THE ISA PROCESS AND ITS CONTRIBUTION TO ELECTROLYTIC COPPER

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Abstract

Since the discovery of the process to produce electrolytic copper in the late nineteenth century, the ISA PROCESS remains the most significant process change to date, and remains the benchmark in the industry after 21 years of operation. It has allowed great improvements to productivity and cathode quality. This review locates this process change in the history of electrolytic copper refining and briefly describes the benefits of the technology over conventional starter sheet technology.

Introduction

The ISA PROCESS has played a significant role in the evolution of electrolytic copper production by allowing increased productivity, reduced operating costs and most importantly consistent high quality cathode copper. Since its inception 20 years ago, ISA PROCESS users continue to advance the technology to new levels of productivity and cathode quality to meet the ever increasing demands of the down stream users of copper.

Place in History

Copper, first used in ancient times was produced by working native copper followed by pyrometallurgical processes. Fire refined, Lake copper set the standard for purity and conductivity up until this century.

The first patents for metal electrorefining, were for copper and were granted to James Elkington in England in 1865. The first copper refinery was built in Newark by Balbach Smelting and Refining Company in 1883. Early electrorefineries had difficulty producing firm cathode deposits of high purity copper. The use of additives to the electrolyte, in particular salt and improved electrolyte circulation were the most important developments in overcoming the early difficulties. As the art of electrorefining grew so did the competition and it was secrets like this which were jealously guarded to retain an edge over a competitor. Even though electrolytic copper was being produced with higher purity and conductivity than fire refined Lake copper, it took many year before consumers gave recognition to this fact. Electrolytic copper became the official basis for price quotation in 1914.

During the early part of this century the industry grew rapidly with copper refineries being built throughout America, Europe and Australia. Large scale electrowinning of copper was developed between 1912 - 1915 at Chuquicamata in Chile.
As the industry grew to meet the consumer demands there were steady improvements in productivity mainly through mechanisation of the electrode handling.

The most significant change to the fundamental process of electrorefining of copper came with the development of the permanent stainless steel cathode technology, by I.J. Perry and others at the Copper Refineries Pty Ltd in Townsville, Australia in 1978.

This new technology was incorporated into a refurbishment of the 20 year old refinery in Townsville in 1978 –-1979.

Within a few years of operation and after papers were presented at international conferences about this new cathode technology, the industry showed considerable interest and MIM Holdings the parent company of Copper Refineries Pty Ltd, decided to market the technology as the “ISA PROCESS” in 1980.

The ISA PROCESS today has 49 licensees throughout the world and when all are operational will produce more than 4,000,000 tonnes of cathode copper per year, or approximately 1/3 of the world cathode copper production.

Through its wide spread acceptance and use, the technology is recognised as the benchmark for today’s copper refining practices.

Fig 1: Events in the Evolution of Electrolytic Copper Production

	Fire refined Lake copper the standard for price quotation.
1865	First Patents granted to James Elkington for electrolytic copper refining
1883	First electrolytic copper refinery built at Newark, USA
	Electrorefining art developed at many locations
1912-15 1914	Large scale electrowin plant at Chuquicamata in Chile Electrorefined copper becomes basis for price quotation
1968	First copper electrowin plant to use SXEW at Ranchers Bluebird Arizona
1968-78	Mechanisation of starter sheet operations
1978	***Introduction of the ISA PROCESS permanent stainless steel cathode technology to Copper Refineries Pt Ltd, Townsville, Australia***
1980	Marketing of the ISA PROCESS technology worldwide
1982	First electrorefinery in USA to use ISA PROCESS, at White Pine, Michigan
1985	First electrowin plant to use ISA PROCESS at BHAS, Port Pirie, Australia
1986	First electrowin plant in USA to use ISA PROCESS, at Magma, San Manual
1988	First electrorefinery in Europe to use ISA PROCESS, at Montanwerke, Brixlegg
	Continual expansion of the ISA PROCESS licensees throughout the world
1999	Modernisation and expansion of Copper Refineries Pty Ltd, Townsville, Australia
1999	Commercialisation of ISA PROCESS 2000 Technology

Fig 2: List of ISA PROCESS Licencees

ISA PROCESS LICENCEES

Electrowinning

As at August 1999

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	45
BHP Copper, Miami, USA	1989	15
Mexicana De Cananea, Mexico	1989/90	40
Aberfoyle Resources Ltd, Gunpowder Division, Australia	1990	45
Mount Isa Mines Limited, Australia	1990	3.5
Compania Minera Disputa De Las Condes SA, El Soldado Chile	1992	6.5
WMC (Western Mining Co) Nifty, Australia	1993	16
Girilambone Copper Company, Girilambone, Australia	1993	15
Excondida, Antofagasta, Chile	1994	80
Compania Minera Quebrada Blanca SA, Iquique, Chile	1994	75
Minera Michilla SA, Chile	1994	27
Codelco Quebrada M, El Salvador, Chile	1994	26
Codelco Chuqui LGSO, Chuquicamata, Chile	1994	16
Compania Minera Cerro Colorado Ltd, Iquique, Chile	1994/98	120
Compania Minera Zaldivar, Antofagasta, Chile	1995	100
Mexicana De Cobre, La Caridad, Mexico	1995	21
Phelps Dodge Refining Corporation, Morenci, USA	1995/98	240
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
Straits Resources Mount Cuthbert, 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 NYC	1998	25
Compania Minera Disputada De Las Condes, Los Bronces, Chile	1998	7
Carlota Copper Company, Claypool, USA	NYC	26
Equatorial Tonopah Inc., Tonopah, USA	NYC (1999)	25
Noriliskij Mickel, Severonickel, Monchegorsk, Russia	NYC	15
Summary: 31 Licensees 1,118,500 T/y		

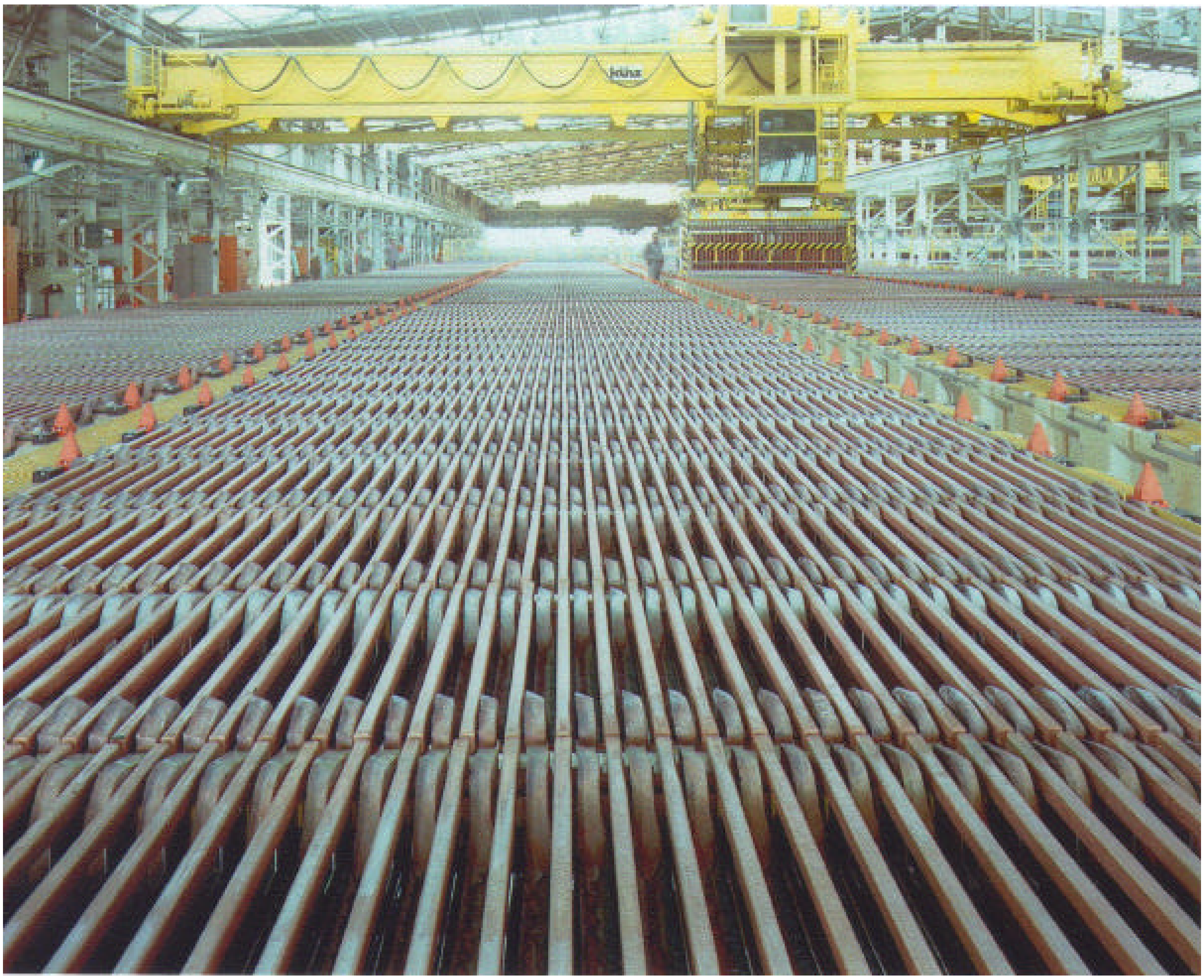
ISA PROCESS LICENCEES
Electrorefining

As at August 1999

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	215
Montanwerke Brixlegg, Brixlegg, Austria, 1988	1988	72
Norddeutsche Affinerie AG, Hamburg, Germany	1989/92	370
IMI Refineries Ltd, Walsall, United Kingdom	1992	49
Cyprus Miami Mining Corporation, Claypool, USA	1994	188
Huttenwerke Kayser AG, Lunen, Germany	1994	176
Atlantic Copper SA, Huelva, Spain	1995	235
Boliden Mineral AB, Skelleftchamn, Sweden	1995/00	210
Union Miniere, Olen, Belgium	1996	300
Sterlite Industries, Silvassa, India	1996	90
PT Smelting Company, Gresik, Indonesia	1998	200
Birla Copper, Baruch, India	1998	100
Port Kembla Copper, Port Kembla, Australia	NYC (1999)	120
Thai Copper Industries Public Co Ltd, Rayong, Thailand	NYC (2000)	165
Swil Limited, Maruch, India	NYC (2000)	50
Hindustan Copper, Khetri, India	NYC (2001)	70
Summary: 18 Licensees 2,950,000 T/y		

Conversions from Starter Sheet Operations

Fig 3: ISA PROCESS Tankhouse at Copper Refineries, Australia



The Electrorefining Process

Electrorefining of copper consists of electrolytically dissolving copper from impure anodes of about 99.7% copper, and selectively plating the dissolved copper in pure form onto the copper cathode. This reaction takes place in a cell containing an electrolyte which is basically copper sulphate and sulphuric acid. Metallic impurities more noble (electro positive) than copper do not tend to enter the electrolyte at the current densities employed, but settle in the bottom of the cell as anode slime.

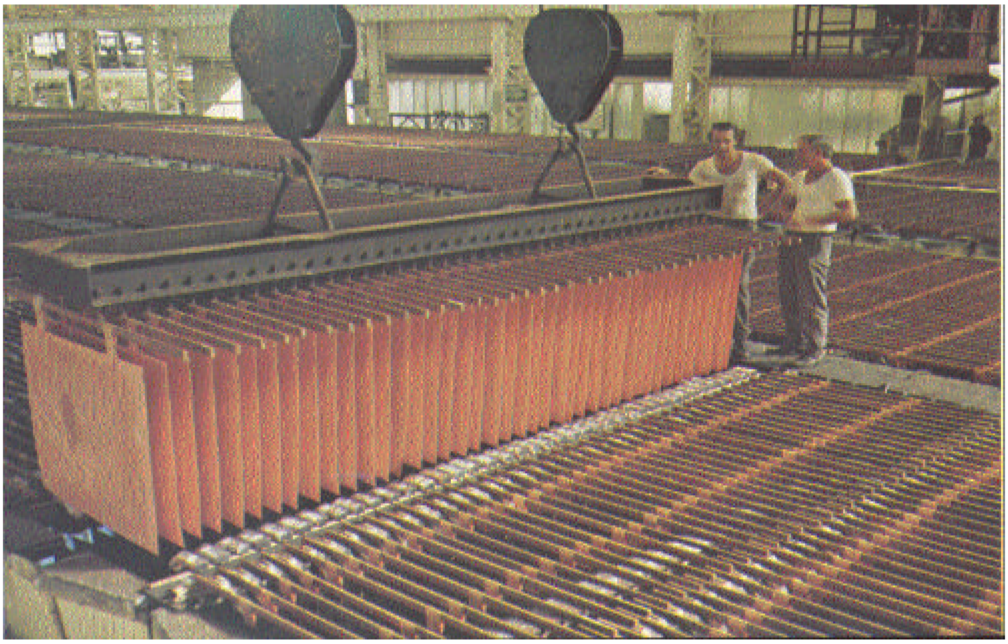
Metals which do enter the electrolyte with copper are either precipitated as insoluble compounds, or, being less noble than copper remaining in the solution and do not deposit electrolytically at the cathode.

Electrolytic refining is carried out in a multiple system of cells in series to form practical sections. The electrodes, anode copper and cathodes are connected in parallel in the cells.

The conventional electrorefining practice is to use starter sheets of higher purity copper, as the cathode substrate upon which the copper is electro deposited. These starter sheets are produced in special electrolytic cells by a 24 hour electro deposition of copper, onto either hard rolled copper or titanium blanks. Preparation of the starter sheet included washing, straightening and stiffening of the sheet. The sheets are then suspended from rolled copper hanger bars by attached loops of copper strips.

Fig 4: Cathodes grown from Starter Sheet

Fig 5: Rack of Starter-sheet Cathode (CRL 1976)



The electrolytic cells are loaded with anodes and starting sheet prior to the electric current being connected. The starter sheets are generally plated with copper for 12 - 14 days before they are removed and a second starter sheet inserted between the anodes. The anode cycle is generally between 24 – 28 days. At the end of the cathode cycle the anode scrap is removed, washed and returned to the casting facility for melting and recasting into anodes. The cells are drained of electrolyte and the anodes slimes containing the precious metal is washed from the bottom of the cells, collected and further processed.

The fundamental difference between the ISA PROCESS and the conventional starter sheet technology is that ISA PROCESS uses a permanent reusable cathode blank instead of a non-reusable copper starter sheet.

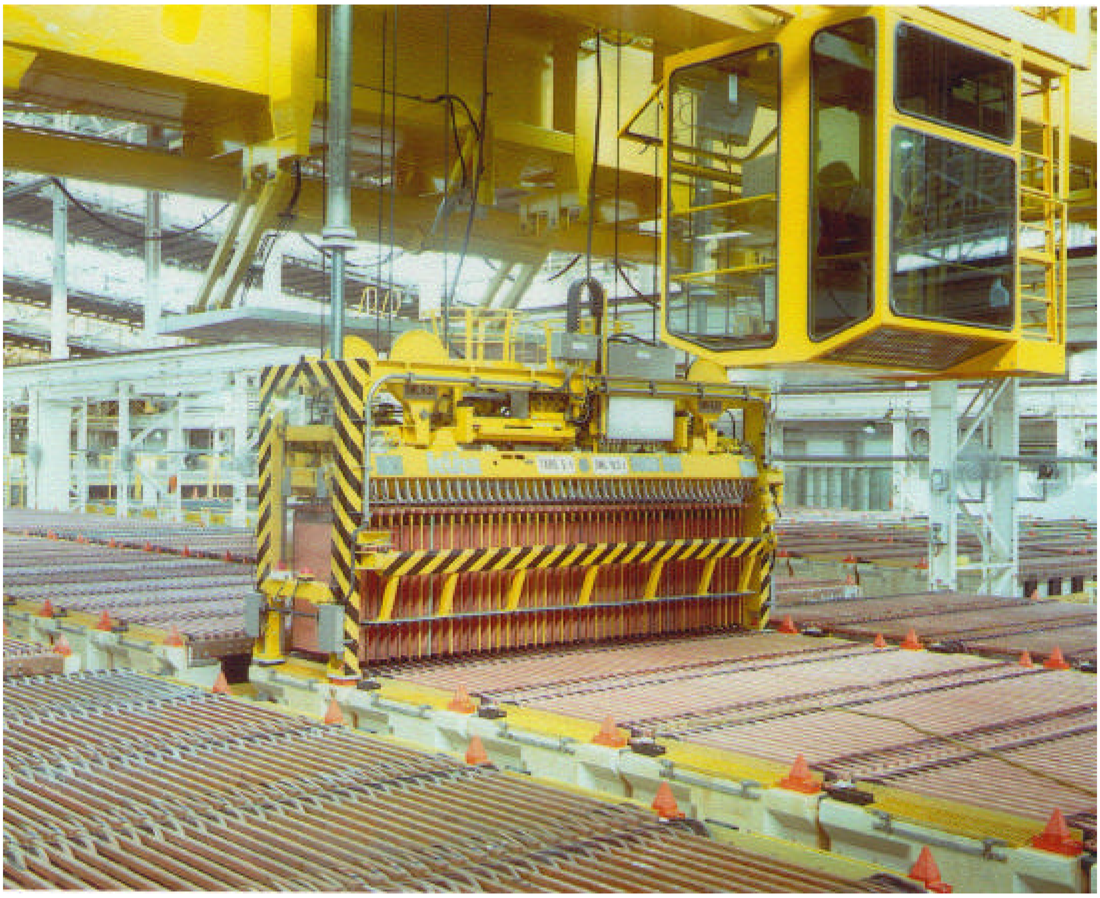
The ISA PROCESS cathode plate is made of a 316 stainless steel blade 3.25mm thick, which is welded to a hollow stainless steel section hanger bar. To improve electrical conductivity, the hanger bar is encapsulated with a 2.5mm thick electroplated copper coating.

The vertical edges are marked 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, while preventing the copper enveloping the plate, does not provide a ledge to collect falling anode slimes which would contaminate the cathode copper.

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.

Fig 6: Modern ISA PROCESS Tankhouse showing automatic "Kunz" crane (CRL 1999)



The Development of the ISA PROCESS

During the mid 70's MIM Holdings conducted a feasibility study into establishing a zinc refinery in Townsville. This study gave MIM staff the opportunity to visit all the zinc refineries in the world that demonstrated the latest developments in that industry. The zinc industry at the time had developed a permanent cathode plate and associated cathode stripping technology.

After this study, a research programme was commenced aimed at the development of a permanent cathode for copper refining. The result of this research was a unique stainless steel cathode plate which became the core of a complete modernisation programme of the 150,000 t/y copper refinery in Townsville.

The principal features incorporated in the modernisation programme were;-

- The elimination of starter sheets and the introduction of the permanent reusable stainless steel cathode plates.
- Automatic stripping of the copper deposits from the stainless steel blanks.
- Mechanised anode straightening and spacing.
- Computerised cell voltage monitoring.

The driving forces behind the modernisation programme were to reduce the manual work and improve safety performance, reduce the cost of labour, and to eliminate the practice of “job and finish” where a fixed quantum of work was performed by a fixed number of men per shift. This work practice had become common in electrolytic industries throughout the world and contributed to large labour costs.

The original cathode stripping machines at Townsville had their origin in the zinc cathode stripping machines at the Hikoshima plant of Mitsui Mining and Smelting Company of Japan. Considerable development work was necessary to modify the machine designs to handle the heavier copper cathodes and process the cathode plate without damage. Side and bottom waxing facilities were also required in the design.

Many improvements have been made to the cathode stripping machine designs in the last 20 years. The stripping capacity of the large machines have increased from 250 plates per hour for the original machine to 650 plates per hour with the latest machine. Various capacity machines are available to suit the budget and needs of the user. The stripping concept is the same for the small to large capacity machines.

Through the users of the technology worldwide the ISA PROCESS has enjoyed continual improvement, driven by industry requirements for high productivity with consistent high quality at lower costs.

The ISA PROCESS Users Conference is held every two years and is a forum for operators to exchange ideas and developments in the technology, as well as to share operation experiences.

Benefits of ISA PROCESS

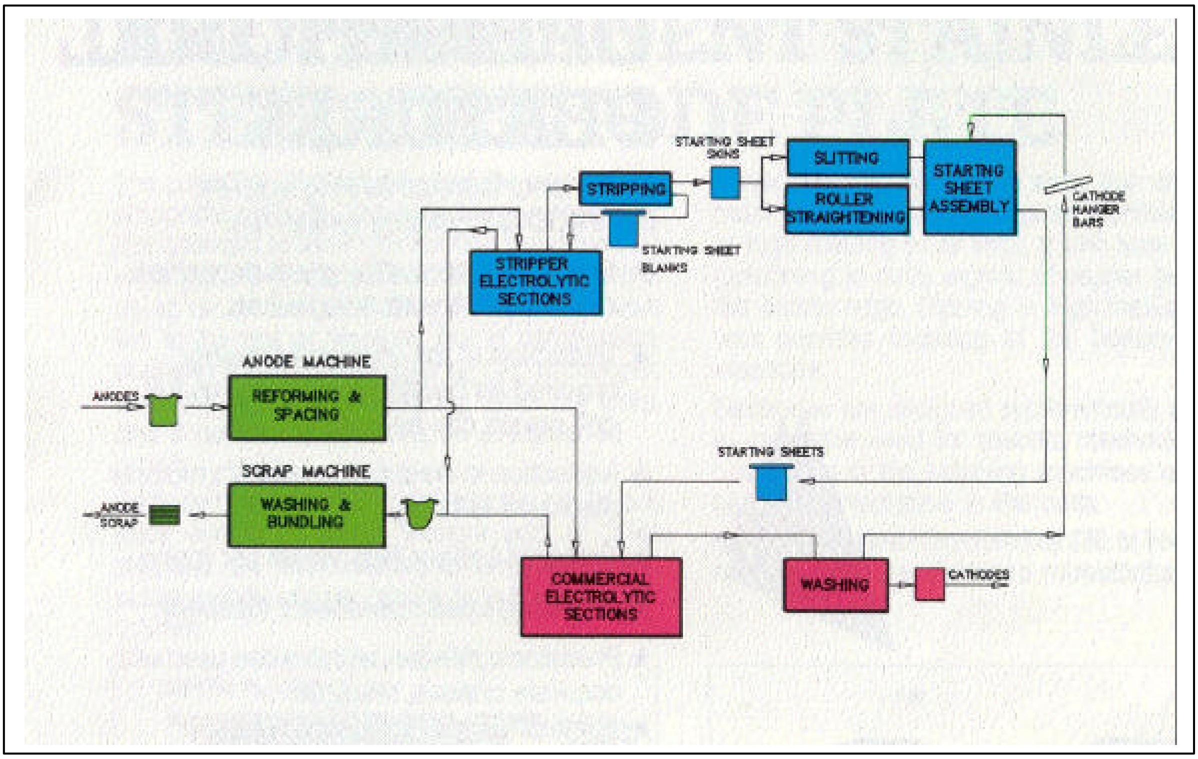
The elimination of the starter sheet

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.

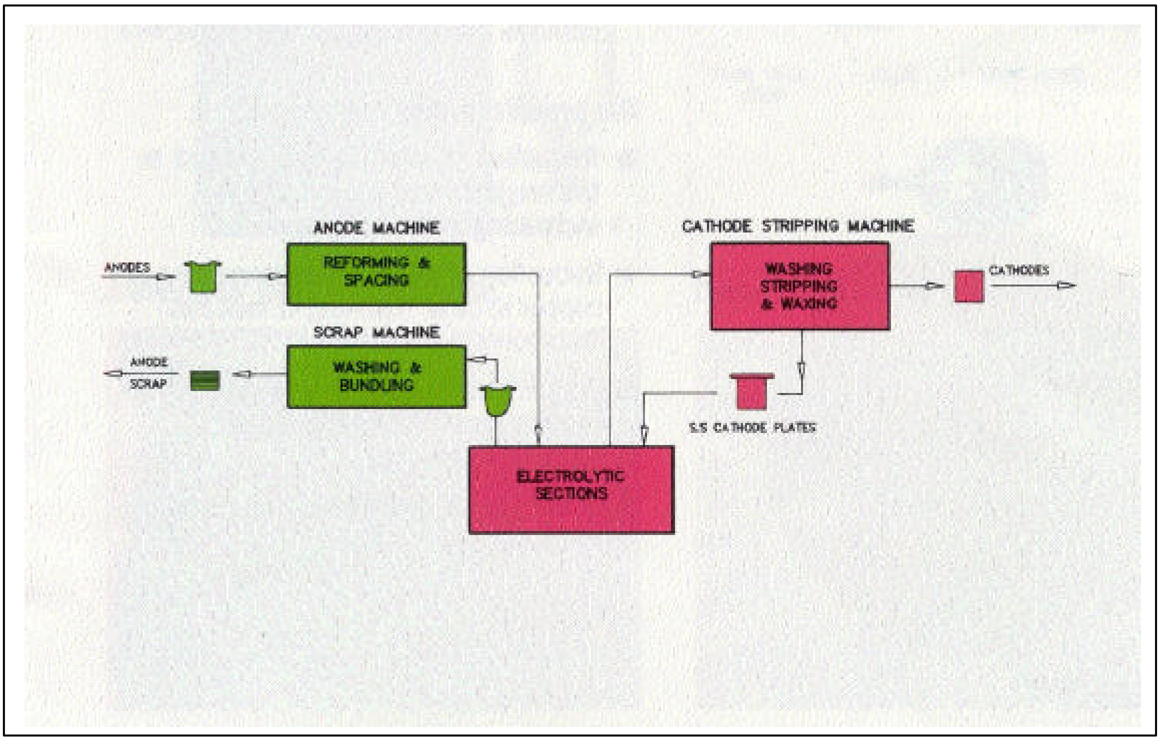
Because the manufacture and changing of starter sheets is such a costly exercise, conventional refineries usually operate two cathode cycles to one anode cycle ie. the cathode age is generally between 10 and 14 days. While the ISA PROCESS cathode technology can accommodate variable cathode ages from 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

Fig 7: Simplification of the Copper Refining Process

7(a) Typical Starter Sheet Tankhouse



7(b) Typical ISA PROCESS Tankhouse



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, possible with the introduction of the reusable cathode plate improves current efficiency as 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.

Table: Typical Cathode Analyses (in ppm) and LME Grade A Limits

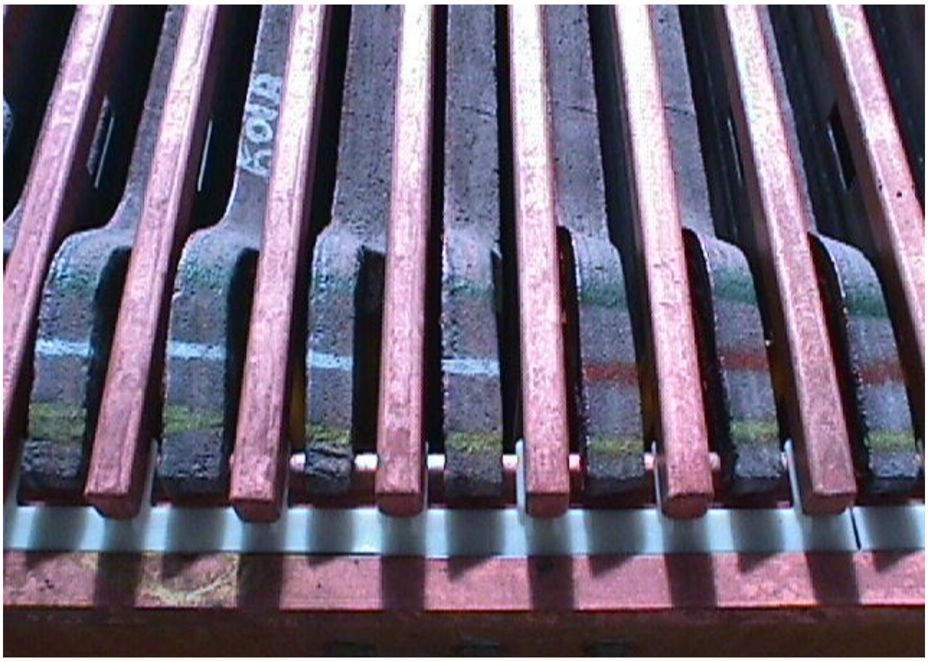
Impurity	Refined Cathode	Electrowon Cathode	LME Grade A Upper Limit
S	4	3-5	15
Pb	<0.1	<1	5
Ni	<1	<1	-
As	<1	<1	5
Ag	12	<1	25
Sb	<0.5	<1	4
Bi	<0.5	<1	2
Se	<0.1	<0.1	2
O	35	35-50	-

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 be increased, and today, ISA PROCESS refineries are operating at 330 A/m^{2,} where as conventional starter sheet refinery operate at around 240 A/m^2.

Fig 8: High Intensity Refining with ISA PROCESS (Close interelectrode gap)



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%.

Increased Productivity

The productivity improvements gained by the use of the ISA PROCESS are achieved by the elimination of starter sheets 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 approximately one third that of a conventional starter sheet operation. The cell room automation afforded by the use of reusable rigid stainless steel blanks 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 to achieving consistent high cathode quality from high current density operations. Starter sheet technology despite several innovations such as embossing, rigidising and repressing 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 constant electrode gap down and across the face of the anodes.

Cathode Stripping Machines

Since the installation of the first machines at Copper Refineries in 1978/79 there has been an additional 48 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 marking system employed to form two single sheet cathodes, has allowed the development of the 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 customers 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.

Fig 9: ISA PROCESS - Automated Cathode Stripping Machine

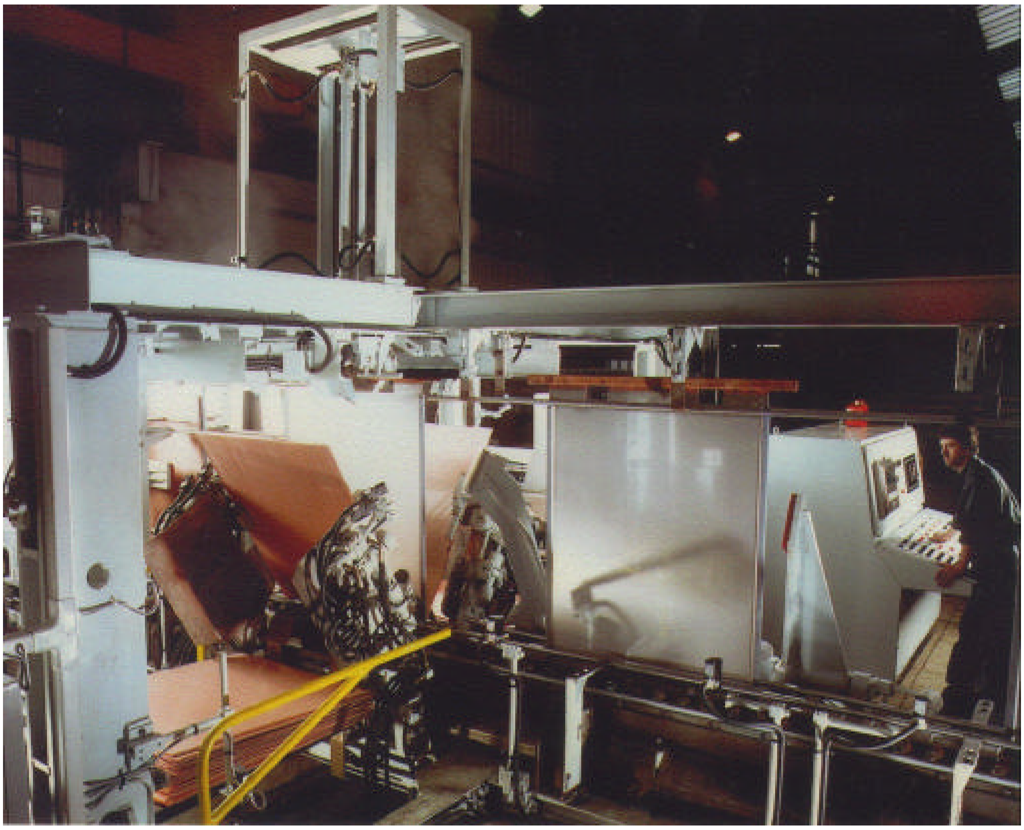


Fig 10:Cathode Product Bundles awaiting Dispatch (a) flat cathode and (b) corrugated

Copper Electrowinning

Following on from the success of solvent extraction reagents in the extraction of uranium in the 1950 – 60, organic extractants for copper were developed and the first commercial plant was built at Ranchers Bluebird, Arizona in 1968. This technology was a step change in the process of producing better quality electrowon copper, but it was the advent of the ISA PROCESS technology which took electrowon copper from second rate, inconsistent quality cathode to consistent high quality copper greater than “four nines” purity.

Of the 49 ISA PROCESS licensees 31 produce electrowon copper and all are capable o f producing LME grade A copper quality or better.

Fig 11: ISA PROCESS Electrowinning Tankhouse

Fig 12: "Live Stripping" Electrowon Cathode

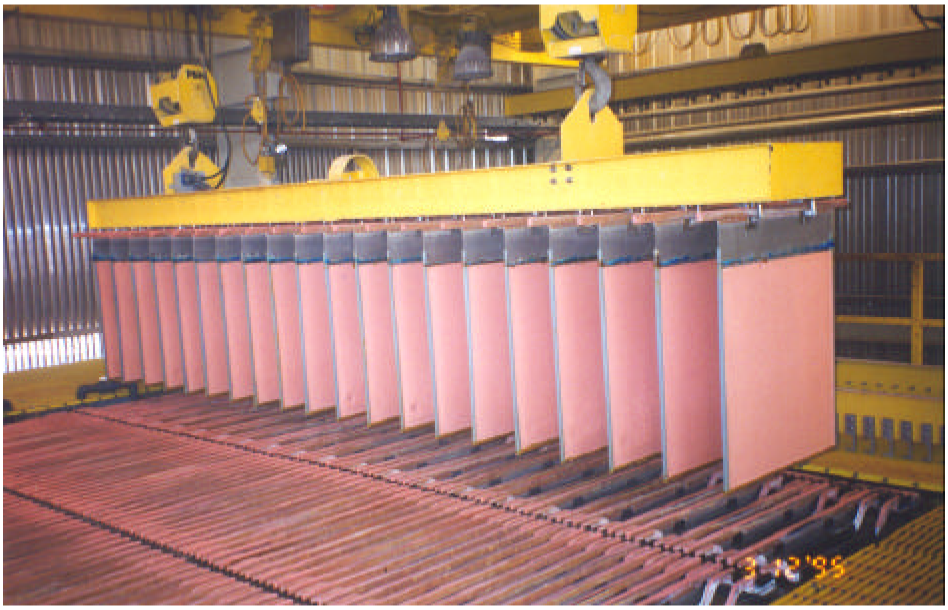


Fig 13: Electrowin Cell showing ISA cathode motherplates, Lead anodes and mist suppressant layer

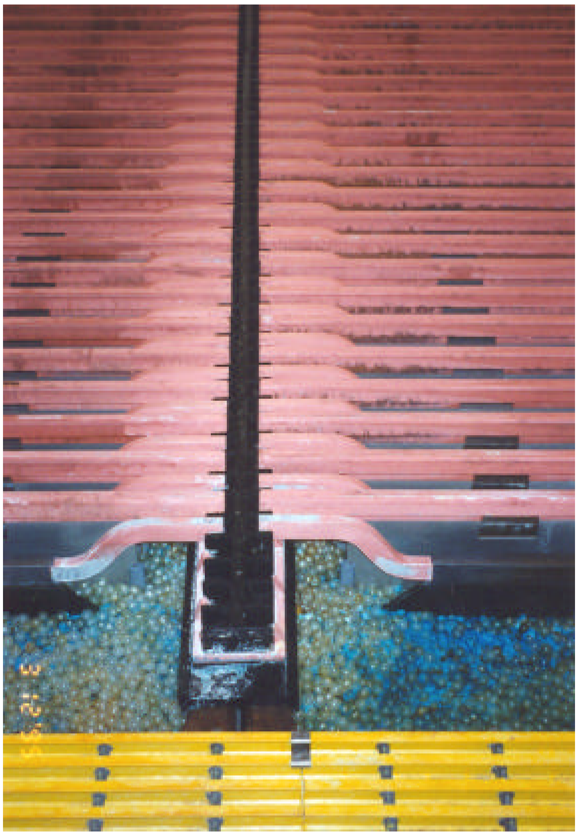


Fig 14: Electrowon ISA PROCESS Cathode

ISA PROCESS Cathode Product

The ISA PROCESS cathode pack is easily recognised by the smooth surfae of the cathode facing upwards. The pack is 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.

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.

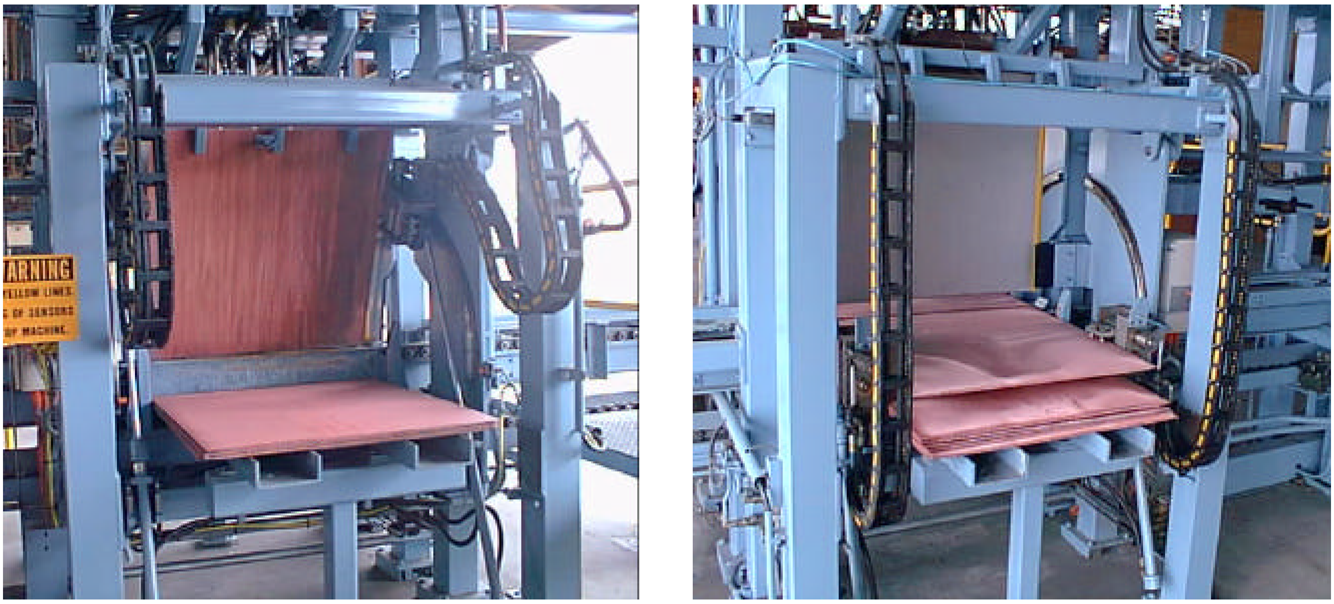
Process Developments

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 permanent stainless steel technology (the KIDD process) 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, 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 new stripping concept has been demonstrated in a prototype cathode stripping machine in Townsville and is planned for inclusion in a number of projects in the immediate future.

Fig 15: ISA PROCESS 2000 Prototype Stripping Machine



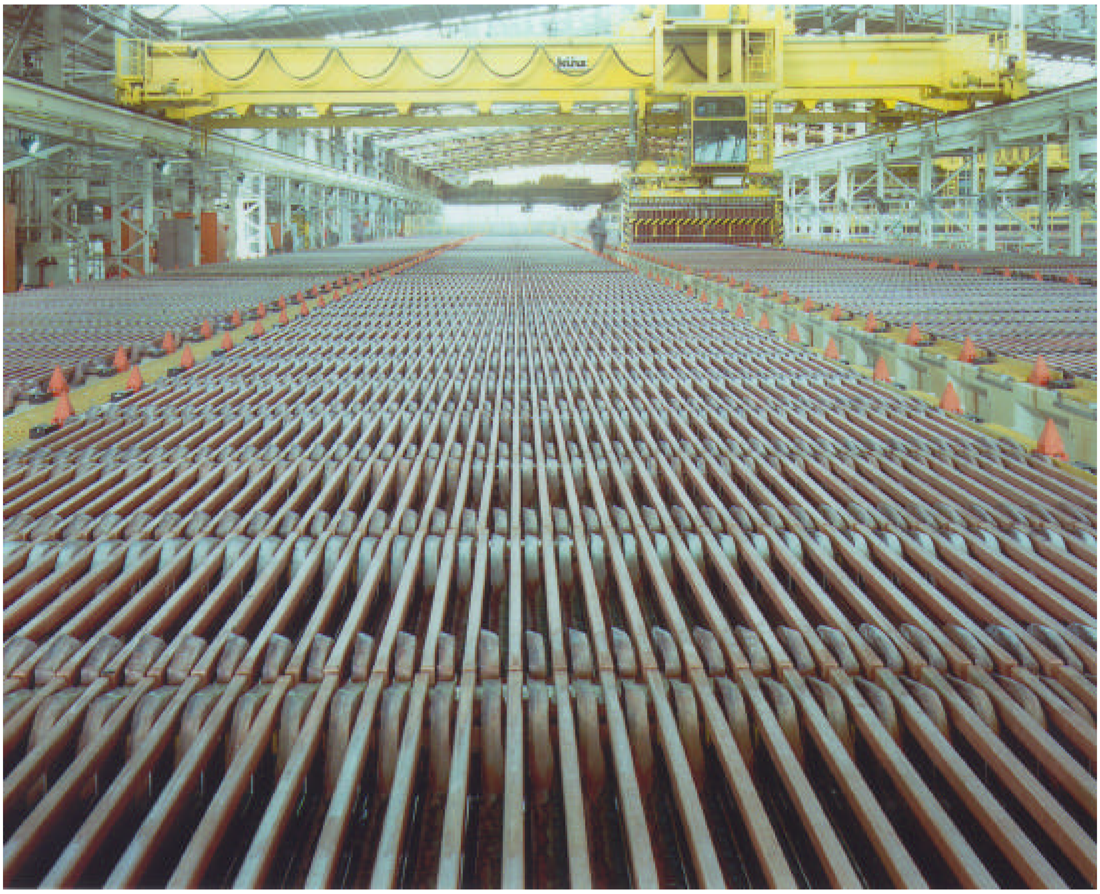
Figs 16 & 17: "ISA PROCESS 2000" Copper Cathode (waxless)

Copper Refineries Pty Ltd Tank House Refurbishment

The planned increase in the output of anodes from 200,000 t/y to 270,000 t/y from Mount Isa Mines gave Copper Refineries Pty Ltd the opportunity to refurbish the tank house after 20 years operation of the ISA PROCESS technology. The experience gained in 16 years of marketing the ISA PROCESS technology to the world gave CRL extensive knowledge of best practice on which to design a world class facility. This refurbishment was completed in March 1999.

The new tank house design has focused particular attention on customer requirements, operational improvements, materials handling and equipment modernisation. Equipment which has been upgraded includes cranes, anode preparation, cathode stripping and scrap washing machines along with the total replacement of the electrolyte and electrical reticulation systems. Side stream electrolyte filtration has been introduced. Improvements to electrode alignment afforded by the conversion to polymer concrete cells, precise electrode location, and the upgrade of the electrode handling machines will ensure that CRL continues be on of the world's major quality copper cathode producers.

Fig 18: Modernised ISA PROCESS Tankhouse at Copper Refineries



Conclusion

The ISA PROCESS electrolytic copper technology has made a major contribution in improving the electrolytic process for refining of copper, to meet the ever increasing demands of the end users. The standard of productivity and cathode quality achieved by ISA PROCESS plants cannot be matched by any other competing technology. This mature technology continues to evolve, keeping pace with this dynamic industries requirement. This is achieved by the sharing of knowledge and experiences with all licensees and cathode stripping machine manufacturers during the biannual ISA PROCESS Users Conference.