

Amperage Increase in EGA Al Taweelah Potline 3

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Abstract

EGA's DX+ technology was conceived as high productivity version of DX technology, operating in potlines 1 and 2 in EGA Al Taweelah smelter. After successful demonstration in five DX+ cells in Jebel Ali smelter in 2010, the DX+ technology was selected for Al Taweelah Potline 3, which started up 444 DX+ cells at 440-444 kA from September 2013 to June 2014. Amperage increase started soon after the completion of the start-up and reached 450 kA in September 2014 and 455 kA in March 2015. The following year was very active, bringing the amperage to 460 kA in March and to 465 kA in December 2016, which was already 5 kA above the maximum design amperage. This was enough for the first generation of DX+ cells. The installation of DX+ Ultra cathodes with copper inserts in the collector bars in the second generation of cells finally enabled further amperage increase to 470 kA in March 2020. In April 2021, the amperage was increased to 472 kA. At anode current density of 1 A/cm², this is a benchmark of highest metal productivity per utilised plant area and people involved in operation. The potline performance remained excellent through all these years. The metal production increased from 3397 kg/pot-day at the end of potline start-up in June 2014 to 3554 kg/pot-day in full year 2021. The yearly average current efficiency has been between 94.0 and 94.6 % the gross specific energy consumption between 13.2 and 13.5 kWh/kg Al and the net carbon consumption between 412 and 417 kg C/t Al. The second generation of cells with DX+ Ultra cathodes improved the performance to 94.6 % current efficiency and lowered gross specific energy consumption to 13.2 kWh/kg Al. Premium metal purity with very low iron has been produced throughout the years. This paper will describe the potline performance and challenges and strategy of amperage increase as well as the turnover from the first to the second generation of the cathodes.

Keywords: DX+ technology, Amperage increase, Cell performance, Cell relining, Potlife.

1. Introduction

EGA Al Taweelah Potline 3 (444 pots) with DX+ technology was started at 440 -440 kA [1] and increased amperage to a maximum of 470 kA in different stages. Potline parameters were adjusted at different amperages to maintain pot stability and heat balance. Some cathode design modifications, including the use of collector bar copper inserts, were also made. The first pot replacement started from the end of 2017 was completed by 2020 at the rate of approximately 4

pots per week, achieving potlife of more than 1800 days for the first generation. The pot replacement allowed for further amperage increase.

In 2021, Al Taweelah potlines were extended by 66 pots, of which 14 DX+ Ultra pots were in Potline 3 [2]. This increased nominal Potline 3 annual production at 465 kA and 94.2 % current efficiency, by approximately 18 000 tonnes per year for a total production of approximately 572 000 tonnes per year.

2. Summary of Amperage Increase Milestones

From the start-up initially at 440 kA, Potline 3 amperage increase to 472 kA proceeded in several stages.

- The first stage was increasing amperage from 440 kA to 450 kA which was completed in the first year of operation.
- The second stage was from 450 kA to 455 kA in 2015.
- The third stage was from 455 kA to 462 kA on 2016.
- The fourth stage was from 462 kA to 465 kA in 2017, where it stayed for three years.
- The fifth stage was mainly after replacing approximately 90 % of generation 1 cathodes by generation 2 cathodes; in this stage, amperage was increased to 470 kA in April 2020 until June 2021.
- Thereafter, the amperage was decreased to 465 kA, while waiting for an additional rectifier, anode length increase to lower the anode current density, and generation 3 cathode design.

Figure 1 shows the different stages of amperage increase from the start-up to June of 2022.

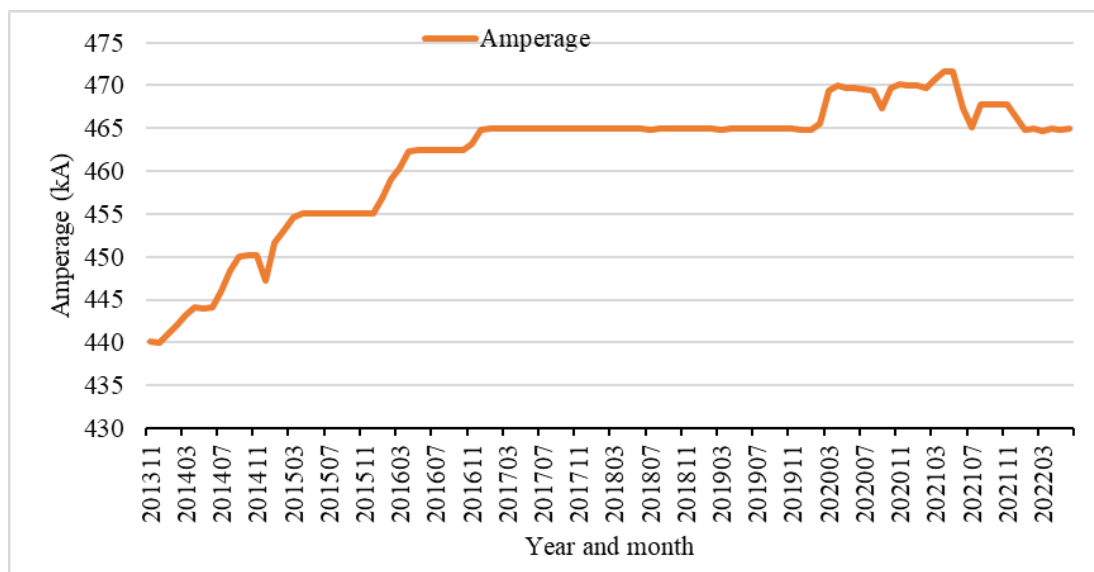


Figure 1. Amperage evolution from November 2013 to June 2022.

3. Major Changes during Amperage Increase

The enablers for amperage increase from 440 kA to 470 kA were design changes and adjustment of pot operation parameters to maintain pot stability and heat balance.

3.1 Base Resistance Setpoint (BRSP) and Pot Voltage

Figures 2 and 3 show BRSP and pot net voltage with amperage increase. Potline at early age started with BRSP of 5.8 $\mu\Omega$. The start-up of 444 pots was completed on June 2014 when the line stabilized at pot BRSP of 5.6 $\mu\Omega$ and 4.25 V net voltage. Constant voltage approach was adopted for amperage increase from 455 kA to 462.5 kA. In the following stage to 465 kA, the voltage and anode-cathode distance (ACD) were decreased in order to keep good heat balance. The voltage was decreased to 4.235 V in the first-generation pots. As the pot change over started in 2017, further voltage reduction was achieved due to lower cathode voltage drop in pots with copper collector bar inserts. This voltage decrease did not cause a decrease of the ACD.

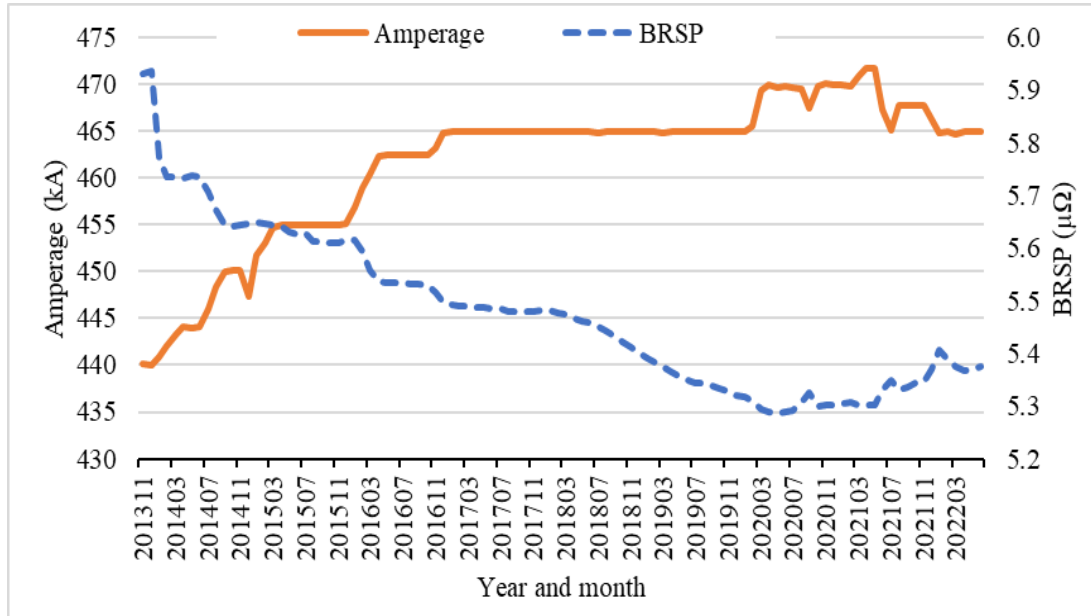


Figure 2. Pot amperage and BRSP.

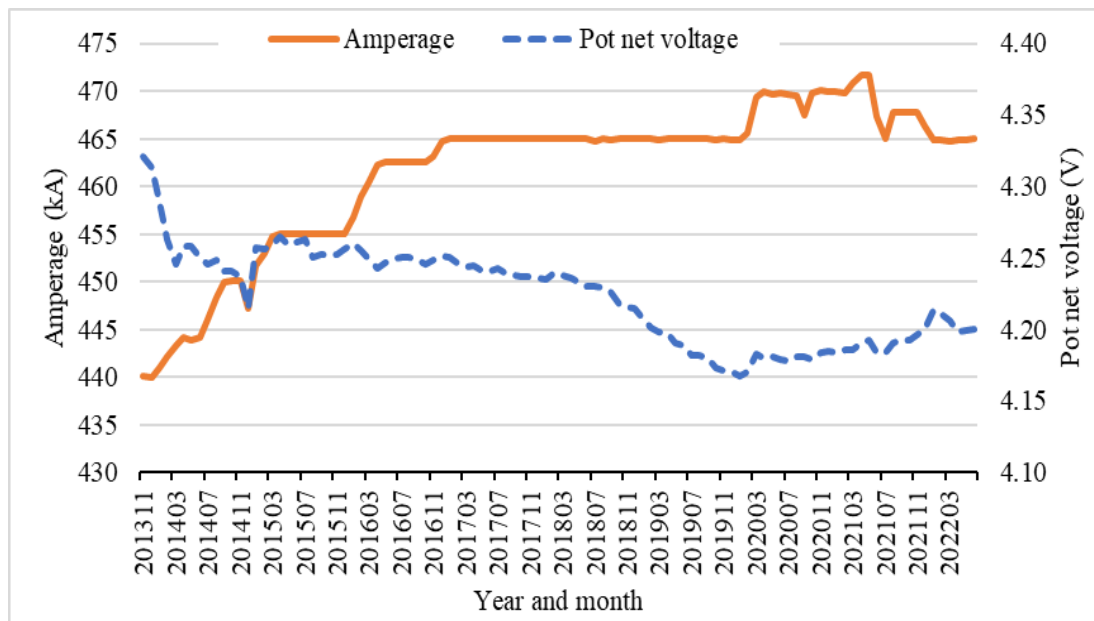


Figure 3. Pot amperage and net voltage of established pots.

3.2 Pot Design Changes

In 2017, the changeover of the first generation of pots started with new collector bar design with copper inserts. Figure 4 shows the changeover progress during amperage increase. This change was a major enabler to reach 470 kA.

Cathode voltage drop (CVD) between the metal pad and the end of collector bars increased with pot age by about 30 mV to about 270 mV in the first few years after start-up when only G1 pots were in the potline (Figure 5). Then it started to decrease in early 2018 when G2 pots with copper inserts started to replace G1 pots. It reached the minimum of 180 mV at the end of 2019 when all G1 pots had been replaced. After that the CVD started to increase again with pot age. It is estimated that the average CVD over the pot life will be by 60 mV lower in copper insert pots than steel collector bar pots. The 14 DX+ Ultra pots of Potline 3 extension have lower CVD because of somewhat longer copper insert in the collector bars and because they are all young.

An additional benefit of copper inserts was an increase of heat loss from the cathode, which is welcome during amperage increase.

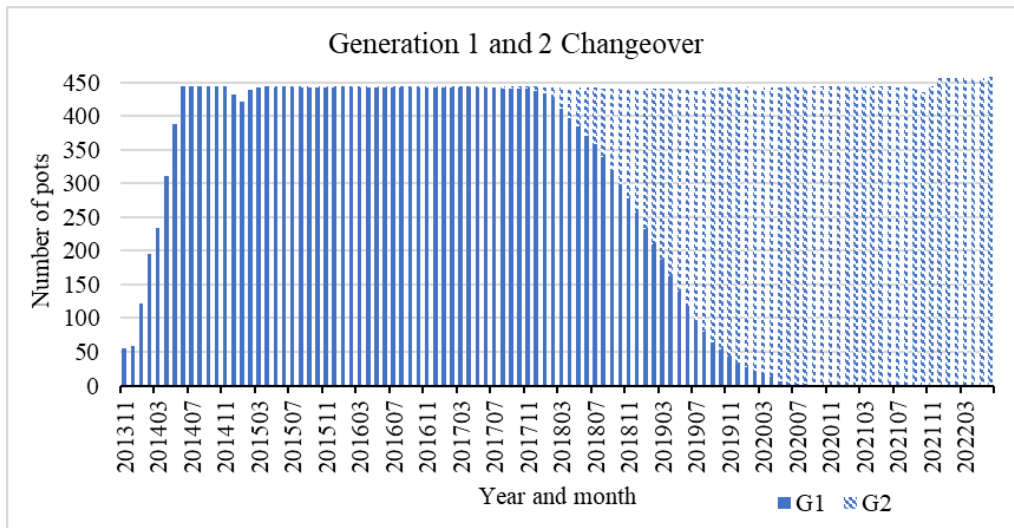


Figure 4. Generation 1 (G1) changeover to generation 2 (G2) pots. All G1 pots were changed by November 2020.

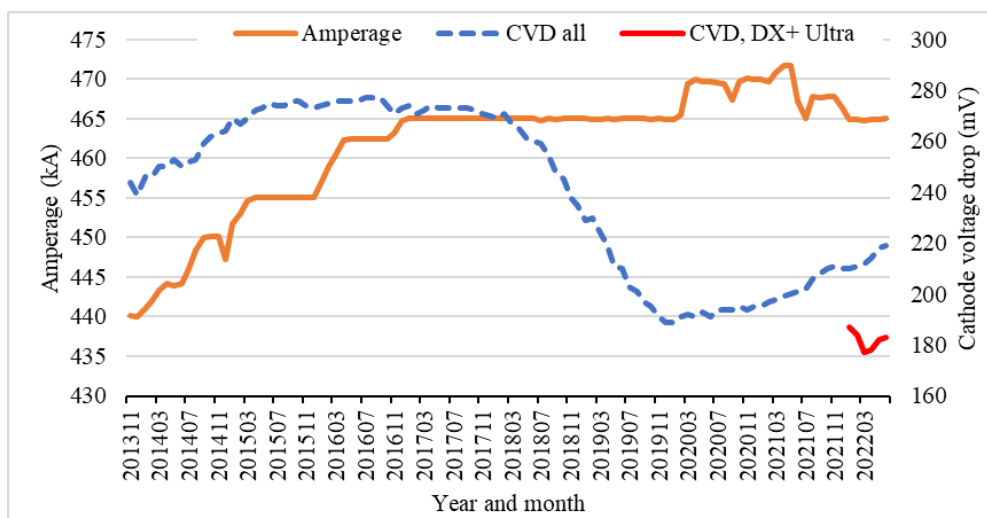


Figure 5. Cathode voltage drop until June 2022.

3.3 Potline Parameters

Adjustment of potline parameters were needed to maintain the pot operation with minimum heat balance disturbance. Increased heat generation with amperage increase was compensated by increased heat loss from anode top through anode cover height decrease, and metal height increase.

3.3.1 Anode Cover Height

Figure 6 shows the evolution of the anode cover thickness. The potline was started with 12 cm anode cover height target. It was decreased to 10 cm at the approach of 455 kA, then to 7 cm as we crossed 460 kA. This increased the heat loss from top of anodes. As the changeover to G2 cathodes started in 2017, the cover height was increased back to 12 cm to balance the increased heat loss due to copper inserts. Reaching 470 kA, the anode cover height was adjusted back down to 8 cm and then to 9 cm at 465 kA.

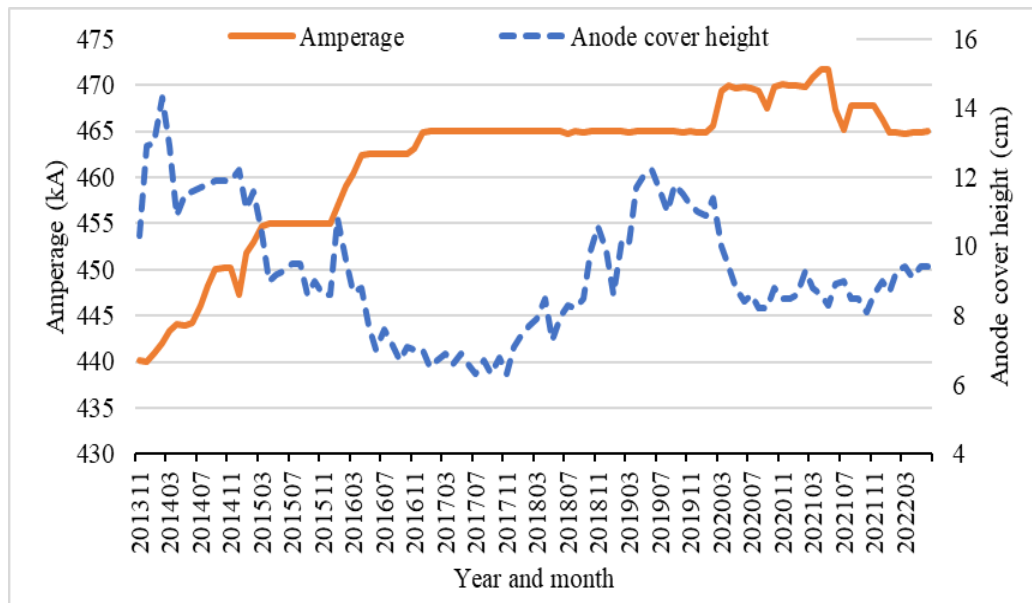


Figure 6. Anode cover height and amperage until June 2022.

3.3.2 Metal Height

Metal height is an effective tool to control the heat balance. Figure 7 shows the metal height increase. The potline was started at 20 cm metal height. This was increased to 21 cm as 465 kA was reached. An additional 1 cm increase was at 470 kA, and then further to 24 cm. This was good for pot heat balance and also for pot stability.

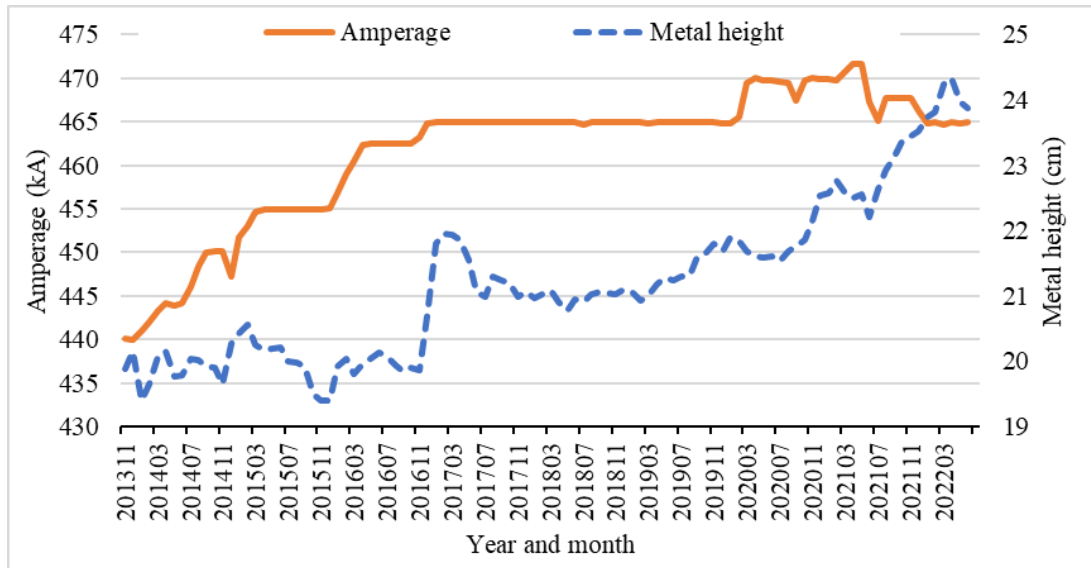


Figure 7. Amperage and metal height until June 2022.

4. Challenges

There were two major challenges during the amperage increase: Anode current density and busbar current density.

4.1 Anode Current Density

The first challenge was anode current density. The nominal anode current density is defined as pot amperage divided by the total area of new anodes. Figure 8 shows the anode current density with amperage increase. In DX+ pots the original anode length of 1880 mm has not been changed. The original anode current density at 440 kA was already high at 0.95 A/cm². With amperage increase to 470 kA it was 1.01 A/cm² and is 1.00 A/cm² at 465 kA now. This is unprecedented in high amperage pots. The main challenge of this is high internal heat per heat loss area of the pot. With amperage increase, the heat loss balance was achieved with cathode shell design, using cooling fins, anode cover thickness, metal height increase, and lowering ACD. It is quite remarkable that the pot performance remained excellent throughout the amperage increase journey.

A relief to anode current density is the design of DX+ Ultra with 1880 mm anode length within the same potshell size as in DX+. Figure 8 shows that at 480 kA, the anode current density of 0.985 A/cm² will still be smaller than at 465 kA with the present DX+ anode length. The way forward for the planned amperage increase to 480 kA is to increase the anode length in DX+ pots to 1860-1880 mm. This will require a considerable investment in anode production.

The anode shift life remained at 72 shift all along, but the carbon under stub decreased from 7 cm in 2014 to 4 cm in 2022.

The effective anode current density in the bath is lower than the nominal current density quoted above because of current fanning on the anodes. The effective current density used in ACD calculation at EGA follows Haupin [3].

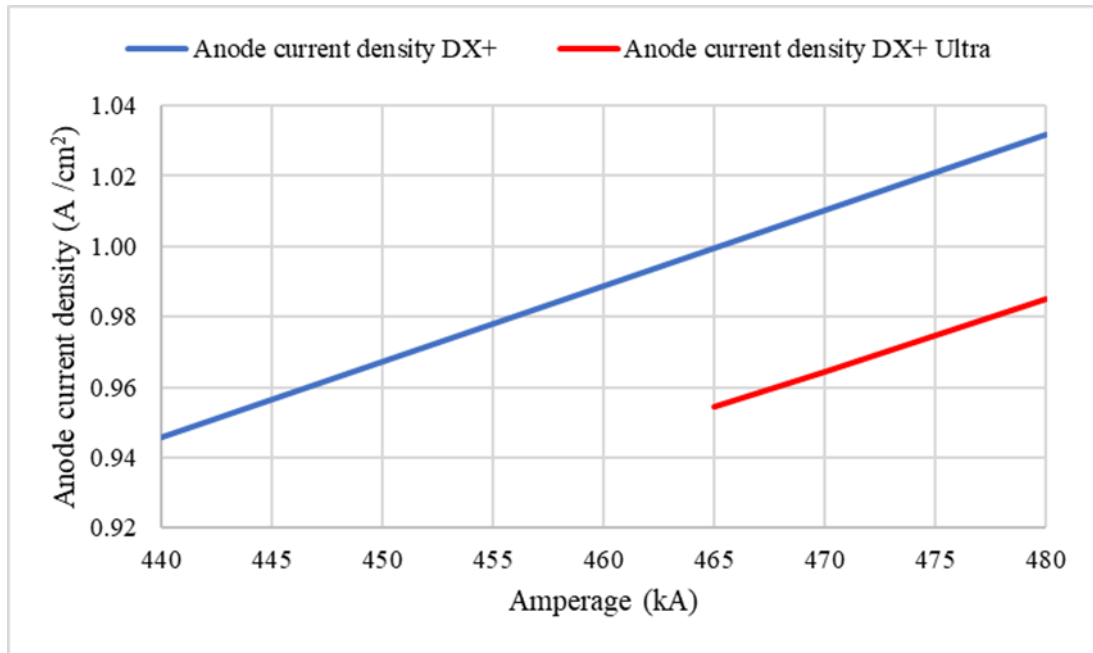


Figure 8. Nominal anode current density in DX+ and DX+ Ultra pots at Al Taweelah.

4.2 Busbar Current Density

The second challenge was the increase in the current density in specific location of pot cathode ring busbar during cell cut-out. The DX+ technology for Al Taweelah Potline 3 was designed for 420-460 kA, but the maximum design amperage was already surpassed in 2016. As the amperage was increasing, those locations were getting hotter at pot cut-out. The first action was measurement of busbar temperatures at those location for each pot cut-out to understand the issue. The EGA modelling team proposed installation of some auxiliary wedges to reduce the current density in those locations. In addition to that, the practice of measuring the busbar temperature at those locations for each cut-out pot was established as routing measurement. If those locations are found to be above 200 °C, force cooling is applied until the pot is back in the circuit.

5. Performance of DX+ Technology

5.1 Main KPIs

Table 1 summarizes the performance of the DX+ technology in Al Taweelah Potline 3. DX+ Ultra extension pots are included in the table for the last 3 months of 2021 and for 2022. The DX+ technology has proven to be consistently good in current efficiency, specific energy consumption, and net carbon consumption throughout the years at all amperage levels. It also has extremely low CO₂ eq. of PFC emissions due to low anode effect frequencies and durations.

Table 2. Historical performance of Al Taweelah Potline 3 until the end of June 2022.

Parameter	Unit	2015	2016	2017	2018	2019	2020	2021	2022
Amperage	kA	454.6	461.8	465.0	465.0	465.0	468.8	468.6	464.9
Tap CE	%	94.6	94.0	94.1	94.1	94.3	94.5	94.2	94.2
CE adjusted for Hm *	%	94.6	94.2	94.1	94.1	94.4	94.6	94.3	94.3
Metal production*	kg/pot-d	3463	3502	3524	3523	3534	3569	3554	3528
Pot voltage	V	4.257	4.250	4.242	4.229	4.186	4.179	4.190	4.205
DC net spec. energy*	kg/t Al	13.42	13.44	13.43	13.40	13.21	13.16	13.25	13.29
Net carbon cons.	kg/t Al	418	414	416	416	412	417	416	412
Gross carbon cons.	kg/t Al	557	550	547	558	561	543	550	564
Fe	%	0.0389	0.0348	0.0358	0.0610	0.0710	0.0520	0.0600	0.0650
Si	%	0.0250	0.0249	0.0230	0.0290	0.0300	0.0290	0.0260	0.0290
Bath temperature	°C	961	961	964	963	962	959	964	961
Excess AlF ₃	%	10.7	10.3	9.4	9.8	10.1	10.9	9.7	10.4
AE frequency	AE/pot-d	0.11	0.08	0.07	0.08	0.07	0.04	0.05	0.07
AE duration	s	19.7	10.0	7.5	26.0	38.0	21.0	25.0	42.0
PFC emmissions**	CO ₂ eq kg/t Al	38	14	10	38	48	15	23	53

*Adjusted for metal height increase in each period.

**CO₂ equivalent is calculated as in Reference [4], using the Tier 2 method and SAR (Second Assessment Report).

5.2 Fluoride Emissions

Figure 9 shows total fluoride emission of Potline 3 from 2015 until July 2022. The emissions have been well under control, all but in 2019 below 0.25 kg F/t Al. This is well below the global average for prebake pots of 0.52 kg F/t Al [7].

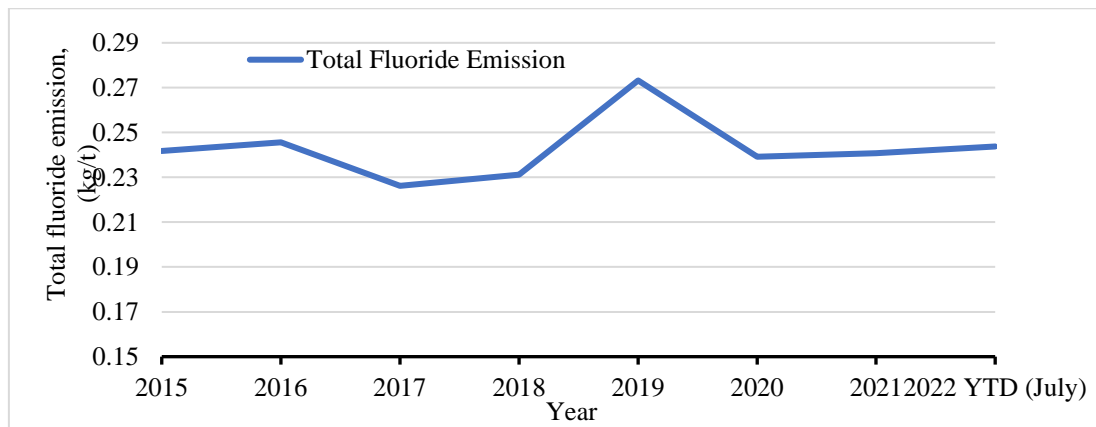


Figure 9. Total fluoride emission performance.

6. Conclusions

Al Taweelah Potlines 3 using DX+ technology successfully increased amperage from 440 kA to 470 kA, which increases the annual metal production by approximately 30 000 tonnes per year. Another 18 000 tonnes of aluminium were added with the potline extension of 14 pots using DX+ Ultra technology. The KPIs during the whole period were maintained at an excellent level. The pot lining performance was also excellent with good average age of generation 1 pots. The potential for further amperage increase has been proven in DX+ Ultra demonstration pots in EGA's Jebel Ali Eagle section and in Alba Potline 6, which open the path to the future of Al Taweelah Potline 3. Further amperage increase in Al Taweelah Potline 3, it will require a new cathode design, an additional rectifier and increased anode length.

7. References

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