

## Seasonal Protocol – Strategies to Improve Thermal Balance in an Aluminium Potline

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### Abstract

Seasonal ambient variation plays a key influence in defining the operational window of an aluminium reduction cell, which is mostly determined by potline thermal balance. Even though gas treatment plants often study these basic features of environmental changes separately, the parameters of the potline are related and must be addressed to have minimal effect. Thermal balance influences the pot current distribution, the dissolution of alumina, and the instability of the pot. Bath superheat is a key indicator of thermal balance in the potlines. The productivity and energy consumption of the system are both ensured by keeping the superheat within a close range. Significant shifts in superheat can bring about unfavourable consequences, inefficient dissolution of alumina, formation of sludge and a decrease in the efficiency of the pot line. Seasonal fluctuations also make cell operations more complex because of the impact of varying heat losses on thermal balance. Higher cell instability and poor thermal control leads to higher metal bath interface instability, which consecutively accounts for higher back reactions.

Sohar Aluminium is a pioneering greenfield aluminium smelter and a market leader in Oman's manufacturing industry. To keep the thermal balance consistent throughout the year, regardless of the weather (summer-winter), this paper presents a predictive control method that adjusts the bath temperature set point, adds thermal resistance, and optimizes the pot forced cooling network (FCN) using real-time data or estimates of different indicators. The paper delves into the seasonal routine and provides an insight into thermal balance management for changes in the context of Sohar Aluminium's experience.

**Keywords:** Aluminium reduction pots, Seasonal variation, Thermal balance, Forced convection network, Superheat.

### 1. Introduction

The Sohar Aluminium plant is operating a single potline of 360 cells that is divided into two pot rooms with AP40/42S design and with a potential total metal production of 399 692 tonnes per year. It also has a carbon plant producing baked anodes and a cast house to cast the molten aluminium into final ingots and sows' format. Sohar Aluminium facilities include a smelter that utilizes advanced technology and employs best practices along with a dedicated power plant and port facility.

Sohar Aluminium has helped to establish and supply four downstream partners, of which all are in operation. Sohar Aluminium operates its own state-of-the-art 1000 MW natural gas-fired power plant and dedicated port facility in the Sohar industrial port area.

Modern primary aluminium production utilizes the Hall-Héroult process. Bauxite ore undergoes Bayer processing to yield alumina ( $\text{Al}_2\text{O}_3$ ). This alumina is then dissolved in molten cryolite ( $\text{Na}_3\text{AlF}_6$ ) within a high-temperature electrolytic cell. Direct current electrolysis breaks down the alumina into its elemental components, aluminium and oxygen. The denser molten aluminium accumulates at the cell bottom, while carbon dioxide ( $\text{CO}_2$ ) evolves at the anode. The aluminium is then siphoned off for further processing.

Aluminium smelters face a unique challenge regarding seasonal heat balance. During summer months, the already significant heat generated by the electrolytic process can be exacerbated by rising ambient temperatures. This excess heat can cause inefficiencies in the reduction process and increased energy consumption for the cooling system, or in other words, bringing challenges for efficient operation. Conversely, winter months might necessitate additional heating to maintain optimal operating temperatures, impacting overall energy usage and current efficiency. This seasonal fluctuation in heat balance can affect production output and energy costs. To address these seasonal variations, smelters leverage several strategies. Utilization of heat recovery systems to recover waste energy, heat insulators, water coolers, and heat exchangers in a gas treatment plant. Additionally, some operational practices are adjusted seasonally to optimize efficiency. These engineering solutions play a crucial role in energy conservation and process optimization and ensure optimal cell temperatures, maintaining process efficiency. However, effective process control remains paramount. By proactively adapting cell operating parameters within established windows, smelters can accommodate seasonal changes and prevent significant disruptions to current efficiency and energy consumption. By managing the seasonal heat balance, smelters can strive for consistent performance throughout the year.

Maintaining stable bath temperatures in aluminium reduction cells is becoming harder. Growing demands for higher current and energy savings create conflicting goals. This necessitates precise pot control, including a deeper understanding of heat and mass flow within the cell. Notably, some smelters experience hotter pot side shell temperature and lower efficiency during summer, exceeding predictions based on a constant ambient temperature. This phenomenon is more pronounced in smelters located in regions with hot and humid summers. Places like the Southern U.S.A., parts of the Middle East, and some regions in Asia might see a more significant impact on efficiency during summers. So, in this paper we will explore the potential reasons for this phenomenon. It combines theoretical analysis, targeted tests, and real-world data to identify seasonal variations in key parameters and overall performance. The research shows multiple factors contribute to thermal balance, with varying impact. Importantly, a novel "seasonal protocol system" (SPS) by Sohar Aluminium addresses these challenges. This protocol adapts to extreme seasonal shifts by adjusting thermal setpoints, adding or reducing cell resistance, and optimizing the forced convection network (FCN) crucial for side ledge formation [8].

In this paper we will cover the Sohar Aluminium experience in the implementation of the seasonal protocol system and how the new thermal regulation system improves the cell performance and efficiency. The Sohar Aluminium trial approach was designed to gradually introduce new procedures, hence limiting potline disruption.

## 2. Why Thermal Control Matters in Aluminium Reduction Potlines and Sohar Aluminium

Many factors contribute to the behaviour of modern cells. Some parameters are defined by the cell design (cell lining thermal insulation, maximum amperage capacity, magnetohydrodynamic conditions), while others are controlled automatically by a computerized-algorithm system like cell resistance, alumina feeding - regulations, and still others are dependent on human interaction, or operations (anode changing, anode covering, bath corrections, metal tapping). Any incremental process improvement in industrial production might have a significant impact on energy consumption.

Thermal equilibrium is defined as a state where the heat input (from electrical energy and exothermic reactions within the cell) equals the heat output (through conduction, convection, and radiation). This therefore ensures that the aluminium production process remains stable, efficient, and cost-effective, which is known in the industry as operational stability. The importance of this concept in energy efficiency is to optimize operating temperature as it maintains the thermal balance that ensures the cell is operating at the optimal temperature, usually around 950–970 °C. Deviations from this range can significantly impact efficiency [1].

This temperature range minimizes energy consumption for the electrochemical reactions, thus improving overall energy efficiency. As well, minimizing heat losses by proper thermal balance that helps in reducing unnecessary heat losses, thus ensuring that more of the input energy is used for the aluminium reduction process rather than being wasted. This will lead to cost saving and a reduction in environmental impact with efficient productivity. Furthermore, it enhances cell stability by promoting a uniform temperature distribution throughout the cell. This reduces temperature variations within the cell, leading to more consistent operating conditions. This uniformity is critical to prevent localized overheating or overcooling, which can cause localised damage to the cell components, such as the cathodes and anodes, as well avoiding thermal runaway, a condition where excessive heat generation leads to uncontrollable temperature increases, potentially causing catastrophic pot failure.

Maintaining thermal equilibrium offers numerous advantages. Improved bath properties, like viscosity and conductivity, enhance ion flow and reduce electrical resistance, leading to efficient metal production and consistent quality due to reduced back reactions in electrolysis process. Additionally, it minimizes thermal stress, reducing wear and tear on potline components and extending their lifespan. Furthermore, it mitigates safety hazards like hot spots and side leaks that could damage the pot-shell or endanger workers. Finally, precise thermal control contributes to a more sustainable process by lowering emissions of CO<sub>2</sub> and PFCs. This ensures the aluminium production facility's success economically, environmentally, and operationally – a true mark of sustainability [2].

Sohar Aluminium is currently implementing an amperage increase process, gradually increasing the electrical current through their reduction cells to enhance production. While this strategy promises benefits, it presents significant challenges, especially during seasonal temperature fluctuations. Precise thermal control becomes even more critical throughout the year and for several reasons. Firstly, increased current generates more heat, and maintaining a stable bath temperature within a narrow range is essential for optimal alumina dissolution and efficient metal production. Secondly, amperage increase can exacerbate superheat fluctuations, potentially leading to side ledge melting or alumina dissolution problems, both of which can negatively impact cell stability and lifespan.

Finally, tight thermal management becomes even more critical during Oman's hot summer months, when ambient temperatures add further strain to the heat balance equation. Recognizing

these challenges, Sohar Aluminium is actively seeking ways to improve thermal equilibrium. This is not just about maximizing efficiency and production; it is also about protecting the integrity of their reduction cells and ensuring their long-term operational stability.

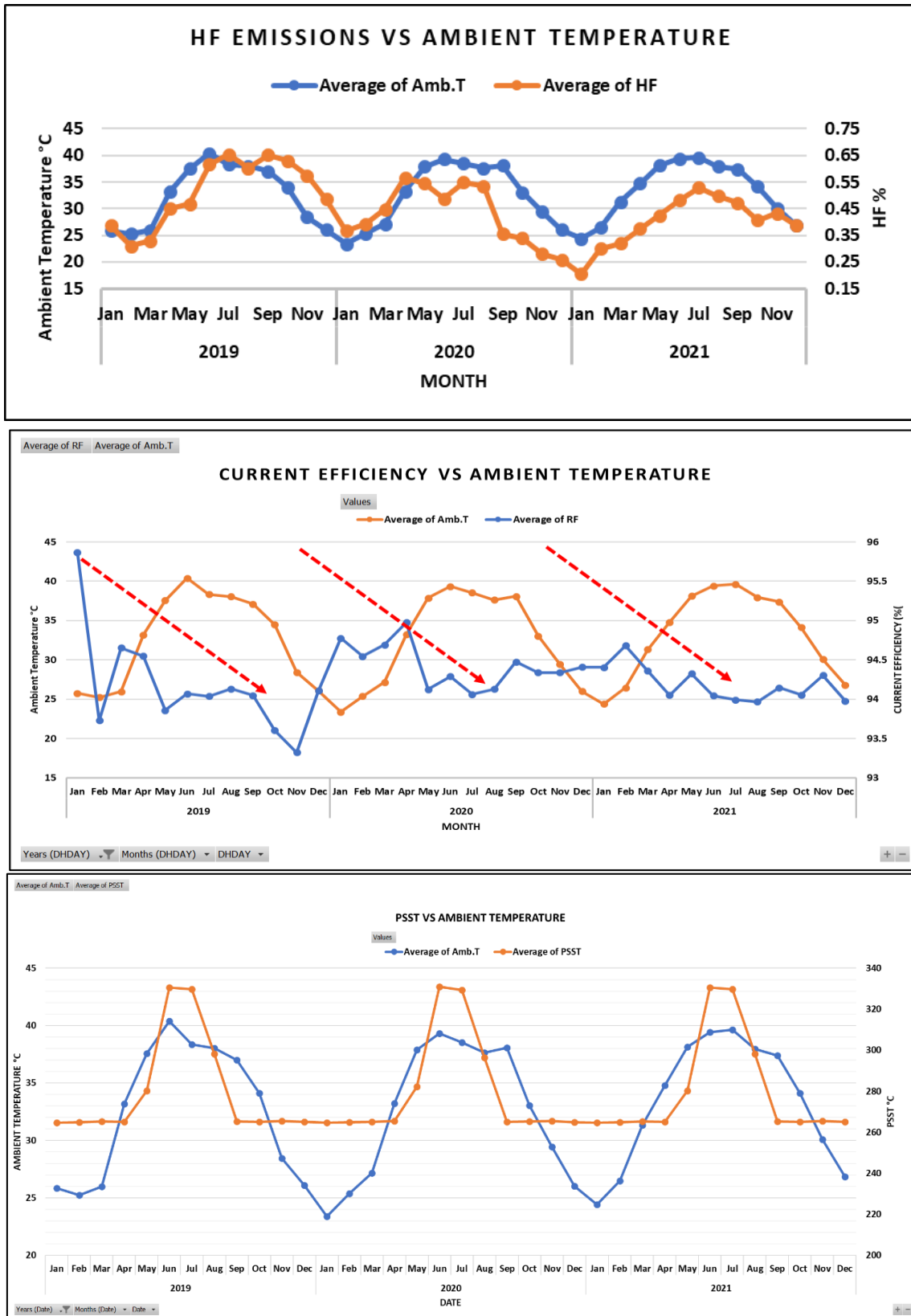
### 3. The Challenges

The past decades have seen significant progress in aluminium smelting, with improved performance, data acquisition, and accuracy. This has brought both opportunities and challenges, particularly as we push technologies to increase production. Operating cells with tighter margins leaves less room for error. Although cell design improvements often come with generational leaps, fully grasping the impact of specific factors like thermal control during amperage increase can be a lengthy process. Additionally, these effects may vary between smelters due to differences in equipment, operating practices, and even local climate, achieving precise thermal balance remains a significant hurdle for aluminium smelters, especially during the summer months [3].

Previous studies established a predictable relationship between ambient temperature and pot shell temperature, bath superheat and line losses. In aluminium electrolysis, line loss, also termed as external drop in some smelters, signifies voltage drop between a pot and the potline's electrical circuit. Higher line losses can be caused by busbar malfunctions, pot shell damage, or cathode connection issues, leading to production halts, safety risks, and challenges in low resistance operation of potline. However, recent experiences at Sohar Aluminium deviate from this trend. As shown in Figure 1 (bottom), pot shell temperatures exhibit significantly larger variations compared to ambient temperatures, reaching to higher level with increased operating amperage. This translates to pot shell temperature increases of around 80 °C for a seasonal ambient temperature difference of just 30 °C. This significant rise is accompanied by a parallel increase in fume inlet temperature during the summer season. These combined effects pose substantial challenges for Sohar Aluminium in maintaining good fluoride emission levels. These summer disruptions not only create tighter operational margins but also introduce significant difficulties for both process control and overall operational management at Sohar Aluminium.

Furthermore, bath superheat, the temperature difference between the bath and its melting point, plays a crucial role in maintaining thermal balance, and this balance is particularly challenged during the summer season. While the optimal superheat range is 8–12 °C, achieving this range becomes more difficult in extreme summer heat. The traditional methods for calculating superheat, which rely on bath temperature and theoretical liquidus temperature, become unreliable. This is because excess  $AlF_3$  concentration, which can be impacted by operational adjustments to cope with summer heat, also influences the liquidus temperature. As a result, Sohar Aluminium experiences difficulty in precisely maintaining the desired superheat range during the summer months.

The trend highlights a clear link between seasonal changes and current efficiency (CE). These observations suggest a complex interplay of factors contributing to the seasonal phenomenon during Oman's hot summers. Understanding these factors is crucial for Sohar Aluminium to refine their process control strategies and achieve optimal thermal equilibrium within their potline.



**Figure 1. Seasonal variation (2021-2023) – Ambient temperature (°C) vs. HF (%) (top), CE (%) (middle) and PSST (bottom). The red dashed lines show the decrement in CE from winter to summer.**

The above graphs show a clear link between the ambient temperature and HF emissions, current efficiency and PSST.

Briefly description of what graphs show:

- 1- HF Emissions
  - Increased ambient temperature (summer):
    - Higher evaporation rates of fluoride compounds.
    - Increased fume generation due to intensified chemical reactions.
    - Potentially higher HF emissions.
  - Decreased ambient temperature (winter):
    - Lower evaporation rates of fluoride compounds.
    - Reduced fume generation.
    - Potentially lower HF emissions.
- 2- Current Efficiency
  - Increased ambient temperature (summer):
    - Increased heat loss from the pot, requiring more energy to maintain operating temperature.
    - Potentially lower current efficiency due to increased energy consumption.
    - Increased electrolyte vaporization, affecting bath composition and conductivity.
  - Decreased ambient temperature (winter):
    - Reduced heat loss from the pot, leading to better energy efficiency.
    - Potentially higher current efficiency.
    - Reduced electrolyte vaporization, impacting bath composition.
- 3- Pot Side Shell Temperature (PSST)
  - Increased ambient temperature (summer):
    - Higher heat transfer from the pot to the surroundings.
    - Potentially lower pot side shell temperature.
  - Decreased ambient temperature (winter):
    - Lower heat transfer from the pot to the surroundings.
    - Potentially higher pot side shell temperature.

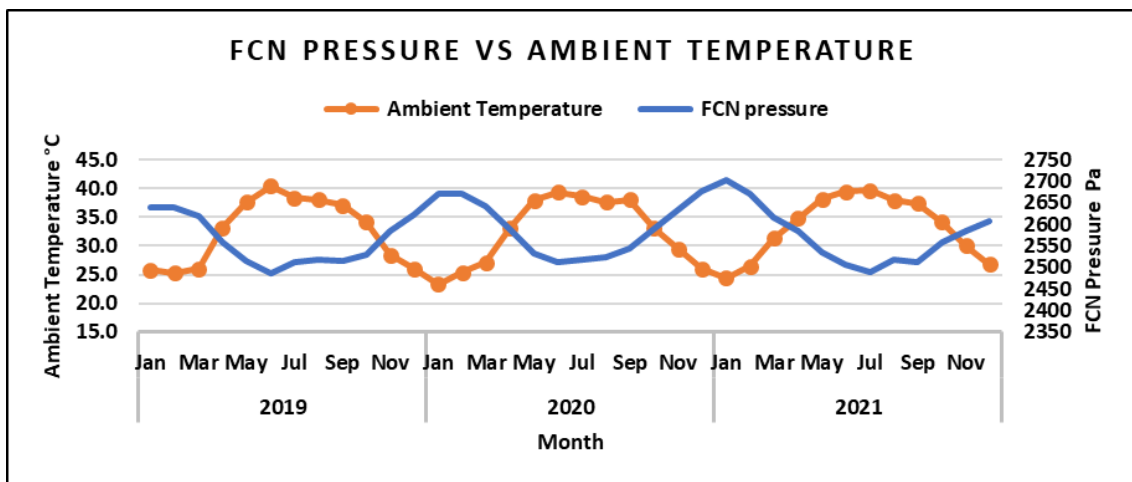
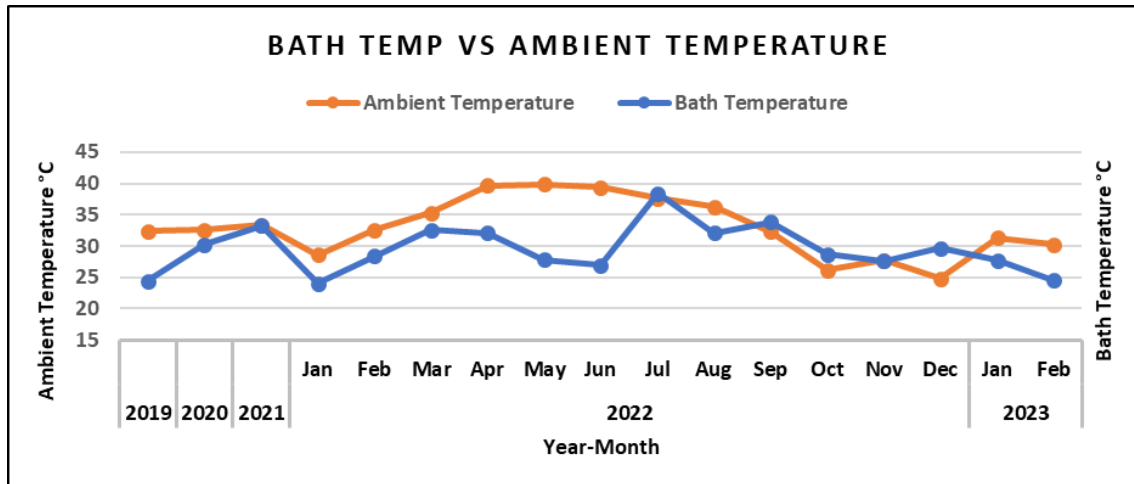


Figure 2a. Seasonal variation (2021-2023) – FCN pressure (Pa) vs ambient temperature (°C).



**Figure 2b. Seasonal variation (2021-2023) – Bath temperature (°C) vs ambient temperature.**

Achieving thermal balance in the potline at Sohar Aluminium presents a significant challenge due to two key factors: amperage increase and seasonal variations. This, combined with the inherent fluctuations in ambient temperature and other environmental factors throughout the year, disrupts the desired process control and poses difficulties in adhering to acceptable fluoride emission and productivity levels.

#### 4. Methodology for Seasonal Protocol

To address the significant challenges posed by amperage increase and seasonal variations on thermal balance in the Sohar Aluminium potline, a multi-faceted methodology is proposed. This approach focuses on real-time monitoring, data-driven adjustments, and strategic implementation of thermal management techniques across different seasons.

1. Cell Monitoring and Amperage Increase Control. The first pillar of this methodology involves establishing a robust cell monitoring system. This system will continuously track key parameters like cell voltage, current, and pot shell temperature. Analysing this real-time data allows for the development of a protocol for regular amperage adjustments.
2. Seasonal Bath Chemistry Management. The thermal and electrical properties of the bath are susceptible to fluctuations in ambient temperature across seasons. To address this, the methodology proposes a seasonal approach to thermal management. This involves developing a protocol for adjustments based on the season.
3. Pot Ventilation and Heat Transfer Optimization. Effective pot ventilation plays a crucial role in managing heat dissipation throughout the year. This methodology proposes an evaluation of the existing FCN management systems to assess their effectiveness in handling thermal variations across seasons. Based on this evaluation, adjustments to FCN flow rates based on process optimisation strategies may be necessary, particularly during peak winter or summer months [9].

Adjusting the FCN flow allows for targeted heat management within the potline. By increasing or decreasing the FCN flow, we can control the amount of heat delivered or removed, minimizing disturbances to the pot shell temperature. For instance, heat loss (Q) is estimated by Equation (1) [6]:

$$Q = h_n A (T_s - T_a) \quad (1)$$

where:

$h_n$  Effective heat transfer coefficient of air in natural convection + radiation, W/m<sup>2</sup>°C

$A$  Surface area, m<sup>2</sup>

$T_s$  Average temperature of pot side shell, °C

$T_a$  Ambient air temperature, °C

During summer months the rise in ambient temperature poses a particular threat. This increase in temperature leads to a decrease in air density. Because of this change in density, the static pressure of the air delivered by the FCN can drop even if the flow rate remains constant [5].

4. Data Analytics and Predictive Strategies. A crucial element of this methodology is the utilization of data to both understand and predict thermal behaviour within the potline. Historical data and real-time monitoring information will be combined to develop a comprehensive thermal balance model for the entire potline.

Following a six-sigma phased approach, the proposed methodology was implemented in stages. Initial steps involved the data collection, model development, and pilot testing specific strategies within a select group of pots. Upon successful pilot testing, the seasonal protocol has been progressively rolled out across the entire Sohar Aluminium potline. The effectiveness of the protocol is continuously monitored through key performance indicators (KPIs) such as pot shell temperature consistency, thermal stability, fluoride emission levels, energy consumption, and cell operating efficiency. By analysing these KPIs, adjustments and optimizations made to ensure the ongoing success of the seasonal protocol.

#### 4.1 Measurement Campaign (Design of Experiment)

##### Phase 1: Data Collection

**Historical Data Acquisition:** Compile existing data from process control systems, including: (Reference pot measurements)

- Pot side shell temperatures
- Ambient temperatures
- Fume inlet temperatures
- Bath composition (AlF<sub>3</sub> concentration, temperature etc.)
- Cell operating parameters (amperage, voltage, CE etc.)

**Seasonal Monitoring:** Implement a focused data collection campaign throughout a full seasonal cycle (e.g., one year) to capture variations:

- Increased additional measurements on selected pots to monitor pot shell temperatures at multiple locations and time.
- Measure wind speed/direction near the potline.
- Collect more frequent bath samples for analysis.
- Monitoring of seasonality effects on thermal measurements like superheat, free alumina% and cooling curves with help of the STAR probe.
- Automatic sensors in GTC to capture fume inlet temperatures before and after dilution.
- Seasonal side ledge profile measurements for selected pots.

### Phase 2: Modelling and Analysis

The second phase focuses on data sorting and analysis. A thermal model of the potline is developed, incorporating cell operation parameters and ambient conditions. This model is calibrated using the historical and seasonal data to ensure accurate predictions. Subsequently, a sensitivity analysis is conducted to identify the factors that most significantly impact pot shell temperature and thermal situation in potline. Finally, based on the analysis, the key drivers contributing to the "thermal imbalance" during summer and winter, or seasonal changes have been prioritized.

### Phase 3: Protocol Development and Testing

The third phase leverages the insights gained from the measurement campaign and analysis to refine existing regulations into a seasonal protocol system (SPS). This refined SPS targets the identified key drivers and involve adjustments to:

- Thermal set points for different seasons.
- Optimisation of set points including cells target resistances, thermal impact component and algorithm parameters.
- Forced convection network (FCN) operation to optimize heat dissipation, particularly during peak of the seasons.

Following the refinement, a pilot test (90 pots) is conducted on a selected group of pots to evaluate the effectiveness of the protocol in mitigating thermal imbalance seasonally. The data from the pilot test is analysed to assess the impact of the naval methodology, and the protocol will be further optimized based on the results.

This methodology offers a structured approach for Sohar Aluminium to develop and implement a robust Seasonal Protocol System. By combining historical data analysis, focused measurement campaigns, modelling, and pilot testing, Sohar Aluminium gained valuable insights into the factors affecting pot productivity. This knowledge enabled us to achieve optimal thermal balance within our potline for improved process control, operational efficiency, and year-round environmental compliance.

## **5. Seasonal Protocol – A Proactive Approach**

Ongoing tests demonstrate that the thermal impact of seasonal variation on pots can be minimized using the following levers:

1. Better control of the *FCN* flow rates, with continuous monitoring on fan amperage and pressure
2. The RTH table is an additional thermal resistance table, which can be positive or negative based on measured bath temperature and effective over base resistance to cool or warm up the pot. It is adjusted dynamically (asymmetrically) based on the constantly monitored temperature of the molten metal (bath) in each pot. This adjustment can be increased for either heating or cooling depending on the overall needs of the potline. This dynamic approach helps maintain a consistent temperature across all the pots in the potline
3. A strategy focusing the thermal behaviour of the pots by adjusting the *set points* of temperature and excess AIF<sub>3</sub>; and
4. Reviewing the *shutdown and restart* events by introducing FCN adjustment over the period of amperage stabilisation.

## 5.1 FCN Adjustment Seasonal

Figure 3 depicts the relationship between average ambient temperature (green line) and FCN pressure (static pressure) in the potline. FCN, or Forced control network, regulates the flow of cooling air directed towards the pot shell. During summer, rising ambient temperatures lead to a decrease in air density. This, in turn, can cause a drop in FCN static pressure even if the flow rate remains constant. Conversely, winter months with lower temperatures experience an increase in air density, potentially requiring adjustments to maintain optimal FCN pressure [5].

As evident from the graph, FCN pressure is adjusted throughout the year, corresponding to changes in ambient temperature.

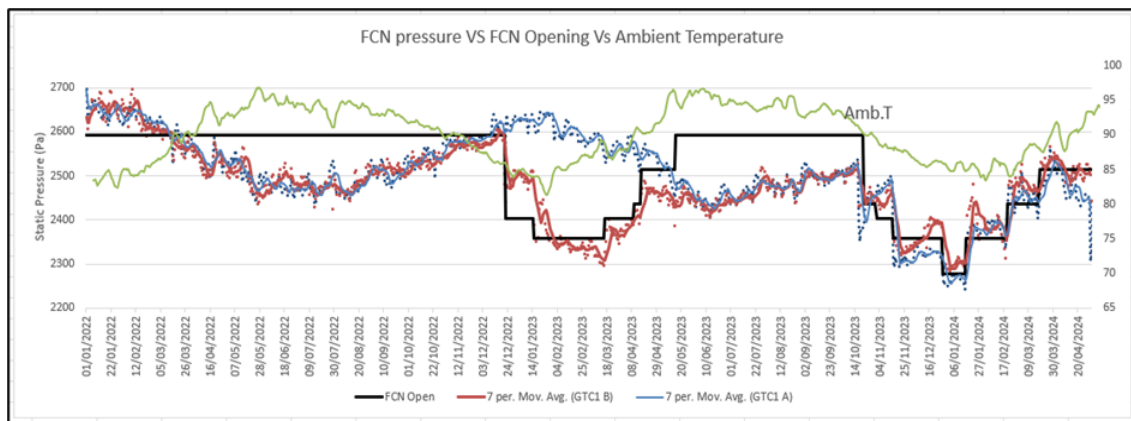


Figure 3.-FCN pressure vs. ambient temperature.

The graph indicates a trial conducted in GTC1 B (90 pots) during the period 2022-2023. This trial involved strategically adjusting FCN opening (partially visible black line) based on ambient temperature variations. The success of this trial led to the implementation of this seasonal FCN adjustment strategy across all 360 pots in the potline during the current year (2023-2024).

## 5.2 Cell Resistance Adjustment – Seasonal

A well-established principle states that electrical resistance in metals increases with temperature. This variation can be approximated by a linear relationship for small relative changes. Within the aluminium electrolysis cell, various metal components like the anode assembly experience this phenomenon.

Seasonal changes in ambient temperature can indirectly affect the anode-cathode distance (ACD) in opposing ways:

- **Summer:** As ambient temperature rises, the electrical resistance of the potline busbars and steel conductors increases and correspondingly, the voltage drop. Assuming a constant current density and total cell voltage, this rise in voltage drop in metallic conductors leads to a corresponding decrease in bath voltage drop, and a decrease of ACD.
- **Winter:** Conversely, during winter months with lower temperatures, the electrical resistance of the metal components decreases. This can lead to an increase in the voltage drop across the ACD and potentially a slight increase in the ACD.

Previous research suggests that both increases and decreases in ACD can have consequences for cell performance, particularly regarding current efficiency (CE). A decrease in ACD below a

certain limit can lead to reduced CE, while a very large ACD might also negatively impact current efficiency and energy consumption of a potline.

This protocol targets the optimization of cell resistance relative to base resistance based on bath temperature. The key aspects of this protocol are following [7]:

- **Asymmetric Resistance Target Table for Heat Balance (RTH):** This table accounts for the changing relationship between pot resistance and bath temperature throughout the year. As the bath temperature fluctuates, the RTH table dynamically adjusts the pot resistance to optimize thermal stability. This helps to counteract the seasonal temperature swings ("seasonal offsets") and maintain a more consistent thermal environment within the pot.
- **Seasonal Cooling and Heating Tables:** In addition to the year-round adjustments, separate tables are used for summer and winter. The summer cooling table provides specific adjustments that promote heat removal from the pot shell, helping to manage the increased heat during warmer months. Conversely, the winter heating table focuses on adjustments that retain heat within the pot, mitigating heat loss during colder seasons.
- **Gradual Implementation:** The transition between the summer and winter tables is achieved through 3-4 incremental steps. This gradual approach helps to minimize thermal shocks to the potline and ensure a smoother transition between the cooling and heating modes.
- **Reduced Dependence on  $\text{AlF}_3$  Shots:** By implementing the seasonal protocol with adjustments to thermal resistance and targeted cooling or heating, the reliance on  $\text{AlF}_3$  shots for thermal regulation is lessened. This can offer several benefits, including potentially reducing operational costs and environmental impact.
- **Maintaining Bath Superheat:** The seasonal protocol also considers the importance of maintaining optimal bath superheat. This is crucial for factors like side ledge protection and alumina dissolution, hence better pot stability.

The overall impact of seasonal ACD variations on cell performance requires further analysis. Factors like the interplay between CE, Joule heating (heat generated by electrical resistance), and the critical ACD limit need to be considered. Additionally, it is important to determine if the estimated ACD changes due to seasonal temperature fluctuations are significant enough to cause substantial effects on CE, especially if the cell is already operating near its critical ACD limit.

### 5.3 Thermal Set Point Adjustment

Sohar Aluminium's seasonal protocol is further enhanced by incorporating adjustments to set points for bath temperature and excess  $\text{AlF}_3$  concentration throughout the year. This strategy focuses on optimizing the thermal behaviour of individual pots based on seasonal variations.

- **Bath Temperature Set Point:** During summer months, the bath temperature set point might be slightly lowered to promote better CE and compensate for lower ACD. Conversely, winter months could tolerate higher bath temperature set point to promote alumina dissolution.
- **Excess  $\text{AlF}_3$  Concentration:**  $\text{AlF}_3$  plays a role in heat balance in the bath. By adjusting the excess  $\text{AlF}_3$  set point along with the temperature set point seasonally, we can influence the pot thermal profile.

By fine-tuning bath temperature and excess  $\text{AlF}_3$  based on season, the potline achieved better thermal stability throughout the year. Seasonal set point adjustments for bath temperature and excess  $\text{AlF}_3$  can complement adjustments made to FCN flow (as depicted in Figure 3). This combined approach can potentially reduce the need for drastic changes in FCN settings, leading to more stable pot operation (Figure 4).

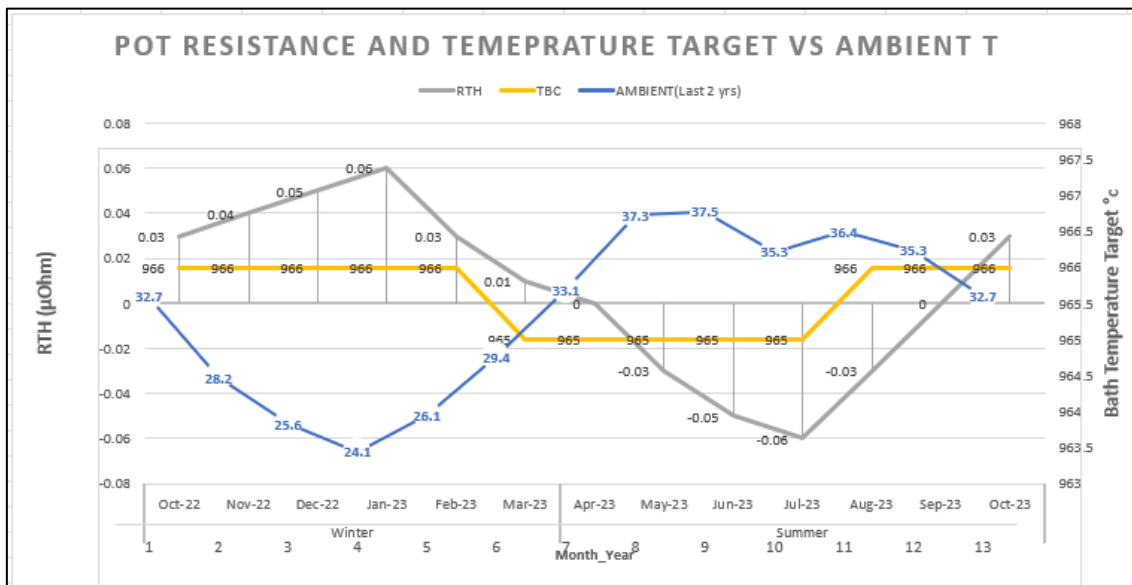


Figure 4. Seasonal variation of pot resistance target (RTH) adjustment from average, and adjustment of target bath temperature set point (TBC).

This strategy of adjusting bath temperature and excess AlF<sub>3</sub> set points is seamlessly integrated with the existing seasonal protocol in Sohar Aluminium's potline. By considering these additional factors alongside thermal resistance adjustments, targeted cooling/heating, and gradual transitions, the potline can achieve even more precise and effective thermal management throughout the year.

## 6. Conclusion and Further Work

The successful implementation of this seasonal protocol demonstrates a proactive approach to thermal management in the Sohar Aluminium potline. By dynamically adjusting FCN flow and potentially other parameters based on seasonal variations, the potline achieved a more stable and efficient operation throughout the year. The Sohar Aluminium seasonal protocol offers a comprehensive approach to thermal management in the potline.

By dynamically adjusting thermal resistance, implementing targeted cooling and heating strategies, and reducing dependence on AlF<sub>3</sub> shots, the potline can achieve:

- **Improved process control:** Consistent side ledge profile due to improved superheat ensures optimal operating conditions for the pots.
- **Enhanced pot health:** Minimizing thermal fluctuations reduces stress on the pots, potentially extending their lifespan.
- **Reduced operational costs:** Lower reliance on AlF<sub>3</sub> shots can lead to cost savings.
- **Environmental benefits:** The protocol may contribute to a more sustainable operation by potentially reducing fluoride emissions.

By proactively managing seasonal temperature variations, Sohar Aluminium's seasonal protocol demonstrates a commitment to efficient and stable potline operation.

While observed changes in ambient temperature, FCN flow rate, thermal set points are insufficient to fully explain the "summer effect," they still contribute to a slight rise in cell temperature. Warmer pot shells present a challenge for heat evacuation, often requiring compensatory measures like reduced anode side ledge thickness or decreased ACD [4].

Sohar aluminium understands the relationship between ACD and current efficiency (CE), which had been established scientifically before. It suggests that even a small reduction in ACD can influence cell energy balance, particularly if the cell operates near its lower ACD limit. This could lead to a paradoxical situation where a decrease in ACD, which typically reduces heat generation, might actually increase heat generation due to loss of current efficiency.

Further research with additional tests and measurements is planned to explore CE-ACD relationship. This will help to develop even more effective strategies to mitigate the "summer-winter effect" and ensure optimal cell performance throughout the year.

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