Paper Title:
ISASMELT™ – A Quiet Revolution

Paper Presented at:
EMC 2003

Authors:
Philip Arthur, James Edwards, Xstrata Technology

Date of Publication:
2003

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

ISASMELT™ – A Quiet Revolution

Philip Arthur, James Edwards

M.I.M. Holdings Limited
Level 2, 87 Wickham Terrace
Brisbane, Queensland 4000, Australia

www.mimpt.com.au

Abstract

The ISASMELT process[i], a technology that matured into a commercially viable alternative to more established smelting technologies during the 1990s, is now processing more than three million tonnes of raw materials each year. ISASMELT plants produce either copper matte, lead metal or copper metal in Australia, England, USA, Belgium, India, Germany, Malaysia and China. M.I.M. Holdings Limited[ii] licenses the process to external companies through its technology division, MIM Process Technologies.

The Copper ISASMELT furnace at Mount Isa has a capacity of more than one million tonnes of feed per year. Furnace campaigns of more than two years are standard.

This paper briefly describes the various ISASMELT operations and summarises key operational data from Mount Isa as well as listing some of the lessons learned during more than ten years of commercial operation.

Introduction

M.I.M. Holdings Limited (MIM) is an international mining company with almost 80 years mining and minerals processing experience, primarily in the extraction of copper, lead and zinc. MIM has developed a number of world-class technologies, one of which is the ISASMELT process. The ISASMELT process is recognised by an increasing number of companies as the most flexible, cost effective copper and lead smelting process available in the world today. The history of the process has been documented in a number of earlier published papers [1-10].

The ISASMELT process was developed from pilot plant to commercial scale during the 1980s and 1990s at MIM's smelting operations in Mount Isa, Australia. Eight companies in eight different

---

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

[ii] MIM Holdings Limited is now owned by Xstrata. MIM Process Technologies is now Xstrata Technology

countries are now using the technology in large-scale operations. Two further plants are currently under construction in China and India. A quiet revolution has been occurring over the past ten years as various plants have come on line and demonstrated the flexibility and economic advantages of this new process.

The ISASMELT Process

ISASMELT is a bath smelting process utilising the unique ISASMELT lance. The lance is inserted into a molten slag bath contained within the ISASMELT furnace - a stationary, vertical, refractory-lined vessel. The injection of air, or oxygen-enriched air, through the lance into the slag results in a highly turbulent molten bath. Feed material falling into the turbulent bath from above reacts rapidly, resulting in extremely high productivity for a relatively small bath volume. The copper ISASMELT furnace at Mount Isa has smelted up to 194 tonnes per hour of copper-bearing feed (concentrate, reverts, and other internal smelter recycle materials) in a total bath volume of approximately 15 m^3.

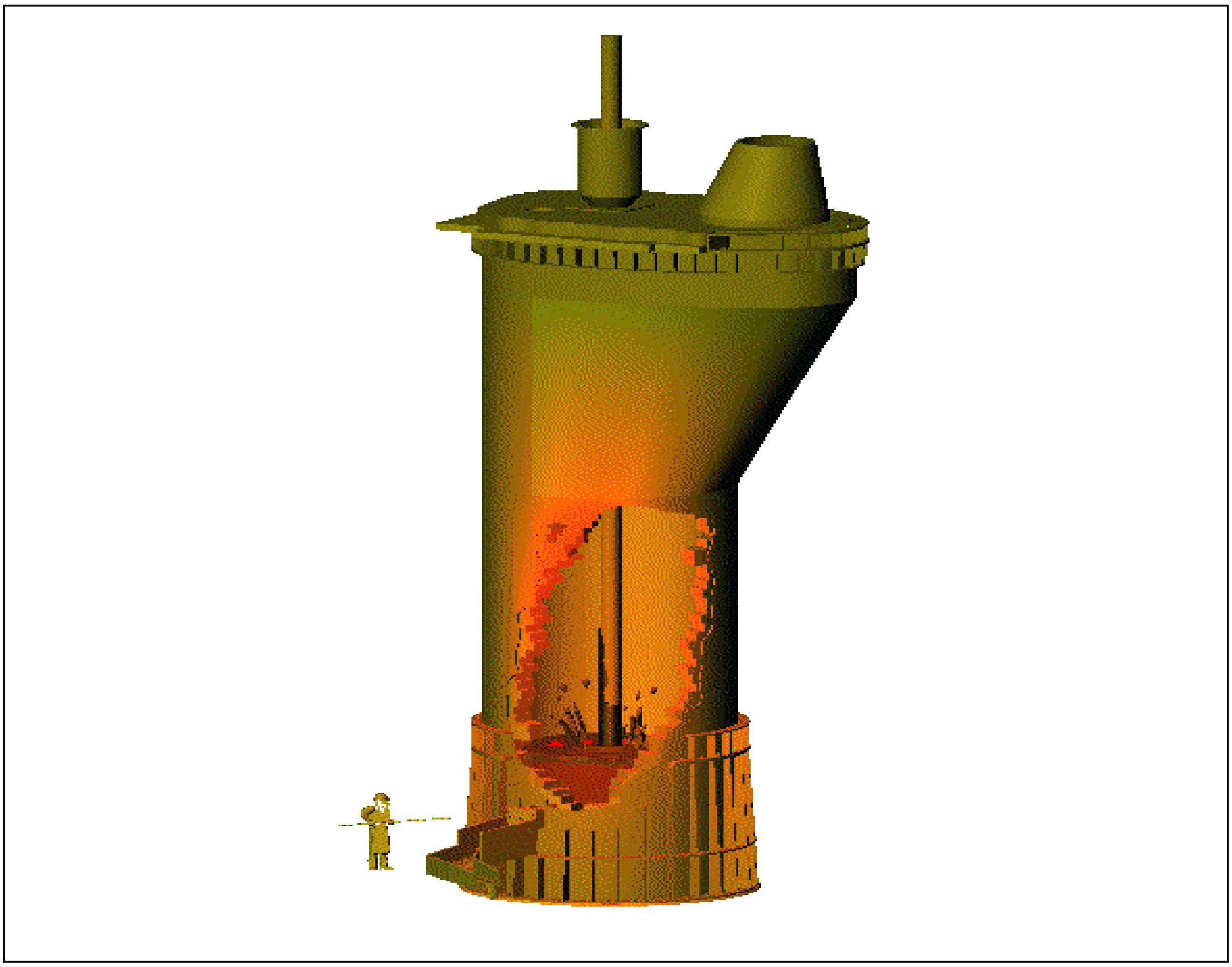

Figure 1: ISASMELT Furnace

A layer of slag frozen on the outer surface of the ISASMELT lance protects it from the molten bath. This allows the lance to operate submerged in the slag layer for extended periods of days to weeks.

A swirler inside the lance increases the velocity of the process air down the lance thus increasing the heat transfer rate from the steel to the process air. The specially designed low-pressure drop swirler allows the lance to operate with a total pressure drop of less than 80 kPa. A single stage blower can thus be used to provide process air to the lance.

The following commercial operations are now using the ISASMELT process:

- Britannia Refined Metals, Northfleet, UK (secondary lead materials producing 30,000 tpa lead);
- Hüttenwerke Kayser, Lünen, Germany (150,000 tpa secondary copper materials);
- Metal Reclamation Industries, Pulau Indah, Malaysia (secondary lead materials, plus concentrate producing 40,000 tpa lead);
- MIM, Mount Isa, Australia (1,000,000 tpa copper concentrate);
- Phelps Dodge, Miami, Arizona (700,000 tpa copper concentrate);
- Sterlite Industries #1, Tuticorin, India (500,000 tpa copper concentrate);
- Sterlite Industries #2, Tuticorin, India (1,300,000 tpa copper concentrate – under construction);
- Umicore Precious Metals, Hoboken, Belgium (200,000 tpa secondary copper and lead materials, plus concentrate);
- Yunnan Copper Corporation, Kunming, China (600,000 tpa copper concentrate); and
- Yunnan Metallurgical Group, Kunming, China (145,000 tpa lead concentrate—under construction).

Process Features

Some of the key features of the ISASMELT process are:

- Simple design

The ISASMELT furnace is a stationary vertical cylinder. The design allows it to be fabricated and maintained easily. The ISASMELT lance can be removed from the furnace easily at any time if maintenance is required.

- Flexible fuel type

The ISASMELT process can use various types of coals, coke, oil and natural gas for balancing the energy requirements. The fuel is selected based on the situation at each plant location.

- Long lance life

ISASMELT lances have long lives and lance replacement can be achieved in less than one hour. Lance repair requires merely the replacement of a short section of the lance tip.

- Ease of operation

Operators can learn to control the process quickly. A distributed control system is used for overall plant control. MIM has developed sophisticated algorithms to automate control of critical process parameters.

- Minimal feed preparation

ISASMELT feed needs only mixing or pelletising on a pelletiser. There is no need to grind or dry the feed material.

- High specific smelting rate

The bath is very turbulent because the lance tip is submerged in the molten slag. Feed material hitting the surface of the bath is immediately drawn under the surface and reacts very quickly. A high production rate is possible per unit volume.

- Low dust production

ISASMELT has very low dust production. Typically one to two percent of feed material reports to the offgas system in the copper ISASMELT plants. There is very low recycle of dust within the plant, reducing capital and operating costs.

- Small footprint

ISASMELT has a small footprint so can be fitted into tight locations between existing equipment. Existing plants can continue operation during the construction of the new plant.

- Efficient offgas capture

The ISASMELT furnace design allows efficient capture of all the gases from the process.

- Oxygen enrichment

The process air injected through the lance is generally enriched with oxygen. Oxygen contents of up to 80% are used on the existing plants.

Copper ISASMELT Plants

Mount Isa Mines Copper ISASMELT

The copper ISASMELT process was initially demonstrated at Mount Isa on a 15 tonnes per hour pilot plant that operated from 1987 to 1992 [4]. The full-scale Copper ISASMELT Plant, initially rated at about 700,000 tonnes of concentrate per annum, was commissioned in 1992. Since 1998 all the copper concentrate smelted at Mount Isa has been processed in the ISASMELT furnace, that now treats more than 1,000,000 tonnes of copper bearing feed per year. A schematic diagram of the Mount Isa Copper ISASMELT flowsheet appears in Figure 2.

Mount Isa concentrate and purchased concentrates are mixed and stored in a 60,000 tonne blending plant. The concentrates are mixed with fluxes, reverts and some lump coal, and pelletised in a disc pelletiser, prior to being fed to the ISASMELT furnace. Bath temperature is controlled using a mixture of natural gas injected through the lance and lump coal added to the feed mixture. Process air injected through the lance is enriched to 60-65% oxygen content. The ISASMELT lance life is about 10 days. The lance changing operation typically lasts 30-60 minutes.

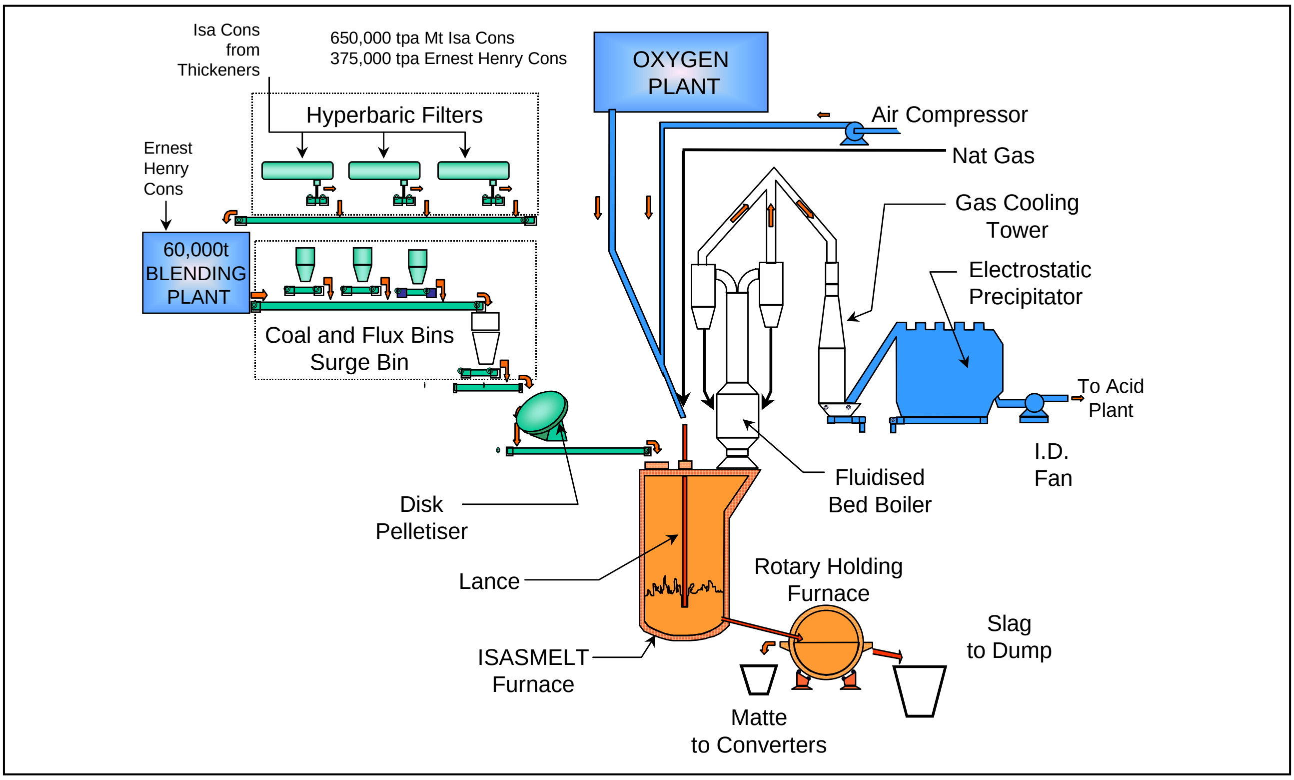

Figure 2: The Mount Isa Copper ISASMELT Flowsheet

The furnace produces copper matte with a copper content of approximately 60%. There is a single tap hole, through which matte and slag are tapped into a Rotary Holding Furnace that is used both for separation by gravity settling, and as a holding vessel. The matte is subsequently converted to blister copper in Peirce-Smith converters. The slag is removed in ladles by 'Kress' hauler truck.

Offgas from the ISASMELT furnace passes into a circulating fluidised bed waste heat boiler for cooling, before being cleaned in an electrostatic precipitator and passing to a sulfuric acid plant.

Phelps Dodge Miami Copper ISASMELT

The Phelps Dodge Miami copper ISASMELT plant, located in Arizona USA, is now processing more than 700,000 tonnes of copper concentrate each year. The ISASMELT furnace was commissioned in 1992 as a replacement for an electric smelting furnace, once power cost increases made that technology uneconomic. The ISASMELT was installed before the process had been fully proven on a commercial scale. The design was based on the 15 tonnes per hour pilot plant at Mount Isa.

The furnace smelts Phelps Dodge concentrates together with some purchased materials. These materials are blended in a bedding plant and transferred to concentrate feed bins. The concentrate feed, fluxes and revert material are mixed in a paddle mixer and fed to the furnace. Bath temperature is controlled using natural gas, which is injected down the lance. Process air through the lance is enriched to 50% oxygen content. The average ISASMELT lance life is greater than 15 days and a maximum of 31 days has been achieved. The furnace produces copper matte with a copper content of approximately 60%. The matte and slag are tapped from the furnace and flow into the electric furnace that was modified to act as a settling furnace. The slag is tapped and hauled to a discard dump with Kress Haulers while the matte is transferred to Hoboken converters for further processing. The offgas passes from the furnace into a waste heat boiler and subsequently to an electrostatic precipitator and sulfuric acid plant.

A number of papers have been written about the operational difficulties encountered during the first years of operation [11-13]. These difficulties are now resolved and the plant has been running smoothly for a number of years.

Sterlite Industries Copper ISASMELT

The Sterlite Industries copper ISASMELT is located at Tuticorin, on the southern tip of India. It was commissioned at the end of 1996, having a design capacity of 60,000 tonnes per year of copper in matte. It has been expanded with installation of additional tonnage oxygen to now have an annual capacity of more than 150,000 tonnes of copper per year, equivalent to 500,000 tonnes per year of concentrates.

Belt conveyors feed concentrates, petroleum coke and fluxes directly to the ISASMELT furnace. Fuel oil is injected through the lance for fine control of bath temperature. The oxygen content of the air injected through the ISASMELT lance is 80%. The matte grade is approximately 60%. Matte and slag are separated in a Rotary Holding Furnace and the slag granulated in a pit. Matte is transferred to Peirce-Smith converters for further processing. The offgas is quenched in an evaporative cooler located directly above the furnace gas offtake. The cooled gas is cleaned in an electrostatic precipitator before passing to a sulfuric acid plant.

MIM Process Technologies completed design of a new ISASMELT furnace for the Sterlite copper smelter in early 2003. The new ISASMELT furnace will have the largest capacity of any built to date enabling the smelter to produce 300,000 tonnes per annum of copper anodes. The new furnace will replace the existing ISASMELT furnace.

Umicore Precious Metals Copper ISASMELT

In co-operation with MIM Process Technologies, Umicore Precious Metals enhanced the ISASMELT process to make it suitable for treating a mixture of concentrates, scrap and residues. The Umicore smelter at Hoboken, Belgium, needed dramatic modifications to continue operating given present day economic conditions and environmental regulations. The ISASMELT furnace, commissioned in 1997, replaced a large number of unit processes, allowing the company to reduce operating costs and meet tightly monitored environmental standards.

More than 200,000 tonnes per year of pre-blended raw materials, coke and flux are fed directly to the ISASMELT furnace and fall into the molten bath. Oxygen enriched air, and oil are injected through the ISASMELT lance into the melt. Slag and metal are tapped from separate tap holes. Offgas exits the furnace into a waste heat boiler comprising furnace roof, vertical radiation channel and downcomer. Further cooling is achieved in an evaporative cooler, followed by dedusting in an electrostatic precipitator. The clean gas is ducted to a sulfuric acid plant.

Hüttenwerke Kayser Copper ISASMELT

Hüttenwerke Kayser (HK) commissioned a new ISASMELT plant for secondary copper smelting within their existing smelting and refining operation at Lünen, Germany during 2002. The ISASMELT furnace replaced three blast furnaces and two Peirce-Smith converters. HK enhanced the ISASMELT process to enable them to treat sulfur-free residues and scrap materials with a wide range of copper contents.

Approximately 150,000 tonnes per year of raw materials are fed directly into the furnace. Oxygen enriched air and oil are injected through the ISASMELT lance into the molten bath. Slag and metal are tapped from separate tap holes. Offgas exits the furnace into a waste heat boiler comprising furnace roof, vertical radiation channel and down comer. Further cooling is achieved with quench air and if necessary with injection of water. The gas is subsequently cleaned in bag filters.

Yunnan Copper Corporation Copper ISASMELT

Yunnan Copper Corporation Limited (YCC), based in Kunming, Yunnan Province, China, commissioned a copper ISASMELT plant in 2002. The ISASMELT furnace has a nominal design capacity of 600,000 tonnes per year of copper concentrate and replaced a sinter plant and electric furnace that had been used to smelt copper concentrate.

Copper concentrates are sourced from many mines throughout Yunnan province, as well as from outside China. They are blended in a bedding plant, then mixed with coal and flux and pelletised prior to being fed to the ISASMELT furnace. Process air enriched to 50% oxygen is injected down the ISASMELT lance, together with oil for fine temperature control. Copper matte with a copper content of approximately 60% and slag are tapped into the electric furnace, that has been modified to act as a settling furnace. Slag is granulated and matte is transferred to Peirce-Smith converters for further processing. Offgas exits the furnace into waste heat boiler comprising furnace roof, vertical radiation channel, downcomer and convection section. The cooled gas is cleaned in electrostatic precipators and ducted to a sulfuric acid plant.

The ISASMELT furnace installation has significantly improved the environmental performance of the smelter and has resulted in a significant reduction in operating costs. More information on the plant can be found in the literature [14].

Lead ISASMELT Plants

Mount Isa Mines Lead ISASMELT

Lead smelting in Mount Isa is presently carried out using a sinter plant and blast furnace. In 1991 a commercial scale lead ISASMELT plant was commissioned to supplement the blast furnace production, increasing the lead production capacity to approximately 210,000 tonnes per year.

The ISASMELT plant was designed to produce 60,000 tonnes per year of lead metal from approximately 20 tonnes per hour of Mount Isa lead concentrates containing 47% lead. The plant consisted of a smelting furnace and a reduction furnace. Concentrates and fluxes were smelted in the smelting furnace to produce a high lead slag (50% lead oxide). The slag flowed continuously by launder into the reduction furnace. In the reduction furnace the high lead slag was reduced by crushed coal injected through the lance to produce lead bullion and a discard slag.

The plant was decommissioned in 1995 because there was insufficient concentrate to satisfy the needs of both the sinter plant/blast furnace and the ISASMELT plant. At time of writing MIM are evaluating the use of an open cut mine at Mount Isa to increase lead concentrate production. If this project proceeds the lead ISASMELT will be recommissioned.

Britannia Refined Metals Lead ISASMELT

A secondary lead ISASMELT plant was commissioned in 1991 at Britannia Refined Metals (BRM) at Northfleet, England. BRM is a subsidiary of MIM. The plant was designed to accept whole batteries and produce approximately 30,000 tonnes per year of lead in alloys. Desulfurised battery paste and grids are fed to the furnace. Recycled oil and air are injected down the lance into the molten bath. Lead metal and slag are tapped from the furnace. Offgas is quenched in an evaporative cooler. Further information on this plant can be found in the literature [10].

Metals Reclamation Lead ISASMELT

A secondary lead ISASMELT plant was commissioned during 2000 at Metal Reclamation Industries (MRI) in Pulau Indah, Malaysia. The plant is based on the BRM design and has a capacity of 40,000 tonnes per year of lead metal. Battery paste, grids and some lead concentrate are processed in the ISASMELT furnace. Offgases from the furnace are quenched in an evaporative cooler before passing to a bag filter for dedusting. Sulfur dioxide is removed from the offgas with limestone addition in a wet scrubber. The plant produces refined lead and a discard slag.

Yunnan Metallurgical Group Lead ISASMELT

In early 2002 MIM Process Technologies and Yunnan Metallurgical Group signed a Licence and Engineering Agreement for a Lead ISASMELT Plant. The plant will be installed at a greenfield lead-zinc complex planned for construction at Qujing, Yunnan Province, China.

The design capacity will be 80,000 tonnes per year of lead bullion. The ISASMELT furnace will produce lead bullion and a high lead slag. The slag will be cast and fed to a blast furnace for reduction to bullion. The cooled and cleaned offgas from the ISASMELT furnace will flow to an acid plant for conversion into sulfuric acid. Construction has commenced on site.

Pilot Plants

Britannia Refined Metals ISASMELT Pilot Plant

A 250 kg/h pilot plant is installed at the Britannia Refined Metals site in England. The plant was installed to allow MIM to carry out testwork on the ISASMELT process and to develop new applications for the process. It is an ideal size for developing bath smelting processes using ISASMELT. MIM arranges test campaigns, as a critical step in developing new process concepts for clients.

Freiberg University ISASMELT Pilot Plant

During 2002 a 250 kg/h pilot ISASMELT furnace was constructed at the Technische Universität Bergakademie Freiberg in Germany. This furnace is based on the design installed in England. The plant is designed for use in a range of applications, including treatment of residues. The university staff is equipped to carry out test work for their clients while providing access to MIM's experience in process development. Clients are able to apply for an ISASMELT licence to use the technology for commercial applications, based on testwork carried out in Freiberg.

Recent Performance of the Mount Isa Copper ISASMELT Furnace

Production

Figure 3 shows the total number of tonnes of copper-bearing feed treated by the Mount Isa Copper ISASMELT furnace each financial year (from 1 July to 30 June in Australia) since it was commissioned in August 1992. The furnace treated 1,070,000 tonnes of feed during the 2001-2002 financial year, with an average grade of 26.9% copper.

The plant was originally designed to treat concentrates at an average rate of 104 tonnes per hour, equivalent to 180,000 tonnes per year of contained anode copper [5]. It initially replaced one of the two existing reverberatory furnaces. During the first five years of operation a number of process difficulties relating to the choice of technologies for ancilliary equipment restricted plant throughput.

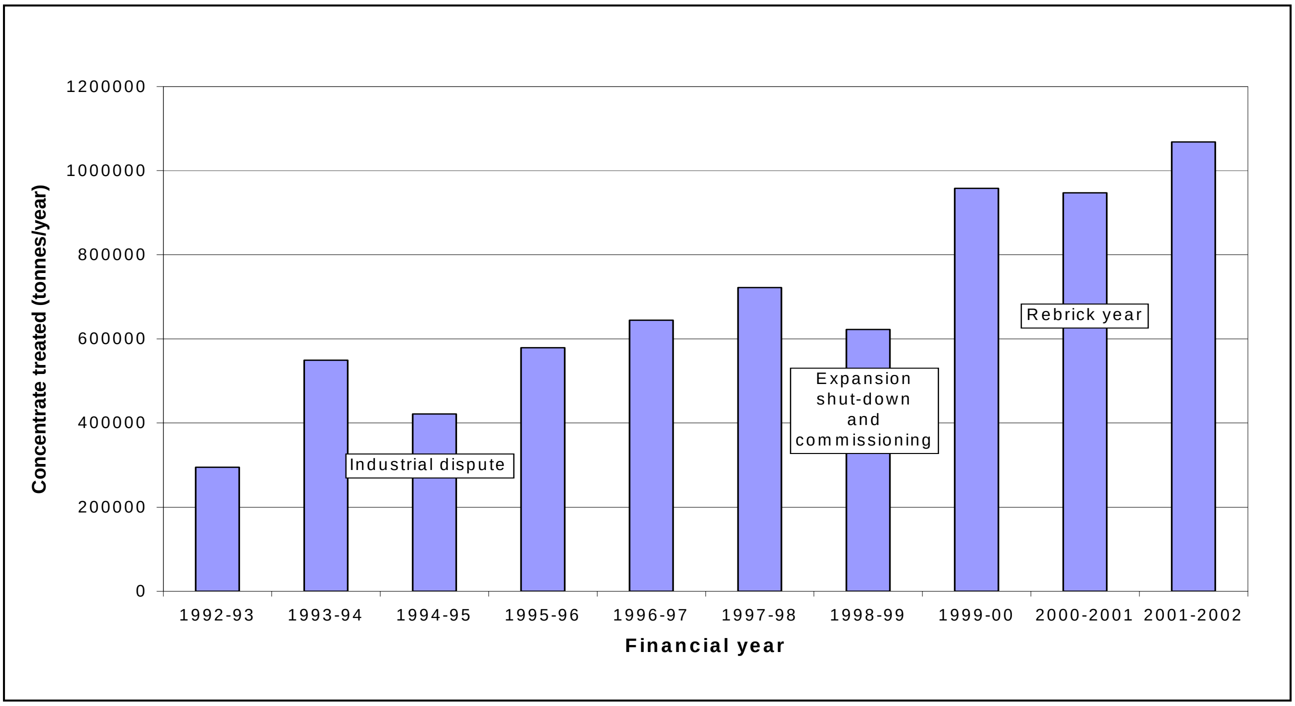

Figure 3: Feed Smelted in the Copper ISASMELT Plant since Commissioning

The plant achieved the target of an annual average of 104 tonnes per hour of concentrate during the 12 months to the end of April 1997. This amount of time required to reach design capacity during the early years of commercial operation contrasts with the most recent ISASMELT commissioning in which the plant reached design capacity within two months of heatup.

By 1997 MIM had decided to upgrade the copper smelter to increase the throughput to 250,000 tonnes per year of contained copper. The modifications made have been described in more detail elsewhere [8] and were completed in 1998. No changes were made to the ISASMELT furnace itself, but the remaining reverberatory furnace was shutdown. Since 1998 all copper concentrate smelted at Mount Isa has been processed in the copper ISASMELT furnace.

Refractory Life

The refractory bricks used to line the ISASMELT furnace shell in Mount Isa are magnesite chrome and have no water cooling applied to them. 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 tonnes per hour 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 4, the refractory wear rate during the first five campaigns was higher than expected. Figure 4 includes the longest campaign life experienced on the pilot plant to allow comparison.

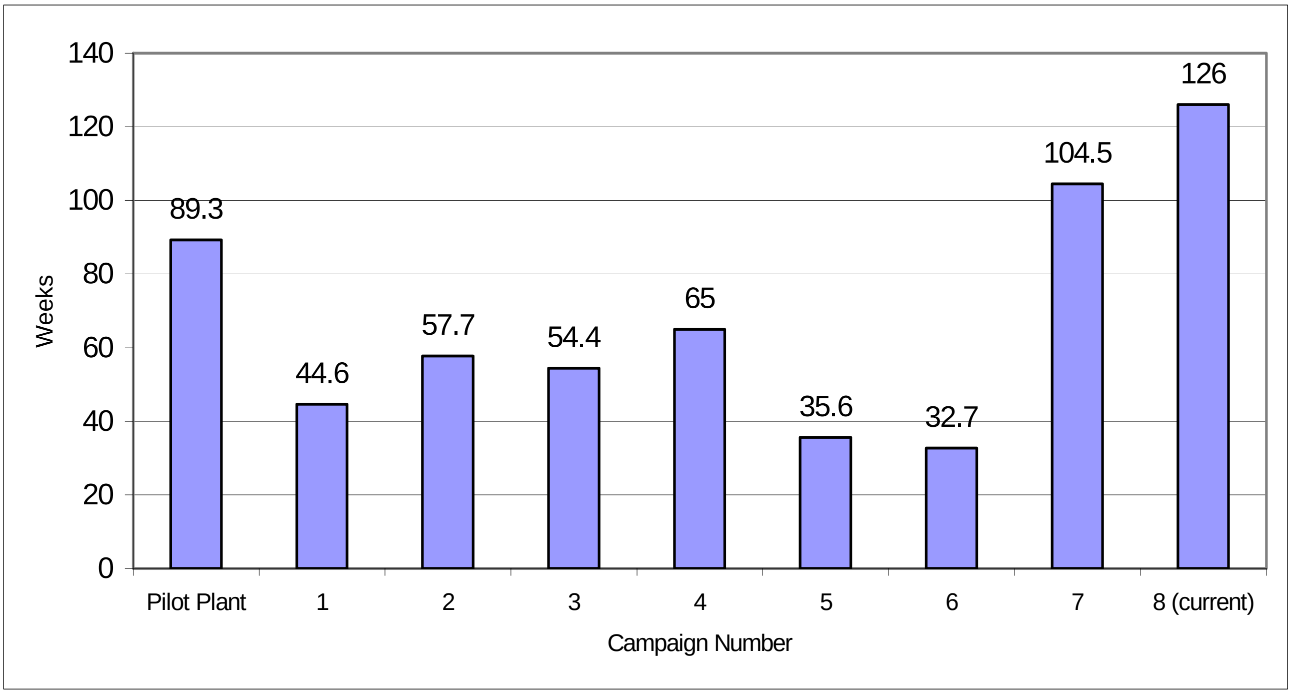

Figure 4: ISASMELT Furnace Refractory Campaign Duration to March 2003

Most of the early campaign lives of the ISASMELT furnace lasted little more than one year, while Campaign 5 lasted only 35 weeks. It had been planned to undertake many of the changes needed for the 1998 Copper Smelter upgrade during the rebrick at the end of that campaign. However, when the lining failed prematurely, the engineering of the upgrade project had not progressed sufficiently to take advantage of the downtime. Consequently Campaign 6 had to be cut short to allow the plant modifications to proceed on schedule.

The cause of the premature failure of Campaign 5 was identified and rectified during Campaign 6. The results can be seen in Campaign 7 which lasted 104 weeks and Campaign 8 which is currently at 126 weeks and still continuing. This long refractory life has been achieved after years of operation, and with the development of innovative control systems that ensure smooth operation of the furnace. Campaign life of significantly longer than 24 months is the aim for the future.

Energy Consumption

The ISASMELT process is extremely energy efficient, using much less fuel than traditional smelting processes. The furnace makes effective use of the energy contained within the concentrate while being capable of treating reverts, slag and other recycle materials. The process is also extremely flexible with regard to fuel type. Depending on the most economic fuel available at each particular site, coal, petroleum coke, coke fines, oil, or natural gas can be used to maintain the energy balance and control the bath temperature. In Mount Isa the ISASMELT furnace was initially operated using coal as the primary fuel and oil as a trim fuel but since 1999 natural gas has been used. The ISASMELT lances were converted to natural gas operation after a natural gas pipeline was constructed, bringing natural gas to the region for the first time..

Table 1 shows the annual energy consumption of the Mount Isa Copper ISASMELT plant compared with that of the fluid bed roasters and reverberatory furnaces that it replaced. The fuel included in Table 1 includes all the oil used to maintain temperature when the furnace is off-line, and the oil or gas used in auxilliary burners and the Rotary Holding Furnace.

Table 1: Comparison of Copper ISASMELT Fossil Fuel Use with Reverberatory Furnaces

	Roaster-Reverb Furnaces	Copper ISASMELT Plant
Feed treated (t)	650,000	1,070,000
Coal used (t)	85,000	6,300
Natural gas used (000 Nm^3)	0	6,120
Oil used (kL)	2,400	1,980
Energy consumption per tonne of concentrate (GJ/t)	4.12	0.47

The total fossil fuel energy consumed by the Copper ISASMELT plant in 2001/2002 was equivalent to 0.47 GJ/t of feed, an 89% 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 proportion of feed materials containing little chemical energy. The reverberatory furnaces could not smelt reverts and could treat only very small quantities of slag concentrate. The ISASMELT furnace is well suited to treating these materials and would operate autogenously without them.

Technology Development in an Operations Environment

The ISASMELT process is an emerging technology. It has been successfully developed for commercial use and continues to be developed. The capacity of the technology is being increased and the flexibility of the process in treating different materials and operating on various fuels continues to broaden. For more than 10 years the process has been operated on a commercial scale by MIM and the ISASMELT licensees.

Since the commissioning of the first commercial scale plants at Mount Isa and Northfleet in 1991 and Mount Isa and Miami Arizona in 1992, a large number of improvements and enhancements have been made to the process. These improvements have always being made based on practical experience within the MIM smelters and those of the ISASMELT licensees. This strategy has resulted in continuous improvement of the process.

The Mount Isa copper ISASMELT suffered from high waste heat boiler maintenance during the early years of operation. The fluidised bed boiler was a major cause of plant downtime until a satisfactory method was developed to reduce the amount of boiler tube wear caused by circulating slag. Although the boiler now operates well, MIM feels that the high pressure drop across the fluidised bed makes more conventional boiler systems the most appropriate choice for future applications.

Initial operating difficulties with the offgas system installed at Miami eventually led to its redesign, resulting in an offgas system that is both robust and low maintenance. The problems were resolved with the installation of a boiler tube furnace roof and modifications to the vertical radiation channel and downcomer while retaining the original convection section.

The use of natural gas as fuel through the lance was successfully pioneered at Miami. Phelps Dodge Miami achieve average lance lives of 15-20 days. The longest lance life to date was more than 30 days of continuous operation. The Miami plant also demonstrated that pelletisation of feed is not necessary. They use only a paddle mixer for conditioning the feed prior to charging to the furnace while retaining extremely low carryover of dust to the offgas system.

The Sterlite plant has an extremely simple feed preparation system, the concentrates, flux and fuel being fed to the furnace without any pretreatment. The offgas system design is also very simple, utilising an evaporative cooler with water sprays in the vertical duct immediately above the furnace outlet. Sterlite have managed to lift the capacity of a plant that was originally designed for 60,000 tonnes per year of copper to more than 150,000 tonnes per year. The plant was designed as a low cost smelter and has proven a great success because of its design simplicity and ease of operation. The result of low operating and maintenance costs was achieved with minimal capital expenditure.

The Umicore ISASMELT plant at Hoboken introduced a number of new features that had not previously been trialled. The boiler tube roof proved to be a better solution than the original copper block design used at Mount Isa or the water cooled steel jackets used at Miami. Similar roofs have since been installed at Miami, HK and YCC. The Umicore plant was also the first to use a radiation channel in conjunction with an evaporative cooler.

Scale-up in large steps, although enabling fast tracking of projects, inherently has high risks associated with it. MIM believes that it is preferable to base a design as close as possible to a proven commercial scale plant, and to make only small incremental improvements, testing each improvement if possible prior to implementation. For example, at Mount Isa a series of high rate trials were run on the ISASMELT furnace, prior to commencement of the 1998 upgrade. A liquid oxygen tank was installed on site, and the existing oxygen plant was used to store excess oxygen over a number of days. The liquid oxygen was then revapourised and the oxygen content in the process air was lifted from 45% to more than 60% for a limited time, allowing smelting to be demonstrated at the higher rates planned for the future in the existing furnace. This strategy confirmed that the higher rates of concentrate could be processed in the furnace reducing risk involved in upgrading the plant.

Prior to construction of the full scale plant at Hoboken, a demonstration plant was constructed on the site and the novel process aspects were trialled for some months. Following completion of the trials, the full scale ISASMELT plant was designed and constructed. Initial operation proved that the demonstration scale plant had been extremely valuable. This strategy reduced the risks involved in extending the envelope beyond that which had already been proven on a commercial scale. The plant has now been operating at greater than design capacity for some years.

MIM and the ISASMELT licensees benefit from the exchange of knowledge and experience gained on the respective plants. At a time when companies are finding it increasingly difficult to justify investment in research and development, it can be extremely advantageous to be a member of such a common interest group. Visits to the sites of fellow ISASMELT licensees and to Mount Isa, coupled with attendance at licensees meetings at which operations personnel make presentations on production issues and discuss items of common interest aid the understanding of the technology and can accelerate improvements to the benefit of all.

Operations Training

MIM has learned that good training is critical in order to achieve fast ramp up of new plants and to maximise returns on capital invested. Prior to commissioning the MRI plant, it was decided that senior MRI operations personnel would be trained at the BRM lead ISASMELT in England. This training, coupled with training on site in Malaysia from experienced BRM and MIM staff during commissioning, resulted in improved understanding of the process by MRI staff prior to startup.

For the HK project, some training took place at Mount Isa in the copper smelter and other process specific training occurred on the ISASMELT pilot plant in England. In this way HK staff gained an appreciation for furnace operation and rebricking practices on the full scale, while learning the details of the process chemistry on the small pilot scale. This exposure to the plants helped to demystify the process and made comprehension more straightforward prior to plant startup.

MIM conducted an extensive training program for key YCC personnel. The main training program was held at the Mount Isa copper smelter over a seven month period. It covered all aspects of ISASMELT operation and maintenance. More than 25 YCC operations personnel including operators, engineers and metallurgists took part. Senior operators were running the Mount Isa furnace unaided by the end of the training period. When the YCC furnace was commissioned, the YCC staff were able to start up the plant without having to concentrate on learning the process. MIM provided experienced operations personnel from Mount Isa and Brisbane to assist with operation of the smelter for about six weeks. Although their presence was also critical to the success of the startup, they were able to assume a support role, only rarely intervening directly with the operation of the plant. The training was one of the key factors leading to the extremely smooth and successful startup at YCC.

Conclusions

The ISASMELT process has successfully been installed in many smelters around the world. A combination of high intensity, simple design and ease of operation make the process ideal for new copper and lead smelting installations either in remote locations or in more populated areas. The process has proven to have low capital, operating and maintenance costs. Operating personnel can learn to operate the process through training programs held at MIM's operating smelters. MIM and the ISASMELT licensees have worked together over the past ten years to improve the efficiency of the process and will continue to learn from each other how to improve it further. Recent ISASMELT furnace commissionings have benefited from experience gained at Mt Isa, and the co-operation between MIM and licensees.

ISASMELT is already quietly revolutionising copper and lead smelting technology in the 21st century and the revolution is set to continue.

References

[1] W.J. Errington, J.H. Fewings, V.P.Keran, and W.T. Denholm, "The Isasmelt lead smelting process." Transactions of the Institution of Mining and Metallurgy, Section C, 96 (1987), 1-6.

[2] M.D. Coulter and C.R. Fountain, "The Isasmelt process for copper smelting" (Paper presented at the Non-ferrous Smelting Symposium, Port Pirie, South Australia, 17-21 September 1989, Aus.I.M.M., Melbourne, 1989), 237-240.

[3] C.R. Fountain, M.D. Coulter, and J.S. Edwards, "Minor element distribution in the Copper Isasmelt process," Copper '91, Volume IV, ed. C. Diaz, C. Landolt, A Luraschi, C.J. Newman (Pergamon Press, New York, 1991), 359-373.

[4] R. Player, C.R. Fountain, T.V. Nguyen, and F.R. Jorgensen, "Top-entry submerged injection and the Isasmelt technology," Proceedings of the Savard/Lee International Symposium on Bath Smelting, ed. J.K. Brimacombe, P.J. Mackey, G.J.W. Kor, C. Bickert and M.G. Ranade (The Minerals, Metals and Materials Society, Warrendale, Pennsylvania, 1992), 215-229.

[5] J.L. Cribb, J.S. Edwards, C.R. Fountain, and S.P. Matthew, "Isasmelt technology for the smelting of copper," 15th CMMI Congress, Johannesburg, Vol. 2., (SAIMM, 1994), 99-103.

[6] R. Player, "Copper ISASMELT - Process Investigations", The Howard Worner International Symposium on Injection in Pyrometallurgy, July 1996, ed. M. Nilmani and T. Lehner, Melbourne, (The Minerals, Metals and Materials Society, Warrendale, Pennsylvania, 1996), 439-446.

[7] W.J. Errington, P.S. Arthur, C.R. Fountain, "ISASMELT - Clean Efficient Smelting", (Paper presented at GME'99 Global Metals Environment Conference, Beijing, 24-27 May 1999, Nonferrous Metals Society of China, Beijing, 1999), 164-172.

[8] J.S. Edwards, C.R. Fountain, and R.L. Morland, "ISASMELT—extending the envelope," W. Poole (Ed.), Proceedings of the Brimacombe Memorial Symposium, October 1 to 4, 2000: Poster Session Proceedings, (CIM, October 2000).

[9] J.L. Bill, T.E. Briffa, A.S. Burrows, C.R. Fountain, D. Retallick, J.M.I. Tuppurainen, J.S. Edwards, and P. Partington, "ISASMELT—Mount Isa copper smelter progress update", In: Sulfide Smelting 2002, ed R.L. Stephens and H.Y. Sohn, (The Minerals, Metals and Materials Society, Warrendale, Pennsylvania, 2002), 181-193.

[10] R.B.M. Brew, C.R. Fountain, J. Pritchard, "ISASMELT for Secondary Lead Smelting", In: Lead 90: 10th International Lead Conference, (The Lead Development Association), 1991, 170-181

[11] R.R. Bhappu, K.H. Larson, R.D. Tunis, "Cyprus Miami Mining Corporation Smelter Modernization Project Summary and Status", In: EPD Congress 1994, ed. G. Warren, (The Minerals, Metals and Materials Society, Warrendale, Pennsylvania, 1994), 555-570

[12] A.H. Binegar, R.R. Bhappu, "Cyprus ISASMELT Start-Up and Operating Experience", Proceedings of Copper 95-Cobre 95 International Conference Volume IV – Pyrometallurgy of Copper, ed. W.J. Chen, C. Diaz, A. Luraschi and P.J. Mackey, (The Minerals, Metals and Materials Society, Warrendale, Pennsylvania, 1995), 117-131

[13] J.E. Sallee, F. Ushakov, "Electric settling furnace operations at the Cyprus Miami Mining Corporation copper smelter", In: Proceedings of Copper 99-Cobre 99 International Conference Volume V – Smelting Operation sand Advances, ed. D.B. George, W.J. Chen, P.J. Mackey and A.J. Weddick, (The Minerals, Metals and Materials Society, Warrendale, Pennsylvania, 1999), 629-643

[14] Y. Li, P. Arthur, "Yunnan Copper Corporation's new smelter – China's first ISASMELT", In: Proceedings of Yazawa International Symposium on Metallurgical and Materials Processing Volume II – High Temperature Metal Production, ed. F. Kongoli, K. Itagaki, C. Yamauchi and H.Y. Sohn, (The Minerals, Metals and Materials Society, Warrendale, Pennsylvania, 2003), 371-384