ALBA Potline 6 Operation during Amperage Increase

Sajid Hussain[1], Nadia Ahli[2], Khalil Ebrahim[3], Nabeel Al Jallabi[4], Vasantha Kumar Rangasamy[5], Abdulla Habib[6], Sergey Akhmetov[7], Abdalla Alzarooni[8], Konstantin Nikandrov[9] and Alexander Arkhipov[10]

1. Engineer I - R&D
2. Manager Technology Transfer Contracts
Emirates Global Aluminum (EGA), United Arab Emirates
3. Manager Potline 6
4. Senior Manager Process Control and Development
5. Superintendent Reduction Line 6, Process Control and Development
6. Chief Operating Officer
Aluminum Bahrain (ALBA), Askar, Kingdom of Bahrain
7. Executive Vice President Midstream
8. Vice President Technology Development & Transfer
9. Manager - Pot Control System
10. Manager - Modelling
Emirates Global Aluminum (EGA), United Arab Emirates
Corresponding Author: sajhussain@ega.ae

Abstract

ALBA (Aluminium Bahrain) Potline 6 is operating 424 cells of EGA (Emirates Global Aluminium) DX+ Ultra technology. Potline 6 start-up was completed on 31 July 2019 at 460 kA. The cell performance test was successfully carried out at 465 kA from 1 October to 30 November 2019, achieving KPIs well above the contractual figures. EGA has demonstrated the operation of DX+ Ultra technology at 480 kA on five demonstration cells at EGA Jebel Ali site, which confirmed the robustness of DX+ Ultra technology. EGA agreed with ALBA to support amperage increase from 465 kA to 480 kA in Potline 6 and an agreement to this effect was signed between EGA and ALBA in February 2020. In December 2021 ALBA Potline 6 already reached 478 kA. EGA is providing remote and onsite technical support to ALBA operation and process teams. During amperage increase, Potline 6 faced various challenges of maintaining thermal balance, sustaining current efficiency, anode problems, and high bath generation rate. In order to keep cell thermal balance, anode cover was gradually decreased from 15 cm to 6 cm, and metal height target was increased from 20 cm to 25 cm. Bath temperature target was decreased from 957 °C to 955 °C. Potline current efficiency decreased during a few months due to anode problems and carbon dust, but was quickly restored by improving anode quality, cell thermal balance, metal tapping accuracy, and by controlling bath height. Potline was monitored daily for red potshells and action was taken on the red shell pots. Cells with high silicon content in the metal were identified and ranked, and special guidelines were formulated to treat such cells. This paper describes the details of ALBA Potline 6 operation during amperage increase, challenges faced, and actions taken to maintain excellent potline performance.

Keywords: DX+ Ultra technology, Amperage increase, Cell performance, Aluminium Bahrain Potline 6.

1. Introduction

The Kingdom of Bahrain was the first Gulf Cooperation Council (GCC) country to open an aluminium smelter [1]. ALBA started aluminium production with the commissioning of two Potlines 1 and 2 in 1971 using side–break, un-hooded, end-to-end Montecatini technology operating at 100 kA with a capacity of 120 000 tonnes per year. The first expansion was Potline 3 in 1981 using Kaiser end-to-end cell technology. Potline 4 and Potline 5, using the AP30 technology were respectively commissioned in 1992 and in 2005 [2] and are operating at 400 kA at the end of 2021. Then ALBA took a giant leap by commissioning Potline 6 with 424 cells operating EGA DX+ Ultra technology in 2018/2019 [3]. This enabled to increase its annual production capacity by 556 257 tonnes in 2021, bringing total ALBA's aluminium production to 1.561 million tonnes in 2021.

EGA is the largest industrial company in the UAE outside oil and gas and the world's biggest 'premium aluminium' producer. EGA operates aluminium smelters at Jebel Ali in Dubai and at Al Taweelah in Abu Dhabi, with a combined production of 2.501 million tonnes of metal in 2021. EGA is operating its own cell technologies: D18+, CD20, D20, D20+, DX, DX+ and DX+ Ultra. DX+ Ultra technology was developed as low energy version of DX+ technology, operated in EGA Al Taweelah Potline 3 since 2013 [4]. The goal of designing and building DX+ Ultra demonstration cells was to test for future Brownfield expansion or Greenfield smelter with lower CAPEX, higher productivity and lower energy consumption cell than with using DX+ cells. Successful performance of DX+ Ultra technology was demonstrated in five Eagle cells in Jebel Ali Potline 5 from 2014-2021 at 460-480 kA [5]. It is now operating in ALBA Potline 6 and in recent Al Taweelah Potline 3 extension [3, 6].

The Technology Licence Agreement for Potline 6 between EGA and ALBA was for the amperage of 440 kA to 460 kA. In practice, this was the potline start-up amperage. Immediately after the end of potline start-up, the amperage was increased to 465 kA. The Technology Performance Test was successfully carried out at 465 kA in October and November 2019 [3]. Following the successful demonstration of DX+ Ultra technology at 480 kA in EGA Jebel Ali, Potline 5 Eagle section, the Technology Enhancement Agreement between EGA and ALBA was signed in March 2020, with the objective to increase the amperage in ALBA's Potline 6 to 480 kA. This paper describes the amperage increase from 465 kA to the present amperage of 478 kA; 480 kA should be achieved by the end of 2022.

2. Amperage Increase Strategy

ALBA Potline 6 was started up at 440 to 460 kA from 9 December 2018 to 31 July 2019 and the amperage was increased to 465 kA by mid-September 2019. The analysis of potline operation in this paper starts on 1 October 2019, when nearly all cells were "established" (cell age > 56 days) and the potline operation was stabilized. The average cell age on 1 October 2021 was 142.8 days for the age range of 62-296 days. The Cell Performance Test, governed by Technology License Agreement, started on 1 October 2019 for 60 days to 30 November 2019 [3]; during this period, the line amperage was kept constant at 465 kA (Figure 1). After successful completion of the performance test, the amperage was increased further to reach 470 kA in January 2020 and 472 kA in February 2020. Potline operation was kept at 472 kA from 11 February 2020 to 26 September 2020.

Gradual potline amperage increase was resumed from 27 September 2020, reaching 475 kA on 22 October 2020, but then it was reduced by 2 kA (475 kA to 473 kA) for one month (from mid-November to mid-December 2020) due to significant increase of anode problems, including spikes. The amperage reduction and improved carbon quality helped to reduce anode problems.

After overcoming the anode problems, potline amperage increase was resumed on 18 December 2021 and 477 kA was reached on 26 January 2021.

On 2 March 2021, potline amperage was reduced by 2 kA again to 475 kA to prepare the potline for summer conditions and tackle the increased number of red-hot potshells. Potline amperage increase strategy was revised and it was decided to increase the amperage in steps of 0.5 kA with a long stabilization at each step. Thus, potline amperage was increased from 475 kA to 478 kA from 22 May 2021 to 20 December 2021. Currently, Potline 6 is operating at 478 kA. Refer to Figure 1 for the history of amperage increase.

Go-no-go criteria were defined to make decision for each step of amperage increase. These include all KPIs which are directly impacted by the amperage increase. The criteria were reviewed and agreed between EGA and ALBA operation teams before going ahead with each step of amperage increase.

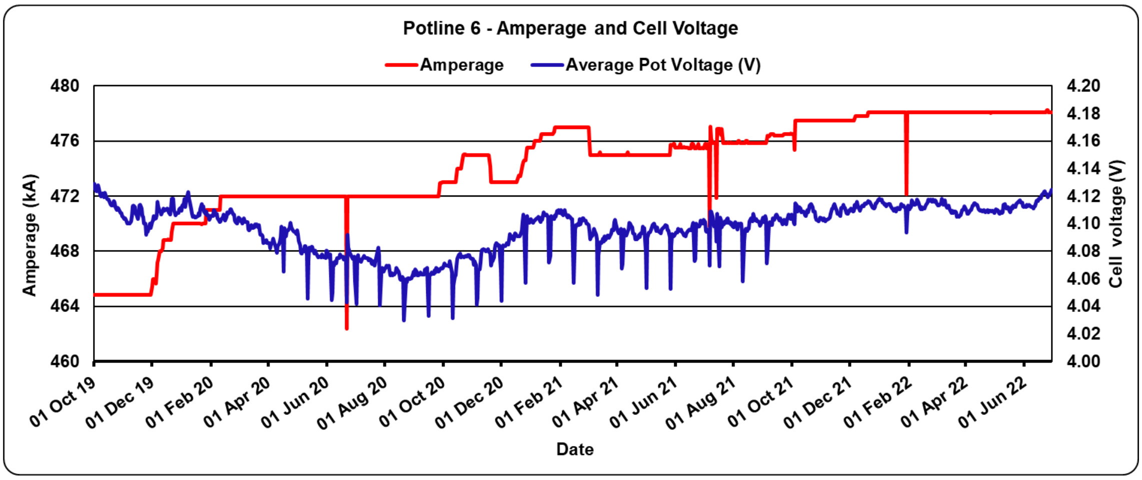


Figure 1. ALBA Potline 6 - History of amperage increase and cell voltage. The drops of voltage correspond to a skip of anode change to achieve 76 shift anode life.

EGA's strategy for amperage increases is to use mathematical models for key cell parameter calculations. EGA has full mathematical modelling capability for cell design and amperage increase studies [7-8]. With these models, the planned amperage increase is evaluated beforehand so that there is greater certainty when actual cells are tested. In the DX+ Ultra demonstration cells the cell parameter adjustments were linked to three strategies: constant anode-cathode distance (ACD), constant voltage and constant internal heat. Often a combination of these three strategies is required.

2.1 Base Resistance Setpoint Adjustment

The main cell energy control parameter is the Base Resistance Set Point (BRSP), shown in Figure 2. On top of BRSP, additional cell resistance is added by the cell control system for cell early life, anode changing, cell instability and bath temperature corrections. The net cell voltage is:

$$V_{cell} = V_{base} + V_{adders} \tag{1}$$

$$V_{base} = BRSP\ (\mu\Omega) \times Amperage\ (kA) / 1000 + 1.65\ V \tag{2}$$

In ALBA Potline 6, the contribution of all voltage adders to the cell voltage was approximately 43 mV for the analysis period. In Figure 2, we can see that the BRSP varied with amperage increase between 5.19 µΩ and 5.02 µΩ. Cell voltage varied in a similar manner within a range of 50 - 60 mV. This implied squeezing ACD by 2.2 mm as shown in Table 1.

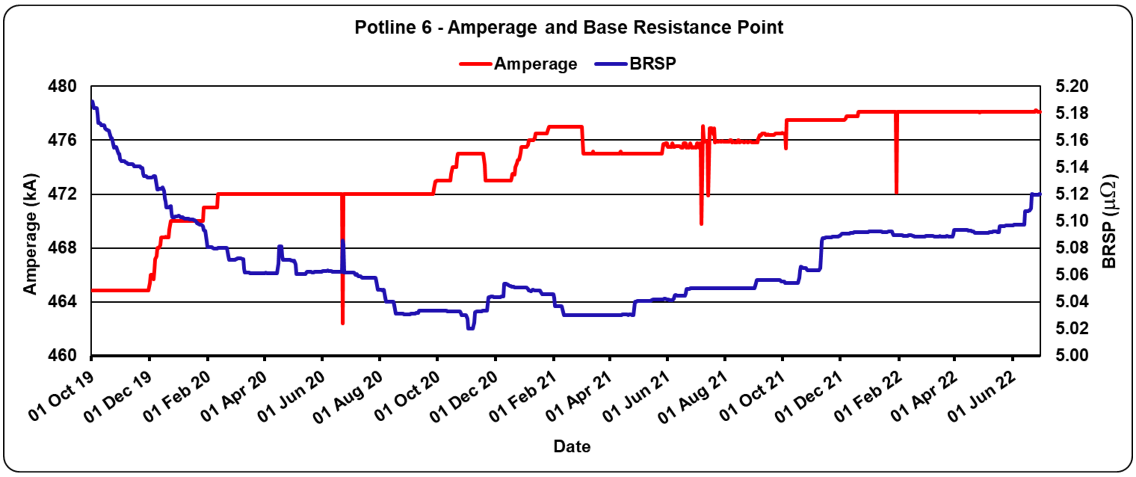


Figure 2. ALBA Potline 6 amperage and BRSP.

2.2 Heat Balance and ACD

2.2.1 Internal Heat and ACD

EGA's cell energy balance analysis is based on the concept of the cell internal heat, which is the net heat within the pre-determined boundaries of the cell, i.e., the heat generated minus the heat absorbed as shown in Equation (3). The boundaries are defined by the surface of the cathode shell and the top of anode cover [5]. Cathode collector bars to the end outside the shell and anode rods to the top below the anode beam are included within these boundaries. Heat generated in the busbars outside these boundaries is excluded; this is expressed by subtracting external voltage drop from the cell voltage. The balance requires that all the internal heat is lost across these cell boundaries shown in [5]. Within these boundaries heat is generated by electrical current and voltage drops within the boundaries, but also by aluminium re-oxidation (current efficiency loss) and by air burn of anode carbon and carbon monoxide. Heat is absorbed by the electrochemical reaction to make aluminium and by some auxiliary processes, such as anode changing, anode butt removal, net bath tapping, fluoride feeding, reactions with alumina impurities, and by evaporation of water.

The main generator of electrical heat is the bath in the interpolar space, determined by ACD.

$$Q_{\text{int}} = \left[V_{cell} - V_{external} - (V_{Al} + V_{aux}) + xV_{\text{C}\ burn} + yV_{CO\ burn}\right] I \tag{3}$$

where:

Q_{int}	Cell internal heat, kW
V_{cell}	Cell voltage, V
$V_{external}$	External voltage drop (the one outside the System Boundary 2), V
V_{Al}	Voltage equivalent of enthalpy to make aluminium, for forward and back reactions, V
V_{aux}	Voltage equivalent of heat removed from the cell by auxiliary processes, such as anode butt removal, cavity scoop, aluminium fluoride and impurity additions, etc., V
$xV_{C\ burn}$	Fraction *x* of voltage equivalent of enthalpy of excess carbon burn (air and CO_2), V
$yV_{CO\ burn}$	Fraction *y* of voltage equivalent of CO burn within the chosen heat loss boundary, V
I	Cell current, kA.

The ACD is calculated according to Haupin [9]. Table 1 gives the internal heat and ACD in different target amperage increase stages. These data do not include transition stages between amperage levels. Anode, cathode and external voltage drops were adjusted proportional to amperage. The period at 475 kA was not steady; it comprises reaching 475 kA, decreasing to 473 kA, increasing to 477 kA and decreasing to 475 kA again as explained above and shown in Figure 1. This variation was because of anode problems; the result was lower current efficiency and higher internal heat. In Table 1, the period of 475 kA is the last stable period before further amperage increase.

Table 1. Internal heat according to Equation (3), and ACD.

Period		**1 Oct 2019 to 5 Dec 2019**	**11 Feb 2020 to 27 Sept 2020**	**4 Mar 2021 to 26 May 2021**	**20 Dec 2021 to 30 Jun 2022**
Target amperage	kA	**465**	**472**	**475**	**478**
Amperage in period	kA	464.9	472.0	475.2	478.1
Current efficiency	%	94.4	95.0	93.3	93.9
Cell voltage	V	4.110	4.078	4.092	4.113
ACD	mm	29.5	27.9	27.7	27.3
Current density	A/cm^2	0.969	0.979	0.985	0.992
Anode length	mm	1850	1860	1860	1860
External voltage	V	0.239	0.243	0.244	0.246
V_{Al}*	V	2.079	2.088	2.059	2.070
Internal heat, Q_{in}	kW	833	825	849	859

*This is voltage equivalent of enthalpy to make aluminium, including V_{aux} of 0.044 V and no carbon or CO burn.

The increased internal heat must be compensated with higher heat loss. Even though DX+ Ultra cells operate at low voltage, the cells generate a lot of heat because they are designed for high current density (defined with bottom surface of new anodes) as shown in Table 1. Anode length originally at 1850 mm was increased to 1860 mm in April 2021 and to 1870 mm at the end of May 2022.

In the operation of ALBA Potline 6, two key methods were used to dissipate and balance excess heat: a) decreasing anode cover thickness and b) increasing metal height.

Figure 3 shows the decrease of anode cover thickness from 15 cm to 6 cm while the amperage was increased from 465 kA to 478 kA. Figure 4 shows the metal height increase with cell amperage.

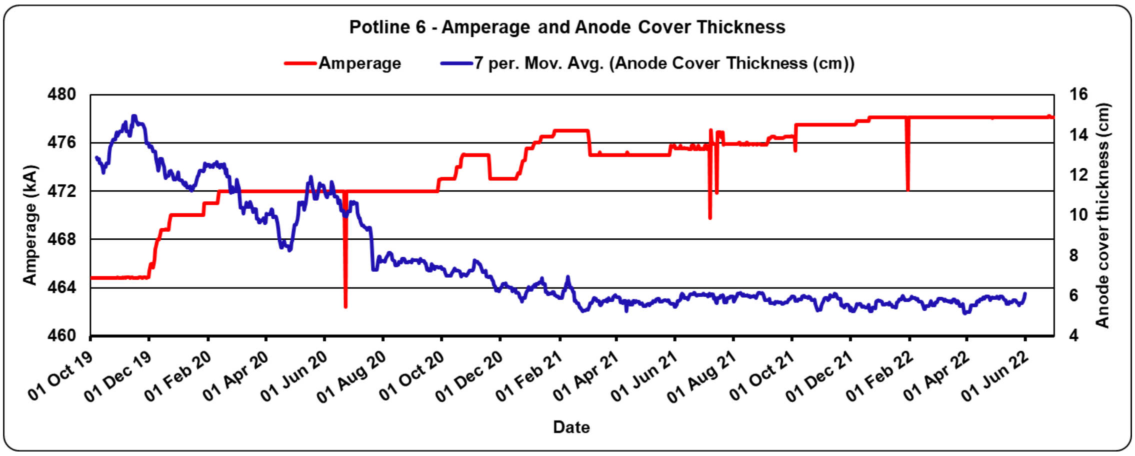


Figure 3. Potline amperage and anode cover height (7 days moving average).

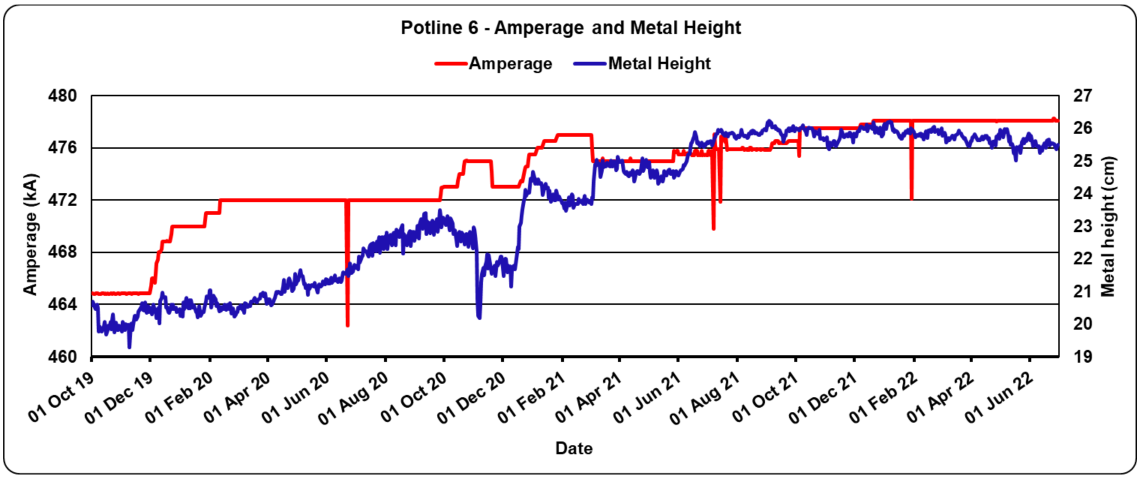
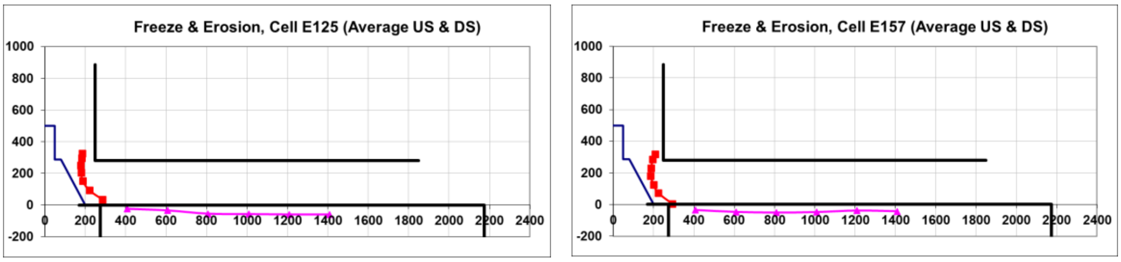


Figure 4. Cell amperage and metal height.

2.2.2 Freeze Profiles

Freeze profiles were measured several times at various stages of amperage increase to confirm that the side and end walls were well protected. Figure 5 shows freeze profiles, measured in technology validation campaign in November 2020. We can see that the sidewalls are well protected.



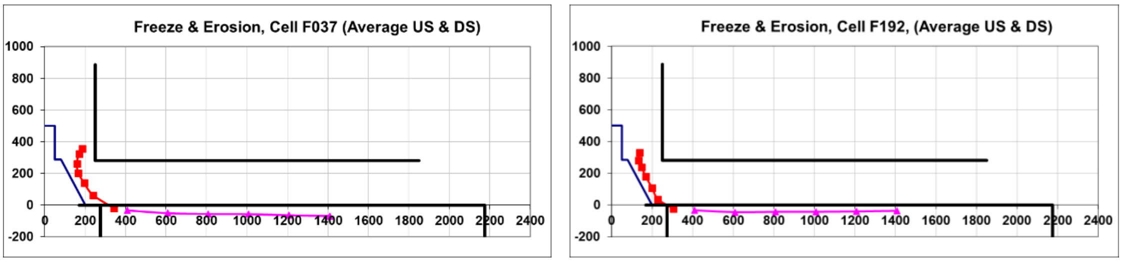


Figure 5. Freeze profiles and erosion at 475 kA in four cells, measured in November 2020.

2.2.3 Potshell Temperatures

During amperage increase, close monitoring of potshell condition is very important. The monitoring consists of regular potshell temperature measurements and visual observations for possible occurrence of red shells.

Figure 6 shows average potshell temperature, measured with optical pyrometer along the cell sides at each collector bar at the metal level where the temperatures are the highest vertical-wise as shown in Figure 7. Figure 6 therefore shows the average of the maxima along the cell sides. The linear curve fit shows that the average shell temperature increases very little with amperage, only by 7 °C from 465 kA to 478 kA. The variations we see are due to general thermal condition of the cells, bath superheat, freeze thickness at metal level, anode cover thickness and also ambient temperature.

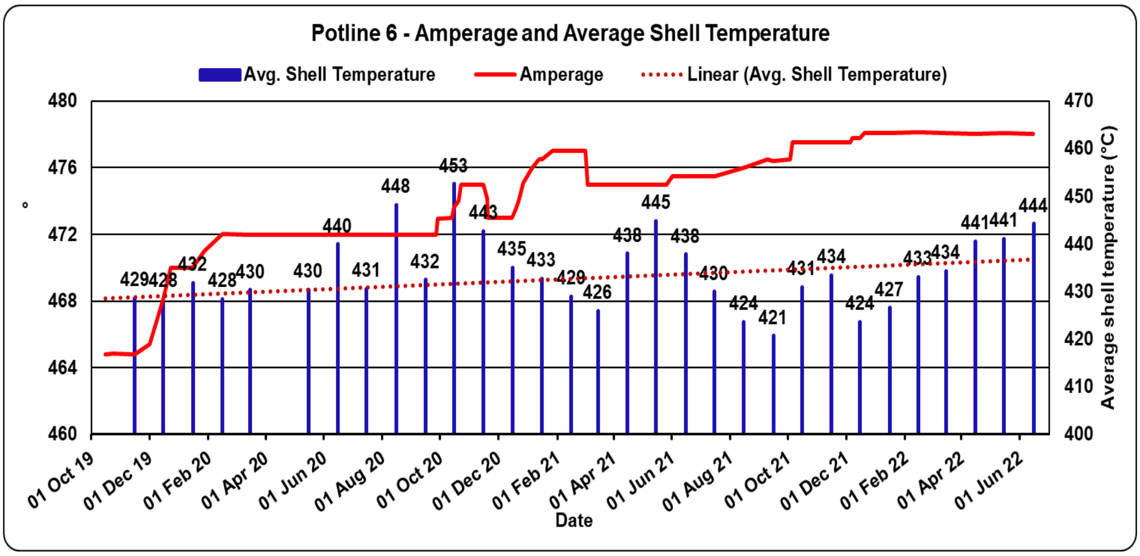


Figure 6. Potline amperage and potshell temperatures, which are monthly averages of averages along the potshell sides.

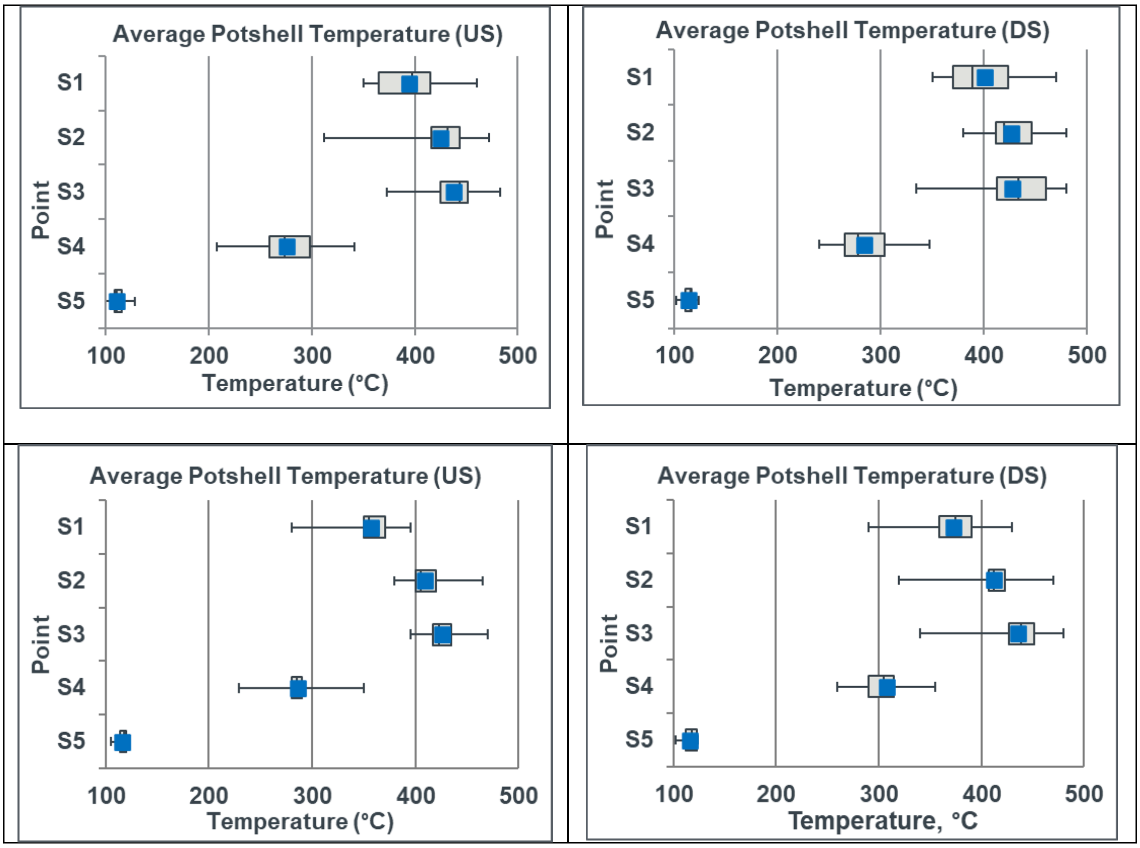


Figure 7. Average potshell temperatures along vertical position on the potshell, measured at 5 cathode blocks along the pot sides. US: upstream, DS: downstream, S1: middle of bath height, S2: metal-bath interface, S3: metal level, S4: above collector bars, S5: in the middle between the collector bar and shell bottom. Top: At 465 kA. Bottom: At 475 kA, measured in technology validation campaign in November 2020.

Potline 6 operation started rigorous practice of red shell surveys in June 2020 at 472 kA after appearance of some red shells. Red-shell survey is being carried out on one section (53 cells) every day in the night shift. Potline 6 consists of 8 sections; thus, one cycle of red shell survey is completed in 8 days. The red shell observations are categorized as mild, medium and bright. Hot spots are more frequent at older anodes. Even though bright-red shells are found on less than 1% of cells, immediate action is taken on the potshell locations observed with bright-red shells. Shell temperature is measured, and typically found to be around 530 °C. Key actions taken for bright-red shell locations include installation of cooling pipes, breaking the crust on sidewall channel (in case of shell temperature greater than 580 °C), cleaning the basement to increase air circulation at cells with repeated bright-red shell, and measurement of side freeze in case of silicon content increase.

2.3 Anodes

Since ALBA Potline 6 start up, anode length has been increased from 1850 to 1870 mm. Anode height has been increased from 660 mm to 680 mm and anode slot height has been increased form 355/385 mm to 400/430 mm. Anode length was increased to reduce current density in the anodes and in the bath, anode height was increased to keep anode shift life of 76 shifts earlier, and currently 72 shifts due to faster consumption of carbon because of increased amperage. Anode butt thickness at 478 kA is 20.7 cm. Anode slot height was increased to reduce bath bubble voltage by increasing the life of anode slots.

Anode butt thickness and carbon under stub are shown in Figures 8 and 9, respectively. They show that the amperage can be increased to the planned 480 kA without any change in anode dimensions.

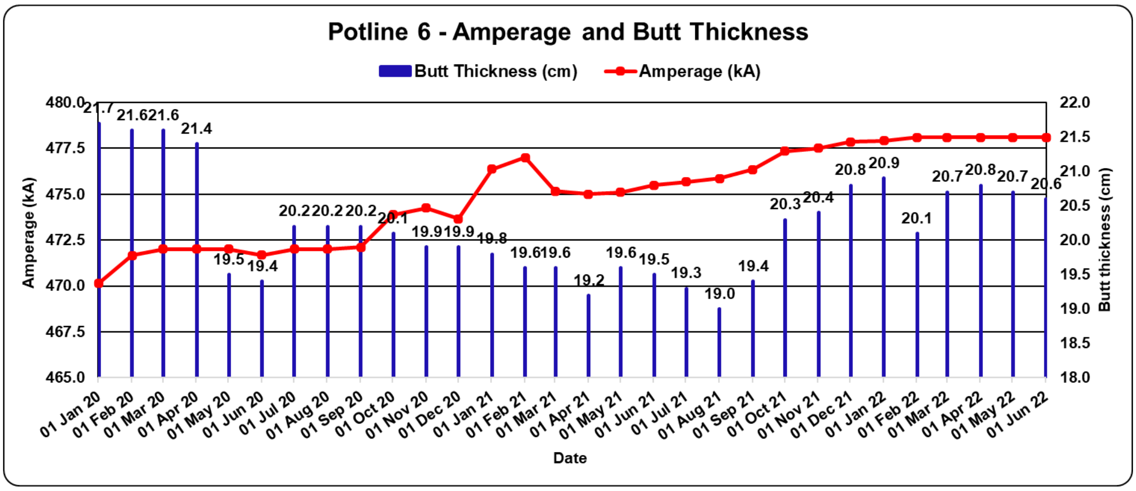


Figure 8. Anode butt thickness at different amperage and adjusted anode life.

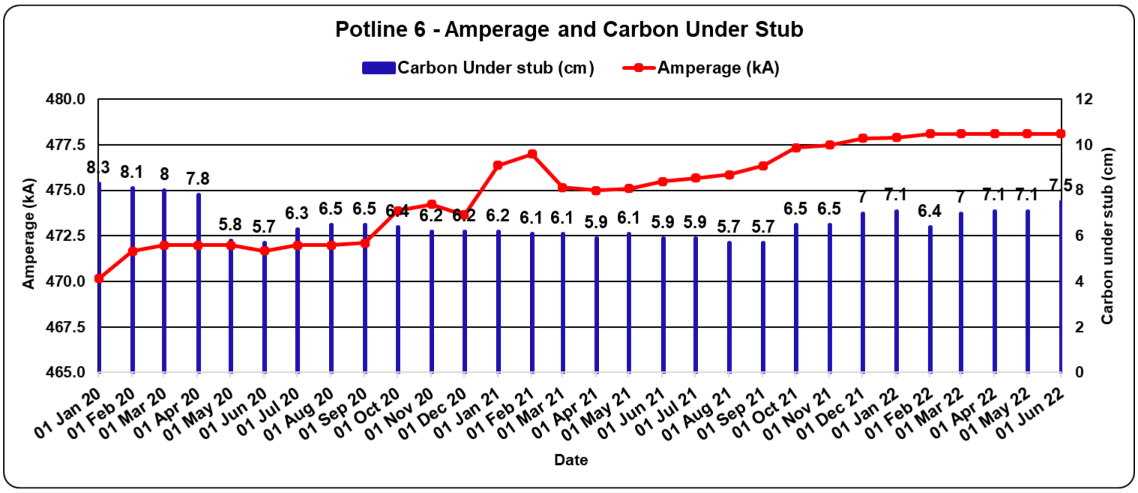


Figure 9. Carbon under stub at different amperages and adjusted anode life.

3. Cathode Voltage Drop

As energy saving initiative, DX+ Ultra pots are equipped with copper inserts, both in the original and the industrial design whereby the copper inserts were made somewhat longer in the industrial design cells [5]. This reduces the cathode voltage drop (CVD) and can be used to lower pot voltage and specific energy consumption. It also allows more amperage increase. Figure 10 shows the CVD evolution with cell age and amperage increase.

The CVD increases with amperage and cell age. The dependence on cell age is shown in the line normalized to constant amperage of 478 kA. We see that the CVD increase with cell age is very modest, 21 mV over 1000 days if we exclude the effect of amperage increase.

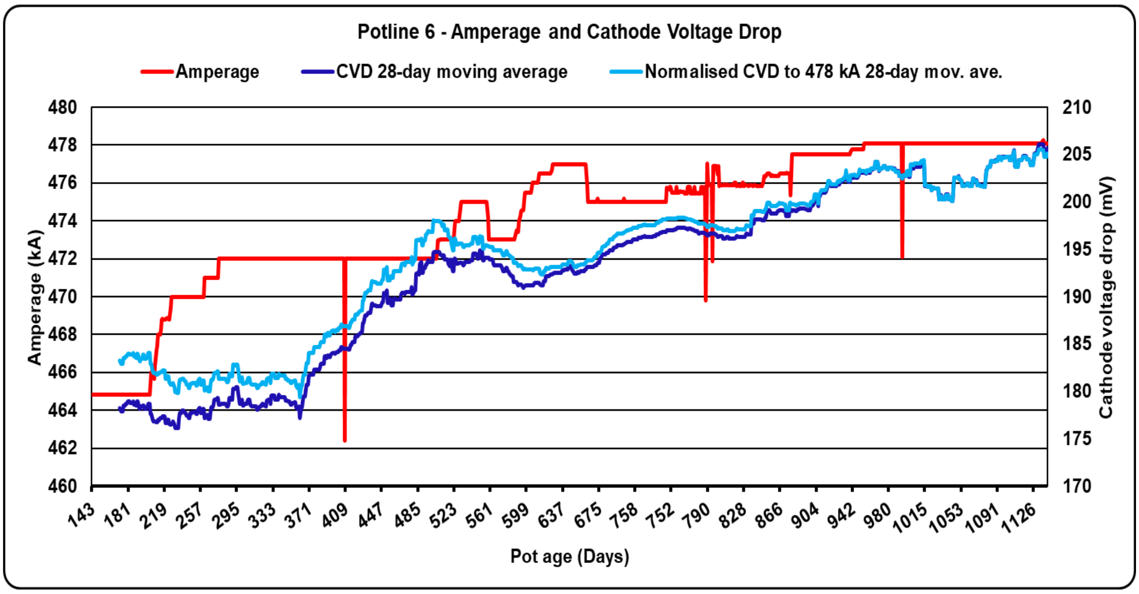


Figure 10. Cathode voltage drop evolution with cell age and amperage increase

4. Cell Control

ALBA Potline 6 uses EGA's advanced Pot Control System (PCS) based on standard programmable logic controller (PLC) hardware architecture, which gives increased human machine interface (HMI) capabilities and assures easy maintenance and future upgrades because the PCS is under continuous development [10]. The key new features include new iPots-based AlF_3 control logic, optimization of bath temperature adder, based on iPots program, optimization of anode setting voltage adder, etc. EGA usually deploys updated software every year according to a dedicated support contract with ALBA to maintain the cell control system.

5. Optimization of Operational Practices

In order to operate the potline smoothly, various process control and operational practices have been optimized. The key practices optimized during amperage increase are described below.

5.1 Bath Temperature and Excess AlF_3

Figure 11 shows excess AlF_3 and bath temperature. With metal height increase to 25 cm, and considering the potline operating condition, bath temperature target was decreased from 957 °C to 955 °C but target excess AlF_3 was kept at 9.5 %. Low excess AlF_3 is compensated by high CaF_2 concentration of 7.5 %, average over the whole period from 1 October 2019 to 30 June 2022. This was low superheat operation, an average of 7 °C for the whole period. Practical results for different periods of amperage increase show steady values of both, bath temperature and excess AlF_3, with a small increase of excess AlF_3 to 9.9 % and a slight increase of superheat to 7.5 °C.

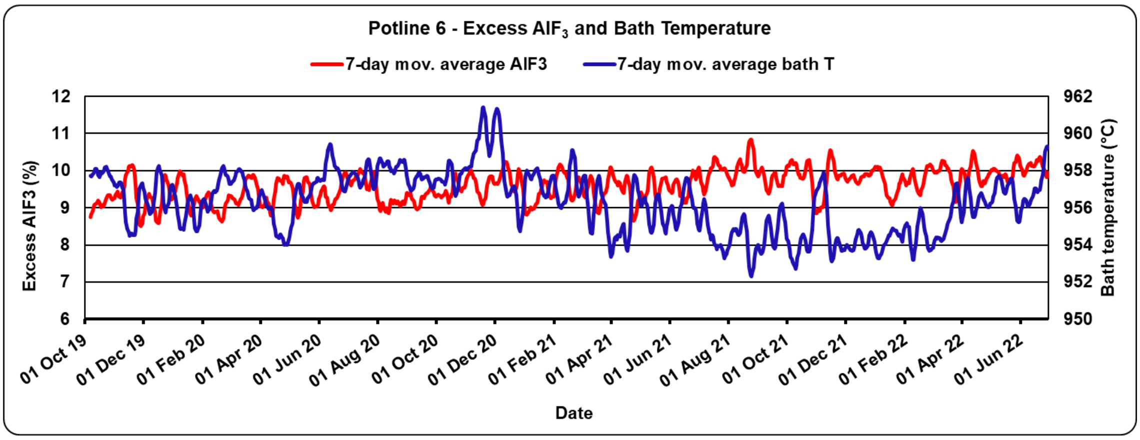


Figure 11. Excess AlF_3 and bath temperature.

5.2 Optimization of Metal Tapping Accuracy

Tapping accuracy is defined as the difference between the cruce weight (= metal weight received from the casthouse) and potline weight (= recommended weight of metal as per metal height; this number is taken from the tapping ticket). Potline 6 benchmarking is carried out periodically with EGA Al Taweelah Potline 3 with DX+ technology. This showed that Potline 6 tapping accuracy was less consistent than in Al Taweelah. Generally, tapped crucible weight, containing the metal from three cells, a variation of ±150 kg is acceptable, but in Potline 6 the tapped metal per crucible was mostly out of the acceptable limits. Special attention was paid to improve the tapping accuracy as tapping more metal than recommendation leads to lower metal height, which affects the cell thermal balance. With the improvement of tapping accuracy, the metal height became more consistent. Figure 12 shows the tapping accuracy and metal height.

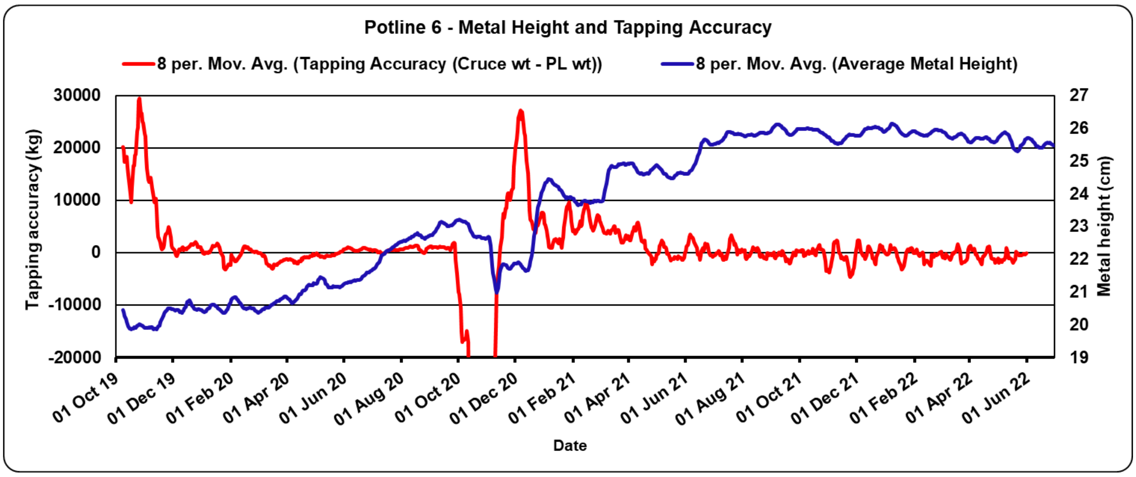


Figure 12. Tapping accuracy in the whole Potline 6 and metal height.

5.3 Optimization of Bath Generation

During amperage increase, an increase in bath generation was observed during each step of amperage increase (Figure 13). Moreover, it was observed that bath generation at ALBA Potline 6 was quite high. The analysis of bath poured into the sow mould indicates that around 5 to 7 % metal is tapped along with total generated bath. This confirms that more bath generation leads to more metal tapped during bath tapping which negatively impacts cell metal height and thermal balance. Various actions were taken to reduce bath generation which include delaying new anode covering time, stopping the practice of tap hole covering using pot tending machine (PTM);

instead, local material was used, increasing the alumina content in anode covering material by 10 % (from 28 % to 38 %). All these actions helped to control bath generation and metal height on the target.

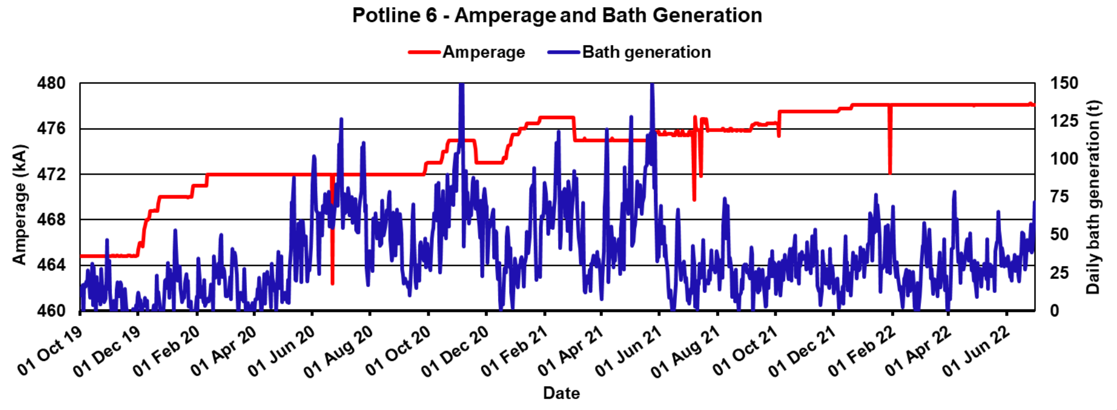


Figure 13. Daily bath generation in Potline 6.

6. Design Validation Measurement Campaign at 465 kA and 475 kA

Potline 6 electrical and thermal design validation measurement campaign was carried out at 465 kA and at 475 kA. At 475 kA, the measurement campaign was carried out on four cells, two cells in each potroom. The design validation measurement campaign data indicate that the potline is thermally and electrically well balanced. Good thermal balance is confirmed by freeze profiles, shown in Figure 5. External voltage drop (from the end of collector bars of a cell to anode rods below the anode beam of the next cell) at 465 kA was 239 mV, and at 475 kA it was 247 mV, which is by 3 mV greater than proportional to the amperage increase. However, in Table 1, it is taken proportional to the amperage from the value at 465 kA; this has a very small effect on the ACD. Cathode voltage drop is measured on regular basis by the Process control team; the measurement campaigns just confirmed the data of the regular measurements. Anode voltage drop from the anode rods below the anode beam to the bottom of the anode carbon was 420 mV at 465 kA and 452 mV at 475 kA; which is by 23 mV greater than proportional to the amperage. The average anode voltage drop over the whole anode bottom surface is calculated by the model as explained in [11], which was 365 mV at 465 kA. This value is used for the ACD calculation in Table 1, with values proportional to the amperage for other amperages in the table.

7. Cell Performance

Table 3 gives cell key performance indicators (KPIs) for full period of 465-478 kA, 465-472 kA, 472-478 kA and 478 kA.

Table 2. Performance of ALBA's Potline 6 cells from 465 kA to 478 kA.

Parameter	Unit	1 Oct 2019 - 30 June 2022	1 Oct 2019 – 31 Jan 2020	1 Feb 2020 - 31 Dec 2021	1 Jan 2022 - 30 June 2022
Target amperage	kA	465-478	465-472	472-478	478
Actual amperage	kA	474.20	467.04	474.43	478.070
Current efficiency- tapped	%	94.00	94.71	93.90	93.920
Current efficiency, adjusted for metal height increase*	%	94.17	94.79	94.14	93.81
Metal production*	kg/cell-day	3596	3568	3597	3612
Net cell voltage	V	4.097	4.110	4.090	4.113
BRSP	µ□	5.069	5.131	5.052	5.094
Net specific energy (DC)*	kWh/kg Al	12.96	12.92	12.95	13.07
Net carbon consumption*	kg C/t Al	408	398	407	411
Gross carbon consumption	kg C/t Al	544	547	540	559
Excess AlF_3	%	9.6	9.3	9.6	9.8
CaF_2	%	7.5	8.0	7.5	7.5
Bath temperature	°C	956	957	956	956
Metal height before tap	cm	23.6	20.3	23.6	25.7
Fe	%	0.073	0.083	0.072	0.071
Si	%	0.031	0.029	0.030	0.034
Anode effect frequency	AE/pot-day	0.036	0.051	0.028	0.056
Anode effect duration	s	12.5	16.3	10.6	17.5
PFC emissions, CO_2 equivalent**	CO_2 kg/t Al	8	15	5	18
Cathode voltage drop	mV	193	178	193	204

***** Adjusted for metal height increase in each period.
******CO_2 equivalent is calculated as in Reference [12], using the Tier 2 method and SAR (Second Assessment Report).

8. Conclusions

ALBA has successfully increased amperages in DX+ Ultra Potline 6 from 460 kA to 478 kA. It will be able to increase the amperage further to the next short-term target of 480 kA, which has been already demonstrated in EGA Eagle DX+ Ultra cells.

During amperage increases from 465 kA to 478 kA, reported here, excellent results were achieved: current efficiency of 94.2 %, energy consumption of 13 kWh/kg Al, net carbon consumption of 408 kg C/t Al, and benchmark 8 kg CO_2 eq./t Al of PFC emissions.

9. References

1. Abdulla Habib et al., Alba's journey to 1.5 million tonnes site capacity - Challenges and opportunities, *Proceedings of the 38th International ICSOBA Conference,* 16 – 18 November 2020*, Travaux* 49*,* 17 and KN01 Presentation.

2. Abdulla Habib, Historical development of the largest aluminium smelter in the Middle East, *Proceedings of the 37th International ICSOBA Conference*, Krasnoyarsk, Russia, 16 – 20 September 2019, *Travaux* 48, 25 and KN04 Presentation.
3. Michel Reverdy et al., The successful implementation of EGA DX+ Ultra *technology at ALBA*, *Proceedings of the 38th International ICSOBA Conference,* 16 – 18 November 2020, *Travaux 49,* 539-549.
4. Shaikha AlShehhi, Amperage increase in DX+ Potline 3 in EGA Al Taweelah smelter, *Proceedings of the 40th International ICSOBA Conference*, Athens, Greece, 10-14 October 2022, *Travaux* 51, Paper AL01.
5. Nadia Ahli et al., Amperage increase in DX+ Ultra demonstration cells at EGA's Jebel Ali smelter, *Proceedings of the 39th International ICSOBA Conference,* 22 - 24 November 2021, *Travaux* 50, 637-646.
6. Nicole Teeling, Olivier Charette, Jean-Denis Carrier and Saif Alhashmi, Smelter potline extension at EGA Al Taweelah smelter, *Proceedings of 39th International ICSOBA Conference*, Virtual, 22-24 November 2021, Paper AL07, *Travaux* 50. 647-657.
7. Abdalla Al Zarouni, Lalit Mishra, Nadia Ahli, Marwan Bastaki, Amal Al Jasmi, Alexander Arkhipov and Vinko Potocnik, Energy and mass balance in DX+ cells during amperage increase, *Proceedings of 31st International Conference of ICSOBA and 19th Conference Aluminium of Siberia*, Krasnoyarsk, Russia, September 4 – 6, 2013, 494-499.
8. Abdalla Zarouni, Lalit Mishra, Marwan Bastaki, Amal Al Jasmi, Alexander Arkhipov, Vinko Potocnik, Mathematical model validation of aluminium electrolysis cells at DUBAL, *Light Metals* 2013, 597-602.
9. W. E. Haupin, Interpreting the components of cell voltage, Light Metals 1998, 531-537.
10. Michel Reverdy and Abdalla Alzarooni, EGA's advanced pot control system—simple and flexible, *International Aluminium Journal* 1-2, February 2018, 32 and 34.
11. Alexander Arkhipov et al., Review of thermal and electrical modelling and validation approaches for anode design in aluminium reduction cells, *Proceedings of 36th International ICSOBA Conference,* 29 October – 1 November 2018, Belem, Brazil, Paper AL01, *Travaux* 47, 589-605.
12. Ali Al Zarouni et al., DX+, an optimized version of DX technology, *Light Metals* 2012, 697–702.