AL01 - Amperage Increase in EGA Al Taweelah DX Technology Potlines

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Abstract

EGA operates two DX technology potlines (Lines 1 and 2) in Al Taweelah, with 808 pots (202 pots in each potroom) today. The amperage has increased from 350 kA at start-up in 2010 to 437 kA in 2023.

The new generation of pots has collector bar copper inserts, which enabled amperage increase. Amperage was increased to 422 kA by April 2018, and after a few months, it was decreased after some challenges with carbon. Another amperage increase started in October 2021. At first, amperage was increased by 2 kA per month to reach 435 kA in March 2022. This was followed by five months of process optimisation, completed in August 2022. Pot operation parameter changes were made according to the following rules:

- Pot voltage should be reduced according to theoretical calculations, in order to maintain the heat balance in the pots.
- Unscheduled anode changes should not cause any increase in gross anode consumption.
- Anode effect frequency should remain the same.
- Cathode resistance should not increase.
- Standard deviation of thermal parameters should not increase from its starting value.
- Current efficiency should be at the same level as at starting.
- Superheat should also remain the same, with no increase in its standard deviation.
- Metal height is to be raised by 2 cm from 22 to 24 cm gradually to make sure that the magneto-hydrodynamic stability was maintained.

Once the above process requirements had been achieved and maintained, the two potlines were set for a new target of 436 kA, which was reached in September 2022 with good KPIs since. In this paper amperage increase from 416 kA will be described in continuation of the ICSOBA 2018 paper [1].

Keywords: DX technology, Amperage increase, Pot performance criteria.

1. Introduction

EGA's Al Taweelah Potlines 1 and 2 (then 378 pots per pot line) were started at 350 kA during 2009 and 2010 using DX Technology [1]. Line amperage was successfully increased up to 380 kA in the potlines by October 2012 [2]. During the first-generation pot changeout, a few strategic pot design changes were carried out which enabled the amperage Al Taweelah DX potlines to 422 kA by April 2018 [3-5]. As part of the P100 expansion project, an additional 26 pots were added to each DX potline in 2021 [6].

This paper is focused on Al Taweelah DX potlines journey to 437 kA by May 2023, close to the existing rectifier and busbar system capacity. This was achieved by executing a plan developed by identifying the enablers, applying, monitoring, and correcting them. Anode size, Cu inserts in collector bars, pot side insulation design, and pot bath chemistry modifications based on the source of alumina, are among the identified enablers which are discussed in this paper.

2. Major Milestones of the Amperage Increase Plan

Figure 1 shows the different stages of amperage increase from 2018 to 2023. The graph from the start-up to 2018 is given in [3].

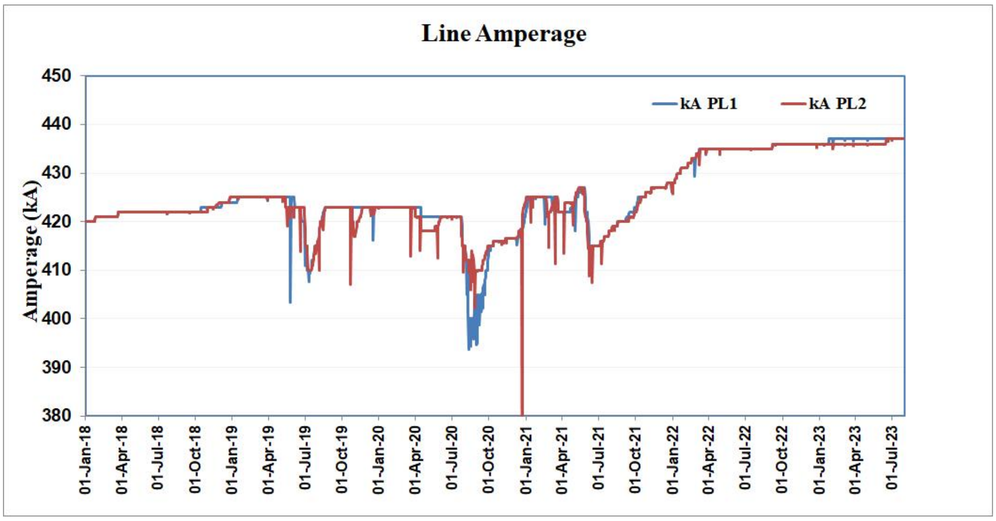

Figure 1. Amperage increase stages from 2018 to July 2023.

Pre-Ramp-up stage: Potline amperage was raised from 422 kA to 427 kA in May 2021, but it could not be sustained at 427 kA due to ongoing anode quality issues, so the amperage was reduced to 415 kA as part of the mitigation plan.

Amperage Increase Stage 1: The Amperage programme was re-initiated after stabilizing the operation; 435 kA was achieved in March 2022.

Amperage Increase Stage 2: From 435 kA to 437 kA, achieved in June 2023, after confirmation of rectifier and busbar capacity to sustain this amperage. Currently, both Al Taweelah DX potlines are operating at 437 kA.

3. Major Modifications

A few modifications in pot lining and pot shell structure were made in view of the strategic amperage increase in EGA potlines with DX technology. These modifications broadly intend to improve heat loss to maintain the pot thermal balance stable while increasing the amperage.

3.1 Potshell Design Modifications

In addition to the modification discussed in the previous paper [3], it was experienced through the second pot generation that red hot spots on the potshell are more visible on the duct end and tap end of the pots. The EGA modelling group provided the solution by making a minor modification of the potshell, increasing the length of the end wall colling fins, and using graphitized end wall carbon inserts (Figure 2). Estimated impact was an additional heat loss of approximately 5 kW to help the higher amperage operation.

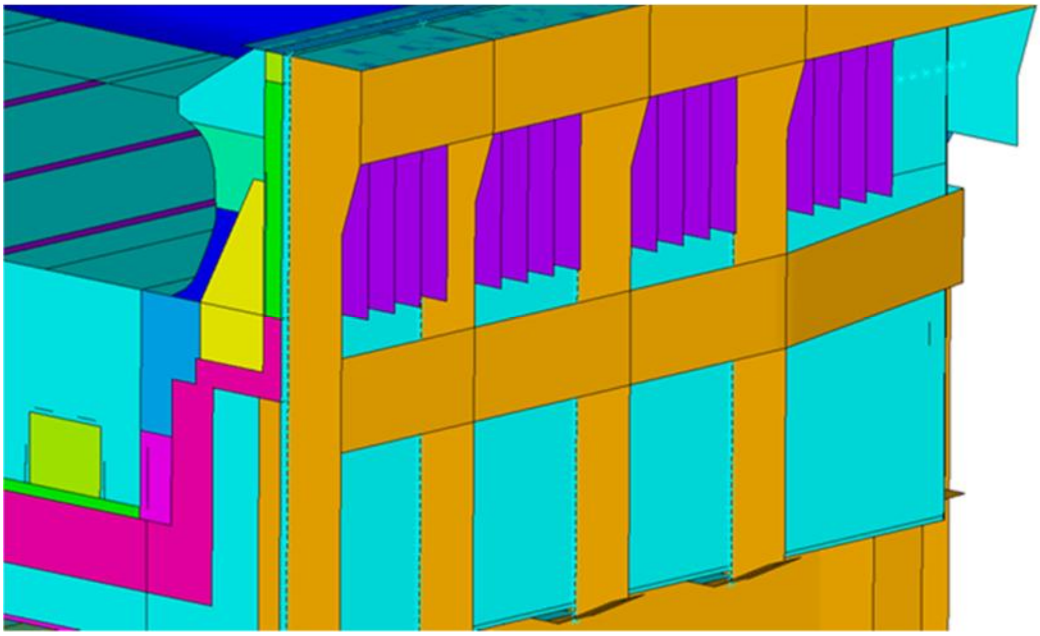

Figure 2. Modified end shell design model with improved cooling fins.

Pot side lining was also modified. Figure 3 shows the temperatures of the side shells for the different types of side shell configurations at line amperage of 435 kA. Note that some of the generation 1 (G1) shells were modified by adding fins to generation 2 (G2) shell with collector bars Cu inserts.

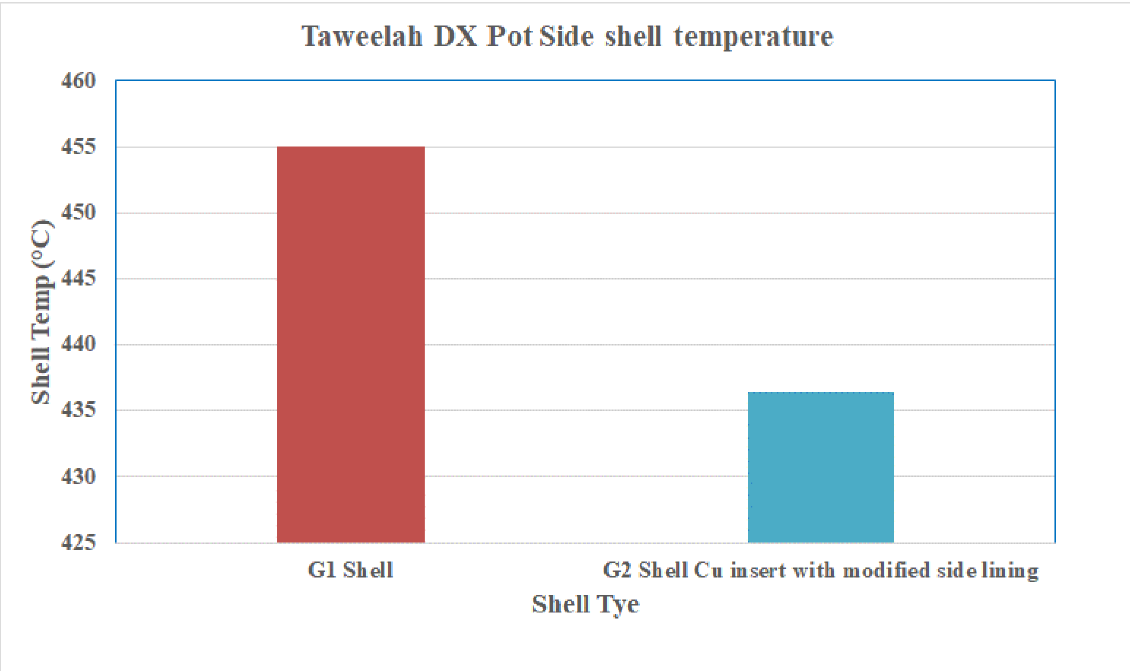

Figure 3. Average side shell temperatures for the different shell types.

3.2 Collector Bar Cu Insert

Generation 2B pots were installed with collector bar Cu inserts. This was the most effective design change for amperage increase in DX technology potlines. The established gain in cathode voltage drop, and increased heat loss from the collector bars provided leverage to operate the pots at manageable internal heat. The details of internal heat management are explained in Section 4.1.

3.3 Anode Length Increase with Anode Top Profile Modification

The baked anode length was increased from 1690 mm to 1705 mm to provide additional anode surface area to assist the amperage increase plan. This was a strategic modification to optimise carbon under stub as well as the current density at higher amperage. A strict criterion average of minimum carbon under stub (Min CUS) > 4.5 cm was adopted, to avoid the overconsumption of anode butts at given amperage and anode shift life. Previous experience shows that when CUS falls below 4.0 cm, the anode butts tend to break at the end of the anode service cycle. Broken butts that stay in the bath get soaked with Na, and when recycled to anode production, they deteriorate anode core properties.

Also, the top anode profile was modified to protect the stubs from bath attack (Figure 4).

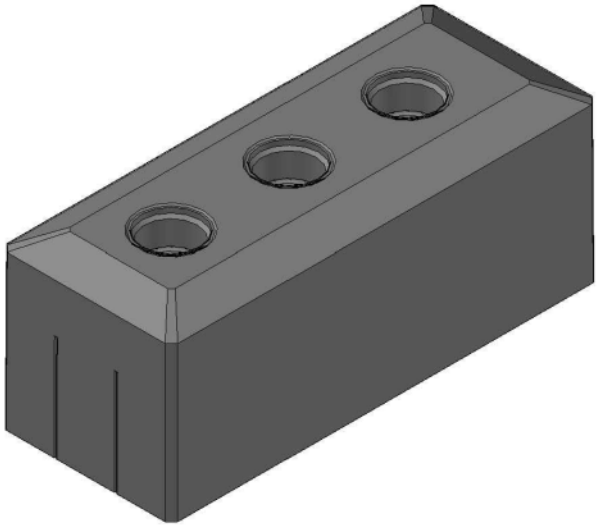

Figure 4: Existing anode top profile for EGA DX potlines.

3.4 Bath Chemistry Modification

Roughly 80 % of the alumina provided to the potlines originates from the EGA's Al Taweelah alumina refinery. It has become apparent that since the introduction of Al Taweelah-produced alumina, there has been a noticeable increase of %KF and %MgF_2 in the bath. Table 1 displays the incremental growth in %KF and %MgF_2, along with the corresponding adjustments in calculated superheat, using Solheim equation [7]. Following a comprehensive analysis of the overall mass equilibrium of these oxides, the excess AlF_3 % was reduced by 1.0 % which not only offset the alteration in liquidus temperature due to higher KF and MgF_2 but increased the liquidus temperature by 2 °C. This adjustment aimed to attain somewhat higher target bath temperature and lower superheat. However, the result was lower bath temperature than in previous years (Tables 2 and 3), because anode challenges were no more there since 2021.

Table 1. Changes of liquidus temperature due to increased % of KF and MF$_2$ in bath.

Compound	Without Al Taweelah alumina	With Al Taweelah alumina	Change %	Corresponding change in liquidus temperature, °C	Corresponding change in liquidus temperature, °C
%KF	0.11	0.22	0.11	0.4	**1.4**
%MgF$_2$	0.55	0.80	0.25	1.0	

4. Strategy of Amperage Increase from 415 kA to 437 kA

4.1 Strategy Summary

Various strategies of amperage increase were based on an in-house model for the calculation of pot voltage components, anode-cathode distance (ACD) and internal heat (Q_{in}). The strategy for amperage increase from 415 kA to 437 kA was based on a combination of the following approaches:

a. Constant ACD; this implies an increase in pot voltage and Q_{in} with potline amperage increase.
b. Constant voltage; this implies lower ACD and higher Q_{in}.
c. Constant internal heat (Q_{in}); this implies lower pot voltage and lower ACD.

The decision for the use of different approaches was based on freeze thickness and bath temperature.

4.2 Strategy Details

From 415 kA to 425 kA, constant internal heat strategy was used, and the ACD and the pot net voltage were gradually decreased. The anode length was 1690 mm during this period. At 426 kA, 1705 mm anode length started to replace the 1690 mm anode length. A mixed strategy was used from 426 kA to 435 kA; the internal heat was kept below 795 kW and the ACD was cautiously decreased. The increase in internal heat (Q_{in}) was managed by adjusting pot mass balance and heat dissipation. This is discussed in detail in Section 4.2.
Figure 5 shows the amperage increase plan in terms of internal heat (Qin), pot voltage and ACD.

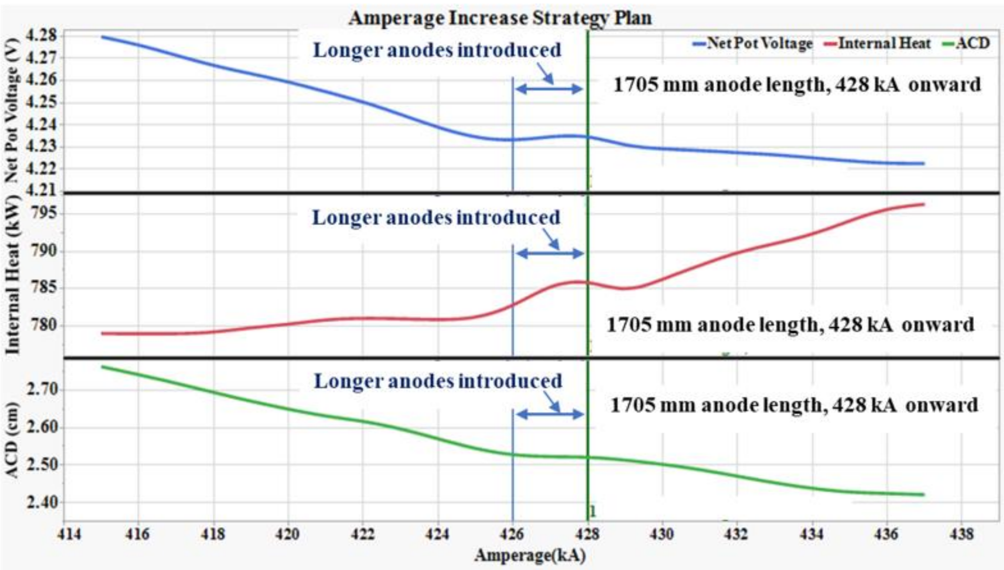

Figure 5. Amperage increase strategy plan.

Figure 6 shows the amperage increase from 415 kA to 437 kA and pot voltage of both potlines.

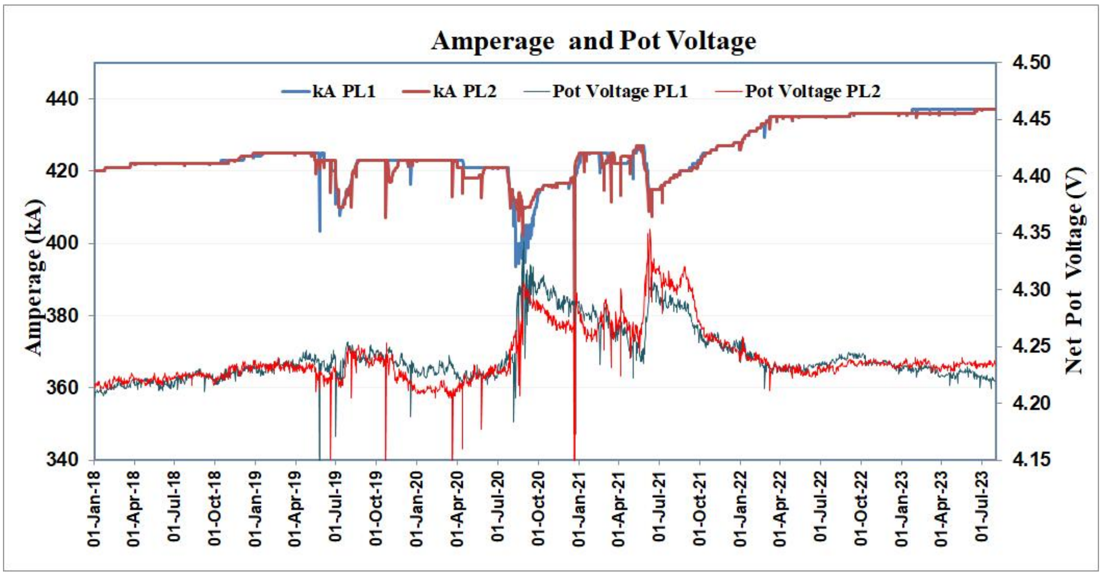

Figure 6. Amperage increase and pot voltage variation of Al Taweelah DX potlines.

5. Potline Health Index Tool

Each amperage step was decided by evaluating the potline health condition by applying the 360° evaluation tool called '**Amperage Increase Decision Matrix**'. Figure 7 shows brief details of monitoring key parameter indicators (KPIs) for the calculation of the health confidence index. If the health confidence index of the respective potline fails to pass the criteria, the amperage increase plan was put on hold until the health confidence index turned green.

Al Taweelah DX Potlines Amperage Increase – Decision Matrix Dashboard

S.No	Parameters	Limits	Latest (4shifts)	Last 8 days average	Weightage multiplier	Index Proposal	0.75
1	% of Pending tapping	10%	-6.1%	-1.7%	100%	1.00	↑
2	% of Pending anode setting	10%	0.0%	0.0%	100%	1.00	↔
3	% of Pending anode dressing	10%	0.0%	0.3%	70%	1.00	↔
4	Line at target shift life	100%	100.0%	100.0%	100%	1.00	↔
5	Anode problems %	5%	3.1%	2.0%	100%	0.75	↓
6	% of pots >975 deg C	10%	7.8%	5.9%	70%	0.75	↓
7	% of pots >990 degC	1%	0.0%	0.0%	100%	1.00	↔
8	% of pots with carbon dust	30%	22.5%	14.3%	60%	0.75	↓
9	% of pots <= -1 metal height from target	15%	14.4%	16.1%	100%	0.00	↑
10	% of pots < 1 Std alumina dumps	15%	12.9%	15.7%	100%	0.00	↑
11	Number of pots burst last 2 days	3	0	0	100%	1.00	↔
12	%pot with silicon >0.06%	3%	0.3%	0.3%	80%	1.00	↔
13	Rodded anode inventory in days	100%	3715	4162	75%	1.00	↓
14	% of High Combined Drop Pots	5%	0.5%	0.5%	100%	1.00	↔
15	% of pots > 15 deg calc superheat	10%	21.0%	17.9%	70%	0.00	↓
					Confidence Index	75.3%	↔

Raw Material forecast(Alumina etc..)	No change is expected in source Alumina/CPC as per the raw material strategy team for next 3 month	
Comment	Line General health is okay, however, Anode problems are on increasing trend	
Final Remark	**Recommend Hold Amperage**	
Area Approvals (emails)	Line Lead Process Engineer	done
	Process Control Sr. Manager	done
	Line Superintendents	to be reviewed
	Line Sr. Manager	to be reviewed

Figure 7. Amperage increase decision matrix dashboard.

6. Other Control Parameters at Various Stages of Amperage Increase

6.1 Side Shell Temperature Trend in Different Steps of Amperage Increase

The average side shell temperatures, measured in various stages of line amperages are given Figure 8. It is evident that the applied design changes and improved thermal balance helped to reduce the side shell temperature by 10-20 °C from 415 kA to 437 kA.

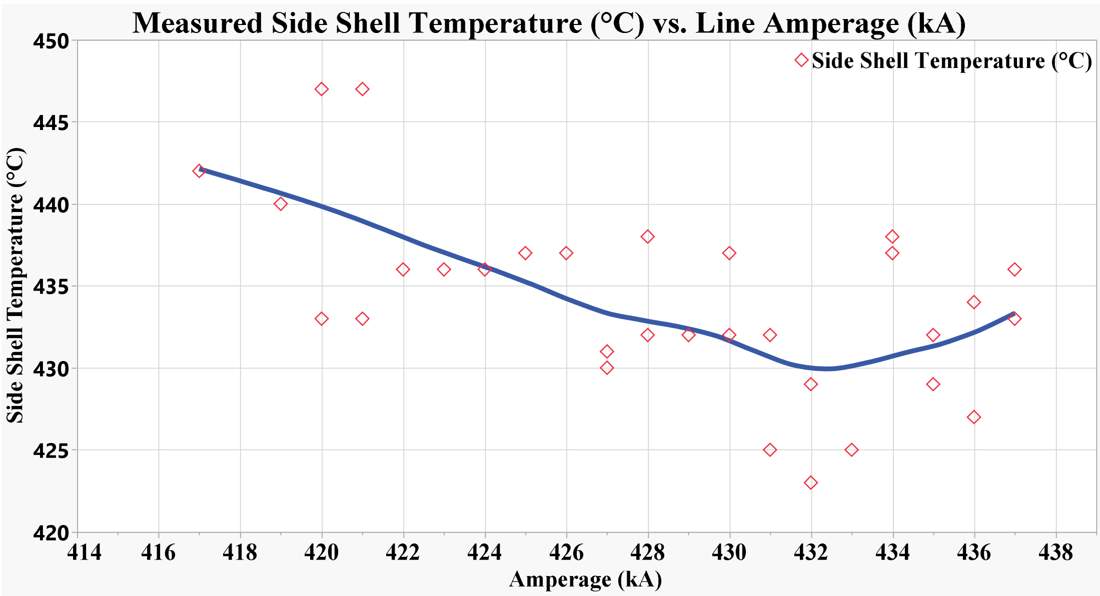

Figure 8. Side shell temperature variation at the different line amperages for DX potlines

6.2 Side Freeze Profile Comparison

The lower shell temperatures were also confirmed by side freeze measurements done at 427 kA and 435 kA on the same sample pots (Figure 9).

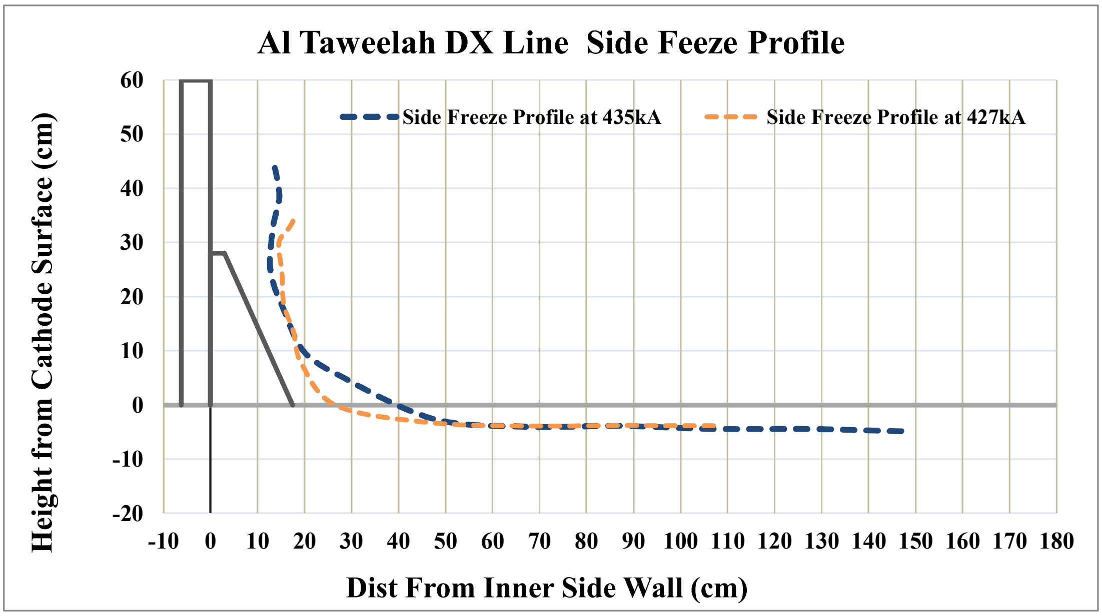

Figure 9. Side freeze profile at 427 kA and 435 kA in DX potlines.

6.3 Anode Top Cover Thickness

During the amperage increase from 415 kA to 437 kA, the anode to cover the thickness target was changed from 16 cm to 8 cm in steps. Figure 10 shows the actual anode top cover measurement done at various amperages in DX potlines. The decrease on anode top cover thickness was based on the thermal model to keep the internal heat in control during the amperage increase programme.

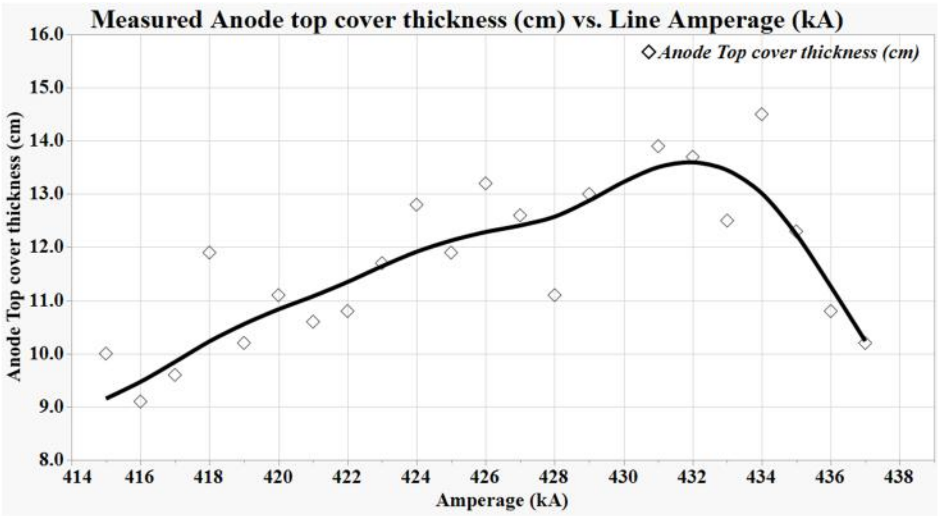

Figure 10. Anode top cover thickness vs amperage.

6.4 Bath Superheat Trends

The measured bath superheat of potlines is found to be between 9 °C and 11 °C. The amperage increase did not impact the superheat significantly. The bath chemistry modifications discussed earlier helped to control the bath superheat and enabled the amperage increase with no significant impact on bath superheat.

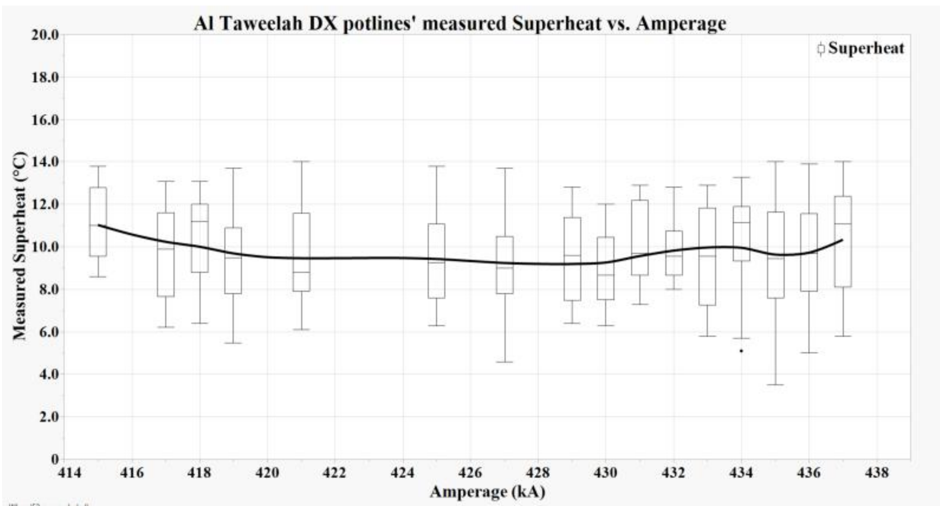

Figure 11. Measured superheat vs amperage.

6.5 Bath Temperature and Chemistry in Terms of Excess AlF_3

As mentioned earlier, excess AlF_3 target was set to 8.5 % and bath temperature target was set to 960°C to maintain a good side freeze. The AlF_3 addition programme, which enables the bath chemistry regulation on the pot-by-pot level, is in use in all EGA potlines. Figure 11 shows the variation of average excess AlF_3 and bath temperature against the line current. No abnormal period of high temperature was recorded at any stage.

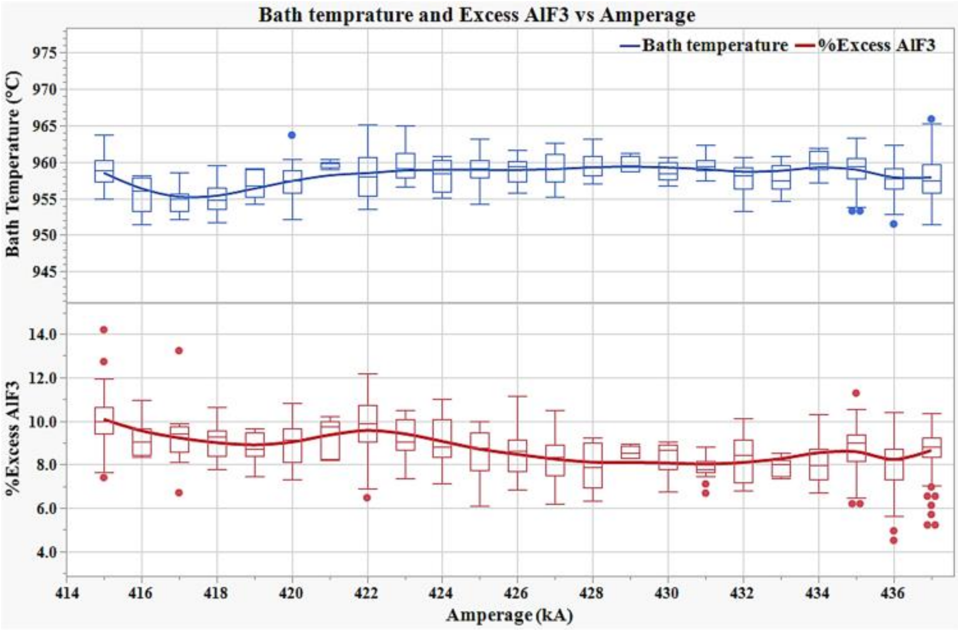

Figure 12. Bath temperature and AlF_3 variation in DX potlines.

7. Performance of Al Taweelah DX Potlines

Tables 2 and 3 show yearly KPIs since 2018 with respect to potline amperages. It has been an amazing story of these two DX potlines in terms of various performance KPIs. The potlines had the best performance in 2022 and 2023 at 435-437 kA, after successfully recovering from operational issues due to anode quality problems in 2019 and 2021, mentioned at the beginning of the paper. Throughout, the potlines have very good environmental KPIs with low AE frequency and duration and benchmark PFC emissions.

Table 2. KPIs of Potline 1.

Parameter	Unit	2018	2019	2020	2021	2022	2023 Jan - July
Amperage	kA	422.0	422.6	417.8	422.8	434.6	436.9
Current efficiency	%	93.6	92.6	92.8	93.6	94.1	94.3
Metal production	kg/pot-d	3182	3152	3126	3189	3292	3319
Net pot voltage	V	4.221	4.240	4.264	4.281	4.237	4.228
DC net sp. energy cons.	kg/t Al	13.43	13.67	13.70	13.63	13.42	13.36
Net C consumption	kg/t Al	415	417	419	413	408	408
Gross C consumption	kg/t Al	521	546	567	581	550	546
Fe	%	0.054	0.090	0.137	0.124	0.068	0.061
Si	%	0.030	0.037	0.043	0.038	0.031	0.028
Bath temperature	°C	965	965	961	958	958	958
Excess AlF_3	%	9.1	10.0	10.3	9.6	8.8	8.8
AE frequency	AE/pd	0.04	0.07	0.13	0.14	0.03	0.02
AE duration	sec	8	27	48	53	14	8
PFCs emissions, CO_2 equivalent*	CO_2-eq kg/t Al	7	48	150	178	14	4

*PFC CO_2-eq is calculated as explained in [8].

Table 2. KPIs of Potline 2.

Parameter	Unit	2018	2019	2020	2021	2022	2023 Jan.-July
Amperage	kA	422.0	422.3	418.3	422.6	434.6	436.2
Current efficiency	%	93.3	92.3	92.3	92.3	93.8	93.6
Metal production	kg/pot-d	3169	3140	3111	3146	3284	3288
Net pot voltage	V	4.224	4.237	4.253	4.291	4.234	4.235
DC net sp. energy cons.	kg/t Al	13.50	13.74	13.74	13.86	13.45	13.48
Net C consumption	kg/t Al	416	419	423	418	409	411
Gross C consumption	kg/t Al	523	552	582	601	553	552
Fe	%	0.050	0.085	0.129	0.119	0.068	0.065
Si	%	0.031	0.036	0.041	0.035	0.031	0.030
Bath temperature	°C	965	964	961	959	958	958
Excess AlF_3	%	9.4	10.1	10.3	9.4	9.0	9.4
AE frequency	AE/pd	0.04	0.08	0.16	0.20	0.04	0.02
AE duration	sec	14	33	62	65	12	9
PFCs emissions, CO_2 equivalent*	CO_2-eq kg/t Al	16	63	306	306	13	9

8. Conclusions and Way Forward

Through the developmental initiatives undertaken at EGA, the inhouse developed DX technology has demonstrated remarkable efficiency, cost-effectiveness, and energy consumption. EGA's commitment to environmental responsibility is evident in its adoption of low-emission technology, which has set an industry benchmark in reducing environmental impact [9].

Currently, EGA's Al Taweelah DX potlines are planning to achieve another significant amperage milestone of 440 kA, having received the rectifier and busbar system capacity clearance from the original equipment manufacturer (OEM) to accommodate the increased potline amperage. A pivotal aspect for the success of this amperage increase plan is the seamless collaboration of all teams and the swift rectification of any deviations. The potline health index will guide us to the goal.

9. References

1. Ali Al Zarouni et al., The successful implementation of DUBAL DX Technology at EMAL, *Light Metals* 2012, 715-720.
2. Michel Reverdy et al., Successful implementation of amperage increase to 380 kA in DX cells at DUBAL and EMAL, *31st International Conference of ICSOBA, 19th Conference, Aluminium Siberia*, Krasnoyarsk, Russia, 4-6 September 2013, Travaux 542-545.
3. Vinod J. Nair, Vishal Ahmad, Shaikha Al Shehhi, Amperage Increase from 340 kA to 425 kA and beyond in EGA DX cell technology, *Proceedings of 36th International ICSOBA Conference*, 2018, Paper Al07, *Travaux* 47, 663-674.
4. Vijayakumar Pillai, Amperage increase in DX potlines at EMAL, *Proceedings of 33rd International ICSOBA Conference*, Dubai, 29 November to 1 December 2015, *Travaux* 44, 511-521.
5. Rawa Ba Raheem, Arvind Kumar, Sergey Akhmetov, DX cell technology at 400 kA and beyond, *Proceedings of 33rd International ICSOBA Conference*, Dubai, 29 November to 1 December 2015, *Travaux* 44, 505-510.

6. Abdallah Abdelrahman Rahbar et al., Potlines extension project in EGA Al Taweelah smelter, *Proceedings of 40th International ICSOBA Conference*, Athens, Greece, 10-14 October 2022, Paper AL03, *Travaux* 51, 1029-138.
7. Asbjorn Solheim et al., Liquidus temperature and alumina solubility in the system Na_3AlF_6-AlF_3-LiF-CaF_2-MgF_2, *Light Metals* 1995, 451-460.
8. Ali Al Zarouni et al., DX+ an Optimized Version of DX Technology, *Light Metals* 2012, 697-702.
9. Sergey Akhmetov, Sustainability at Emirates Global Aluminium: Safeguarding the environment, social responsibility and good governance, *Proceedings of 41st International Conference of ICSOBA*, 5-9 November 2023, Dubai, Paper KN01, *Travaux* 52.