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Authors:
Philip Arthur, Xstrata Technology
Britt Butler, James Edwards, Chris Fountain, Simon Hunt, Jorma Tuppurainen, Mount Isa Mines Ltd

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For further information please contact us at isasmelt@xstratatech.com.au

THE ISASMELT™ PROCESS—AN EXAMPLE OF SUCCESSFUL INDUSTRIAL R&D

Philip Arthur[1], Britt Butler[2], James Edwards[2], Chris Fountain[2], Simon Hunt[2], Jorma Tuppurainen[2]

[1]Xstrata Technology; Level 4, 307 Queen Street, Brisbane, Queensland 4000, Australia
[2]Mount Isa Mines Limited; PMB1, Mount Isa, Queensland 4825, Australia

Abstract

The ISASMELT process[i] is making a significant contribution to the global metals industry. ISASMELT furnaces are now operating successfully in eight different countries and treating approximately 3 million tonnes of concentrates and secondary materials per year. The process is currently used in both lead and copper smelting. The most recently commissioned plants were in Germany and China, one for treating scrap copper and the other treating low-grade copper concentrates.

The Copper ISASMELT furnace ("CIF") at Mount Isa Mines Limited[ii] ("MIM") has continued to set new operational records, with throughput of more than 1 million tonnes of concentrate per year and very low operating costs.

This paper summarises the latest operational data from the Mount Isa Copper ISASMELT plant and outlines the successful approach to industrial R&D taken by MIM in the development of the ISASMELT process.

Introduction

The closing decades of twentieth century were a time when there was intensive development of new smelting processes in the non-ferrous industry. Smelter operators were under increasing pressure to reduce emissions while keeping costs under control. Existing processes were seen as requiring expensive capital input to reduce emissions and expensive to operate. Processes either newly developed or under development included: Contop flame cyclone reactor, Kaldo top blown rotary furnaces, QSL, Kivcet, the Mitsubishi copper furnaces, the Noranda reactor, the El Teniente converter, and MIM's ISASMELT process.

While many of the other processes have either failed to achieve commercial success, or have been adopted in niche applications, the ISASMELT process is going from strength-to-strength, with eight companies in eight different countries now using the technology, and a ninth plant being built by the Yunnan Metallurgical Group in China. In addition, Sterlite Industries is expanding its Tuticorin copper smelter to 300,000 tonnes of anode copper per year by replacing

[i] ISASMELT™ is a registered trademark of Xstrata Technology

[ii] Mount Isa Mines is now owned by Xstrata. Mount Isa Mines Process Technologies is now Xstrata Technology

its existing Copper ISASMELT Furnace with a larger unit. ISASMELT furnaces now treat approximately three million tonnes per year ("t/y") of concentrates and secondary materials.

The ISASMELT technology was developed by MIM at its Mount Isa operations. Its history has been documented in other papers [1-9]. This paper will give a brief description of the ISASMELT process, and discuss the recent performance of the Copper ISASMELT furnace at Mount Isa. It will conclude with some comments about the approach taken to the development of the ISASMELT process that has made it so successful.

A brief description of the ISASMELT process

The ISASMELT process can be adapted to treat a variety of feed materials. It has had the following commercial applications:

- MIM, Mount Isa, Australia (copper concentrate and lead concentrate);
- Phelps Dodge, Miami, Arizona (copper concentrate);
- Sterlite Industries, Tuticorin, India (copper concentrate);
- Yunnan Copper, Kunming, China (copper concentrate);
- Umicore, Hoboken, Belgium (secondary copper and lead materials, plus concentrate);
- Hüttenwerke Kayser, Lünen, Germany (secondary copper materials);
- Britannia Refined Metals, Northfleet, UK (secondary lead materials);
- Metal Reclamation Industries, Pulau Indah, Malaysia (secondary lead materials); and
- Yunnan Metallurgical Group, Kunming, China (lead concentrate—under construction).

The process is based on a specially-designed submerged-combustion lance. The lance is inserted into the ISASMELT furnace, which is a stationary, vertical, refractory-lined vessel. The injection of air, or oxygen-enriched air, results in very intense agitation of the molten bath and a rapid reaction rate. The Copper ISASMELT furnace at Mount Isa has smelted up to 194 tonnes per hour ("t/h") of copper-bearing feed (concentrate, reverts, and other internal smelter recycle materials) in a bath volume of approximately 15 m^3.

The ISASMELT lances are based on the SIROSMELT lance developed by the Australian Government's research organisation, the CSIRO. They are protected from damage by the bath contents by a layer of slag frozen onto the outer surface of the steel. An internal swirler forces the process air against the steel to cool it. ISASMELT lances have a unique low-pressure swirler that allows them to operate at about 80 kPag. A single stage blower can thus be used to provide combustion air rather than a more expensive compressor.

A schematic diagram of the Mount Isa Copper ISASMELT flowsheet is shown in Figure 1. All the concentrate treated at Mount Isa is smelted by the ISASMELT furnace, which treated over 1,000,000 tonnes of concentrate and reverts during the 2001-2002 financial year.

The Mount Isa Copper ISASMELT furnace is fed with pelletised concentrate. It has a single tap hole, through which matte and slag are tapped into a Rotary Holding Furnace ("RHF") for separation. The furnace is equipped with an Ahlstrom Flux-Flow boiler. It can use coal, oil, or natural gas as a fuel to supplement the energy contained within the concentrate being smelted.

Recent performance of the Mount Isa Copper ISASMELT furnace

Production

The Mount Isa Copper ISASMELT plant was originally designed to treat concentrate at an average rate of 104 t/h, equivalent to 180,000 t/y of contained anode copper [5]. It achieved the target of an annual average of 104 t/h of concentrate during the 12 months to the end of April 1997. MIM then upgraded the Copper Smelter to increase the throughput of the Copper ISASMELT furnace to 265,000 t/y of contained copper. The modifications made have been described in more detail elsewhere [8]. They included:

- the installation of a second 525 t/d oxygen plant;
- the removal of the original slag granulation system and its replacement with Kress haulers;
- the addition of a fourth Peirce-Smith converter;
- the replacement of the two converter aisle cranes;
- the replacement of the old 45 t/h anode casting wheel with a new 80 t/h wheel;
- the installation of a "stacker-reclaimer" to improve the blending of the ISASMELT feed;
- the construction by WMC-Fertilizers Limited of an acid plant to capture the Copper Smelter sulfur dioxide; and
- the replacement of the ISASMELT Induced Draft ("ID") fan with a larger one.

No changes were made to the ISASMELT furnace itself.

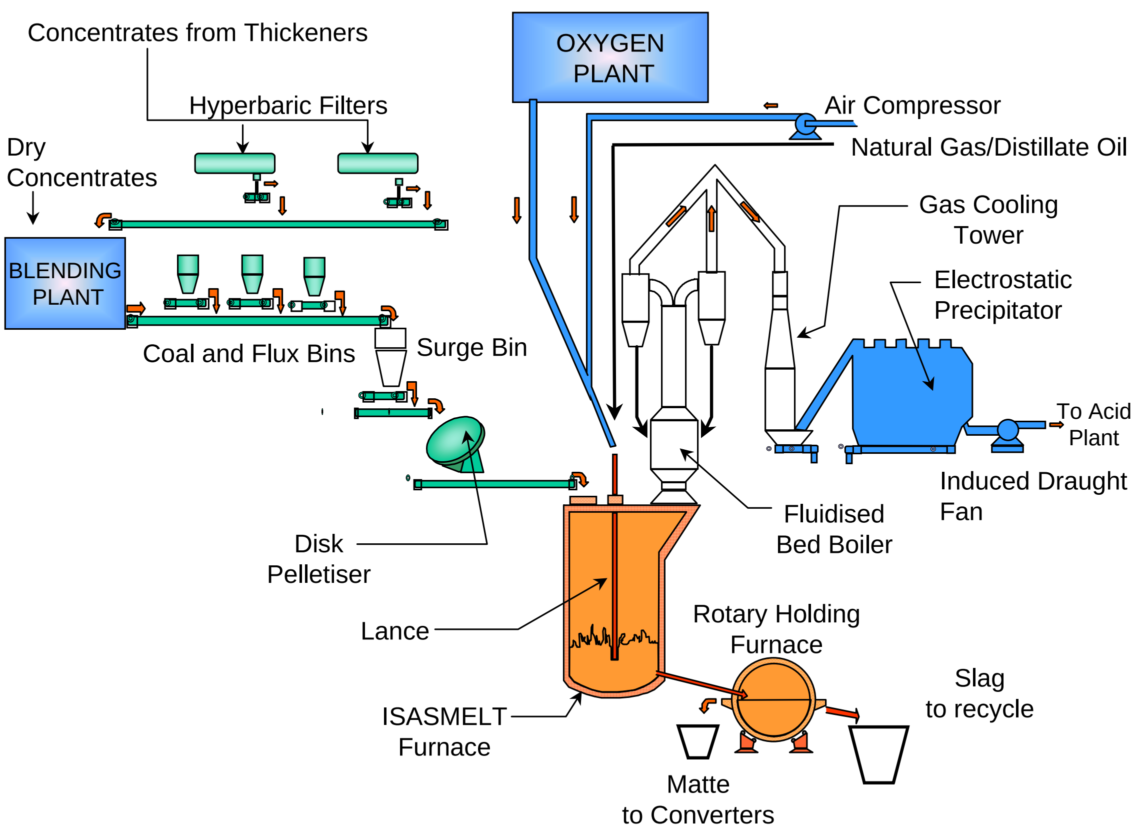

Figure 1 – The Mount Isa Copper ISASMELT Flowsheet

Figure 2 shows the total number of tonnes of copper-bearing feed treated by the ISASMELT furnace each financial year (from 1 July to 30 June in Australia) since it was commissioned in August 1992. The Copper Smelter production is still being ramped up to meet the new target. The ISASMELT furnace concentrate treatment rate is constrained by bottlenecks elsewhere in the smelter, but its annual production rate is increasing as these bottlenecks are eliminated. Figure 3 shows the number of tonnes of concentrate smelted each month during the 2001-2002 financial year.

The Copper ISASMELT furnace set new production records during the 2001-2002 financial year. The ISASMELT furnace treated 1,068,228 tonnes of feed with an average grade of 26.90% copper. The monthly production record was set in April 2002 when the ISASMELT furnace smelted 104,345 t of feed containing 26.95% copper at an average rate of 158 t/h.

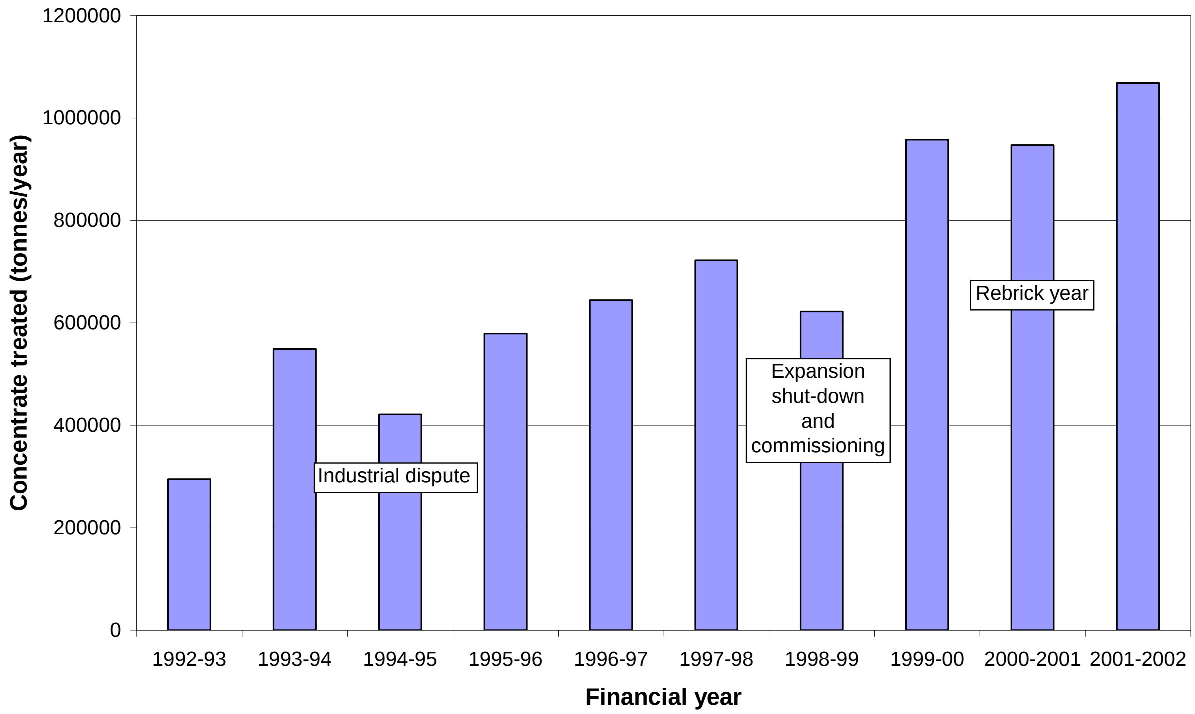

Figure 2 – Concentrate smelted by the Copper ISASMELT plant since commissioning

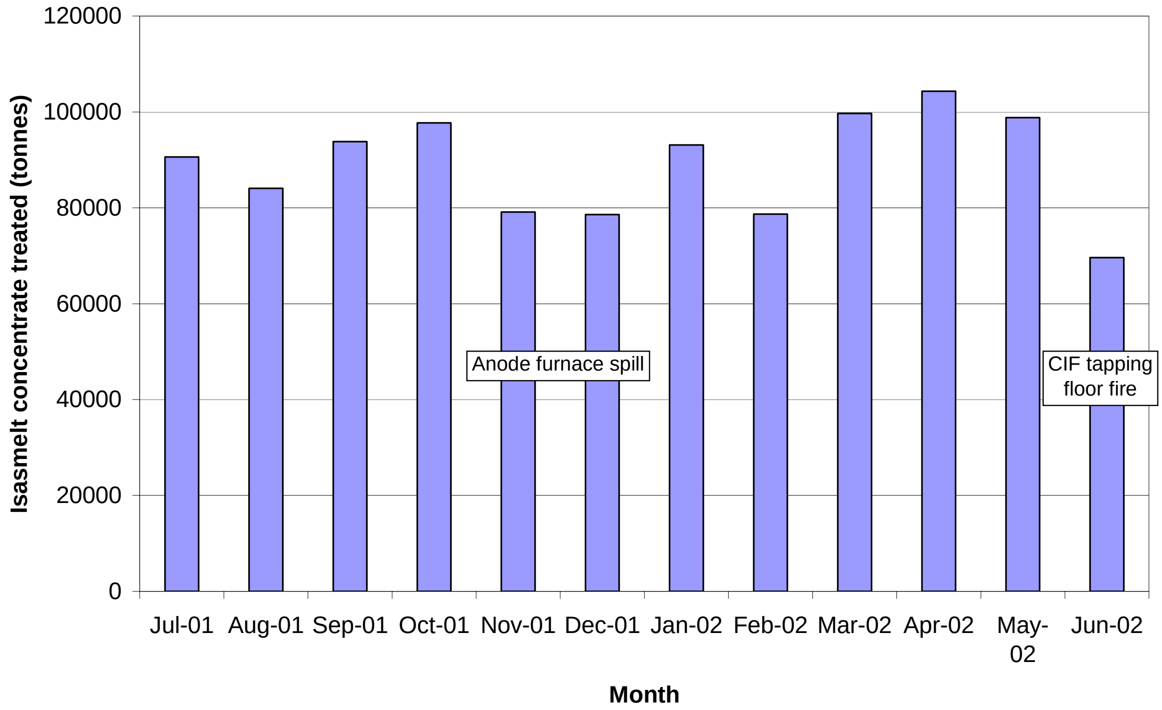

Figure 3 – Concentrate smelted by the Copper ISASMELT furnace during the 2001-2002 financial year

The concentrate treatment rate exceeded 80,000 tonnes in all but three of the months. In November and December 2001, production was reduced because a fault with one of the anode furnaces resulted in approximately 140 tonnes of anode copper flowing under the anode wheel, shutting it down for four weeks. The ISASMELT furnace operated at a reduced rate during this period. A fire broke out on the ISASMELT tapping floor in mid-June 2002, resulting in the loss of over one week's production.

Production was also reduced in the early part of the financial year because the ID fan had a vibration problem that limited the draft available to the furnace.

ISASMELT Operating Time

The operating time of the Mount Isa ISASMELT furnace has been constrained over the years by two major factors:

1. the necessity to shut down the Copper Smelter to preserve the air quality in the city of Mount Isa; and

2. insufficient surge capacity between the ISASMELT furnace and the Peirce-Smith converters.

Prior to the installation of the WMC-Fertilizers Limited acid plant, Air Quality Control downtime ("AQC") amounted to over 10% of the year. This downtime has been considerably reduced with the commissioning of the acid plant.

Downtime and reduced operating rates arising from the lack of surge capacity in the RHF has been reduced by improving converter and anode furnace operations.

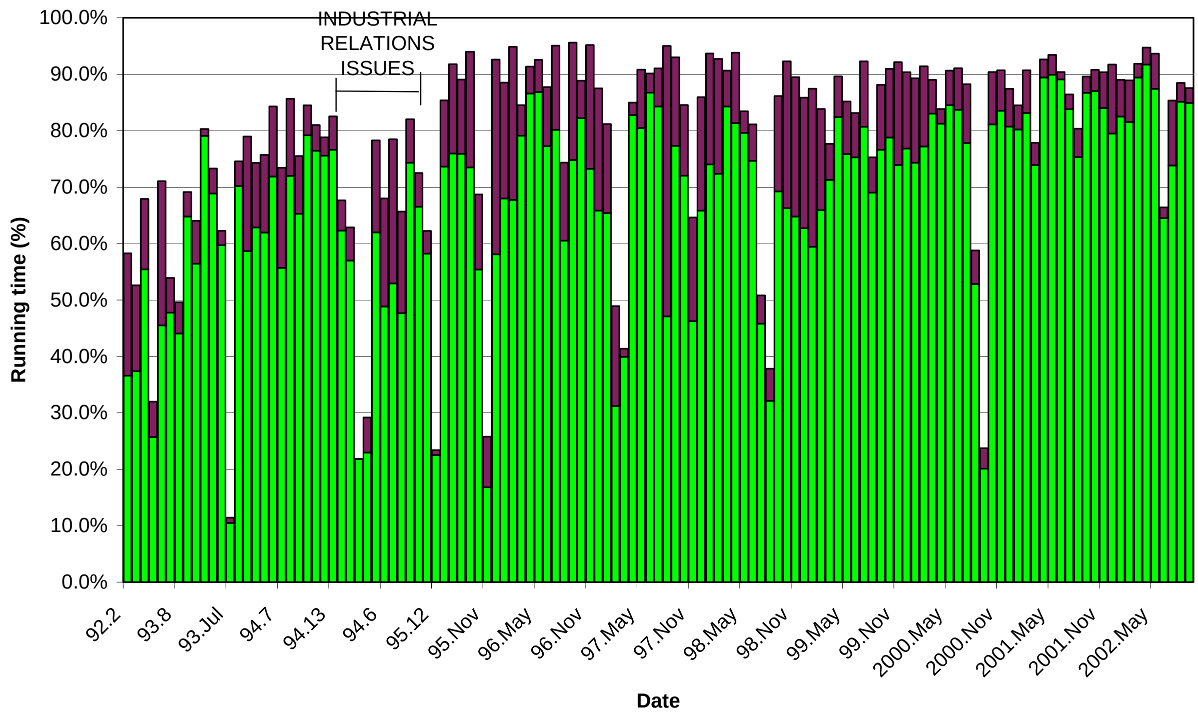

Figure 4 – Monthly average operating time since the ISASMELT plant was commissioned

These improvements saw the operating time of the Mount Isa ISASMELT furnace increase significantly. This is shown in Figure 4, which charts the monthly average operating time since the ISASMELT furnace was commissioned. The lighter bars represent the percentage of each month that there was feed flowing into the furnace and the darker bars at the top represent the percentage of each month that the furnace was shut down by AQC or a full RHF. This percentage has significantly decreased since the beginning of 2000. The best monthly operating time achieved to date was 91.7% achieved in April 2002, and the average for the 2001-2002 financial year was 82.8%.

Refractory Life

Most of the large dips in the operating time seen in Figure 4 are related to furnace rebricks. The key exceptions include a replacement of the refractory lining in the mixing chamber of the Flux Flow boiler in early 1993 and a lock-out of employees in May 1995 as a part of an industrial relations dispute.

It was expected, when the Copper ISASMELT furnace was constructed in 1992, that it would achieve a two year refractory life. This was based on experience gained on the 15 t/h pilot plant that was operated from 1987 to 1992 [4]. It was also a convenient time period because it matched the length of time between statutory inspections of the waste heat boiler. However, as is shown in Figure 5, the refractory wear rate during the first five campaigns was higher than expected and the life of the lining shorter than two years.

Figure 5 includes the longest campaign life experienced on the pilot plant to allow comparison. The early campaign lives of the ISASMELT furnace were little more than one year, with Campaign 5 being only 35 weeks. It had been planned to undertake many of the changes needed for the Copper Smelter upgrade during the rebrick at the end of the campaign. However, when the lining failed prematurely, the engineering of the upgrade project had not progressed sufficiently to take advantage of the downtime, and Campaign 6 had to be cut short to allow the modifications to be made.

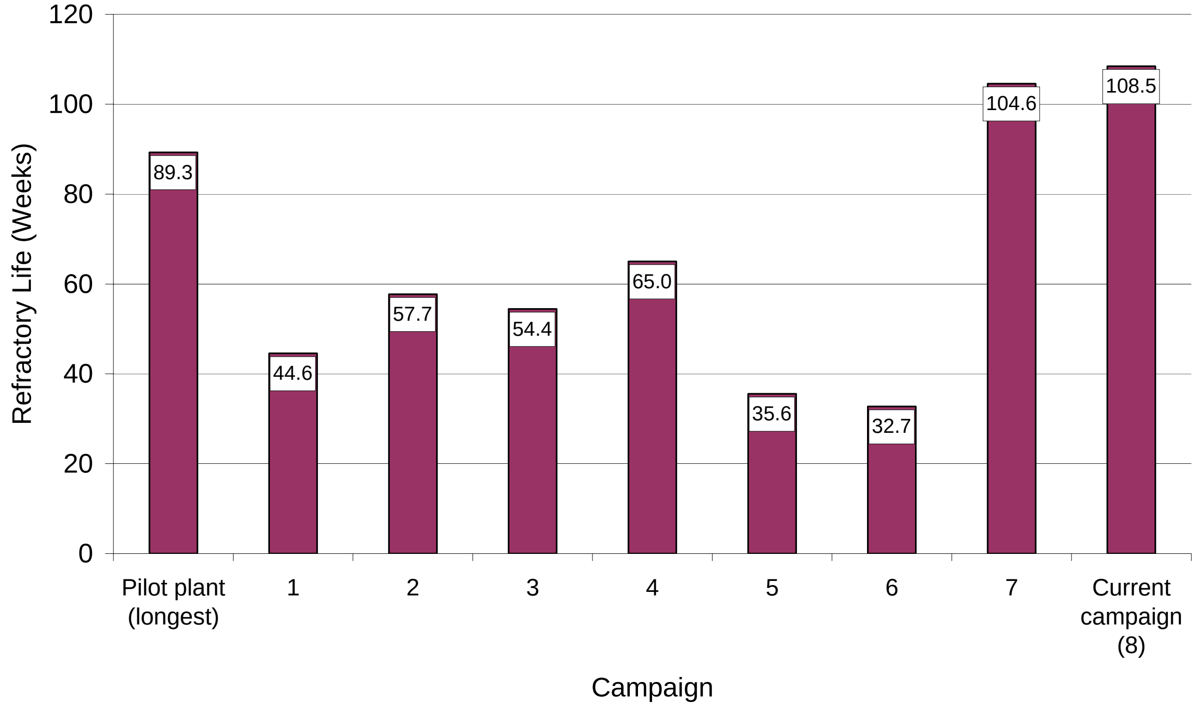

Figure 5 – ISASMELT furnace refractory life to October 2002

The cause of the premature failure of Campaign 5 was identified and rectified during Campaign 6. The results can be seen in Campaigns 7 and 8, where two-year refractory life has been achieved without the addition of water-cooling to the furnace.

The high wear area in the early campaigns was the lower part of the furnace. Figure 6 shows the decrease in brick length in this area during Campaigns 7 and 8. The broken lines show the wear rates that would give a three or five year lining life. At the end of Campaign 7, there was still 170 mm of brick remaining, and the wear rate had virtually stopped. The wear rate during Campaign 8 has been even slower. The wear in the lower part of the furnace, which has been the focus of attention, is consistent with a three year refractory life.

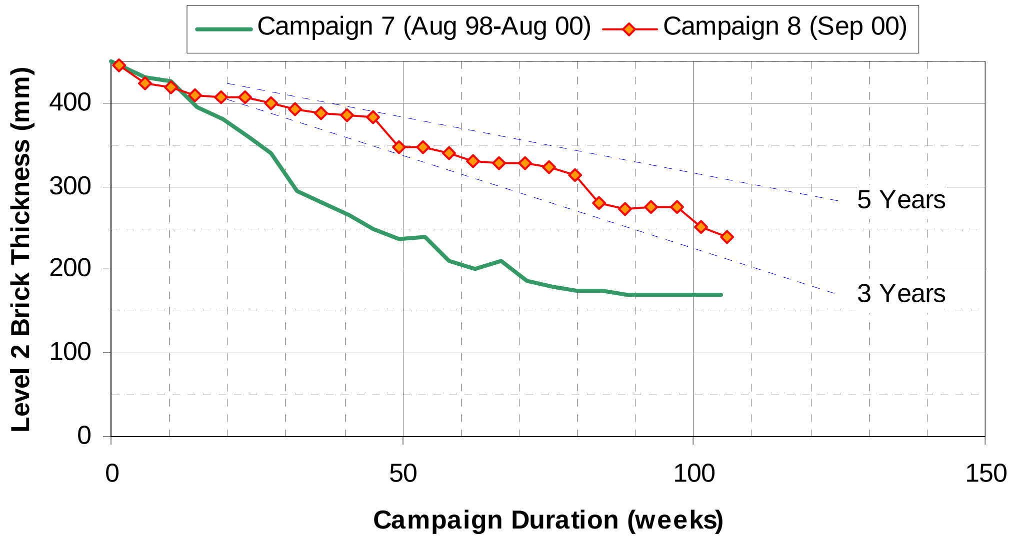

Figure 6 – ISASMELT furnace brick thickness in the high-wear zone during Campaigns 7 & 8

There has, however, been higher than expected wear in the upper part of the furnace during Campaign 8. The cause for this has been identified and will be corrected for Campaign 9.

Other Significant Causes of Downtime

Figure 7 shows the causes of downtime of the ISASMELT plant during the 2001-2002 financial year. Both the number of hours of downtime arising from each cause and the percentage of the total downtime attributable to the cause are given.

The biggest cause of downtime was AQC at 221 hours. The installation of the acid plant has reduced this number to about 25% of its former total. The second largest contributor ("Other Utilities") was the fire on the tapping floor that occurred in mid-June. Problems with the converters, anode furnaces and cranes ("Converter aisle (RHF Full)") accounted for another 13.7% of the downtime. The fourth largest contributor ("Feed Preparation") arose mainly from difficulties with the pelletiser (66.8 hours) and the mobile equipment used to reclaim the concentrate (55.5 hours). Downtime due to "Mines Power Station" primarily arose from leaks and repairs to the waste heat boiler (114.6 hours).

Energy Consumption

The ISASMELT furnace makes effective use of the energy contained within the concentrate. Coal, oil, or natural gas can be used to maintain the energy balance. The Mount Isa ISASMELT furnace was initially operated using coal as the primary fuel and oil as a trim fuel. The ISASMELT lances have recently been converted to natural gas operation.

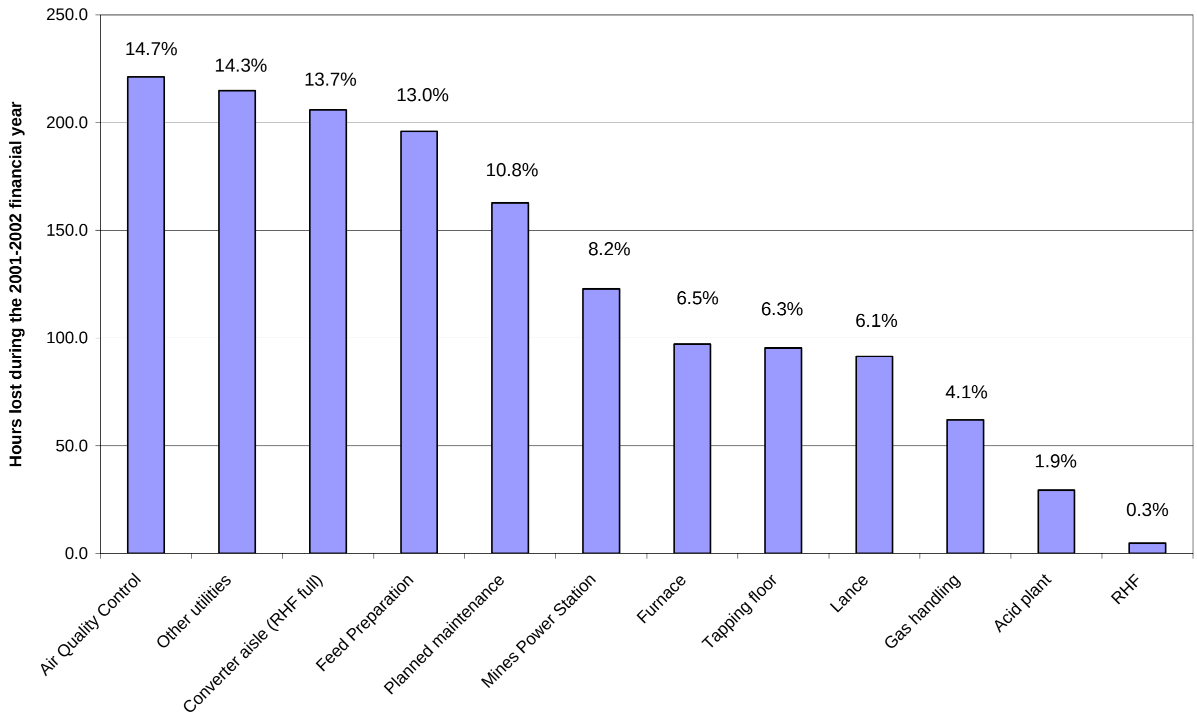

Figure 7 – Causes of downtime during the 2001-2002 financial year (absolute hours and percentage of downtime)

Table I shows changes in energy consumption by the Mount Isa Copper ISASMELT plant as the operating time and throughput have increased. The energy consumption of the reverberatory furnaces that were replaced by the ISASMELT furnace is included for comparison. The fuel included in Table I includes all the oil used when the furnace is shut down, and the oil or gas used in the tapping launder and the RHF. The total fossil fuel energy consumed by the Copper ISASMELT plant in April 2002 was equivalent to 0.28 GJ/t of concentrate, a 93% decrease from the 4.12 GJ/t used by the roaster and reverberatory furnaces in the 1991-1992 financial year. This decrease was achieved while treating a range of feed materials containing little chemical energy. The feed in April 2002 included 1,773 t of reverts and 6,536 t of slag concentrate. The Mount Isa reverberatory furnaces could not smelt reverts and could treat only very small quantities of slag concentrate. The ISASMELT furnace would operate autogenously without these recycle materials.

The energy figures given in Table I do not include the electrical energy used in the plants, because this number is not easily calculated for either the roaster and reverberatory furnaces or the Copper ISASMELT plant. However, if the net electrical energy used to operate the lance-air blower and the oxygen plants were included it would add about 0.12 GJ/t to the April 2002 figure.

Operating Cost

The installation of the Copper ISASMELT plant has placed the Mount Isa copper smelter at or near the bottom of the cost curve. Figure 8 shows the position of Mount Isa Mines Limited on the 2001 copper smelting and refining cost curve. The combined smelting and refining costs for the first three months of the 2001-2002 financial year are shown as “Mt Isa 2002”. During this period, the combined smelting and refining costs for copper production totalled 8.64 Usc/lb. However, there was an increase in the cost as a result of the anode furnace spill in November.

Table I – Comparisons of Copper ISASMELT fossil fuel consumption with the Mount Isa reverberatory furnaces

	Roaster-Reverb furnaces (July 1991 to June 1992)	Copper ISASMELT plant (July 1993 to June 1994)	Copper ISASMELT plant (March 2000)	Copper ISASMELT plant (April 2001)	Copper ISASMELT plant (April 2002)
Concentrate treated (t)	650,254	548,987	89,781	97,344	104,345
Coal used (t)	84,658	14,991	1,437	636	326
Natural gas used (Nm^3)	0	0	0	602,790	395,475
Oil used (kL)	2,407	2,730	227.2	100.9	109.2
Energy consumption per tonne of concentrate (GJ/t)	4.12	1.02	0.58	0.47	0.28

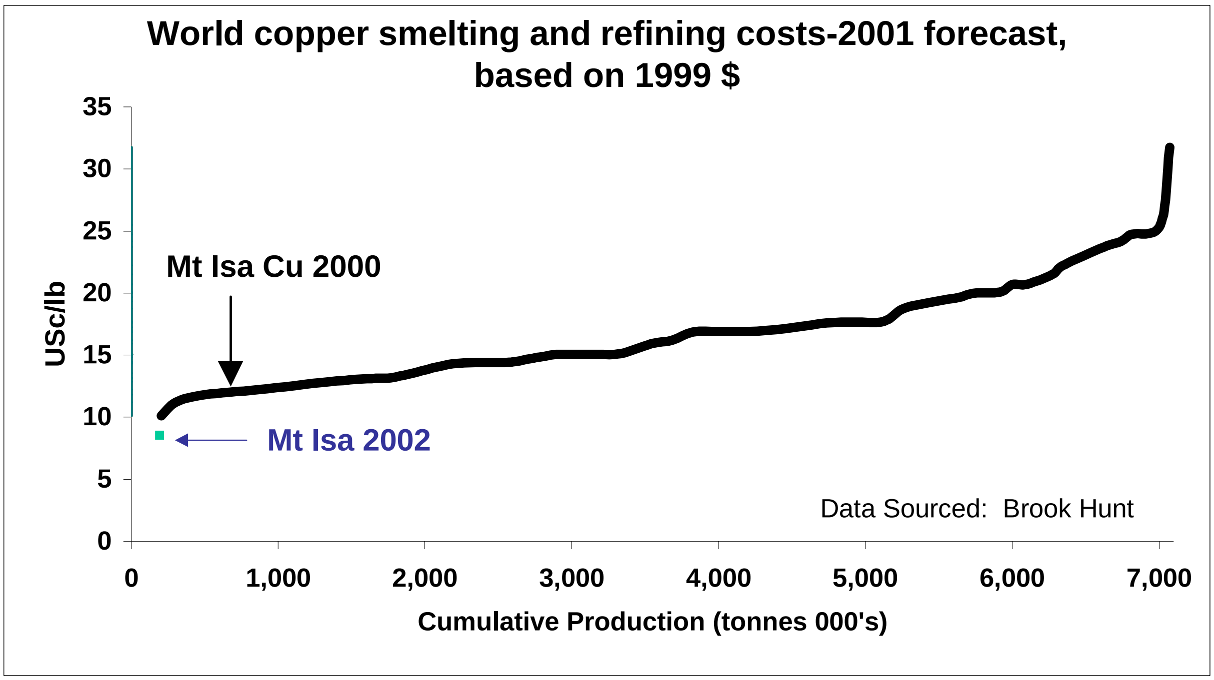

Figure 8 – The 2001 copper smelting and refining cost curve

A Successful Approach to Industrial R&D

The Copper ISASMELT process has low capital, operating and maintenance costs. The Mount Isa ISASMELT furnace has treated concentrate at rates up to 194 t/h and has an external diameter of only five meters. It can treat a wide range of feed materials. It is a good example of the outcome of successful industrial Research & Development (R&D).

The approach taken in the development of the ISASMELT process at Mount Isa was different from that taken by many other companies. Key success factors included:

1. *Rigorous alignment of the R&D program with MIM's strategic interests.* The development of the ISASMELT process was driven by the need to reduce operating

costs and improve environmental performance. MIM personnel examined existing and developing technologies and determined that none of them suited its needs.

2. *Basing R&D personnel at operating sites.* MIM's R&D personnel have largely been based at its operating sites. The ISASMELT technologies were developed by people based in Mount Isa who knew intimately the operating plants and the people who worked in them. In this way, operations personnel had joint ownership of the development process. MIM's R&D personnel worked closely with the operations personnel, and many of the operations personnel started their careers in the R&D departments.

3. *Rigorous pilot plant testing.* MIM was rigorous in pilot plant testing the technologies. The cost of building such pilot plants can lead to the temptation to skip this vital stage of development. MIM applied the philosophy that the ISASMELT process should be scaled up in increments. This strategy reduced the risk of spending vast amounts of money on full-scale plants that did not perform. The Copper ISASMELT pilot plant operated from 1987 to 1992.

4. *Using pilot plants to increase production.* One of the most difficult steps in the commercialisation of new technologies is the financing of large-scale pilot and demonstration plants. Such plants in the mining industry can cost tens or hundreds of millions of dollars. The ISASMELT processes were initially tested on a small scale to prove the concepts and were then scaled up in the smelters as operating units. In this way, they largely paid for their own development. The Copper ISASMELT pilot plant increased smelter production.

5. *Involvement of operations and maintenance personnel in pilot plant design and operations.* The ISASMELT R&D programs were collaborations between the R&D, operations, maintenance, and engineering personnel from the beginning. Each area brought its own skills to the development of the technology. This focussed attention on the plants whenever operating or maintenance issues arose.

6. *High level champions*. The R&D programs had high-level champions at the senior management and Board level who pushed them through.

7. *Ongoing development coupled with marketing of technology to external clients*. As shown by the example of the refractory life, it takes many years of operation for a new process to achieve stable operation. Development has continued during the ten years since the copper ISASMELT was commissioned at Mount Isa. By marketing the technology, further improvements have occurred, and external clients have pursued a variety of adaptations to the process. MIM maintains contacts with all ISASMELT licensees in order to encourage a spirit of cooperation between operating sites.

This approach was applied in the development of other successful MIM technologies, such as the Isa Process, Jameson Cell and IsaMill technologies that are also being marketed globally. It has resulted in MIM producing innovations for the mining industry disproportionate to the company's size.

Conclusions

The development of new smelting technologies is a high risk exercise, as can be seen from the experience with some of the new processes that were being developed towards the end of the last century. The cost of failure can total hundreds of millions of dollars, particularly when full-scale versions of new processes do not perform as expected.

MIM developed the ISASMELT process through rigorous pilot plant testing at Mount Isa, using the pilot plants to gain valuable scale-up information, to reduce the risk of the next stage of development, and to boost production in its lead and copper smelters. The result is a process that is now being adopted around the world. The Copper ISASMELT process has provided MIM with a competitive cost advantage over other smelters using more traditional technologies. MIM continues to cooperate with other ISASMELT licensees to further improve the technology.

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