Utilisation of a Modern Scale Management Technique for Precipitation Tanks

Pradeep Mudgala[1], Suresh Yadav[2], Ahlam AlMajrafi[3] and Ahmed AlBreiki[4]
1, 2. Senior Process Engineer
3. Process Engineer I
4. General Superintendent
Al Taweelah alumina refinery – Emirates Global Aluminium, Abu Dhabi, UAE
Corresponding author: aalmagrefi@ega.ae
https://doi.org/10.71659/icsoba2024-aa022

Abstract

Scale management in Precipitation circuits is of vital importance in an alumina refinery to ensure adequate availability of equipment for meeting the production targets. A common problem in alumina refineries is scale formation in precipitation tanks which, if not managed properly, could lead to heavy scaling in the tanks, requiring lot of time and efforts to resolve the problem and a significant production loss. At Al Taweelah alumina refinery, which is set up with an oxalate co-precipitation circuit, enhanced gibbsite and oxalate scaling was observed in the precipitation tanks during the first 2 years of operation with an impact to the precipitation yield and a potential loss of control on availability of tanks. Enhanced scaling led to longer outage of tanks, as well as frequent flow drops and availability issues of Interstage Coolers (ISCs), requiring multiple Caustic Cleaning Liquor (CCL) washes to clear scales. This paper presents how Al Taweelah alumina employed modern thermal imaging techniques, combined with heat transfer concepts, to develop an in-house estimation of the scale quantity in tanks. Through better estimation of scale formation, tank turnaround schedules were optimised and tanks exhibiting increased scaling could be identified in advance. Additionally, the paper discusses in-house solutions aimed at reducing ‘gravel’ scale impacts on ISCs, including the concept of ‘milking’ tanks (small quantity of slurry taken out from tank and passed through a trommel screen to remove some of the suspended scales from the tank), modifications to ISC scale trap design and operation. These have resulted in a significant reduction in the scale quantity in precipitators, increased availability and utilisation rate of equipment, hence leading to an improvement in yield and reduction in caustic consumption.

Keywords: Gibbsite scaling, Oxalate co-precipitation, Oxalate scaling, Precipitation yield, Thermal imaging.

1. Introduction

In March 2019, Al Taweelah alumina refinery commenced operations. Overcoming initial start-up challenges, it swiftly reached its design capacity of 2.0 Mt/a. Through continuous focus and numerous enhancements, the refinery has substantially creeped production to an impressive 20 % above its original nameplate capacity.

At Al Taweelah alumina, there are five common agglomeration tanks, that serve two trains of sixteen (16) growth tanks to the Precipitation circuit. Al Taweelah alumina has co-precipitation of sodium oxalate with hydrate in the growth trains. Eight ISCs are installed in each train to help improve productivity [2].

In the precipitation facility, hydrate is precipitated from the liquor solution. Precipitation of hydrate is maximised by cooling of the hydrate slurry. Maximising yield must be balanced against the requirement to maintain the quality specifications of particle size, strength, and impurity content. These competing requirements of yield and quality influence the cooling profile, the caustic concentration, and how mass distribution is controlled in the facility.

During startup, all precipitation tanks were initially clean. A staggered approach was employed to commence the cleaning of tanks, aiming to prevent simultaneous cleaning of multiple tanks. However, as we progressed with caustic cleaning based on the design residual life, significant scaling was observed on the tank walls and dip tubes.

Frequent changes in temperature profiles, alumina/caustic (A/C) ratio, and other parameters (particularly following oxalate precipitation) were necessary to control particle sizing. These variations in operating parameters led to a substantial increase in scaling across all tanks. Tanks equipped with ISCs were notably affected due to the temperature drops. The heavy buildup of scale significantly extended the tank cleaning duration, disrupting the management and turnaround time of precipitation tanks. This resulted in the need for a more effective scale management strategy.

This paper presents the implementation of a modern scale management technique for precipitation tanks, aiming to enhance yield and reduce tank turnaround time.

2. Scale Management.

Scale formation around the walls of precipitators has led to considerable financial expenses for the refinery. In the Bayer process, precipitation of alumina trihydrate ($Al(OH)_3$), also known as hydrate, frequently leads to significant build-up of gibbsite and oxalate scales on the internal surfaces of the precipitation tanks.

The hydrate precipitation reaction is represented by Equation (1):

$$NaAl(OH)_4 \text{ (liquor)} \rightarrow Al(OH)_3 \text{ (solid)} + NaOH \text{ (liquor)} \quad (1)$$

Sodium oxalate precipitation chemical relationship is represented by Equation (2):

$$Na_2C_2O_4 \text{ (liquid)} \rightarrow Na_2C_2O_4 \text{ (solid)} \quad (2)$$

Precipitation tanks installed with interstage coolers, located mid-growth train, have had their residual life reduced significantly due to excessive scale formation; this is indicative of a difference in scaling mechanism as compared to the front of precipitation tanks.

Gibbsite growth rates are much higher at the front of precipitation tanks and scaling at the front of the precipitation tanks is considered to be particulate fouling that shows strong inter-particle growth (crystallisation scaling), with surface coverage of very fine gibbsite particles resulting from oxalate crystallisation that has driven gibbsite nucleation [1]. Scale rate in precipitation tanks can be calculated using Equation (3).

The root cause for excessive scaling is attributed to an accumulation of organics in the process that stabilise oxalate and influence the oxalate precipitation behaviour. It is considered that the recycled oxalate and the freshly precipitated oxalate at the front of precipitation have their surface poisoned by organics in the liquor that stabilise the oxalate. These stabilising organics are likely to come in the form of humics (from the bauxite) and potentially from additives to the process, such as Crystal Growth Modifier (CGM). This causes the oxalate to precipitate once the oxalate Supersaturation (SSAT) has breached a particular threshold [3].

By establishing the new philosophy of scale management, notable enhancements achieved including:

- Improvement in hydrate yield, as accumulation of 10 cm of scale in each tank represents an estimated 0.2 g/L Yield, equivalent to ~5 830 t/a.
- Improvement in ISC performance. ISC flow issues directly impact the cooling capacity in the precipitation trains. Every 1 ºC temperature higher across both precipitation trains represents an estimated 0.5 g/L Yield, equivalent to ~14 600 t/a.
- Increasing the frequency of ISC tanks CCLW which reduced the overall scaling rates.
- No overcleaning of the non-scaled tanks.
- Maintaining residual life of the tanks in control.
- Improvement in tank availability. Precipitation tanks turnaround cycle reduced from 30 days to 10 days subsequently number of offline tanks in day reduced from average of 6.3 to 3.2 tanks/day. Availability of 1 tank extra, increases the production by 36 t/day.
- Cost consumption reduced as requirement of caustic cleaning brew reduced. Before each tank required 2 brews to clear off the scales. Currently at times, 2 tanks could be cleaned with 1 brew.
- There are also intangible gains associated to operational costs with strainers cleaning, hydro blasting for scaling removal, valve cleaning, gate cleaning, etc.

3.1 Future Opportunities

With great outcomes achieved using the scale management thermal scanning method, future opportunities are being explored, such as:

- Utilisation of drone-mounted cameras equipped with thermal imaging technology which can cover the entire circumference of the tanks for an even better visualisation and estimation.
- Development of an artificial intelligence application to automate the process of generating the temperature information from the image directly in to the excel utility. This will be automating scale calculation.
- A reliable predictive scale formation relationship to eliminate the need for thermal imaging.

4. Conclusions

In conclusion, scale management in precipitation circuits is crucial in alumina refineries to ensure equipment availability and meet production targets. At Al Taweelah alumina refinery, enhanced gibbsite and oxalate scaling posed challenges during the initial operational years, impacting precipitation yield and potentially escalating loss of control on tank availability. Utilising modern thermal imaging techniques, Al Taweelah’s in-house estimation method for scale quantity in tanks helped optimise tank turnaround schedules with proactive identification of tanks susceptible to an increase in scaling level. Aided with a good quantification of scales, additional in-house solutions implemented to mitigate scale impacts on Interstage Coolers (ISCs), including tank 'milking' via trommel screens, modifications to ISC scale trap design, Dip-tube modification and rim cleaning significantly improved the scale condition in precipitators, thereby, enhancing equipment availability and utilisation, yield, and reducing caustic consumption.

5. References

1. Alistair Gillespie et al., Scale Predominance Diagrams for Bayer Precipitation Tanks, *Proceedings of the 9th International Alumina Quality Workshop*, 18-22 March 2012, Perth, Australia, 237-244.
2. Sami Albastaki et al., Application of Split Growth in a Greenfield Alumina Refinery, *Proceedings of Alumina 2024, the 12th International Alumina Quality Workshop*, 22-25 April 2024, Dubai, UAE.

3. R.T. Chester and J.D. Kildea, Management and Control of Sodium Oxalate Precipitation in the Bayer Process, *Proceedings of Alumina 2018, the 11th International Alumina Quality Workshop*, 9-14 September 2018, Gladstone, Queensland, Australia, 60-68.
4. C.P. Kothandaraman, *Fundamentals of Heat and Mass Transfer,* 3rd Edition, New Age International, 2006, pages 30-40.