SCALE INHIBITION AND CONTROL: RESULTS OF A FIVE YEAR FIELD STUDY INTO UNIQUE ELECTROCHEMICAL TECHNIQUES

Scaddan R* and Laurila T

Savcor Group Ltd

Abstract

In the alumina industry, hundreds of millions of dollars are lost annually due to the effects of scale formation in process vessels and pipework. These operating losses are associated with:

- Unrecoverable product in scale
- Production losses with vessels off-line for cleaning
- Production losses when vessels are on-line because of reduction in available volume
- Steam costs for cleaning liquor
- High pressure water and/or physical cleaning costs
- Production opportunity cost with recoverable product in scale
- Management of safety issues
- Area operations personnel diverting their focus from maximising production onto scale issues.

An electrochemical technique developed by Savcor in Finland and with a (20+ year) track record of scale control in caustic liquors in the pulp and paper industry has been adapted to Bayer process liquors and the technique further tested and refined through a series of site based trials in Australia. The trials were conducted over a five year period and focused on the control of whiteside scale in seed thickeners and precipitator circuits.

The trials were conducted in three consecutive stages:

- The first trial phase established the correct operating parameters in a Bayer liquor environment and the effectiveness of these parameters by using test plates in operating seed thickeners
- The second trial phase was a 180 day campaign conducted on an overflow pipe between a first row final precipitator and second row final precipitator to confirm similar scale control could be achieved in precipitation circuits
- The third trial phase was based on the success of the first and second trial phases with a large pilot installation to a 60m diameter seed thickener completed and then operated for a period of 114 days (a normal thickener maintenance turnaround period).

The third trial phase pilot test period demonstrated reductions in scale thickness in the order of 90–95% when compared to the previous seed thickener turnaround period.

Also, without any electrochemical treatment, the seed thickener wall does not clean to bare metal and is normally returned to service with a residual 3–5mm of uniform hard scale. The residual scale film that was formed under the test conditions was able to be cleaned at lower than normal water blasting pressures and an estimated 80–90% of the tank wall exhibited complete shelling of "old" scale back to the bare metal surface.

---

1. Introduction

The Bayer process is the most common method used to produce alumina from bauxite ore, involving the digestion and precipitation of hydrated alumina. An unwanted part of this process is the formation of hard scale build-up (usually gibbsite or sodalite) in process pipes, vessels, heat exchangers and tanks. The costs of dealing with impurities (including scale) in the Bayer process are well over A$1 billion per year in Australia alone [1].

Scale in the alumina industry affects both "redside" (digestion and clarification) and "whiteside" (precipitation). Costs associated with scale include but are not limited to:

- Production losses with vessels off-line for cleaning
- Production losses when vessels are on-line because of reduction in available volume
- Steam costs for cleaning liquor
- High pressure water and/or physical cleaning costs
- Unrecoverable product in scale
- Production opportunity costs associated with the recoverable product in scale.

There are also indirect costs in:

- safety management of operations personnel and contractors involved in scale removal
- area operations personnel distracted by responding to scale issues
- increased complexity in maintenance planning
- the risk of environmental spillage.

Current methods to remove or control scale build-up include high pressure water blasting, jack hammering, on-line dissolution with caustic liquors, using sacrificial coatings (removed by water blasting) and scale retarding coatings. These methods have varying costs, labour, safety and maintenance issues associated with them.

This paper discusses successful field based trials on a unique (patent pending) electrochemical technique developed by Savcor in Finland, which were conducted at Australian alumina refineries over the past five years. The field trials culminated in a full sized pilot installation in a 60 metre diameter seed thickener demonstrating the effectiveness of the technique under normal refinery operating conditions.

2. Initial simulation (plate) trials

Scale inhibiting effects experienced when applying electrochemical corrosion protection in the pulp and paper industry worldwide led to the development of a unique anti-scaling electrochemical technique which has been used for the past 20 years.

As the technique and equipment was already developed and available and given the magnitude of the scale problem in alumina refineries, initial plate trials were commenced in June 2002 to determine its effectiveness in Bayer process scales and in particular whiteside precipitation circuits.

A set of six mild steel test plates were mounted on a Teflon backboard to provide electrical isolation between the plates and electrical isolation from the steel support frame [Figure 1]. Teflon coated conductors and special reference electrodes provided the control and measurement connections to the Savcor Lmon control and measurement module [Figure 2]. The test plates were later modified to two sets of three for ease of handling in future tests.

Figure 1.

Figure 2.

As part of the installation of the trial system, a sample of the liquor was taken from the tank and a polarisation curve was measured in the liquor using plain steel as a test electrode. The objective of the polarisation scan measurement was to define the applicable operating range in the Bayer process. The measurement was conducted using an automated measurement device from ACM Instruments.

The objectives of the tests were to determine how effective the pulp and paper industry anti-scaling parameters would be in the Bayer process environment and find the optimal operating parameters for a larger pilot installation. The operative parameter variables included polarity of the surface charge, magnitude of the charge and current feeding pattern.

Six test plates (each 550mm x 220mm) were used [Figure 3], of which, five test plates received a specific electrochemical anti-scaling treatment and one plate acted as a reference plate.

A series of tests commenced in June 2002 by lowering the test plates into seed thickener liquor with various cathodic, anodic and untreated control parameters applied. The test duration was 59+75 days, during which 10 different parameter settings were tested.

The test plates were inspected and photographed every second week and a record from the inspections was kept with remarks and notes from the inspection. Recorded data from the control system were downloaded remotely every second week and then gathered in Finland to be analysed so that the test parameters could be re-defined for the next stage of the tests.

The final photographs of the second test period are shown below [Figure 4] and a summary of the test plate results is as follows:

- Cathodic constant current parameters caused faster scaling than on the reference plate indicating the cationic nature of scale forming particles
- Anodic constant current parameters had scale-repelling properties, more so at the lower of the tested levels. This implies that unnecessary high current density may create electrochemical reaction products that adhere to the surface
- Parameters having both anodic and cathodic pulsing induced scaling with high adhesion qualities
- When pulsing with only anodic current was tested, the scale removal effect was clear. The scale composition changed significantly so that the adhesion to the steel surface was weakened. Scale even slid off spontaneously when lifting the test plates up
- Inspection of the plates after the trial revealed that the plates were in excellent condition. There was no corrosion evident on any of the plates.

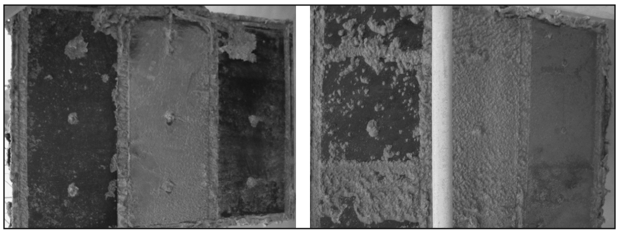

Figure 3.

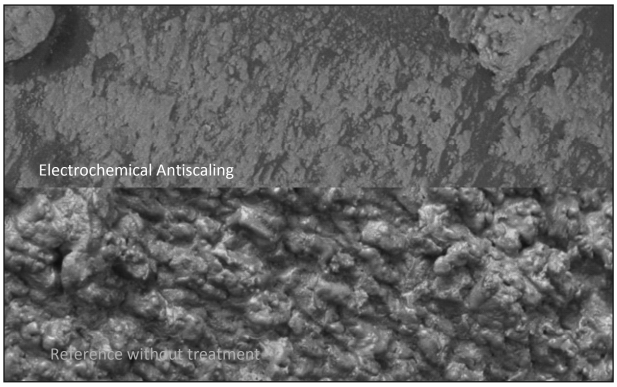

Figure 4.

3. Thickener pilot installation

In February 2005 design work commenced on a full-sized pilot installation for a 60 metre diameter seed thickener.

A conventional permanent cathode installation in a precipitator would consist of fixed cathodes designed to enable periodical replacement at service life intervals expected to be between 8 to 10 years.

A unique concept of “floating cathodes” for the thickener pilot installation was used and was driven by necessity. It was preferred that current density be directed at the thickener wall from the liquor surface to achieve the most effective voltage gradients. Had fixed cathodes been used in a thickener with large fluctuations in operating liquor level, they would have been left dry and ineffective on many occasions. This “floating cathode” design concept would not be necessary in tall precipitator vessels.

Three computerised power units were used (3 cathodes per power unit) to achieve the required distribution of current densities and these were remotely monitored and controlled from Perth, Western Australia, Finland and at site.

Pulsed anodic parameters based on the previous plate trial results were programmed and measured using a total of five Teflon coated special references, three of which were anode references spaced equidistantly around the tank wall and two cathode references to monitor cathode performance.

A small amount of hydrogen evolution was expected (Pourbaix diagram [Figure 5]) though even at the highest operating parameters was barely detectable at the cathodes.

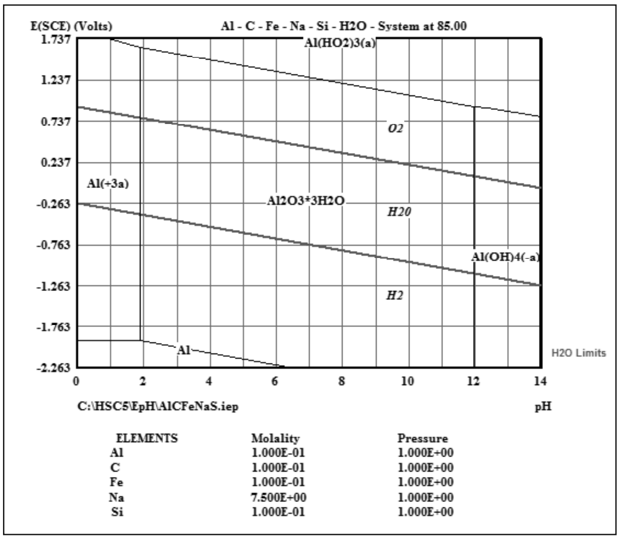

Figure 5. Pourbaix diagram

The thickener pilot study concluded after 114 days and the tank was emptied, photographed and inspected prior to routine maintenance cleaning.

The scale thickness was reduced by approximately 90–95% [Figure 7] when compared to the previous tank outage [Figure 6] with the only exception being the very top of the “tidal” zone where the surface crust was unchanged as expected because it is normally clear of the electrochemical protection zone.

A one metre wide test area was abrasive grit-blasted to a totally clean surface at the beginning of the test period. This was used to compare scale growth on a totally clean surface versus scale growth on the residual scale from high pressure water jetting on the remainder of the tank wall. At the conclusion of the test period, the grit-blasted test area showed between 2–3mm of scale only which was similar to the deposition on non-grit-blasted surfaces.

Cleaning of scale from the treated tank wall surface was also vastly improved compared to the previously untreated surface. Controlled low pressure water cleaning tests produced a better cleaning result with partial shedding of scale when compared to the routinely used high pressure water blasting which leaves a residual scale of 2–3mm.

When normal high pressure water procedures were applied, an estimated 80–90% of the tank wall exhibited complete shelling of scale back to the bare metal surface (i.e also removing the original scale that was present at the beginning of the test period and unable to be removed by high pressure water jetting at that time).

Inspection of the one metre wide test area, the remainder of the tank wall, centre well and rake blades showed no signs of corrosion.

Figure 6.

Figure 7.

4. Conclusions

Initial electrochemical scale control simulations with test plates in precipitators and seed thickeners confirmed pulsed anodic parameters under very specific control conditions were more effective than non-pulsed anodic parameters and more effective than pulsed or un-pulsed cathodic parameters.

The electrochemical technique when applied to a large vessel under normal service conditions (seed thickener) was effective in dramatically reducing scale.

The electrochemical technique is capable of removing pre-existing residual scale. This was demonstrated in pre-design cathode tests immersed in the process liquor as well as when applied to a large operating thickener vessel.

There was no evidence of corrosion to tanks, pipes or fittings when applying the technique and no changes observed by area operations in routine seed thickener performance for the duration of the test period.

References

1. *Document on WWW* Vernon, C (Project leader) 2008, *Impurities Issues Project: Objectives* Retrieved: May 20, 2008, from http://www.parkercentre.com.au/research/Impurity_Issues.html