STAINLESS STEEL "PERMANENT" CATHODE PLATES - FIXED ASSETS OR CONSUMABLES?

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ABSTRACT

Glencore Technology (GT) has over four decades experience supplying stainless steel cathode plates ("cathode plates") to the electro-refining and electro-winning industry. Cathode plates are typically the single biggest capital investment in a refinery. Refineries may view cathode plates as fixed asset or consumables depending on their operational characteristics.

This paper examines the issue of cathode plate life and the strategies and philosophies used by different plants in the management of their cathode plate asset. Some plants operate with their original plates after more than 20 years. Others accept high turnover and regular maintenance as normal operating practice. Reference data are provided on plate life for various operating plants including benchmark plants achieving best-practice plate life and operating cost. The role of the electrode handling equipment on cathode plate longevity is also examined, including latest developments in Cathode Stripping Machine, robotic copper stripping, and full-automation production cranes.

The ability to identify and manage the population of plates in service is also critical for maximising plate life and minimising its overall operating cost. This paper discusses a novel and unique RFID system for tracking and managing cathode plate inventory.

KEYWORDS

Cathode, Duplex, Electrorefining, Electrowinning, ISA PROCESS™, ISAKIDD™, Kidd Process, Permanent, Robotic, RFID, Stainless Steel, Stripping, Tracking

INTRODUCTION

Permanent cathode plates

The adoption of permanent stainless steel cathode electrodes in the electro-refining of copper was the most significant process development since the first commercial electro-refineries were built in the late 19th century. It provided significant improvement over the labour intensive and complicated starter sheet system. Copper grows over the permanent cathode blade for a number of days before being stripped, and the permanent cathode can be returned straight back to cells for the next cathode cycle.

Glencore Technology (formerly Mount Isa Mines (MIM), then Xstrata Technology) has been manufacturing permanent stainless steel cathode plates from the late 1970s with the birth of ISA PROCESS™, and the Kidd process that came one decade later. Invented and commercialised by Mount Isa Mines, the ISA PROCESS™ was first implemented into Copper Refineries Limited (CRL), Townsville, in

1978. The KIDD PROCESS by Falconbridge evolved in the 1980s and was first implemented into the Kidd Creek Tankhouse, both operations converting from traditional copper starter sheets.

Glencore Technology has supplied over 2 million cathode plates to over 100 users over the past 30 years allowing an in-depth understanding of the issues affecting cathode plate life and performance across a range of different operating conditions and types of application. The experience from technology implementation in multiple sites shows that different operations treat their cathode plates differently.

The condition of the cathode plate population and their on-going management has a major impact on the performance, and profitability of the refinery operation, including production rate, copper cathode deposit quality and operating cost.

Some plants operate with their original cathode plates after more than 20 years. They need to be mindful of the risks that a large population of plates may deteriorate at the same rate and start failing together. Others accept high turnover and regular maintenance as normal operating practice and operate with a range of cathode plate ages thereby avoiding the risk that all plates may fail together.

Operational issues affecting cathode plate life and performance are discussed in detail including various mechanical conditions (bending, poor hanging, "wobble-board" / steel instability), surface conditions (corrosion, passivation, strip-ability), and electrical performance. The importance of tailoring blade materials and hanger bar design to the operating environment is also discussed. Cost/performance trade-offs are reviewed for various blade materials from low-cost standard grade 316L to the premium Duplex (LDX) blade with higher corrosion resistance and mechanical properties.

CATHODE PLATE REPLACEMENT RATES

Electrorefining

Electrorefining operations typically have longer plate life than EW operations, due to higher level of automation in the electrode handling system (less mechanical damage to plates), less aggressive electrolyte conditions (less corrosion) and longer cathode growth cycles. Based on plates ordering history, plate replacement rates in various refineries are presented in Table 1.

Table 1. Plate Replacement Rate in ISAKIDD Electrorefineries

Electrorefining	Plant age, years	Estimated plates in service (rounded)	% replacement from startup	% replaced per year	Plate weighted age, years
ER-1	38	52,000	97	2.5	16.5
ER-2	24	48,000	88	3.6	15.2
ER-3	24	32,000	4	0.2	23.7
ER-4	20	34,000	48	2.4	15.2
ER-5	22	42,000	5	0.2	21.3
ER-6	20	47,000	13	0.6	17.5
ER-7	21	52,000	75	3.5	10.8
ER-8	17	37,000	6	0.3	16.5
ER-9	15	88,000	24	1.6	13.2
ER-10	14	21,000	18	1.3	12.3
ER-11	13	38,000	6	0.5	12.4
ER-12	12	36,000	12	1.1	10.2
ER-13	14	35,000	24	1.7	11.8
ER-14	11	33,000	17	1.5	9.6
ER-15	10	46,000	5	0.5	9.4
ER-16	8	13,000	22	2.9	7.4
ER-17	3	52,000	0	0.0	3.0

Plant age is determined from date of first start up or conversion and considered expansion timings. Plates in service includes expansions subsequent to the initial start-up. Weighted average cathode plate age shown above is a theoretical calculation, which assumes the oldest of the plates in service are replaced by new cathode plates each time a batch of new cathode plates are installed. This will not be the case in practice so actual weighted age is likely to be slightly higher than the presented values.

The ER data in Table 1 were collected from 17 electro-refineries, 15 of them are running for 10 years or more including 7 which are running for more than 20 years. Two operations use cathode plates with weighted plate age of 20+ years in their refineries. ER-1 is the Copper Refineries Ltd, Townsville. In 1978, the plant was first converted to the ISA PROCESS and in 1997–1999 went through a major expansion and modernisation (O'Rourke, 2000). The cathode plate age since major expansion/ modernisation when a large population of the cathode plates were changed and newly installed is 16.5 years.

The average cathode plate replacement rate is 1.4% per annum (Figure 1). In 6 out of 15 refineries running more than 10 years, cathode plate replacement rate is less than 1%. These operations have good cathode plate management practice in terms of accidental damage or corrosion.

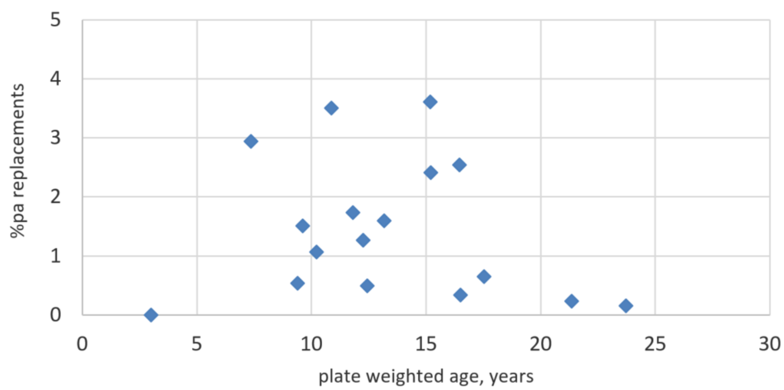

Figure 1. Electrorefinery Operating Plate Age and Plate Replacement Rate per Annum

Only 5 plants had records of replacing 2–4% per annum. Even in the highest rate of 3.6% per annum, full plate replacement will be achieved only after 27 years without a major capital replacement decision.

One concern that is yet to be determined is whether there will be a critical time when the bulk of cathode plate population fails at the same time, and a large replacement in short period becomes unavoidable. Based on historical data, so far there has been no refinery replacing large percentages of their plate inventory in one single order for this reason.

Electrowinning

Useful life of cathode plates in electrowinning plants are different to refineries. They are typically much shorter life and involve more intensive ongoing maintenance activities (Weston & Webb, 2003). There are multiple reasons which makes cathode plate life in EW shorter than ER, for example: acid mist, chlorides attack at solution line, thinner copper deposit, manual crane operation, and shorter cathode harvest cycles.

Data from selected electrowinning operations with 4–26 years of age since start-up are presented in Table 2 and Figure 2. The average plate replacement rate is 6.1% per annum, approximately 4–5 times that of electro-refineries.

Table 2. Plate Replacement Rate in ISAKIDD Electrowinning Plant

Electrowinning	Plant age, years	Estimated plates in service (rounded)	% replacement of plates in service	% replaced per year	Plate weighted age, years
EW-1	26	26,000	87	3.3	10.0
EW-2	24	7,000	114	4.8	12.8
EW-3	24	24,000	96	4.0	11.1
EW-4	23	20,000	185	23.2	7.2
EW-5	22	42,000	73	3.3	6.9
EW-6	18	16,000	66	3.7	9.9
EW-7	13	28,000	143	11.0	5.9
EW-8	10	38,000	31	3.1	6.2
EW-9	10	33,000	71	7.1	7.4
EW-10	8	12,000	22	2.8	7.7
EW-11	8	37000	43	5.4	5.7
EW-12	4	53,000	4	1.0	3.9

Among 9 electrowinning plants with 10–26 years of operation, 3 of them use cathode plates with weighted plate age of 10+ years. Average cathode plate replacement rate in this group is 6%. EW-2 has the oldest weighted plate age of 12.8 years and this plant had been operating for 24 years. The lowest reported replacement rate is 1.0% plates per annum — however this plant has only operated for 4 years. In the highest case of 11% per annum, full cathode plate replacement will be achieved after 9 years.

Note: Some plants are known to be using a majority of GT-supplied cathode plates while others are using a mixture of plates from different suppliers. Only GT-supplied cathode plates are included in the data above and to maintain accuracy, plants that are known to be using large numbers of non-GT cathode plates in their operation have been excluded from the data set.

Figure 2. Electrowinning Operating Plate Age and Plate Replacement Rate per Annum

Cathode plates in EW plants are also more likely to go through surface reconditioning process (buffing) to restore cathode strippability. The poor strippability is often related to corrosion on the blade or contamination of the steel with organics. After several buffing treatments, the blade thickness which is initially around 3.1–3.25 mm can be reduced and this can affect the steel's rigidity and long term performance.

The data point shown in red in Figure 2 represents EW-4, an electrowinning plant that replaced the majority of their cathode plates after a serious chloride corrosion event. The blade material was changed from stainless steel 316L to duplex stainless steel to combat the chloride issue. This plant had reported longer cathode plate life by changing the blade material from 316L to GT's LDX.

STRATEGIES TO MAXIMIZE CATHODE LIFE

Cathode plate and electrode handling machine selection

Efforts to maximize cathode plate life should start during the design phase of a new copper tankhouse. Critical decisions must be made to select the cathode plate, cathode stripping machine, and production crane, to insure success for the large capital investment.

Factors for consideration in choosing the correct stainless steel cathode plate design include:

- Preference of split cathode or enveloped cathode. It is typically impractical to convert from one type of product to another after start up.
- Cathode plate blade material - with regard to the design of expected handling system and exposure to corrosive environment
- Matching the cathode plate design with mine life expectancy.
- Matching electrode hanger bar design to suit method of acid mist control in electrowinning cells.
- Use of proven reputable suppliers to reduce risks of early cathode plate failures or under-performance in terms of current efficiency, power consumption and cathode deposit quality.
- Consideration of extra investment in higher-grade material for longer cathode plate life expectancy
- Trade-off between cathode plate capital cost and on-going power consumption and maintenance cost.
- Compatibility with shorting frames used for cell isolation in EW operations

Factors for consideration in choosing the optimum cathode stripping machine design include:

- Preference for split or enveloped cathode; machines cannot easily be converted from one to the other
- Expected machine throughput to match production capacity and desired working hours
- Level of automation; smaller operations with fewer maintenance resources may prefer to use semi-automated stripping machine.
- Matching stripping machine with crane capacity (and number of electrodes per cell).
- Machine with more manual interventions are usually harsher towards the cathode plate.
- Robotic CSM - stripping using robotics is generally smoother than linear or carousel stripping machine so it is expected that the cathode plates will have less operational stresses and less physical impacts.

Factors for consideration in choosing the production crane design include:

- Automated production cranes are generally less harsh on the cathode plates due to high placement accuracy and other features that align and support the cathode plates during handling.
- Manual crane and crane bale, depending on the design, can have much higher risk of causing physical damage to the cathode plates due to unwanted impacts when loading into cells and machine zones – especially in the hands of inexperienced operators.

Harvesting cycle

Cathode deposits are separated from cathode plate blade in the stripping machine using flexing devices, sometimes in combination with impact hammers to release copper from the blade. Once the copper deposits are detached, chisel blades are used to strip them completely.

Reduced cathode growth cycle and target copper deposit weight will increase the cathode plate exposure to handling/stripping processes. For example: in an electrowinning plant with 5 day cathode cycle, cathode plates will go through cathode stripping machine 80% more frequently than a electro-refinery with 9-9 days operation. The plates in the 5 days cycle, will be stripped 73 times per year compared to only 40 times in 9 days cycle operation.

In many cases, lighter cathode deposit can be more difficult to strip from the cathode plates than thicker/ heavier cathode. Targeting low cathode deposit weight may have significant impact on cathode plate life as it is more likely to involve additional flexing, manual operation and eventually hand stripping to deal with stuck copper. Hand-stripping can be particularly damaging on cathode plates as operators use a variety of methods to separate the copper including hammers, levers, bars and air chisels.

Designing with flexibility to allow a harvest cycle targeting heavier deposit to lessen stripping frequency can be applied to maximize cathode life.

Cathode plate management

Proper cathode plate management is clearly a critical factor to ensure long life expectancy of these assets. Some management best practices include:

- Good tankhouse operating practice to produce good copper deposit with consistent weight.
- Consistent plate monitoring to remove damaged plates out of the operation for repair
- Effective plate maintenance unit to ensure only good plates are returned back in service
- A long term cathode plate replacement plan

PLATE DAMAGE AND MAINTENANCE

Cathode plates are removed from operation for different reasons including: broken edge strips, bent blade, damaged hanger bar, and stuck copper deposits requiring manual stripping. Specific to some operations are blade corrosion, hanger bar corrosion, organic burn and blade degradation (which may cause sticky copper deposits or just cosmetic staining).

Damaged cathode plates need to be repaired in order to keep the operation stable. Leaving damaged plates in operation can affect plant performance such as:

- high number of shorts leading to nodulated growth
- irregular cathode weight,
- slow stripping rate as bad plate and poor copper plating causes machine downtime,

All of the above will result in lower current efficiency and lower time efficiency.

Table 3 shows the reported or estimated number of plates going through plate repair areas in 5 ER operations, and 13 EW operations. EW operations have significantly higher repair rates than ER operations even for very new operations. This is due to the different nature of EW copper deposit which is usually softer and thinner, making it more difficult to separate from the plate during flexing.

Each operation has different ways to reject the cathode plate from the stripping machine, it can be automated or manual. After rejection, the cathode plates will either be repaired or replaced depending on the severity of the damage. Repair procedures applied in the cathode plate maintenance facility can either be done manually or using mechanical equipment. Common repair tasks performed in the cathode plate repair facility are:

- Manual stripping
- Edge strip replacement
- Surface reconditioning (buffing)
- Plate straightening

Table 3. Plate Repair Estimates in ER and EW

Plant name	Plates in service (rounded)	Straightening, plates/year	Buffing, plates/year	Reweld Hanger Bar, plates/year	Replating Hanger Bar, plates/year	Estim Scrapped plates/year	% Scrap vs Plates in service
Refinery-1	52,000	5,150	-	-	-	700	1.3%
Refinery-2	47,000	3,600	-	-	-	30	0.1%
Refinery-3	36,000	9,800	4,900	-	-	900	2.5%
Refinery-4	13,000	5,600	-	-	-	40	0.3%
Refinery-5	52,000	90	55	-	-	30	0.1%
Electrowinning-1	26,000	96,000	96,000	-	8,000	2,000	7.7%
Electrowinning-2	15,000	6,000	6,000	400	-	500	3.3%
Electrowinning-3	9,000	36,000	36,000	1,500	-	1,000	11.1%
Electrowinning-4	20,000	30,000	30,000	-	1,000	1,000	5.0%
Electrowinning-5	20,000	3,600	3,600	400	-	500	2.5%
Electrowinning-6	9,000	12,000	12,000	400	-	500	5.6%
Electrowinning-7	60,000	240,000	240,000	20,000	-	8,000	13.3%
Electrowinning-8	16,000	72,000	72,000	3,000	-	3,000	18.8%
Electrowinning-9	55,000	96,000	96,000	4,500	-	2,000	3.6%
Electrowinning-10	8,000	60,000	60,000	700	-	500	6.3%
Electrowinning-11	28,000	84,000	110,000	-	4,000	4,000	14.3%
Electrowinning-12	33,000	48,000	48,000	5,000	-	4,000	12.1%
Electrowinning-13	12,000	48,000	48,000	3,000	-	2,000	16.7%

Manual stripping

Copper deposits need to be removed by manual stripping before the cathode plate goes for other repair. Primary reasons for manual stripping are when the copper deposit fails to strip in the stripping machine due to thin growth, soft copper, broken edge strip, or corrosion related sticky copper deposit. Copper deposit may also need to be stripped manually if the cathode plate is rejected to conduct a visual surface quality inspection. Manual stripping is often carried out using manual or pneumatic hammer. This process can often damage the cathode plate if not carried out carefully.

Edge strips

Edge strip replacement is the most common reason for cathode plates to be sent to the plate repair area. Cracked edge strips need to be replaced immediately, otherwise copper can grow over the edge strip and cause stripping problems. Damaged edge strips do not directly cause the entire cathode plate to be scrapped or replaced from service. During edge strip replacement work, cathode plates can be assessed for other criteria such as surface condition, flatness, and verticality to ensure only good cathode plates are returned back in service.

Blade surface reconditioning

Minor surface damage can be restored with reconditioning process (buffing) to maintain good stripping performance. Buffing process should only be applied when there is clear evidence that surface damage is significant enough to affect the stripping process of cathode deposits in the normal weight range. Poor stripping due to lightweight copper deposit must not be mistaken as a surface damage issue. Buffing will restore the cathode strippability for a certain period, after which the next buffing is required. Repeated buffing will eventually make the cathode plate too thin to be used in operation. Care must be taken to use the correct buffing method and equipment to avoid permanently damaging the cathode plate. Buffing is less common in ER operations but normal practice in many EW operations. Referring to the Table 3, some EW operations send their plates 4 times a year for surface reconditioning.

Cathode plate blade surface can also be damaged during operation for reasons such as corrosion, passivation, and scratching from machine chisel or manual tools.

- Chloride in electrolyte is known to cause pitting corrosion on 316L cathode plate. This issue is reported more from electrowinning operations than electrorefining, especially in regions known for high chloride in the make-up water. Once the blade is corroded, copper will be harder to remove. Anodic corrosion occurs when a plate accidentally becomes anodic and rapidly corrodes away. This can occur if polarity of the cell is accidentally reversed (e.g. incorrect set-up of busbar insulators or incorrect placement of electrodes), or if the cathode plates make physical contact with anodes at the same time as they are electrically isolated from the busbar contact. Severe anodic corrosion makes the blade thinner. In this case the plate is typically not repairable.
- Passivation on cathode blade makes the deposit "lacy" around the edges. Surface reconditioning can be used to restore the cathode plates and eliminate lacy edges. This phenomenon is often seen in refinery plants with aging cathode plates and is related to the deposition of impurities on the cathode plate which makes the surface electrically passive. Minimising exposure of the bare stainless steel to the electrolyte by using appropriate overlap dimension between anode and cathode plate will help reduce the risk of this occurring.
- Scratches from poorly maintained chisel blade will cause visual damage in the chiselling zone. Good chisel maintenance practice will minimize this type of damage. Chisel tips should be fitted with a softer material to avoid harsh scratching. The scratch does not usually effect cathode plate strippability and performance.

Black stains are often visible on the blades of older cathode plates, which imparts a 'mirror' image stain on the back of the cathode deposit. The stains are usually caused by natural oxidation products of the stainless steel. These stains affect the aesthetics of the copper deposit but will not affect the chemical purity, or strippability of the copper, and should not be reason to down-grade the quality of the copper product. Serious damage to the plate surface means the cathode will need to be discarded and replaced.

Non-vertically hanging cathode plate

New cathode plates should be supplied with certain blade flatness and verticality tolerance from the manufacturing process. Older cathode plates circulating in the tankhouse need to continue to meet acceptable flatness and verticality in order to prevent short circuits generation in the cell. Most of the poorly hanging plates have bent blades or hanger bars — more to be discussed in the next section. It is important to confirm cathode plate verticality is within acceptable limits after repair.

Bent plate

Rough handling in the refinery can bend cathode plates. Manual crane operation, frequent problems on the stripping machine, inexperienced operators, and manual stripping process can cause plates to bend. Other possible causes of bent plates are:

- Impacts with anodes during insertion in the cells
- Thin copper deposit difficult to strip which lead to repeated flexing at longer stroke
- Incorrectly set up stripping machine flexing stroke and reaction bar position.
- Keeping flexing order unchanged for long periods of time. In this case, typically all cathode plates will bow in one direction — matching the last flexing stroke on stripping machine. Ideally the flexing stroke is reversed every anode cycle to avoid flexing memory.

The majority of slightly bent cathode plates can still be repaired. If they are left unrepaired, these cathode plates are likely to cause repeated shorts in the cell. Irrepairable bent cathode plates must be removed from operation and scrapped or discarded.

There are several methods used by operators to straighten cathode plates including hammering, pyramid-rollers, bending with hydraulic ram, heat-distortion, peening and roller-levelling. Not all methods are successful at removing the internal stresses from the damaged steel and often the plates will revert to their bent condition after being returned to service. Peening is a simple method that restores the plate's straightness and removes memory from the steel. It only requires ball peen hammer, working table, and semi-skilled operators. Peening will leave small dents in the plate which do not affect the adhesion of copper on the plate. It should be done with care as excessive peening can compromise the plate's rigidity. After a certain number of peening processes the plates are usually deemed to be not repairable. Straightening with a roller-leveller machine is the preferred option as it reduces the human factor in straightening process, is faster and does not leave dents in the plate.

Bent hanger bar

Bent hanger bars can affect the hanging behaviour of the cathode plate. Verticality can usually be restored by twisting or hammering the bars back to their original shape. Plates with severely bent hanger bars need to be replaced.

Blade aging

After several years of use, blade material can become 'softer' and less stable dimensionally. "Wobble board" is a phenomenon when the stainless steel blade retains its bow to one side instead of staying flat. A gentle push to the middle of the blade will make the blade bow to the other side and retain that shape. This usually occurs in older cathode plates. The cathode plate stainless steel blade loses rigidity, and appears "floppy" when shaken. Good quality steel blade material should retains its rigidity longer.

Blade and hanger bar deterioration

There are refineries re-welding new stainless steel blades to existing hanger bar as economical alternative to replacing the whole cathode plate. In electrowinning, solid copper hanger bar type can be replaced with new one if major deterioration has occurred due to corrosion. Copper replating is a similar procedure to put the copper back on the ISA Process hanger bar. These procedures are not needed in electrorefineries. More on this will be explained in the discussion below around electrical performance. Quality of workmanship is critical for hanger bar or blade replacement. Poor refurbishment technique can lead to plates not hanging vertically.

Electrical performance

EW operations, especially those with acid mist suppression hood systems, are highly aggressive towards copper on the hanger bar and particularly towards bi-metallic welded joints between copper and stainless steel. In these operations, copper on the hanger bar will be corroded and gradually become thinner. Loss of copper in the solid copper hanger bar weld region increases power consumption of the plate and compromises the structural integrity of the cathode plate. This can lead to catastrophic separation of the blade from the hanger bar which is a serious safety concern. If identified early enough solid copper hanger bars can be replaced (Donaldson & Detulleo, 2003). Repairs will often require part of the blade to be cropped which can limit the number of repairs. Loss of plated copper will also increase plate electrical resistance, however the stainless steel weld between hanger bar and blade will guarantee the structural integrity of the plate even in the most aggressive environment. Hanger bars can be re-plated to restore electrical conductivity if required however this is not always practical as it requires cathode plates to be sent offsite.

CATHODE PLATE SELECTION CONSIDERATION

Blade design

Choosing the right blade material is critical. Corrosion resistance and material strength are the main factors that need to be considered. Two main blade materials in common use in the permanent cathode plate technology are 316L and duplex stainless steel. A comparison of the two materials is provided in Table 4.

SS316L comes with certain mechanical strength as determined during the steel mill manufacturing process. Higher strength 316L may attract higher price compared to the standard 316L, however this can often be justified by the longer life expectancy and better performance over the life of the cathode plate. Duplex material has different composition from 316L giving it higher mechanical strength and higher resistance towards chloride corrosion.

Table 4. Stainless Steel 316L and Duplex LDX2101 Comparison

		Duplex (LDX2101)	S/S 316L
Composition			
Cr	%	21.5	17.2
Ni	%	1.5	10.2
Mo	%	0.3	2.1
C	%	<0.03	0.02
Mn	%	5	-
N	%	0.22	<0.04
Mechanical Properties			
- Yield strength, $R_{p0.2}$	MPa	530	240–300
- Tensile strength, R_m	MPa	700	600
- Elongation, A_s	%	30	50

Cost differs between 316L and LDX depending mainly on the price of the metal constituents at the time of production. The most significant pricing factor in the past (mid 2000s) was due to the high price of nickel. More recently, the difference has been less significant.

Mechanical strength of LDX has been the most sought after feature in new orders for cathode plates, particularly in emerging market such as Africa.

Some refinery and EW plants originally designed with 316L blades have also moved towards using LDX, following extended testing periods. The higher material strength can better tolerate common operational issues that can cause excessive blade bending such as impact during insertion between anodes, excessive flexing stroke, and manual stripping.

The likelihood of chloride pitting corrosion is typically predictable during plant design. If occasional chloride spikes are likely to happen, then higher Cl-resistant stainless steel such as LDX would be an appropriate choice. Some plants also prefer to run with higher chloride levels in electrolyte for improved copper cathode quality, and this will favour the use of LDX plates over 316L stainless steel.

Hanger bar design

All hanger bars type are suitable for electrorefining and electrowinning operations. They may deteriorate differently under operational condition in each tankhouse and the various cost trade-offs need to be considered. ISA type hanger bars have been successfully used in ER and EW worldwide for more than four decades. ISA hanger bars are popular among refineries in Europe, Asia, and electrowinning plants in Africa where open tankhouses with good ventilation and low corrosion rates are common. KIDD type design with solid copper hanger bar have been used for three decades. This design is popular in the Americas. Many electrowinning plants in Chile use solid copper bar.

The ISAKIDD hanger bar design is the newest type offered by Glencore Technology. These hanger bars represent the highest level of corrosion resistance and are suitable for electrowinning plants with high acid mist levels and ventilation hoods. The copper core is fully encapsulated inside a hollow stainless steel tube. There are no exposed bi-metallic joints susceptible to corrosion. The bi-metallic joint between copper core and stainless steel bar is completely protected form the environment. The joint between the copper contact and stainless steel hanger bar consists of a specially developed seal weld (patent pending) which is highly resistant to corrosion. The joint between hanger bar and blade is a continuous stainless steel weld so the electrical conductivity of the plate is not compromised by corrosion. ISAKIDD hanger bars can also be used to replace corroded solid copper or copper plated hanger bars, where the stainless steel blade is still in good condition and usable.

The ISAKIDD hanger bar can also be modified to accept shorting frames (EW operation) by adding a secondary copper contact on top of the bar. Corrosion resistant weld (patent pending) seals the joint between the shorting frame contact and stainless steel hanger bar.

Plate identification and tracking

An innovation in managing cathode plates is RFID tagging and tracking system developed in partnership by Glencore Technology and VRT. Plates are fitted with an RFID tag which can be scanned either automatically in the cathode stripping machine or manually by operators in the repair workshop or in the cells. This allows accurate recording of the maintenance history of each cathode plate and other operational benefits such as identification of bent or damaged cathode plates. It also allows simple monitoring and comparison of the performance of different batches of plates such as those of different age. Unlike laser etched identification, readability of RFID is not affected by surface deterioration or contamination on the blade.

Effective tracking and performance monitoring of individual electrodes will be the next key step change in copper cathode systems for improved operational efficiencies and cost reduction.

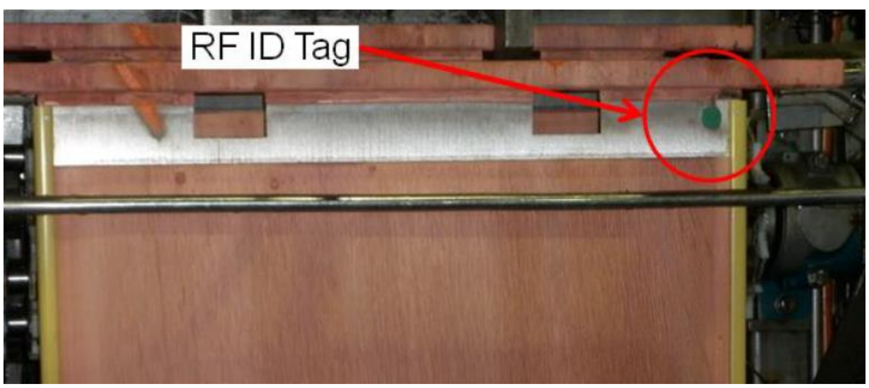

Figure 3. RFID tag on cathode plate

PLATE MAINTENANCE FACILITY

Cathode plate management must include a reliable plate maintenance program in a dedicated facility. The best configuration for a cathode plate maintenance facility is described below.

Manual stripping station

Manual stripping station can be as simple as a set of racks with air hammer or manual hammer and chisel. Complex machinery may be required to minimize manual handling. In a well-run operation, number of cathode plates to be manually stripped should be minimal, hence complex machinery is often not required.

Flatness and verticality inspection rack

This is the important unit in a cathode plate repair shop. Operator must only release cathode plates meeting certain flatness and verticality criteria. Simple rack with fixed hanging points and reference will be sufficient for quick visual assessment by operator.

Edge strip fitting machine

Edgestrip fitting can be manual or automated. Mechanised fitting tables offer higher throughput, with less potential for damage to the edgestrips. It is important that the operator cleans the edges from any remaining copper before fitting the edgestrips. Residual copper on the blade can affect the seal between edgestrip and plate surface, and also grow larger with each cathode cycle eventually causing failure of the edgestrip.

Peening table

Bent plates can usually be fixed by peening with small metal hammer. This procedure is effective at removing the stress memory from the plate and ensuring it stays straight when put back into service. It leaves minor indentations on the blade which does not affect cathode plate performance.

Roller leveller machine

Roller levellers offer faster throughput and higher success rate than other methods. Severely bent cathode plates may require roller-levelling. Similarly 'loose' or "wobbly" cathode plates that have lost rigidity may be recoverable with roller-levelling.

Plate linishing/ buffing facility

Cathode plates with surface damage will need to be buffed/ linished to restore its operability. Handheld power tools with abrasive pads are relatively easy to find. If the quantity of cathode plates with damaged surface is too high, more sophisticated belt-linishing machines may become justifiable. Good ergonomic design of the area will ensure cathode plates can be maintained properly. Capital expenditure to build a cathode plate repair facility is likely to be paid back by consistent plant performance and longer fixed asset life.

CATHODE STRIPPING MACHINE

The cathode stripping machine is a very important element in copper refining operations. Its main functions are to wash the cathode deposit of any remaining electrolyte, remove copper deposit sheets from the cathode plate, stack the copper deposits into neat bundles, and return the cathode plates back into operation. Cathode stripping machines are often equipped with automated weighing, product labelling, and automated strapping units.

Due to the permanent re-usable nature of the cathode plates, it has been a critical design requirement of electro-refineries to have an efficient and reliable integrated electrode handling and cathode stripping system. Machine operational mishaps can cause damage to the plates.

Split sheet cathode stripping machine

The ISA PROCESS™ started as split sheets where the smooth side of the copper deposit are always on the top. It enables rod producers to feed the cathode sheets one-by-one into their furnace using vacuum lifters. The ISA 2000 Waxless machine uses hydraulics to drive a set of stripping knives between the copper deposit and stainless steel blade. The ISA 2000 machines have been operating successfully in refineries and electrowinning operations since 2001. They provide full control of copper deposits, produce a split sheet copper cathode product bundle and require minimal operator intervention during stripping (Aslin, Eriksson, Heferen, & Sue Yek, 2010).

Split sheet cathode machines allow variation of deposit weight from 50–110 kg per side. The heaviest split sheet ISA PROCESS™ cathodes are produced at PT Smelting, Gresik. This electro-refinery plant operates with 7 and 12 day cathode cycles, producing 110 kg copper deposits per side on the second crop.

ISA 2000 Flexor Stripper stripping system is a development based on the proven low capacity flexor stripper system patented by GT for use in electrowinning operations to allow operation without bottom edge strips or wax (Aslin et al., 2010). The ISA 2000 Flexor Stripper uses a similar stripping function to that of the high capacity ISA 2000 Waxless machine.

Enveloped sheet cathode stripping machine

The enveloped sheet cathode stripping machine was developed for the original Kidd process. Typically, enveloped cathode weight is in the range of 80-140 kg per pair. After copper deposit removal from the cathode plates, the two sheets still joined at the bottom will be closed together and stacked on the product discharge conveyor. The cathode bundle with enveloped sheets are rough-side face up.

Robotic cathode stripping machine

Recent development of cathode stripping machines utilise a robotic system for better accuracy and consistency (Aslin et al., 2010). The Kidd process has used robots for cathode plate transfer and copper deposit bundling in stripping machines since 2003. GT has since developed new systems for robotic cathode stripping of both split and enveloped copper sheets. In addition to smooth and accurate operation the robots also adds new functionality to the stripping sequence that enhance stripping performance and helps to protect the cathode plates for longer life expectancy. The latest operation using GTs patented robotic stripping function is Antucoya EW plant, Chile, operating since 2015.

ARE CATHODE PLATES FIXED ASSETS OR CONSUMABLES?

The answer for each plant may be different considering many of the factors described in this paper. Based simply on the significant capital cost, GT advocates during design phase and ongoing operations training on site that the cathode plates should qualify as a fixed asset, especially for SXEW operations or toll smelter/refineries with long life. Cathode plate maintenance facilities and proper operational management are important in either case to minimize operating expense / sustaining capital expenditure on replacement cathode plates.

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