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PROVEN TECHNOLOGIES FROM XSTRATA AND THEIR APPLICATIONS FOR COPPER SMELTING AND REFINING IN CHINA

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1.0 INTRODUCTION

The world's non-ferrous industry has achieved significant improvements in efficiency in the last 20 years owing to the advanced technologies such as ISASMELT™ and ISA PROCESS that have been invented and developed at Mount Isa Mines in Australia,. A number of large nonferrous mining operations in the world are still in business today largely because of the commercial benefits that resulted from applying these technologies.

ISASMELT and ISA PROCESS technologies are marketed worldwide by Xstrata Technology, a division of the Xstrata plc group of companies, which was formed upon Xstrata's takeover of MIM Holdings Limited in mid 2003. Xstrata PLC is a diversified international mining company and has operations in Australia, the United Kingdom, Germany, Spain, South Africa, Chile, and Argentina with around 20,000 employees worldwide. Major products are copper, lead, zinc, silver, coal, ferrochrome, and ferrovanadium. In addition to these commodities, an integral part of the group is their independent process technology business – Xstrata Technology. Xstrata group companies have a long record of developing process technologies for in-house use and for sale to external clients.

2.0 ISASMELT™ TECHNOLOGY

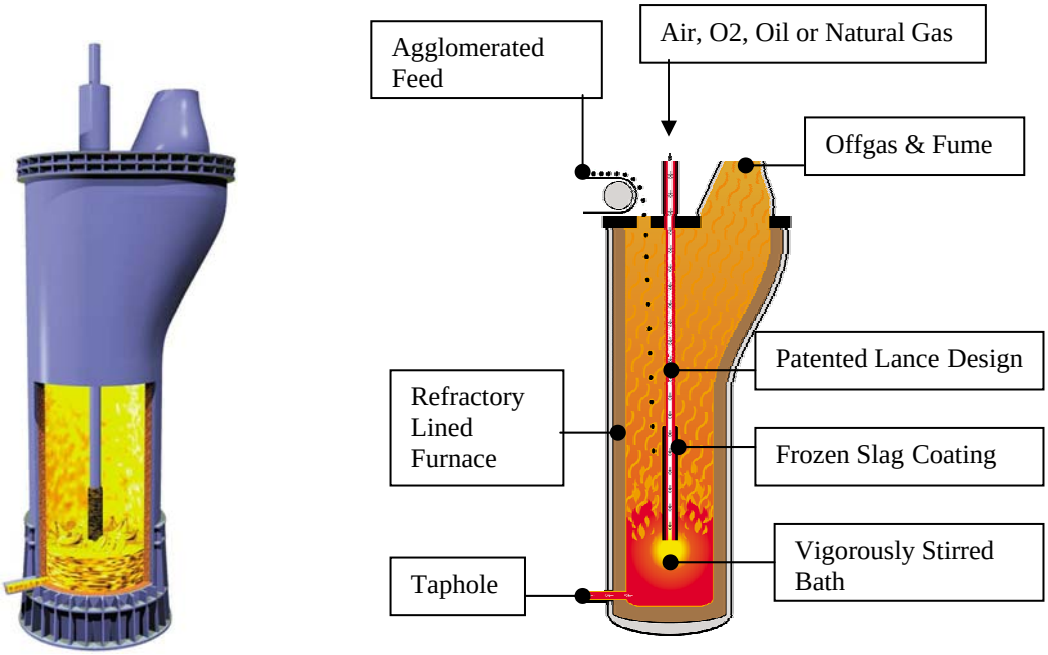
ISASMELT is a modern bath-smelting process for the production of non-ferrous metals. It can be used for many applications including primary and secondary copper and lead smelting, copper / nickel smelting and copper converting.

ISASMELT technology was developed by Mount Isa Mines, and derived from the original SIROSMELT submerged lance technology developed by the Commonwealth Scientific and Industrial Research Organisation (CSIRO). The ISASMELT furnace, as is shown in Figure 1, is a cylindrical vessel that is brick lined with a flat roof. A central lance injects air, oxygen and fuel into a molten bath of slag and matte/metal. The blast of air, oxygen, and fuel down the lance violently stirs the liquid. This stirring ensures very rapid reaction between the raw materials and the oxygen. A frozen layer of slag on the outside of the lance protects it from the aggressive environment in the furnace. The products of the ISASMELT process, matte/metal and slag, are tapped from the bottom of the furnace through a water-cooled taphole. The products then flow into a settling furnace, where the matte/metal separates from the slag.

There are many commercial and technical benefits of applying the ISASMELT technology for nonferrous metal smelting. These include:

Low capital and operating costs

The ISASMELT furnace is simple in construction and small in volume. The off-gas volume is small, minimising the size of the off-gas handling system. These and other features make the capital cost low. The low maintenance costs, long refractory life, high energy efficiency, and low manning levels result in a low total operating cost for the ISASMELT furnace.



a. ISASMELT Furnace b. ISASMELT Major Features

Figure 1: ISASMELT Technology

Low energy consumption

The ISASMELT furnace makes effective use of the chemical energy contained in the concentrate. This reduces the amount of energy for smelting. Operational data from Mount Isa Mines indicate that the installation of the Copper ISASMELT Furnace has reduced the energy consumed directly in smelting concentrate by over 80% compared with the old process using fluid bed roaster and reverberatory furnace.

Flexible in feed and fuel

ISASMELT can be used to smelt a wide range of feed materials including copper and copper-nickel concentrate, secondary copper materials, lead concentrate and secondary lead. ISASMELT furnaces operate using coal (of various grades), coke fines, oil (of various grades), natural gas, or a combination of these fuels. They can be designed for the cheapest fuel available, and can be adapted to other fuel types should the relative costs change. The Copper ISASMELT Furnace at Mount Isa was designed to use coal and oil, but now uses coal and natural gas, while the Phelps Dodge Miami ISASMELT furnace in the U.S.A. uses natural gas exclusively. The Sterlite Industries ISASMELT furnace in India has used coal and oil, depending on the economics of the alternative fuels. The secondary lead ISASMELT furnace in the United Kingdom has used recycled oil as fuel.

Easy Stop and Start-up Procedure

One of the most significant operating advantages is that the ISASMELT furnace can be easily stopped and re-started in order to rectify problems with associated equipment. Typically the furnace can be stopped within 20 seconds and re-started within 5 minutes. A holding burner is used to maintain the temperature of the molten bath until re-start is required.

Low dust carry-over

The carry-over of feed from an ISASMELT furnace is much lower than in some other technologies. Dust from mechanical carry-over is typically 1-2% of feed weight.

Long lance life

ISASMELT furnaces use a lance rather than tuyeres, so there are no problems with tuyere blockages or tuyere-line refractory wear. Lance changing when required is a simple task, and has been fully mechanised on some installations. Improvements to lance design and lance control strategies on the Mount Isa Copper ISASMELT over the past 15 years have led to greatly enhanced lance life. Lance life has averages 14 days with a lance change typically taking 30 to 40 minutes. Lance repair is simple and cost effective only requiring replacement of the tip section.

Because of the above benefits from ISASMELT technology, it has been installed in Australia, USA, England, Germany, Belgium, India, Malaysia and China for copper and lead smelting. Further plants are under design or construction in India, Peru and Zambia (see appendix 1 – ISASMELT worldwide installations). ISASMELT development in recent years has resulted in the three primary copper smelters using the ISASMELT technology being among the lowest-cost producers in the world. With the addition of the new ISASMELT copper plants under design or construction there will be a combined smelting capacity of over 6 million tonnes of copper feed per year.

3.0 ISA PROCESS TECHNOLOGY

The ISA PROCESS Technology is the world's leading copper refining technology. It is a proven permanent cathode technology for the copper electro refining and winning industries. The technology package incorporates reusable stainless steel cathode plates and associated stripping machinery that offers the longest cathode plate life on the world market, the highest and most consistent current efficiency, and the safest and best layout for integral stripping machines.

The fundamental difference between the ISA PROCESS and the conventional starter sheet technology is that ISA PROCESS uses a permanent reusable cathode plate instead of a non-reusable copper starter sheet. The standard ISA PROCESS cathode plate is comprised of a 316 stainless steel blade of thickness 3.25mm, which is welded to a rectangular hollow section stainless steel hanger bar. To provide electrical conductivity, the hanger bar is encapsulated with a 2.5mm thick electroplated copper coating. The vertical edges are masked with plastic edge strips to prevent the copper cathode growing around the edges. The bottom edge is masked with a thin film of wax, which prevents the copper from enveloping the plate, while not providing a ledge to collect falling anode slimes which would contaminate the cathode copper. The “ISA PROCESS 2000” is a waxless process and has been successfully applied in China and Japan recently on industrial scales. The cathode plate when stripped produces two single sheets of pure cathode copper. This cathode technology has led to major advancements in the electrode handling systems of copper tank houses.

Figure 2 shows the ISA PROCESS technology package including tank house concept design, stainless steel cathode plate and cathode stripping machines. Benefits to the operators of the ISA PROCESS Technology include world's best cathode purity, highest operating intensity

a. ISA PROCESS Tank House b. Stainless Steel Plate c. Stripping Machines

Figure 2: ISA PROCESS Technology Package

up to 350 A/m^2, the world's most power efficient permanent electrode, increased labour productivity, improved safety and lower operating costs. Over 55 ISA PROCESS Technology plants have been installed throughout the world (see Appendix 2), producing a combined total of more than 5 million tonnes of copper per annum. This accounts for more than 35% of the world's copper production.

The benefits derived from using the ISA PROCESS for copper electrowinning and electro-refining are summarised below.

The elimination of the starter sheet

The ISA PROCESS is a cathode technology which has replaced the thin distorted starter sheet with a reusable rigid, flat substrate onto which the cathode copper is electrodeposited. The associated cathode stripping technology has proved to be simple and reliable. Because the manufacture and changing of starter sheets is such a costly exercise, conventional refineries usually operate two cathode cycles to one anode cycle. The cathode age is generally between 10 and 14 days. While the ISA PROCESS cathode technology can accommodate variable cathode ages from 5 to 14 days, in general a 7 day cathode cycle is considered ideal as it fits with the weekly work schedule and shorter working weeks. The shorter cycle has numerous benefits to cathode quality.

Improved Cathode Chemical Quality

Cathode chemical quality has improved remarkably. This was achieved by the straightness and verticality of the stainless steel cathode plate compared to the thin starter sheet. The permanent stainless steel cathode has less chance of trapping falling slimes and other impurities in the cathode deposit during electrolysis. The shorter cathode life made possible by the introduction of the reusable cathode plate, improves current efficiency since less short circuits occur and hence less copper nodulations are formed. Cathode quality was also improved by the elimination of starter sheet loops. Cathode chemical quality is far more important today with more stringent demands (exceeding LME Grade A) being placed on the copper rod producers by the fine wire drawers, and in turn on the cathode copper refineries. The ISA PROCESS is meeting these demands despite its high intensity operations. While the major benefits of the ISA PROCESS have been to the refiners, it has produced a more consistent higher quality product for the end user.

Increased Refining Intensity

Refining intensity was greatly increased by the benefits of the permanent stainless steel cathode. The interelectrode gap between the electrode pair could be reduced thereby increasing the active area for electrolysis per metre length of cell. The electrical current density for electrolysis could also be increased. Today, the ISA PROCESS is widely recognised as the benchmark technology for very high intensity refining with several operating greater than 340 A/m2. Conventional starter sheet refineries typically operate at around 240 A/m2.

Reduction of In-Process Copper Inventory

In process copper inventory is an important consideration in a refinery operation. The ISA PROCESS provides the opportunity to reduce the in process copper by allowing shorter anode ages, shorter cathode ages at a higher current density operation. This reduction is in the order of 12% for a typical refinery conversion.

Increased Productivity

The productivity improvements gained by the use of the ISA PROCESS are achieved by the elimination of the starter sheet manufacturing step and the lower incidence of short circuits between the electrode pairs and hence less labour required for shorts correction. The operating labour requirement for an ISA PROCESS plant is typically one third that of a conventional starter sheet operation. The cell room automation afforded by the use of reusable

rigid stainless steel plates and the reliability of the cathode stripping machinery have increased productivity levels still further.

Improved Electrode Alignment

Improved electrode alignment offered by the ISA PROCESS technology has contributed greatly in achieving consistent high cathode quality from high current density operations. Starter sheet technology despite several innovations such as embossing, rigidising and re-pressing the cathode after two days growth achieved very little in this area because of the inadequacy of suspension loops and suspension bar designs. Improved electrode alignment gives better current distribution between the parallel electrodes in the cell and a more uniform gap between the face of adjacent electrodes.

Highly Efficient and Reliable Cathode Stripping Machines

Since the installation of the first machines at MIM's Copper Refineries Pty Ltd in 1978/79 there have been more than 55 machines commissioned around the world. These have ranged in capacity from 60 plates per hour to 650 plates per hour. The simple stripping techniques used to remove the copper cathode from the stainless steel plates and the bottom edge masking system employed to form two single sheet cathodes, has allowed the development of high performance cathode stripping machines. Many optional features are now available, particularly with the larger capacity machines. The cathode stacking and discharge area provides uniform cathode bundles which ensures secure strapping and ease of transport. Cathode bundles can be formed interleaved with corrugated cathodes to the customer's configuration. Automatic cathode sampling, bundle weighing, labelling and strapping are included in the bundle discharge machining prior to when the bundle is removed for dispatch.

ISA PROCESS stripping machines are manufactured to the highest standards by engineering firm Mesco Inc of Japan. ISA PROCESS and Mesco have a long-standing relationship dating back to the first ISA PROCESS stripping machines built for MIM's Copper Refineries Pty Ltd in the late '70's.

High Quality of ISA PROCESS Cathode Product

The ISA PROCESS cathode pack is easily recognised by the smooth surface of the cathode facing upwards. The pack is neatly formed with single sheet cathodes and not two sheets joined at one edge as is the Kidd process cathode. The single sheet pack provides easy handling when cathodes are charged individually into small furnaces. Where shaft furnaces are used for melting some customers prefer corrugated bundles which they believe aids pack separation and cathode melting characteristics.

A normal seven day ISA PROCESS single side cathode will weigh between 45 and 55 kg depending on the active cathode area, current density and current efficiency. Heavier cathodes can be produced by increasing the cathode age and in fact one ISA PROCESS refinery produces cathodes up to 100kg in weight for specific customers. Another refinery clinches cathode pairs together to form heavier individual pieces. The pack weight itself can also be made to suit the customer's requirements and are generally in the range of 2.0 - 3.5 tonnes.

Robust Cathode Plates

The ISA PROCESS cathode plate is fully constructed from stainless steel which gives it unique performance advantages over alternative permanent cathode designs. The rigid stainless steel hanger bar gives stability to the blade and maintains its verticality and flatness. This allows better current efficiency performance over the life of the plate and minimises on-going plate maintenance costs. Currently there are several ISA PROCESS refineries operating with their original plates after more than 15 years of service and still achieving high operational efficiencies. A further benefit of the

stainless steel hanger bar is that the welded joint between hanger bar and blade is not susceptible to corrosion by acid mist or galvanic corrosion.

Low Resistance Cathode Plates

The steel cathode plate hanger bar is electro-plated with pure copper which provides the hanger bar's electrical conductivity. A unique feature of the electro-plated ISA PROCESS design is that copper plating extends partially down the stainless steel blade, to minimise the higher resistance electrical path from solution line to hanger bar. The recently developed 'ISA Cathode BR™' extends the copper plating still further down the blade resulting in lower plate resistance and reduced refinery power costs.

Waxless ISA PROCESS

Wax has been used as a bottom edge masking agent on the cathode plate since the inception of the ISA PROCESS. It has also been used to prolong the life of the vertical edge strip. With the emergence of a competing technology in the early 90's which did not use wax, the disadvantages of wax were highlighted and pressure was applied by the cathode customers on the producers to remove any residual wax from the cathode copper. It is generally accepted that the use of wax creates an unwanted house keeping problem and that an alternative wax free ISA PROCESS would be preferred by some customers - providing the advantages that wax masking gave to the stripping process was not lost. A development programme commenced in 1997 aimed at the elimination of wax from the process. From this successful programme a waxless ISA PROCESS was born. This new process is know as the ISA PROCESS 2000 and has retained the typical ISA PROCESS single sheet cathode, produced from a cathode plate without bottom edge masking. The ISA PROCESS 2000 has been successfully installed and commissioned in five electrowinning and electro-refining large scale operations including one in China.

4.0 ISASMELT AND ISA PROCESS APPLICATIONS IN CHINA

China is successfully applying Xstrata's technologies in a number of national projects. These include Yunnan Copper Corporation ISASMELT plant for 600,000 tpa of copper concentrate commissioned in 2002 (see Figure 6), Guixi ISA PROCESS copper refinery for 200,000 tpa of refined copper metal commissioned in 2003 (see Figure 7) and Qujing Lead ISASMELT for 140,000 tpa of lead concentrate under construction at present (see Figure 8).

Figure 6: Yunnan Copper Corporation ISASMELT Plant

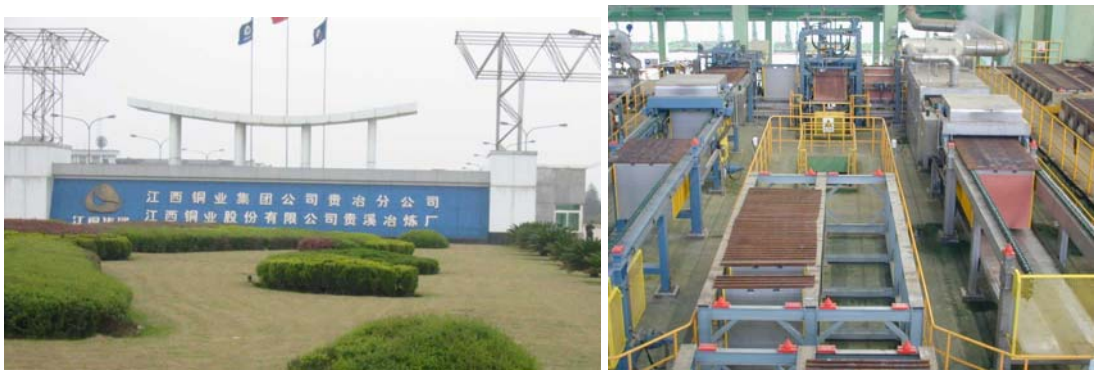


Figure 7: Gui Xi Refinery and ISA PROCESS Designed Stripping Machines

Figure 8: Yunnan Qujing Lead ISASMELT under Construction

The success of Xstrata's technologies in China is well demonstrated by Yunnan Copper Corporation's ISASMELT plant, which was commissioned in 2002 to replace a sinter plant and electric furnace. Design capacity was reached within two months of start up, aided by extensive technical assistance from Mount Isa copper smelter. The new plant has significantly improved the environmental performance and has resulted in a significant reduction in operating costs. It is the first copper ISASMELT furnace that has operated for more than two years with the first refractory brick liner since start up.

Another milestone for Xstrata Technology's success in China was the commissioning of an ISA PROCESS 2000 plant at Guixi Copper Refinery in February 2003. The Guixi ISA PROCESS plant incorporates all the advantages of the ISA PROCESS developed by Xstrata Technology over the last 25 years. It was also the second ISA PROCESS licensee in the world to benefit from the latest technology "ISA PROCESS 2000" which uses a waxless cathode plate design. One and half years after startup the Guixi ISA PROCESS 2000 plant is performing well and meeting key design requirements.

5.0 SUMMARY

Xstrata's ISASMELT and ISA PROCESS technologies have both been successfully applied in Australia for copper production for more than 20 years. They are now becoming benchmarking technologies for the coper industry and are well proven with many installations around the world. They are also new generation of copper processing technologies offering low energy consumption, low capital and operation costs, high productivity and a minimum impact on the environment.

There have been a number of successful projects in China applying the ISASMELT for YCC and CYMG and ISA PROCESS for Guixi Copper Refinery. With more cooperation between Xstrata Technology and the Chinese copper industry, China will benefit further from applications of Xstrata's technologies to national copper projects to save energy, improve operation efficiency and protect the environment.

Appendix 1 ISASMELT Installations around the world

Company Name	Start Up Time	Metal Type	Feed Rate (tpa)
Primary Smelter			
Mt Isa (Australia)	1992	Cu	1,000,000
PD Miama (USA)	1992	Cu	700,000
Sterlite #1 (India)	1996	Cu	600,000
Sterlite #2 Design (India)	2004	Cu	1,300,000
YCC (China)	2002	Cu	600,000
CYMC Design (China)	2005	Pb	160,000
SPCC Design (Peru)	2006	Cu	1,200,000
MCM Design (Zambia)	2006	Cu	850,000
Secondary Smelter			
Umicore (Belgium)	1997	Cu	200,000
MRI (Malaysia)	2000	Pb	40,000

Appendix 2 ISA PROCESS LICENSEES – ELECTROWINNING

Location	**Year of Startup**	**Capacity kT/y**
BHAS Port Pirie, Australia	1985	5
Gibraltar Mines Ltd, McLeese Lake, BC Canada *	1986	5
BHP Copper, San Manuel, USA	1986/88	60
BHP Copper, Pinto Valley, Miami, USA*	1989	12
Mexicana De Cananea, Mexico	1989/90/01	60
Western Metals, Mt Gordon, Australia (formerly Gunpowder)	1990/98	45
Mount Isa Mines Limited, Australia *	1990	3.5
Compania Minera Disputa De Las Condes SA, El Soldado Chile	1992	6.5
Straits Resources, Nifty Copper, Australia	1993/00	43
Straits Resources, Girilambone Copper, Australia *	1993	15
Escondida Coloso, Antofagasta, Chile *	1994	80
Compania Minera Quebrada Blanca SA, Iquique, Chile	1994	83
Minera Michilla SA, Chile	1994	27
Codelco Quebrada M, El Salvador, Chile	1994	26
Codelco Chuqui LGSO, Chuquicamata, Chile	1994	20
Compania Minera Cerro Colorado Ltd, Iquique, Chile	1994/98	120
Compania Minera Zaldivar, Antofagasta, Chile	1995	130
Mexicana de Cobre, La Caridad, Mexico	1995	22
Phelps Dodge, South Side, Morenci, USA	1995/98	140
Mexicana de Cobre, Southern Peru Copper, Toquepala, Peru	1995/99	50
Impala Platinum Limited, Springs, South Africa	1996	10
Hellenic Copper Mines Ltd, Nicosia, Cyprus	1996	8
Great Australia Copper Mine, Cloncurry, Australia *	1996	6.5
Matrix Metals, Cloncurry, Australia	1996	5.5
Codelco Chuqui Ripios, Chuquicamata, Chile	1997	65
Nicico National Iranian Copper Industries Co, Sarchesmeh Iran	1997	15
Myanmar Ivanhoe Copper Company, Yangon, Myanmar	1998	25
Compania Minera Disputada De Las Condes, Los Bronces, Chile	1998	7
Phelps Dodge, Central, Morenci, USA	1998	140
Equatorial Tonopah Inc., Tonopah, USA *	2000	25
Phelps Dodge, Stargo, Morenci, USA	2001	112
El Tesoro, Sierra Gorda, Chile	2001	75
Norilisk Nickel, Severonickel, Monchegorsk, Russia	2001	15
Umicore, Hoboken, Olen, Belgium	2003	40
Korea Zinc, Onsan, Korea.	NYC (2004)	15
First Quantum, Kansanshi, Zambia	NYC (2005)	60
Carlota Copper Company, Claypool, USA	NYC	26
Summary: 37 Licensees 1,603,000 T/y		

☐ Converted from Starter Sheet Operation * Shut down

APPENDIX 3 ISA PROCESS LICENSEES – ELETROREFINING

Location	**Year of Startup**	**Capacity kT/y**
Copper Refineries Pty Ltd, Townsville Australia	1978/98	270
Copper Range Company, White Pine, USA	1982	70
Olympic Dam Operations, Roxby Downs, Australia	1988/98	230
Montanwerke Brixlegg, Brixlegg, Austria, 1988	1988	75
Norddeutsche Affinerie AG, Hamburg, Germany	1989/92	370
IMI Refineries Ltd, Walsall, United Kingdom*	1992	60
Phelps Dodge Miami, Claypool, USA* (formerly Cyprus Miami)	1994	190
Huttenwerke Kayser AG, Lunen, Germany	1994	180
Atlantic Copper SA, Huelva, Spain	1995	250
Boliden Mineral AB, Skelleftchamn, Sweden	1995/00	230
Union Miniere, Olen, Belgium	1996	350
Sterlite Industries, Silvassa, India	1996/01	175
PT Smelting Company, Gresik, Indonesia	1998/03	230
Hindalco Industries (Birla Copper), Dahej, India	1998/01	250
Port Kembla Copper, Port Kembla, Australia*	2000	120
Nippon Mining & Metals, Hitachi, Japan	2002	180
Jiangxi Copper Company, Guixi, China	2003	200
Swil Limited, Bharuch, India	2004	50
Thai Copper Industries Public Co Ltd, Rayong, Thailand	2004	165
Sterlite Industries, Tuticorin, India	NYC (2004)	140
Japanese Refinery (TBA)	NYC (2005/6)	110
Egyptian Metals, Egypt	NYC	6
Hindustan Copper, Khetri, India	NYC	70
Summary: 23 Licensees 3,971,000 T/y		

Converted from Starter Sheet Operation

* Shut down

Total Number of Licensees ***60***

Total Licensed Capacity ***5,249,000 T/y***