



# Isasmelt technology—current status and future development

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## Synopsis

The Isasmelt process was developed at Mount Isa Mines Limited in Queensland, Australia in collaboration with CSIRO, the Australian Government research organisation. Originally developed for primary lead smelting, culminating in the construction of a 60,000 tonnes per annum lead smelter at Mount Isa, this technology now also provides a major part of the current 200,000 tonnes per annum copper smelting capacity at Mount Isa. A programme is now in place to expand copper production to 250,000 tonnes per annum. The technology has also been applied to secondary lead smelting at Britannia Refined Metals, a MIM subsidiary company, where a 30,000 tonnes per annum lead plant based on battery scrap feed has been operating since 1991.

Mount Isa Mines Limited decided to license the technology in 1988, and copper smelting plants utilising Isasmelt technology are now operated by Cyprus Miami Mining Corporation in the USA and by Sterlite Industries in India. In addition, the technology was adopted by AGIP for smelting copper/nickel concentrates in Australia. Union Minière are currently constructing an Isasmelt furnace to smelt and convert copper-containing materials at their plant at Hoboken in Belgium.

This paper discusses these developments and also some likely future developments which include the application of the technology for continuous copper and nickel converting and applications in the treatment of zinc-containing residues.

## Introduction

The Isasmelt process was originally developed for primary lead smelting, the development occurring in collaboration with CSIRO, the Australian Government research organisation, via laboratory testwork at CSIRO and pilot plant and demonstration scale plants at Mount Isa Mines<sup>1</sup>.

The lead demonstration plant was used to increase the output of the lead smelter by augmenting the sulphur burning capacity of the sinter plant which was the main constraint to lead production. The plant was run for several years smelting 7–9 tph of concentrate to produce a high lead slag which was fed to the blast furnace via the sinter plant. Later a second furnace was added to demonstrate this process as a stand alone lead smelting technology.

The development of the technology for copper smelting was also carried out on pilot plant and demonstration scale plants at Mount Isa<sup>2</sup>. The copper smelting demonstration plant also contributed significantly to the output of the copper smelter, smelting 530,000 tonnes of concentrate over its 5-year life.

The success of the lead and copper demonstration plants gave confidence in the application of the technology at the large commercial scale for both lead and copper production at Mount Isa Mines, and also prompted the initiative to license the technology to external clients. Table I shows a list of these installations to date.

## Isasmelt copper smelters

Since 1993 three copper smelters have been commissioned. Table II gives some details of these smelters.

### Mount Isa copper smelter

The current copper smelting capacity at Mount Isa Mines is approximately 200,000 tpa of copper from an operation which includes a roaster/reverberatory furnace combination together with a copper Isasmelt furnace. The Isasmelt furnace smelts the major part of the concentrate together with the revert material generated by matte transfer from the reverberatory operation.

A schematic diagram of the Mount Isa copper Isasmelt is shown in Figure 1. The plant includes several unique features including the use of hyperbaric filters for concentrate dewatering and the use of the Ahlstrom 'Fluxflow' recirculating fluidised bed boiler for waste heat recovery. A detailed description of the plant operation has been given in Reference 3.

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Table I

Isasmelt installations

Date	Plant operator	Plant location	Plant type	Plant capacity
1983	Mount Isa Mines Limited	Mount Isa, Australia	Lead smelter	5–10 tph concentrate
1985	Mount Isa Mines Limited	Mount Isa, Australia	Lead slag reduction + Dross treatment	5 tph lead slag
1987	Mount Isa Mines Limited	Mount Isa, Australia	Copper smelter	15–20 tph concentrate
1991	Mount Isa Mines Limited	Mount Isa, Australia	Primary lead smelter	60,000 tpa lead metal
1991	Britannia Refined Metals	Northfleet, UK	Secondary lead smelter	30,000 tpa lead metal
1991	AGIP Australia Pty Ltd	Radio Hill, Australia	Nickel/copper smelter	7.5 tpa concentrate
1992	Cyprus Miami Mining	Arizona, USA	Copper smelter	160,000 tpa copper
1992	Mount Isa Mines Limited	Mount Isa, Australia	Copper smelter	180,000 tpa copper
1996	Sterlite Industries (India) Ltd	Tuticorin, India	Copper smelter	60–100,000 tpa copper
1997	Union Miniere	Hoboken, Belgium	Copper/lead smelter	200,000 tpa feed

Table II

Isasmelt copper smelters

Plant	Designed tonnage (tpa copper)	Supplementary fuel	Offgas cooling	Sulphur capture
Cyprus Miami, USA	160,000	Natural gas	Conventional W.H.B.	Acid plant
Mount Isa Mines, Australia	180,000	Lump coal	Flux flow W.H.B. + Evaporative cooler	Air dispersion (Acid plant 1999)
Sterlite Industries, India	60,000–100,000	Lump coal + oil	Evaporative cooler	Acid plant

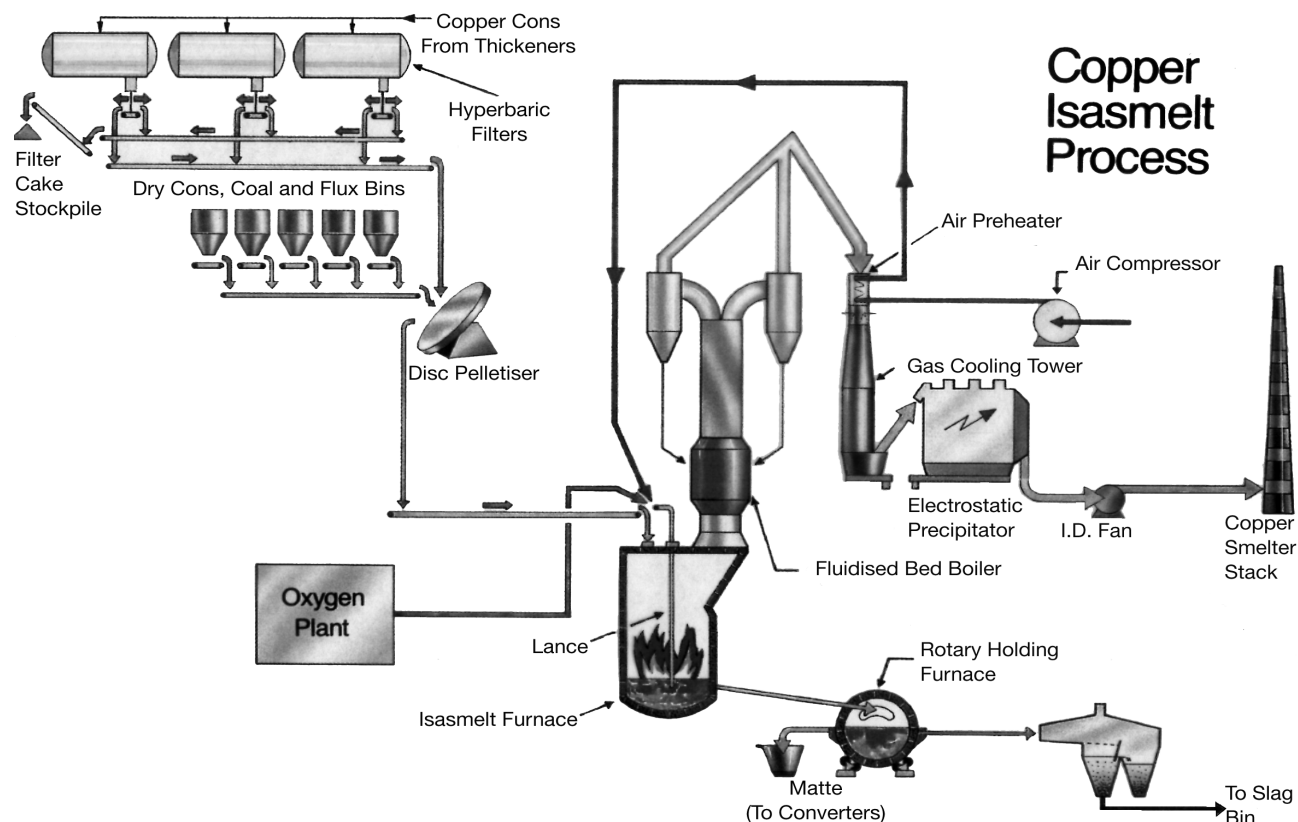


Figure 1—The Mount Isa copper Isasmelt plant

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The Fluxflow boiler has some very attractive features in that it is relatively compact, easy to operate and eliminates the problems with offtake accretions which are common in copper smelters. In addition, the shock cooling of the gases in the fluidised bed minimises  $\text{SO}_3$  formation and thus results in off gases with low dew points. However, in the early years of operation, the boiler caused more downtime than all the other equipment combined due to erosion of the boiler tubes by the recirculating bed of fine slag particles. Solutions to this problem involved the redesign of the tube bundles to minimise upper tube erosion and the development of protective 'boots' to prevent erosion of the lower parts of the tubes.

Other areas which require a rigorous maintenance schedule to ensure a high availability are the hyperbaric filters and the slag granulation system.

The Isasmelt furnace itself has been largely trouble-free. The large (450mm diameter) lances have proved to be robust and no decrease in oxygen utilisation has been noted when compared with smaller lances. Premature failures can occur from matte attack if the lance is inserted too deeply in the bath and thus it has been important to implement an automatic lance positioning system so that the lance is maintained at a constant immersion in the slag. Lances typically last five days and then require replacement of a short section of the stainless steel tip.

The bricks in the furnace shell are high grade magnesite chrome and have no water cooling applied to them. Typical campaign lives between brick replacement have been 14 months. Testwork has indicated that with a well-designed water cooling system the brick life could be extended to >4 years and this is likely to be implemented at the next rebrick in 1998.

The furnace was designed to smelt 105 tph of concentrates using lance air enriched to 45% oxygen while producing a matte grade of 50% copper. Continuous operation at rates in excess of 120 tph of concentrates and the use of lance air enriched to 55% oxygen have been demonstrated. The normal matte grade is near to 60% and a discard slag (0.6% Cu) can still be achieved by simple settling in the holding furnace at these matte grades.

### **Cyprus Miami copper smelter<sup>4</sup>**

The Cyprus Miami plant in Arizona was designed to smelt 590,000 tpa of concentrates. Smelting was previously carried out in an electric furnace which was shortened for use as a settling furnace for the Isasmelt matte and slag products.

The furnace smelts Cyprus concentrates together with some purchased materials which are all blended in a bedding plant and transferred to two concentrate feed bins. The concentrate feed is blended with fluxes and revert material in a mixer and the mixed material is fed directly to the furnace. A pelletiser was used in the initial years of operation but has been found to be unnecessary. Bath temperature is controlled using natural gas, the furnace producing a 60% copper matte which is tapped together with the slag into the electric furnace for settling.

The offgas passes through a vertical, water-cooled offtake and then down into the radiation section and convection section of a conventional Ahlstrom boiler. The initial offtake design used cold water at atmospheric pressure

and suffered from corrosion due to condensation of acid from the offgases. This resulted in frequent stoppages to repair leaks. The replacement of the offtake with a modified design using high pressure water at 250°C has eliminated the problem and allowed the smelter to achieve design capacity.

Cyprus have implemented automatic control of lance positioning and bath temperature. In addition they have developed an automatic control system which maximises the use of the available oxygen and acid plant capacity. This programme ramps up the Isasmelt feed rate when a converter is turned out of stack and maintains a constant flow and  $\text{SO}_2$  strength to the acid plant. The Cyprus control room operation is now essentially a 'hands off' operation.

### **Sterlite Industries copper smelter**

This smelter is located at Tuticorin, in the southern tip of India and is designed to smelt imported concentrates to produce 60,000 tpa of copper with the potential to expand to 100,000 tpa copper. The plant is on a greenfield site and includes Peirce-Smith converters, anode furnaces and an acid plant. A phosphoric acid plant will shortly be commissioned on the site.

Concentrates are stored in a shed and transferred to bins supplied with individual weighfeeders which allow blending of the concentrates. The concentrates, together with lump coal and fluxes are transferred to a disc pelletiser for blending and agglomeration. The resulting pellets, containing approximately 9% moisture are fed directly to the Isasmelt furnace by belt conveyer.

The slag and matte products (target matte grade 50% copper) are separated in a rotary holding furnace and the slag granulated into a pit with removal of the slag to a storage bin being carried out by a mechanical grab. Matte is transferred to the converters by ladle.

### **Nickel/copper smelting**

#### **The AGIP Radio Hill plant**

AGIP Australia decided to use the Isasmelt process at its nickel/copper deposit at Radio Hill in Western Australia. The plant began operating in September 1991 and within three months was running at design capacity of 7.5 tph and producing a 45% nickel/copper matte from a concentrate containing approximately 7% nickel and 3.5% copper. The matte and slag products were tapped into an oil-fired settling furnace and the separated products were then granulated.

Having demonstrated the technical success of the project AGIP had to close the mine, concentrator and smelter after less than six-months' operation due to the collapse in nickel prices.

### **Primary lead smelting**

#### **The Mount Isa lead plant<sup>5</sup>**

Until 1983 lead smelting in Mount Isa was carried out using only a conventional sinter plant-blast furnace combination. Between 1983 and 1990 the lead production was augmented by product from the lead Isasmelt demonstration plants. In 1991 a commercial scale lead plant was installed to increase

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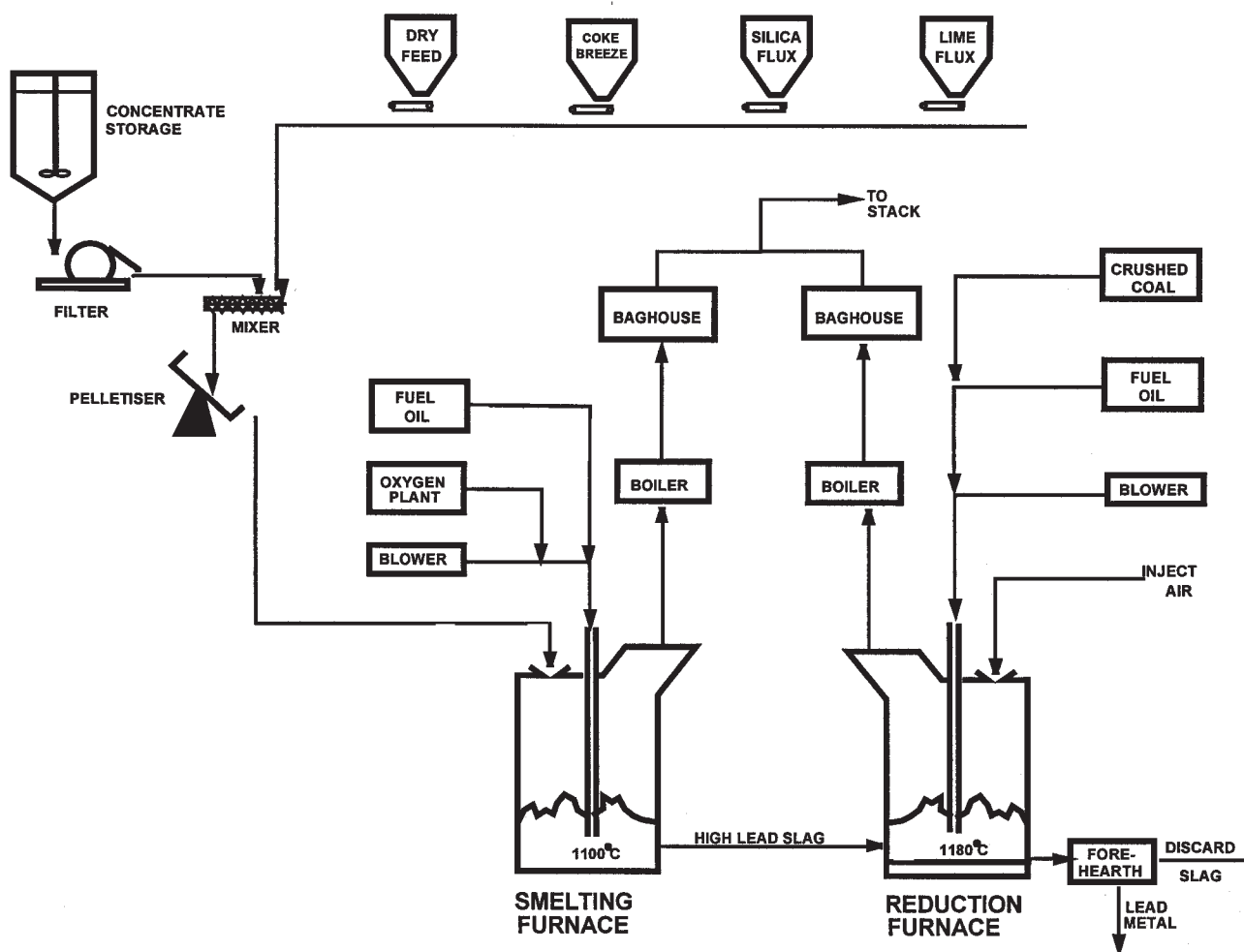


Figure 2—The Mount Isa lead Isasmelt plant

the lead smelting capacity at Mount Isa to approximately 210,000 tpa while allowing the sinter plant-blast furnace to be de-rated from 170,000 to 150,000 tpa so that it could meet emission targets.

A schematic diagram of the lead plant is shown in Figure 2. The plant was designed to produce 60,000 tph of lead metal when treating approximately 20 tph of Mount Isa lead concentrates containing 47% lead and was commissioned in 1991. The plant is currently mothballed while a feasibility study is carried out to determine if the George Fisher lead-zinc deposit located near Mount Isa will be exploited to replace the rapidly declining Mount Isa reserves.

The plant consists of a 2.5m I.D. smelting furnace and a 3.5m I.D. reduction furnace. Concentrates and fluxes are smelted in the smelting furnace to produce a high lead slag (50% lead oxide) which is continuously transferred by launder to the reduction vessel. In the reduction vessel the lead slag is reduced by crushed coal injected through the lance to produce lead metal and a discard slag.

The main fuel used in the smelting vessel is coke breeze which is mixed with the feed. The coke breeze is obtained at no cost from the screening of the blast furnace coke. Fuel oil is used in a trimming capacity for fine temperature control. Fuel oil is used as the main fuel in the reduction furnace but

a significant fraction of the fuel requirement is supplied by the fines component of the coal injected through the lance.

The off gases from both furnaces are cooled to 200°C by individual waste heat boilers, each consisting of a vertical radiation section followed by a horizontal convection section. The cooled gases are cleaned in a reverse pulse baghouse before being vented via the main lead smelter stack.

Lead metal is tapped to ladles and transferred to dropping kettles while the slag is granulated.

The smelting step has proved to be a very simple operation with some attractive features. The presence of zinc ferrite crystals in the molten lead slag product results in protective layers of zinc ferrite forming on the lance and refractory walls thus protecting them from slag attack. Lances typically last more than one month and little wear occurs on the furnace walls in normal operations.

The oxidising conditions and highly-agitated bath in the smelting furnace combine to totally suppress the fuming of the volatile PbS. Fuming occurs only by vaporisation of PbO and thus is limited to less than 10% of the lead in feed. The overall fume rates for smelting and reduction are approximately 15% of the lead in feed.

Most development work has been concentrated on the reduction furnace where significant problems were initially

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encountered with short lance lives and blockages and wear in the coal pneumatic transfer equipment. This resulted in erratic lead contents in the final slag.

The problems were largely overcome by improved screening of the coal, redesigned bends in the pneumatic transfer system and the use of modified lance tips. Refractory wear was acceptable in the reduction furnace with brick replacement required after two years. Final lead in slags are higher than the blast furnace at 2–5% lead but the reduced slag fall in the Isasmelt means that overall recovery to lead is similar.

The vertical radiation sections of the boilers proved to work well with minimal problems with offtake accretions. The convection sections suffered some tube failures from a manufacturing fault which was subsequently modified, but in addition removed less heat than calculated resulting in the requirement for a bleed of cold air to achieve the required entrance temperature to the baghouse.

### Treatment of high lead concentrates

The lead Isasmelt plant was designed to smelt the relatively low lead Mount Isa concentrates. The most suitable process route for these concentrates is full oxidation of the lead sulphides to lead oxides for subsequent slag reduction in the second furnace. For concentrates with higher lead contents a significant fraction of the lead metal can be produced directly by partial oxidation in the smelting furnace.

This was demonstrated when over 4000 tonnes of a concentrate containing 67% lead was smelted in the plant at rates of up to 32 tph. The assay of both the Mount Isa and high lead concentrates are shown in Table III. During these trials approximately 50% of the lead in feed reported directly to lead metal in the smelting furnace while producing the same weight of high lead slag to be reduced in the second furnace as was produced by 20 tph of Mount Isa concentrates. It was thus determined that the lead production capacity of the existing lead plant could be effectively more than doubled by treating such a high grade concentrate.

### Secondary lead smelting

#### Britannia Refined Metals Isasmelt Plant<sup>6</sup>

The Isasmelt process for smelting battery pastes and grids was implemented on a commercial scale in 1991 at Britannia Refined Metals (BRM) at Northfleet, UK. The plant was designed to accept whole batteries and produce approximately 30,000 tpa of lead in alloys. The plant was previously producing approximately 10,000 tpa of lead using a short rotary furnace. The rotary furnace was retained for treatment of refining drosses and slags.

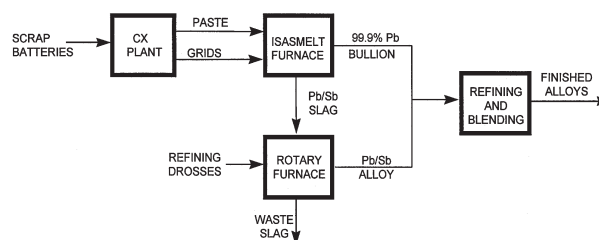


Figure 3—Schematic diagram of the BRM secondary lead plant

Figure 3 shows a simplified flowsheet of the plant.

Batteries are crushed and separated into their individual components in an Engitec CX battery breaker. The main component fractions are metallic grids, lead oxide/sulphate paste, polypropylene, ebonite and PVC. The paste slurry is desulphurised by reaction with sodium hydroxide to form sodium sulphate solution and a lead oxide paste which is dewatered on a filter press. The paste and the metallic grids are delivered to separate storage bins for charging to the Isasmelt furnace.

The paste and grid materials are generally treated in separate campaigns to simplify the subsequent refining process. In a typical paste campaign a starter bath of molten paste is first formed. Paste is then continued to be fed to the furnace together with coke as reductant. The bulk of the antimony, silica, iron and other constituents of the paste report to the slag phase, while the lead in the paste is reduced to form a low antimony (0.01 – 0.1%) soft lead which is tapped from the furnace at intervals into pots and transferred molten to the refinery kettles.

The production of soft lead continues until 120–150 tonnes of paste has been fed to the furnace by which time the slag has become very antimony-rich and contains 55–65% lead oxide. This slag can be reduced *in situ* in the Isasmelt furnace to produce a lead antimony alloy but plant throughput is maximised by using the rotary furnace to reduce the slag. The rotary furnace also treats drosses from the refining kettles. Figure 4 shows the lead distribution in the process.

The plant was designed to smelt 7.5 tph of paste but now routinely smelts 12 tph of paste. Grids are smelted in a separate campaign at rates of up to 35 tph to produce a soft lead (but containing higher antimony than the paste cycle).

In the early years of operation production was limited by delays associated with feed-conveying difficulties and with maintenance requirements in the CX battery breaker plant. Following improvements to the conveying system and continuous progress with the CX plant the plant exceeded its specifications in 1995 and continues to grow without any change to the original plant design.

Table III

Comparison of Mount Isa and high lead concentrates

Concentrate	Composition (wt. %)					Direct lead production	Estimated plant capacity (tpa lead)
	Pb	Zn	Fe	S	SiO <sub>2</sub>		
Mount Isa Mines	47.3	7.0	12.8	23.8	2.8	0%	60,000
High lead concs.	66.9	3.4	4.4	16.5	2.6	50–60%	130,000

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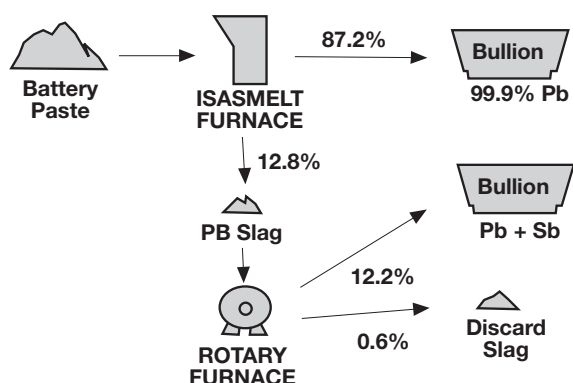


Figure 4—Lead distribution in the BRM process

Significant improvements have been achieved in the performance of the refractory lining of the furnace despite the aggressive nature of the litharge slag. Typically in excess of 20,000 tonnes of lead is produced before partial brick replacement is required. A full brick replacement is only required after the production of 60–70,000 tonnes of lead.

Unit operating costs have steadily decreased year by year as improvements have been implemented and production rates increased so that, for example, the cost per tonne of lead for 1995–1996 was 55% of the unit cost in 1992–1993.

Technical improvements have progressed hand in hand with the development of self-directed work teams to run the plant without metallurgical supervision. These teams are multi-skilled and part of their duties involves carrying out their own lance repairs (currently 6 per month).

The outlook for the BRM plant is for a plant producing 35–40,000 tpa of lead bullion, satisfying emerging environmental standards and with further reductions in unit operating costs anticipated.

### Future developments

#### Copper smelter expansion

Both Cyprus Miami and Mount Isa Mines are embarking on major copper smelting expansion programmes. In both plants the Isasmelt capacity will be increased by using additional oxygen so that the lance air is increased to approximately 60% oxygen. High rate trials have been carried out at both plants to confirm the benefits of the additional oxygen.

The Mount Isa expansion is driven by the requirement to smelt the concentrates from the new Ernest Henry deposit in addition to the Mount Isa concentrates. The Ernest Henry deposit is jointly owned by MIM and Savage Resources and is located near Mount Isa.

It is planned to increase the maximum smelting rate of the Mount Isa copper Isasmelt to 160 tph of concentrates to achieve a copper production in excess of 250,000 tpa.

#### Continuous copper converting

Peirce-Smith batch converters are still standard equipment for converting copper and nickel mattes. However, continuous converting is an increasingly attractive option for smelters as the requirement to capture SO<sub>2</sub> and reduce in-plant fugitive emissions increases.

It is believed the Isasmelt will prove to be an attractive technology in this area. Extensive laboratory work with CSIRO and pilot plant testwork has been carried out to demonstrate the potential of this technology to achieve a low sulphur (<0.1% S) blister copper product from a continuous feed of crushed solidified matte. Most work has been carried out using lime-ferrite slags but tests have also been carried out with silicate slags. Laboratory and pilot plant results showing the dependence of sulphur in blister copper on the copper content of lime ferrite slags are shown in Figure 5 together with a correlation calculated from thermodynamic modelling. Pilot tests were carried out at MIM pilot plants at both Mount Isa and BRM in 1993 and 1994, hence the labels on the graph.

Testwork has also been carried out to examine various treatment routes for the high copper slags which are inevitably formed when trying to achieve low sulphur blister copper. A few tests of slag reduction in the furnace have shown promise, with reduction to 1% copper in slag being achieved in approximately 30 minutes. However, the most likely process route for an Isasmelt-based smelter is recycling the high copper slag to the smelting process while producing a 65–70% matte grade in the smelter to minimise converter slag production.

Although the process can be operated with a continuous molten feed of matte, it is believed the advantages of decoupling the smelting and converting steps by using an intermediate stockpile of crushed or granulated matte outweighs the increased energy requirements for remelting the matte. In addition, the use of solid feed allows high levels of oxygen enrichment to be used in the converting process, producing a low volume of offgas, rich in SO<sub>2</sub>.

The great advantage of the Isasmelt process compared with a flash smelting process is that the solid matte can be

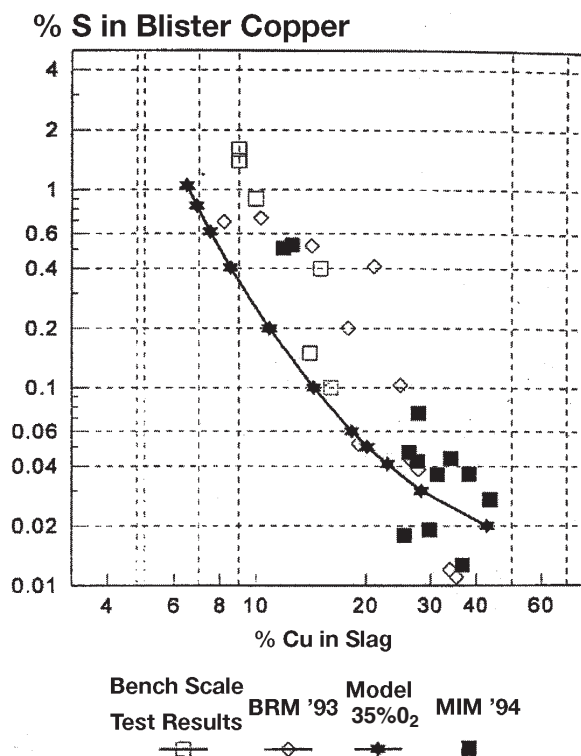


Figure 5—Variation of copper in slag with sulphur in blister

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added to the furnace as relatively large pieces, while the matte feed for a flash furnace converter requires to be granulated, dried and milled to a fine particle size suitable for burning in a flame. The known advantages of very low dust production in the Isasmelt copper smelters will also apply to converting.

### Continuous converting of nickel/copper mattes

Pilot tests have been carried out to demonstrate continuous converting of low grade nickel/copper mattes to produce a low iron product suitable for further processing. This process shows considerable promise to replace Peirce-Smith converters for this purpose due to the ease of operation of the process and the benefits of a continuous high strength stream of SO<sub>2</sub> with minimal emissions.

### Copper-lead smelting/converting

1997 will see the commissioning of an Isasmelt plant to treat copper/lead materials at Union Minière in Hoboken Belgium. The process involves the smelting of the mixed materials to produce a lead slag and a copper-lead matte. The slag is tapped from the furnace for treatment in the existing blast furnace while the matte is converted in the Isasmelt reactor to produce blister copper.

### Treatment of zinc residues

Pilot testwork through the 1980s and 1990s on a variety of zinc-containing materials including slags, dusts and leach residues have confirmed the technical feasibility of fuming

the material to collect most of the zinc and lead in a dust product while producing a slag product suitable for sale or disposal. However the economics of the operations have not proved to be attractive enough as the Isasmelt furnace does not have the advantage of the counter-current heat exchange which is a feature of, for example, a Waelz kiln. However Isasmelt furnaces are capable of producing much lower lead and zinc contents in the final waste product as well as high recoveries of the valuable silver, germanium and indium in the feed, and studies have indicated that this would be the preferred technology where these factors are predominant.

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## Full steam ahead for coal confab...\*

The Fossil Fuel Foundation in association with the South African Institute of Mining and Metallurgy, the Geological Society of South Africa, the Coal Processing Society of South Africa, and the South African Coal Ash Association, are organizing a two-day conference (*3rd Indaba '97 on Coal Science and Technology*) to be held at Mintek on 18-19 November, 1997.

The conference aims to bring to the attention of professionals and practitioners in the energy and fossil fuels industries, to government and to the public at large, up-to-date developments, trends research and innovation in specific sector industries that will impact on their productivity, and on the environment. It will also deal with

research and innovation in the coal chain to highlight the interdependencies that exist between the resource, its upgrading potential, its utilization, and its waste products, as well as the disposal of secondary or waste products.

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