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ISASMELT™ – Not Just a Flash in the Pan

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ISASMELT™ - Not Just a Flash in the Pan

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ABSTRACT

The Copper ISASMELT™ processⁱ, a technology that emerged into the global metals industry during the 1990s, is now processing more than three million tonnes of concentrates and secondary copper materials each year. The submerged lance smelting technology produces either copper matte or copper metal in plants located in Australia, the United States of America, Belgium, India, Germany and China. M.I.M. Holdings Limited (MIM)ⁱⁱ licenses the process to external companies through its technology division, MIM Process Technologies. MIM, as an operating company and technology supplier, is able to provide external clients with proven process design and continuous operational improvements together with full training and commissioning assistance services from experienced operations personnel.

The Copper ISASMELT furnace at Mount Isa Mines is treating more than one million tonnes of copper-bearing feed per year. Furnace campaigns of more than two years are now standard.

This paper describes the current status of the copper ISASMELT furnace at Mount Isa and compares its performance with that of the two most recent installations in China and India. It includes a summary on development of a continuous converting process. This process will employ similar process fundamentals to ISASMELT and has the potential to replace Peirce Smith converters.

ⁱ ISASMELT™ is a registered trademark of Xstrata Technology

ⁱⁱ MIM is now owned by Xstrata. MIM Process Technologies is now Xstrata Technology.

INTRODUCTION

M.I.M. Holdings Limited (MIM) has almost 80 years mining and minerals processing experience, primarily in the extraction of copper, lead and zinc. MIM, operator of a large copper/lead/zinc deposit in Mount Isa, Australia, has developed a number of world-class minerals processing and smelting technologies, one of which is the ISASMELT™ process. The Copper ISASMELT process as used at Mount Isa Mines is recognised by an increasing number of companies as the most flexible, cost effective copper smelting process available in the world today. The process and some details of smelters using the process have been described in earlier published papers (1-7).

Yunnan Copper Company Limited (YCC) has been operating a copper smelter at Kunming, Yunnan Province, China, for just over 40 years. One of the current aims of the Chinese government is to increase industrial efficiency while reducing the effect of heavy industry on the environment. This is starting to be achieved through the privatisation of state owned companies. Those companies that are selected for privatisation are being encouraged to replace outdated technology. YCC chose to import new smelting technology from outside China, identifying ISASMELT as the most suitable process for modernisation of their smelter. The ISASMELT plant was commissioned in May 2002, making it the newest ISASMELT plant currently in operation.

Sterlite Industries (India) Limited (SIIL) is a relative newcomer to the copper smelting industry, commencing smelting operations in 1996. It is also one of the most successful in recent times and is the first company to construct a second ISASMELT plant. The SIIL smelter located at Tuticorin in the state of Tamil Nadu, had an original design capacity of 60,000 tpa of copper anode, and has steadily increased production until now it is producing up to 180,000 tpa of anode through the original ISASMELT furnace. Having reached the limit on the existing furnace, SIIL are currently constructing a larger furnace to replace the existing one with a capacity of 1.3 million tpa of concentrate, equivalent to 300,000 tpa of anode copper.

THE ISASMELT PROCESS

The Copper ISASMELT process is a bath smelting process utilising the unique ISASMELT lance. The lance tip is immersed in a molten slag bath contained within the stationary, vertical, refractory-lined ISASMELT furnace. 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 190 tonnes per hour of copper-bearing feed (concentrate, reverts, and other internal smelter recycle materials) in a total bath volume of approximately 15 m³. At this smelting rate the furnace has the capability to treat 1.3 million tpa of copper-bearing feed.

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. The first commercial scale Copper ISASMELT furnaces were commissioned in 1992 at Mount Isa, Australia, and Miami, Arizona. Table I lists the smelters that currently treat copper feed materials in an ISASMELT furnace.

Table I- Smelters using ISASMELT furnaces for copper production

Company	Location	Rated Capacity
Mount Isa Mines	Mount Isa, Australia	1,000,000 tpa copper concentrate
Phelps Dodge Miami	Arizona, USA	700,000 tpa copper concentrate
Sterlite Copper No. 1	Tuticorin, India	600,000 tpa copper concentrate
Sterlite Copper No. 2 (under construction)	Tuticorin, India	1,300,000 tpa copper concentrate
Yunnan Copper Corporation	Kunming, China	600,000 tpa copper concentrate
Umicore Precious Metals	Hoboken, Belgium	200,000 tpa secondary copper and lead materials, plus concentrate
Hüttenwerke Kayser	Lünen, Germany	150,000 tpa secondary copper materials

DESCRIPTION OF MIM, SIIL & YCC COPPER ISASMELT PLANTS

Many improvements have been made to the ISASMELT process since MIM commissioned its plant at Mount Isa in 1992. These improvements have been captured in the design and operating practices used at YCC and are planned for the new SIIL furnace. Table II summarises key design data for the three smelters.

Table II - MIM, YCC and SIIL copper ISASMELT design data

Plant	Mount Isa	YCC	SIIL (current)	SIIL (upgrade)
Copper concentrate Capacity (tpa)	1,000,000	600,000	600,000	1,300,000
Furnace details				
Diameter, inside brick (m)	3.75	4.4	2.87	4.4
Molten bath depth (m)	1 to 2	1 to 2	1 to 2	1 to 2
Number of tapholes	1	2	1	2
Lance details				
Nominal bore (mm)	450	400	250	450
Volume % oxygen in process air	60 to 65	50	60 to 80	60 to 80
Hydrocarbon fuel	Natural gas	Diesel oil	Furnace oil	Furnace oil
Feed details				
Feed preparation	Moist, pelletised	Moist, pelletised	Conveyed direct to furnace	Conveyed direct to furnace
% copper in concentrate (%)	25 to 27	18 to 22	25 to 30	25 to 30
% H ₂ O in concentrate (%)	9	9	7	7
Matte/slag Product				
Destination	Rotary holding furnace	Electric furnace	Rotary holding furnace	2 Rotary holding furnaces
Temperature (°C)	1200	1180	1200	1200
Liquid products after settling				
Matte grade (% Cu)	60 to 63	55	60 to 65	60 to 65
Destination	Peirce Smith Converters	Peirce Smith Converters	Peirce Smith Converters	Peirce Smith Converters
Slag SiO ₂ :Fe	0.8	0.9	0.8	0.8
Slag Cu	2.6*	0.7	0.8	0.8
Off gas				
Volumetric flow rates (Nm ³ /hr)	65,000 (excludes ingress)	60,000 (includes ingress)	60,000 (includes ingress)	77,000 (includes ingress)
%SO ₂	27 (at inlet to waste heat boiler)	14 (at inlet to electrostatic precipitator)	22 to 27 (at inlet to evaporative cooler)	22 to 27 (at inlet to waste heat boiler)

*The slag at Mount Isa is milled to recover the copper

Mount Isa Mines Copper ISASMELT

The Copper ISASMELT Plant at Mount Isa, initially rated at about 700,000 tonnes of concentrate per annum, was constructed at the same time as the Phelps Dodge plant located in Miami Arizona. Both plants based their design on a demonstration scale pilot plant that operated in Mount Isa from 1987 to 1991. One of the consequences of both plants being constructed simultaneously was that neither of the operations was able to benefit from the lessons learned by the other prior to startup. As a result both plants experienced numerous process upsets during the first years of operation. The difficulties associated with the Miami plant startup are described in a paper that was presented at the Copper 95 – Cobre 95 conference (3).

Mount Isa Mines encountered its own set of difficulties. These were largely overcome by about 1996 when it was decided to upgrade the copper smelter utilising the original ISASMELT furnace. The upgrade has been described in another paper (6). Since completion of the upgrade in 1998 all the copper concentrate smelted at Mount Isa has been processed in the ISASMELT furnace. The furnace 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 1.

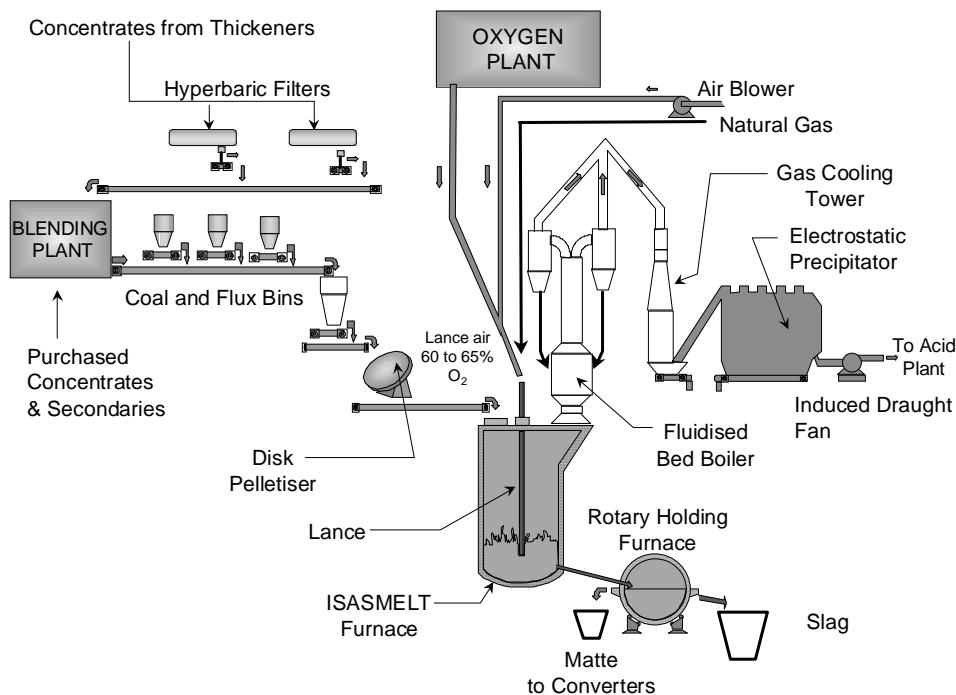


Figure 1 - Mount Isa copper ISASMELT flowsheet

Mount Isa Mines concentrate is blended with purchased concentrate from the Ernest Henry mine 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 the lump coal added to the feed mixture and natural gas injected through the lance. Process air injected through the lance is enriched to 60-65% oxygen content. The ISASMELT lance has a nominal bore of 450 mm. Lance immersion in the bath is controlled automatically, ensuring extended lance life, which averages about 8 days. The lance changing operation, which takes place during maintenance stoppages, typically lasts 40-60 minutes.

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. This furnace is a horizontal cylindrical vessel that is stationary during normal operation, it can be rotated in one direction to pour off slag and rotated in the other direction to pour matte. The matte is poured into ladles and transferred to the Peirce-Smith converters for converting into blister copper. The slag is poured into ladles and removed by 'Kress' hauler truck. Slag is subsequently milled for copper recovery.

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

Refractory campaigns of more than two years are now standard on the Copper ISASMELT furnace at Mount Isa. As of May 2003 the current campaign is in its 31st month.

Sterlite Industries Copper ISASMELT

The SIIL copper ISASMELT at Tuticorin was commissioned with a design capacity of 60,000 tonnes per year of copper in matte. Production has increased each year, mainly through provision of additional oxygen, bringing the annual capacity to 180,000 tonnes of copper, equivalent to 600,000 tonnes of concentrate. The process flowsheet is shown schematically in Figure 2.

The plant was constructed on a greenfield site and includes Peirce-Smith converters, anode furnaces, anode casting facilities, sulfuric acid plant and a phosphoric acid plant. Concentrates are imported through the port facilities at Tuticorin and stored in a purpose built storage facility. After blending, concentrates are fed directly to the ISASMELT furnace by belt conveyer along with petroleum coke and fluxes. Fuel oil is injected through the lance for fine control of bath temperature. The oxygen content of the process air injected through the ISASMELT lance is 75-80%. The matte grade is controlled between 55 and 65% copper. Matte and slag are tapped from the ISASMELT furnace through a single taphole into a rotary holding furnace, where they separate by gravity settling. The slag is skimmed intermittently from the rotary holding furnace and granulated for discard. Matte is poured into ladles and transferred to the converters.

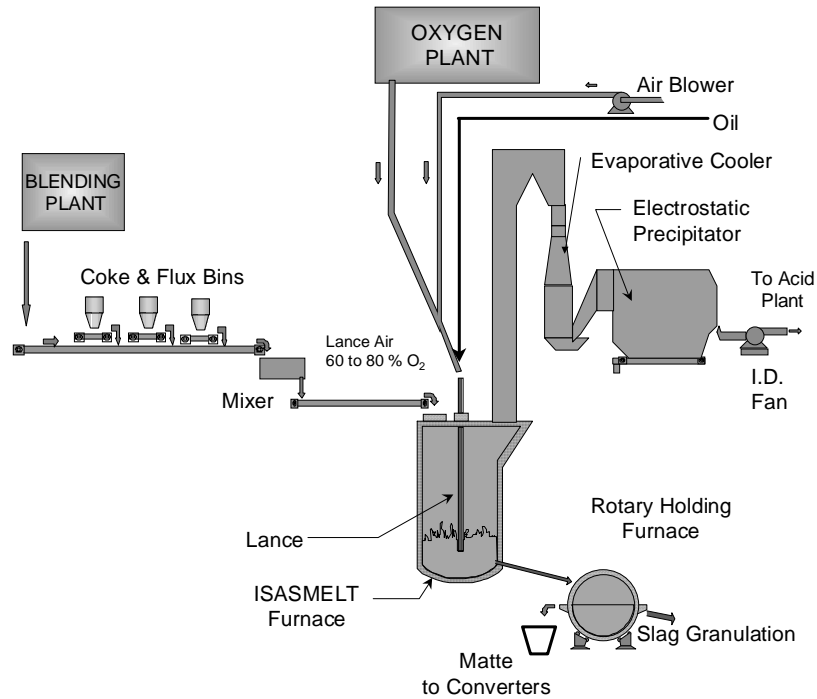


Figure 2 - SIIL copper ISASMELT flowsheet

Offgases from the ISASMELT furnace pass into a water-cooled offtake and spray cooler and are quenched, prior to passing into an electrostatic precipitator for cleaning. The cleaned gases pass to the sulfuric acid plant.

Yunnan Copper Company Copper ISASMELT

The design capacity of the YCC Copper ISASMELT furnace is 600,000 tonnes of concentrate per year. The process flowsheet for the plant is shown schematically in Figure 3. A number of different concentrates, mostly brought by road or rail from mines within Yunnan province, are blended with flux in a blending plant. The majority of the coal required for the process is added to the blended mix. The feed mix is pelletised and a further small amount of coal and silica is added to the pelletised mix before it is fed into the ISASMELT furnace. Oxygen enriched air is injected into the bath through the ISASMELT lance. Oil can be injected through the lance, if necessary, for fine adjustment of the bath temperature. The molten slag and matte is tapped intermittently from the ISASMELT furnace through one of two tap holes into an electric settling furnace. The slag and matte separate by gravity in the settling furnace. Matte is subsequently transferred by ladle to Peirce-Smith converters for further processing. Slag is granulated and removed for disposal. Converter slag is returned to the electric settling furnace for reduction and slag cleaning.

The process offgas is directed to a sulfuric acid plant after passing through a waste heat boiler and electrostatic precipitator to lower its temperature and remove the dust. The dust collected in the waste heat boiler is crushed and returned to the electric furnace. The dust collected in the electrostatic precipitator is conveyed to the electric furnace.

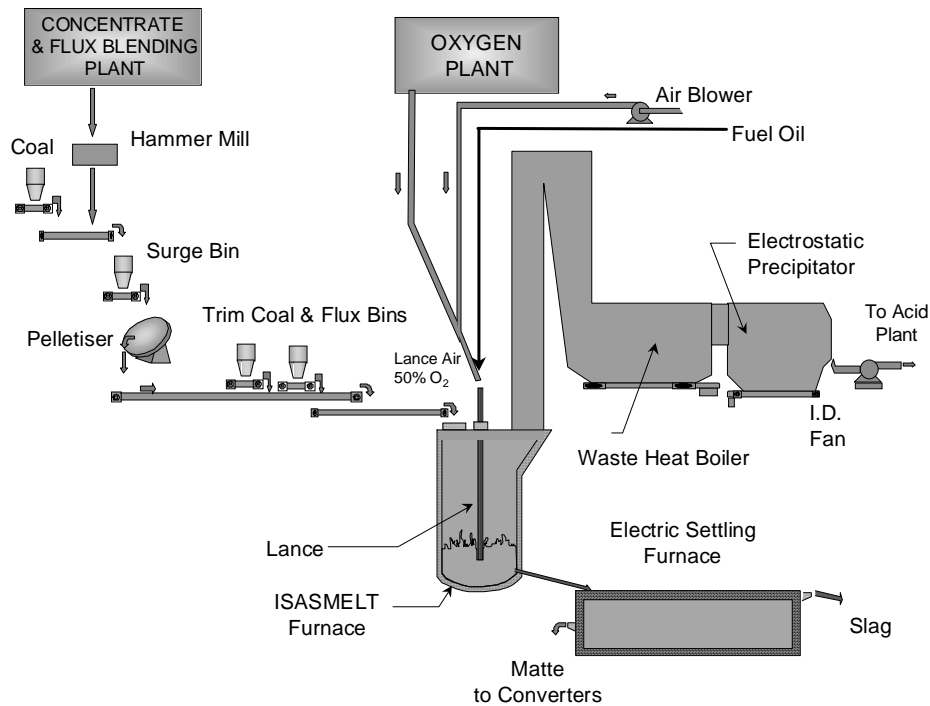


Figure 3 - YCC copper ISASMELT flowsheet

In contrast to the SIIL plant, the construction of the YCC plant resulted in a number of unique challenges, because of its location within the existing smelter. The ISASMELT furnace and waste heat boiler had to be installed in a very restricted area between existing plant facilities. It was necessary to construct the ISASMELT furnace adjacent to the electric furnace, so that the electric furnace could be used as the settling furnace once the ISASMELT furnace started operation. The available space was restricted by the converter aisle on one side and the electric furnace offgas bag filter building on the other. The compact nature of the ISASMELT furnace enabled it to be constructed within such a confined space without interrupting operation of the smelter. A furnace elevation is shown in Figure 4.

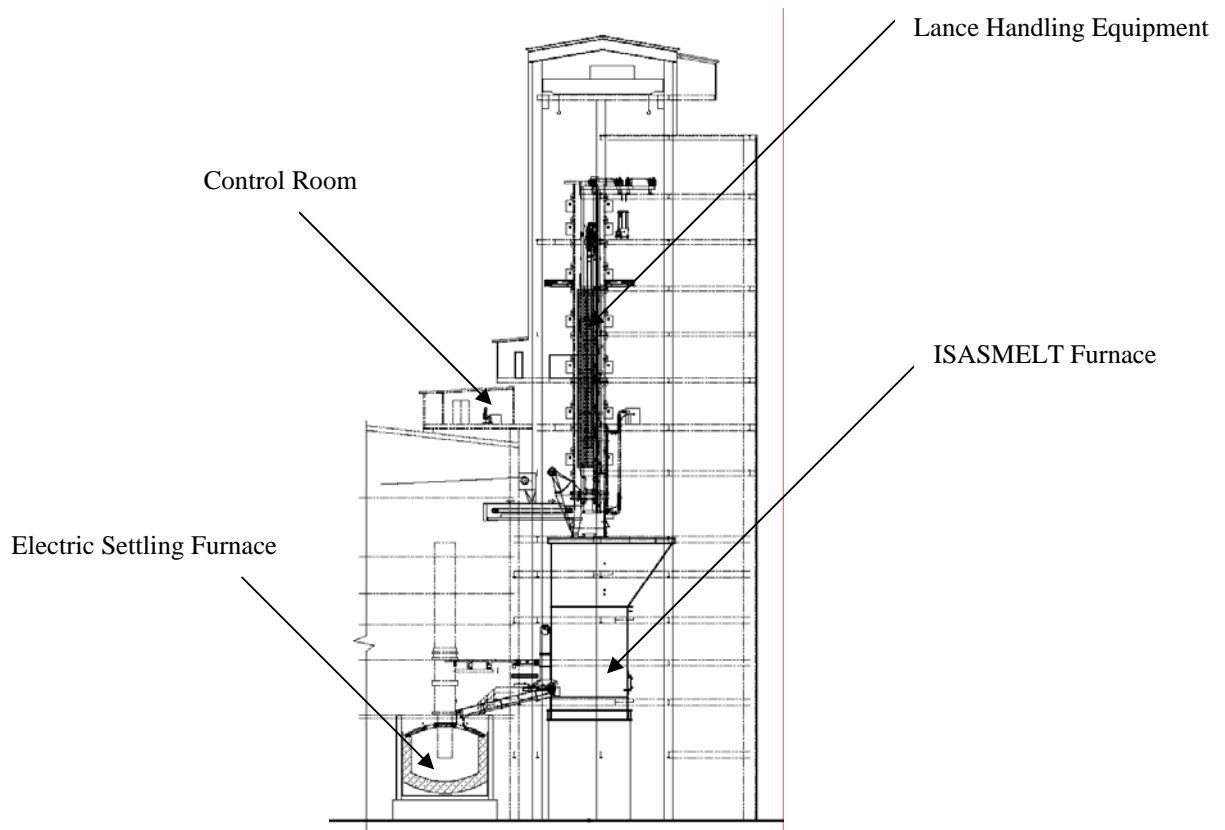


Figure 4 - YCC ISASMELT building elevation

YCC OPERATING RESULTS

The first year of operation at YCC was very successful. Within a week of charging of the first feed to the furnace the plant was running smoothly. In recent months the main difficulty for YCC has been obtaining sufficient concentrate to feed the ISASMELT furnace, with the current tight concentrate market limiting the amount that is available.

Production

The production rate at YCC quickly ramped up to design capacity after plant startup. Figure 5 shows the daily feed tonnages to the furnace and the annualised weekly sum for the month of July 2002. Within two months of first feed on 19th May 2002, the plant had demonstrated the design capacity averaged over a period of one week.

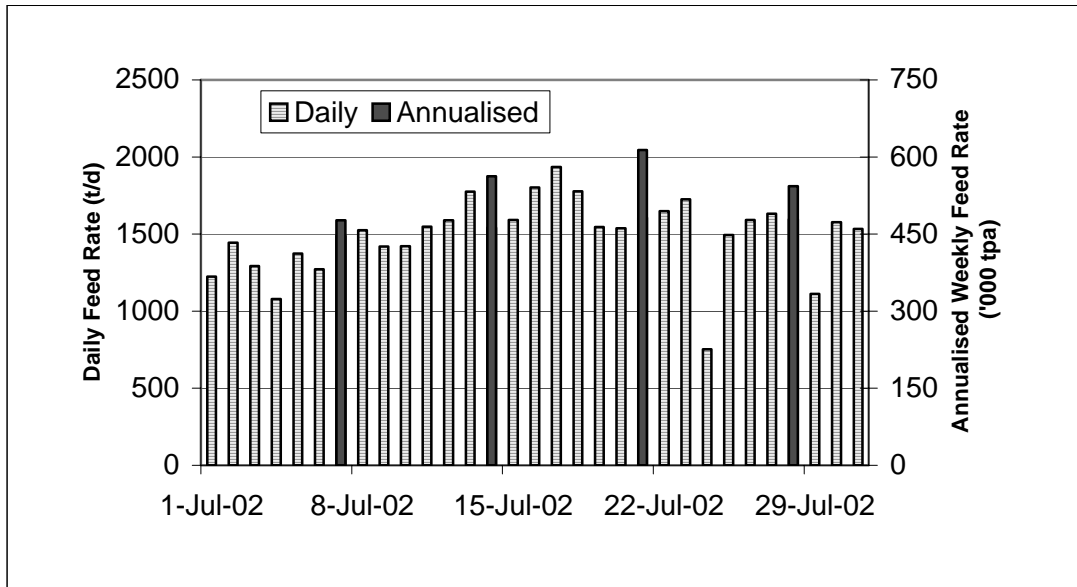


Figure 5 - YCC ISASMELT feed rate July 2002

The plant has continued to perform well in recent months apart from occasional plant outages, principally caused by leaks in the waste heat boiler. Figure 6 shows the feed rates for February 2003. The plant was shut down for five days in the middle of the month for repairs to the waste heat boiler.

In the first twelve months YCC have smelted 446,000 tonnes of dry copper concentrate in the ISASMELT furnace.

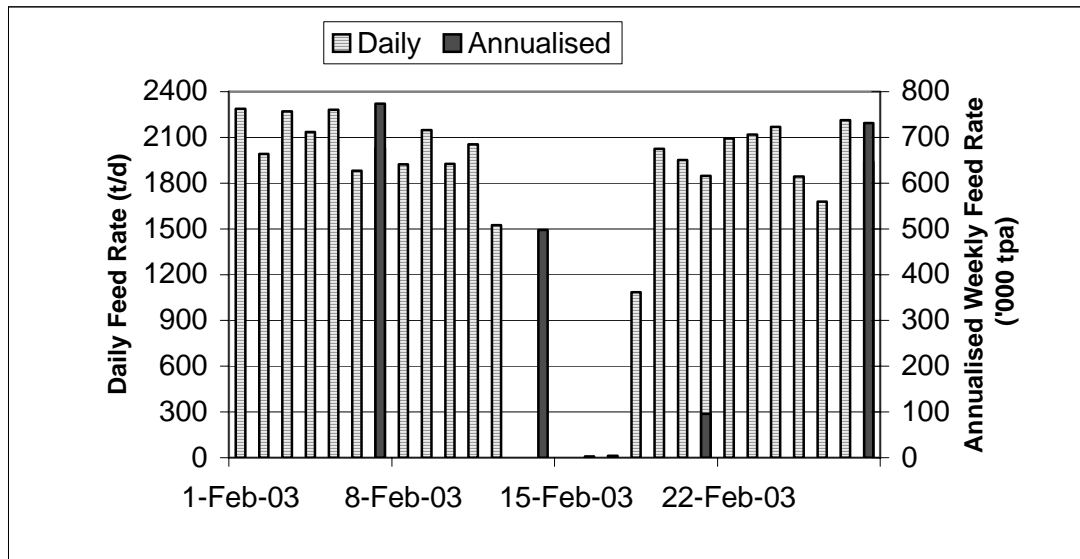


Figure 6 - YCC ISASMELT feed rate February 2003

Plant Availability

The YCC plant achieved high plant availability within weeks of initial heat up. MIM provided an extensive training program for key YCC personnel resulting in them having a detailed knowledge and appreciation of process operation prior to plant startup. YCC personnel independently operated the Mount Isa furnace during their training, thus providing them with an instinctive feel for the process before they took responsibility for control of their own plant. The training program is detailed in another paper (7).

Figure 7 shows the average monthly availability for the ISASMELT. These figures do not take into account time when the furnace was offline for problems with the waste heat boiler or process air blower.

In October 2002 blower air supply surging made it difficult to maintain steady operation of the ISASMELT furnace. This surging was due to incorrect set up of the diffuser vane. Once this was corrected the diffuser vane acted according to the controller output signal and the surging was eliminated.

The waste heat boiler experienced leaks in the convection section boiler tube wall on three occasions in October 2002, February 2003 and March 2003. The ISASMELT furnace design allows YCC to isolate the boiler for carrying out repairs. During this time the furnace temperature is maintained by using the holding burner. On each occasion the boiler was repaired to return to production as quickly as possible. YCC is working with the boiler supplier to implement a permanent solution.

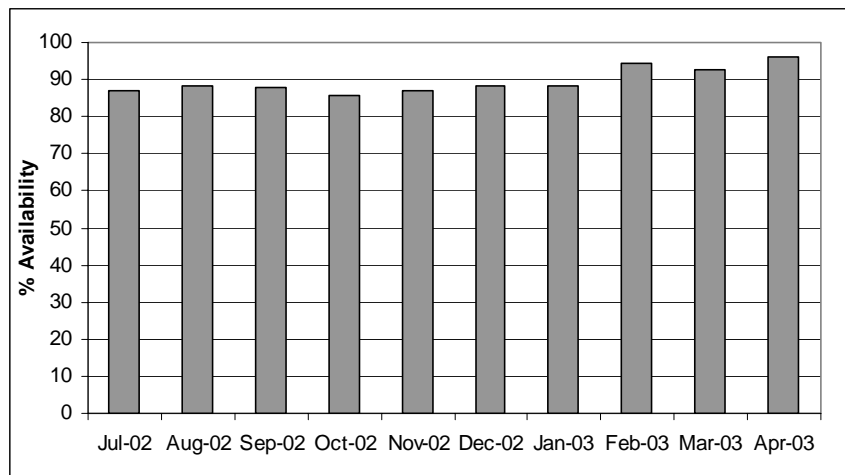


Figure 7 - YCC ISASMELT availability

Refractory Life

One of the key performance indicators for YCC's project was to achieve at least 12 months for the first refractory campaign on the ISASMELT furnace. At Mount Isa it had taken several years to establish the optimum refractory materials and operating methodology to obtain extended campaigns in the ISASMELT furnace. This underpinning knowledge was passed onto YCC during the design, construction, training and commissioning phases of the project. Generally the refractory wear during the first campaign on any furnace is expected to be higher than subsequently experienced because the operators are in the process of learning how to control the new plant. However, YCC's operators took full advantage of their training program at Mount Isa to learn how to control the process and consequently there has been very low refractory wear during the first year's operation.

Figure 8 shows the refractory wear trend since start up. After 50 weeks of operation, 100 mm of brick was worn. This refractory life has been achieved without the use of any water-cooling of the bricks.

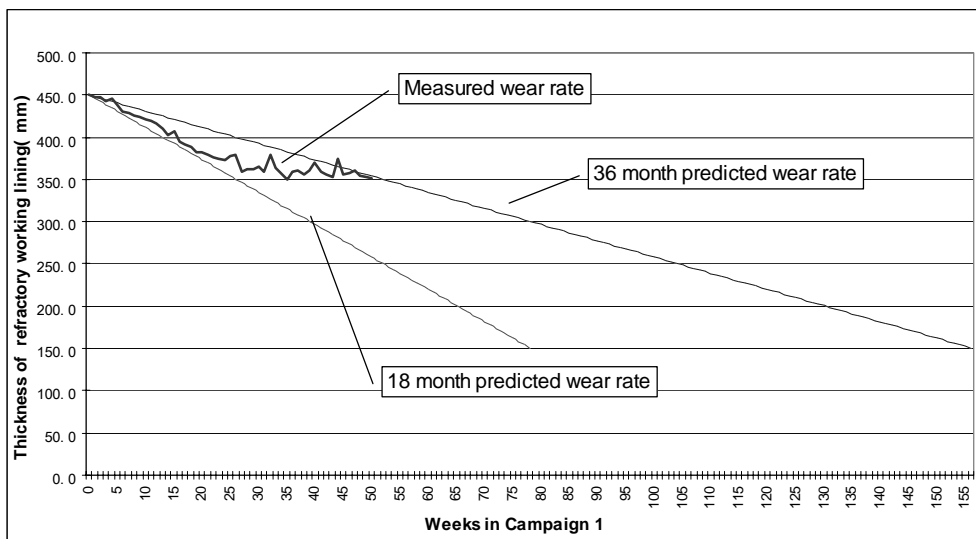


Figure 8 - YCC refractory wear trend

Lance Life

Another of the key performance indicators for YCC was quality and performance of the ISASMELT lances and achievement of long lance life. Advanced lance control algorithms developed at Mount Isa by MIM were incorporated into the YCC control system software and YCC were instructed in lance operating and maintenance procedures. As a result, YCC have experienced good lance life virtually from the start of operation with average lance life of about seven days and maximum life of 18 days has been achieved. Lances are returned to service after repair of the lance tip. Figure 9 shows the lance life over a six month period.

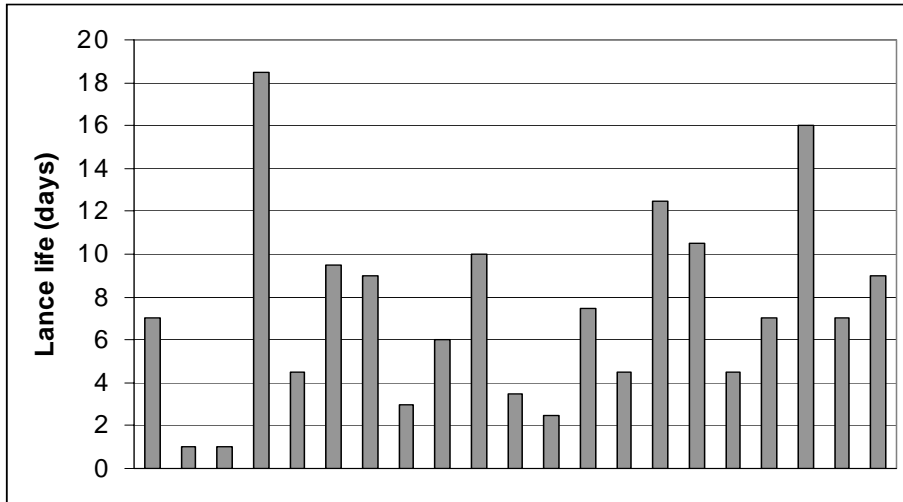


Figure 9 - YCC lance life

Electric Settling Furnace and Copper Loss

The electric settling furnace is used primarily for gravity settling of the matte and slag from the ISASMELT furnace to achieve low copper losses in the discard slag. Converter slag is also returned to the settling furnace for reduction. Figure 10 shows the typical copper content of slag tapped from the electric furnace since startup. From May 2002 a gradual decrease in copper in slag was experienced to a low value of 0.6% in September 2002. From start up of the ISASMELT furnace build up occurred in the electric furnace, reducing the settling volume and hence the residence time required to achieve a low copper in slag. To counteract this YCC adjusted the slag composition in the ISASMELT furnace and converters to decrease the magnetite level and therefore the buildup. As a result of this copper in slag values returned to low levels as shown in Figure 10.

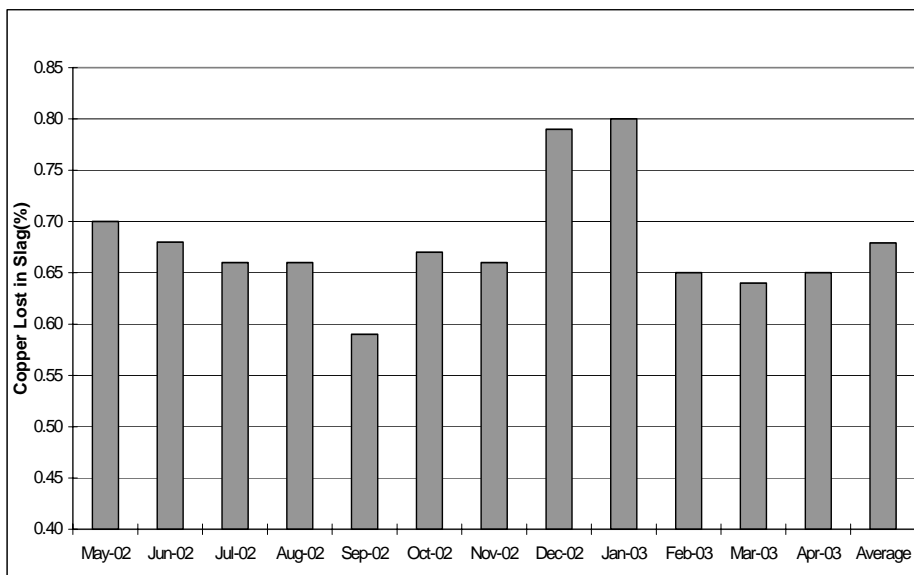


Figure 10 - YCC typical copper content of electric furnace slag

INCREASING PRODUCTION OF ISASMELT FURNACES

Oxygen enrichment of the process air injected through the ISASMELT lance is a relatively cost effective way to increase production in an ISASMELT furnace. This has been adequately demonstrated at Mount Isa and Tuticorin, with Mount Isa Mines and SIIL achieving a significant increase in production capacity by increasing the amount of oxygen enrichment. Figure 11 shows the amount of concentrate treated by Mount Isa and SIIL since 1992. Since commissioning the ISASMELT plant at Mount Isa there has been a steady increase in the amount of concentrate treated.

SIIL have achieved consistent increases in concentrate treatment rate since 1996. They have now reached the limit for concentrate throughput for their existing furnace and are therefore currently constructing a new, larger ISASMELT furnace.

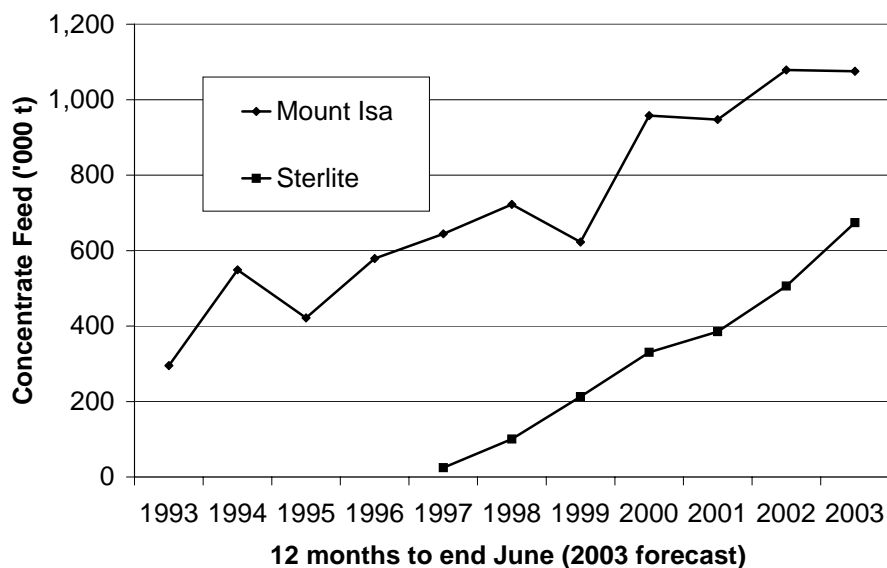


Figure 11 - Mount Isa and SIIL feed rates

SIIL's new ISASMELT furnace, scheduled to be commissioned in 2004, will have the largest capacity of any built to date, enabling the smelter to produce 300,000 tonnes per annum of copper anodes. It will replace the existing furnace. The process flowsheet will be very similar to that of the existing plant, with two major changes being the installation of a waste heat boiler and the installation of a second settling furnace. Figure 12 shows an elevation of the new furnace.

Belt conveyors will feed concentrates, petroleum coke and fluxes from bins directly to the ISASMELT furnace. Although petroleum coke will be used as the main fuel, some fuel oil will be injected through the ISASMELT lance for fine control of bath temperature. The oxygen content of the air injected through the ISASMELT lance will be 60-80% depending on the type of concentrate processed. The matte grade will be approximately 60%. Matte and slag will be tapped into two rotary holding furnaces for gravity settling and separation. The slag will be granulated for discard. Matte will be transferred to Peirce-Smith converters. The offgas will pass

to a waste heat boiler for cooling prior to cleaning in an electrostatic precipitator. The clean gas will pass to a sulfuric acid plant.

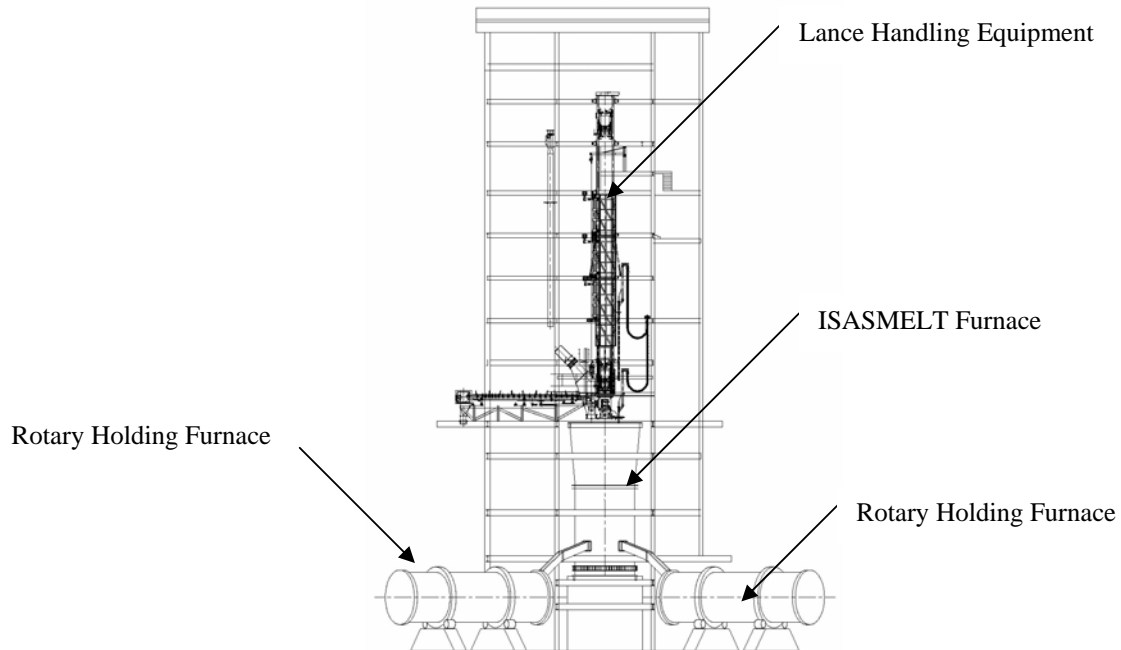


Figure 12 - Future Sterlite Industries copper ISASMELT furnace elevation

CONTINUOUS CONVERTING

The ISASMELT process offers the potential of an alternative to batch copper converting operations, such as Peirce-Smith converting. It is an attractive option due to its flexibility to treat solid feed, efficiently capture sulfur dioxide and reduce in-plant fugitive emissions.

MIM has confirmed, through extensive pilot scale testing, that continuous converting of copper matte into low sulfur blister can be achieved. The majority of pilot scale testing to date has concentrated on converting crushed copper matte produced in the ISASMELT smelting furnace.

A two stage smelting and converting process is being considered for future installation at Mount Isa. It is envisaged that solid matte, from a stockpile, would be fed to the converting furnace. This would decouple the smelting and converting operations; thus removing the dependency on each other giving improved operating flexibility compared with the existing plant. Plant availability will be maximised, as the smelting operations will be independent of converting operations. The smelting furnace will be able to operate at its optimum throughput while stockpiling the matte for subsequent treatment in the converting furnace. On the other hand, the converting furnace will be able to continue operating at the optimum matte feedrate independent of smelting furnace operation.

Before proceeding with a commercial scale installation MIM is planning to install a large-scale pilot plant. An eighteen-month test campaign is planned to investigate key process issues. MIM has carried out detailed engineering for the installation of the pilot plant. Figure 13 is a schematic diagram of the plant.

The main drivers for developing and considering the installation of a large scale operation at Mount Isa are:

- Increased copper production;
- Simplified smelter operation;
- Improved environmental and safety performance;
- Reduced operating costs; and
- Low capital cost.

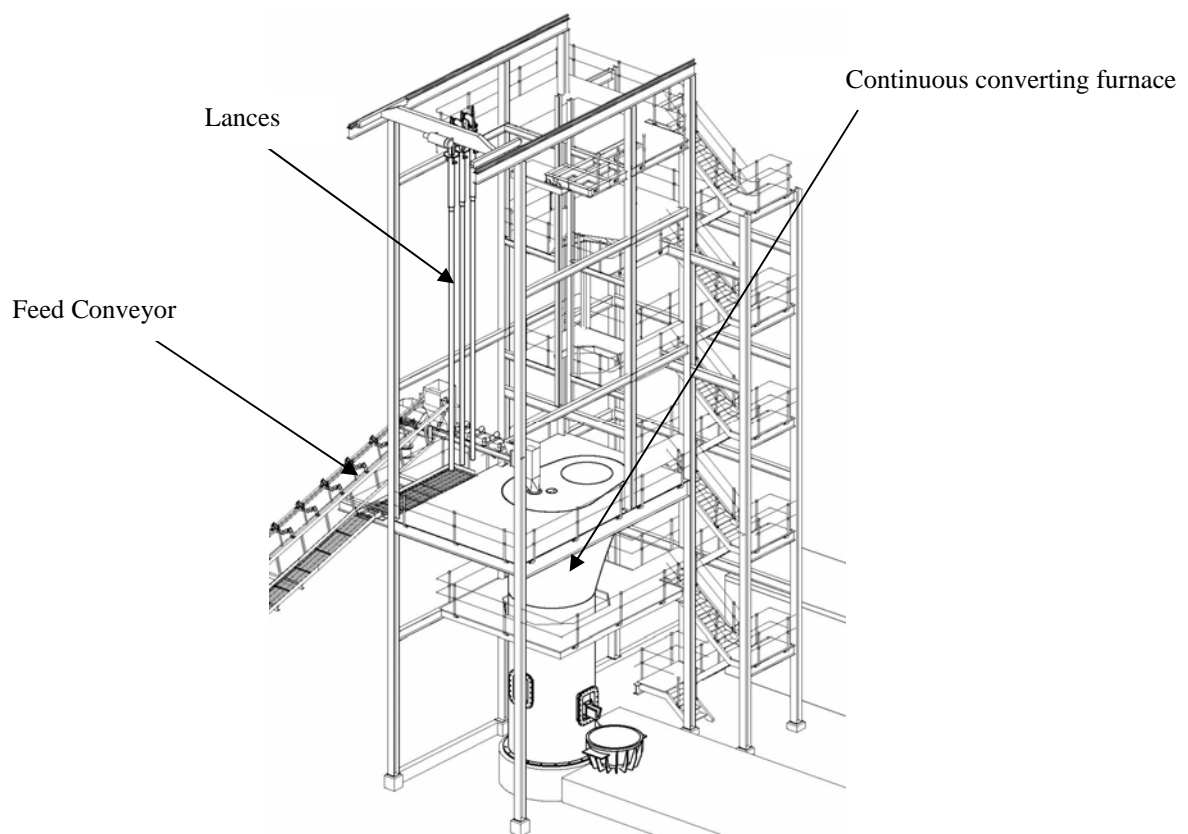


Figure 13 - Continuous converting pilot plant

CONCLUSIONS

The ISASMELT process has successfully been installed in smelters around the world. A combination of high intensity, simple design and ease of operation make the process ideal for new copper smelting installations. The success of the first year's operation in the most recently constructed plant in China has demonstrated the robustness of the technology, with availabilities of over 85% and refractory life of more than 12 months achieved in the first campaign and design throughput achieved within two months of startup. Refractory campaign life of more than 2 years is now standard at Mount Isa. Experience at Mount Isa over the past 11 years and in India over the past 7 years has demonstrated how the throughput of the furnace can be increased significantly by increasing the oxygen enrichment of the process air injected through the ISASMELT lance.

Training programs held at the Mount Isa copper smelter allow operating personnel to learn to operate the process prior to commissioning of their own plant, dramatically improving the understanding of the process and facilitating optimum technology transfer.

A large-scale demonstration plant for continuous copper converting has been designed for installation at Mount Isa. The converting process has the potential to provide a much simpler alternative to existing converting technologies. ISASMELT technology has proven that it certainly is more than just a flash in the pan.

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