

Intec Ltd

A.B.N. 25 001 150 849

Gordon Chiu Building, J01
Department of Chemical Engineering
Maze Crescent
University of Sydney NSW 2006
Australia

Telephone: +612-9351-6741
Facsimile: +612-9351-7180
Email: mail@intec.com.au
Website: www.intec.com.au

THE INTEC ZINC PROCESS

J. Moyes, K. Rogers, D. Sammut & F. Houllis (Intec Ltd, Australia)
Email for correspondence: mail@intec.com.au

Abstract

The Intec Process is a generic process for the production of pure base metals and precious metals from sulphides concentrates derived from copper, nickel, zinc and lead ores. The development program for the Intec Process initially focussed on the treatment of copper concentrates, (the 'Intec Copper Process'), and more recently of zinc concentrates, ('the Intec Zinc Process').

Developed and proven in Sydney, Australia at a cost of US\$15m over the last ten years, the Intec Copper Process is now ready for commercial application. The knowledge gained during the development of the Intec Copper Process has been applied to the Intec Zinc Process, which utilises the same basic chemistry to produce high purity zinc ingot from metallurgically complex zinc sulphide concentrates containing lead, copper, iron, silver and gold.

The demonstrated ability of the Intec Zinc Process to treat low grade mixed zinc/lead/copper concentrates, including those with high iron and manganese levels, holds out the real prospect of overcoming major metallurgical hurdles that have long affected the zinc industry.

The Intec Zinc Process consists of the three consecutive circuits of leaching, purification and electrowinning. The leach circuit is of single stage configuration with a series of reactors to which concentrate and lixiviant are fed. Purification consists of cementation and precipitation by pH adjustment. Electrowinning employs an electrolytic cell very similar in design to that of the Intec Copper Process, but differs in that a conventional plate cathode is produced.

During electrowinning, the same mixed halide species (BrCl_2 , HalexTM) that is integral to the Intec Copper Process is generated in solution at the anode and exhibits powerful leaching characteristics capable of directly leaching the sulphide concentrate feed. The need to roast the concentrate prior to leaching, as is practised in the conventional Roast/Leach/Electrowin (RLE) process, is thus eliminated whilst a range of by-products (notably lead, copper and precious metals) can be extracted in the simple, single-stage leach.

This paper describes the Intec Zinc Process; the technology, predicted economics and its environmental aspects.

Introduction

The Intec Process is a generic process for the production of pure base metals and precious metals from sulphides concentrates derived from copper, nickel, zinc and lead ores. The Company's development program for the Intec Process initially focussed on the treatment of copper concentrates, (the 'Intec Copper Process'), and more recently of zinc concentrates, ('the Intec Zinc Process').

Commercial and technical development of the Intec Process to date has been focussed on copper production, but the process holds similar commercial promise particularly in relation to zinc and associated by-products such as lead and silver and also to nickel (the 'Intec Nickel Process'). This proprietary hydrometallurgical process produces high purity base metals and associated precious metals from concentrates of sulphide ores.

The process is based on the electrolytic deposition at the cathode of high purity metal (copper, zinc or nickel) from a purified sodium chloride-sodium bromide electrolyte. During electrowinning, the mixed halide species BrCl_2^- ("HalexTM") is generated in solution at the anode and exhibits powerful leaching characteristics when it is re-circulated to treat incoming concentrate feed.

The use of a mixed halide lixiviant makes the Intec Process unique among the range of hydrometallurgical and biohydrometallurgical alternatives to conventional smelting technology for the production of base metals from sulfide concentrates.

The Intec Zinc Process

The knowledge gained during the development of the Intec Copper Process has been applied to the Intec Zinc Process, which utilises the same basic chemistry to produce high purity zinc ingot from metallurgically complex zinc sulphide concentrates containing lead, copper, iron, silver and gold. The Intec Zinc Process essentially consists of the same three sequential circuits as in the Intec Copper Process of leaching, purification and electrowinning, as shown in the block diagram in Figure 1 below.

The leach section is of single-stage co-current configuration with finely ground (P_{80} of 40 μm) concentrate and fresh lixiviant fed together into the front of the circuit. All economic metals are leached into solution and subsequently recovered as valuable by-products, or in the case of zinc, as high purity metal ingots.

The process is based on the same chemistry as the Intec Copper Process, producing high purity zinc from a purified chloride-bromide electrolyte of slightly different composition to that of the Intec Copper Process. During electrowinning, the same mixed halide species (BrCl_2^- , HalexTM) that is integral to the Intec Copper Process is generated in solution at the anode, and exhibits powerful leaching characteristics capable of directly leaching the sulphide concentrate feed. The need to roast the concentrate prior to leaching, as is practised in the conventional Roast/Leach/Electrowin (RLE) process, is thus eliminated whilst a range of by-products (notably lead, copper and precious metals) can be extracted in the simple, single-stage leach.

With the exception of the single-stage leach, the Intec Zinc Process resembles in concept the hydrometallurgical processes employed in the sulphate medium for the treatment of the calcine product from roasting. In particular, the purification step in the Intec Zinc Process relies heavily on cementation, whilst zinc is electrowon in the form of a conventional plate.

Iron is rejected from within the leach circuit as crystalline haematite (Fe_2O_3) by the injection of air.

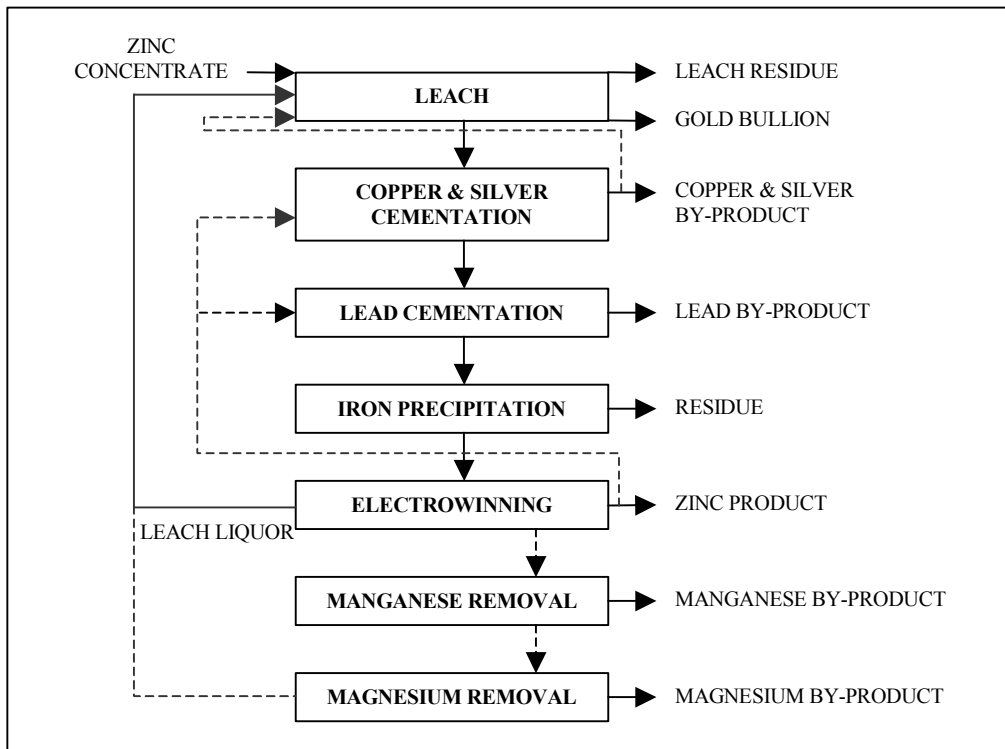


Figure 1 – Intec Zinc Process Block Diagram

The Intec Zinc Process consists of the three consecutive circuits of leaching, purification and electrowinning, and is shown in the simple flow diagram presented in Figure 2. The leach circuit is of single stage configuration with a series of reactors to which concentrate and lixiviant are fed. Purification consists of cementation and precipitation by pH adjustment. Electrowinning employs an electrolytic cell very similar in design to that of the Intec Copper Process, but differs in that a conventional plate cathode is produced.

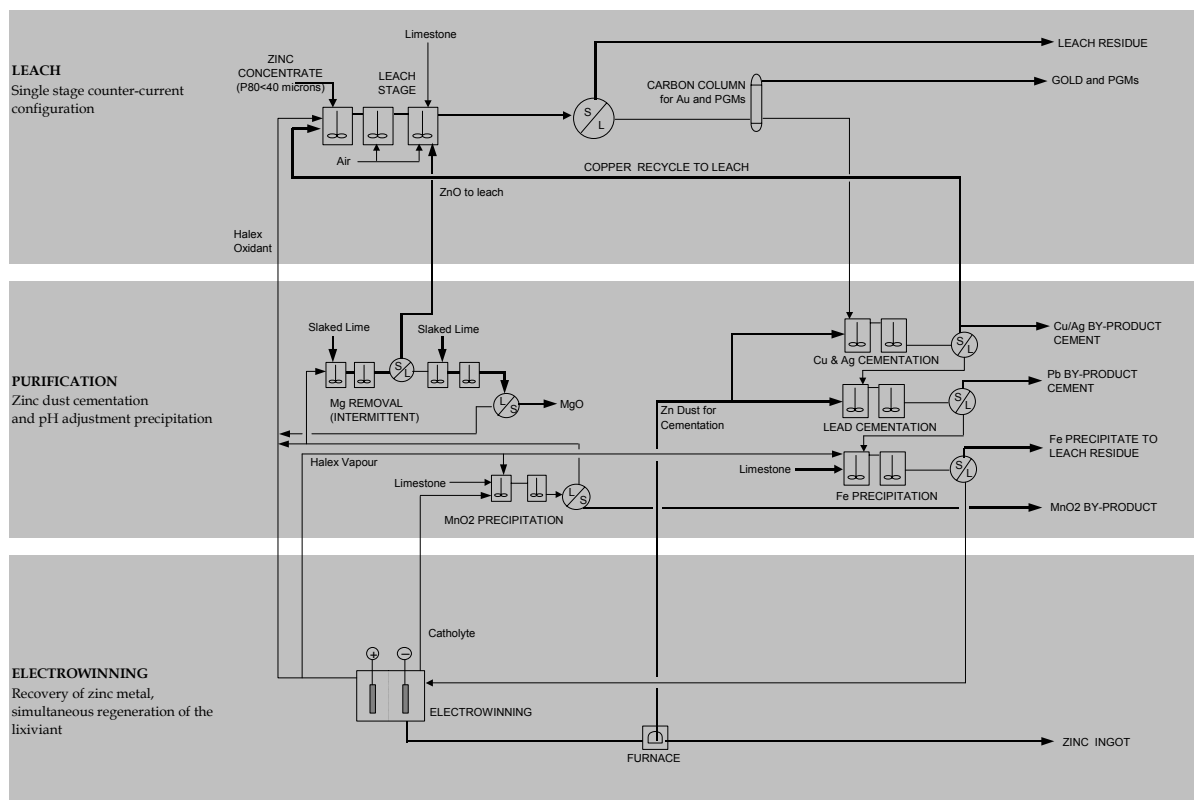
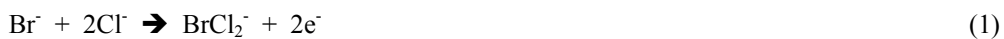


Figure 2 - The Intec Zinc Process Simple Flow Diagram

Zinc metal is electrowon from purified electrolyte, which has a composition of 100 gpl zinc, 50 gpl sodium chloride (NaCl), 50gpl calcium chloride (CaCl₂) and 110 gpl sodium bromide (NaBr). All other constituents, which include 'equilibrium' levels of many other elements (manganese, magnesium, etc.), are regarded as impurities. Through the passage of an electric current at a density of 500 A/m² of electrode area, high purity zinc is formed on the negatively charged cathode. The feed electrolyte zinc tenor is depleted from 100 gpl to 50 gpl, which is the steady state concentration of the cell.

The Lixiviant

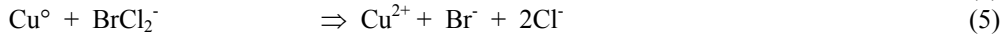
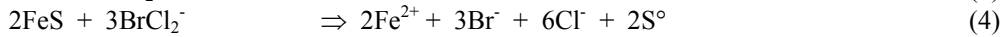
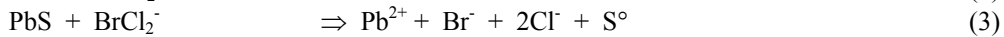
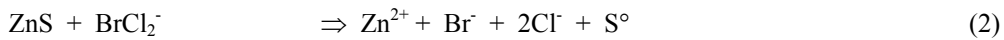
The spent catholyte continuously permeates through a woven cloth membrane to the positively charged electrode (anode). In a totally chloride medium, the anode reaction is the oxidation of chloride ion to form chlorine gas. However, because of the presence of both chloride (Cl⁻) and bromide (Br⁻) in the Intec solution, there is a preferential formation of the halogen species BrCl₂⁻ (Halex™, Equation 1). Halex can be considered as a chlorine molecule held in solution by a bromide ion. This electrolyte is now a very powerful lixiviant at an oxidising potential (Eh) of 1,000 mV (vs Ag/AgCl). It is this lixiviant that is used for the leaching of the zinc concentrate feed.



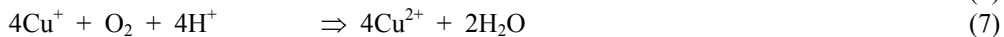
Leaching

Finely ground zinc concentrate (P80 of 40 microns) and lixiviant are fed to the single stage leach, which operates at a temperature of 85°C and atmospheric pressure. Leaching is divided into three steps, with the Halex lixiviant, concentrate and recycle copper cement introduced into step 1. Copper is used as an electron transfer intermediate but requires only a 2-3gpl background to be effective. In the case of copper-bearing concentrates, this recycle is not necessary.

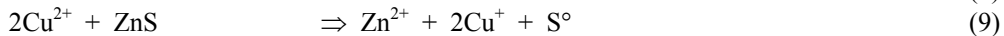
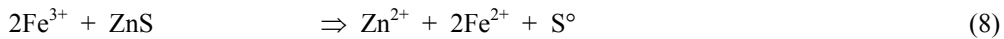
In step 1, all of the Halex is consumed and the majority of the sphalerite is leached along with galena, pyrrhotite and the recycled copper cement according to the following reactions:



Reaction initially proceeds without air sparging (aeration) until all Halex™ oxidant (BrCl₂⁻) is consumed. Significant iron dissolution occurs in this initial reaction step and aeration is subsequently initiated to precipitate iron into the leach residue as haematite. Recycled copper cement from the first stage purification is added to the aeration leach to enhance both oxygen uptake and metal extraction.



In step 2 (aeration leach), air sparging is used to convert essentially all soluble iron and copper to the ferric and cupric state according to reactions (6) and (7). Both the ferric and cupric are then utilised to leach more sphalerite.



The precipitation of iron as haematite (reaction 10) is pH dependent. By consuming acid in the oxidation of cuprous and ferrous ions, the aeration leach continuously precipitates haematite and regenerates acid for the oxidation reactions.



When leaching is complete, limestone is added in step 3 to raise the pH and reject any residual iron remaining in solution. The leach residue is then separated from the zinc-rich liquor by filtration and washed before disposal.

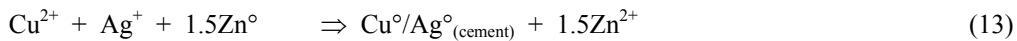
A small proportion of the elemental sulfur formed by the leach reactions is oxidised to sulfate by the high oxidation potential Halex™, as shown in equation (11). Through the generation of acid, this sulfate formation can be beneficial in negating the effect of contaminant metals in the mineral concentrate, such as manganese, that are not recovered in metallic form. Indeed, if acid is not generated in excess of that required to leach the contaminant metals, then sulfuric acid must be added to the leach system. Due to the high background of calcium ions in the electrolyte, sulfate ions precipitate rapidly as gypsum, leaving the protons available to regenerate oxidant according to reactions (7).



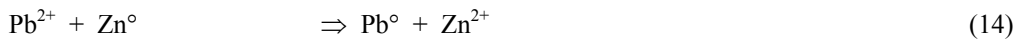
Overall, the leach reactions are exothermic, maintaining the temperature (85°C) in the single-stage leach. This, coupled with the addition of air, causes the evaporation of water from the leach, and the Intec Zinc Process thus has no liquid effluents.

Purification

The zinc-rich liquor is first passed through a series of columns containing activated carbon, onto which gold, if present, is adsorbed and subsequently recovered. From the columns, the liquor is purified via a cementation reaction with zinc dust reagent that is produced on-site from molten zinc. The purification is a two-stage operation with copper and silver predominantly removed in the first stage.



In the second stage, excess zinc dust is added to remove remaining impurities such as cadmium, lead, nickel, cobalt, thallium, etc. These reactions are carried out under conditions similar to those practiced in conventional electrolytic zinc plants.

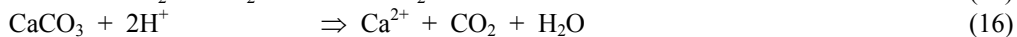
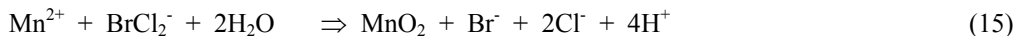


To the now relatively pure liquor, a small amount of cell anolyte (containing Halex™) is added until an Eh of 700mV (vs Ag/AgCl) is achieved. This ensures any remaining iron is oxidised to the ferric (Fe³⁺) oxidation state. The subsequent addition of ground limestone to raise the pH to 4.5 precipitates any remaining iron. Other impurities (eg bismuth, indium, etc) may also precipitate to this residue. The precipitate is removed by filtration and is either discarded or reprocessed to recover economic by-products such as indium. The few impurities that remain in solution do not contaminate the zinc product during electrowinning and are removed in either the manganese or magnesium purification circuits. These circuits treat spent catholyte from electrowinning using limestone and Halex in the manganese circuit and slaked lime in the magnesium circuit.

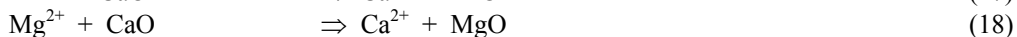
The purified zinc-rich liquor is electrolysed as described earlier, to produce high purity zinc metal and to regenerate the lixiviant for recycle to the leach. Zinc product is washed and dried prior to melting in a furnace and conversion to ingot for sale.

Manganese and Magnesium Precipitation Circuits

The manganese circuit treats a spent-catholyte bleed from the electrowinning circuit using limestone and Halex™ vapour to selectively precipitate manganese as MnO₂ at pH 3.2 with minimal zinc loss.



Magnesium build-up in the process liquor can be managed by treating an appropriate portion of the liquor from the manganese circuit with lime at pH 7 to precipitate ZnO for return to the leach followed by magnesium precipitation as MgO with lime at pH9 according to the following reactions:



Economics of the Intec Zinc Process

The most compelling advantage of the Intec Zinc Process is its economic superiority over the conventional RLE technology used throughout the world for the production of zinc metal, as shown in Figures 3 and 4. The estimates contained in these figures have been generated from an internal Intec database. The estimates are to an accuracy of $\pm 30\%$ and have been determined based on the following key assumptions:

- a plant capacity of 200,000 tpa-Zn
- the treatment of a 50% Zn concentrate feed; and
- a power cost of 5US¢/kWh.

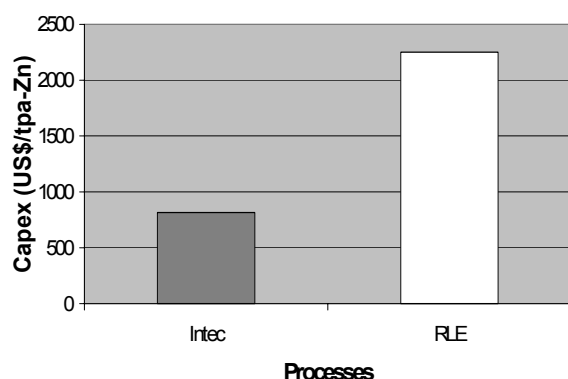


Figure 3 - Comparison of capital costs at 200,000tpa-Zn plant capacity.

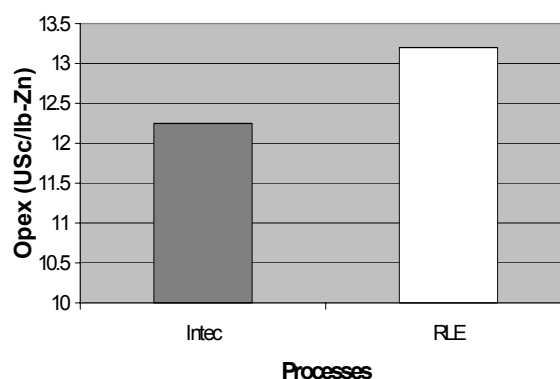


Figure 4 - Comparison of operating costs at 200,000tpa-Zn plant capacity.

The significant capital cost advantage of the Intec Zinc Process is principally due to the elimination of the roasting step. For example, Korea Zinc's 170,000tpa-Zn refinery in Townsville, Queensland was completed at a cost of approximately US\$425 million in 1999. This corresponds to US\$2,500 per annual tonne of capacity.

In addition, the economics of the Intec Zinc Process remain robust at plant capacities significantly lower than that required for RLE operations. Therefore, the potential to locate metal production at the mine site is greatly enhanced. However, as the cost of electrical energy constitutes about 70% of the operating cost of the Intec Zinc Process (at a unit cost of 5US¢/kWh), plant location will be influenced by, among other factors, the trade-off between energy costs and concentrate transportation costs. Figures 5 and 6 detail capital and operating cost estimates for a range of Intec Zinc Process plant capacities.

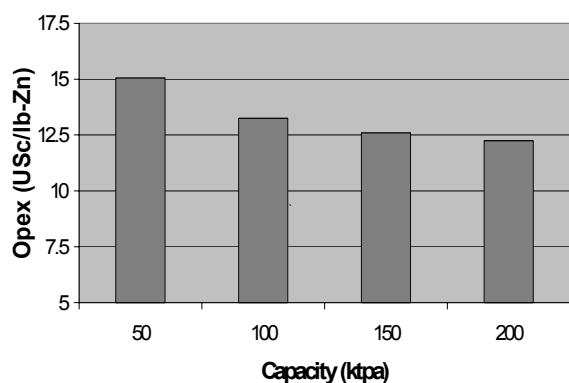


Figure 5 - Effect of plant size on the operating cost of the Intec Zinc Process.

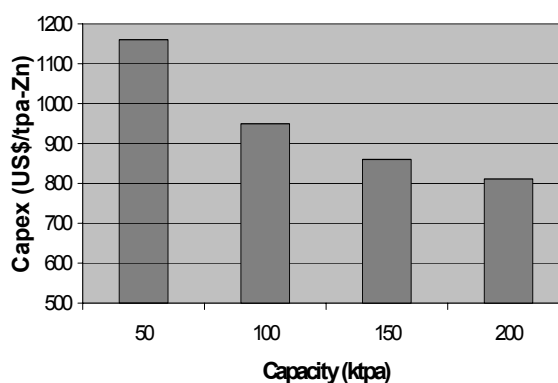


Figure 6 - Effect of plant size on the capital cost of the Intec Zinc Process.

Market Opportunities for the Intec Zinc Process

A major market opportunity exists for the Intec Zinc Process because of (i) the greater pollution problems associated with zinc smelting, (ii) the common difficulties in achieving high metallurgical flotation recoveries of lead and zinc from ore at concentrate grades suitable for smelters and Intec's ability to treat instead low grade concentrates (with consequently much higher flotation recoveries), (iii) Intec's attractive projected economics, (iv) the deportment of iron to stable haematite (rather than harmful jarosite) in the Intec Zinc Process and (v) Intec's ability to separate manganese from zinc concentrates, thereby overcoming a significant metallurgical problem for certain specific zinc projects.

The Intec Zinc Process, in addition to its economic advantages, has a demonstrated ability to successfully treat zinc concentrates whose levels of deleterious elements render them either unable to be treated by conventional methods or economically unattractive. An example is the presence of high levels of manganese in a zinc concentrate creating onerous metallurgical problems for the conventional RLE processing route.

Intec has identified two major zinc orebodies, being Dugald River in northwest Queensland, (owned by Pasmaenco Limited (Administrators appointed)) and Gamsberg in South Africa (owned by Anglo American Operations Limited, a subsidiary of Anglo American plc) where these problems have so far held back development. In the case of both deposits, many different alternative treatment methods have been considered over a long period of time. The methods so far considered have proved to be either not viable technically or insufficiently economically robust in the current low zinc price environment.

Intec has conducted comprehensive laboratory testwork on Dugald River zinc concentrates with great success and has financially modelled a considerable enhancement of project value, even at the current subdued zinc price levels. The resource at Dugald River contains an estimated 47.9 million tonnes of ore grading 12.1% zinc, 2.1% lead and 44g/tonne silver. This resource makes Dugald River one of the world's largest undeveloped zinc projects.

At current low zinc prices, many operating zinc mines worldwide are uneconomic. Naturally this inhibits bringing new zinc projects into production. However, the economic advantages of the Intec Zinc Process are such as to potentially change the industry cost curve over time. This is particularly the case for zinc deposits that are high in iron and/or manganese and for deposits where metal recoveries into smelter grade concentrates are low due to complex mineralogy.

Environmental Aspects of the Intec Zinc Process

No Liquid Emissions or Noxious Vapours

Neither the Intec Copper Process nor the Intec Zinc Process produce any liquid emissions. This is achieved through the evaporation of water from the exothermic leach sections. Only benign gases in the form of spent air and water vapour are produced. This is in stark contrast to conventional roasting where large quantities of sulphur dioxide (SO₂) and other noxious substances such as mercury are generated in off-gases. The capture of these substances is never complete and thus contamination of the surrounding environment at least to some degree is an unavoidable consequence.

Stable Solid Residues

The overwhelming majority (typically >90-95% by mass) of the solid residues from the Intec Copper Process come from the leach section of the process (Leach Residue). This residue consists primarily of haematite (Fe₂O₃), elemental sulfur (S) and gypsum (CaSO₄.2H₂O) plus unaltered gangue minerals. The remainder of the solid residue is formed during the electrolyte purification process, consisting of a complex and concentrate-specific mixture of metal oxides and hydroxides plus unreacted alkalis (primarily limestone). These residues are blended together for the purposes of disposal.

As both the Intec Copper and Intec Zinc Processes precipitate iron from the ferric state in solution under almost identical conditions of electrolyte composition, temperature, pressure and redox potential, and as the basic leach reactions are also comparable, the observed parallels between the solid leach residues of the two processes are easily explained. Iron, in both processes, is precipitated overwhelmingly as haematite, with the presence of calcium in the electrolyte principally excluding the formation of jarosite compounds (MFe₃(OH)₆(SO₄)₂, where M⁺ = H₃O⁺, Na⁺, Ag⁺, K⁺, etc) . Sulfur in both processes is precipitated in elemental form, with a minor percentage oxidised to sulfate, which then precipitates as gypsum.

As the Intec Zinc Process utilises recycled-zinc (as zinc dust) for purification of the pregnant leach solution by cementation, only minor amounts of purification residues are produced. These may either be co-disposed in stable form with the leach residue, or may be re-treated to recover economic by-products, such as cobalt. Manganese is recovered separately from solution as MnO_2 , and the only alkaline precipitation residue associated with the Intec Zinc Process is the magnesium oxide (MgO) which would result if a bleed stream treatment was required. Given the overall similarity between the solid residues of the Intec Copper and Intec Zinc Processes, then, the results of studies performed on residues from the former are equally applicable to the latter.

Extensive studies have been commissioned on the residues from the Intec Copper Process to assess the stability of the residue for disposal in the environment. Described in another paper (Sammut & Welham, 2002), these consisted of a combination of empirical studies and residue characterisation studies.

The result of these investigations was the development of a detailed understanding of the mechanisms for the formation of the haematite as the primary iron oxide phase under the Intec Process leach conditions, and the generation of a significant quantity of empirical data to demonstrate the stability of the Intec Process solid residues, even under conditions exceeding those that would be expected in an unmanaged, uncapped landfill. This empirical data is then supported by widespread theoretical evidence associated with the existing literature. While Cornell & Schwertmann (1996) indicate that haematite and goethite share similar stabilities under typical environmental conditions, and are the most stable of the iron oxide/oxyhydroxide species, most literature (eg Welham, Malatt and Vukcevic, 2000) tends to hold haematite marginally more stable.

Overall, the weight of empirical and theoretical evidence is sufficient for Intec to maintain a high degree of confidence in the stability of the Intec Process solid residues. Prior to designing a residue disposal system for a future processing facility, it would be advisable to perform lysimeter trials to determine whether sub-aqueous or capped landfill disposal options would be preferable, and to give a long-term demonstration of the stability of the residues, but in the interim, the results obtained provide an excellent guide for discussions on this topic.

Lower Energy Consumption

The elimination of the roasting step is the main contribution to lower energy consumption in the Intec Zinc Process when compared with RLE.

A further advantage specific to the Intec Zinc Process is the higher metal recoveries for zinc and by-products by comparison with an RLE operation. The higher recoveries result in reduced energy consumption per unit of zinc equivalent produced.

For both the Intec Zinc Process and RLE, electrowinning is the most energy intensive process component. Electrowinning at $500A/m^2$ in the Intec halide medium consumes $3,000kWh/t-Zn$ compared to $3,250kWh/t-Zn$ in the conventional sulphate medium.

Favourable Life Cycle Assessment

Australia's Commonwealth Scientific and Industrial Research Organisation (CSIRO) conducted a detailed Life Cycle Assessment of the Intec Copper Process in 2001 (Norgate, 2001) using published data and information provided by Intec Ltd. Discussed in a previous paper (Moyes et al, 2002), this report compared several of the available hydrometallurgical options as well as pyrometallurgy for the recovery of copper from mineral sulfide concentrates. While the model and assumptions used are too extensive to reiterate here¹, the results of the study (Norgate, 2001) demonstrated the particular advantages of the Intec Copper Process:

- The economic flexibility of scale associated with the Intec Process allows production directly at the mine site, reducing the economic and environmental costs associated with transport;
- The ability for the Intec Process to treat low-grade and metallurgically complex concentrates allows the production of lower grade concentrates, in many cases thus increasing the overall metal recoveries at the mill;
- In addition to the economic advantages of retaining the value of mined metal and more complete utilisation of the mineral resource, the LCA indicated the environmental advantages of the Intec Copper Process at lower grades on a cradle-to-gate basis;
- The CSIRO LCA did not incorporate the environmental advantages associated with preventing the loss of metals to the mill tailings;

¹ Readers are encouraged to view the complete CSIRO LCA report (Norgate, 2001), which is available at <http://www.intec.com.au>

- Additionally, greater utilisation of a resource may extend the mine life. This also extends the period of benefit to the local community;
- The production of stable haematite compares favourably against other hydrometallurgical alternatives, many of which would be expected to produce significant quantities of unstable jarosites; and
- Intec Process residues do not require additional treatment steps, such as lime boil and/or cyanidation to recover precious metals. These precious metals are recovered within the Process circuit.

As the Intec Zinc Process recovers metal from the divalent state as compared to the monovalent state for the Intec Copper Process, the CSIRO LCA is not directly applicable to the Intec Zinc Process. The advantages of flexibility of scale, the ability to treat low grade and metallurgically complex concentrates, and the production of stable solid residues, are however generic to the Intec Process technology, both in its application to copper and to zinc, or both.

Conclusion

At current low zinc prices, many operating zinc mines worldwide are uneconomic. Naturally this inhibits bringing new zinc projects into production. However, the economic advantages of the Intec Zinc Process are such as to potentially change the industry cost curve over time. This is particularly the case for zinc deposits that are high in iron and/or manganese and for deposits where metal recoveries into smelter grade concentrates are low as a result of complex mineralogy.

References

Cornell, R.M. and Schwertmann, U., "The Iron Oxides: Structure, Properties, Reactions, Occurrence and Uses", VCH, Weinheim (Germany), 1996.

Moyes, A.J., Rodgers, K.G., Sammut, D. and Houllis, F., "The Intec Copper Process – Ready for Commercialisation", paper to be published in *Minerals Engineering*, 2002.

Norgate, T. *A Comparative Life Cycle Assessment of Copper Production Processes*, CSIRO Report DMR-1768, Oct. 2001. Available at <http://www.intec.com.au>

Sammut, D. and Welham N.J., "The Intec Copper Process: A Detailed Environmental Analysis", to be published in the *Proceedings of the Green Processing 2002 Conference*, Australian Institute of Mining and Metallurgy, Cairns, May 29-31, 2002.

Welham, N J, Malatt, K A and Vukcevic, S, 2000, The stability of iron phases presently used for disposal from metallurgical systems – A review", *Minerals Engineering*, 13(8-9):911-931.