INTRODUCTION

Having already incurred the often significant costs of mining a base or precious metal ore, there are four key factors that impact the economics of the beneficiation of that ore to a concentrate product, and therefore the economics of the whole operation. These are:

- the total recovery of payable metal from the ore to the concentrate,
- the grade of the concentrate product,
- the by-product credits, and
- the contaminant penalties.

Depending on the mineralogy of the ore and the metallurgy of the beneficiation process, these factors can individually or collectively determine whether an ore body is worth developing or must wait for advances in technology to become economic.

The most common beneficiation techniques for gold, silver, copper, lead, zinc and nickel ores involve crushing and grinding to liberate the preferred minerals, followed by either froth flotation or gravity separation to selectively divert those minerals into a concentrate product.

Under theoretical ideal conditions, these techniques should yield 100% of the selected mineral (such as chalcopyrite, galena or sphalerite) to a pure concentrate product, while disposing 100% of the gangue minerals (such as pyrite or arsenopyrite) to a tailings slurry for disposal. However, in reality, ore bodies in the real world are seldom so neat, because of their mineralogy (example, finely dispersed gold in ‘solid solution’ in a pyrite matrix), and/or because the mechanics of the beneficiation technique such as flotation are not 100% selective for the mineral of choice.

As a result, concentrate products can become diluted with gangue (reducing the grade, which can in turn negatively affect the payment terms for the concentrate) or by-product minerals (for which sale terms will offer less or zero value); or can become contaminated with deleterious elements (such as arsenic) that attract penalties in typical concentrate sales contracts.
Typical ore beneficiation technologies require compromises between these four factors to yield the best economic outcome, such as accepting lower recoveries (as example) to push the grade up to minimum smelter requirements or to minimise contamination with penalty elements.

Prior to commencing operations, miners will determine a ‘grade-recovery curve’, which plots the sacrifice of metal recovery in order to achieve the optimum product grade and recovery. Every tonne of otherwise-payable metal lost to tailings represents a tonne of metal for which the operator has paid to mine, mill, and process, but for which it gains no value – money literally thrown away. Moreover, that metal disposed to the tailings represents an ongoing management cost and environmental liability for the hazard posed by leaching mine tailings.

As discoveries of large, near-surface ore bodies with ‘relatively simple ’ mineralogy and metallurgy, are becoming less common (particularly in politically stable regions in reasonable proximity to sales markets), the minerals processing industry is looking to new technologies that offer a means of more efficiently exploiting known resources, which have previously been uneconomic. It is also looking for technologies that can recover the sometimes significant lost value remaining in former tailings dams.

The Intec Process has emerged as a technology breakthrough with the ability to unlock value from resources that produce low-grade, polymetallic or contaminated concentrates. These products would typically attract poor sales terms from smelter customers, or in many cases would be altogether unsaleable. For the purposes of this paper, such concentrates and the ores from which they are sourced will be described as ‘secondary resources’.

The Intec Process is a family of patented hydrometallurgical technologies for the recovery of base and precious metals from sulphide and oxide feedstocks. It is based on the use of halide (chloride, bromide and/or iodide) chemistry to solubilise metals through the leaching process, followed by the recovery of high purity metals by electrowinning or as intermediate products.

In addition, the application of the Intec Process has been expanded over the last couple of years, into the commercial-scale recycling of heavy metals from industrial waste waters, sludges, and filter residues. This technology and know-how is directly applicable back to the recovery of heavy metals from mine tailings dam and acid-mine-drainage overflows, as an alternative to conventional lime treatment that could offer many mines an economic and environmental solution to this problem.

**THE INTEC PROCESS**

**The Intec Process Technology**

The Intec Process is applicable to the extraction and recovery of gold, silver, copper, zinc, lead, silver, nickel, indium and a range of other metals from mineral concentrates. All of these applications share a common principal chemistry, although the optimum electrolyte composition and process conditions will vary according to the relative levels of the primary, co-product and by-product metals.

For the purposes of this paper, the application of the technology for recovery of LME Grade A copper metal as the primary product, with by-product gold, silver, lead and zinc will be discussed. An example flowsheet of the process is shown in Figure 1. Fewer or additional unit operations may be required depending on feedstock characteristics.
**Mixed Halide Electrolyte**

The solubility of metals is significantly enhanced in the presence of concentrated halide brines. For example, gold, silver and lead are readily solubilised in the Intec Process liquors, while they remain virtually insoluble in the sulphate lixiviants of competing hydrometallurgical technologies. Furthermore, a broader range of metallic species are also stable in halide liquors, such as the cuprous oxidation state of copper (Cu⁺), which does not exist in sulphate.

The Intec Process brine matrix typically uses a total halide concentration of 6-8 moles/litre, with a boiling point of 115-120°C. The chloride components are a mixture of sodium and calcium chloride; with the ratio depending on overall halide requirements for metal solubility, and the calcium required for sulphate precipitation.

The mixed halide system - usually using sodium bromide in conjunction with sodium/calcium chloride - is at the core of Intec’s patents for metal recovery by halide electrowinning. The Intec Process anode forms the powerful oxidant called Halex™ (NaBrCl₂), which is soluble in the process liquor and is readily recycled through the closed loop system, providing the primary driving force to the leach step.

The high metal leaching rates and efficiencies associated with the Intec Process leach create some challenges for the physical plant. As such, the appropriate selection of materials of construction is important to ensure longevity of equipment. All wetted parts of the plant are fabricated from high performance plastics, or in some sections exotic alloys or titanium.

Reactors are typically constructed from comparatively inexpensive fibreglass reinforced plastic (FRP) using specialty resins, which permits continuous operation at over 100 °C. The costs are similar to or less than equivalent steel tanks. Various linings can be used where required for additional protection, e.g. in high wear zones. Titanium or coated steel agitators have been successfully used, with the final design specific for the
mixing duties required. Piping is generally a mixture of PVDF, FRP or random co-polymer polypropylene depending on temperature and pressure duties.

The performance of these items of equipment has been systematically and successfully proven by Intec at both laboratory and demonstration plant scales, along with ancillary items such as instrumentation, heat-exchangers, ducting, structural framework, and control systems.

**Leaching Processes**

There are two types of feedstock; metal-sulphides (eg the common copper sulphide minerals CuFeS₂, CuS, and Cu₂S) and metal-oxides (eg CuO and Cu₂O).

<table>
<thead>
<tr>
<th>Table 1: Minerals Suitable for Treatment Using the Intec Gold Process</th>
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<tbody>
<tr>
<td><strong>Parameter</strong></td>
</tr>
<tr>
<td>Arsenides</td>
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<td></td>
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<tr>
<td>Sulphides</td>
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<tr>
<td></td>
</tr>
<tr>
<td>Tellurides</td>
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<tr>
<td></td>
</tr>
<tr>
<td>Elemental</td>
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<td></td>
</tr>
<tr>
<td>Antimonides</td>
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The Intec Process has been proven for a wide range of copper-bearing minerals, and a summary of the typical leach conditions is given in Table 1. Notwithstanding the feedstock-specific limitations of particle size and mineral occlusion, typically 98% (95-99.5%) extraction of copper is achieved, and co-extraction of credit metals (e.g. gold, silver, indium, bismuth, etc) is similarly high.

**Sulphides**

Metal sulphides are oxidised by sparging air to supply oxygen and the recycling of liquid anolyte from the halide electrowinning cell, as shown in Reactions 1 and 2.

\[
4\text{CuFeS}_2(s) + 5\text{O}_2 + 20\text{HCl} \rightarrow 4\text{CuCl}_2 + 4\text{FeCl}_3 + 8\text{S}(s) + 10\text{H}_2\text{O} \quad \text{RXN 1}
\]

\[
2\text{CuFeS}_2(s) + 5\text{NaBrCl}_2 \rightarrow 2\text{CuCl}_2 + 2\text{FeCl}_3 + 4\text{S}(s) + 5\text{NaBr} \quad \text{RXN 2}
\]

An oxidation-reduction couple (eg. Cu⁺ → Cu²⁺ + e⁻) is employed to facilitate the transfer of oxygen as shown in Reactions 3 and 4. Put simply, the copper acts as a ‘catalyst’ to maximise the efficiency of oxygen uptake by the process liquor.

\[
4\text{CuCl} + \text{O}_2(g) + 4\text{HCl} \rightarrow 4\text{CuCl}_2 + 2\text{H}_2\text{O} \quad \text{RXN 3}
\]

\[
\text{CuFeS}_2(s) + 4\text{CuCl}_2 \rightarrow 5\text{CuCl} + \text{FeCl}_3 + 2\text{S}(s) \quad \text{RXN 4}
\]

As may be seen in Reactions 1 and 2, the sulphide component (S²⁻) is only partially oxidised to elemental sulphur (S), resulting in a significant reduction in the total oxygen requirement for the system. By comparison, sulphate-based pressure oxidation technologies commonly oxidise sulphur to sulphate (SO₄²⁻).
It is worth noting that the overall leach reaction for sulphides, including the iron precipitation reactions (10 and 11 below) is acid-generating, and thus requires the addition of small quantities of alkali if operated without other metal-bearing acid-consuming feedstocks.

**Oxides**
Metal oxides are leached with acid, which is normally added to the circuit according to Reaction 5. In the case where mixed oxide and sulphide minerals are co-processed, required acid can be generated in-situ via the oxidation of sulphur or sulphides (e.g. the oxidation of pyrite as shown in Reaction 6) and this can be a cheaper alternative to purchasing fresh acid.

$$\text{CuO}_{(s)} + 2\text{HCl} \rightarrow \text{CuCl}_2 + \text{H}_2\text{O} \quad \text{RXN 5}$$

$$2\text{FeS}_{2(s)} + 15\text{NaBrCl}_2 + 4\text{CaCl}_2 + 16\text{H}_2\text{O} \rightarrow 2\text{FeCl}_3 + 4\text{CaSO}_4_{(s)} + 32\text{HCl} + 15\text{NaBr} \quad \text{RXN 6}$$

Where acid is added directly to the process as a reagent, sulphuric acid is purchased, as it is a lower cost reagent than hydrochloric acid. The calcium chloride in the process liquor reacts with the sulphate to form calcium sulphate and hydrochloric acid according to Reaction 7. Due to the high temperatures in the circuit and the concentrated halide brine used in the Intec Process, the anhydrous form of calcium sulphate (anhydrite) is precipitated, as opposed to the hydrated form (gypsum). The anhydrite is highly crystalline and does not form scale on the process equipment, as is normally the case with gypsum in sulphate-based systems.

$$\text{H}_2\text{SO}_4 + \text{CaCl}_2 \rightarrow 2\text{HCl} + \text{CaSO}_4_{(s)} \quad \text{RXN 7}$$

**Arsenic Bearing Feedstocks**
One of the major environmental reasons for selecting hydrometallurgical processing rather than smelting for many copper concentrates is the presence of arsenic. Arsenic is a toxic metal which is difficult to control in the off-gas from smelter operations. As such, an upper limit of 0.5% arsenic in the concentrate feedstocks is normally applied by smelters, and price penalties apply in typical smelter contracts for the presence of arsenic in the concentrate.

In the Intec Process leach circuit, arsenic is readily leached and re-precipitated as highly crystalline ferric arsenate according to Reactions 8 to 10. The crystalline ferric arsenate readily passes conventional TCLP (toxicity characteristic leach procedure) and MEP (multiple extraction procedure) tests as a measure of environmental stability, and the residue has been recognised by environmental authorities as being safe for disposal. Feedstocks containing up to 10% arsenic have been successfully treated by this method.

$$\text{FeAsS} + 7\text{CuCl}_2 + 4\text{H}_2\text{O} \rightarrow \text{FeCl}_3 + 7\text{CuCl} + \text{S} + \text{H}_3\text{AsO}_4 + 5\text{HCl} \quad \text{RXN 8}$$

$$\text{FeCl}_2 + \text{CuCl}_2 \rightarrow \text{FeCl}_3 + \text{CuCl} \quad \text{RXN 9}$$

$$\text{H}_3\text{AsO}_4 + \text{FeCl}_3 \rightarrow \text{FeAsO}_4_{(s)} + \text{H}_2\text{O} \quad \text{RXN 10}$$

**Gold-Bearing Feedstocks**
Current conventional technologies require an oxidative pre-treatment step such as roasting, pressure oxidation or biological oxidation to liberate gold from sulphide concentrates. The oxidised residue is then leached using an alkaline cyanide solution, followed by purification and gold recovery.

In contrast, use of a mixed halide lixiviant in the Intec Process permits gold dissolution to occur concurrently with sulphide mineral oxidation. Therefore, the Intec Process differs from all current commercial practices for treatment of refractory gold concentrates, where gold is extracted from the oxidation residue using cyanide. Cyanide systems require a separate dedicated leach circuit and costly measures for residual cyanide destruction. Importantly, however, the Intec Process can be retrofitted to existing operations where a cyanide strip is employed to recover gold from activated carbon, prior to an electrowinning circuit. An owner may choose this option to increase project productivity for a limited capital expense.
The Intec Process has successfully treated concentrates containing the full range of minerals associated with gold (Table 1). However, highly carbonaceous feeds that contain “active” carbon may be unsuitable for direct treatment using the Intec Gold Process due to excessive preg-robbing behaviour during leaching. In these cases, concentrate pre-treatment or leach residue treatment techniques are recommended to attain high gold recovery.

**Iron Residue**
A potential issue for any process leach circuit is control and precipitation of solubilised iron. Many technologies encounter significant difficulty with the physical handling, filtration and poor environmental stability of precipitated iron wastes.

Leaching of copper minerals using the Intec Process is conducted in the pH range of 1-2, where leachable iron is re-precipitated as hematite according to Reaction 11. The acid generated in this reaction is re-used to oxidise the copper cations as shown in Reaction 12.

\[
2\text{FeCl}_3 + 3\text{H}_2\text{O} \rightarrow \text{Fe}_2\text{O}_3(s) + 6\text{HCl}
\]

\[
4\text{CuCl} + 4\text{HCl} + \text{O}_2 \rightarrow 4\text{CuCl}_2 + 2\text{H}_2\text{O}
\]

The hematite is crystalline and is thus readily filterable. Hematite is one of the most stable forms of iron, and extensive testing has demonstrated that hematite product is environmentally stable, unlike iron jarosites.

**Leach Conditions Summary**
The Intec Process technology has been applied to a wide range of copper-bearing minerals at the laboratory, pilot and/or demonstration plant scales. Table 2 summarises the required leach conditions for copper-bearing minerals suitable for processing by the Intec Process.

<table>
<thead>
<tr>
<th>Table 2: Summary of Leach Conditions using the Intec Process</th>
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</thead>
<tbody>
<tr>
<td><strong>Mineral</strong></td>
</tr>
<tr>
<td><strong>Sulphides</strong></td>
</tr>
<tr>
<td>Chalcocite</td>
</tr>
<tr>
<td>Covellite</td>
</tr>
<tr>
<td>Chalcopryite</td>
</tr>
<tr>
<td>Bornite</td>
</tr>
<tr>
<td>Enargite</td>
</tr>
<tr>
<td>Tennantite</td>
</tr>
<tr>
<td>Tetrahedrite</td>
</tr>
<tr>
<td><strong>Oxides</strong></td>
</tr>
<tr>
<td>Azurite</td>
</tr>
<tr>
<td>Cuprite</td>
</tr>
<tr>
<td>Malachite</td>
</tr>
<tr>
<td>Tenorite</td>
</tr>
<tr>
<td><strong>Other</strong></td>
</tr>
</tbody>
</table>

**By-Product Credit Metals Recovery Options**
The process steps required to recover by-product metals such as gold, silver, indium and bismuth can vary significantly, depending on the concentration of the metals in the feedstock and their relative value to any particular project.
Where the by-product contents and/or values are comparatively low, the chosen recovery methods will be simpler, producing lower-grade products at lower operating cost to maximise overall profitability. Conversely, where the by-product contents and/or values are comparatively higher, there is value in using more sophisticated techniques to recover higher-value products, in many cases in metallic form.

As the methodology can vary quite significantly based on the individual project needs, this discussion provides only a rough guide to the process options available for by-product metal recovery.

**Gold**
Gold recovery from Intec Process leach liquors is achieved using activated carbon or ion-exchange resins in packed columns. These columns are contacted with clear leach solution advancing from the cupric thickener, where the oxidation-reduction potential is sufficient to maintain the gold in solution.

The activated carbon can be saturated with gold and then ashed to recover gold metal. Alternatively the loaded activated carbon is stripped using conventional cyanide or thiourea reagents and the eluted gold is electrowon. The eluted carbon is then reactivated as required, and returned to the process. Test results have shown that re-activation is not required for at least five cycles. The latter route is also applicable to ion-exchange resins.

**Silver**
The liquor exiting the gold recovery stage (or directly exiting the leach, if gold recovery is not required) is advanced to another series of columns containing selective silver adsorption resins developed primarily for the Intec Process. The loaded silver is stripped using acid, with the silver precipitated as a chloride for direct sale or smelted to produce silver metal. The barren adsorbent is returned to the process.

For solutions containing cuprous ions, i.e. when a counter-current leach design is used, the silver is recovered using copper amalgamation promoted by trace mercury. A stoichiometric amount of reducing agent is added to the solution, such as copper dendrites from the electrowinning cell, to control the potential of the solution.

**Zinc and Lead**
Zinc and lead are normally present in minor amounts in copper feedstocks. Depending on the economics of the project, zinc and lead are typically precipitated as mixed hydroxides using lime. Selective recovery is possible if sufficient amounts of zinc or lead are present.

Of course, in feedstocks where lead or zinc represent the primary value in the concentrate, variations of the Intec Process can be applied to directly electrowin these metals as high purity metal product rather than as mineral intermediates. The choice of by-product recovery method is a compromise between incremental by-product value and incremental operating cost.

**Copper Halide Electrowinning**
Intec has developed a copper electrowinning cell specifically for mixed-halide electrolyte systems. The technology can be adapted for specific project requirements, and a such the description below is indicative of a typical cell.

The cell is divided into two compartments via a porous diaphragm (eg conventional filter cloth). The feed solution is directed to the cathode compartment, where metallic copper dendrites are electrowon onto a patented corrugated titanium cathode (Reaction 13). The depleted solution passes through the diaphragm into the anode chamber, where NaBrCl, is generated at the anode (Reaction 14). Some pictures of the titanium cathode (wiped and un-wiped), copper dendrite, as well as the conveyor are given in Figure 2.
Figure 2: (TOP LEFT) Titanium corrugated cathode, (TOP RIGHT) Dendrite, (BOTTOM LEFT) Un-wiped titanium cathode, (BOTTOM RIGHT) Copper dendrites being removed from the EW cell by conveyor belt

The sodium bromo-chlorine complex called Halex™ is a dissolved species with a low vapour pressure. Halex behaves like chlorine gas in terms of oxidation power and chemistry, but with obvious considerable handling advantages compared to a gas. It has a potential of around +1,000 mV (vs Ag/AgCl) and is highly reactive. As a liquid, the oxidant is easily recycled to the leach circuit, where it is more easily utilised than a gas. Halex enhances the leaching of refractory minerals, which often host gold.

Intec has operated a number of cells ranging from laboratory scale to the full commercial 1 tonne per day scale. Larger plants would use multiples of the 1 tonne per day cell. The nominal operating conditions are summarised in Table 3.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Current Density</td>
<td>500-1,000 A/m²</td>
<td>Average in sulphate EW is 400 A/m²</td>
</tr>
<tr>
<td>Cell voltage</td>
<td>2.4-3.2 V</td>
<td></td>
</tr>
<tr>
<td>Cell efficiency</td>
<td>&gt;98%</td>
<td></td>
</tr>
<tr>
<td>Metal Purity</td>
<td>LME Grade A</td>
<td></td>
</tr>
<tr>
<td>Electrodes per bath</td>
<td>32</td>
<td></td>
</tr>
</tbody>
</table>

The key advantages of the Intec Process cell compared to copper-sulphate electrowinning cells are summarised below:
When producing copper dendrites as product, these are removed in-situ using a wiper mechanism and a conveyor belt. This eliminates the cost of cathode removal and stripping, allowing continuous production;

Three times the average current density of a sulphate cell is used in the Intec Process, thereby significantly reducing the overall tankhouse footprint. The copper production rate is up to eight times that of a conventional sulphate cell;

The Intec Process cell can be fed with cuprous (Cu+) ions, thereby reducing the overall energy requirements;

The oxidant (Halex™) generated at the anode is re-used in the leach circuit, whereas the oxygen from the sulphate cell anode is wasted to the atmosphere. This also means that the electrical energy applied to the cell is fully recovered as copper metal and leach reagent.

The copper dendrites are washed and converted to oxygen-free copper wirerod, which attracts a premium of typically 4-8% over LME A grade cathodes. Intec has successfully drawn 8mm wirerod, produced from electrowon copper dendrites, to 0.1mm magnet wire, which meets normal wire standards.

For some projects (typically those of small scale), economic considerations dictate that a cupric leach is preferred. The electrowinning cell can be operated using Cu2+ ions, with the only detrimental impact being a higher energy demand.

**USING THE INTEC PROCESS TO UNLOCK SECONDARY RESOURCES**

**Low Grade Resources**

While the Intec Process offers a cheaper and cleaner alternative to smelting for conventional high-grade, low contamination concentrates, the technology’s key competitive advantage lies in the prospect to unlock value from secondary resources, particularly those which are undervalued due to the inability to economically develop them via conventional technology and product sales avenues.

As the Intec Process can economically treat and achieve high recoveries (>98%) of high-purity metal products from concentrates that fall below saleable smelter grade (as example 10-15% Cu; 30-45% Zn; 30-50% Pb; or 20-30% Cu+Pb+Zn), this raises the possibility for the miner to re-evaluate the product decision process from the grade recovery curve (Figure 3) for its orebody.

![Figure 3: Nominal grade recovery curve for lead recovery from the Hellyer tailings retreatment operation](image-url)
Taking NSW and Queensland base metals mines and resources as example, many of these resources (both developed and undeveloped) need to sacrifice recovery to achieve single-metal, high-grade concentrate products. To achieve 25% copper concentration in the concentrate, a miner may need to sacrifice recovery down to, say, 60%. In other words, to achieve smelter grade product, the miner is throwing away 40% of the contained (primary) metal value. By changing the set-point in the flotation recovery process and accepting the inclusion of more gangue, the product grade could be dropped to 15% copper in concentrate, raising the total metal recovery from the ore to 90%.

A calculation using the assumptions above shows that, for a miner processing one million tonnes of ore at 5% copper, it could produce 120,000tpa of 25% copper concentrate at 60% ore-to-concentrate recovery (losing 20,000tpa of contained copper to tailings), or 300,000tpa of 15% copper concentrate at 90% recovery. The 15,000tpa difference in contained copper at the current copper price of around A$7,000/t and a smelter payment of 75% of the contained metal value yields the miner extra revenues of A$79 million per annum, an increase of 50%. Of course, this is a highly simplified version of the complex arrangements that underpin minerals processing production, transport and smelter sales economics, and is indicated for demonstrative purposes only.

The example above is a copper concentrate, but the Intec Process is well suited to the full range of single and polymetallic base metals, plus gold, silver and other metals. Around Australia, just a couple of the resources to which the Intec Process could add value include Macarthur River, Lady Loretta, Dugald River and Browns.

Given that the miner pays to dig, grind and process the same amount of ore in either case, and given that the incremental cost of producing the lower grade concentrate will be moderate (higher filtration costs, but lower reagents expenditures, etc), then the additional recovered value effectively represents a substantial windfall to the miner when using the Intec Process.

**Polymetallic and Contaminated Resources**

Standard concentrate sales contracts include discounted payment terms for by-product metals, and penalty clauses for deleterious contaminants. A standard copper concentrate contract, as example, will offer little or no value for any contained lead.

For this reason, it is very common for miners of polymetallic resources to try to produce two (or more) separate concentrates, one high in copper, gold and silver, the other high in zinc and lead. In doing so, the miner inevitably sacrifices recovery between the two products, and very commonly ends up with low to moderate levels of ‘cross-contamination’ of product metals as low-value by-products into each other concentrate.

By contrast, the ability of the Intec Process to co-treat the metals for high recoveries from a single polymetallic feedstock removes this problem for the miner, allowing simpler (and therefore cheaper) beneficiation operations, with higher overall metal recoveries and full recovered value for the metals in the polymetallic concentrate product.

Contaminant elements such as arsenic do not pose the environmental challenge to the Intec Process that they do to high-temperature smelting. The Intec Process does not suffer from the hazard and associated environmental control costs associated with airborne arsenic, and therefore the processing costs for arsenic-bearing concentrates is much lower. Furthermore, as the ferric arsenate produced by the Intec Process is inherently stable (being equivalent to the naturally-occurring mineral, scorodite), the operation does not suffer the substantial additional costs of stabilising the arsenic residue prior to disposal. The ability to
economically treat arsenic in concentrate is a particular advantage for gold and copper-bearing mineral feedstocks, in which arsenic is a common contaminant.

**Mine Tailings**

A significant potential application of the Intec Process is the extraction and recovery of metals from retreated mine tailings. Tailings dams have the advantage that they are found at surface, and are easy and cheap to mine. However, having already been processed once, it is often very difficult to reapply standard beneficiation techniques to achieve smelter-grade products, and in doing so then overall metal recoveries can be very poor.

This is the same problem described above for metallurgically-difficult ores, and the outcomes are the same. Taking the Hellyer mine tailings dam in Tasmania as example, Intec purchased the asset from the receivers of Western Metals in 2004, and operated the existing Hellyer mill and concentrator during 2006-2008 to reprocess the tailings to produce a zinc/lead concentrate. At a minimum grade of 48% Zn + Pb, zinc recoveries were acceptable (around 70%), but lead recoveries were very poor at 15%.

Testwork showed that without interrupting the existing concentrate production, the mill operation could be adjusted at minor cost to produce a second concentrate product from the ‘rougher tails’ (the process stream immediately prior to disposal). This ‘intermediate lead concentrate’, at 15% Pb concentration, allowed the total lead recoveries to be increased from 15% to over 65%. While this intermediate product would not be saleable to a smelter at that grade, it represents an acceptable feedstock for the Intec Process. The same model is equally applicable to other operations, and has generated significant interest within the Australian minerals industry.

Unfortunately, due to the adverse circumstances of the global financial crisis and the collapse of international metals prices, Intec was forced to sell its Hellyer assets before it had the chance to implement the technology for improved site operations.

**Mine Tailings Water**

As a hydrometallurgical technology, the principles of the Intec Process described above invoke the extraction of metals into solution from mineral feedstocks, followed by the recovery of those metals either in elemental form or as chemical compounds.

Mine tailings water and tailings overflows are effectively equivalent, except in a slower and more dilute form. With the presence of leachable minerals and/or minerals that create conditions amenable to mineral leaching, particularly acid-generating pyrite, mine tailings waters commonly accumulate metals that, if left unregulated, would cause adverse effects on the environment – particularly copper, lead and zinc.

In most operations, these metals are present due to inefficiencies in the primary operation, and the management of the negative environmental effects thus represents a second cost in addition to the economic losses associated with their disposal to tailings.

A common practice is to add alkali to the tailings dam water to counter the effects of acid generation and to raise the pH to around 8-9, at which pH range many of the target metals become less soluble and precipitate as unstable metal oxides and hydroxides. However, in addition to this being costly in labour, reagents and monitoring, a single acid event due to loss of pH control can cause a bulk redissolution of metals and a spike in the concentrations in the dam overflow, with resulting negative environmental effects.
An alternative is to apply aspects of the Intec Process to capture and recover the metals as sulphide mineral products, which can then be either mixed with the outgoing product from the mill, or can be fed with the ore to the beginning of the mill process circuit. Either way, the result is that the metals are recovered in saleable form, offsetting the tailings management costs, and eliminating these recovered metals as long-term environmental legacies.

Many operations have existing tailings water treatment facilities to manage the overflows, and the Intec Process metal recovery circuits could be easily retrofitted to this existing equipment. Equivalent commercial metals recovery to mineral concentrate product is currently being operated at Intec’s Burnie operating facility in Tasmania.

**CONCLUSIONS**

The Intec Process has been proven as a means of unlocking value from secondary resources: mineral concentrates that are low-grade, polymetallic and/or contaminated, for which the economics of production for smelter customers is sub-optimal or unviable.

Intec is currently working on or considering a range of projects utilising the Intec Process for this purpose. In some cases, the application of the Intec Process means the difference between being able to economically exploit a stranded resource or continuing to leave such a resource undeveloped.