Development of a low resistance, low corrosion cathode plate for electrowinning and electrorefining

Nigel J. Aslin1[*1], Christian Pasten[2], Addin Pranowo[3], Graham J. Heferen[4]

1. *Glencore Technology, Australia*

ABSTRACT

For nearly 40 years Glencore Technology (formerly Mount Isa Mines Copper Refineries) has been the mainstay supplier of permanent cathode plates to the copper industry with its ISA PROCESS and KIDD PROCESS cathode plates. Improvement to the cathode plate design remains a key area for research, and on-going developments by Glencore Technology have led to the commercialisation of a new design. The ISAKIDD cathode plate is universally suited to both electro-refining and electro-winning bringing major cost efficiencies to the operations through improvements in hanger bar strength, corrosion resistance and electrical conductivity. A variation of the this design uses a 'steer-horn' shaped hanger bar to lower the resistance path across the cathode plate giving significant tank-house power savings in electrowinning refineries. Technical aspects and results of commercial trials of the ISAKIDD and 'HP' cathode plate are discussed in this paper. A novel new contact system which allows shorting frames to be used with Stainless Steel hanger bars will also be tested. Trial results will demonstrate savings in a typical EW tankhouse of up to 720k USD per year in power costs alone, with further savings in maintenance costs and operational efficiencies.

***Corresponding author**: Glencore Technology, Technical Manager, c/- Copper Refineries Pty Ltd, Hunter St, Stuart, 4811, QLD, Australia. Phone: +61 418887034. Email: nigel.aslin@glencore.com.au

INTRODUCTION

Glencore Technology were the pioneers of Permanent cathode technology for copper and remain committed to continuous improvement and innovation of the technology forty years later. The latest design hanger bar represents the most significant advance in cathode technology offered by Glencore Technology since the introduction of the Duplex cathode blades ten years ago.

The ISAKIDD hanger bar was jointly developed by Glencore Technology and their manufacturing partners Bendtech. It provides a range of operational advantages over current designs, including electrical efficiency, mechanical strength, corrosion resistance, cost of supply and life-cycle cost of maintenance.

The hanger bar consists of a Stainless Steel tubular bar with high conductivity copper core encapsulated inside the bar. The copper core is exposed at each end of the bar to form contacts and a patented weld is used to form a non-corroding and air-tight seal between the copper contacts and Stainless Steel bar (Figure 1 below).

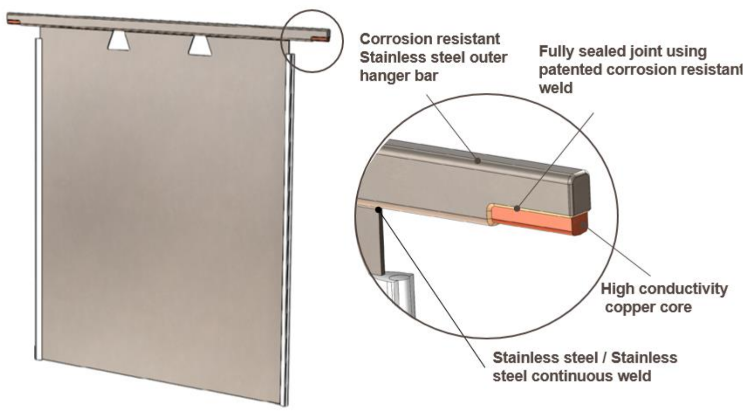


Figure 1 ISAKIDD hanger bar construction details

A mechanical bond between the copper core and Stainless Steel tube provides an efficient and robust electrical connection from blade to hanger bar. All exposed surfaces of the bar are resilient to corrosion from the tankhouse environment including acid mist, chlorides and electrolyte salts. The copper / stainless steel electrical joint is fully enclosed inside the bar and protected from corrosion. The Stainless Steel tubular bar provides mechanical strength superior to that of a solid copper bar and will not bend or sag when exposed to high temperature shorting. A homogeneous weld between the Stainless Steel blade and Stainless Steel hanger bar avoids the galvanic corrosion issues that are common with many conventional alternative designs[2].

The ISAKIDD hanger bar is equally suited to both Electro-refining and Electro-winning, however the greatest benefits will be seen in EW plants with aggressive corrosion conditions, such as cells with ventilation hoods.

The hanger bar can be manufactured as either a conventional straight bar, or a novel new 'Steerhorn' design with significantly lower power consumption. The fundamental principal of the Steerhorn design is to reduce the high resistance pathway from electrolyte to the hanger bar. Resistivity of Stainless Steel is approximately forty times higher than copper so minimising the 'freeboard' distance from electrolyte to hanger bar has a major benefit in reducing voltage drop across the cathode and ultimately reducing tankhouse power costs[3,4].

This paper presents the results of a commercial trial carried out with the Steerhorn version of the ISAKIDD hanger bar.

A second hanger bar type included in the trials is a traditional KIDD HP cathode hanger bar modified to a Steerhorn configuration for still-lower power consumption. This design consists of a solid copper bar welded to Stainless Steel blade, with a wrap-around Stainless Steel sheath protecting the weld from corrosion. The void between the sheath and copper bar is sealed internally with a resin which also prevents ingress of electrolyte and acid mist to the interior of the bar.

Figure 2 ISAKIDD Steerhorn Cathodes in service

METHODOLOGY

Trials were carried out during normal operations at an EW plant in Chile, using two commercial cells. One cell was installed with KIDD HP Steerhorn cathodes and the other with ISAKIDD Steerhorn cathodes. Plate performance was monitored over one cathode cycle (6 days) with particular focus on current distribution, power consumption, ease of handling in the overhead crane and Cathode Stripping Machine. A shorting frame test was also carried out to assess the functionality of the plates under full current load during a simulated maintenance activity.

Test Conditions;

Current density	360 A/m^2
Electrodes per cell	61 cathodes / 62 anodes
Anode type	conventional lead/calcium/tin alloy
Cathode pitch	100mm
Test duration	6 days (one cathode cycle)
Cathode deposit weight (avg)	110 kg per cathode (55kg per side)
Cathode deposit type	enveloped (KIDD Process)
Ventilation type	fan-forced cross ventilation (no hoods)

Measurements / observations during the test;

- Internal plate resistance; calculated from measured plate voltage and measured plate currents. Plate voltage was measured from solution line to copper contact using a DC voltmeter and plate current was measured using a DC clampmeter placed around hanger bars.
- Current distribution – measured individual plate currents during normal operation and shorting frame operation
- Compatibility with cranes and CSM – observation during washing and stripping operations
- Compatibility with shorting frames (old and new type) – checking current distribution and plate / contact temperatures during operation of the shorting frame.
- Two cells adjacent to test cells were used as a reference to assess comparative performance.

RESULTS / DISCUSSION

Internal Plate Resistance / Power Consumption

In a typical EW cell, internal plate resistance accounts for 2-3% of overall cell voltage[1]. The majority of cathode plate resistance occurs within the stainless steel 'free-board' zone between electrolyte solution line and hanger bar. A much smaller resistance exists in the hanger bar itself.

Steerhorn shaped hanger bar results in much shorter current path across the stainless steel blade, therefore reducing voltage drop and DC power consumption. The bar is cranked downwards in the centre to minimise the high resistance path from electrolyte to hanger bar.

Also important is the ability of the cathode plate to maintain low resistance over the full duration of its life. Conventional design cathodes use a copper weld between the solid copper hanger bar and Stainless Steel blade, which is highly vulnerable to galvanic corrosion and deterioration over time. This leads to increasing plate voltage and higher power consumption over time and on-going cycle of weld repairs every 5-8 years[2]. Inconsistent corrosion from plate to plate can also impact current distribution within a cell particularly when new plates are intermixed with older plates. ISAKIDD hanger bars have no corrodible parts exposed to the outside environment and are designed to achieve stable performance over the full life of the plate.

In the demonstration trials, Ohmic resistance of the plates was determined by calculation R = V / I (Ohm's Law) where V = measured voltage drop from electrolyte to copper contact and I = individual plate current measured with a clamp meter.

Results of the test are shown in Figure 3 below. KIDD HP plates demonstrate a large reduction in plate voltage, averaging 30μΩ per plate, approximately 60% lower than the Reference plates. ISAKIDD Steerhorn plates averaged 67μΩ, or 12% less than the Reference plates.

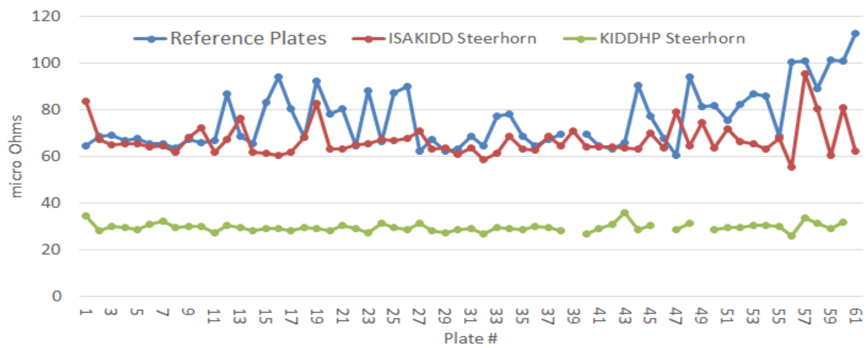


Figure 3 Internal Plate Resistance Comparison, Trial plates versus Reference plates

Power Savings

In the following hypothetical example the power savings of the HP Steerhorn plate (HPSH) is calculated, based on the plate resistance measured during the trial. The following typical EW parameters are used to demonstrate the expected savings in operating cost;

Table 1 Typical parameters and power savings, 150 ktpa EW tankhouse using HPSH cathodes

plant capacity (tpy)	150,000
current density (A/m^2)	350
current efficiency (%)	92
plate area (m^2/plate)	2
no. plates	20,328
plates/cell	66
no. cells	308
average cell voltage (mV/cell)	2,100
rectifier current (kA)	51
power consumption (MWhr/yr)	78,154
power consumption (kWhr/TCu)	1,862
power cost (USD/kWhr)	0.15

Reduction in plate resistance, HP Steerhorn vs Conventional = 46 μΩ

Equivalent voltage saving $V_{plate} = I_{plate} \times R_{plate}$

$$= 51{,}000/66 \times 46 \times 10^{-6}$$
$$= 35.4 \text{ mV (per cell)}$$

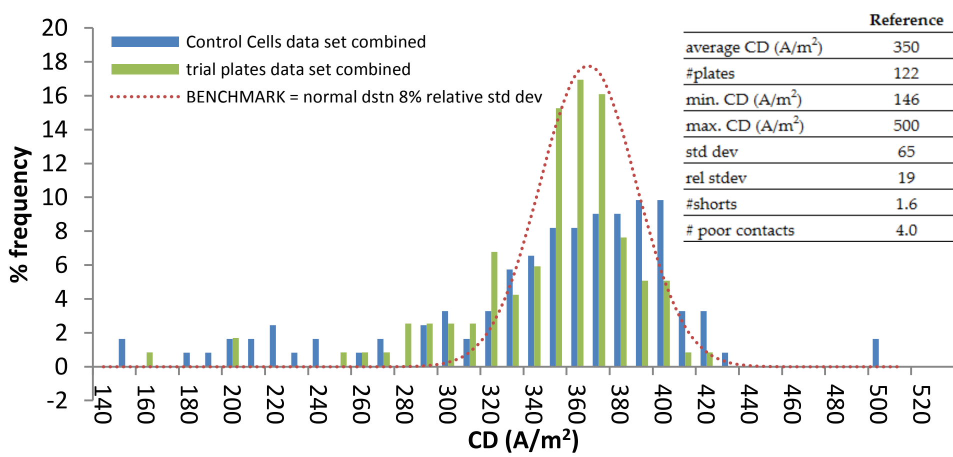
For typical cell voltage 2,100mV this represents 1.7% reduction in total tankhouse power consumption, an annual saving of 728,000 US$ per year, for the example given above (equivalent to 36 US$/plate/yr).

Table 2 Power Consumption data, Steerhorn plates versus Conventional

Plate type	plate resistance	Amps/ plate	plate voltage	plate voltage total	plate power consumed total	plate power cost	saving vs conventional	saving per plate per year
	μΩ	Amps	mV	V	kW	USD/yr	USD/yr	USD/yr
Conventional	76	770	59	18.0	916	$ 1,203,608	$ -	
ISAKidd Steerhorn	67	770	52	15.9	808	$ 1,061,075	$ 142,533	$ 7.0
Kidd HP Steerhorn	30	770	23	7.1	362	$ 475,108	$ 728,500	$ 35.8

Current Distribution

Current distribution was measured for the trial plates and two reference cells containing standard cathode plates. Current densities were measured for each cathode and plotted as a histogram (Figure 4 below).



	Reference	HPSH	IKSH
average CD (A/m²)	350	350	350
#plates	122	61	61
min. CD (A/m²)	146	193	153
max. CD (A/m²)	500	371	414
std dev	65	36	41
rel stdev	19	11	12
#shorts	1.6	0.0	0.0
# poor contacts	4.0	3.3	3.3

Figure 4 Current Distribution Trial versus Control plates

The trial plates had significantly less variation than the Reference cells as shown in the table above. Relative Standard Deviation (RSD)* of plate current density was 11% for the trial plates combined, and 19% for the Reference Plates. Ideally the data should follow a Normal Distribution with RSD less than 10%, in a 'best practice' operation (shown in Figure 4 for comparison). Major factors affecting current distribution are, in order of importance;

- inter-electrode spacing (alignment of anode to cathode)
- cathode plate internal resistance, and
- contact resistance (between hanger bar and intermediate busbar)

** standard deviation divided by average current density*

Handling Equipment compatibility

The Steerhorn plates were designed to be easily integrated into the existing tankhouse and completely interchangeable with the existing cathode plates, in terms of handling in the Cathode Stripping Machine and Overhead Cranes.

Manual overhead cranes were employed at the test site to transport the plates to and from the Cathode Stripping Machine. Handling of the SH plates was via Stainless Steel hooks welded to the top of the hanger bars, in the same fashion as the windows used in the existing plates. No handling issues were observed with the cranes throughout the trials.

Test site uses a KIDD 'Carousel' type Cathode Stripping Machine with the following steps carried out in sequence; flexing, hammering (if required), stripping and removal of copper deposit. The plates are handled via the lugs in the CSM feed conveyor system and transfer to the carousel. The standard chisel system used by these machines is compatible with the Steerhorn design plates without modification. The chisels were found to work efficiently with only 30mm freeboard (distance from electrolyte level to hanger bar) on the Steerhorn plate (reduced from 180mm standard plate). A small modification was made to one of the sensors on the feed-in conveyor to accommodate the different hanger bar shape, otherwise no issues were observed with the operation of the CSM during the trial.

Shorting Frame Compatibility

A shortcoming of hanger bar designs using full stainless steel encapsulation is they are incompatible with shorting frames which are commonly used to bridge out cells during maintenance and cleaning operations. The ISAKIDD hanger bar incorporates two secondary copper contacts on the topside of the bar which allow the use of a standard shorting frame (Figure 5 below). Shorting frame operation was tested during the trials with two different shorting frame designs.

The first frame tested was an older style frame with rigid bridging bar. Thin sheets of copper cathode were laid between the bridging bar and copper hanger bars to help distribute current across all the hanger bars, per normal operating practice. A repeat test was carried out using a more contemporary design shorting frame with spring contacts that apply even pressure to all hanger bars and compensate for small variations in hanger bar height across the cell (Figure 6 below).

Figure 5: ISAKIDD Steerhorn Cathode with top-mounted shorting frame contacts

Figure 6 Spring-contact shorting frame in operation with IK cathode bars employing

During the test, rectifier current was ramped from zero to full operating current (45kA) at the rate of 5kA per minute, while monitoring the current distribution and temperature of the plates using an infrared thermal camera (Figure 8 below). Steady state temperature distribution of the cathode plates was stable and well within the safe working temperature of the plates. Figure 7 below shows the steady-state current distribution at maximum current 45kA with normal distribution (one plate not making contact).

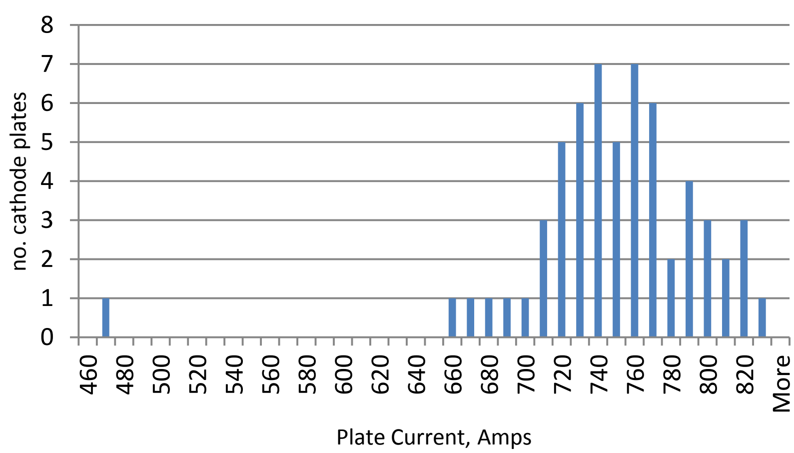


Figure 7 Current Distribution during Shorting Frame Operation

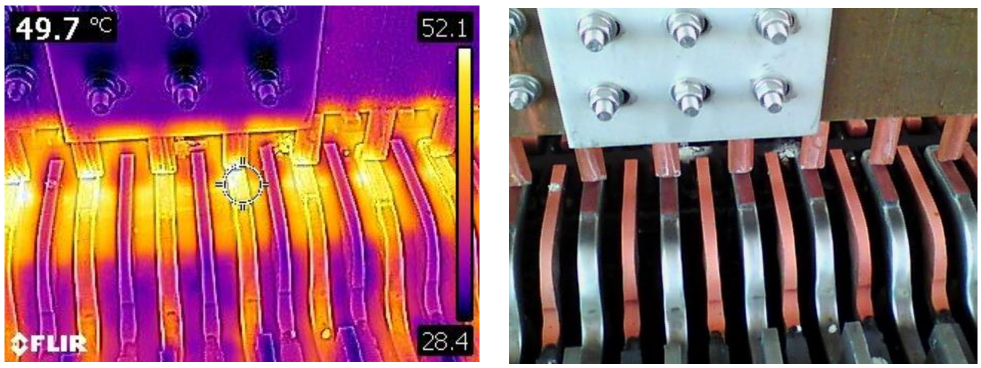


Figure 8 Infrared testing of contact temperatures during shorting frame operation

CONCLUSIONS

- Trials were successfully completed with two new hanger bar designs using a novel 'Steerhorn' shaped hanger bar.
- Major reduction in DC power consumption was demonstrated with KIDD HP Steerhorn cathode - up to 720k USD per year based on a typical tankhouse scenario.
- New design ISAKIDD cathodes offer superior mechanical strength and anti-corrosion properties to existing designs, significantly reducing repair costs over the life-cycle of the plate.
- Secondary contacts on the ISAKIDD cathodes allow use of shorting frames despite utilising a full stainless steel exterior for corrosion protection.
- Steerhorn plates were shown to be fully compatible with the cells, cranes, CSM and shorting frames, and interchangeable existing conventional cathode plates in existing operations.

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