AL01 - The Successful Implementation of EGA DX+ Ultra Technology at ALBA

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Abstract

Emirates Global Aluminium (EGA) launched the design and engineering phase of DX+ Ultra technology in 2013 in order to further lower CAPEX and cell energy consumption of the successful high productivity DX+ technology operating in EGA's Al Taweelah Potline 3. It was followed by the commissioning of five demonstration pots in 2014 in the Eagle section at EGA's Jebel Ali smelter. In February 2016 Aluminium Bahrain (ALBA) signed a Technology Licence Agreement with EGA for a single potline with 424 cells. Following Front End Engineering Design (FEED), construction of the potline started in August 2017 and it took only 23 months to reach Last Hot Metal, i.e., the startup of the last cell. The 424 DX+ Ultra technology cells of ALBA Potline 6 were all started between 9th December 2018 and 31st July 2019, making ALBA the world largest single-site aluminium smelter outside of China. As stipulated in the Technology Licence Agreement, a Performance Test of the DX+ Ultra technology was carried out on a group of 30 adjacent cells over a period of two months in October and November of 2019. The key performance indicators achieved by the performance test cells and by the rest of the potline exceeded the guaranteed performance criteria. This was achieved through excellent teamwork and continuous coordination between ALBA's operations and process team with EGA's support team on site. In this paper, detailed analysis of the results of DX+ Ultra technology operation at 465 kA and a description of the Technology Performance Test are given.

Keywords: ALBA potline 6, DX+ ultra technology, performance test, high amperage - low energy consumption cells.

1. Introduction

EGA has developed the proprietary DX+ Ultra technology and proved its performance in five DX+ Ultra demonstration cells in the Eagle section of EGA's smelter at Jebel Ali from 2014 onwards [1]. DX+ Ultra is EGA's high productivity, low energy cell technology, which evolved from DX+ technology first installed in 5 demonstration cells in EGA Jebel Ali in 2010 and in 2013 in EGA's Al Taweelah Potline 3 [2]. The DX+ and DX+ Ultra potshell and superstructure are the same and the main design change is the shorter centerline distance between two adjacent pots reduced from 6.3 to 6.0 m, leading to reduced CAPEX per tonne of installed capacity. This

was made possible by a modification of the pot-to-pot busbars including split anode risers, leading to reduced external voltage drop. The other improvements included collector bars with copper inserts and longer anodes, all combined leading to reduced cathode, anode and bath voltage drops. All the design changes lead to a reduced specific energy consumption ranging from 12.5 to 13.0 kWh/kg Al (depending on the operating amperage). The DX+ Ultra demonstration cells started with an initial amperage of 450 kA and after that, step-by-step, the cell amperage was increased to 480 kA.

ALBA selected DX+ Ultra technology for its Potline 6 Expansion Project (Figure 1) to take advantage of the shorter pot-to-pot distance, which allowed increasing the number of cells from 404 DX+ cells to 424 DX+ Ultra cells in the same potroom buildings (Figure 2). Due to some limitations in site area the distance between the two potrooms ended up being lower than initially proposed and additional magnetic field compensation using asymmetric busbars was required [1]. It was decided that this solution would be proven in EGA Jebel Ali DX+ Ultra demonstration section, where two cells were stopped and replaced by industrial design cells with ALBA asymmetric busbar design and somewhat modified potlining.

All 424 DX+ Ultra pots of ALBA Potline 6 were started between 9 December 2018 and 31 July 2019 [3]. A Performance Test Protocol was prepared to define the detailed organization and unwinding of the Performance Test of the DX+ Ultra reduction technology, which was carried out in a single section with a group of 30 adjacent reduction pots E110 to E139 over a period of sixty days from 1st October 2019 to 30th November 2019.

In this paper, a detailed analysis of the results of DX+ Ultra cell operation at 465 kA and a description of the Technology Performance Test are given. Contractual and non-contractual data were monitored and are reported here as well.

Figure 1. Aerial view of ALBA smelter with Line 6 in the center.

2. Milestones in the Development of DX+ Ultra Technology

2.1. DX+ Ultra Eagle demonstration cells

The goal of designing and building DX+ Ultra demonstration cells was to test for a future expansion or Greenfield smelter with lower CAPEX, higher productivity and lower energy consumption cell than with using DX+ cells. The cells were started up between January and May

2014 at 450 kA and were all in stable operation at 455 kA from May 2015 onwards with good performance parameters [1].

2.2. DX+ Potline 3 Cells at EGA's Al Taweelah smelter – Amperage Increase Journey

EGA (then EMAL) began the Construction of Potline 3 (Phase II) at Al Taweelah in October 2011 and started-up the first cell on 11 September 2013 three months ahead of the original start-up plan. The last, 444th cell was started up on 13th June 2014. Al Taweelah Phase II was built and started-up in shorter time than planned and was completed below the projected budget.

The DX+ cells in Potline 3 were started up at 440 – 444 kA but immediately after the end of start-up, the amperage was gradually increased and reached 455 kA in March 2015 [4]. Line amperage of 460 kA was reached in March 2016 and on the way up to 465 kA, which was achieved in January 2017. This was not the end and in February 2020 the amperage was raised once again and reached 470 kA in March 2020. This is remarkable, particularly considering that the anode size has not changed from the beginning and that the anode current density is now 1.02 A/cm^2. This demonstrates the robustness of EGA high amperage cell technology, which continues with the DX+ Ultra technology used in ALBA as described further on in this paper.

3. ALBA Line 6 Start-up and Commissioning [3]

In June 2015 ALBA Board approved the Line 6 Expansion Project. The Notice to Proceed was issued in January 2017. ALBA Potline 6 construction site-works started in the second quarter of 2017. The first cell was started-up 24 months after Notice to Proceed – six months faster than the industry standard. All 424 DX+ Ultra pots of ALBA Potline 6 were started between 9th December 2018 and 31st July 2019. The 424 reduction cells are arranged in two potroom buildings connected by one central passageway at the mid-point of the potrooms and a passageway at the north and the south end of the potline.

The start-up strategy consisted of using two temporary cross-over bridges between the two potrooms (Room E and Room F); the first one to start-up 20 cells in each potroom and the second one at the center passageway to complete the start-up of the first half of the potline. This allowed starting-up of the cells in the energized sections while continuing construction work in the rest of the potline. The last cell in the first half of the potline was started-up on 17th April 2019. The priority in the second half of the potline was welding the DC busbar circuit and potlining. When this was completed, the second half of the potline was energized and the cell start-up continued, while completing the construction of the potline further away, such as structural steel, cell superstructures, etc. The overall start-up rate was 3.88 cells per day, but the second half of the potline was started up at an accelerated rate of 4.5 cells per day with a peak of 8 cells per day. The operation of all Potline 6 cells was well established and steady by the beginning of the Performance Test on 1st October 2019.

Figure 2. DX+ Ultra Line 6 at ALBA.

4. ALBA Potline 6 Performance Test

4.1. Performance Test Criteria

The two performance criteria to be met by the Performance Test pots as per the Technology Licence Agreement were:

- Specific DC energy consumption lower or equal to 13.58 kWh/kg Al and,
- Average primary aluminum production per pot and per day greater or equal to 3 200 kg.

4.2. Performance Test Procedure

As specified in the Technology Licence Agreement, a Performance Test of the reduction technology provided by EGA was carried out on a group of 30 adjacent typical reduction cells (E110 to E139), chosen by ALBA, over a period of sixty days starting on 1st October 2019. During the test period, the line amperage was kept stable at 465 kA, above the maximum contractual line amperage of 460 kA.

The performance of the test cells throughout the 60-day test period was done by both monitoring individual cells and the cells as a group. EGA advisors were present (shift coverage) to monitor the tested cells, demonstrating excellent collaboration with and support to the ALBA operation team.

Metal tapping operations took place every 32 hours for each of the test cells without any delay or backlog. During the test period, metal from cells was sampled every four days as well as at the beginning and the end of the test period. The metal reserve was measured using the copper dilution method in each of the test cells before and after the test period. Corrections for the metal produced were made for solid metal recovered from crucible cleaning and metal skimming, as well as from bath tapping sows. This means the overall methodology had accurate results for the actual metal produced in the cells.

Bath samples for the analysis of excess AlF_3 and CaF_2 concentration were taken in every cell with a frequency of once every four days. Therefore, a total of fifteen series of bath analyses were carried out during the test period in each cell. Bath temperatures of the test cells were measured every 32 h and a total of 45 bath temperatures was reported during the whole test period. To determine the net carbon consumption of the cells, 108 baked anode assemblies were weighed at the beginning of the test and installed in the performance test pots. The corresponding 108 spent anode assemblies were weighted after their 72 shifts in the pots. Net carbon consumption was calculated from the measured average weight of baked anode assemblies minus the average weight of spent anode assemblies.

Total fluoride emissions through the roof were measured according to the US EPA 14A cassettes method in the performance test group as well as in the adjacent group of pots in room E. The cassettes in room F were not yet operational. All sections were also to be equipped with open path laser instruments from Boreal Laser but those were not yet available during the performance test.

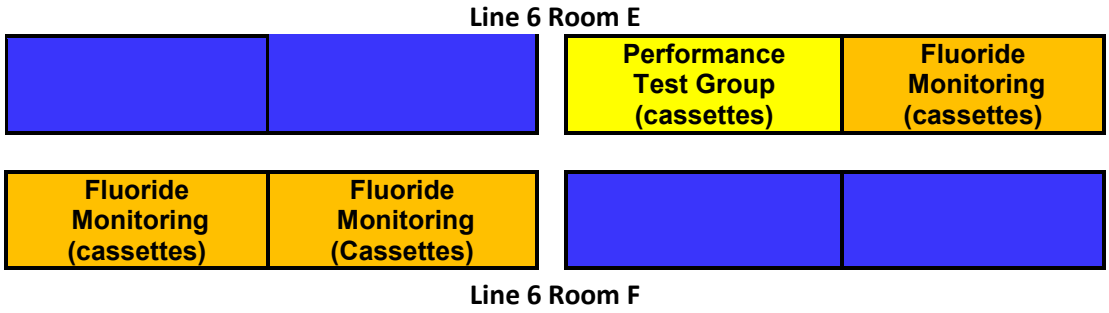

Figure 3. Location of Performance Test group (yellow) and fluoride monitoring sections (orange) in Potline 6.

4.3. Performance Test Results

ALBA Potline 6 was started up at 440 to 460 kA and by mid-September of 2019 the amperage was increased to 465 kA. The Performance Test was carried out at 465 kA so during this period the line amperage was kept stable. After the test was completed, the amperage was increased further to reach 470 kA in January 2020 and 472 kA in February 2020. Table 1 presents the KPIs for the Performance Test pots and for the full Potline 6 for two full months of October and November 2019. Presented as well is the performance of the potline from February to August 2020, which was operating at 472 kA in that period.

The net specific DC energy consumption does not include the share of linkage busbar voltage drops. The inclusion of these (11 mV) gives gross voltage and gross specific energy consumption of 4.102 V and 12.84 kWh/kg Al, respectively, for the Performance Test group (after inventory and solid metal corrections). For the full potline the gross values were 4.125 V and 13.01 kWh/kg Al (after solid metal corrections only). In the period from February to August 2020, the gross pot voltage was 4.095 V and the gross specific energy was 12.85 kWh/kg Al. Compared to the guaranteed value in the technology license agreement this is an excellent result.

During the test period, a total of 2700 anode assemblies were changed on the 72 shifts schedule. This was tracked and no anode assembly was replaced ahead of schedule.

Total fluoride emissions through the potroom roof, measured with cassettes according to EPA 14A method, were 0.24 kg/t Al, of which 0.18 kg/t Al was gaseous and 0.06 kg/t Al particulate fluorides.

Table 1. DX+ Ultra ALBA Potline 6 key performance indicators during the Performance Test in October-November 2019 and at 472 kA in 2020.

KPI	Units	30 Performance Test pots, Oct.-Nov. 2019	Full Potline 6, (424 pots) Oct.-Nov. 2019	Full Potline 6, (424 pots) Feb.-Aug. 2020
Amperage	kA	464.84	464.84	471.91
Current efficiency	%	95.2 (Note 1)	94.5 (Note 2)	95.0
Metal production	kg/pot-day	3 565 (Note 1)	3 537 (Note 2)	3 609
Net cell voltage	V	4.09	4.11	4.08
DC net specific energy consumption	kWh/kg Al	12.79 (Note 1)	12.96 (Note 2)	12.81
Gross carbon consumption	kg C/t Al	550	550 (Note 3)	537
Net carbon consumption	kg C/t Al	391	391 (Note 3)	401
Bath temperature	°C	955	957	957
Excess AlF_3	%	9.5	9.3	9.4
CaF_2	%	8.0	8.0	7.6
Fe	%	0.089	0.089	0.068
Si	%	0.030	0.033	0.029
AE frequency	AE/pot-day	0.034	0.044	0.031
AE duration	s	14.4	16.6	9.0
PFC emissions CO_2 equivalent (Note 4)	kg/t Al	9	13	5

Notes:
1) After metal inventory and solid metal corrections.
2) After solid metal corrections only: there was no metal inventory measurement for the full potline.
3) The carbon consumption in the full potline was assumed to be the same as for Performance Test.
4) CO_2 equivalent of PFC emissions in kg/t Al is calculated from anode effect frequency and duration, using the IAI Tier 2 method and IPCC Second Assessment Report as described in detail in [5].

4.4. Graphs of ALBA Potline 6 Performance Test

The 4-day moving average of cell parameters in the test group of cells during the Performance Test period is shown in Figures 4 to 15. During the first week, current efficiency was very high and the specific energy consumption was very low. This was because the metal height was being adjusted in some cells from above target to target. This was adjusted for the averages in Table 1 by metal inventory measurements before and after the Performance Test.

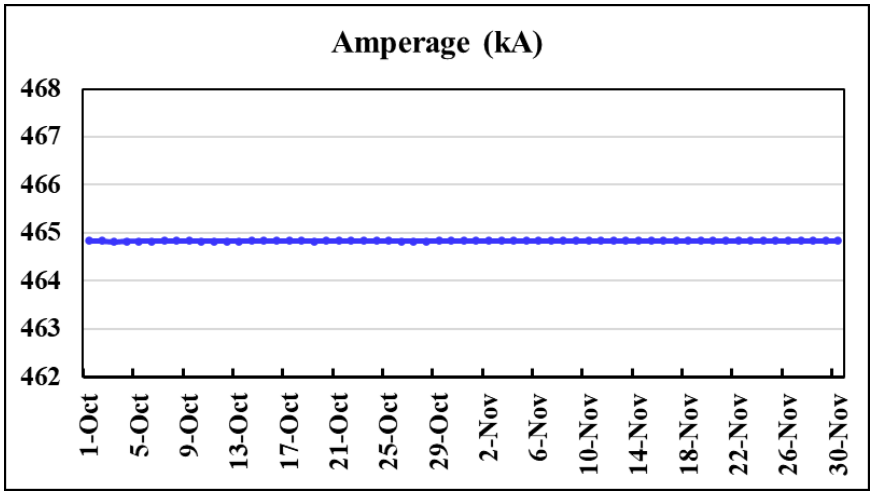

Figure 4. Line amperage in Potline 6.

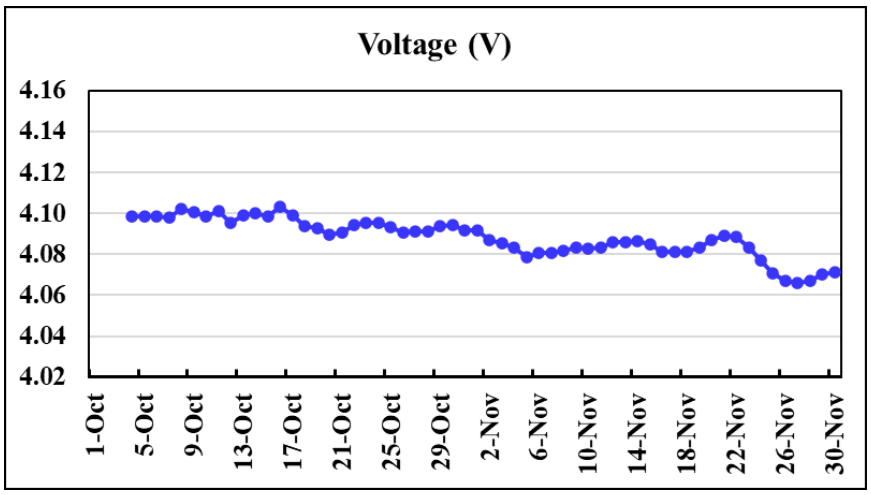

Figure 5. Cell voltage.

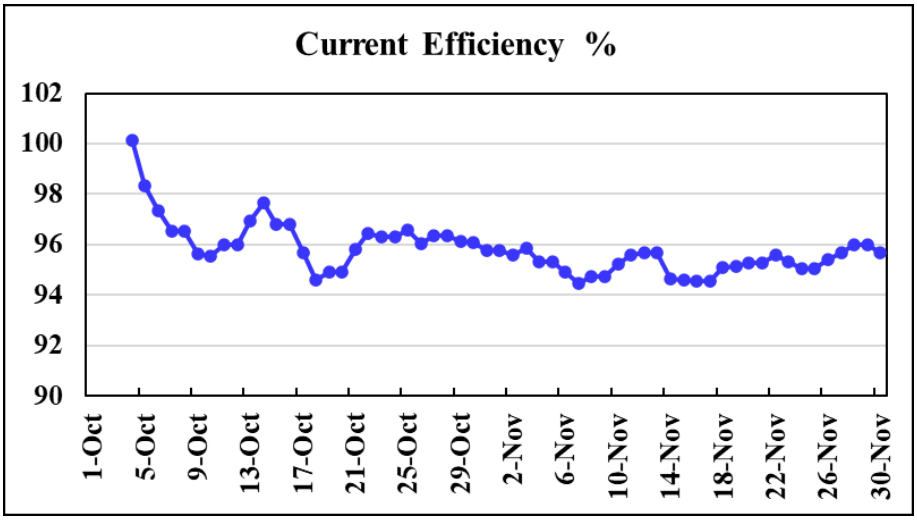

Figure 6. Current efficiency.

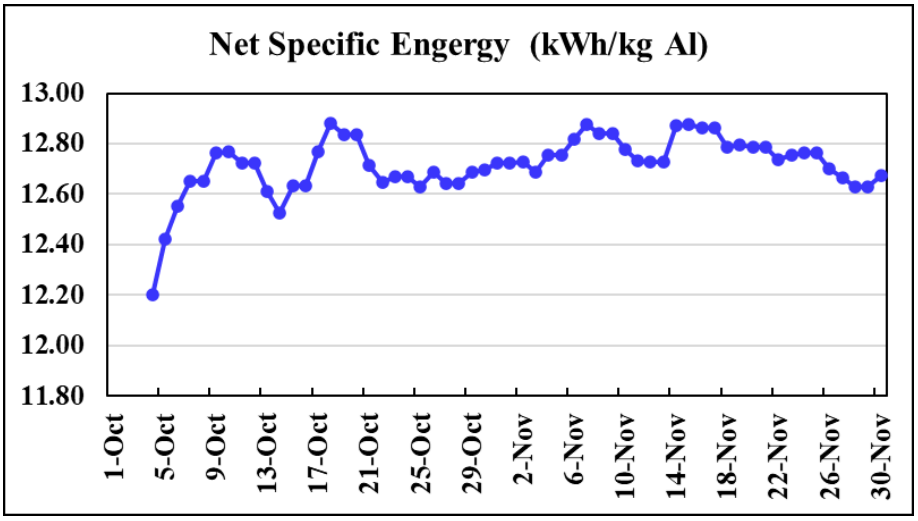

Figure 7. Net specific energy consumption.

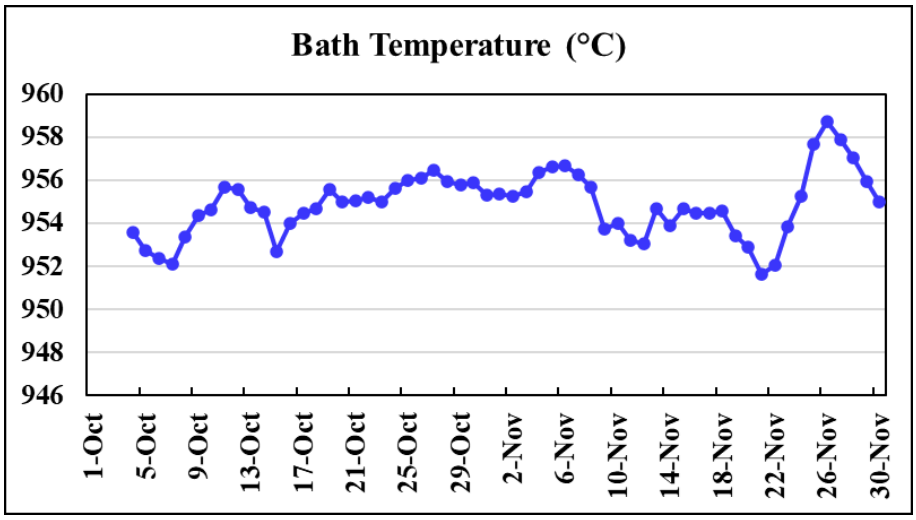

Figure 8. Bath temperature.

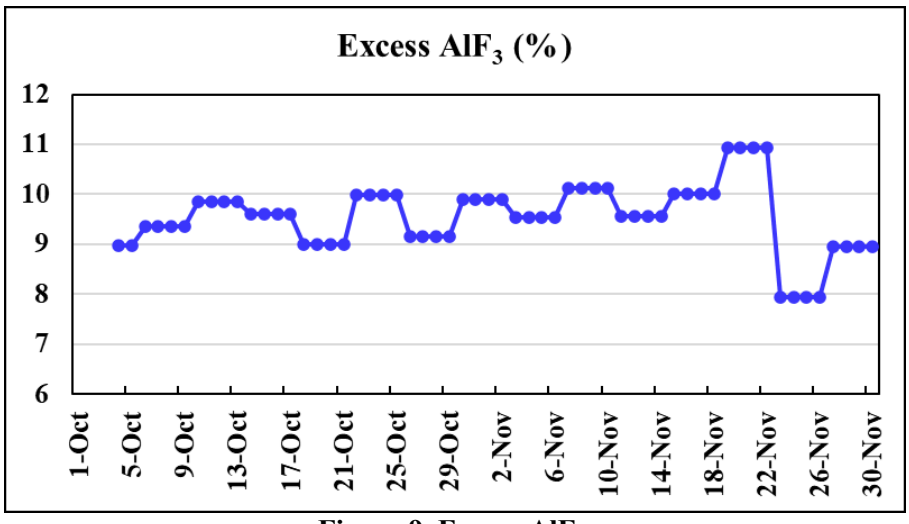

Figure 9. Excess AlF_3.

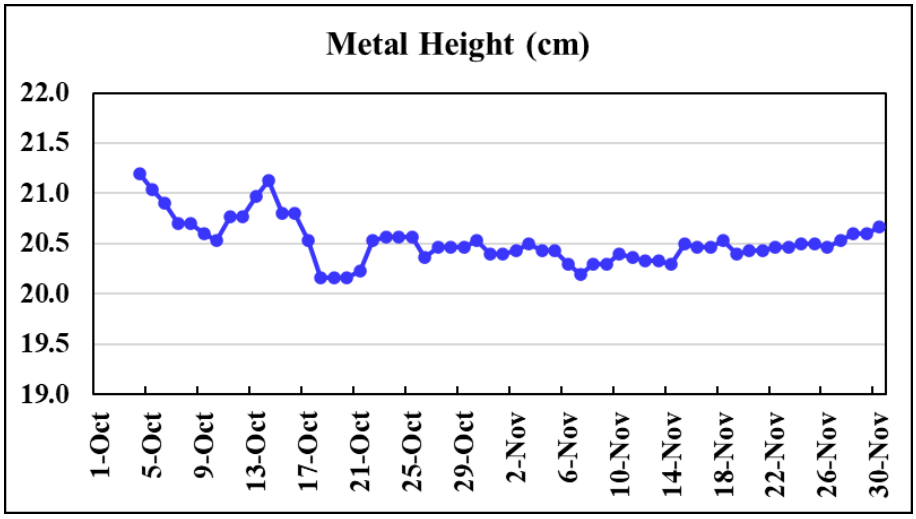

Figure 10. Metal height.

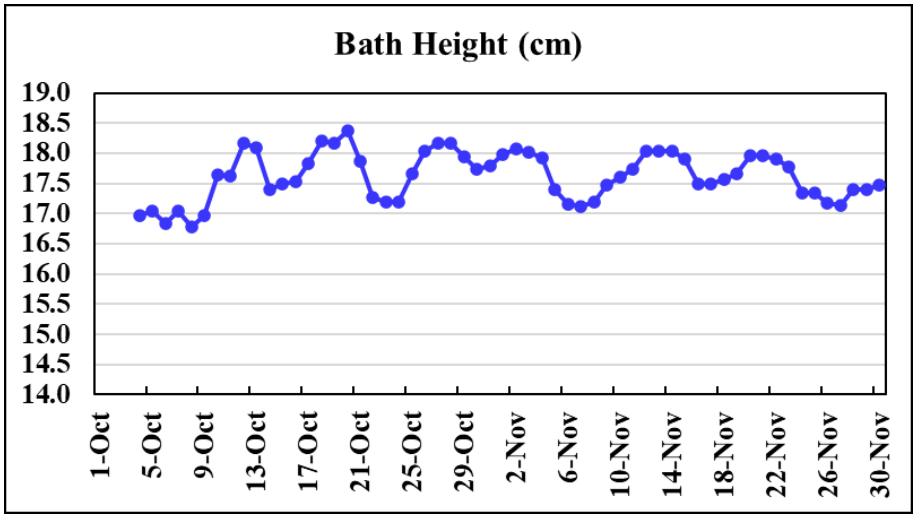

Figure 11. Bath height.

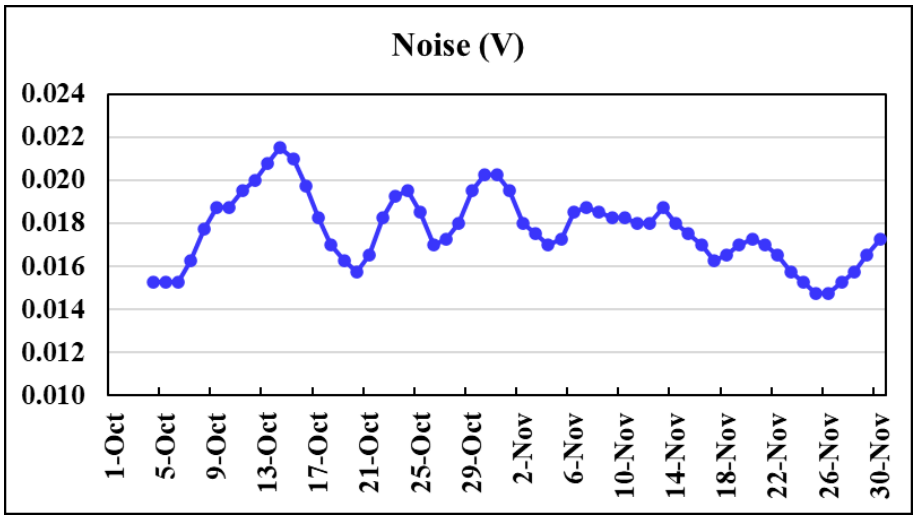

Figure 12. Noise.

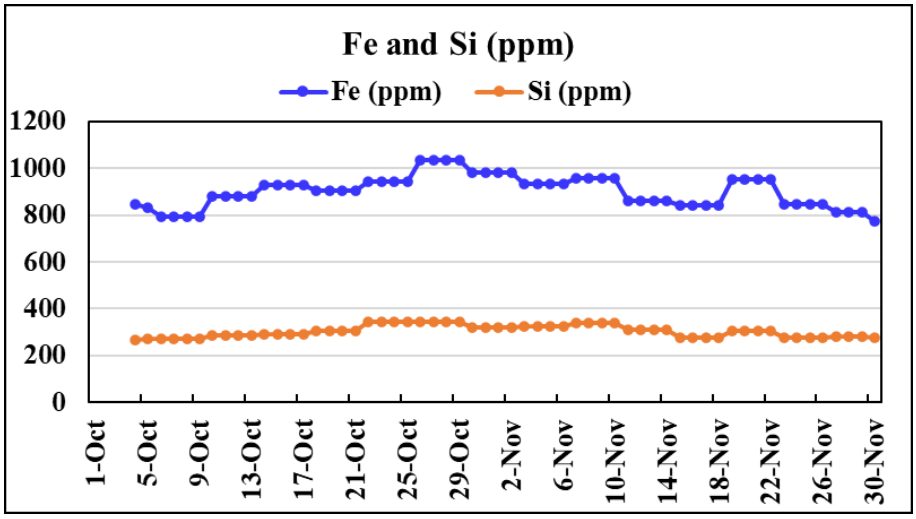

Figure 13. Fe and Si in metal.

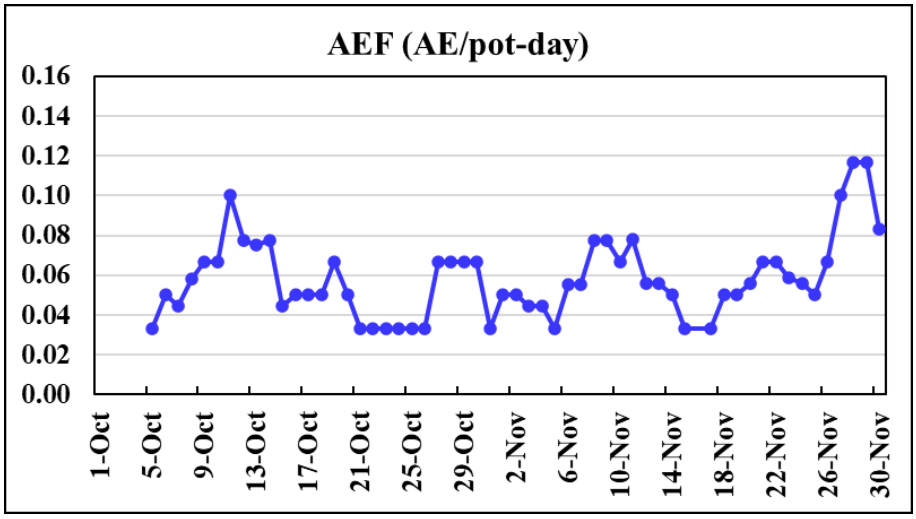

Figure 14. Anode effect frequency.

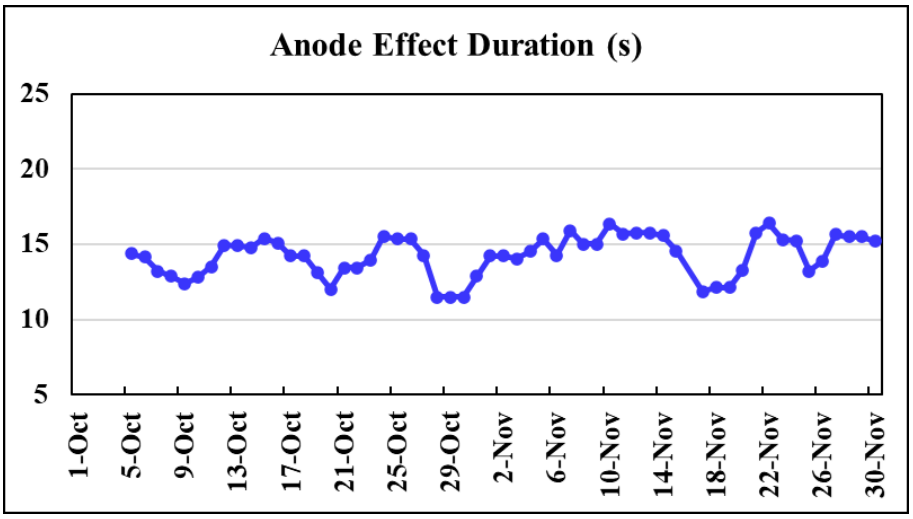

Figure 15. Anode effect duration.

5. Conclusions

EGA's DX+ Ultra Technology has progressed from the conception and modeling phases through to industrial implementation in a very short period. In ALBA's Potline 6 the Performance Test confirmed that the DX+ Ultra pot performance exceeded by a large margin the Performance Criteria set in the Technology Licence Agreement and is of world class for high amperage cells. As presented, other performance parameters that were not specified in the Licence Agreement but of keen interest, were also excellent. Development work is ongoing and DX+ Ultra pilot cells in EGA Jebel Ali Eagle section are currently operating at 480 kA, providing advanced knowledge on the operating parameters before applying it to a full potline.

6. References

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