

FROM LIABILITY TO ASSET - THE HELLYER METALS PROJECT

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ABSTRACT

The Hellyer Metals Project involves the application of the Intec Polymetal Process to the re-treatment of the tails dam at the former Hellyer mine site. The Hellyer orebody was a volcanic hosted massive sulphide orebody that contained some 15 million tonnes of ore grading 13 % zinc, 6.7 % lead, 0.4 % copper, 158 g/t silver and 2.4 g/t gold. The ore was metallurgically complex and despite a state-of-the-art flotation circuit, flotation recoveries of both base and precious metals were low with significant metal value lost to the tails dam. The resource in the tails dam is estimated to be 10.9 million tonnes grading 2.8 % zinc, 3.0 % lead, 0.16 % copper, 88 g/t silver and 2.6 g/t gold.

The tails are stored under water to minimise sulphide oxidation and the consequent release of heavy metals into the environment. Constant monitoring is carried out to ensure that discharge levels are within legislative requirements. The proposed re-treatment of the tails will effectively remove all active base-metal sulphides and approximately 30 % of the pyrite, very significantly reducing the potential environmental impact and allow effective rehabilitation of the site.

The proprietary Intec Process is a halide-based hydrometallurgical process that was originally developed for the treatment of copper sulphide minerals but is now applicable to all sulphide base metal minerals, nickel laterite ore, refractory gold ore and environmentally hazardous residues such as electric arc furnace dust.

The application of the Intec Polymetal Process to the Hellyer polymetallic tails will result in the extraction and subsequent recovery of all five economically valuable metals. The tails will be recovered by dredging and fed directly to the Intec plant without feed preparation. The zinc will be electrowon as Prime Western Grade zinc and then cast into ingots; silver and lead will be precipitated as a cement by-product for sale to a lead smelter; gold will be recovered on carbon columns and electrowon as bullion and copper will be precipitated as an intermediate product in the form of copper oxychloride for conversion to copper sulphate. All process residues will be disposed of into a new tails dam on the existing Hellyer mining lease.

A Project pre-feasibility study has been completed using input data derived from laboratory testwork and a four-month pilot plant campaign. The pre-feasibility study also considered an enhanced Project where the Hellyer tails are co-treated with other zinc-bearing residues such as lead smelter slags and electric arc furnace dust. A demonstration plant program and a bankable feasibility study are currently in progress with first commercial production scheduled for 2008.

INTRODUCTION

Intec Ltd (Intec) has developed and patented innovative halide-based hydrometallurgical processes for the extraction and recovery of base and precious metals from ores, concentrates and waste products (the Intec Process(es))¹⁻³.

Intec acquired the Hellyer mine assets in Tasmania, formerly owned by Aberfoyle Ltd (Aberfoyle) and Western Metals Ltd (Western Metals), in January 2004. The assets acquired include an existing crushing, grinding and flotation mill, and a tails dam, which contains significant quantities of zinc, lead, gold, silver and copper. The Hellyer Metals Project (the Project) involves the application of the Intec Process to recover, in saleable form, approximately 80 % by value of the base and precious metals contained in the Hellyer tails dam.

Bench-scale testwork has been conducted at the Intec laboratory in Sydney and at a laboratory facility in Burnie, Tasmania operated by Ammtec Ltd (Ammtec). The laboratory testwork has shown that the Intec Polymetal Process can recover approximately 80 % of the metal values from the Hellyer tails. A pilot-scale plant has been built and operated over a period of four months to verify the results of the bench-scale testwork and to establish and optimise the design parameters for a full-scale operation⁴.

A pre-feasibility study completed by H.G. Engineering Ltd of Toronto, Canada (HGE) in August 2004 defined the requirements and costs for a full-scale plant to recover zinc and metallic by-products from the Hellyer tails⁵. Process flow sheets and equipment lists were developed based on information provided by Intec. A plant layout was also developed showing the new plant and its relation to the existing mill and concentrator.

A demonstration plant with the capacity to treat up to 4 tonnes per day of Hellyer tails has been built in Burnie, Tasmania. All of the core unit operations of a commercial plant have been included in the design and most importantly the zinc electrowinning cell is equipped with super-jumbo size electrodes of the same design as would be used in a commercial plant.

PROJECT BACKGROUND

Aberfoyle discovered the Hellyer volcanic massive sulphide (VMS) orebody in 1983. It was defined as 15 million tonnes at 13 % zinc, 6.7 % lead, 158 g/t silver and 2.4 g/t gold ⁶. Mine development began in 1987 and a one million tonne per annum mill was built in 1988 with production starting in April 1989. The mill produced four products, a copper/silver concentrate, a lead concentrate, a zinc concentrate and a bulk lead/zinc/silver concentrate, all shipped to regional smelters. Succeed

Mine output and mill throughput rate was increased to 1.5 million tonnes per annum in the mid 1990's. Aberfoyle was taken over by Western Metals, a Western Australian based mining company, in 1998. The Hellyer orebody was exhausted in June 2000 and the mill placed on a care and maintenance program while Western Metals investigated treatment options for the tails.

Due to the complex fine-grained mineralogy and high pyrite associations of the Hellyer orebody, the total metal recoveries to concentrates were low over the life of mine. They averaged 75 % zinc, 60 % lead, 44 % silver and 17 % gold ⁷. The result is a tails dam that is relatively rich in zinc, lead, silver and gold.

Intec acquired the Hellyer assets from the Receivers and Managers of Western Metals Ltd in January 2004. The assets acquired included the mill, tails resource and prospective mineral leases in the region.

Hellyer Tails Resource

The tails were sub-aqueously deposited in a shallow valley dam, which at the end of mine life covered an area of 50 hectares. The maximum depth of the tails is 19 metres with an average depth of 8 to 10 metres. Water depth ranges from 0.5 to 1 metre.

There have been two drilling programs undertaken on the tails dam, one by Western Metals in 1998 and one by Dominion Mining Ltd in 2000. Both drilling programs used a Vibra-Core technique on a 100-metre grid pattern closing to a 50-metre grid in deeper sections, to calculate contained metals. Both programs confirmed the end of mine life calculations of the tails resource (see Table 1) based on milled ore tonnes and head grades less tonnes of metal in concentrates produced.

Table 1: Hellyer Tails Resource

Tonnes (Millions)	Cu %	Pb %	Zn %	Ag g/t	Au g/t	As %
10.88	0.16	3.00	2.80	88.00	2.58	1.24

Hellyer Tails Mineralogy ⁸

The average particle size of the tails is 80 % passing (p80) 45 microns, however p80s range between 30 microns and 60 microns. Approximately 70 % of the sphalerite in the tails is in the 38 to 7 micron fraction with approximately 50% liberated. The dominant sphalerite composites are sphalerite/pyrite binaries. Less than 10% of the sphalerite is associated with galena.

The galena is fine grained with 50 % less than 7 microns. A majority is liberated and moderately oxidised. Approximately 75% of the silver is associated with the mineral tetrahedrite, a copper antimony sulphide. The remaining 25 % is associated with galena.

Approximately 10 % of the gold is “free” or re-precipitated with 20 to 30 % associated with arsenopyrite and 60 to 70 % as sub-micron inclusions in pyrite. Approximately 70 % of the pyrite is highly crystalline while 15 % is in the form of a primitive melnikovite. The pyrite is predominantly liberated but there are simple binaries with sphalerite and some minor complex ternaries. Almost all the arsenopyrite is liberated.

The non-sulphide gangue includes barite (BaSO_4), calcite (CaCO_3), siderite (FeCO_3) and silica. The mineralogy of the Hellyer tails is shown in Table 2.

Table 2: Hellyer Tails Mineralogy

CuFeS₂ Chalcopyrite %	PbS Galena %	ZnS Sphalerite %	FeAsS Arsenopyrite %	FeS₂ Pyrite %	Non – sulphide gangue %
0.46	3.46	4.17	2.69	51.00	38.20

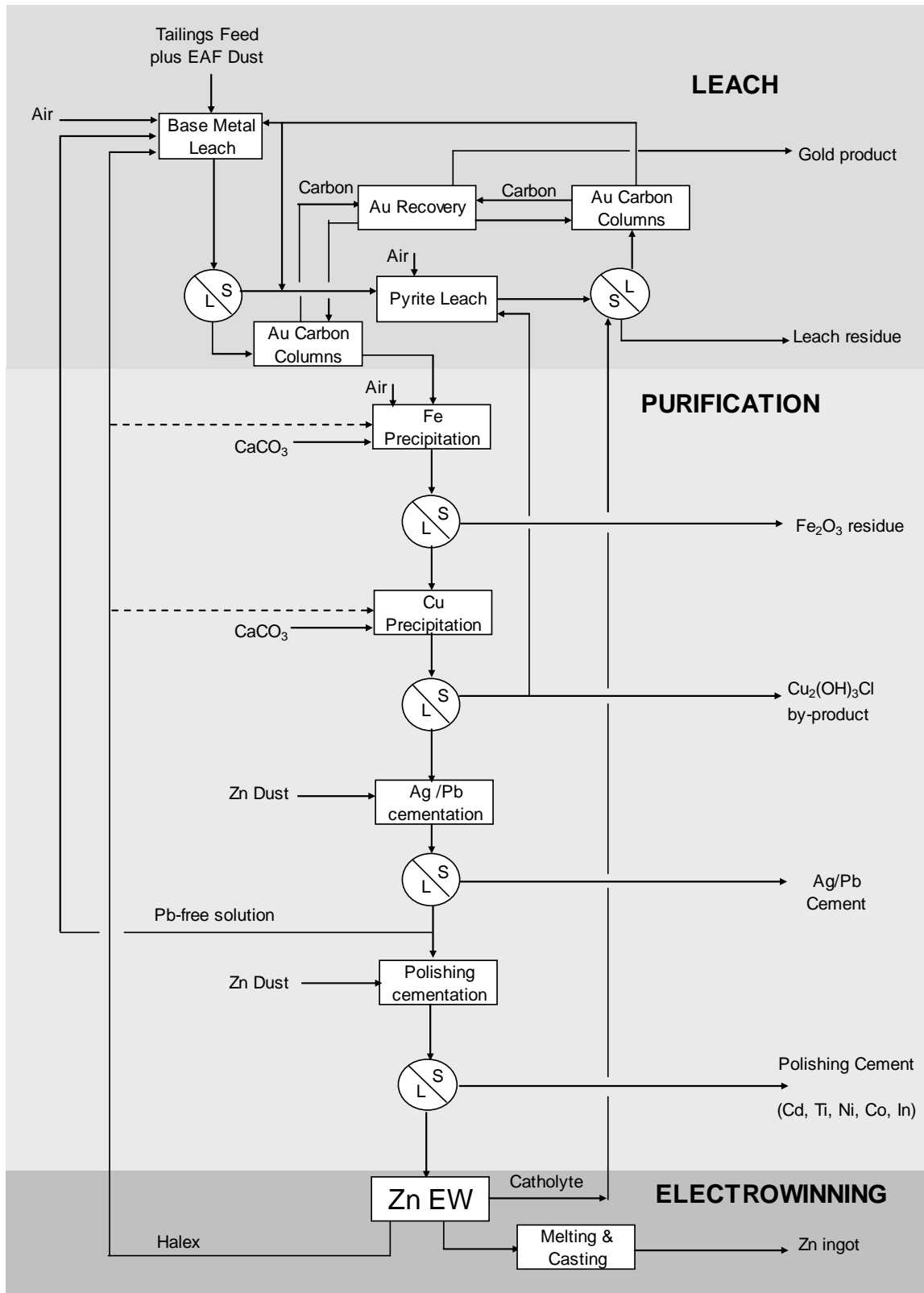
The implications of the mineralogy for leaching are:

- Base metals, particularly lead and zinc, leach quickly with high extraction levels due to their fineness and high degree of liberation.
- Silver in galena is rapidly leached, but is released more slowly from the relatively refractory tetrahedrite.
- Gold extraction is determined by the degree of pyrite oxidation. Pyrite leach kinetics are slower and more costly due to high air (oxygen) input than is the case for the base metals and furthermore, acid is produced, which requires neutralisation with limestone. The high relative cost of pyrite oxidation coupled with the low gold grade dictate that pyrite oxidation beyond about 40 % is not economic.

PROCESS DESCRIPTION

The process flowsheet developed for the treatment of the Hellyer tails is shown in Figure 1. It is based on the Intec Zinc Process (IZP) ¹ that utilises a single stage base metal leach with purification of the pregnant liquor stream before zinc electrowinning. To liberate refractory base-metal minerals and gold bound at atomic scale in pyrite, the residue from the base metal leach is further leached in a second circuit to oxidise pyrite as practiced in the Intec Gold Process (IGP) ².

Figure 1: Block diagram of Unit Operations for the Treatment of Hellyer Tails.

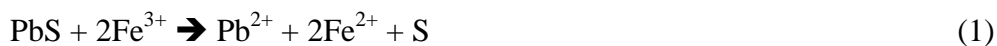


The process liquor is a high-strength mixed calcium chloride/sodium bromide brine (nominally 8 molar halide), which results in the formation of soluble metal halide complexes when the sulphide minerals are oxidised in the leach. Importantly, lead, silver and gold are soluble in the halide brine, which is not the case in the more conventional sulphate medium where such metals have negligible solubility.

There is significant competition between the metal cations for complexation with halide anions. This effect is most noticeable with maximum lead solubility ranging from 10-20 g/L as zinc and calcium concentrations change in different sections of the plant. To accommodate these solubility relationship constraints, a two-stage leach is used to maximise the zinc pickup per pass. The first leach stage is designed to leach the majority of the liberated base metals (Base Metal Leach), while the second stage is designed to leach pyrite and any locked base metals (Pyrite Leach).

Base Metals Leach (BML)

The base metal leach is designed to extract the majority of base metals, free gold and gold associated with arsenopyrite, which occurs relatively quickly at a temperature of 85° C through oxidation by ferric ions according to reactions 1, 2, 3 and 4:



The resulting ferrous ion is re-oxidised to ferric initially by Halex™ (see Zinc Electrowinning section), a powerful oxidant generated at the anodes of the zinc electrowinning cells and subsequently through the sparging of air or oxygen-enriched air to maintain the solution Eh >530 mV (Ag/AgCl).

Oxidation by Halex™ proceeds according to reaction 5:



Oxidation by oxygen is achieved by maintaining a minimum background copper tenor (typically 5 g/L) to facilitate oxygen transfer according to reaction 6, as direct oxidation of ferrous ion requires a larger electro-chemical driving force:



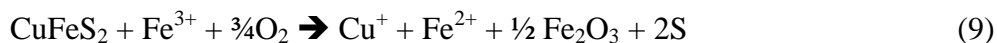
The cupric then oxidises the ferrous according to the equilibrium reaction 7:



The acid required for cuprous oxidation is available as either free acid generated from pyrite oxidation (see section on Pyrite Leach) or from ferric hydrolysis to form hematite according to reaction 8:



Chalcopyrite is oxidised to form cuprous ion and hematite according to the overall reaction 9:



The oxygen does not act directly, but via the ferrous/ferric couple according to reactions 6 and 7, while the iron hydrolyses according to reaction 8.

Arsenopyrite is also oxidised to form stable crystalline ferric arsenate according to the overall reaction 10:

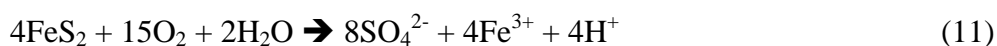


The oxygen does not act directly, but via the ferrous/ferric couple according to reactions 6 and 7. It should be noted that there is no net acid consumption during this reaction.

Pyrite Leach (PL)

The slurry leaving the base metal leach is thickened and the clear overflow liquor pumped to Fe/Cu precipitation via gold recovery, with the underflow slurry fed to the PL.

Metal extraction is maximised in the PL through the oxidation of the pyrite according to reaction 11:



The high calcium chloride content of the liquor causes the sulphate to immediately precipitate as anhydrite according to the overall reaction 12:



In this way, the sulphide minerals and gold locked in pyrite are available for leaching according to reactions 1 to 4. The ferric chloride and hydrochloric acid generated from pyrite oxidation are recycled to the base metal leach to assist in base-metal sulphide oxidation.

The addition of air for pyrite oxidation results in water evaporation into the spent air, which is an important aspect of the water and heat balance for the plant. In particular, an oxygen uptake efficiency of approximately 50 % is required to minimise external heat input to the leach.

The slurry from the pyrite leach is diluted with spent wash waters (to replenish water evaporated in the pyrite leach) before thickening and filtration on a belt filter. A four-stage counter-current water wash is used before the filter cake is re-pulped and sent to a tails dam with the thickener overflow polished and sent to gold recovery.

Gold recovery

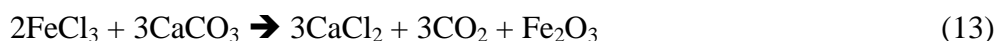
Gold from the BML and PL is recovered onto fixed beds of activated carbon contained in columns arranged in series. A separate circuit is employed for each leach to enhance overall recovery. The gold-free solution from the PL columns is recycled to the BML and the gold-free solution from the BML is pumped to the Fe and Cu precipitation stages.

Once loaded, the first carbon column in each series is taken off line and stripped with a hot cyanide solution, which is then sent to electro-winning with the resultant gold sludge melted and cast to ingot. The filtrate and wash water are recycled to the cyanide dissolution tank.

Iron and Copper Precipitation

The ferric generated from the oxidation of pyrite along with cupric are removed from the liquor in two separate circuits by precipitation with limestone.

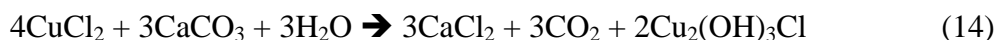
Sufficient oxidant from the EW circuit is added to raise the Eh to >650 mV to ensure that all iron and copper are present as ferric and cupric. Ferric is selectively precipitated first at pH 1 to <50 mg/L according to reactions 13:



The precipitation is carried out at 95 °C with recycle for seeding to ensure the formation of hematite. Under non-ideal conditions, akaganeite (FeO(OH,Cl)) will form and can contain up to 13 % chloride⁹. The calcium ions precipitated in the PL as anhydrite are restored via this reaction.

The hematite slurry is thickened, filtered and washed before discarding to the tails dam.

Cupric is then selectively precipitated at pH 3 to 50-100 mg/L with recycle for seeding to improve settling characteristics according to reaction 14:



The copper oxychloride slurry is thickened with a portion of the underflow bled out for conversion to copper sulphate for sale. The remaining copper oxychloride is recycled to the PL, where it is re-leached with the abundant free acid from pyrite oxidation, to supply soluble copper for oxygen transfer. The clear thickener overflow passes to the Pb/Ag cementation stage.

Lead/Silver Cementation

The Pb/Ag cementation stage of purification uses zinc dust to reduce silver and lead as well as residual copper to their metallic state according to reactions 15, 16 and 17¹⁰:



The zinc dust addition rate is 105 – 110 % of the stoichiometric ratio. High-shear mixing is used to promote contact between the zinc particles and the liquor to ensure maximum zinc utilisation. The residual copper performs the important role of controlling the cement morphology by eliminating the tendency of the lead to form large agglomerations that are difficult to suspend and can block pumps¹¹. The resultant slurry is thickened with the underflow filtered and washed before being briquetted and sent for refining.

Polishing Cementation

The clear liquor overflow is sent to a polishing cementation step where supplementary zinc dust is added at the rate of 500 – 1000 % of the stoichiometric ratio to remove residual lead, cadmium, thallium, nickel, cobalt and indium. The slurry from polishing cementation is thickened, filtered and washed prior to reprocessing to recover indium and zinc.

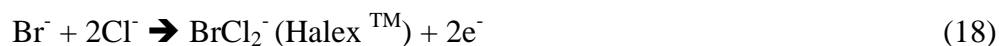
Zinc Electrowinning (EW)

The overflow liquor from polishing cementation is sent to electrowinning, which takes place in rectangular cells each containing 40 flat plate titanium cathodes of super-jumbo size (1.0m x 1.5m active dimensions) and 41 rare earth coated titanium mesh anodes. Each anode is housed in a diaphragm bag of conventional filter cloth. Catholyte is pumped through the cells via a network of pipes and overflows to a holding tank from where it is cooled and pumped back to the catholyte supply tank with a portion bled out for the removal of manganese and magnesium.

The electro-deposition of a smooth coherent zinc cathode with long stripping cycle times from high-strength chloride/bromide liquor is difficult due to the tendency to form dendrites that can cause short circuiting. Plating additives can be very effective in smoothing the morphology of the cathode deposit and in the halide environment lead is particularly effective¹². Lead is sourced from within the overall process by sending some lead-rich liquor free of Fe, Cu and Ag, to the EW cells. The volume of liquor (typically 2.5 % of the total flow) is calculated to achieve 1 % lead in the cathodes, giving a Prime Western Grade product meeting the ASTM B-06 or AS 1242 specifications.

The zinc product can be deposited at a current density of 600 A/m² at very high efficiencies (>95 %) due to the low acidity in the catholyte liquor. A minimum stripping cycle of 24 hours is used.

The remaining spent catholyte passes through the diaphragms into the anode chambers where the proprietary Intec oxidant HalexTM is produced in soluble form according to reaction 18:



A network of pipes collects the HalexTM from the anode bags, which drains into a surge tank under the tank house floor. The HalexTM is then re-circulated to either the Fe/Cu precipitation or the BML. Half of the cathodes are removed from the cells every 12 hours for stripping.

The zinc cathodes are melted in an electric furnace with molten zinc pumped to a casting machine, where ingots are produced for sale. A second pump transfers a portion of the molten zinc from the furnace to a zinc atomisation step to produce zinc dust for use in the cementation step.

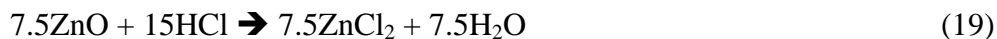
Zinc Secondaries Leach

Pyrite oxidation generates a significant amount of acid that can be utilised to leach secondary oxidised zinc-bearing materials such as electric arc furnace dust (EAFD) and smelter slags.

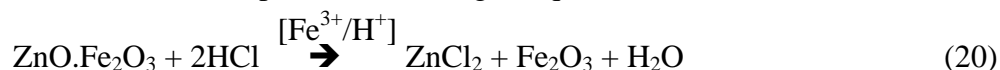
When steel is produced by recycling scrap using an electric arc furnace, about 15 - 20 kg of dust is formed per tonne of steel. This dust is considered a toxic waste due to its content of heavy metals. It is estimated that the worldwide production of EAFD could be as high as 3.2 million tonnes, all of which must be either retreated or sent to land fill¹³.

The EAFD forms due to vaporisation of volatile metals (like zinc and lead) at furnace operating temperatures. These vapours are oxidized and cooled in the extractive airflow and report to the resulting dust both as free oxides and in the form of composite structures with iron oxides. These latter compounds are notably of the spinel or ferrite type, $MO.Fe_2O_3$ ($M = Fe, Zn, Ni, Mn$ or Cd).

The HCl generated in the PL according to reaction 12 is used to leach free oxides from EAFD according to reaction 19:



However the ferrites are quite refractory, requiring more severe conditions to liberate the zinc. The ferrite reaction can be expressed according to equation 20:



The conditions necessary for the ferrite reaction to occur are present in the PL where significant levels of ferric and acid are generated from the leaching of pyrite.

PILOT PLANT RESULTS - HELLYER TAILS & EAF DUSTS

Metal Extractions

Metal extractions achieved for two typical campaigns when operating under steady-state conditions are summarised in Table 3. Individual pilot plant campaigns extended up to eight weeks in length but steady-state conditions were usually maintained for periods of two to three weeks. During each campaign, solids assays from each of the leach reactors were routinely carried out to establish metal extraction versus pyrite oxidation. The relationship between metal extraction and pyrite oxidation is controlled by the mineralogy as previously described. Statistical analysis of the data was used to calculate metal extractions at 10, 20, 30 and 40 % pyrite oxidation.

Table 3: Metal extractions as a function of pyrite oxidation

Metal	Campaign 2 (reground)				Campaign 3 (unground)			
	Pyrite Oxidation %				Pyrite Oxidation %			
	10	20	30	40	10	20	30	40
Lead	98.2	98.8	99.2	99.5	98	98.7	99.2	99.5
Zinc	86.7	93.3	97.2	98.9	87.9	93.9	97.3	98.7
Copper	78.5	89.2	94.8	96.6	73.3	89.2	96.3	97.6
Gold	6.6	26.3	39.3	46.6	10	27.2	39.3	46.4
Silver	69.5	81	88.4	92.6	76.5	84.6	89.3	91.6

From the above data, it can be seen approximately 98 % of the lead leaches rapidly with the remainder leaching as the pyrite is oxidised. However the more refractory component of the pyrite contains very little lead. Zinc demonstrates a similar trend as for lead, but has a higher proportion locked in the pyrite.

With 75 % of the silver associated with the copper mineral tetrahedrite, both metals should leach together. This is shown in the results, however approximately 10 % of the silver is quite refractory.

For campaign 2, pyrite oxidation as high as 80 % was measured, but gold extraction did not rise significantly beyond the level for 40 % pyrite oxidation. Consequently for gold, and indeed the other metals, the data indicates that only a limited increase in metal extractions occurs when pyrite oxidation is increased beyond 40 %. Increased pyrite oxidation results in higher capital and operating costs and analysis indicates that increasing pyrite oxidation beyond 40 % has minimal economic benefit.

Environmental Stability of Leach Residue

The stability of the leach residue in the environment was examined by Toxicity Characteristic Leaching Procedure (TCLP) testing ¹⁴. The results from a composite leach residue from pilot plant operations are shown in Table 4 along with Specific Contaminant Concentration (SCC) data. The results demonstrate that in spite of the relatively high arsenic level, all contaminant leachate levels meet the inert waste category.

Arsenic reports to the leach residue as ferric arsenate, which is particularly stable as is highlighted by the ability to meet the inert waste category under the TCLP procedure. The lower content of arsenic in the leach residue as compared with the content in the feed is due to the mass increase of the residue during the leach. As discussed in the literature ^{15,16}, an inert waste category for the residue can be achieved given the manner in which arsenic is stabilised.

Table 4: Leach Residue Stability

Element	Hellyer Tails	SCC		TCLP	
		Leach Residue	Inert waste limit	Leach Residue	Inert waste limit
Arsenic (ppm)	11,000	6,600	500	0.1	0.5
Cadmium (ppm)	99	3.5	100	<0.1	0.1
Chromium (ppm)	68.2	29.5	1,900	<0.1	0.5
Copper (ppm)	2,100	188	N/A	0.3	N/A
Nickel (ppm)	30	5.5	1,050	<0.1	0.2
Lead (ppm)	31,000	305	1,500	0.25	0.5
Zinc (ppm)	28,500	275	N/A	2.4	N/A
Selenium (ppm)	<15	8.5	50	<0.1	0.1
Mercury (ppm)	6.2	2.5	50	<0.01	0.02

Pilot Plant Summary

The pilot plant campaigns demonstrated high extractions of base metals and silver at pyrite oxidation levels of 30 to 40 %. Gold extraction is limited to 35 to 40 % due to the majority of the gold component being locked in sub micron inclusions in pyrite. The pilot plant also partially addressed the filtration of leach residue and the precipitation of iron. Process leach residues were submitted for TCLP environmental testing with a favourable outcome. Laboratory test programs in parallel with the pilot plant program were successful at identifying process conditions for the following:

- Zinc electrowinning
- Lead/silver cementation
- Iron precipitation
- Settling and filterability of leach and iron residues.

The pilot plant outcomes and laboratory programs formed the basis for a pre-feasibility study into the construction of a full-scale plant at Hellyer.

HELLYER METALS PROJECT – PRE-FEASIBILITY STUDY

The pre-feasibility study undertaken by HGE and completed in August 2004 evaluated two cases:

1. A “Base Case” that provides for the treatment of Hellyer tails at an annual rate of 1.0 million tonnes per annum for an 11 year project life; and
2. An “Enhanced Case” that provides for the co-treatment of Hellyer tails and zinc-bearing residues such as EAF dusts. The throughput rates for the “Enhanced Case” assume the treatment of 0.5 million tonnes per annum of Hellyer tails and the treatment of 0.1 million tonnes per annum of zinc bearing residues for a 21 year project life

Forecast annual production for the two flowsheet options are shown in Table 5.

Table 5: Forecast Annual Project Production

Parameter	Base Case	Enhanced Case
Zinc Ingots tpa	25,500	32,200
Copper Oxychloride tpa	3,000	3,400
Lead in Silver/Lead Cement tpa	29,400	16,660
Silver in silver/lead Cement mozs pa	2.60	1.45
Gold Bullion ozs pa	23,000	17,400

Indicative Project Economics

Intec used the cost parameters established in the HGE pre-feasibility study to evaluate the indicative financial performance of the Hellyer project. Metal prices and the US\$/A\$ exchange rate employed in the evaluation were those prevailing in early September 2004. Table 6 displays the results of the indicative financial analysis.

Table 6: Summary Project Indicative Financial Analysis

Parameter	Base Case	Enhanced Case
Project Life	11 years	21 years
Capital Cost	A\$153 M	A\$137 M
Annual Net Sales Revenue	A\$103 M	A\$85 M
Annual Operating Cost	A\$35 M	A\$28 M
Net Annual Cashflow	A\$67 M	A\$56 M
Net Present Value: Pre-Tax *	A\$258 M	A\$317 M
Net Present Value: Post-Tax *	A\$165 M	A\$205 M
Internal Rate of Return: Pre-Tax	38.6 %	36.6 %
Internal Rate of Return: Post-Tax	30.1 %	29.3 %

* 10 % discount rate

INTEC HELLYER DEMONSTRATION PLANT

Overview

The Intec Hellyer Metals Demonstration Plant (IHMDP) was built after the successful raising of A\$12 M to demonstrate the Intec Polymetal Process technology for the Hellyer Metals Project. The IHMDP took 9 months to design and build and was officially opening on 15 September 2005. Following three months of commissioning requiring some equipment modifications, the IHMDP is now approaching “steady state” operation when full representative samples will be taken and analysed for metallurgical evaluation of plant performance. The operation and engineering data will be fed to the bankable feasibility study which is lead by WorleyParsons.

Demonstration plant design and construction

The IHMDP plant was designed based on the laboratory and pilot plant engineering data. The components of the five-stage demonstration plant with a capacity to treat 4 tpd of Hellyer tails are summarised below:

1. Leach
 - Base Metals – two 2 m³ continuous flow stirred tank reactors (CSTRs) equipped with turbine mixers for gas dispersion and a thickener.
 - Pyrite – five 2 m³ CSTRs with turbine mixers for gas dispersion and a thickener.
 - Residue filtration – 2 m² belt filter.
2. Gold Recovery
 - Gold recovery – two lots of four columns in series containing activated carbon.
 - Two polishing filters are used to protect the columns from clogging with fine particles.
3. Purification
 - Iron precipitation – two 1.5 m³ CSTRs and a thickener.
 - Copper precipitation – two 1.5 m³ CSTRs and a thickener.
 - Manganese and magnesium bleed – a 2 m³ tank with a pressure filter operated in batch mode.
 - Iron precipitate filtration – recessed plate membrane pressure filter.
4. Cementation & Polishing
 - Lead/silver cementation – Merrill-Crowe zinc well and filter press recirculating system.
 - Polishing cementation – Merrill-Crowe zinc well and filter press recirculating system.
5. Zinc electrowinning
 - Zinc electrowinning – a 5000 A rectifier is used to electrowin zinc at 600 A/m² on 2 cathodes with the dimensions of 1 m wide by 1.5 m deep. The cathodes are placed between three bagged DSA-type anodes. The electrodes are housed in a 2 m³ rectangular tank. Maximum production rate is approximately 140 kg/d.

The total capital expenditure was about A\$5 M and the plant was fully operational in October 2005, except for the iron precipitate pressure filter, which was not required as the belt filter had sufficient capacity for both duties. In order to collect physical data more cost effectively and to provide an advanced level of monitoring and control of the process, a Honeywell Process Knowledge System (PKS) was installed.

Commissioning and modification

The HMDP was water tested before process liquor was prepared. The leach circuit in conjunction with the leach residue belt filter and precipitation circuits, was commissioned first. The zinc and lead tenors were allowed to rise as they were leached from the Hellyer tails feed. Purification and polishing circuits were brought on line when the lead in solution had built up to the level for continuous removal. The zinc electrowinning cell was brought on-line in late September to close the complete circuit.

Several significant problems were resolved during the 4th quarter of 2005 as summarised below:

- The electrowinning cell operation was initially intermittent as a result of poor control of the purification circuits allowing high levels of contaminants to enter the cell. This has been rectified by implementing the following modifications:
 - Halex™ oxidant delivery to both the iron and copper precipitation circuits was insufficient to oxidise residual ferrous and cuprous ions, requiring a new dosing system.
 - The zinc dust screw-feeders required modification before the slow dosing rates could be controlled.
- Iron precipitation should operate at 95 °C to ensure the formation of hematite. Higher than expected heat losses resulted in a solution temperature of 65 °C temperature and the production of akaganeite. A portable boiler and heat exchangers were installed, which has corrected the problem.

After the December 2005 shut down for plant refurbishment, the plant has been operating continuously with minimum interruption and steady-state operation is expected to be achieved during the first quarter 2006.

Plant operating results

Definitive data on the plant performance will not be available until all circuit modifications are finalised, some of which are still in progress. However, results to date clearly indicate that most unit operations are either close to or on specification.

Leach extractions are shown in Table 7 for typical periods when the feed was 100% Hellyer tails and a combination of tails and EAFD.

Table 7: Metal leach extraction efficiency

Metal	Leach Extraction Efficiency (%)		
	Target	Hellyer tails	Hellyer tails + EAFD
Zn	95	92	92
Pb	95	95	95
Cu	85	83	91
Ag	85	83	89
Au	35	-	30

The modifications to the iron precipitation circuit (as explained above) are nearing completion. Importantly, the performance of the circuit over a three-month period is approaching specification as shown in Table 8.

Table 8: Iron precipitation circuit exit-liquor and residue composition

Metal	Exit-liquor Assay		Residue Assay	
	Target	Actual	Target	Actual
Fe	<20 mg/L	5-20 mg/L	55-65%	49% (55% high)
Zn	-	-	<0.1%	0.1%
Pb	-	-	<0.1%	0.1%
Cu	-	-	<0.1%	0.2%
Ag	-	-	<10 ppm	2 ppm
Ca	-	-	<2%	0.7%
Cl	-	-	<1%	1.3%

The important requirements are that hematite be formed with minimal co-precipitation of the economic metals as the residue is sent to waste. The residual soluble iron in the process liquor exiting the circuit is currently at or better than specification. However, the iron residue is often off specification, which is the result of incomplete conversion of akaganeite to hematite as explained earlier. Hematite formation is controlled by temperature, retention time and seeding. Laboratory trials have clearly shown by chemical and XRD analysis that hematite can be produced.

Modifications to the copper precipitation circuit are the same as those for the iron circuit, however the specifications for the copper oxychloride precipitate are less critical as the majority is recycled to the PL to supply soluble copper to assist oxygen transfer. The portion bled out for copper production is converted to high-purity copper sulphate for sale. All co-precipitated metals are recycled to the process. Recent liquor and precipitate compositions are shown in Table 9.

Table 9: Copper precipitation circuit liquor and precipitate composition

Metal	Liquor Assay		Residue Assay	
	Target	Actual	Target	Actual
Fe	<5 mg/L	4-6 mg/L	<5%	3-5%
Zn	-	-	<2%	3-6%
Pb	-	-	<1%	0.4-1.2%
Cu	<50 mg/L	20-40 mg/L	30-40%	25-37%
Ag	-	-	<10 ppm	6-11ppm
Ca	-	-	<2%	1-3%
Cl	-	-	NA	NA

The lead/silver cementation circuit has satisfactorily recovered lead and silver at high efficiency, however zinc dust utilisation has been below specification due to insufficient mixing. New reactors with much improved mixing employing a high level of shear are currently being installed for both the Pb/Ag and polishing cementation operations. Small-scale pilot work has successfully produced a cement product with a lead to zinc ratio of 98:1 and this is the target for demonstration plant performance.

Prime Western Grade zinc specifications are based on the product in ingot form. During the electro-deposition of zinc onto the cathode, some process liquor is invariably entrained, which reports to the dross during the melting and casting process. This can be seen in the assays of cathode, ingot and dross shown in Table 10. This cathode was produced during the development of the EW cell design that used synthetic liquor, however it clearly demonstrates the rejection to dross of Ca, Cl, Mg and Na. The melting process conveniently reduces the copper content of the ingot relative to the cathode and effectively eliminates the aluminium.

Table 10: Chemical composition of zinc cathode, ingot and dross

Element	Unit	Cathode	Ingot	Dross	ASTM B-06	AS 1242
Al	ppm	44	<0.1	928	<100	
Ca	ppm	482	25	4810		
Cd	ppm	0.3	0.3	6.2	<2000	<2000
Cu	ppm	450	200	5500	<2000	
Fe	%	0.02	0.02	0.03	<0.05	<0.05
Mg	ppm	19.7	<0.1	133		
Na	ppm	380	<0.1	1230		
Pb	%	1.258	1.475	0.29	0.5-1.4	<1.4
Zn	%	98.50	98.28	90.34	>98	>98.5

The zinc cathode produced since the re-start in 2006 has been well within the Prime Western Grade as shown in Table 11. Melting trials will be undertaken as part of the steady-state campaign.

Table 11: Chemical composition of zinc cathode

	Zn (%)	Pb (%)	Cu (%)	Fe (%)	Cd (%)	Al (%)
Cathode	98.9	1.0	0.01-0.02	0.02-0.05	<0.002	Not analysed
ASTM B-06	>98	0.5-1.4	<0.2	<0.05	<0.2	<0.01
AS 1242	>98.5	<1.4	-	<0.05	<0.2	-

Some uneven distribution of the lead across the face of the cathode product has been observed. This is caused by insufficient mixing in the cell, which also causes some dendrite growth requiring a shorter than optimum strip cycle. Mixing is by liquor recirculation with finely dispersed air bubbles injected into a distribution manifold positioned underneath the electrodes. This system simulates the mixing that is automatically generated by oxygen evolution from the anodes in the Electrolytic Zinc Process. Improvements to the liquor recirculation system to effect a more even distribution of liquor are currently being installed.

CONCLUSION

The Hellyer Metals Project is an exciting new hydrometallurgical development aimed at maximising value from an existing tails resource. Although low grade, the Hellyer tails contain a suite of economic metals that can be extracted and recovered into saleable products using the Intec Polymetal Process. The advantages of the halide leach system include good leach kinetics and oxygen transfer at atmospheric pressure and moderate temperature, the ability to extract lead, silver and gold into solution and the ability to recover the gold directly onto activated carbon without the need for a separate gold recovery circuit such as a carbon-in-pulp plant and the associated cyanide detoxification circuit.

The process has no liquid effluents with all water inputs leaving the process as vapour in the spent air from the leach. The residue from leaching is essentially free of potentially mobile base metals and readily passes TCLP testing. Consequently, the environmental impact of the process will be minimal and about 80 % of the value of the economic metals in the tails will be recovered generating a final residue that will be environmentally stable.

The Hellyer demonstration plant project is now in the final stages with all process unit operations at or near specification.

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