MOUNT ISA MINES NECESSITY DRIVING INNOVATION

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ABSTRACT

Mount Isa Mines (MIM) acquired a reputation for the successful application of R&D to develop break-through technologies for the mining industry starting in the 1978's through until the early 2000's. The ISAPROCESS™ tank-house technology has been licensed to copper refineries throughout the world, and a significant per cent of the world's copper is refined using this technology. Since development in the late 1980's more than 20 ISASMELT™ copper and lead smelting furnaces are now installed in countries around the world. Jameson Cell flotation technology developed jointly by Mount Isa Mines and Professor Graeme Jameson is widely used in the Australian coal mining industry and increasingly in the base-metal and gold industry. The IsaMill™'s developed at Mount Isa and McArthur River made it possible to develop the McArthur River and George Fisher orebodies and has been successfully implemented into base metal fine grinding applications around the world. The most recent commercialised innovation is the atmospheric leach Albion Process™ with its supersonic HyperSparge™ gas sparger, is being adopted as a solution to the increasing complexity of orebodies.

MIM's contribution to the industry was significant given the size and the remote location of its operations with Townsville Copper Refineries more than 1350 km and Mount Isa 1800 km from the nearest state capital of Brisbane. This paper will briefly discuss the development of each of these technologies and why MIM – now owned by Glencore - was so successful innovating and developing such technologies over a period of nearly 40 years.

KEYWORDS

Innovation, Mount Isa Mines, ISAPROCESS™, IsaKidd™, ISASMELT™, IsaMill™, Jameson cell, Albion Process™, HyperSparge™, ZipaTank™

INTRODUCTION

Mount Isa is located in the Gulf Country region of Queensland about 1800 kilometers North West of Brisbane (see Figure 1). It came into existence because of the world class mineral deposits found in the area. In 1923 the orebody containing lead, zinc and silver was discovered by the miner John Campbell Miles. Mount Isa Mines Limited (MIM) was founded in 1924 to develop the minerals discovered by Miles, but production did not begin until May 1931. It paid its first dividend in 1947 after 16 years of troubled production. In 1954 the 1100 copper orebody was discovered and with rapidly rising reserves during the 1950's and 1960's led to the construction of new concentrators to treat lead/zinc/silver ores in 1966 (#2 concentrator) and copper ore's in 1973 (#4 concentrator). The difficult nature of the Mount Isa lead-zinc orebodies has meant that the company had always needed to be at the forefront of mining technology. In the 1970's through to the 1990's, it became a world leader in developing new mining techniques and processing technologies as a response to declining metal prices and rising costs. Mount Isa has been smelting copper since 1953 and lead since the early 1930's. Copper Refining at Mount Isa's fully owned subsidiary of Copper Refineries Proprietary Limited (CRL) had commenced operations in 1959.

Figure 1 – Location of Mount Isa and Townsville relative to Brisbane the nearest Capital City

Technologies to come out of Mount Isa include the ISAPROCESS™ copper refining technology, the ISASMELT™, The Jameson Cell, the IsaMill™, the Albion Process™ and the Hypersparge™. Mount Isa Mines Ltd was acquired by Xstrata in 2003 and Xstrata was then merged with Glencore in 2015. The level of innovation achieved at Mount Isa Mines is unsurpassed and was the result of the difficult nature of the Mount Isa ore bodies and its response to declining metal prices and rising operational costs in the 1970's and 1980's. By the 1990's, Mount Isa had become a world leader in innovative mining techniques and state of the art processing technologies. The processing technologies are discussed below.

INNOVATIONS

Each of the innovations developed at Mount Isa Mines had a driver but the overarching desire was to make technology more efficient and cost effective. Each of these process developments will be discussed separately.

ISAPROCESS™

The development of the ISAPROCESS™ tank house technology had its beginning in the zinc industry. During the mid-1970s, MIM was considering building a zinc refinery in Townsville to treat the zinc concentrate produced by its Mount Isa operations. As a result, MIM staff visited the zinc smelters using the best-practice technology and found that modern electrolytic zinc smelters had adopted permanent cathode plate and mechanised stripping technology. MIM realised that the copper refineries performance was constrained by the conventional practice of copper starter sheets. The preparation of these copper starter sheets was labour intensive and the overall cycle was several weeks in duration.

MIM initiated a research program aimed at developing similar permanent cathode technology for copper refining. CRL, a subsidiary of MIM, had been operating in Townsville since 1959, using conventional starter-sheet technology and treating blister copper produced in the copper smelter at Mount Isa. Permanent cathode technology was developed and adapted over many years of in-plant experimental work and successfully introduced to the Townsville refinery in 1978. . The fundamental difference between the new ISAPROCESS™ and the conventional starter sheet technology is the use of a permanent reusable cathode blank instead of a non-reuseable copper starter sheet and the introduction of mechanised and automated electrode handling machines replacing labour-intensive manual operations. The vertical edges had plastic strips and the bottom cased in wax to prevent copper cathode from growing around the edges of the cathode plate during, stripping and allowing two separate copper sheets from each cathode plate. This technology led to major advances in the electrode handling systems and automation in copper tank houses. The improved geometry of the cathode plates and the significantly shorter cathode cycle times allowed for increased intensity and efficiency of the refining process. Introduction of permanent cathode technology resulted in higher capacity, better copper cathode quality with less defects, safer operation and a four-fold improvement in productivity. Considerable development work was required to modify the original stripping machines from their zinc cathode origins due to the heavier cathodes. The stripping capacity of the machines has increased from 250 plates per hour to 600 plates per hour in the latest designs. More recent developments include the elimination of wax masking from the cathode plate, robotic electrode handling machines, and the introduction Duplex Stainless Steel cathode plates giving greater durability and corrosion resistance. Through the use of ISAPROCESS™ user forums, to exchange ideas and developments in the technology and to share operational experiences, the technology has enjoyed continued improvement with higher productivity and improved quality at low cost.

Figure 2 – The IsaKidd process

In mid 1981 Falconbridge Limited commissioned a copper smelter near Timmins to treat concentrate from its Kidd Mine. The original copper cathode produced at Kidd suffered from the presence of higher concentrations of lead and selenium and could not meet customer specifications. It was determined that the use of copper starter sheets was preventing the Kidd refinery from meeting its cathode quality targets. Testwork began with the use of permanent stainless steel cathodes after preliminary tests showed a significant reduction in deleterious elements. The Kidd Process cathode used a solid copper header bar welded onto stainless steel resulting in a lower voltage drop than the ISAPROCESS™. Falconbridge began marketing the Kidd Process technology in 1992 providing competition between the two suppliers of permanent cathode technology. Between 1992 and 2006, 25 Kidd technology licenses were sold and 52 ISAPROCESS™ licenses.

The development of the ISAPROCESS™ and Kidd Process set the scene for a run of technology developments that continued until the mid 2000's. Xstrata took over MIM in 2003 and then Falconbridge in 2006. The Kidd Process technology consequently became part of the tank house package and together they have since been marketed as IsaKidd™ representing the dual heritage of the technology. The current robotic stripping machine (Figure 2) is based on over 30 years of copper refining and winning technology. Today over 100 licensees are using IsaKidd™ technology.

ISASMELT™

The sinter plant/blast furnace combination was the dominant technology for lead smelting throughout the 20th century. In the early 1970's companies using this technology came under sustained political and economic pressure as tighter environmental regulations were introduced, and energy costs increased, leading to higher capital and operating costs (Fewings 1988). It was in this environment that Mount Isa Mines sought a process that would improve the performance of the operations at their lead smelter in Mount Isa. After investigating the various processes under development, researchers turned their attention to the Sirosmelt lance. It had recently been developed on a laboratory scale at the Commonwealth Scientific and Industrial Research Organisation (CSIRO) in Melbourne. Following initial investigations Mount Isa Mines recognised the potential of the novel concept for smelting of lead concentrates and embarked on an extensive development program.

In 1978 a joint project was initiated between Mount Isa Mines and CSIRO to investigate the application of the Sirosmelt submerged-combustion technology to the smelting of Mount Isa lead concentrates. The ISASMELT™ process, as it became known, was developed to maturity for smelting copper, nickel, lead and zinc feeds by Mount Isa Mines through the 1980's and 1990's using incremental scale up. Commercialization only occurred once the process had been proven on laboratory, pilot and demonstration scale over many years. Approximately ten years were required for development of the lead and copper ISASMELT™ from crucible to demonstration scale (refer to Figure 4). During this decade the core know-how that was accumulated enabled the development team to reach the point where they were much better equipped to design and construct a full scale commercial plant – the final stage of the scale up process. Key aspects in this process were the selection of the scale up factors and the systematic design, development and re-engineering of several components of the technology. Figure 3 shows a comparison for the scale up stages for the lead and copper ISASMELT™ processes. Pilot scale was defined as unity for scale up comparison.

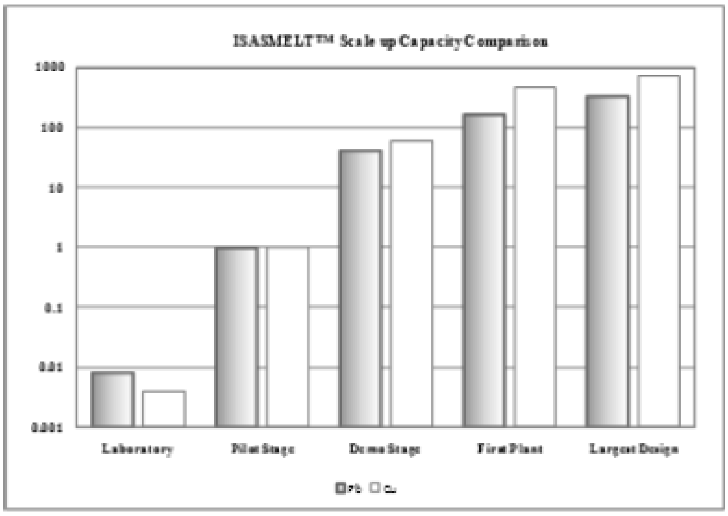

Figure 3 – Lead and copper ISASMELT™ Scale up comparison

During the scale up process, refer to Table 1, several aspects of the technology were developed to a high standard that allowed the ISASMELT™ technology to become a commercial success. As a result, ISASMELT™ technology now operates successfully at numerous plants around the world. The methodical approach to development of the technology has allowed owners to modernise their existing operations or create new businesses with significantly reduced technical risk.

An important parameter in the evolution of the ISASMELT™ technology has been the refractory campaign life. Figure 5 shows the history of the refractory campaigns at the commercial copper ISASMELT™ plant at Mount Isa since commissioning. At the time Mount Isa Mines management considered the installation of water cooling on the furnace refractories undesirable because of the potential for fatal incidents and increased operating costs. As a result the commercial scale furnaces were constructed with minimal water cooling. Although this led to shorter campaign lives initially, a development program was begun that focussed on optimising refractory materials selection and installation methodology. When coupled with process control strategies and continuous on-line monitoring of the bath temperature using systems developed over more than 10 years of operation, it allowed Mount Isa Mines to achieve campaign lives of more than 3 years without using any water cooling of the furnace refractories.

Figure 4 – Tapping matte from the copper ISASMELT at Kazzinc

Table 1 – Key Indicators of ISASMELT™ Plants from pilot to commercial scale

Topic	Unit	Pilot Scale		Demo Scale		First Full Scale		Current Design[1]	
		Pb	Cu	Pb	Cu	Pb[3]	Cu	Pb	Cu
Furnace ID	m	0.4	0.4	1.8	2.3	2.5	3.75	3.6	4.4
Lance Diameter	mm	38	38	150	250	250	350	250	500
Lance Control	-	Manual		Semi	Automatic	Semi Automatic		Automatic	
Oxygen Enrichment	%	21	21	21	28	35	45	70	90
Nominal Feed Rate	tph	0.12	0.25	5	15	20	101	40	183
Offgas Treatment	-	Flue System / Baghouse		Gas cooler/ Baghouse		WHB		WHB[2]	

Notes:
ID: Internal Diameter; WHB: Waste Heat Boiler
[1] Refers to maximum throughput
[2] Some of the plants use a combination of radiation section and evaporative cooler for offgas treatment
[3] Refers to the smelting furnace from the two stage lead ISASMELT™ process

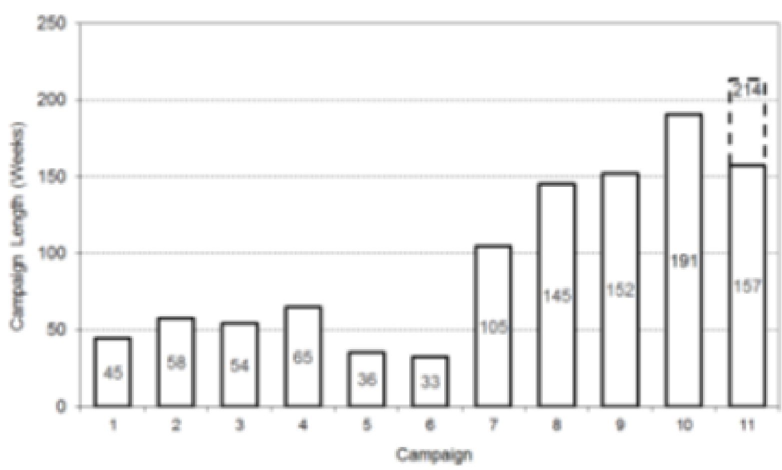

Figure 5 – Mount Isa copper ISASMELT™ plant campaigns (as of 2013)

Jameson Cell

The Jameson Cell (Figure 6) was jointly developed by Mount Isa Mines and Laureate Professor Graeme J Jameson (AO) of the University of Newcastle. Mt Isa had commenced operations with conventional flotation cells but was installing columns in cleaning duties in the mid 1980's. The columns had the benefit of froth washing that was likely to allow significant grade benefits in the very fine lead-zinc circuit. The first observations of the columns was that the collection process was slow necessitating long residence times and large volumes which remains a limitation of columns even today. In 1985 Professor Jameson was commissioned to undertake a project to improve the column sparger design.

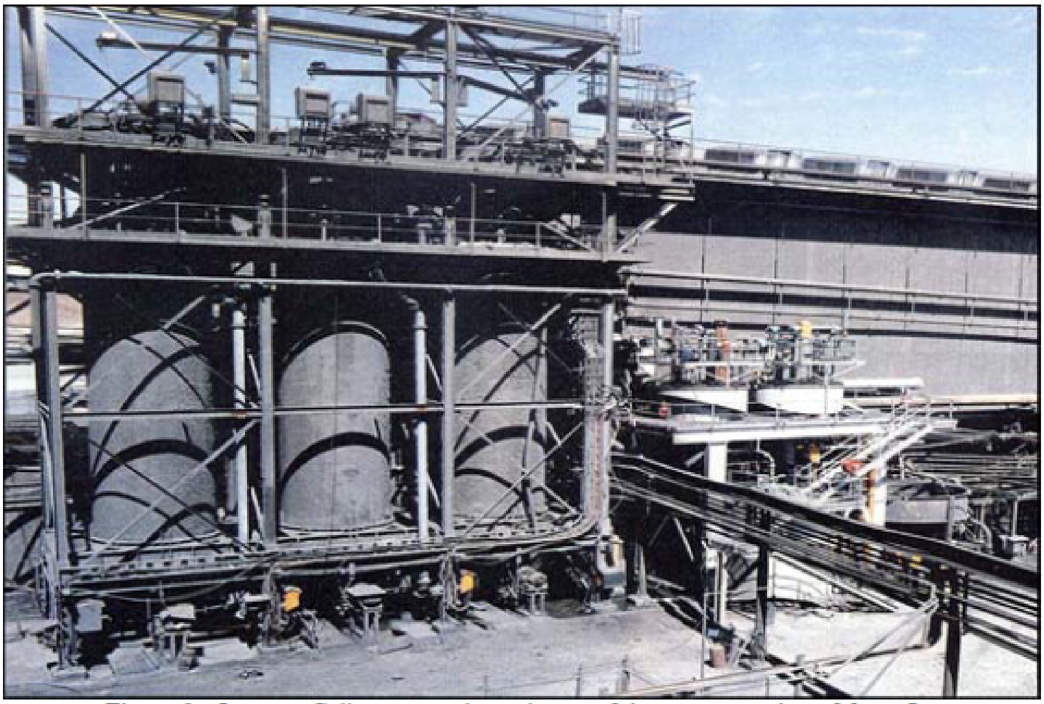
Figure 6 – Jameson Cells compared to columns of the same capacity at Mount Isa

Following initial work to provide an alternate method to bring together bubbles and particles, the downcomer was created. In the downcomer the air and the slurry are co-current with the air being entrained into the plunging jet under vacuum. Investigation showed that all of the bubble particle contact took place in the downcomer and thus the flotation tank could be much smaller. The first application at an industrial scale was in the lead zinc concentrator on the heavy media plant (HMP) lead slimes circuit. The initial improvement in performance were attributed to the very short residence time that allowed the minimisation of oxidation of galena fines. The cells were significantly smaller than the columns and there is no doubt the performance was superior as shown in Figure 3.

The testwork and trials in the early applications showed improved metallurgical performance when operated correctly. The challenge was operating them correctly. The technology hadn't been sufficiently developed to be successfully adopted into plant operations. The cell fell out of favour in base metals and in the 1990's was adopted into the Australia Coal industry and into niche SXEW applications where the main design challenges were resolved. The operability was improved by the introduction of a partial recycle to maintain constant flow and the maintainability of the cell was improved through various design modifications in operating plants. It was a period of continuous improvement. The result was a robust, low maintenance, easy to operate cell with the original features of excellent bubble particle contact.

The final obstacle was overcome when its adaption into the flowsheet was recognised to enable successful installations at the head of cleaner circuits and as low cost brownfield expansions. It is clear that the fast failures have had a significant effect on the success of the cell limiting its adoption into the industry. It is interesting that a significant proportion of sales are to return customers. Once you get over the hurdle of getting a Jameson Cell into your plant then seeing is believing. 2016 was the best year for Jameson cells into base metals and include the first sales back into South America where the cell had been abandoned after the difficulties of operations and maintenance of the Alumbrera installation. The metallurgical performance in Alumbrera was never the issue but the operators and maintainers hated the cells and they failed fast and hard.

The Jameson Cell celebrates its 30th birthday this year and has finally been adopted into mainstream base metals concentrators mainly as cleaner scalper at the head of the cleaner circuit. The cells generally recover up to 80% of the cleaner feed at high grades enabling much lower capital expenditure on the entire circuit. Process performance can be predicted from laboratory and pilot plant testing with demonstrated direct scale-up. It may have taken 30 years but the Jameson Cell is finally a success story. There are many lessons that can be learned from the implementation of innovation into industry from this case study.

IsaMill™

Unlike the developments of some of the other technologies at Mount Isa where efficiency was the main driver, the IsaMill was developed based on necessity. Figure 7 shows photomicrographs with the same scale of 40 micron demonstrating the increased complexity of Mount Isa ore over Broken Hill ore and the very difficult McArthur River ore. Although McArthur River was discovered in 1955 it was not able to be economically processed until the successful development of ultrafine grinding. McArthur River processing began in 1995 – 40 years after discovery when the IsaMill™ made it technically and economically feasible to grind all of the rougher concentrate to 7 micron to facilitate the rejection of non-sulphide gangue. Even at 7 micron galena liberation is not possible and a bulk zinc-lead concentrate is produced.

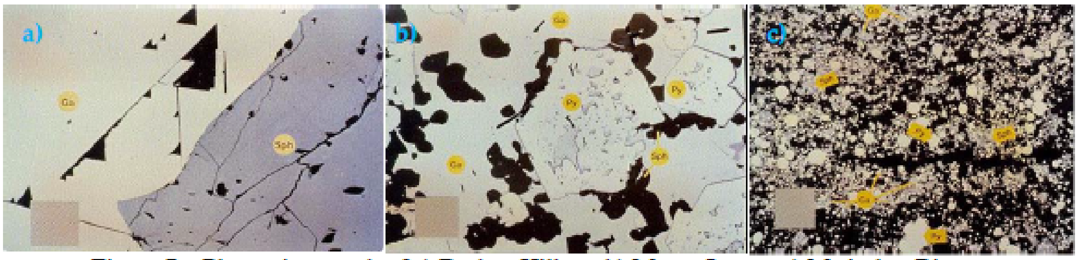

Figure 7 – Photomicrograph of a) Broken Hill ore b) Mount Isa ore c) McArthur River ore

Investigations into fine-grinding started at Mount Isa started in the 1970s using conventional grinding technology to increase mineral liberation by grinding to fine sizes. These technologies were not only found to have high power consumption but also proved to be detrimental to flotation performance as a result of pulp chemistry and iron contamination from steel media. These poor results were revisited during pilot plant and tower mill testwork in the 1980s which also showed an inability of tower mills to economically achieve the required sizes. When it became clear that the solution to efficient fine-grinding did not exist in the minerals industry, MIM looked for ideas to "crossover" from other industries that also ground fine particles – pigments, pharmaceuticals, foodstuffs (e.g. chocolate). While these mills operated at a much lower scale and treated high value products they demonstrated the principle that stirring fine media at high speed was highly efficient. The challenge was transferring this concept to continuous, high tonnage and lower-value streams in the minerals industry.

In 1991 the introduction of a Netzsch laboratory stirred mill to the Mount Isa site was a turning point in fine-grinding and ultrafine grinding. The ½ litre bench scale mill resembled a milk shake maker and used fine copper smelter slag as grinding media. Testwork on McArthur River ore started in 1991, and by January 1992, a small pilot scale mill, LME100, had been designed and installed at the Mount Isa pilot plant. The testwork showed that high speed, inert, horizontal mills could efficiently grind to 7 microns at laboratory scale providing major improvements in metallurgical performance. To make ultrafine grinding applicable to full-scale production a program of development was undertaken between Mount Isa Mines Limited and NETZSCH-Feinmahltechnik GmbH.

After 7 years of development and testing of prototypes in the Mount Isa operations, the IsaMill™ evolved. It was large scale, continuous, and most importantly robust because it was developed by operators. The crucial breakthrough was the perfection of the internal product separator – this allowed the mill to use cheap natural media (sand, smelter slag, ore particles) and to operate in open circuit. These are significant advantages for operating cost and circuit simplicity. Scale-up was tested using trial installations at the Hilton and Mount Isa lead/zinc concentrators. By the end of 1994, the first full scale IsaMill™ (1.1MW) was installed in the Mount Isa concentrator. Improvements to the technology were continually made by the operators, maintainers and engineers working with the technology.

In 1998 the rights for commercialisation of the IsaMill™ where transferred from Mount Isa Mines Limited to MIM Process Technologies (now Glencore Technology) and under an exclusive agreement with Netzsch. In December 1998, the IsaMill™ technology was launched to the metalliferous industry as a cost effective means of grinding down to and below 10 microns. The IsaMill™ is now a mainstream fine grinding machine with over 130 installations around the world.

The Albion Process™

In the 1990's, MIM were studying options for the development of the large Frieda River/Nena project in PNG through its subsidiary Highlands Pacific. The Nena ores were not amenable to smelting, due to the elevated arsenic content, and several hydrometallurgical options were examined. Out of this work, MIM developed the Albion Process™, named after the suburb in Brisbane where MIM's development laboratory was located. The Albion Process™ is a combination of ultrafine grinding using Glencore Technology's IsaMill™, followed by oxidative leaching at atmospheric pressure in a series of reactors designed to achieve high oxygen mass transfer efficiency. The HyperSparge™ was also developed to deliver oxygen to the reactors efficiently.

Various small scale continuous pilot plant campaigns were conducted in 1994 and 1995. A larger pilot plant (120kg zinc cathode/day) was constructed in 1997 to conduct testwork as part of a feasibility study on the zinc/gold resources of Pueblo Viejo in the Dominican Republic. Extensive piloting was also conducted on lower grade chalcopyrite concentrates for Cyprus Amax in 1998, and for Mount Isa Mines in 2000. Pre-feasibility and feasibility pilot testing was conducted on the zinc/lead bulk concentrates from McArthur River and Mount Isa in Australia between 2001 and 2005. During this time the Albion Process™ was successfully tested on over 70 different ores and concentrates. The process is designed to recover gold and base metals from refractory ores. The key to the process is the ultrafine grinding stage followed by a hot oxidative leach at atmospheric pressure.

In the period from 1994 until 2004, the Albion Process™ (see Figure 8) was seen as strategic to the MIM/Xstrata group, and was not marketed externally. In 2005, a decision was made to offer the technology to external clients under licence, and a marketing agent – Core Resources, was appointed to market the technology globally. Interest in the technology has been very strong in the subsequent period, with early licences signed in 2005 for the Las Lagunas Project, and 2006 for the Certej Project. The technology moved into commercial production in 2010 with the commissioning of Glencore's Albion Process™ plant in Spain (4,000 tpa zinc metal), followed in 2011 by the commissioning by Glencore of a second plant in Germany (16,000 tpa zinc metal). The Las Lagunas refractory gold project commissioned in 2012, and the GPM Gold refractory gold project commissioned in 2013.

Figure 8 – The Albion Process oxidative leach plant in Armenia

The major scale up risk with any oxidative leaching technology is oxygen mass transfer. High agitator power demands are common to achieve the shear rates in the vessel required for effective mass transfer at a commercial scale. A different approach was taken in the design of the Albion Leach Reactor to lower the agitator power demand. Glencore developed the HyperSparge supersonic gas injection lance to provide gas injection velocities of the order of 500 $m.s^{-1}$ within the leaching vessel, compared to the 4 – 8 $m.s^{-1}$ achieved with a typical agitator. Supersonic oxygen injection is a far more efficient method of generating shear than conventional agitation, allowing the total power input into the vessel to be significantly reduced, and greatly reducing the scale up risk for the oxidative leach.

The Albion Process™ was enabled by the fine grinding of the IsaMill™ and the process was designed to deliver a lower cost processing option for treating refractory mineral resources. There are now six operating Albion Process™ plants and the process has now an extensive database of potential applications.

CONCLUSIONS

MIM developed a significant number of processing innovations that are technical and economic successes. The ability to innovate at MIM was enabled by very challenging orebodies and the need to process efficiently to remain economically viable. The success has been attributed to the development of these technologies on an operating site with the R&D group solving the technical issues on small scale. Each subsequent scale up was completed in the operating plants where the operators, maintainers, engineers and metallurgists were required to achieve production goals at each step of the scale up to ensure funding for the next step.

The number of innovations, at MIM, was disproportionate to the scale of operations and may have been enabled by the remoteness of the site and the researchers and operators working collaboratively to solve economic and technical problems. The research group were not capital city based but worked on the same site and were required to assist with installation, commissioning and operation of the various stages. This co-operation led to adoption into the plant and a fast feedback loop for improvements. The ultimate success of the innovations has been their widespread adoption into the mainstream industry where feedback from operating sites based on a user group model has enabled continuous improvement of each of the technologies.

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technologies in their plants. The success of these developments continues with the input from end users in the ongoing development.

REFERENCES

Armstrong, W. "The Isa Process and its contribution to electrolytic copper," paper presented at the Rautomead Conference, Scotland, August 1999.

Fewings J.H., Management of Innovation – The IsaSmelt Process. Presented at AMIRA "Innovation in Metal Production" Technical Meeting at Mount Isa, October 3-4, 1988.

Fountain C. Isasmelt and IsaMills – Models of successful R&D – AusIMM Young Leaders conference, 19-21 March 2002, Kalgoorlie, W.A.

Nihill D.N., Stewart C M. and Bowen P. the McArthur River Mine – The First Years of Operation. The AusIMM '98 Mining Cycle. Mount Isa 19-23 April 1998.

Pease, Joe (August 2005), "Complex leaching becomes much simpler" (PDF), Australian Mining, pp. 26–32, archived from the original (PDF) on 12 September 2009, retrieved 6 January 2010

Pease, Joe September 2016, "Crossing the innovation valley of death" Presented to JKMRC.