Sohn International Symposium on Advanced Processing of Metals and Materials Edited by Florian Kongoli
TMS (The Minerals, Metals & Materials Society), 2006

ISASMELT™ – 6,000,000 TPA AND RISING

P. S. Arthur, Xstrata Technology

Keywords: submerged lance smelting, commercialization, rampup

Xstrata Technology, 87 Wickham Terrace, Brisbane, 4000, Australia
isasmelt@xstrata.com.au

Abstract

The ISASMELT™ process is a submerged lance smelting technology operating in smelters in Australia, the USA, Belgium, India, Germany, Malaysia and China. Further plants are under construction in Peru and Zambia.

Following the invention of the Sirosmelt lance technology Mount Isa Mines recognised the commercial potential in the novel top blown bath smelting process and embarked on a development program that has lasted more than 25 years. After successful operation of pilot plants and demonstration plants producing copper and lead, Mount Isa Mines decided to license the technology to external companies. Since the purchase of Mount Isa Mines by Xstrata in 2003, Xstrata Technology has assumed responsibility for transferring the technology to ISASMELT™ licensees.

In the 15 years since the first commercial furnaces started operation plants have been constructed (or are under construction) with a combined annual smelting capacity of more than six million tonnes of concentrates or secondary raw materials. Process development continues on the commercial scale plants at Mount Isa and elsewhere. Many of the improvements implemented by plant operators have been passed on to, and adopted by, other licensees. Exchange of ideas and technical improvements occurs through ad hoc visits to fellow licensee sites and through regular licensee workshops arranged by Xstrata Technology.

This paper updates the reader on the status of various ISASMELT™ plants either operating or under construction. It highlights the important role that the technology provider's operational experience plays in ensuring that new smelting plants ramp up quickly to nameplate capacity.

Introduction

The development of the Sirosmelt lance at the Commonwealth Scientific and Industrial Research Organisation (CSIRO) opened up new opportunities for the non-ferrous pyrometallurgy industry. Prior to its introduction the injection of gases into liquid slag or matte was achieved predominantly through tuyeres, with inherent design complications and refractory problems. Mount Isa Mines Limited were introduced to the submerged lance technology during the 1970's and recognised its potential for improving the efficiency of operations at its lead and copper smelters. The lance enabled the use of stationary furnaces with simple design but very high reaction rates. Following initial joint collaboration with CSIRO the ISASMELT™ process was developed to commercial success at the Mount Isa smelting complex. The history has been summarised elsewhere [1]. Pilot plants and demonstration plants were operated prior to construction of the first commercial plants for lead and copper at Mount Isa in 1991 and 1992 respectively.

Commercial Operations

Development of the ISASMELT™ process has centred on smelting of lead and copper concentrates and secondary materials containing these two elements. The first demonstration scale lead ISASMELT™ furnace was commissioned in Mount Isa, Australia, in 1983. This was followed in 1987 with a demonstration scale copper ISASMELT™. Table I shows the commercial plants have been constructed to date or are under construction.

Table I – ISASMELT™ plants

Startup Date	Plant Owner	Plant Location	Plant Type	Plant Capacity
1991	Mount Isa Mines Limited	Mount Isa, Australia	Lead Smelter	60,000 tpa lead metal
1991	Britannia Refined Metals	Northfleet, UK	Secondary Lead Smelter	30,000 tpa lead metal
1992	Phelps Dodge Miami	Arizona, USA	Copper Smelter	700,000 tpa copper concentrate
1992	Mount Isa Mines Limited	Mount Isa, Australia	Copper Smelter	1,000,000 tpa copper concentrate
1996	Sterlite Industries (India) Ltd	Tuticorin, India	Copper Smelter	450,000 tpa copper concentrate
1997	Umicore Precious Metals	Hoboken, Belgium	Secondary Copper Smelter	300,000 tpa feed
2000	Metal Reclamation Industries	Pulau Indah, Malaysia	Secondary Lead Smelter	40,000 tpa lead metal
2002	Hüttenwerke Kayser	Lünen, Germany	Secondary Copper Smelter	150,000 tpa feed
2002	Yunnan Copper	Kunming, China	Copper Smelter	800,000 tpa copper concentrate
2005	Vedanta	Tuticorin, India	Copper Smelter	1,300,000 tpa copper concentrate
2005	Yunnan Metallurgical Group	Qujing, China	Lead Smelter	160,000 tpa lead concentrate
2006 (under construction)	Southern Peru Copper	Ilo, Peru	Copper Smelter	1,200,000 tpa copper concentrate
2006 (under construction)	Mopani Copper Mines	Mufulira, Zambia	Copper Smelter	850,000 tpa copper concentrate

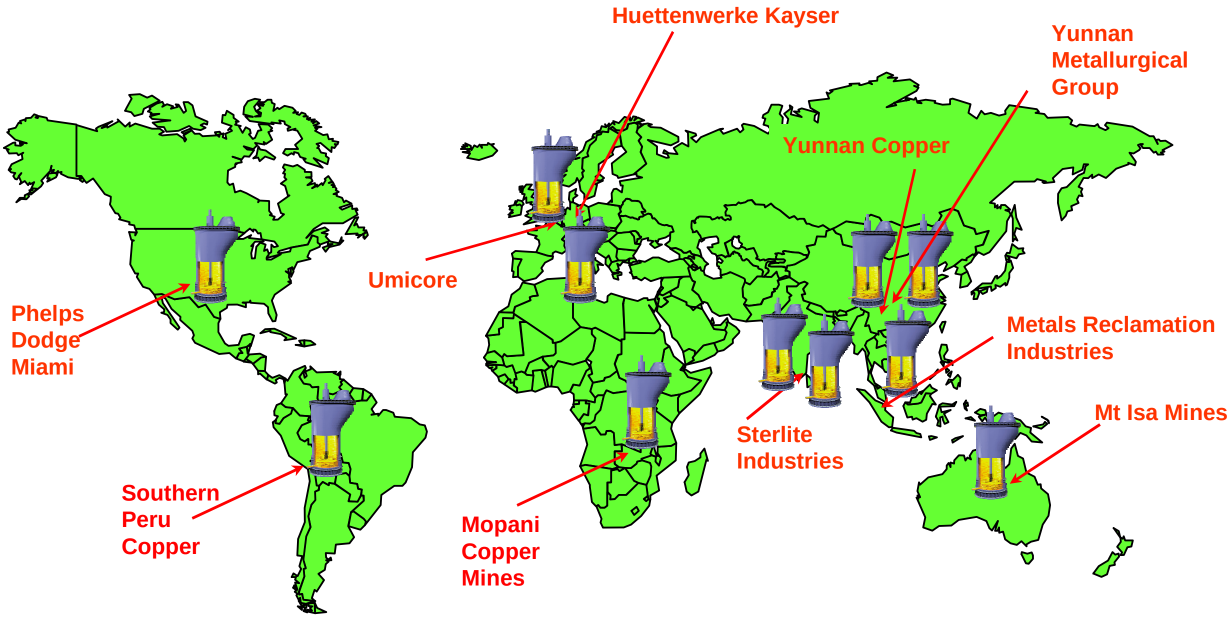

Figure 1 – ISASMELT™ Plant Locations

Mount Isa Mines Copper ISASMELT™

The Copper ISASMELT™ Plant at Mount Isa, initially rated at about 700,000 tonnes of concentrate per annum, was commissioned in 1992, based on the design of a demonstration scale plant that operated in Mount Isa from 1987 to 1991. The Copper ISASMELT™ plant operated in parallel with one reverberatory furnace until 1998. In 1996 Mount Isa Mines decided to upgrade the copper smelter installing an additional oxygen plant to increase the capacity of the ISASMELT™ furnace. The upgrade has been described in another paper [2]. Since completion of the upgrade in 1998 all the copper concentrate smelted at Mount Isa has been smelted in the ISASMELT™ furnace. The furnace now treats more than 1,000,000 tonnes of copper bearing feed per year. Figure 2 shows the tonnes of copper bearing feed charged to the furnace each year since it was commissioned. Figure 3 shows the Mount Isa Copper ISASMELT™ flowsheet.

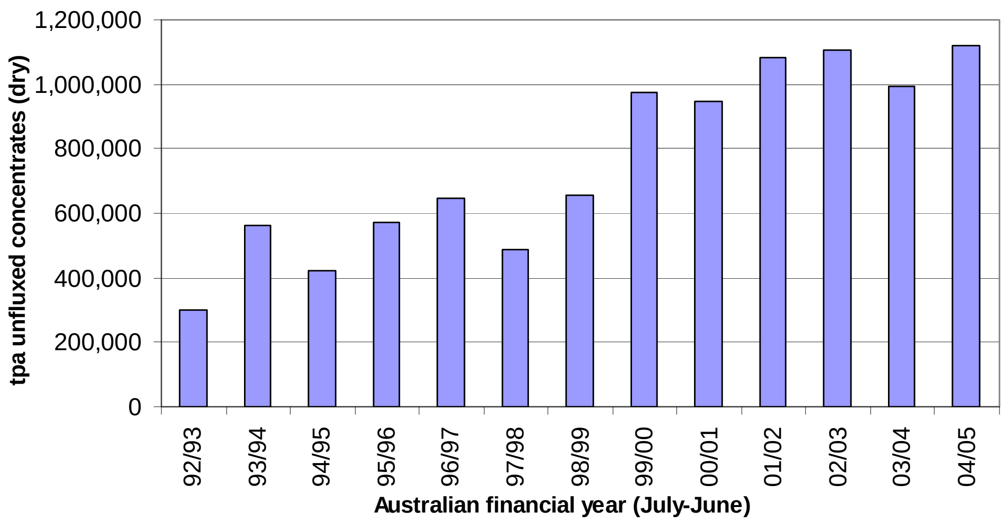

Figure 2 - Mount Isa copper ISASMELT™ annual feedrates

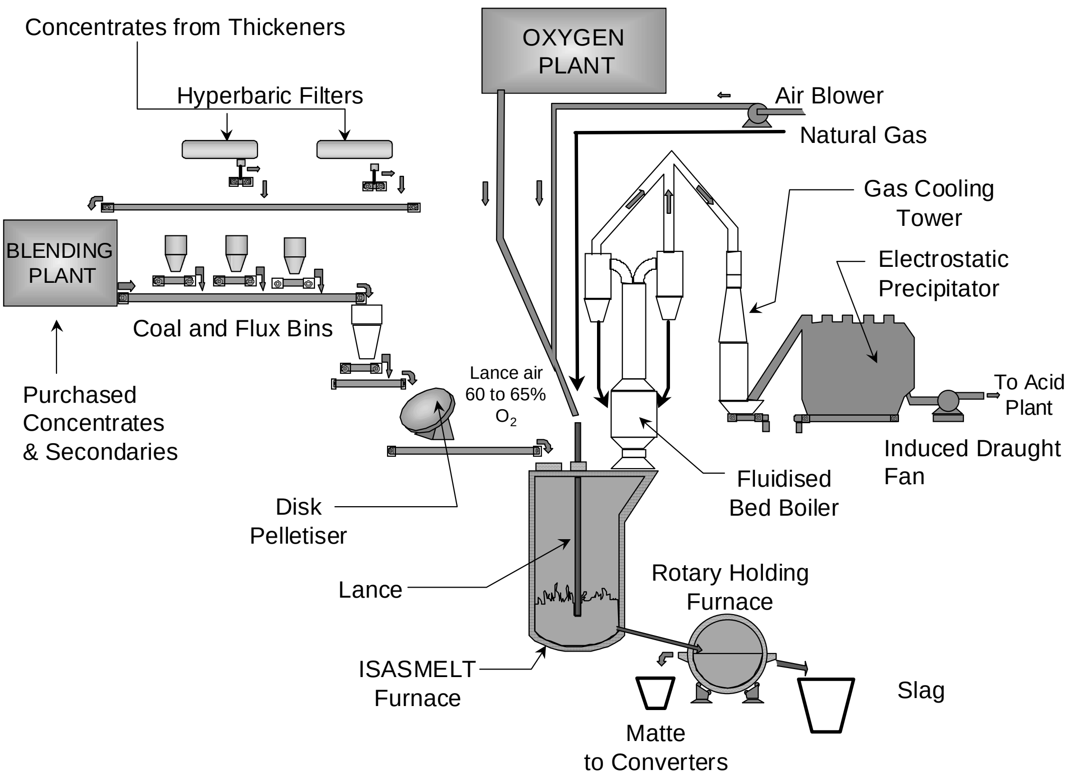

Figure 3 - Mount Isa copper ISASMELT™ flowsheet

Mount Isa Mines concentrate is blended with concentrate sourced from other mines 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 8-12 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 taphole, 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.

During 2006 Mount Isa Mines will commission a second rotary holding furnace that will operate in parallel to the existing rotary holding furnace. The intention is to use the additional residence time achieved with the second rotary holding furnace to produce a discard slag from both of the rotary holding furnaces. This design will be similar to that used at the Vedanta ISASMELT™ plant in India since mid 2005 (see below).

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 achieved on the Copper ISASMELT™ furnace at Mount Isa. Figure 4 shows the campaign lives achieved since the plant was constructed. As of March 2006 campaign 9 is in its 31st month. Improvements in process control achieved over more than 13 years of operation at Mount Isa have resulted in a highly advanced control system that ensures that refractory wear is minimized. This sort of development can only be achieved over many years in an operations environment, and is one of the advantages that Xstrata has when providing the technology to external companies.

Phelps Dodge Miami Copper Smelter

Cyprus Miami Mining Corporation (now Phelps Dodge Miami) selected ISASMELT™ for their modernisation in 1990. The decision was based on their evaluation of the operation of the demonstration copper ISASMELT™ plant at Mount Isa [3]. The Miami plant, located in Claypool Arizona, was designed and constructed at the same time as the copper ISASMELT™ plant at Mount Isa. It was commissioned in June 1992, two months before the Mount Isa plant. Cyprus chose ISASMELT™ after comparing it with Contop, Inco, Mitsubishi, Noranda, Outokumpu and Teniente technologies. Although ISASMELT™ was not yet proven as a commercially viable technology, Cyprus decided to risk its implementation based on the fact that it would reduce their operating costs significantly while requiring limited capital expenditure. An electric furnace, previously used for smelting copper concentrates, was modified to act as a settling furnace for the copper matte and slag, and for reduction of Peirce Smith converter slag. The ISASMELT™ furnace was designed to run with natural gas as fuel through the lance.

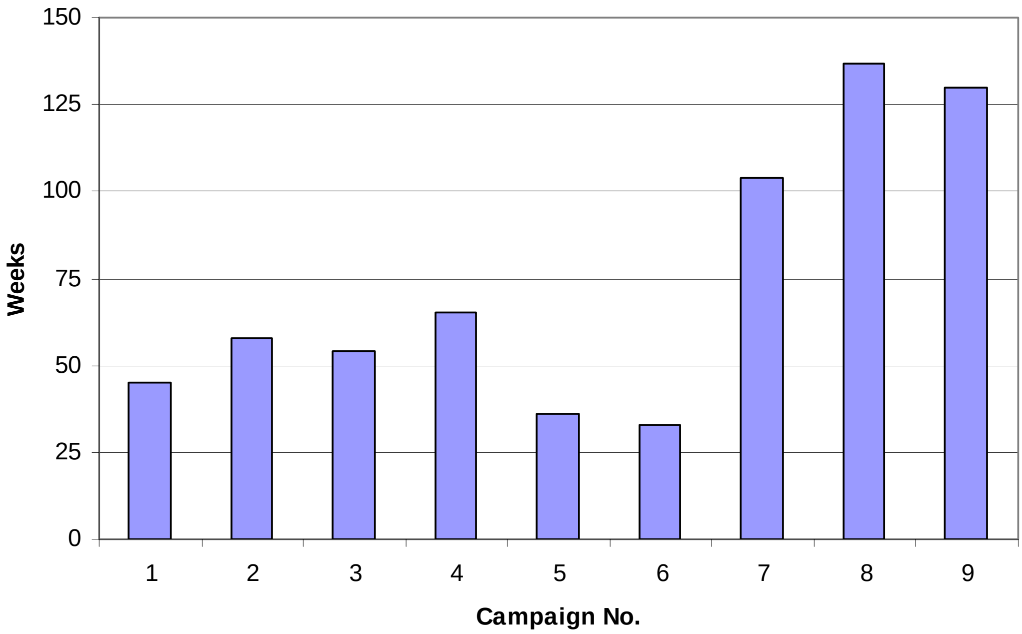

Figure 4 - Mount Isa copper ISASMELT™ campaign lives

Concentrates are brought to the plant by rail or truck and stored in a covered blending area. After blending, the concentrates are transported to day bins. The concentrates and fluxes are metered out of day bins where they are weighed and then mixed in a twin shaft paddle mixer prior to being transported to the ISASMELT™ furnace by conveyer. Natural gas is injected through the lance for fine control of bath temperature. Oxygen and air are also injected through the lance. Matte and slag are tapped from the ISASMELT™ furnace through one of two water-cooled tapholes into the electric settling furnace, where they separate by gravity settling. The slag is tapped intermittently from the settling furnace and granulated for disposal. Matte is tapped into ladles and transferred to the converters.

Offgases from the ISASMELT™ furnace pass into a vertical radiation channel and flow into a convection section waste heat boiler for cooling prior to passing into an electrostatic precipitator for cleaning. The cleaned gases pass to the wet gas cleaning and sulfuric acid plants.

A number of problems were encountered during the first few years of operation, especially with regard to the offtake design, which led to accretions and corrosion. These contributed to very low availabilities in the early years. After about five years a satisfactory solution to these problems was established. Such problems are typical of those encountered when commercializing a smelting technology for the first time. The Mount Isa plant, which started operation at about the same time, had its own set of problems in the first years of operation. By sharing their experiences over this time both companies were able to help each other through this difficult time. This co-operation is one advantage of working with an operating company when adopting a new smelting technology. Information exchange continues 13 years after the furnaces were started up with regular contact between Mount Isa operations and Miami operations personnel.

Vedanta Copper ISASMELT™

Sterlite Industries, now a subsidiary of Vedanta, commissioned its first ISASMELT™ furnace in 1996 at a greenfield smelter located at Tuticorin in Tamil Nadu, India. It was designed to produce 60,000 tonnes per year of copper in matte. Production increased each year through improvements to the surrounding plant and equipment, and provision of additional oxygen, until the annual capacity reached more than 150,000 tonnes of copper. At that stage Sterlite realized that there were limits to how much more concentrate the plant could treat. They decided to construct a larger ISASMELT™ furnace to treat up to 1.3 million tonnes per year of concentrate. The new plant was built adjacent to the original one and was commissioned in May 2005.

The copper smelter includes Peirce-Smith converters, anode furnaces, anode casting facilities, a 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 to day bins. Blended concentrate, fluxes and petroleum coke are metered from the day bins and conveyed to the ISASMELT™ building by enclosed conveyor. This conveyor delivers the mix directly to the final feed conveyor above the ISASMELT™ furnace, where it falls by gravity through the feed chute. Fuel oil is injected through the lance for fine control of bath temperature. Oxygen and air are also injected through the lance. Matte and slag are tapped from the ISASMELT™ furnace through one of two water-cooled tapholes and flow down water cooled launders into one of two rotary holding furnaces, where they separate by gravity settling. The slag is skimmed intermittently from the rotary holding furnace and granulated for disposal. Matte is poured into ladles and transferred to the converters.

Offgases from the ISASMELT™ furnace pass into a waste heat boiler for cooling prior to passing into an electrostatic precipitator for cleaning. The cleaned gases pass to the wet gas cleaning and sulfuric acid plants.

In the final quarter of 2005 Sterlite produced 75,000 tonnes of cathode copper from the Tuticorin plant, the upgraded plant having reached design capacity, measured over a three month period, six months after first feed on[1].

Umicore Precious Metals ISASMELT™

The Umicore Precious Metals smelter at Hoboken, Belgium, uses the ISASMELT™ process to treat a variety of primary and secondary feed materials. The Hoboken site underwent a dramatic modernisation in the late 1990's allowing them to remain competitive whilst operating under strict new environmental regulations. A key feature of the modernisation was installation of the ISASMELT™ furnace. The furnace replaced a large number of unit processes, allowing the company to reduce operating costs significantly while also reducing emissions to the environment. The new smelter has been operating since the end of 1997 and continues to play an important role in Umicore's recycling business.

Hüttenwerke Kayser Copper ISASMELT™

Hüttenwerke Kayser, a subsidiary of Norddeutsche Affinerie, operate an ISASMELT™ plant as part of the Kayser Recycling System (KRS) that treats secondary copper materials within their smelting and refining operation at Lünen near Dortmund in Germany. The ISASMELT™ furnace replaced two blast furnaces and three Peirce Smith converters used for smelting scrap copper.

The ISASMELT™ furnace installation has allowed the company to significantly reduce operating costs while improving the environmental performance of the smelter. Improved environmental performance was a critical feature of the modernization project, given that the smelter is located in a small city in a semi-rural part of Germany as shown in Figure 5.

Figure 5 – Hüttenwerke Kayser Plant

[1] Metals Insider - 20 January 2006

Metal Reclamation Industries Lead ISASMELT™

In 2000 Metal Reclamation Industries (MRI) commissioned a new secondary lead plant at Pulau Indah in Malaysia using an ISASMELT™ furnace as the core technology. The plant design was based on the secondary lead ISASMELT™ that was commissioned at Xstrata Zinc's lead refinery at Northfleet, England, in 1991. The MRI plant treats primarily lead acid battery scrap, producing up to 40,000 tpa of refined lead.

Yunnan Copper Co. Copper ISASMELT™

Yunnan Copper Co. (YCC) commissioned their copper ISASMELT™ plant in May 2002 as part of a copper smelter modernisation project [4,5]. The YCC Copper ISASMELT™ furnace was originally designed to treat 600,000 tonnes of concentrate per year. It is now rated at 800,000 tonnes per year. The furnace replaced a sinter plant and two electric furnaces. One of the existing electric furnaces was modified to act as a settling furnace for the matte and slag from the ISASMELT™ furnace. Xstrata arranged for YCC to have frequent dialogue with Phelps Dodge Miami during the construction and commissioning phases of the project, so that they could learn from the experience made with electric settling furnace operation in Arizona. The process flowsheet for the plant is shown in Figure 6.

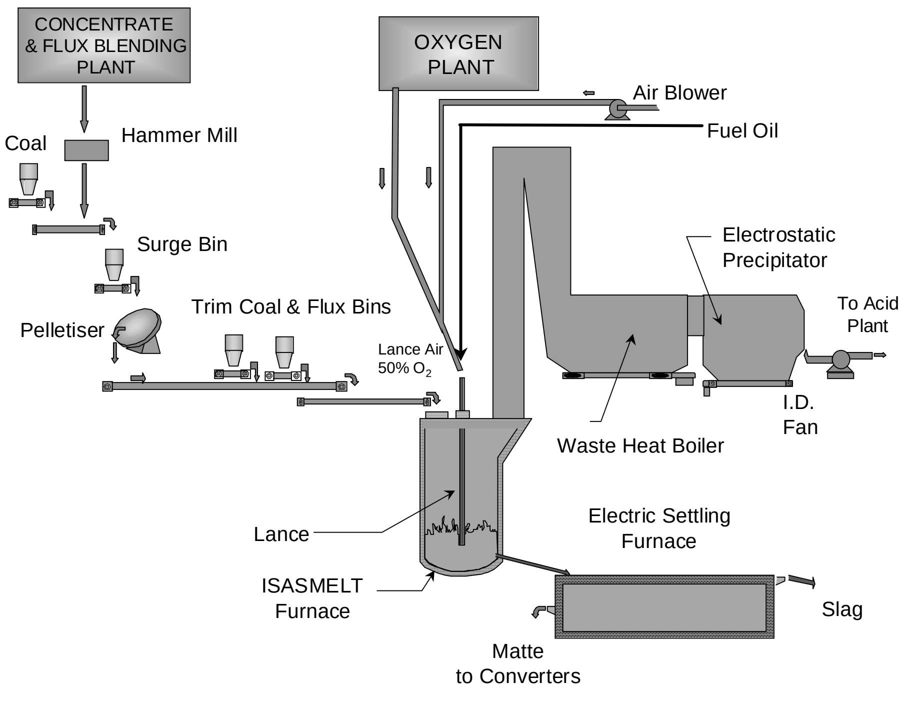

Figure 6 - YCC copper ISASMELT™ flowsheet

The smelter treats a wide range of different concentrates, many of which are brought by road or rail from mines within Yunnan province. The concentrates are blended with flux in a blending plant. The majority of the coal required for the process is sourced locally. The feed mix is pelletised and a 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 are tapped intermittently from the ISASMELT™ furnace through one of two tapholes into the 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 also conveyed to the electric furnace.

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. A requirement of the project was that the existing electric furnace be used as a settling furnace for matte and slag, so it was necessary to construct the ISASMELT™ furnace immediately next to it. 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 7.

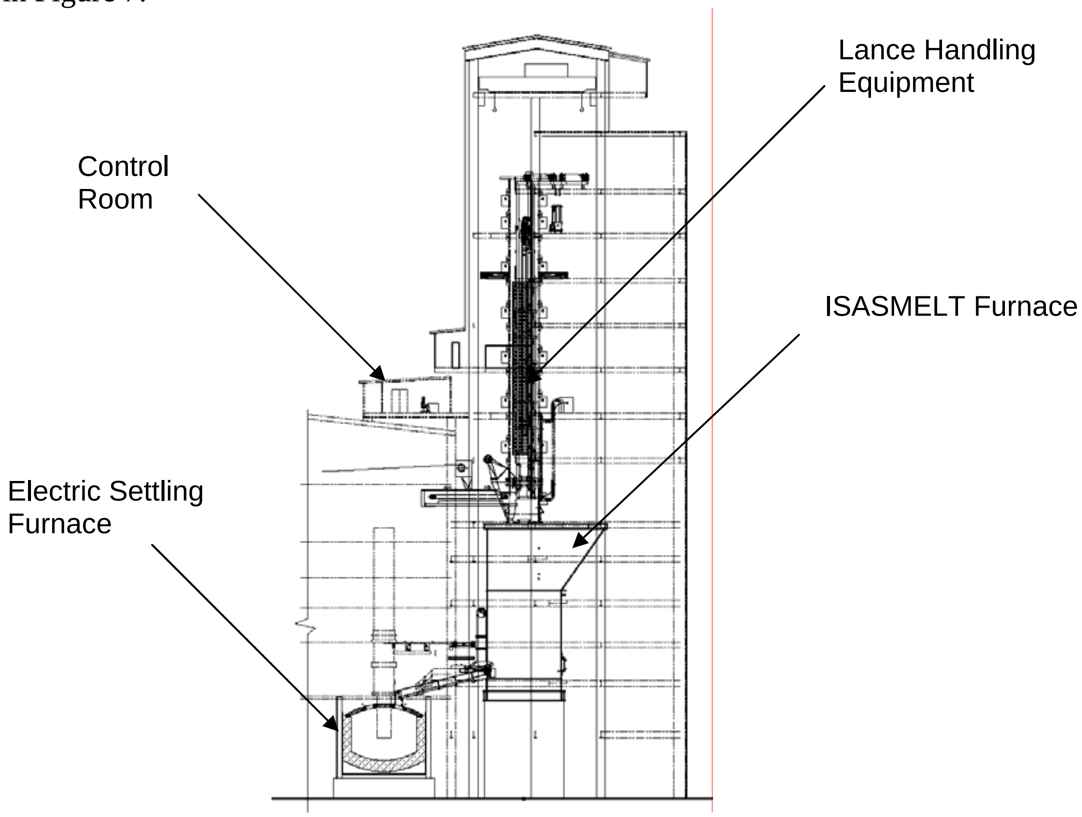

Figure 7 - YCC ISASMELT™ building elevation

A separate paper at this symposium summarises the results of the modernization project and highlights some of the initiatives taken by YCC to ensure that the project was a success [5]. One of these was the extended training program undertaken by YCC personnel who were trained at Mount Isa over a period of 7 months. By spending an extended time in the Mount Isa smelter, YCC employees were able to understand fully the many facets of ISASMELT™ operation. They were able to witness first hand maintenance and operating practices and also to personally operate the furnace. At the end of the training period YCC personnel were running the Mount Isa furnace. This intensive training program along with further training carried out in China, and the attention to detail shown by YCC management, helped ensure that the plant reached design capacity (averaged over a 7-day period) within two months of the first concentrate being fed to the furnace. This was the first time that such a novel smelting technology had been introduced to China for the first time and ramped up to full capacity so quickly.

The ISASMELT™ furnace installation has significantly improved the environmental performance of the smelter and reduced the operating costs, with sulfur capture increasing from 87 to 95% and energy consumption decreasing by 33% [5].

Table II – Key performance indicators before and after modernization

	Concentrate Treatment Capacity (tpa)	Energy consumption (t 'standard' coal /t blister copper)	Total smelter sulfur capture (%)	SO_2 emissions (tpa)
2001 (Electric furnace process)	470,000	0.77	87	107,90
2005 (ISASMELT™ process)	800,000	0.51	95	6,326

The first refractory campaign at YCC lasted for two years and 4 months, from May 2002 to September 2004, demonstrating similar refractory performance to that achieved at Mount Isa. At the end of that period, although the ISASMELT™ furnace could have run longer, it was necessary to rebuild the electric settling furnace, which had only received a partial reline prior to the ISASMELT™ furnace being commissioned. The furnace is now one year into the second campaign.

Mopani Copper Mines Copper ISASMELT™

Mopani Copper Mines Plc (MCM) are planning to commission a new copper ISASMELT™ furnace at the Mufulira copper smelter in Zambia during 2006. MCM decided to install an ISASMELT™ furnace after deciding that it was not feasible to rebuild their existing electric furnace. They selected ISASMELT™ after comparing it with alternative technologies including flash smelting, Mitsubishi process, Teniente converters and Ausmelt TSL [6].

A flowsheet for the new ISASMELT™ plant appears in Figure 8. In addition to the ISASMELT™ furnace, the copper smelter modernization will include a new feed preparation system, electric settling furnace, wet gas cleaning plant, acid plant and oxygen plant, as well as improvements to the converter aisle and anode plant.

The new ISASMELT™ furnace is designed to treat 850,000 tpa of concentrates. The concentrates will be sourced from Mopani's local mines. They are brought by truck to the smelter where they are stockpiled in a blending shed. The blended concentrates will be conveyed to day bins in the new feed preparation system. Concentrates, fluxes, coal and reverts will be metered out of the day bins, mixed in a twin shaft paddle mixer and conveyed to the ISASMELT™ building by belt conveyor. This conveyor will deliver the mix to the final feed conveyor above the ISASMELT™ furnace, which will deliver it to the feed chute. Fuel oil injected through the lance will be used for fine control of bath temperature. Oxygen and air will also be injected through the lance.

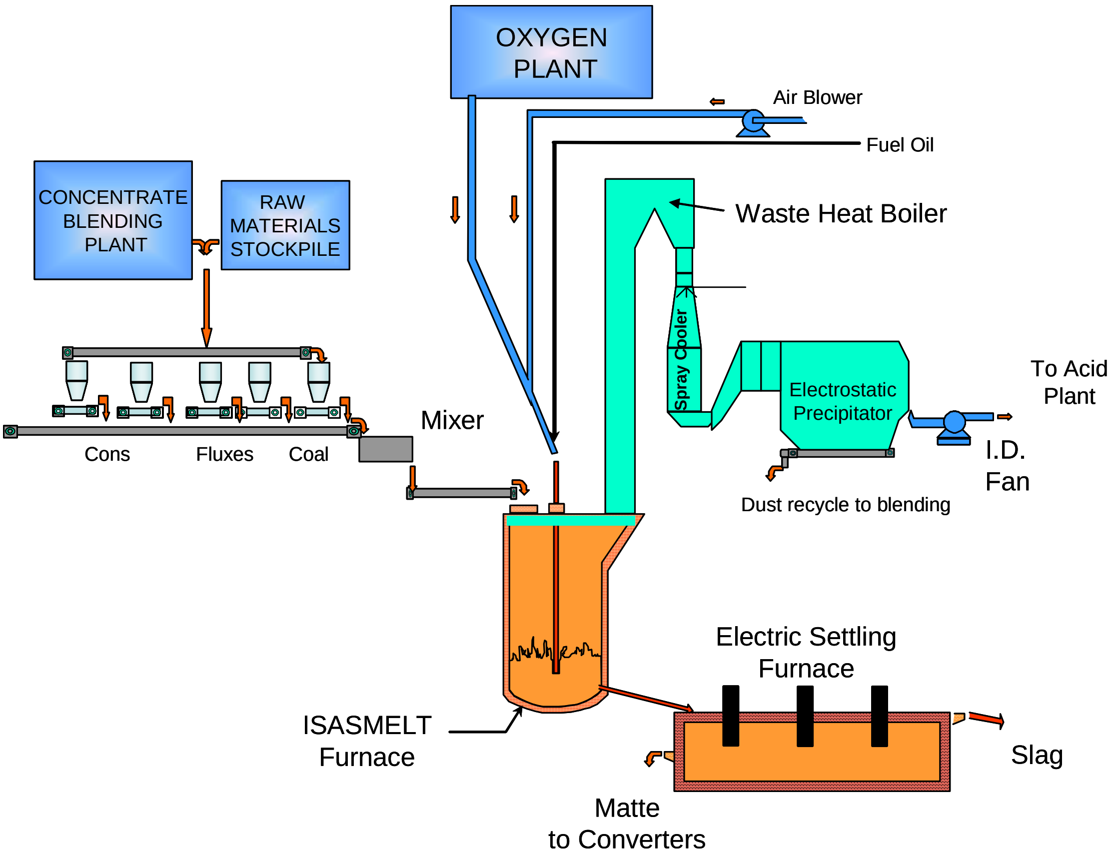

Figure 8 - MCM ISASMELT™ process flowsheet

Matte and slag will be tapped from the ISASMELT™ furnace through a water-cooled taphole and flow down a water cooled launder into the electric settling furnace, where they will separate by gravity settling. The slag will be tapped intermittently from the settling furnace into a granulation system. Matte will be tapped into ladles and transferred by aisle crane to the converters.

A radiation channel, evaporative cooler and electrostatic precipitator will be used to cool and clean the gas before it passes to the sulfuric acid plant.

MCM personnel were trained at Mount Isa Mines prior to startup of their plant. A similar training program was devised as for YCC, to ensure that the MCM operators were able to run the plant by the time they returned to Zambia.

Southern Peru Copper Corporation Copper ISASMELT™

Southern Peru Copper Corporation (SPCC) will commission a new ISASMELT™ furnace at their Ilo copper smelter in Peru in the second half of 2006. The SPCC modernization project was instigated based on a requirement to meet new Peruvian environmental regulations by January 2007. Under these new regulations, SPCC must capture at least 91.7% of all sulfur from the smelting process. They therefore investigated a wide range of alternative technologies including

Outokumpu flash smelting, Teniente Converter, Noranda, Mitsubishi, Ausmelt TSL and ISASMELT™ for replacing their existing reverberatory furnaces. Finally they decided that the ISASMELT™ process could meet all of their requirements. The fact that the capital cost would be significantly less than some of the more established technologies was a critical feature in favour of ISASMELT™ [7,8].

The ISASMELT™ furnace will treat 1,200,000 tpa of concentrate and will replace two reverberatory furnaces and a Teniente converter. In addition to the ISASMELT™ furnace, the copper smelter modernization includes upgrading existing Peirce-Smith converters and their offgas systems, installing two rotary holding furnaces, two anode furnaces, an anode casting wheel, a new sulfuric acid plant and a new oxygen plant.

Concentrates are sourced from SPCC's two mines at Toquepala and Cuajone and brought by rail to the smelter where they are stockpiled in a blending area. The blended concentrates will be conveyed to a new feed preparation system installed as part of the modernization project. Concentrates, fluxes, coal and reverts will be stored in day bins. Blended concentrate, fluxes and coal will be mixed in a twin shaft paddle mixer and conveyed to the ISASMELT™ building by belt conveyor. This conveyor will deliver the mix to the final feed conveyor above the ISASMELT™ furnace, which will deliver it to the feed chute. Fuel oil injected through the lance will be used for fine control of bath temperature. Oxygen and air will also be injected through the lance. Matte and slag will be tapped from the ISASMELT™ furnace through one of two water-cooled tapholes and flow down water cooled launders into one of two rotary holding furnaces, where they will separate by gravity settling. The slag will be skimmed intermittently from the rotary holding furnaces into ladles which will be transported to a slag dump by ladle transporter. Matte will be poured into ladles and transferred by aisle crane to the converters.

A waste heat boiler and electrostatic precipitator will be used to cool and clean the gas before it passes to the sulfuric acid plant. A plant diagram for the ISASMELT™ plant appears in Figure 9.

SPCC also elected to send their operations personnel to Mount Isa for an intensive training program. This program was supplemented by workshops arranged by Xstrata Technology on site in Peru, and at the Phelps Dodge Miami smelter in Arizona.

YMG Lead ISASMELT™

Xstrata Technology designed a lead ISASMELT™ furnace for Yunnan Metallurgical Group's (YMG) new lead smelter at Qujing, China [9]. The lead ISASMELT™ furnace is designed to smelt 160,000 tpa of lead concentrate to produce approximately half the contained lead directly as ISASMELT™ bullion and the other half as a high lead slag. The high lead slag is cast into blocks and fed to a YMG-designed blast furnace for reduction. This process, a joint development of Xstrata and YMG, combines the benefits of the ISASMELT™ furnace for smelting with the benefits of the blast furnace for reduction. The ISASMELT™ furnace replaces the sinter plant of a traditional lead smelter. The ISASMELT™ furnace has an advantage over the sinter plant in that it can convert a fraction of the lead in feed directly to lead metal, thus decreasing the slag reduction duty of the blast furnace. It also produces a concentrated offgas stream, allowing sulfuric acid to be produced in a conventional acid plant. In the YMG plant over 40% of the lead in feed reports directly to lead metal in the smelting furnace. The ISASMELT™ furnace also has the advantage that it is much smaller and simpler than a sinter plant and can be readily enclosed to eliminate emissions. The slag product is low in sulfur compared with sinter and thus the blast furnace offgas contains a lower concentration of sulfur dioxide than in the case of a blast furnace being fed with sinter.

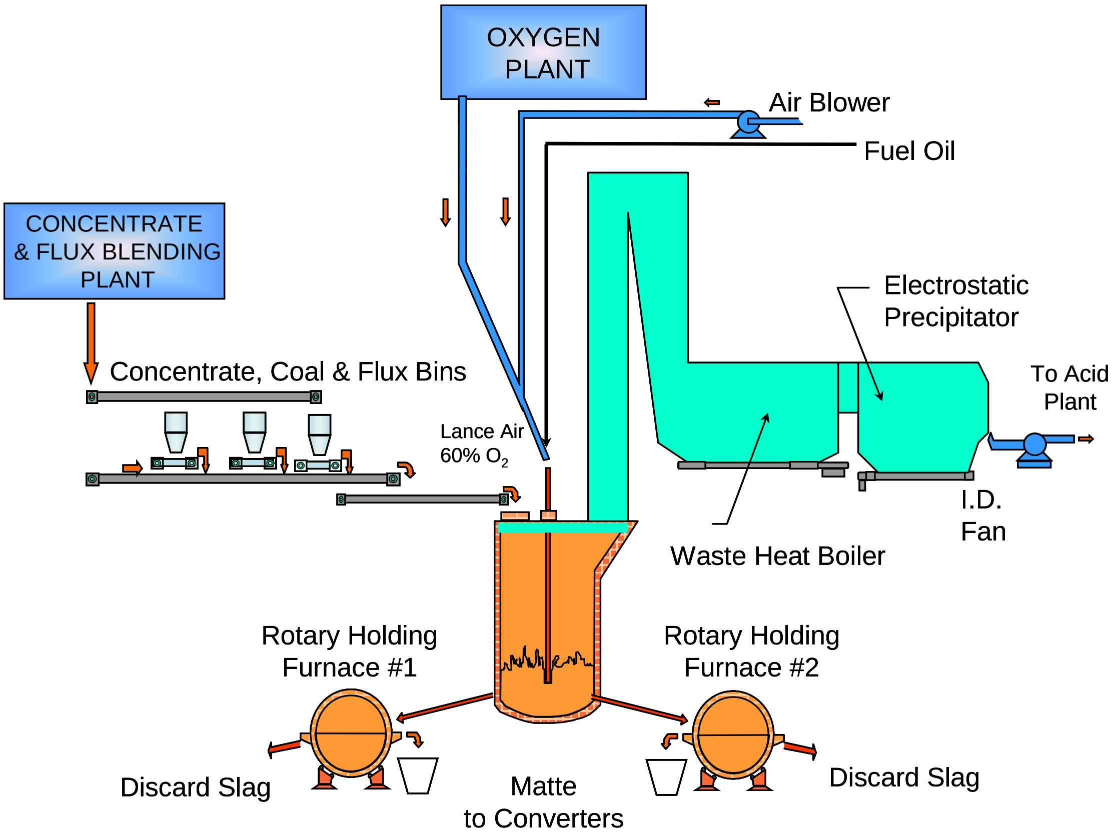

Figure 9 - SPCC ISASMELT™ process flowsheet

Rampup Times

The rampup of both the YCC and Vedanta ISASMELT™ plants, in 2002 and 2005 respectively, were impressive when compared with the first commercial ISASMELT™ plants and general historical precedents. A number of studies have been undertaken comparing at the startup the performance of process plants and these have highlighted factors that play an important role in determining how quickly a new plant ramps up to full capacity. In one study by Charles River and Associates (CRA) [10], it was noted that about 50% of smelters showed an average annual production of less than 70% of the design capacity in the first through third year of production.

They concluded that a major cause of startup problems was the improper scale-up of the commercial plant from the laboratory and pilot plant stages. The extent of laboratory and pilot plant work carried out at Mount Isa contributed to the fact that scale up was not a major problem for the ISASMELT™ process. The CRA study concluded that major causes of delays in pyrometallurgical operations were refractory failures and difficulties in handling hot gases. These problems were certainly encountered during the development of ISASMELT. The offgas system caused major problems at Phelps Dodge Miami for about the first 5 years, resulting in major redesign and modifications. It also was a major cause of downtime at Mount Isa for the first 5-6 years of operation of the commercial plant. About 5-6 years of development were also required on the commercial scale at Mount Isa until satisfactory refractory performance was achieved. Now that these problems have been overcome, however, it is possible to design the complete furnace and offgas system in such a way that ramp up of new ISASMELT™ plants occurs very quickly.

A paper by Terry McNulty [11] analysed case histories for 41 various process plants, including six copper and nickel smelters. He divided the projects into four series based on the percentage of design capacity they had achieved six, 12, 24 and 36 months after startup, as shown in Figure 10.

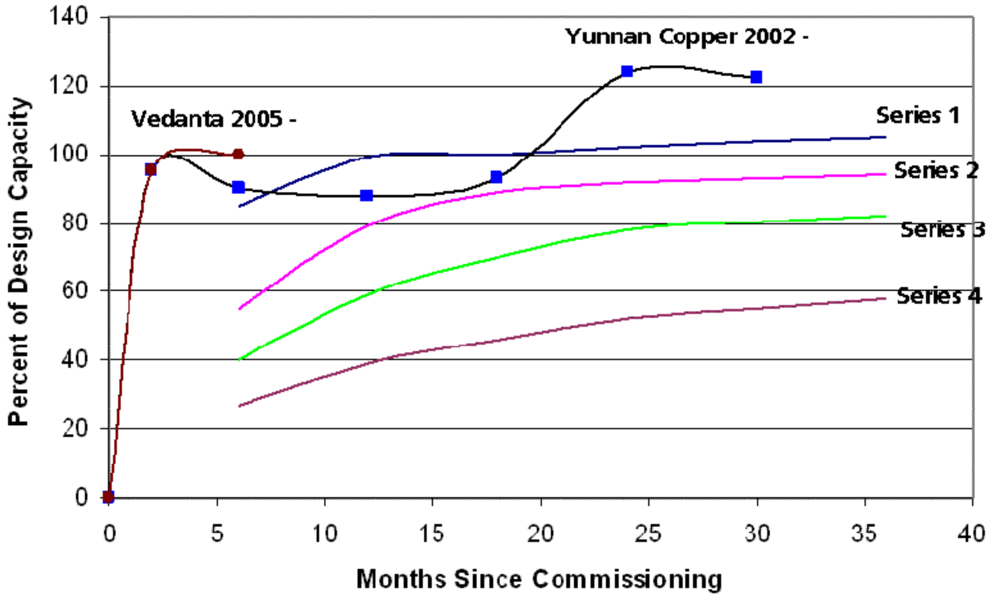

Figure 10 – Rate of Achievement of Annualized Design (after McNulty)

The most successful plants, those in series 1, achieved 100% of design capacity within 12 months of startup. Series 4 plants achieved on average less than 40% of design capacity after 36 months. According to McNulty's system, the Mount Isa and Phelps Dodge Miami copper smelters could be classed as series 2 plants. Series 2 plants have at least one and sometimes two or three of the following characteristics:

- If the process was licensed technology, it was one of the first licenses (this was the case)
- Equipment specified for a unit operation was a prototype in terms of size or application (both furnaces were the first of their size)
- Pilot scale testwork was incomplete (this was not the case)
- Process conditions in the key unit operation were severe eg high temperature (this was the case)
- The innovative sections of the plant may have worked well but other operations had not been properly engineered (offgas systems were the main problem, but it could be argued that these were also innovative)

On the McNulty scale, the YCC and Vedanta ISASMELT™ plants could be classed as series 1 plants. These plants are generally characterised by:

- reliance on a mature technology (this was the case)
- equipment similar in size and duty to that used in earlier successful projects (this was the case)
- if the technology was licensed there were many prior licensees (this was the case)

Growth and Acceptance

The ISASMELT™ process is gradually gaining wider acceptance throughout the non-ferrous industry worldwide. It is now demonstrated as a proven process for implementing in either brown field or green field smelters. Although every new smelter or plant modernization will have some teething problems, it appears that the fundamental simplicity of the ISASMELT™ concept, coupled with Mount Isa Mines' many years of operating experience, and Xstrata's technology transfer process, allows the process to be installed for a relatively low capital cost and ramp up to full capacity quickly. These features make the process very attractive to many smelter operators. Figure 11 shows how the feed rate has increased over the years since the first demonstration plant was installed at Mount Isa in 1987. With the commissioning of the two new smelters in Zambia and Peru during 2006 the cumulative feed rate to all ISASMELT™ furnaces globally will exceed six million tonnes per year.

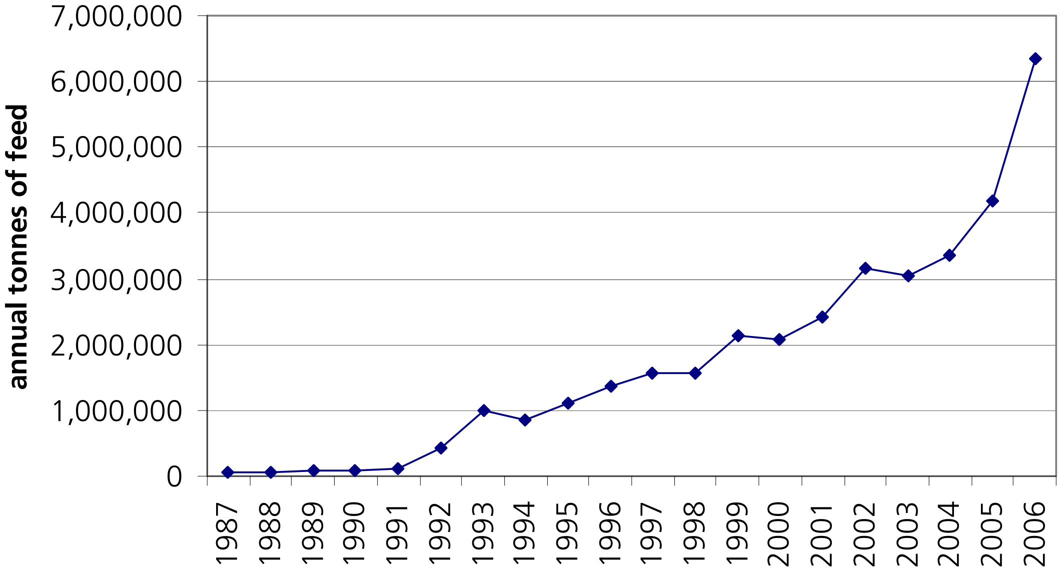

Figure 11 – Global ISASMELT™ plant annual feed rate

Conclusions

Over the last twenty years Mount Isa Mines/Xstrata have developed the ISASMELT™ process from a novel idea to a proven smelting process. In the past 10 years six copper ISASMELT™ plants and two lead ISASMELT™ plants treating in excess of six million tonnes per year of feed materials have been designed and constructed giving it the highest adoption rate of any single base metals smelting process. The ISASMELT™ concept is fundamentally simple but some sophisticated process control systems and operating procedures have been developed over many years of development in the operations environment at Mount Isa. These allow the process to run stably and ensure long campaign lives. Xstrata Technology licenses the process to external companies. Xstrata's technology transfer process, including intensive training programs in the copper smelter at Mount Isa, ensures that new ISASMELT™ plants can ramp up to design capacity within months of charging the first feed to the furnace. The technical and economic success of the existing plants should ensure continuing adoption of the process by smelters around the world.

References

1. P.S. Arthur, S.P. Hunt, "ISASMELT – 25 years of continuous evolution", Floyd International Symposium on Sustainable Developments in Metals Processing, M. Nilmani and W.J. Rankin, Eds., NSC Associates (Australia), 2005

2. J.S. Edwards, "ISASMELT – a 250,000 tpa copper smelting furnace", AusIMM '98 – The Mining Cycle, AusIMM, Melbourne, 1998

3. R.R. Bhappu, K.H. Larson, R.D. Tunis, "Cyprus Miami Mining Corporation smelter modernization Project Summary and Status", EPD Congress 1994, G. Warren, Ed., TMS, Warrendale, 1993

4. Y. Li, P. Arthur, "Yunnan Copper Corporation's new smelter – China's first ISASMELT", Yazawa International Symposium on Metallurgical and Materials Processing, Volume II – High Temperature Metal Production, F. Kongoli, K. Itagaki, C. Yamauchi, H.Y. Sohn, Eds., TMS, Warrendale, 2003

5. Y. Shi, "Yunnan Copper's ISASMELT - Successful Smelter Modernization In China, Sohn International Symposium on Advanced Processing of Metals and Materials, F. Kongoli, Ed., TMS, Warrendale, 2006

6. J. Ross and D. de Vries, "Mufulira smelter upgrade project - 'Industry' Smelting on the Zambian Copperbelt", Pyrometallurgy 05, Capetown, Minerals Engineering International, 2005

7. H. Walqui, C. Noriega, P. Partington and G. Alvear, "SPCC's 1,200,000 TPA copper ISASMELT, Sohn International Symposium on Advanced Processing of Metals and Materials, F. Kongoli, Ed., TMS, Warrendale, 2006

8. Anon, "Passing from a 40-year old technology to one meeting the requirements of the current market - an interview with Mr. Oscar González, Chairman and Managing Director of SPCC", Revista MINERIA, Issue No 316, January 2004

9. B. Errington, P. Arthur, J. Wang and Y. Dong, "The ISA-YMG Lead Smelting Process, Lead & Zinc '05, Vol I, T. Fujisawa Ed., Mining and Materials Processing Institute of Japan, 2005

10. J. Agarwal and F.Katrak, "Economic impact of startup experiences of smelters", Charles River and Associates, A paper based on "Startup of New Mine, Mill/Concentrator, and Processing Plants for Copper, Lead, Zinc and Nickel: Survey and Analysis, World Bank, 1979

11. T.McNulty, "Developing innovative technology", Mining Engineering Magazine, October 1998