A Successful 72-hour Sleeping Mode Operation on AP40 Pots in Kitimat Smelter - A Case Study

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Abstract

Kitimat Aluminium Smelter uses AP40 Technology with eight sections of 48 pots in a single pot line configuration with a unique asymmetric gas treatment centre (GTC) configuration requiring a unique "siphon" alumina conveying pathway. In this type of configuration, an interruption in the continuity in alumina supply can disrupt a smelter operating at full capacity over a long period. The 48-pot section experienced a hyper-dense phase system failure on November 9, 2022, causing 48 pots to lose alumina supply abruptly. Initially, the maintenance diagnosis assumed no foreseeable recovery within 72 hours. A contingency plan was activated, keeping the pots in sleeping mode for a few days by lowering the anode beam such that no electrolysis occurs. Currently, limited information exists on alumina disruption and the use of the sleeping mode on a full section. This paper summarizes the successful process steps in Kitimat that prevented pot failure by employing the sleeping mode. Methods, lessons learned**,** and potline recovery are discussed.

Keywords: Aluminium electrolysis pot sleeping mode, Alumina supply disruption, Contingency plan.

1. Introduction

Aluminium smelting is a continuous process, and any disruption such as a shortage in raw materials (alumina, anodes, or power) or a strike can put a potline at risk of an uncontrolled shutdown. Potline restart is an expensive operation resulting in a loss of revenue and higher costs impacting the financial bottom line. Therefore, any contingency method developed to avert a shutdown can be very valuable for a smelter.

Many publications have been written in the past about the hibernation methodology, in which the anodes are lowered into the metal pad to below two volts, resulting in varying degrees of success depending on the duration of the disruption [1]. With this method, the liquid bath is short-circuited and will cool down until it reaches freezing point.

Over the years, Rio Tinto has developed a sleeping mode methodology where the pot is brought just below the voltage needed to produce aluminium (decomposition voltage), but the anodes are not short-circuited in the metal. By sleeping the pots, the bath temperature does not cool down, and the pot stays alive even if no alumina is added to the pot.

1.1 Sleeping Pot Methodology

The first large-scale use of the sleeping mode method was in 2010 at Laterrière Works, after a major issue with the transmission lines. When one potline had to be shutdown, the second one was restarted without compressed air, as a result there is no alumina feeding. This situation occurred for 8 hours, so the potline was put in sleeping mode to keep the pots alive, and the pots were brought back to normal operation with the return of the compressed air. Every pot was put in sleeping mode for 8 to 12 hours without any pot loss.

Following this event, the sleeping mode method was tested in every smelter of Rio Tinto's Atlantic region, and the method was embedded in the contingency procedures.

In 2021, following many operational problems a sleeping mode trial was performed at the Kitimat smelter for a three-day duration with success. This trial showed that the method may be useful for longer-term contingency problems.

2. Potline Event

The 48-pot section suffered a hyper-dense phase system failure on November 9, 2022, causing 48 pots to suddenly lose alumina supply. Initially, the maintenance diagnosis assumed no foreseeable recovery within 72 hours. As a result, the sleeping mode contingency was initiated.

2.1 Preparation

The Kitimat AP40 superstructure design can hold approximately 18-hours of alumina supply. Therefore, the time was used to prepare the 48-pot section knowing that there was no foreseeable recovery plan within the 18-hour mark.

The first step taken to prepare the affected pots for sleeping mode was to contact other affected areas, such as power operations to ensure they would have available workforce to monitor the voltage and amperage and adjust amperage as needed. Additionally, the gas treatment centre needed to be informed as pots wouldn't be fed with alumina, potentially requiring adjustments to feed rates.

The most crucial step was to ensure that all affected pots (48-pot section) had enough beam movement in both directions. This was achieved through beam raising or metal tapping.

It was also important to lower the bath level in the affected pots and increase the bath levels in unaffected pots to minimize anode pin washing, reduce the risk of cover collapse, and ensure enough bath was available when awakening the pots back to normal pot voltage.

Table 1 shows the workforce organized for the 48-pot section sleeping mode contingency during the preparation phase to ensure that all employees were trained and understood their roles before starting the work.

Table 1. Workforce requirement for sleeping mode contingency.

Initiation Phase	Follow-up Phase	Awakening Phase
1 Technical Lead	1 Technical Lead	1-Technical Lead
4-6 employees putting pots to sleep and monitoring voltage.	3 employees adjusting pot voltage	2-4 employees adjusting pot voltage
2 employees measuring the anode current distribution	2 employees measuring the anode current distribution	1 coordinator (SURMEC Management)
1 employee taking bath temperatures	1 employee taking bath temperatures	3 employees on bath levelling (1 BTV delegated to sleeping mode section)
1 coordinator (SURMEC Management)	1 coordinator (SURMEC Management)	
3 employees on bath levelling (1 BTV delegated to sleeping mode section)	3 employees on bath levelling (1 BTV delegated to sleeping mode section)	
TOTAL = 12-14	**TOTAL = 11**	**TOTAL = 7-9**

2.2 Sleeping Mode Initiated

The sleeping mode of the 48-pot section was initiated at hour 16 of no alumina feeding. The first step was to stop aluminium fluoride (AlF_3) addition to the affected pots to help control the bath temperature while the pots were at a lower voltage. A designated technical person in the control room was responsible for this task and acted as the main coordinator between power operations and the technical lead on the floor. Their role was to determine the rate of pots to put to sleep at as determined by communicating with power operations and monitoring the open circuit protection system (SURMEC) to ensure the proper voltage safety gap.

During the 48-pot section sleeping mode event, pots were put to sleep in groups of five. Four operators and a technical lead would each put one pot to sleep at a time, waiting for approval from the coordinator before moving on to the next five pots. The key steps for putting a pot to sleep were:

- Taking a reference of the beam level, pot voltage and marking the four corners of the beam.
- Lowering the beam in increments and visually checking each corner to ensure no obstructions that could cause potential buckling to the anode beam.
- Once the target voltage was achieved, measuring the bath height and readjusting levels to minimize compromising the anodes and sidewall of the pot shell.

After the 48-pot section was put to sleep, it was important for the first four hours that the designated operators and technical lead on the floor monitored the pot voltage and adjusted as needed approximately every 15 minutes as the pots were quite unstable and tended to drift higher than the decomposition voltage. Additionally, the amperage was reduced by 10–15 kA to manage the bath levelling for the entire line. The lower amperage allowed room for more bath addition by un-squeezing the unaffected pots.

2.3 Follow-up

Once the 48-pot section was asleep, a strategic plan was created for monitoring the pots. The follow-up criteria included:

- Monitoring the voltage every hour (after the 4-hour mark of pots sleeping)
- Following the anode current distribution

- Monitoring the bath temperature and keeping tapping holes open
- Monitoring bath levelling
- Collecting bath and metal samples
- Conducting visual inspections of the flame colour (looking for yellow flames)

During the remaining 68 hours (about 3 days) of the pot's sleeping, the most important follow-up was maintaining bath levelling. The affected pots were continually producing bath and needed continual removal during the 12-hour shift. To help minimize bath production in the affected pots, the amperage was reduced further by 5–10 kA as the anode immersion of the unaffected pots would allow.

On a pot-to-pot basis, various troubleshooting activities were needed. Anode incidents were found by following the anode current distribution. An anode change team addressed incident anodes on the sleeping pots as needed. Majority incidents that occurred during the sleeping process were on anodes that were late to be changed therefore the carbon under pin was already compromised. AlF_3 shots were imposed for a given period to mitigate the rise in bath temperature, compensate for the ongoing bath evaporation, and the fluoride consumption in the bath. Additionally, anode effects were resolved by placing the anodes in the metal for a given time and lowering the beam slightly below it was prior to the anode effect.

2.4 Awakening

Once repairs were made to the alumina feeding system, the awakening phase began. A strategic approach of waking up two pots at a time was used due to anode effects, increasing the potline voltage, and the workload required to perform the task. The SURMEC safety voltage gap required full-time monitoring and adjusting during the awakening phase to limit the risk of a potline trip due to increased pot voltage from anode effects and returning the pot to the operating voltage. The awakening phase lasted approximately 12 hours.

Prior to waking the pots, the crust breakers and feeders were tested to ensure they were functioning properly and that the feeder holes were opening. The anode clamps were tightened to prevent the risk of slipping anodes. The anode beam was then slowly raised in steps to reach the reference voltage, and bath was added as needed to ensure anode immersion.

When the pots were brought back from sleep mode, they went into anode effect and were unstable. After the anode effects were killed, the pots returned to a relatively stable state. To resume normal operation, the AlF3 addition was restarted, and normal operations were allowed on the pots that were classified as stable. Follow-up tasks during the awakening phase included:

- Inspection of the feeder holes
- Bath levelling
- Bath temperature.

3. Results

Potline indicators were successfully recovered after the sleeping mode event. Figure 1 indicates the change in carbon under pin in the pots affected by the sleeping mode compared to a reference section of pots that were not affected. The affected pots showed an increase of 11.4 mm (about 0.45 in) after the sleeping mode event, indicating that operating the pots at the decomposition voltage was successful and did not consume carbon. The anode life was prolonged by approximately 1 day after the sleeping pot event, as shown in Figure 2.

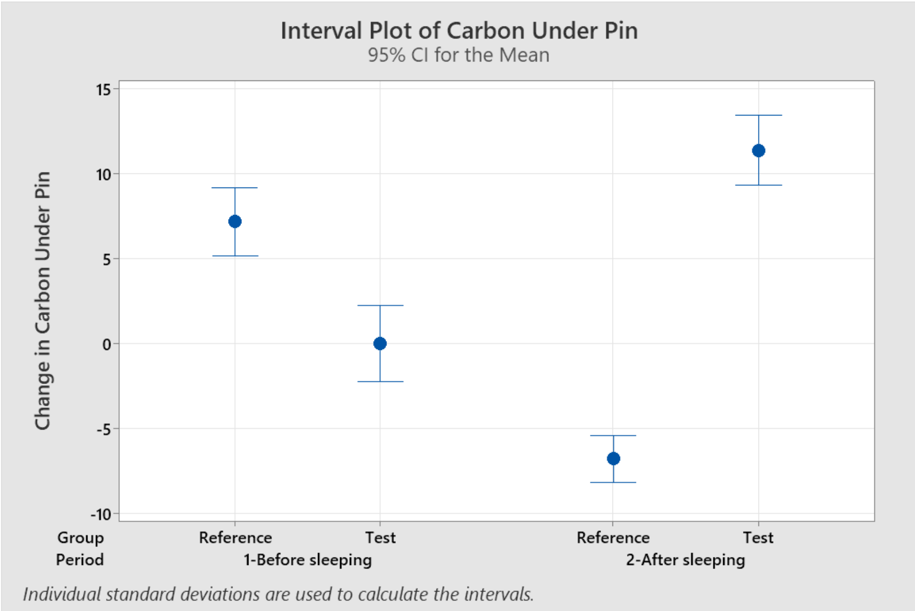

Figure 1. Carbon under pin (mm) impact before and after sleeping.

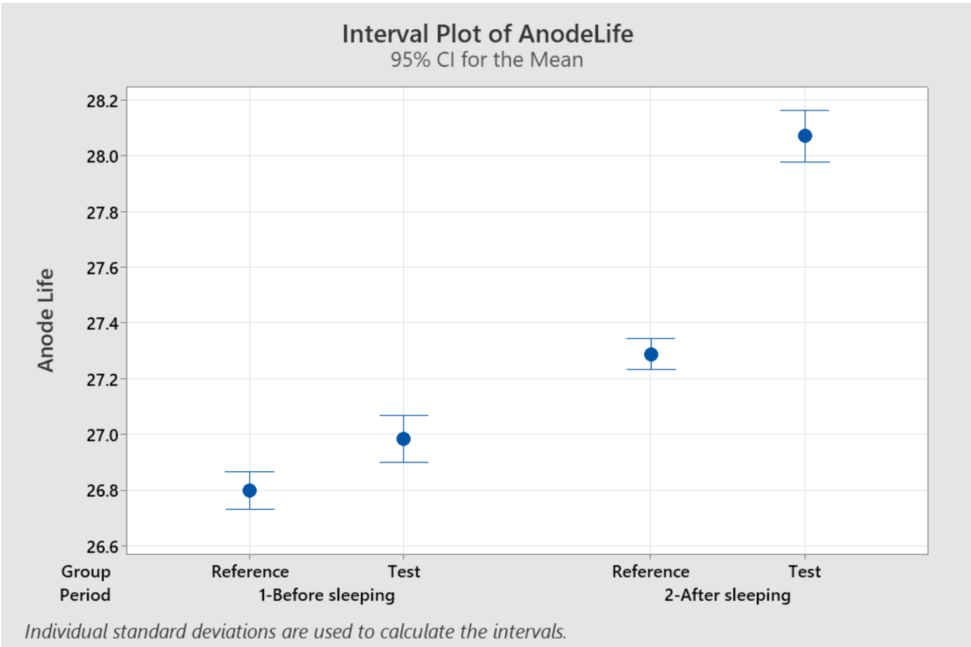

Figure 2. Anode life (days) impact before and after sleeping.

The reduction of the carbon consumption can be explained by the fact that at any moment there are some anodes short-circuiting the bath due to the metal wave and the other anodes do not have enough energy to react with the oxygen. A reaction with the fluoride creates PFC gases, partially isolating the anode. Due to the metal wave, the gases are removed rapidly. The high instability (voltage variation), metal production may occur at a given point of time, but the metal is re-oxidized rapidly due to the low anode-cathode distance. This fine balance helps to maintain the bath temperature.

Late anode changes, anode pin wash, and bath levels contributed to the spike in iron levels in metal. Like iron, the silicon levels in metal increased during the sleeping mode event due to instability, bath levels, temperature, superheat. Both iron and silicon levels began trending down once the pots were brought back to normal operation.

Instability was higher during the sleeping mode event, as shown in Figure 3. A metal wave is triggered due to lowering the anode-cathode distance. This wave is crucial for the success of the sleeping mode. Due to the magnetohydrodynamic equilibrium disturbance, the goal is to have a metal wave constantly in the pot to avoid the metal getting stuck under an anode block and creating an anodic incident.

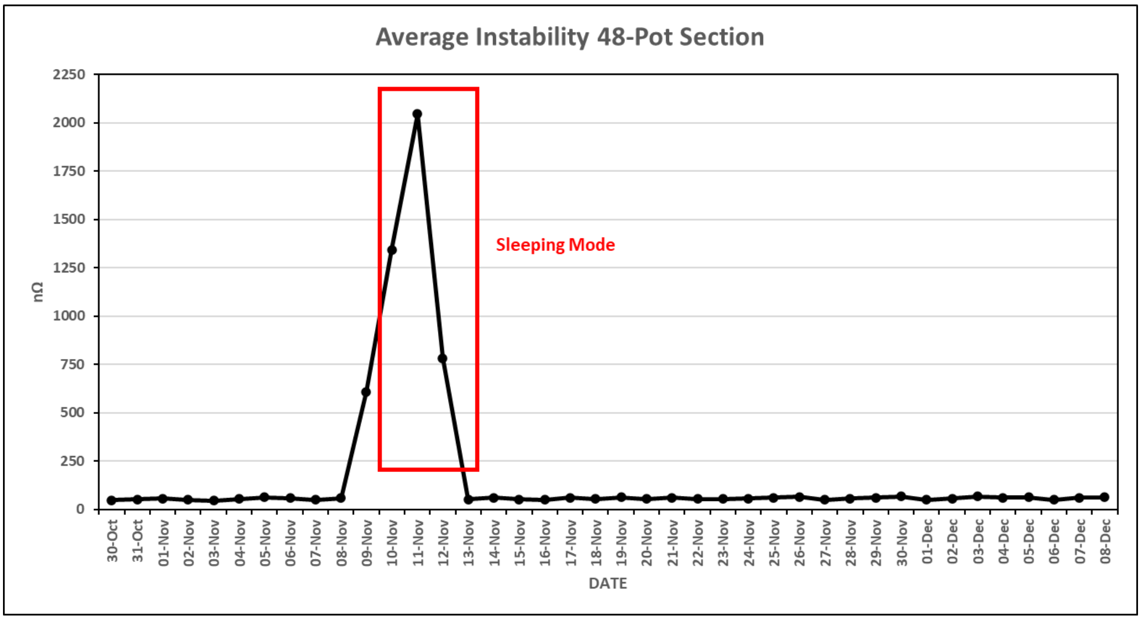

Figure 3. Sleeping mode impact on the 48-pot section instability.

All pots experienced anode effects during the awakening phase. Once the anode effects were terminated and the pots were returned to normal operation, the instability and anode effect frequency returned to pre-event levels.

The potline amperage was reduced by 15–25 kA range to assist with bath management during the sleeping mode event. The return to the target amperage was done gradually to effectively manage bath production in the potlines.

4. Key Learnings

The key challenges were observed specifically in the preparation, follow-up, and awakening phases. During the preparation phase, it was underestimated how large of a team was needed full time in the 48-pot section. Organizational changes were made, and tools developed throughout the 72 hours of sleeping mode to mitigate the risk of workforce fatigue and loss of operating pots.

During the follow-up phase, there was an understanding that bath levels were of the most importance as the levels can increase quite quickly based on the study of the previous 2021 trial. However, the magnitude was not reflected from the previous trial as it was successfully completed on one pot and not on a group of pots. This left little room for compounding equipment break down or workforce issues as the bath tapping vehicle (BTV) had to be in operation continuously. Within the first 24 hours, the bath levels did get quite high on various pots, causing contamination of the metal. Amperage drops favoured optimizing bath generation and bath movements.

Another key learning was regarding bath temperatures and selective pots did become quite hot due to no AlF_3 feeding. The decision was made to impose a correction on an individual pot basis based only on hot pots. The AlF_3 feeding was followed and prohibited once the pot was trending under the hot pot threshold.

The main challenges of the awakening phase included the rate of waking the pots and the bath management. Due to the pots going into anode effect upon waking up, the potline voltage fluctuated significantly, creating challenges with adjusting the SURMEC safety voltage gap.

5. Conclusions

Sleeping pot methodology engaged in 48 pot section for 72 hours is success story in BC works – Kitimat (AP40 smelter) after all pots were successfully returned to service without failure. Subsequent autopsies were conducted on few pots from the sleeping pots section, there were no indications of excessive bath attack, no deterioration on preformed blocks or silicon carbide side-wall. Effectively there was no tangible impact on long term performance and pot life evolution with the current lining age of majority of the pots from sleeping pots section have surpassing the forecasted average pot life.

6. References

1. Xiangwen Wang, M. Laframboise, P. Gagnon, Experience with lengthy pot hibernation at Alcoa Baie-Comeau, *Light Metals* 2021, 393-400.