

## Mitigating the Impact of Varying Alumina Sources on the Smelting Process

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### Abstract

The quality of alumina, in particular the quality of Smelter Grade Alumina (SGA), is paramount in the Hall-Héroult process, the predominant process for aluminium production. Ensuring stable and productive cell operations, achieving high metal quality for the cast house and minimizing environmental impact are critical aspects that depend heavily on the consistency of SGA properties. Only with reliable and constant SGA can smelters adapt and optimize their equipment, operating practices, and control parameters to achieve the highest possible efficiency.

Given the global variations from raw materials and the Bayer process, refineries often produce SGA with differing physical and chemical characteristics. Consequently, aluminium smelters strive to procure alumina with consistent specifications to mitigate adverse effects on production efficiency, process stability, and environmental performance. Despite these efforts, variation in SGA is at times inevitable, requiring adjustments in the reduction process to accommodate these changes. Any significant change in SGA properties can potentially impair the effectiveness of alumina reduction due to non-optimized control parameters established around processing relatively consistent SGA.

The operational efficiency and economic viability of aluminium smelters are significantly influenced by factors that compromise the consistency of SGA properties. These factors include price fluctuations, refinery issues, fluctuating freight costs, supply chain disruptions, geopolitical issues, and natural resource depletion.

This paper aims to investigate the advancements in mitigation strategies employed by Alcoa and its smelters in recent years, focusing on pot process control practices related to SGA variability. Considering the frequency of variation in SGA sources and the mitigation exercised via flexibility in operational practices, the ability to adapt quickly could expand the range of SGA sources that can be utilized, which were otherwise not considered.

**Keywords:** Smelter Grade Alumina, Feed control strategy, Alumina dissolution, Flow funnel sensor, STARProbe™.

### 1. Introduction

Alcoa, as a vertically integrated aluminium corporation, engages in multiple stages of the aluminium production process, encompassing bauxite mining, alumina refining, aluminium production (including smelting and casting), and energy generation. Smelter Grade Alumina (SGA) produced in Alcoa's refineries is distributed to both internal and external aluminium smelters. However, for logistics considerations or when the internal demand for SGA occasionally surpasses the production capacity of Alcoa's refineries, procurement of SGA from external suppliers is sometimes needed to fulfil internal requirements.

Refineries produce SGA with differing physical and chemical characteristics, depending on the raw materials they use and on the Bayer process lead [1, 2]. The variability in SGA sources, or more specifically the transition between different SGA sources, presents more than occasional challenges, particularly for smelters situated at a distance from the refineries. Smelters located in proximity to refineries are evidently better positioned than those situated remotely. Nonetheless, reliance on a single refinery can also result in quality challenges in terms of dependence on SGA sourcing and specific problems within the refineries.

SGA plays, as stated before, a fundamental role in the aluminium production process. Particularly in the electrolysis stage where alumina is dissolved in molten cryolite to produce aluminium. The quality and characteristics of SGA significantly influence various aspects of the smelting operation. This paper only focuses on the process impact, although SGA variability has a broader impact outside of the smelting process.

#### Impact on the Process

- **SGA impurities:** The presence of impurities in SGA, such as phosphorus or sodium, can adversely affect the electrolysis process. These impurities can reduce current efficiency, increase energy consumption, and lead to the formation of unwanted by-products, thereby impacting overall productivity.
- **SGA dissolution rate:** The flowability of SGA inversely correlated to its dissolution rate in the electrolytic bath. High-quality alumina with optimal flowability dissolves more efficiently, ensuring a steady supply of aluminium oxide for the reduction process. Conversely, poor flowability can lead to the formation of alumina rafts, which hinder dissolution and disrupt the process.

#### Impact on Pot Performance

- **Current efficiency:** Optimal SGA quality ensures high current efficiency, which is crucial for maximizing aluminium production. Impurities and poor flowability can reduce current efficiency, leading to lower output and increased energy costs.
- **Pot stability:** Consistent SGA quality helps maintain pot stability by preventing the formation of alumina rafts and mucking. Stable pots operate more efficiently and require less frequent interventions, reducing downtime and maintenance costs.
- **Anode effects:** Poor-quality SGA can increase the frequency of anode effects, which are disruptive events that cause voltage spikes and reduce current efficiency. Managing anode effects requires additional energy and resources, impacting overall pot performance.
- **Environmental:** Hydrogen Fluoride (HF) emissions during the electrolysis process, coupled with inadequate scrubbing mechanisms, represent a substantial environmental challenge. The insufficient HF capture efficiency of smelter grade alumina (SGA) not only exacerbates environmental pollution but also disrupts the fluoride (F) balance within the reduction pots. This disruption can lead to inefficiencies and operational instability in the electrolysis process.

In conclusion, SGA properties are critical factors influencing the efficiency, stability, cost-effectiveness of the aluminium production process, and environment. By continuously optimizing the process for a given SGA, aluminium producers can optimize their pot performance, reduce operational challenges, and achieve greater productivity. To address these challenges, Alcoa has deployed several practices aimed at ensuring stability in the reduction cells and mitigating, or at least delaying, the adverse transitional effects associated with varying SGA sources.

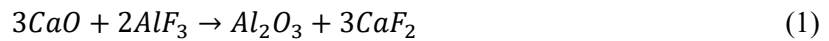
## 2. Properties of Smelter Grade Alumina

SGA is produced globally from a variety of bauxites having different quality, which often require differing processing conditions. Each source of bauxite contains an array of impurities [3]. These impurities matter when they enter the molten electrolytic bath.

### 2.1 Calcium and Sodium

Two major impurities in SGA directly impact the bath chemistry are calcium and sodium [3, 4]. Ideally the amount of CaF<sub>2</sub> in bath should be between 5% and 6.5%. A high amount of CaF<sub>2</sub> in bath deteriorates the bath metal interface, leading to higher bath carry over during metal tapping and changes the metal roll behaviour [5]. As CaF<sub>2</sub> also impacts the molten bath liquidus, adjusting bath ratio/excess AlF<sub>3</sub> target might be in order. CaF<sub>2</sub> content also influences the anode cover hardness. A general belief exists in some smelters that calcium fluoride content does affect the workability of the anode crust.

AlF<sub>3</sub> must be added to liquid bath to maintain the fluorides mass balance. Introducing CaO via alumina impurity creates CaF<sub>2</sub> (Equation 1)



CaF<sub>2</sub> has a significant impact on the liquidus point of the liquid bath, particularly in systems involving cryolite (Na<sub>3</sub>AlF<sub>6</sub>) and excess aluminium fluoride (AlF<sub>3</sub>). Adding more CaF<sub>2</sub> to these electrolytes generally lowers the liquidus temperature [6]. This effect is beneficial for aluminium production as it allows the electrolysis process to occur at lower temperatures, which can influence the efficiency and energy consumption. The catch, however, is to keep the CaF<sub>2</sub> relatively constant and within a certain range. When CaF<sub>2</sub> over time changes significantly a modification of bath ratio or excess AlF<sub>3</sub> might improve process conditions, as depicted in Figure 1. This enables to avoid negative impact on alumina dissolution, liquidus and superheat.

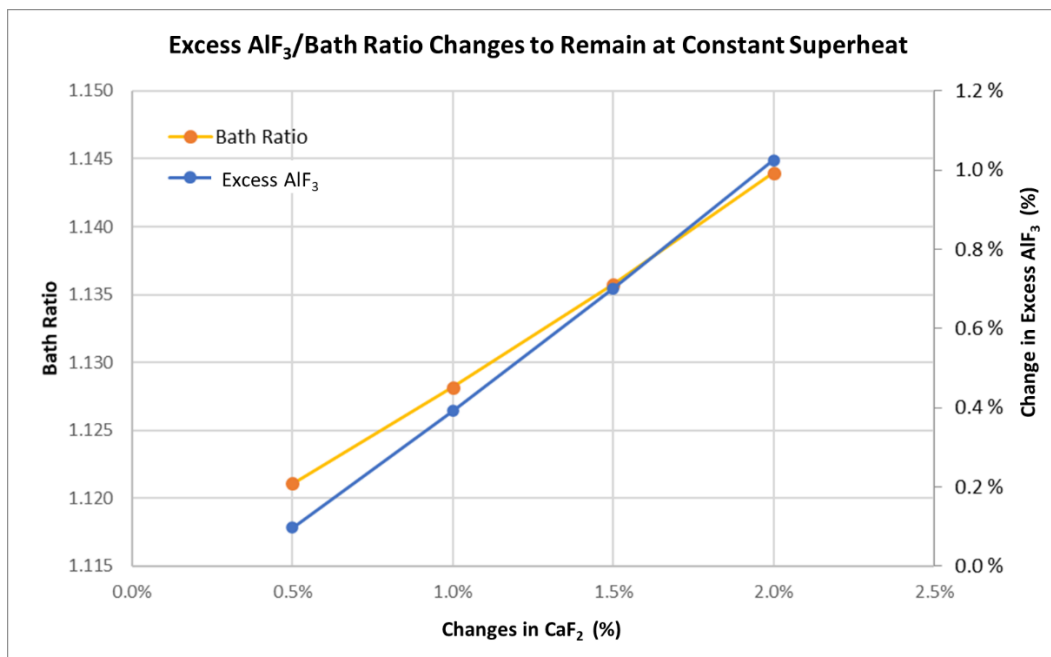
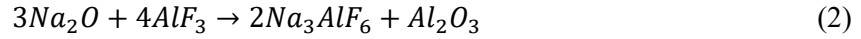


Figure 1. Effects of increasing CaF<sub>2</sub> on bath ratio/excess AlF<sub>3</sub> target requirements.

The CaF<sub>2</sub> tends to accumulate over time and can go out of control if nothing is done to keep the concentration in the desired range of 5 % to 6.5 % The mechanism to control the amount of CaF<sub>2</sub> is dilution by generating pure liquid bath with no CaF<sub>2</sub>. The most cost-effective way of controlling the generating of bath is through the second major impurity, Na<sub>2</sub>O (Equation 2).

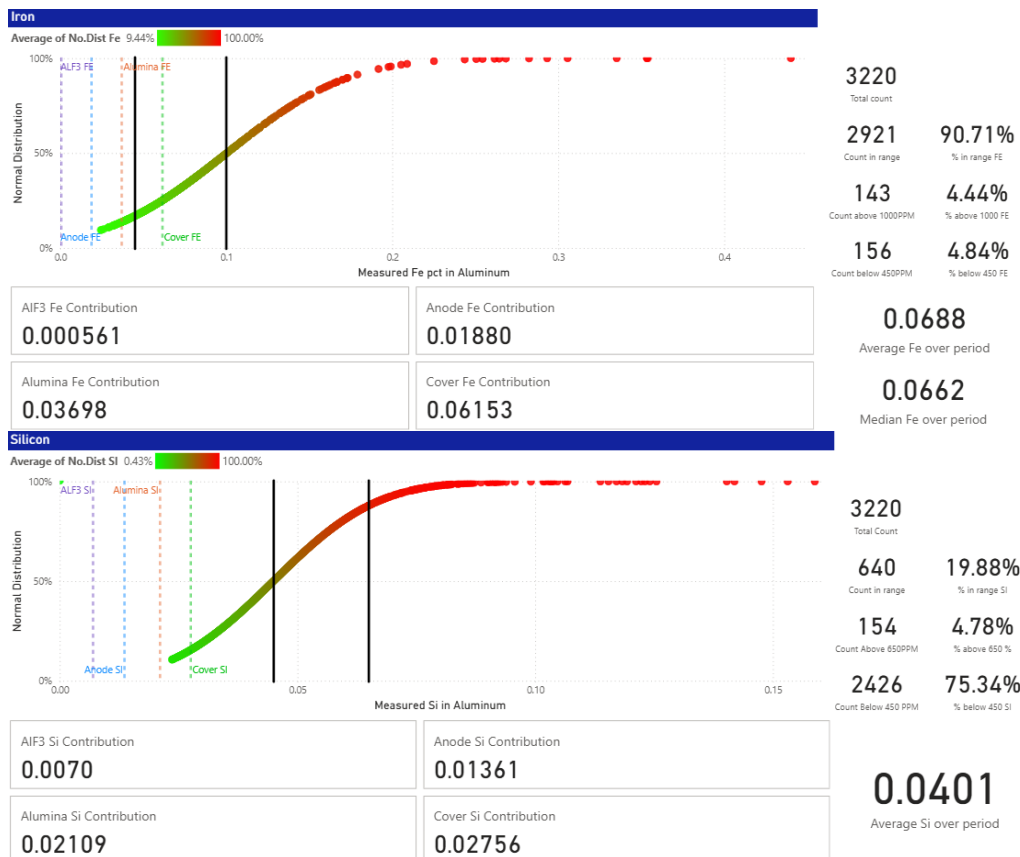


The other way of producing bath is by producing calcium fluoride-free units of electrolyte via additions of sodium carbonate, Na<sub>2</sub>CO<sub>3</sub> (soda ash) and aluminium fluoride. Direct additions of synthetic cryolite may also be used, but this is cost-prohibitive [7]. Most aluminium smelters are considered bath producers due to sodium coming from alumina, reacting with fluoride, leading to a production up to 50 % of their bath inventory [3]. To avoid metal quality issues, it is pivotal to always control bath level.

To avoid the negative impact of increasing CaF<sub>2</sub>, the ratio CaO/Na<sub>2</sub>O is one important parameter to consider. A CaO to Na<sub>2</sub>O ratio of less than 8% will dilute the CaF<sub>2</sub> content in bath, leading to its concentration reduction. A (10 ± 2 %) CaO/Na<sub>2</sub>O ratio is considered as “balanced”, which would maintain the concentration of CaF<sub>2</sub> in bath stable and in a desired range.

## 2.2 Other Impurities

Phosphorus, silicon and iron are important impurities in alumina used for aluminium production due to their significant impact on the efficiency of the electrolysis process and the quality of the produced aluminium in the cast house. Si and Fe impurities ending up in the aluminium metal can affect its purity (Figure 2).



**Figure 2. Monitoring the effects of increasing Fe (Top) and Si (Bottom) on metal quality.**

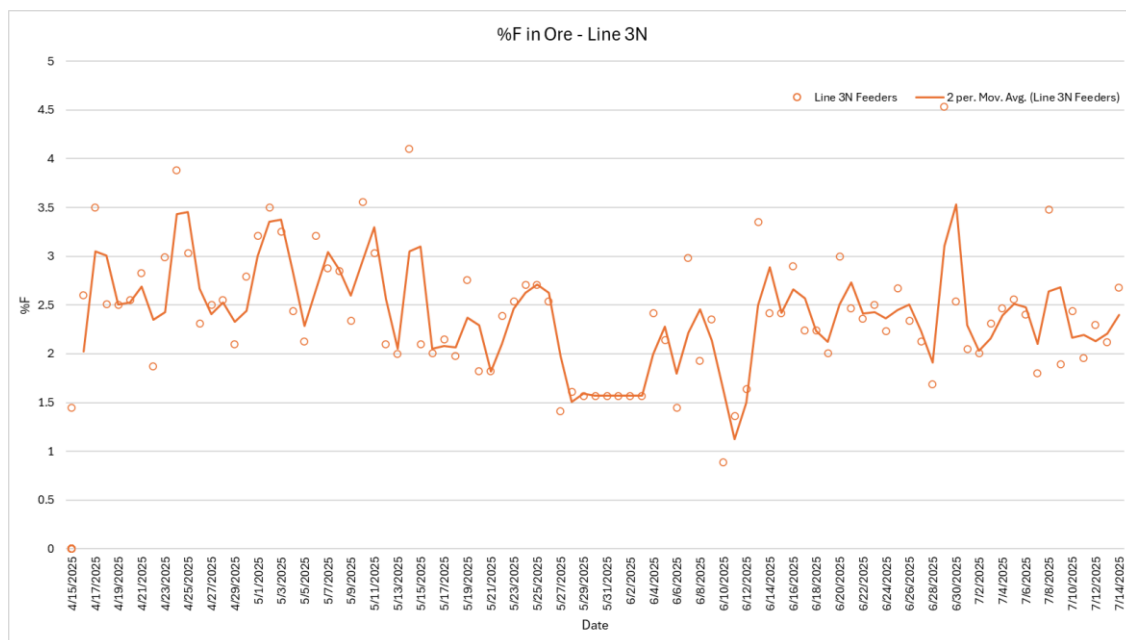
Figure 2 illustrates the overall distribution of silicon (Si) and iron (Fe) within the pots. The graph also projects the contributions of Si and Fe from various sources, including anode quality, alumina, AlF<sub>3</sub> additions, and cover material. In the example provided, 0.02109 percentage point of the total Si is expected to originate from alumina. The numbers can be utilized to identify the primary contributor to the total Fe/Si content in the metal and to estimate the minimum achievable Fe/Si values.

Phosphorus impurities are detrimental to the electrolysis process. They are often referred to as "poison" to current efficiency, because of their significant negative impact. The cyclic redox reactions caused by phosphorus interfere with the aluminium deposition process, leading to a decrease in current efficiency by about 1 % for every 100 ppm of phosphorus added [3].

### 2.3 Impact of Physical Properties

#### 2.3.1 Fluoride Absorption

Hydrogen fluoride (HF) from the smelting process is bound to Smelter Grade Alumina (SGA), primarily through adsorption processes. SGA with a higher specific surface area tends to have a greater capacity to adsorb fluoride. In addition, alumina with a higher Loss on Ignition (LOI) content has more active sites available for HF adsorption. These active sites are crucial for effectively capturing HF from the gas phase. Higher LOI content often correlates with increased surface area, providing more opportunities for HF molecules to interact with the alumina particles. This relationship is monitored, potlines with pushed load preferable need a surface area of > 70 m<sup>2</sup>/g and a surface area / % LOI ratio > 85. As can be seen in Figure 3 the F adsorption can fluctuate. This can happen either by changing the alumina source or a problem at the GTC (Gas Treatment Centre).



**Figure 3. Monitoring the % of fluoride in alumina.**

#### 2.3.2 Density

Density is a fundamental physical property that influences the behaviour of alumina during the smelting process. Most smelters employ volumetric feeders to introduce alumina into the

electrolytic cells. A significant change in SGA density requires adjustments to the base feed interval to ensure the correct amount of alumina is fed into the pots. This adjustment is crucial for maintaining the designed feed rate and achieving optimal smelting conditions. Figure 4 shows the impact of density and the required change of base feed interval.

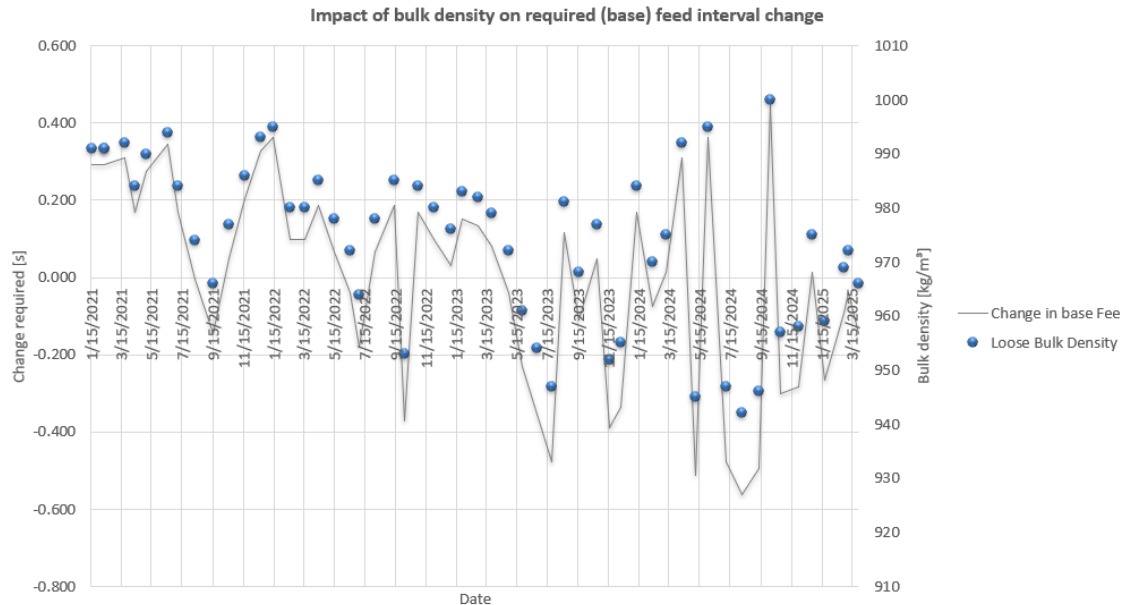


Figure 4. Impact of density on required change in feed.

### 2.3.3 Particle Sizes

The primary focus of smelters for effective feed control is on the particle sizes of coarse particles (% of +100  $\mu\text{m}$ ), fines (% of -45  $\mu\text{m}$ ), and super fines (% of -20  $\mu\text{m}$ ). These particle sizes significantly influence the dissolution rate in the liquid bath. Additionally, a high proportion of fines can lead to several issues:

- Ensuring a uniform particle size distribution with a reduced proportion of particles smaller than 20  $\mu\text{m}$  can significantly enhance the flowability of alumina. Smaller particles, such as those under 20  $\mu\text{m}$ , possess higher surface area-to-volume ratios, which intensifies the cohesive forces between them. This increased cohesion leads to a greater tendency for these particles to agglomerate, thereby decreasing flowability. Improved flowability ensures more consistent feeding rates, which is crucial for maintaining stable operating conditions within the electrolysis cells.
- Formation of rafts: Fines floating on the bath surface tend to aggregate, forming structures known as rafts. These rafts cause excessive bath freezing around the agglomerates, increasing shell thickness and leading to the muck formation.
- Handling and processing complications: The presence of fines can complicate handling and processing, increasing the likelihood of alumina particles adhering to surfaces and forming scale.

### 2.3.4 Flowability

Flowability is quantified by measuring the time required for a given quantity of SGA to pass through a funnel. This measurement is referred to as the Average Funnel Flow Time (AFFT). A shorter AFFT correlates well with fast dissolution rate, whereas longer AFFT values suggest inconsistent flow characteristics and a higher propensity for alumina to form clumps, which subsequently lead to muck formation.

### 2.3.5 Attrition Index

The Attrition Index (AI) quantifies the mechanical strength of alumina particles. High AI values indicate a higher propensity for the generation of fines and super fines during alumina transport. This increase in fines is primarily attributed to mechanical handling within GTC and the transportation of alumina from the silo to the electrolysis cell [8].

### 2.3.6 Alpha Content

High alpha phase alumina exhibits a slow dissolution rate. Consequently, it tends to settle beneath the molten metal, contributing to the formation of muck.

## 2.4 Transformation of Smelter Grade Alumina

The primary objective of effective feed control is to introduce SGA through the feeders in a manner that allows the alumina optimal access to the liquid bath. Upon immersion into the liquid bath, the alumina must be uniformly dispersed. The transformation process encompasses the following stages:

- **Sinking and floating:** The initial behaviour of alumina particles, whether they sink or float, is directly related to their density. Proper feed control ensures that alumina particles have optimal access to the liquid bath (open feeder holes)
- **Formation of frozen bath:** Dense alumina particles contribute to the formation of a frozen bath around alumina particles. This frozen bath must melt back uniformly to allow for effective bath infiltration.
- **Frozen bath melt-back:** With sufficient superheat, frozen bath will melt and expose the alumina to the liquid bath
- **Bath infiltration and distribution:** Infiltrate the bath and disperse uniformly. Higher density alumina may penetrate deeper into the bath, while lower density alumina may remain near the surface (rafts)
- **Increase in density:** As alumina dissolves, the density of the bath increases, impacting the rate of dissolution
- **Initiation of dissolution:** The initiation and rate of dissolution, which is critical for maintaining consistent smelting operations.

Any disruption in the phases as mentioned above can lead to dissolution issues as the occurrences of anode effects and the accumulation of undissolved alumina on the cathode surface. Keeping track of critical indicators and adjust the pot control to mitigate the deterioration of the process are vital.

## 3. Mitigation of Varying Alumina Sources

Varying critical SGA properties can have a significant detrimental impact on the smelting process if no actions are taken to mitigate them. To address those impacts, Alcoa developed different countermeasures ranging from better monitoring of critical parameters, development of new sensors, hardware optimization, changing the control system to automatically adapt to a change in alumina source or manual intervention if required.

### 3.1 Monitoring of Critical Parameters

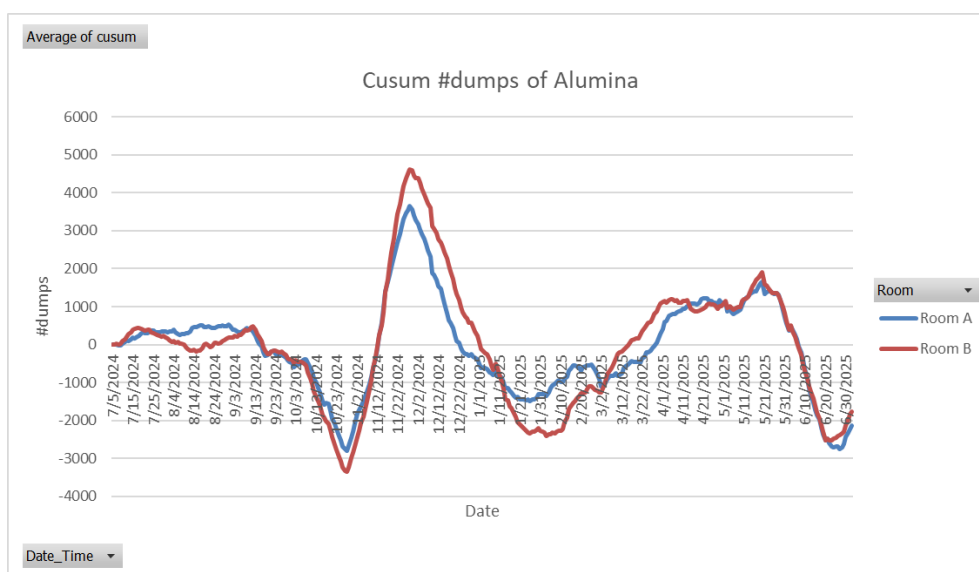
Monitoring of the process is divided into two segments. The first segment involves the examination of the official client Certificate of Analysis (COA), Not all COA are mentioning all

critical properties, and a lab analysis might be necessary. Key Performance Indicators commence with an understanding of the particulate characteristics of the alumina source that is currently in use or will be utilized, as well as the anticipated quantity. It is imperative not only to consider the quality and quantity of the material expected but also to acknowledge that the levels within the alumina silo can significantly influence the effect of SGA on the behaviour of process. Implementing an effective SGA inventory management system and adhering to best practices when introducing new quality into the electrolysis cells is essential.

The second monitoring segment involves monitoring specific smelting process characteristics to ensure that the process control system is functioning in an optimal fashion and does not require human intervention. These characteristics include:

- **Anode effect duration and frequency:** Monitoring the duration and frequency of anode effects to assess the stability of the electrolysis process. See Figure 5, the second graph.
- **Cumulative Sum (Cusum) of alumina consumed:** Adapted from [9], involves tracking the cumulative consumption of alumina to ensure consistent feed rates. The cusum gives an indication if the pot is consuming more alumina (upward trend) than usual or that it is feeding from the cathode (downward trend). See Figure 5, top graph.
- **Track time:** Measuring the time being in the underfeed phase to maintain optimal feed levels. See Figure 5, third graph.
- **Number of dumps:** Recording the number of alumina dumps to evaluate feed efficiency.
- **Difference between base feed interval and actual feed interval:** Comparing the base feed rate with the actual feed rate to identify discrepancies. See Figure 5, bottom graph.
- **Automated base feed correction (fast feed Modifier):** Utilizing automated corrections to adjust the base feed rate promptly.
- **Number of overfeeds:** Monitoring the frequency of overfeeds to prevent excess alumina addition.
- **Pot audits:** Regular audits on feeder hole condition, e.g. blocked feeders and the occurrence of volcanoes.
- **Measurements:** Special measurement campaign to check the amount of material fed into the pot in relation to density of alumina fed.

A combination of these indicators provides a comprehensive understanding of the feed requirements and identifies areas where the control system may require assistance.



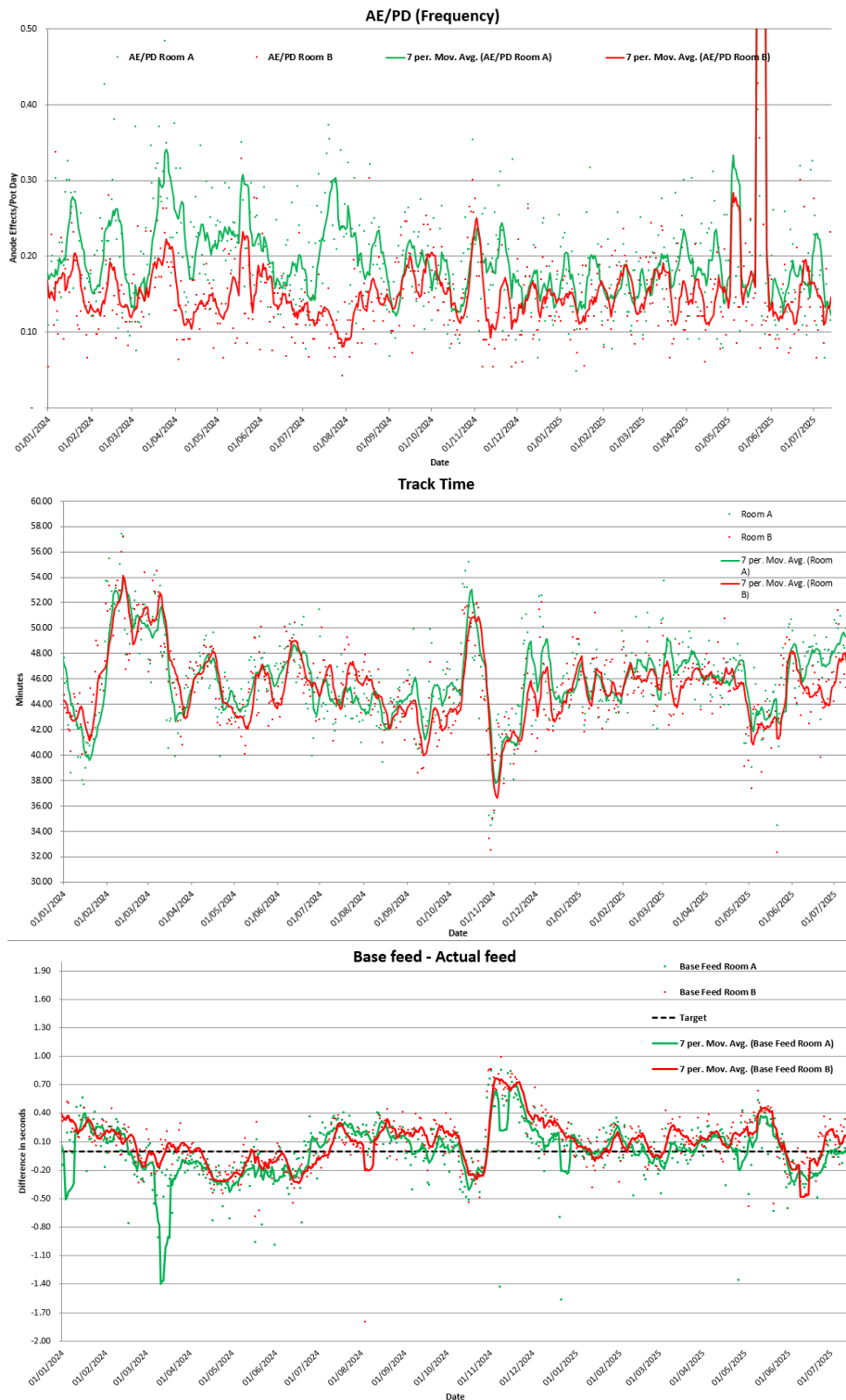


Figure 5. Monitoring of critical process properties

### 3.2 Sensors

The integration of supplementary sensors enables on-line identification of alumina-related issues. Significant advancements have been achieved in the development of these sensors.

### 3.2.1 Flow Funnel

The flow funnel test constitutes a critical component of the assessment protocol for SGA. This test is employed to measure the flowability of alumina. The reduced flowability of alumina adversely impacts its dissolution rate when introduced into smelting pots. This negative effect is primarily attributed to an elevated fines content, which fosters the formation of persistent alumina rafts, thereby increasing the risk of mucking.

In response to these challenges, Alcoa has developed an online sensor equipped with a predictive model designed to infer the flowability of alumina at the point feeder. This system aims to automate responses to high fines dosed into the electrolysis cell, which are challenging to manage manually. Preliminary tests have demonstrated potential results in mitigating the occurrence of sludging pots.

### 3.2.2 STARProbe™

Bath properties such as temperature, superheat, and chemistry can now be precisely measured with automatic data transfer to the plant historian. Industrial devices such as the STARProbe™ are widely utilized at Alcoa [10]. The use of Alcoa’s STARProbe™ has proven to be effective in determining not only the excess aluminium fluoride (excess  $\text{AlF}_3$ ) content of the liquid bath but also the weight percent (wt.%) of aluminium oxide ( $\text{Al}_2\text{O}_3$ ) as can be seen in Figure 6 in the liquid bath. Based on the chemical analysis of the bath conducted by the STARProbe™, actions related to feed control and bath chemistry control can be executed immediately. The  $\text{Al}_2\text{O}_3$  measured by STARProbe™ provides an indication of the alumina content at the time of measurement within the operational cycle, during which alumina is consumed, which is crucial for determining the appropriate immediate actions.

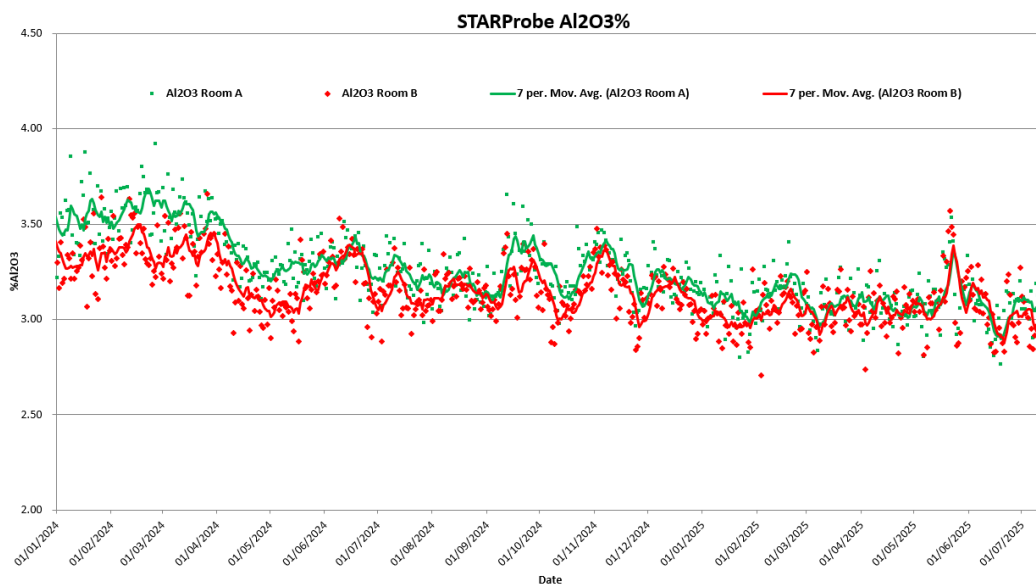


Figure 6a. Monitoring bath chemistry trends on %  $\text{Al}_2\text{O}_3$  with STARProbe.

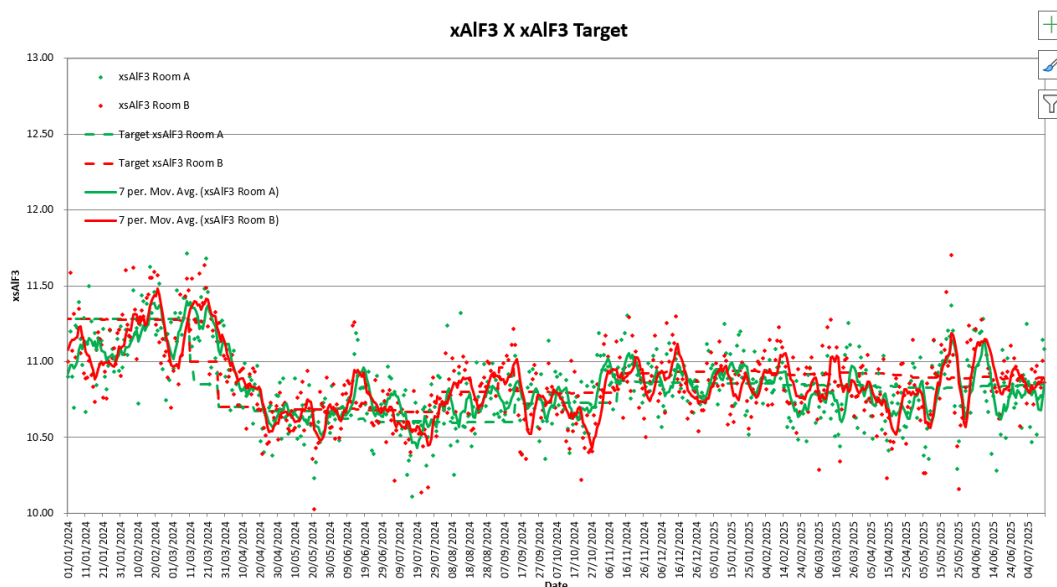


Figure 6b. Monitoring bath chemistry trends on  $\text{AlF}_3$  with STARProbe.

### 3.2.3 Hardware Optimisation

Open feeder holes play a crucial role in the aluminium smelting process [11], particularly in the efficient delivery of SGA into the electrolytic cells. Understanding the significance of these feeder holes is essential for optimizing smelting operations and ensuring consistent production quality. Mechanical components associated with feeder holes, such as breakers and feeders, can malfunction. These failures can result in improper breaking of the crust or inaccurate dosing of alumina. Feeder hole and equipment need to be regularly audited to ensure the holes are properly open to ensure the alumina can reach the molten bath. To open temporary closed feeder holes wood blocks can be used as they will increase the breakers reach and provide turbulence as moisture and other organic compounds will be released.

Once the feeder hole is open, alumina dissolution rate is highly dependent on the way alumina is introduced over the molten bath surface, the pot condition and the alumina properties. The alumina is fed to the molten bath at a specific angle to facilitate particles spreading across the bath surface and hence to enhance the dissolution process. The approach implemented at the AP30 plants involves restricting the flow of alumina to the feeder hole to achieve better distribution. This method promotes higher heat transfer due to the formation of thinner rafts.

## 3.3 Changing Control Parameters

### 3.3.1 Impurities

It is crucial to maintain an optimal  $\text{CaO}/\text{Na}_2\text{O}$  ratio of  $10 \pm 2\%$  to manage impurities effectively. Deviations in the delivered SGA can be accepted based on the current  $\text{CaF}_2$  content of the bath and the calculated impact of the SGA quantity.

The impact on bath chemistry control for  $\text{Na}_2\text{O}$  and fluoride (F) absorbed by the alumina can be detrimental to the process if the required  $\text{AlF}_3$  to compensate them is not considered in the maintenance feed. This refers to the daily required  $\text{AlF}_3$  for an electrolysis cell. By simply updating the system with the latest values of fluoride and  $\text{Na}_2\text{O}$  in the alumina, the process can be better managed. Figure 7 shows an example of how these parameters could be set.

Maintenance Additions Used	
Maint Addition w Adjust	4.48
Maint Addition w/o Adjust	0.00
Total Maint Adjustments	4.48

Adjustments to Maintenance Addition	
Maintenance Offset	0.00
Adjust for Na <sub>2</sub> O in Ore	YES
Na <sub>2</sub> O Nominal	0.40
Na <sub>2</sub> O Actual	0.43
Na <sub>2</sub> O Adjustment	3.64
Na <sub>2</sub> O Gain	1.00
Adjust for Fluoride on Alumina	YES
Fluoride Nominal	0.0172
Fluoride Actual	0.0171
AlF <sub>3</sub> On Ore Gain	0.80
AlF <sub>3</sub> On Ore Adjustment	0.42

Figure 7. Adjusting the maintenance feed based upon alumina quality.

### 3.3.2 Dissolution

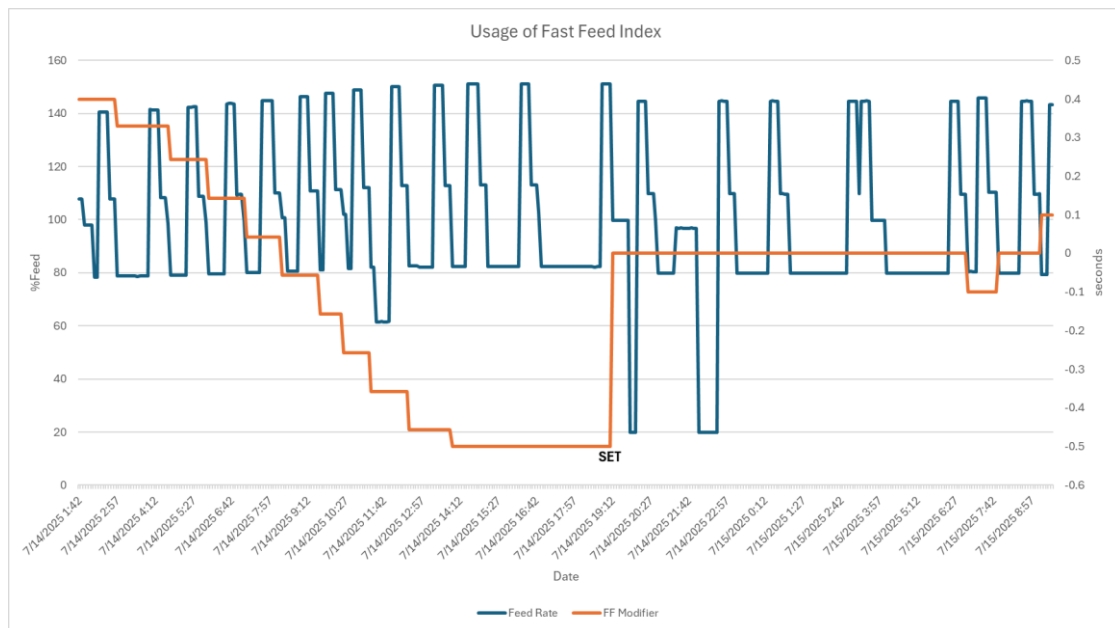
The feed strategy used at Alcoa is a comprehensive collection of mechanisms, that if used correctly can be beneficial in handling a wide range of alumina dissolution characteristics. As mentioned previously, the control system is designed to be able to cope with 90 % of the variation once the system is adjusted for an alumina with different properties. However, when transitioning between two different distinctive alumina, issues may arise. To better help the system to dissolve alumina, the control system should be able to handle situations where there is a temporary upset due to small variations in alumina properties.

Base feed interval is defined as the frequency or interval time at which alumina is fed by means of point feeders. The base feed interval represents the theoretical 100 % feed the pots need minus estimated alumina that comes through cover material and cathode surface.

**Automated adjustment** of the base feed interval is a system that compares the amount of real alumina in seconds given to a pot through the point feeders and the amount of alumina required according to the base feed interval. There are two approaches, one is to look at group of pots that receive a specific alumina quality, the other is to look at it pot-by-pot. If a group of pots (e.g. a line) requests structural different amounts of alumina, the base feed interval is considered changed automatically in that direction with an appropriate modifier. Automated adjustments on a pot-by-pot is considered compensating and hiding problems [9]

**Fast Feed Modifier (FFM)** is calculated based on the latest pair of track times in individual pots. A modification of the base feed interval is permitted to temporarily help the electrolysis cell overcome dissolution issues but also help in cleaning up the cathode.

Figure 8 shows the FFM. The orange line represents the modification of the feed strategy. When the track time gets too short, the feed rate is automatically increased to help the pot feed more alumina.



**Figure 8. Adjusting the feed with a feed modifier.**

### 3.4 Manual Intervention

Manual intervention is needed when variation in alumina sourcing is very significant, and the control system cannot deal with the existing settings.

#### 3.4.1 Groups Versus Outliers

One key insight in managing changes in alumina, particularly regarding its dissolution, is to focus on dissolution parameters of groups (e.g. pot line) and apply a modifier on top of the base feed interval across this group. Group behaviour is next to operations, mostly related to alumina quality changes. Managing individual pot behaviour should be based on investigation of outliers, not pot-by-pot. Prioritizing the resolution of systematic issues caused by alumina sourcing within the operations before tackling individual pot problems can significantly reduce the workload and enhance overall efficiency.

The “base feed interval” set at a specific normalized value, depends on amperage and operational practices. Usually with consistent alumina quality supply and pot conditions, this value is fixed (not the same) on a pot per pot basis. Adjustments to this base feed are usually not necessary unless there is a structural need. Under normal circumstances the feed control strategy must compensate for adjustments to prevent a pot from sludging up and/or having anode effects.

For tuning the base feed interval, the rule is to monitor the behaviour of groups of pots that are fed from the same silo. Key Performance Indicators (KPIs) such as track times, average feed interval, and anode effects are assessed. Feed modifiers are employed, to a certain extent, to facilitate the feeding process. When alumina dissolution issues arise, the following strategies are sequentially applied until the process indicators return to their target values.

If there is an increase in the number of anode effects, shorter track times, and more frequent alumina dumps, the base feed interval is reduced using a special modifier to ensure the pots receive more alumina. Conversely, if track times are increasing or the number of overfeeds is decreasing for a group of pots, the amount of alumina fed to the pots is decreased. To prevent compensatory control, the base feed interval adjustment is kept within a range of -3 % to +4 %.

In the event of dissolution problems, the final step to promote alumina dissolution involves modifying the shot frequency of the overfeed phase by 5–10 % of its duration and increasing the overfeed time to maintain an equivalent enrichment of the liquid bath. These steps have proven relatively successful in managing variations in alumina sourcing.

### 3.5 Other Considerations

When a shipment of SGA is anticipated to adversely affect process performance, and after mitigating or slowing down the deterioration, process conditions can quickly restore normal by introducing a more suitable quality shipment. Another strategy is to mix the bad alumina with some good alumina to even out the effects.

Fines and super fines can lead to scaling of the feeders and ultimately blocked feeders. This required extra personnel to deal with.

## 4. Conclusions

Significant variations in alumina sources can lead to process deterioration when electrolysis cells are unable to effectively process the alumina due to improper parameter settings. From an impurity perspective, maintaining an optimal ratio of calcium oxide (CaO) and sodium oxide (Na<sub>2</sub>O) is essential. Adjusting the bath chemistry based on the Na<sub>2</sub>O, CaO and fluoride (F) content in reacted alumina is crucial to maintaining fluoride balance. The physical properties of alumina and their impact on the electrolysis process are more complex, necessitating the development of effective tools to adapt to new conditions or mitigate the effects of deteriorating conditions.

In recent years, Alcoa has implemented proactive countermeasures to address the significant changes in alumina sources and reduce plant instabilities. By standardizing these measures, Alcoa has successfully minimized the frequency and severity of process excursions. The fundamental strategy involves establishing robust data collection and indicator systems that facilitate informed decision-making regarding the adjustment of control parameters.

Implementing a dashboard that monitors SGA properties in conjunction with key process health indicators helps in tracking the condition of the production lines. Any deviation in these properties and indicators should be considered systematic, warranting action on a group of pots rather than individual pot adjustments. Pot tuning should be reserved for outliers.

Certain aspects of variations in alumina sources remain challenging to manage, particularly when different sources are mixed within the same alumina silo. This complexity arises from the inherent differences in the physical and chemical properties of alumina from various sources, which can affect the consistency and predictability of the electrolysis process. To address these challenges, it is essential to develop advanced monitoring and control systems that can detect and compensate for these variations in real-time.

## 5. References

1. Kai Grjotheim and Halvor Kvande, *Introduction to aluminium electrolysis*, 2<sup>nd</sup> Edition, Dusseldorf, Aluminium-Verlag, 1993, 260 pages.

2. A.R. Kjar and A.J. Crisp, Impact of bauxite source, quality and alumina plant design on alumina quality, *The proceedings of the 1st Alumina Quality Workshop*, Gladstone, Australia, 1988.
3. Stephen J. Lindsay and Barry J. Welch, A review: Understanding the science and the impacts of impurities upon the electrolytic bath of Hall–Héroult reduction cells. *JOM*, 2021, 73, 1196–1209.
4. Stephen Lindsay, Customer impacts of Na<sub>2</sub>O and CaO in smelter grade alumina, *Light Metals* 2012, 163-167.
5. Curtis Landon, Brian Zukas, Stephen J. Lindsay, The influence of calcium fluoride on entrainment of electrolyte during metal siphoning, *Light Metals* 2025, 788-795.
6. Ray D. Peterson, Alton T. Tabereaux, Liquidus curves for the cryolite–AlF<sub>3</sub>–CaF<sub>2</sub>–Al<sub>2</sub>O<sub>3</sub> system in aluminium cell electrolysis, *Light Metals* 1987, 33-38
7. Stephen J. Lindsay and Pascal Lavoie, Alumina quality, HF removal, dissolution and aluminium purity, *Smelter Grade Alumina from Bauxite*, 2022 Edition 1, 577-648, [https://doi.org/10.1007/978-3-030-88586-1\\_11](https://doi.org/10.1007/978-3-030-88586-1_11).
8. Stephen Lindsay, Attrition of alumina in smelter handling and scrubbing systems, *Light Metals* 2011, 163-168.
9. Albert Mulder, Yashuang Gao, Dongfang Zhou, David S. Wong, Liu Ming, Pascal Lavoie, Mark P. Taylor and Xiaodong Yang, New generation control for daily aluminium smelter improvement, *Light Metals* 2014, 835-840.
10. Jayson Tessier, Pascal Lavoie and Albert Mulder, The role of new sensors for Hall-Héroult process control, optimization and advanced analytics, *Proceedings of 41<sup>st</sup> International ICSOBA Conference*, Dubai, UAE, 5 – 9 November 2023, Paper AL30, *TRAVAUX* 52, 1517–1527.
11. Pascal Lavoie and Mark P. Taylor, Impact of aluminium reduction cell parameters on feeder hole condition, *Light Metals* 2023, 56-66.

