The development of a “lower resistance” permanent cathode

(ISA Cathode BR™)

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ABSTRACT

The use of a permanent stainless steel cathode for the electrowinning and electrorefining of cathode copper is a well-accepted technology. As the developers of this technology, the ISA PROCESS Technology (IPT) has continued to improve the technology and maintain leadership.

As the pressure to produce cathode copper more efficiently has increased in the market place, IPT has recognised the need to develop a more efficient cathode plate.

The IPT has now developed a low resistance cathode plate (ISA Cathode BR™) in response to market demand. The ISA Cathode BR™ provides lower electrical resistance by decreasing the distance the between the end of the copper plating and the solution line.

Plant trials in the Townsville ISA PROCESS refinery and in a major Chilean electrowinning plant were undertaken to prove the performance of the new cathode type BR™. Results to date indicate that significant operating cost savings are available with the use of the ISA Cathode BR™ electrodes.

INTRODUCTION

In 1978 MIM's Townsville Copper Refinery permanently changed the electro-copper industry after the introduction of the permanent stainless steel cathode.

The ISA PROCESS Technology (IPT) allowed for the reduction in manning requirements, provided superior mechanical handling systems, reduced copper inventory levels, permitted a more intense operating regime, improved cathode quality and offered a much safer electrolytic operation. It enabled the commissioning of smaller scale electrowinning operations by making them independent of starter sheet supplies.

The introduction of inherently straight permanent cathodes has necessitated the development of anode casting and preparation systems in conjunction with superior contact arrangements. These developments in combination with the ISA PROCESS have seen the introduction of operating current densities up to 350 A/M^2 and current efficiencies in excess of 98%.

The technology assures the production of better than LME "grade A" quality. The process has been so successful, in this regard, that the LME "grade A" standard, is now considered a minimum by the best producers.

The ISA Cathode BR™ is the latest ISA PROCESS cathode plate offering a low resistance electrode with the potential to reduce power costs significantly. On site trials at Compania Minera Zaldivar supported earlier test work conducted by the ISA PROCESS at Townsville, Australia.

Figure 1: ISA Cathode BR™ in service at Compania Minera Zaldivar

"Lowest resistance cathode"

1.1. The permanent cathode plate

Underlying the success of the process is the basic design of the ISA PROCESS cathode. This design, while constantly being improved over the last twenty years still remains true to the design precepts of I.J.Perry's original concept (Perry, Jenkins & Okamoto, 1981).

The ISA cathode consists of a 304L stainless steel hanger bar which is stitch welded to a 316L stainless steel blade (3.25mm+ thick). This assembly has been proven so strong that no bond failure has occurred in a commercial operation due to either corrosion or mechanical handling.

The hanger bar assembly is then electroplated with copper to a thickness of 2.5 mm. The 2.5mm of copper provides sufficient electrical conductivity and imparts a degree of corrosion resistance. Under correct operating conditions will provide an operational life without repair in excess of 7 years in electrowinning situations and over 15 years (perhaps as much as 20) in electrorefining situations.

Deterioration of the ISA PROCESS hanger bar system occurs very slowly and is predictable. This permits operators to carefully plan for the refurbishment of their operating cathodes. No catastrophic failures of this assembly have occurred in commercial production facilities.

The diagrams below illustrate a comparison in cathode plate performance over time for the ISA cathode and solid copper hanger bar systems under electrowinning conditions. Zone A illustrates the region where there is no change in performance of the cathode. Zone B is where the performance of the cathode begins to deteriorate. ISA cathodes exposed to corrosive conditions will exhibit this slight drop off in performance. Solid copper bars will experience corrosive attack on the hanger bar to blade joint.

After hanger bar refurbishment the ISA cathode is restored to its original condition and its electrical performance is restored. The solid copper hanger bar will lose electrical performance due to corrosive attack on the joint and sudden failure is possible. The hanger bar must be reattached to the blade. Only "re-welding" of the hanger bar will restore the performance of the cathode. The advantage of the ISA cathode is that there is no sudden failure. A scheduled removal from service can occur and repair of the cathodes can be undertaken. The solid copper bar may experience a limited Zone A as the rate of progression of corrosion of the copper to stainless joint is unpredictable.

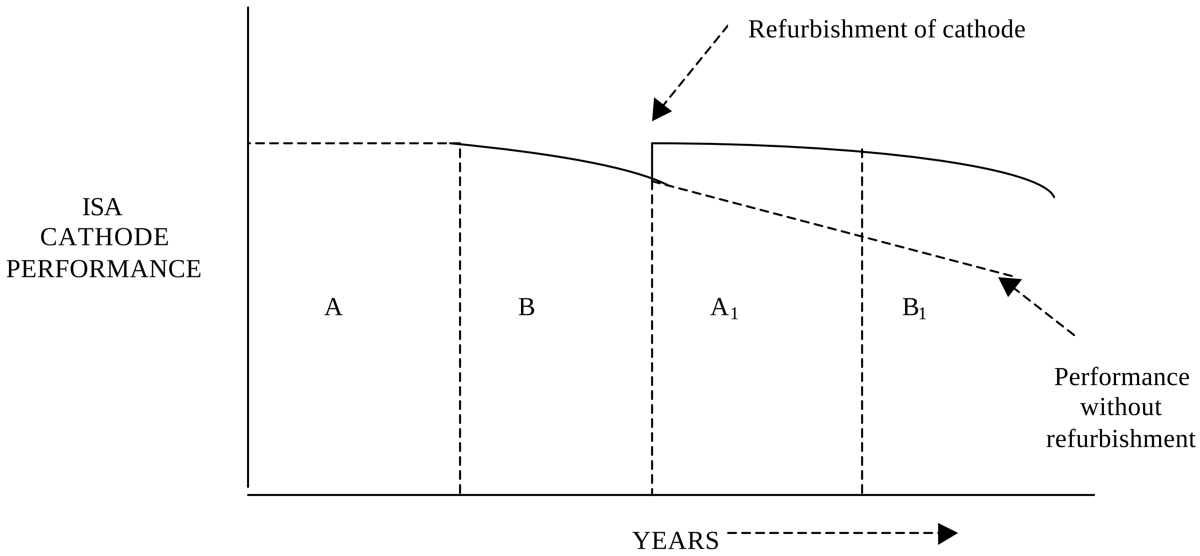

Figure 2: ISA PROCESS cathode performance

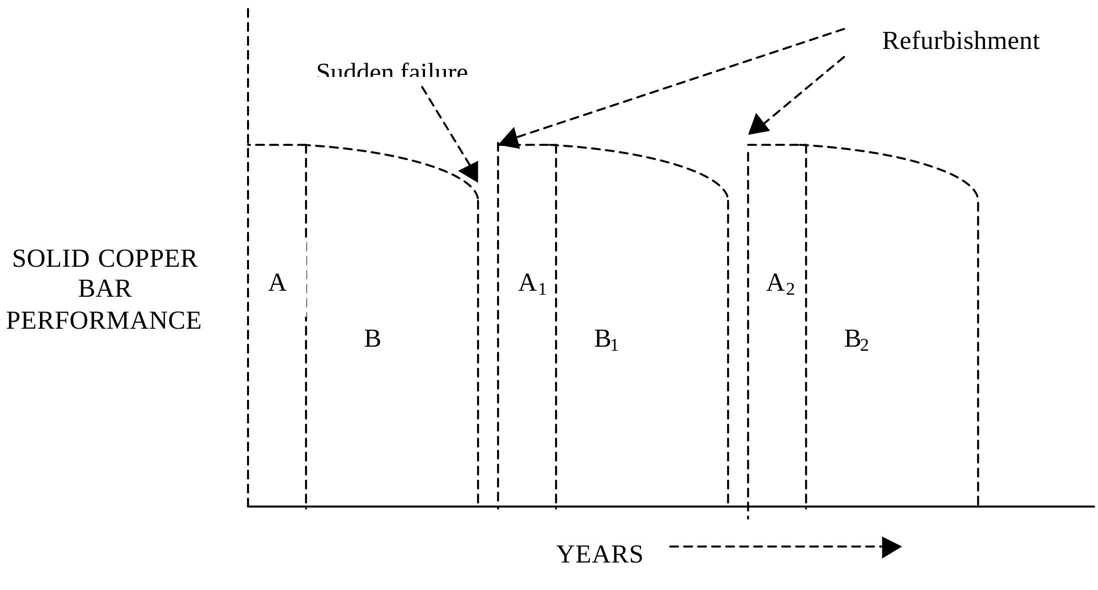

Figure 3: Solid copper hanger bar performance

The assembly of the ISA cathode provides the following key elements:-

- Great mechanical strength
- Inherent straightness, initially and in the long term
- Resistance to annealing (softening) of the hanger bar during the occurrence of electrical shorts
- Sufficient blade thickness to cope with stripping machine stresses, while maintaining the verticality necessary for high current efficiency.
- An edge masking system which is mechanically keyed into the blade.

Since commercialisation, greater than one million ISA PROCESS cathodes have been produced. They have proven to be the most mechanically robust and most corrosion resistant permanent cathode plate on the market. These characteristics are necessary to maintain high current efficiencies in the long term.

1.2.The progression of the permanent ISA cathode plate

The ISA PROCESS cathode has been continuously developed and improved since it was first manufactured in 1978. Figures 4 to 8 illustrate the progression of the ISA PROCESS system.

The first ever ISA Cathode for commercial sale was the I-beam hanger bar illustrated in Figure 4. The copper plating was an average of 1.3mm thick, this was increased to 2.5mm some years later. Prior to this Figure 5 illustrates the rounded bottom I-beam. The design improved the contact pressure and assisted with in cell verticality. The increase in average copper thickness was to improve the corrosion resistance of the hanger bar. Cathode plates with solid copper hanger bars were produced for testing in the Townsville Copper Refinery.

The next development was the move to the rectangular hollow section (RHS) stainless steel bars with a flat top as shown in Figure 6. The RHS bar gave the cathode plate greater rigidity coupled with a much simpler shape to electroplate the copper coating (Armstrong, 2001). The design was modified to a rounded RHS bar shown in figure 7. The rounded top enables a more even distribution of the electroplated copper and ensures any electrolyte will drain off the top of the hanger bar. This reduces the potential for hanger bar corrosion.

The next major development with respect to the cathode plate was the ISA2000 waxless cathode plate. This involved machining a v-groove along the bottom edge of the blade allowing for the separation of the cathode copper into two separate sheets. This eliminated the need for bottom edge wax.

Thinner RHS bars have been used in the manufacture of ISA cathodes based on customers' specific requirements. The latest cathode design, ISA Cathode BR™ is shown in Figure 8. The copper plating has been extended to just above the lifting windows and has an average thickness of 3.0mm

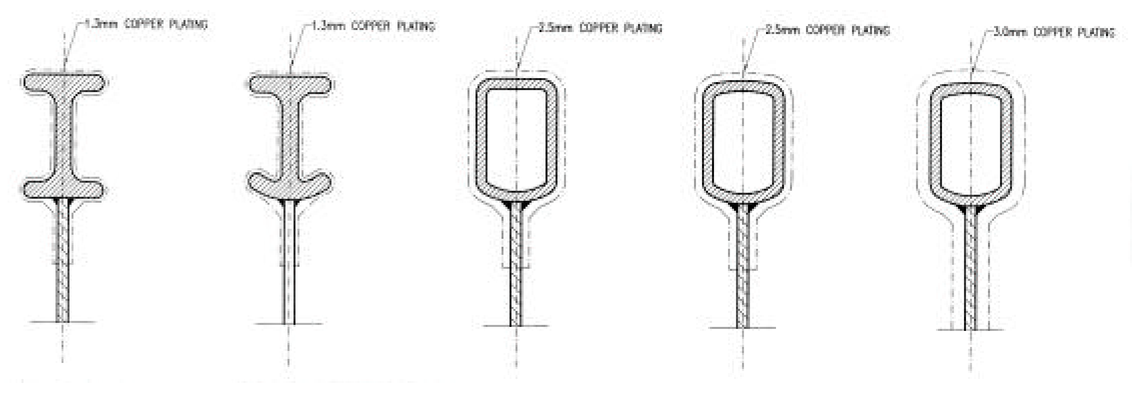

Figure 4 Figure 5 Figure 6 Figure 7 Figure 8

MARKET DEMAND FOR A "LOWER RESISTANCE" CATHODE PLATE

1.3. The earlier ISA cathodes

The earlier ISA cathodes, whilst superior in most aspects had slightly higher resistance than the solid copper hanger bar systems. In spite of the initial higher resistance, the ISA cathode will consume less power per tonne than other cathode types such as the solid copper hanger bar system. While this lower resistance is attractive, the poor long-term performance of the solid copper hanger bar led to its rejection following a large-scale trial at MIM's Townsville Copper Refinery.

Trials were conducted to compare the performance of solid copper hanger bars and ISA cathodes. Approximately 3000 cathode plates with solid copper hanger bars were manufactured and placed into service for testing. A statistical analysis on a significant proportion of tank house data was carried out. The results indicated that the solid copper hanger bars would produce a lower current efficiency than the ISA cathodes (Bailey, 1995). The difference in current efficiency was 2.4%, with crop 1 results indicating higher inefficiencies of the solid copper hanger bars (Bailey, 1995).

These differences were attributed to actual physical characteristics, such as cathode plate straightness (Bailey, 1995). The ISA cathode plate is inherently straight and maintains its integrity over extended periods of time. Even under severe shorting situations the hanger bar remains straight. This is in direct comparison with the solid copper hanger bar, which is prone to bending.

Trials were also conducted at an ISA PROCESS electrowinning plant to compare ISA cathodes with solid copper hanger bars. These trials supported the results at Townsville's Copper Refinery. They found that the ISA cathodes operated at 2% higher current efficiency than the solid copper hanger bars (4th ISA PROCESS User's Conference 1995 - Iquique).

When considering both current efficiency and conductivity, the ISA cathode plate is the most efficient cathode (Armstrong, 2001).

THE DEVELOPMENT OF THE ISA CATHODE BR™

The standard ISA PROCESS permanent cathode is electroplated with copper to approximately 15 mm down onto the blade. This ensures even flow of current into the blade and a more even initiation of the copper deposit. It was theorised that if this copper was projected further down the blade than the high resistance path through the stainless steel would be significantly reduced and a useful reduction in resistance would occur.

The ISA PROCESS Technology has now developed a low resistance cathode (ISA Cathode BR™). The concept of reducing plate resistance by depositing the copper further was theorised and subsequent calculations highlighted the impact of increasing the depth of the copper plating. An $11\mu\Omega$ per plate decrease in resistance with the copper coating down to the windows was calculated. The results showed that the further down the blade the copper coating the greater the potential energy savings.

The BR™ cathode design *differs* from the standard design in two ways:

- The copper plating extends approximately 55mm down the blade compared to 15 - 17mm.
- Increased average copper thickness of 3.0mm compared to 2.5mm.

The *benefits* of this new " high electrical performance cathode" are:

- Extension of the copper plating reduces the amount of electrical resistance that exists between the copper plating and the solution line by reducing the distance the current has to travel through the stainless steel.

- Increasing the thickness of the copper deposit provides greater corrosion resistance, particularly in electrowinning applications where cathodes may be subjected corrosive conditions. (Weston, 2002)

1.4. INITIAL TEST WORK

IPT developed some prototypes of the ISA Cathode BR™. These were tested extensively to determine the electrical characteristics of this cathode plate design. John Nielsen at James Cook University of North Queensland conducted a series of tests relating to this cathode design.

The electrical conductivities of various types of cathode plates were measured. In addition resistive models of the cathode plate were developed to show the electrical losses experienced by each of the cathode types (Nielsen, 2001)

The IPT decided that provided the copper coating does not extend below the lifting windows, no additional restriction would be placed on the operation of the cathodes and on the compatible stripping machines. The concept proved correct and further finite element analysis suggested that compared to a standard cathode, gains as high as 38% could be achieved (Nielsen, 2002). The deeper down the blade the copper coating is deposited the greater the reduction in resistance.

OPERATIONAL TESTING OF THE BR™ CATHODE

Testing of the original cathodes by the ISA PROCESS in the Townsville electrorefinery was commenced and is ongoing. The cathodes have achieved the targeted reduction in resistance while easily fulfilling the operational requirements of the electrorefining process.

A decision was made to extend the testing to electrowinning operations. Following a small test of the BR™ cathode design by a large Chilean electrowinning operation it was agreed to extend the test. Testing of a full cell load of ISA Cathode BR™ electrodes commenced in October 2002.

1.5.Test Data - Compania Minera Zaldivar

A full cell load of trial plates were manufactured to the ISA Cathode BR™ design and placed into service at Compania Minera Zaldivar (CMZ).

Figure 9. Cell load of ISA Cathode BR™ plates on trial at Compania Minera Zaldivar

Figure 10. ISA Cathode BR™ plates on trial at Compania Minera Zaldivar

Since these cathode plates have been in operation their electrical performance has been monitored and the results to date are confirmation of the earlier test work. Current distribution and internal plate resistance measurements have been recorded on a regular basis.

The potential difference between the hanger bar and solution line was measured which enabled the internal plate resistance to be calculated. The results indicate that ISA Cathode BR™ electrodes are a lower resistance cathode plate in comparison with ISA cathodes approximately 7 years old. Figure 11 highlights the difference in performance of the new ISA Cathode BR™ with the older style ISA cathode.

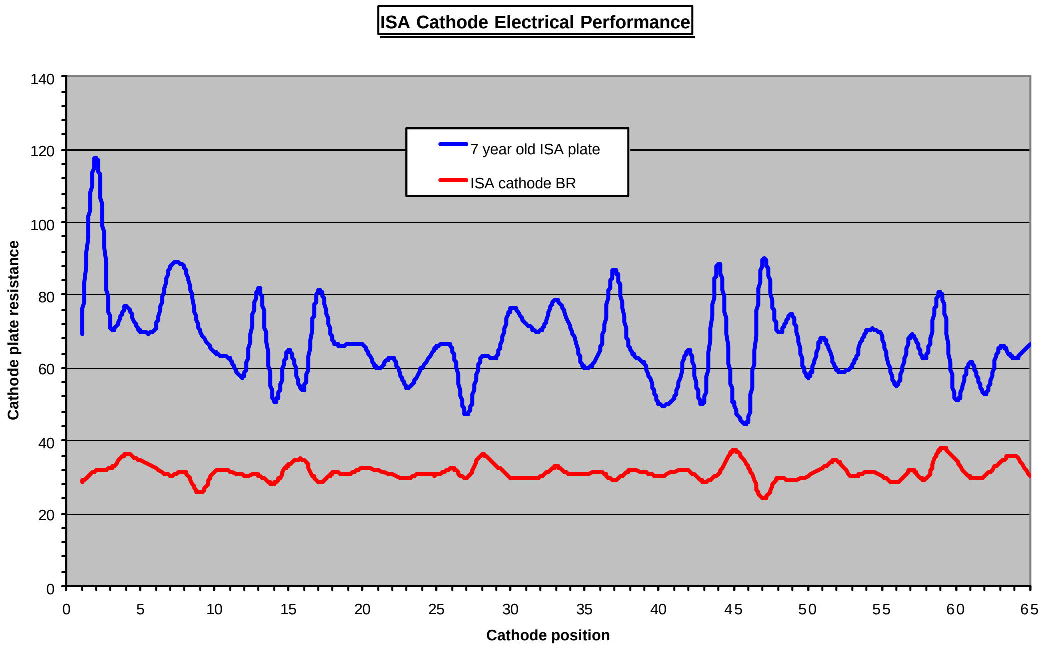

Figure 11: Graph illustrating the difference in cathode plate performance of different cathode types

Further measurements were taken at Compania Minera Zaldivar to compare the performance of a number of cathode plate designs. The results are illustrated in Figure 12. The cathode types that were used in the comparison were as follows:

- ISA Cathode BR™
- Solid copper hanger bars
- Thicker solid copper bars
- Wrapped solid copper hanger bars

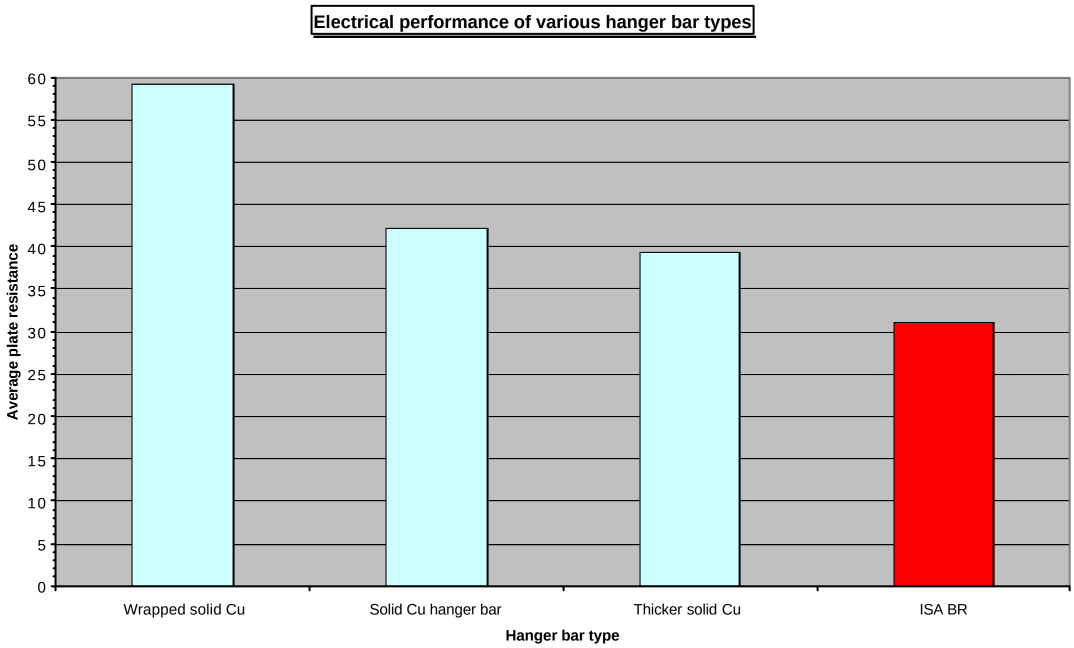

Figure 12: Internal resistance of various types of cathode plates

The results from the last set of measurements taken at CMZ on the 8th January 2003 clearly show that the ISA Cathode BR™ electrodes are electrically superior, exhibiting the lowest plate resistance.

POTENTIAL COST SAVINGS

Measurements recorded at Compania Minera Zaldivar illustrate that the ISA Cathode BR™ has the potential to reduce their power costs by approximately US$100,000 per year in a plant of this size. This is the magnitude of saving that the new ISA Cathode BR™ can provide due to their significantly lower plate resistance resulting from the increased depth of copper plating. (Data supplied by C. Pasten, 2002). This is in comparison 7-year-old ISA cathodes and solid copper hanger bars. These measurements were taken on the 15-16th November 2002. A full cell load containing the new ISA Cathode BR™ was measured along with three other standard cells which contained seven-year-old ISA cathodes and solid copper hanger bars.

Calculations showing potential power savings

Potential from contact to solution line	Average difference: 23mV
Average current per cathode plate	660 Amps
Power per cell	989 Watts per cell
Total number of cells in plant	368
Power cost	US$ 0.032 / kWh
Total power savings across the plant	364kW
Total power COST savings per year	US$102,036

Earlier tests and calculations based on data from the Townsville copper refinery also showed that significant cost savings could be made through the application of deeper copper plated hanger bars.

CONCLUSION

The permanent ISA cathode plate has undergone significant changes since its development. The latest development is the ISA Cathode BR™. Past and present test work suggests it is the most efficient cathode plate available, offering significant savings in power costs. The copper plating now extends to just above the bottom edge of the window and the average copper coating thickness has been increased. The ISA Cathode BR™ is a low resistance, mechanically and chemically stable cathode plate.

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