | Annual Amount **N$** |
| **Afrox Airliquide**  **rental** investment | | | | |
| Labor |  |  |  |  |
| process engineer 1 person/day | 1 person | 300,000 | 300,000 | 300,000 |
| foreman 1 person/shift | 4 persons | 90,000 | 360,000 | 360,000 |
| Shift operator 2 person/shift | 8 persons | 60,000 | 480,000 | 480,000 |
| Day operator 6 persons/day | 8 persons | 42,000 | 336,000 | 336,000 |
| Analyses 2 persons | 2 persons | 80,000 | 160,000 | 160,000 |
| Administration 2 persons | 2 persons | 80,000 | 160,000 | 160,000 |
| Raw coal for fuel | 42,393 t/a | 380 | 16,109,340 | 16,109,340 |
| Raw coal for reduction | 4,923 *Ua* | 380 | 1,870,740 | 1,870,740 |
| Oxygen and Nitrogen |  |  |  |  |
| Afrox rental | 21,763,104 N$/a |  | 21,763,104 |  |
| energy | 35,109,776 kWh/a | 0.29 | 10,181,835 |  |
| Air Liquide Operating costs | 1,929,000 N$/a |  |  | 1,929,000 |
| energy | 14,642,857 kWh/a | 0.29 |  | 4,246,429 |
| Water |  |  |  |  |
| Demineralized | 144,800 t/a | 2.5 | 362,000 | 362,000 |
| Raw | 162,900 t/a | 0.5 | 81,450 | 81,450 |
| Cooling | 4,939,200 t/a | 0.5 | 2,469,600 | 2,469,600 |
| Diesel for F1 & F2 | 184,524 kg/a | 3.56 | 656,905 | 656,905 |
| Diesel for Coal plant | 339,144 I/a | 3.2 | 1,085,261 | 1,085,261 |
| Power | 25,728,000 kWh/a | 0.29 | 7,461,120 | 7,461,120 |

**6.2.4 Operating costs**

Table 1 continued.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Item** | **Rate** | **Annual rate** | **N$ per**  Unit | **Annual Amount N$** | **Annual Amount N$** |
| **Afrox Airliqulde**  **rental investment** | | | | | |
| **Maintenance**  Refractories  materials labor  Lance  materials labor  Equipment spare parts Mechanical  materials  labor  Pump  materials labor  Valve  labor  Painting etc  materials labor  Electricity  labor  Instrumentation  labor  **Recovery of energy Annual operating** costs  Operating costs per ton of slag | 200 I/a | | 22,000 | 4,400,000 | 4,400,000 |
| 362 mandays/a | | 240 | 86,880 | 86,880 |
|  | |  | 9,900,000 | 9,900,000 |
| 60 mandays/a | | 240 | 14,400 | 14,400 |
|  | |  | 715,000 | 715,000 |
|  | |  | 1,760,000 | 1,760,000 |
| 900 mandays/a | | 240 | 216,000 | 216,000 |
|  | |  | 770,000 | 770,000 |
| 180 mandays/a | | 240 | 43,200 | 43,200 |
| 160 mandays/a | | 240 | 38,400 | 38,400 |
|  | |  | 22,000 | 22,000 |
| 45 mandaysla | | 240 | 10,800 | 10,800 |
| 50 mandays/a | | 240 | 12,000 | 12,000 |
| 70 mandaysla | | 240 | 16,800 | 16,800 |
|  | |  | 81,842,835 | 56,073,325 |
| 17,140,800 kWh/a | | 0.29 | 4,970,832 | 4,970,832 |
|  | |  | **76,872,003 N$** | **51,102,493 NS** |
|  | |  | **769 N$** | 511 **N$** |
|  | |  | 70 USO | **46** USD |

**7. Value of the fumes.**

**7.1 Methodology.**

Until now, we have not received offers for the fumes from potential buyers. As it has been mentioned before, on of the major reason is that no representative samples have been available.

To obtain a first valuation of the fumes, the different hypotheses made are the following:

The contents of the metals in the fumes are the data given by KZ Engineering except for gallium. KZ has no experience in the recovery of this element. Also, the recovery yield chosen, 50%, has been based on preceding tests run in Ongopolo in the small pilot oven. Theoretically, the gallium evaporation is lower than the evaporation of germanium and indium.

The buyers of the fumes will pay four elements: zinc, germanium, gallium and indium. The lead contained in the fumes will not be payed.

Some penalties will be applied particularly for the arsenic content The fumes will be delivered CIF Antwerp

The payment of the zinc will be based on the formula applied internationally for the transactions between the miners and the smelters. The conditions applied are the conditions of 2002. The LME zinc price is used for the transaction.

The payment of germanium is copied on the payment conditions applied between Pasminco and Umicore. The electronic germanium metal price is used for the transaction.

Having no reference for the gallium and for the indium, the same conditions have been applied for the gallium and the indium. The reference price for indium being indium metal 99,97 instead of electronic metal price, we have supposed that the indium payment will be 50% of the value of the indium contained in the fumes instead of25% for germanium and gallium where the references are the electronic metal prices.

The value of the fumes have been reckoned for the series of metal prices, the average prices of the last five years and the recent current prices. The recent price drop of all the metals has significantly diminished the value of the fumes: USD 105 per ton of slag compared to USD 150 if the average metal prices are applied.

**7.2 Value of the fumes**

Table 2

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | **Fumes grade** |  | **Value in USD average metal price** |  | **Value in USD current metal price** |
| Zinc | 59,23% | price formula  1,100 USD/ton  0.85T X P - 195 USD per ton of fume | 358 | 850 USD/ton  0.85T X P • 172.5 USD/ton of fume | 255 |
| Germanium | 2,929 ppm | price formula  1,000 USD/ton  25% paid of the electronic metal price | 732 | 650 USD/ton  25% paid of the electronic metal price | 476 |
| Gallium | 900 ppm | Price  650 USD/ton  25% paid of the electronic metal price | 146 | 425 USD/ton  25% paid of the electronic metal price | 95 |
| Indium | 1059 ppm | price formula  250 USD/ton  50% paid of the 99.97% metal price | 132 |  | 108 |
| Other Elements | No value |  | 0 |  | 0 |
| Penalties | As,Cl,F | 60 USD/ton | -60 |  | -60 |
| Transport Tsumeb Antwerp |  | 65 USD/ton | -65 |  | -65 |
| Value per ton of fumes |  |  | 1,243 |  | 874 |
| Value of the annual production 112,034 tons |  |  | 14,958,262 |  | 10,517,716 |
| Value of the fumes per ton of slag |  |  | 150 |  | 105 |

**8. Comparison of the Ausmelt furnace and the Primus oven.**

Paul Wurth has run several tests to volatilize the zinc and the lead contained in ISF slag. The slag tested contained 6.5 % of zinc and 1.2% of lead. The volatilization yields have been respectively of 80% for the zinc and 83% for lead. This slag did not contain rare metals like germanium, gallium and indium. It is thus necessary to run tests to determine the volatilization yields for these elements before being able to establish definitively the technological and the economical interests of this new technology.

The interests of this technology are the following:

• No fine grinding of the coal

• No nitrogen and oxygen consumption

• Low air pressure less than 0.5bar compared with 3bars for the Ausmelt furnace

• No corrosion of the wall oven

• Simplified energy recovery: air heat exchanger instead of steam boiler

• No water-cooling system necessary

• Low coal consumption: 250kg/t of slag compared with 475kg/t for the Ausmelt furnace

• Energy consumption 70 kWh per ton of slag compared with 257 kWh per ton for the Ausmelt furnace

If the volatilization yields of the rare metals of the Primus oven are comparable with the Ausmelt oven, the investment costs and the operating costs will be significantly lower than the Investment and operating costs of an Ausmelt plant.

Paul Wurth evaluates the investment for a Primus oven to process I00,000 tons per year between USD 25,000,000 and 30,000,000 and based on the same unit prices than for the Ausmelt oven, the operating costs per ton of slag will drop from USD 70 and USD 46 to USO 28.

**9. Economics of the project.**

Valuations of the IRR of the project have been determined. The hypotheses are the following:

Annual quantity treated: 100,000 tons Duration of the project: 18 years

No financial lever and no tax have been applied on the profit;

Investment:

39,521 MUSD

Production of 02 and N2

Investment

35,370MUSD

Purchase of 02 and N2

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  |  |  |  |  |
|  | Average Metal prices | Current Metal prices | Average Metal prices | Current Metal prices |
| Internal rate of return. | 31% | 12% | 20% | 7% |

If the investment is 10% lower due to the recovery of some existing equipment.

Investment:

35,569MUSD

Production of 02 and N2

Investment

31,833 M USD

Purchase of 02and N2

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  |  |  |  |  |
|  | Average Metal prices | Current Metal prices | Average Metal prices | Current Metal prices |
| Internal rate of return. | 34% | 14% | 22% | 8% |

The metal prices and the production costs of the oxygen and nitrogen are determining factors on the profitability of the project.

**10. Conclusions.**

The market of all the metals and particularly of the rare metals is very depressed. Instead of having an increase of consumption, in the last five years, the market is stagnant, indeed even in decline. This situation has naturally an impact on the prices of the rare metals. A drop of 1/3 of the prices has been observed in 2001 and the prices have not yet recovered in the beginning of 2000. The optimistic believe that the price could increase again by the end of 2002.

The prices of the rare metals have a very important influence on the profitability of the project and, if we do not observe a recovery of the metal prices in the future, the project could have a too low profitability.

Even if the market is very depressed, four of the companies contacted, the most important in the transformation of rare metals in final products or compounds, are interested to create long term relations to obtain the totality or a portion of the production of fumes. We have to keep in mind that the quantity of germanium contained in the fumes will represent more than one quarter of the world germanium consumption.

It is very difficult to obtain offers from the potential buyers because no representative samples are available. The grades of the samples sent by Ongopolo are too far from the grade that will be obtained with the KZ engineering technology. However, two, even, three companies have agreed to prepare a budgetary offer based only on analyses of the fumes. Both have to invest to process this kind of materials and these companies have not yet had the time to deliver their budgetary offer for the end of April.

The conclusions of the visit by the KZ engineering engineers to Tsumeb have been a disappointment. Indeed, the most important target of this visit was to study the revamping of the existing Ausmelt furnace. Very quickly, the conclusions have been that the existing oven could not be revamped for treating the slag with the KZ Ausmelt technology. The KZ process is to day a continuous process in two ovens in series. The fuel is coal instead of fuel oil. The construction of the oven and the cooling system of the fumes are totally different than the Ausmelt oven of Ongopolo. Some existing equipment can be recovered in the future but it will only be possible to determine precisely these equipment’s during the detail engineering phase.

KZ Engineering has delivered a pre feasibility study based on a new plant, the site of which has been fixed by Ongopolo. The investment is high 32,900,000 USD. Some investments have to be added to the investment defined by KZ Engineering. The total investment estimate is 35,370,000 USD without the oxygen and nitrogen production unit and 39,528,000 USD with the oxygen and nitrogen unit.

The Ausmelt technology developed by KZ Engineering requires Oxygen and Nitrogen. These gases can be produced simultaneously in a cryogenic unit. Two offers have been studied. The first one from Afrox to deliver oxygen and nitrogen and a second from Air Liquide to buy a cryogenic unit to produce, on the site, the required quantities of both gases. The two offer have been compared on a profitability point of view. The profitability of the second offer is quite Beter, the IRR of the project increases from 20% to 31%, all the other parameters remaining constant. The production or the purchase of oxygen and nitrogen has to be studied

in detail because the influence of these parameters on the profitability of the project is very important.

During this first phase, some analytical problems of germanium have been observed: significant variations of analyses of germanium on the same sample. It is well known that the germanium analysis in slag is difficult and then often the level found of germanium is to low. The problem is totally different than the problem often encountered with gold. The germanium is totally dispersed in the slag and a "nugget effect" can not be observed.

The analytical problem of germanium and of the other rare metals has to be solved before starting a new reserve estimation of the slag.

Recently another technology has been developed to volatilize zinc and lead from several zinc oxide materials. Tests have been made on ISF slag and the zinc and lead volatilization yields are higher than the KZ Ausmelt yields mentioned in the pre-feasibility report. The investment and the operating costs will be following Paul Wurth, the firm which has developed this technology, significantly lower than the same costs for the KZ Engineering technology. But to day, Paul Wurth has no practical information concerning the volatilization yield of the rare metals. Tests have to be run to determine the volatilization yields for these metals. These tests had normally to take place during the first phase of the project but due to the problem of obtaining a representative sample of the slag, the tests will be run during the second phase.

The second phase: Piloting program has to be modified to take into account the information and difficulties encountered in the first phase. A suggested work program is annexed to this report.

**11. Work program of Phase II: Piloting.**

Follow up by KZ Engineering of the energy recovery flow sheet

Follow up of the oxygen and nitrogen production: Ongopolo and ZincOx Follow up by ZincOx of the purchasing offers of the potential buyers Analytical problems of the rare metals: ZincOx and Ongopolo

Zinc fuming tests on the small Primus pilot oven on the second sample delivered by Ongopolo.

Following the fuming results obtained on the small Primus pilot oven, the last information obtained from the potential buyers, the market of the rare metals decision has to be taken to run industrial tests with one of the two available technology.

Precise resources estimation and collection of a bulk representative sample. Industrial scale test on RBS

Fumes samples sent to the potential buyers.

New estimation of capital and operating costs Detail Ge, Ga, In market study

Fumes marketing options study.