

Implementation of D18+ Technology in Potline 1 at EGA Jebel Ali

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Abstract

To take the next step in efficiency and productivity, EGA initiated the modernisation of the D18 Technology potlines in its Jebel Ali smelter. Utilising the latest cell technology, seven D18+ test cells were constructed and started-up in March 2012. The test cells quickly met their key design targets with net specific energy consumption of 12.75 kWh/kg Al and anode effect frequency of less than 0.02 /cell-day. After thorough industrial testing and a feasibility study, a project commenced in August 2015 to convert all 248 cells in Potline 1 to the new D18+ Technology. Despite many challenges in the construction and installation of the new cell technology in an operating potroom, the full potline conversion was successfully achieved ahead of schedule. With full Potline 1 conversion completed, amperage will be increased to 235 kA, thus increasing EGA’s hot metal production capacity by more than 23 kt/year while reducing energy consumption by a targeted 2 kWh/kg. Further conversion of 272 cells in Potline 3 from D18 Technology to D18+ Technology will commence in September 2016, resulting in further capacity and energy efficiency increases. The D18+ Technology project has also significantly reduced EGA’s environmental footprint and enabled EGA to increase its competitive edge in the industry.

Keywords: D18+ Technology; DUBAL modernisation to D18+ Technology; DUBAL Potline 1 conversion; DUBAL Potline 3 modernisation.

1. Introduction

Dubai Aluminium (“DUBAL”), an operating subsidiary of Emirates Global Aluminium (“EGA”), commenced operations with three potlines housing 120 P69 cells, with the first hot metal produced in December 1979. The cell design was later redesignated as D18 Technology after significant revision (Figure 1) [1, 2]. After construction of a fourth potline, significant upgrades, higher efficiency and increased amperage, annual production from the original potlines increased from 36 300 tons in 1980 to 291 353 tons in 2014.

To take the next step in efficiency and production, EGA has undertaken a complete revision of D18 Technology. Incorporating the latest cell technological advances such as magnetic compensation, point feeders and direct alumina distribution (Table 1), the new D18+ Technology quickly met and exceeded all major target KPIs during extensive testing and validation in seven test cells (Figure 2) [3].

After economic analysis and a feasibility study, approval was given by the EGA board in March 2015 to implement D18+ Technology in the remaining 241 cells in Potline 1.

Table 1. Comparison between D18 Technology and D18+ Technology.

	D18	D18+
Busbar Configuration	End risers	Four side risers with under cell bus
Al₂O₃ Feeding	Pseudo point feed converted from dual centre breaking	Four point feeders with bath sensing breakers
AlF₃ Feeding	10 kg bags added manually	Dedicated AlF ₃ feeder
Alumina Distribution	Via crane hopper	Air slide system
Number of Anodes	18	20
Anode Beam Control	Pneumatic	Electric
Number of Cathode Blocks	17	19
Collector Bar - Flexible Connection	Bolted	Welded



Figure 1. D18 Technology cells in Potline 1.



Figure 2. D18+ Technology test cells in Potline 1.

2. D18+ Technology Implementation

2.1. Potline 1 sections

Although DUBAL (also known as EGA's Jebel Ali Operations) had previously implemented both brownfield and greenfield projects to increase production capacity, this was the first time where significant cell construction was undertaken in an operating potline. To best implement and manage the conversion of the potline, the cell upgrade occurred in sections of 30 to 32 cells each, with eight sections in total (Figure 3). The D18+ Technology upgrade began in Section 2 and then continued to Sections 3, 1, 4, 6, 7, 5 and finally Section 8.

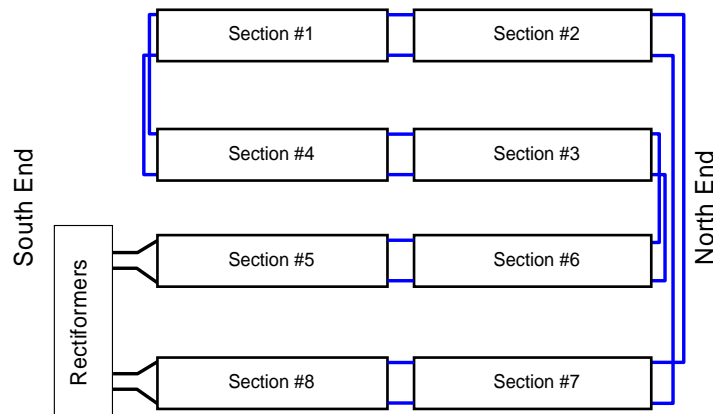


Figure 3. Potline 1 schematic.

2.2. Bypass busbar

To enable removal of the existing D18 Technology cells and construction of the new D18+ Technology cells during continued operation of the rest of the potline, a bypass busbar was placed on the duct end of the potroom. The bypass busbar consisted of separate sections (or wagons) each approximately 12 metres in length (Figure 4), that were positioned on a double set of rails along the potroom section (Figures 5 and 6). The individual wagons were then connected via bolted clamps for the length of the potroom section.

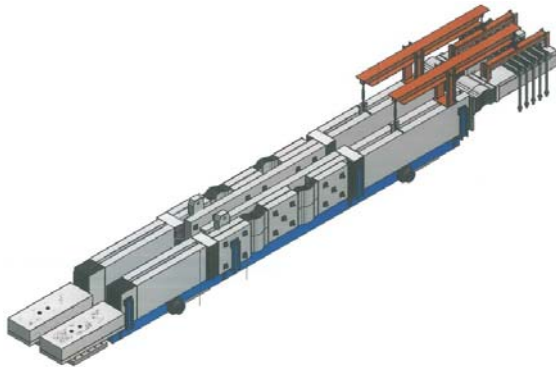


Figure 4. Drawing of bypass busbar.



Figure 5. Bypass busbar in situ.

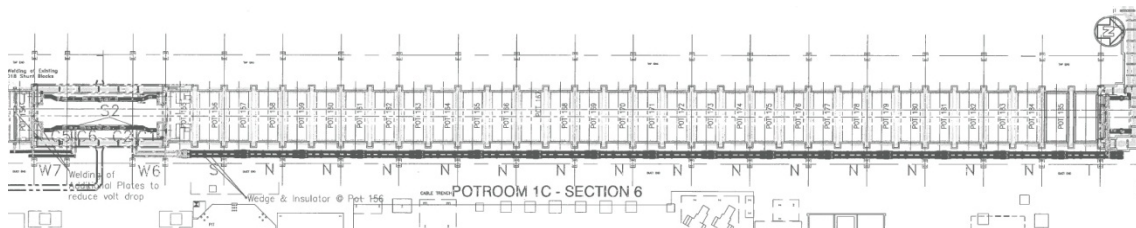


Figure 6. Drawing of bypass busbar installed in potroom section.

Upon installation (but not yet energisation) of the bypass busbar, the cells in a section would be cut-out. Cut-out of the section of existing D18 cells to be replaced typically occurred at the rate of 6 to 7 cells per 8 hour shift, resulting in the full section of 30 to 32 cells being fully cut-out in less than 48 hours.

Once the cut-out of a section was complete, the potline amperage would be temporarily reduced to 50 kA and wedges would be installed so that the bypass busbar would carry current in parallel to the existing D18 busbar. Once the voltage drops of the bypass busbar were confirmed to be within acceptable range, the shunts on the D18 cell busbar would be opened and the bypass busbar would be capable of operating at the full potline current. The voltage drops on the bypass busbar were then re-measured every 24 hours to ensure no deterioration.

2.3. D18 Technology removal

With the D18 cell busbar no longer live, the process to remove the shells and superstructures began (Figure 7). Once this was complete, the existing busbars were then cut and removed (Figure 8).



Figure 7. Original busbar after removal of D18 Technology cells.



Figure 8. Potroom after D18 busbar removal.

Once the D18 Technology was fully removed from the section, the project team would begin the necessary earthworks, civil construction, new busbar, shells, cell control hardware and finally superstructure installation.

2.4. Operation and project team co-operation

One of the complexities of the project was the construction of the new D18+ Technology simultaneously while normal production activities were continuing in the same potroom. Some of these challenges included:

- Restrictions in the centre passage from construction vehicles and trucks transporting busbars, shells and superstructures; as well as normal potroom movements such as anode raising beam, hot metal transportation, and anode transportation.
- Constricted access associated with construction works related to the cross-over busbar.
- Greater number of people and activities in the potrooms, requiring greater care to avoid possible collision and injury.
- Periodic potline amperage reductions to allow for busbar connection and other work.

Despite these obstacles, both the project and operations teams worked co-operatively within the potrooms to successfully implement the D18+ Technology project without incident or injury.

2.5. Section turnaround time

It was important to minimise the time out of circuit for each section, both to keep the project on schedule and to minimise hot metal production losses.

The total time between cut-out of the first D18 Technology cell to bath-up of the last D18+ Technology cell for the first section conversion was on time, at a total 68 days. Learning from experience in the first section, the project and operation teams significantly reduced the time required to convert a section to D18+ Technology, with an average total time of 47 days for the subsequent seven sections converted (Figure 9).

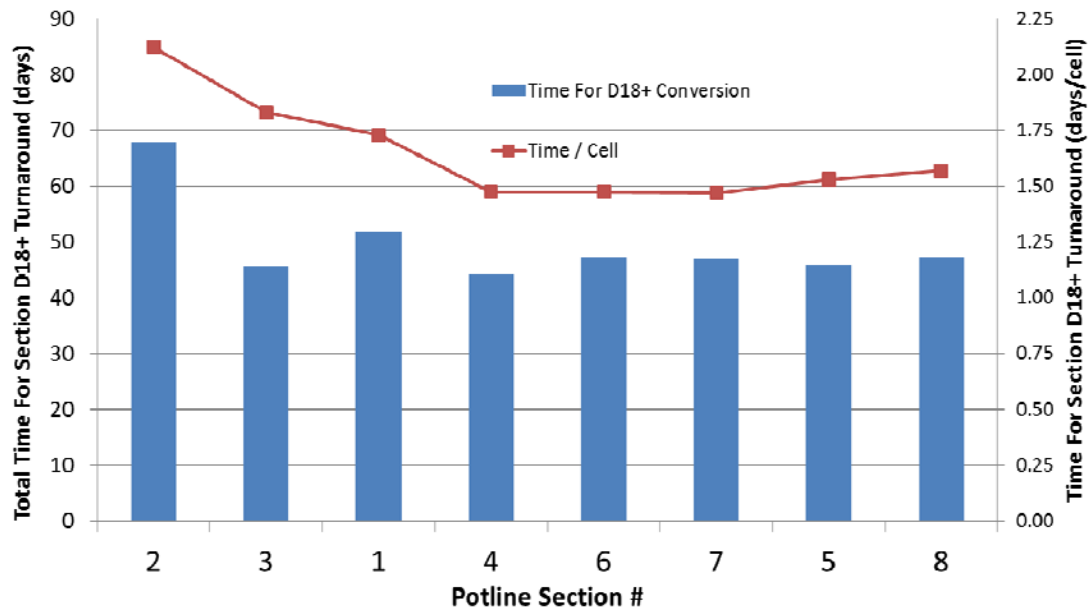


Figure 9. Total time for D18+ conversion per section.

By reducing the section turnaround time, the Potline 1 D18+ Technology project was fully completed 86 days ahead of schedule (Figure 10).

The main bottleneck for further reduction in the section turnaround time was the rate of supply of the new D18+ Technology superstructures. Quicker fabrication was not possible without incurring additional costs. This issue will be addressed during the contract negotiation for the superstructure fabrication for the conversion of Potline 3 to D18+ Technology later in 2016.

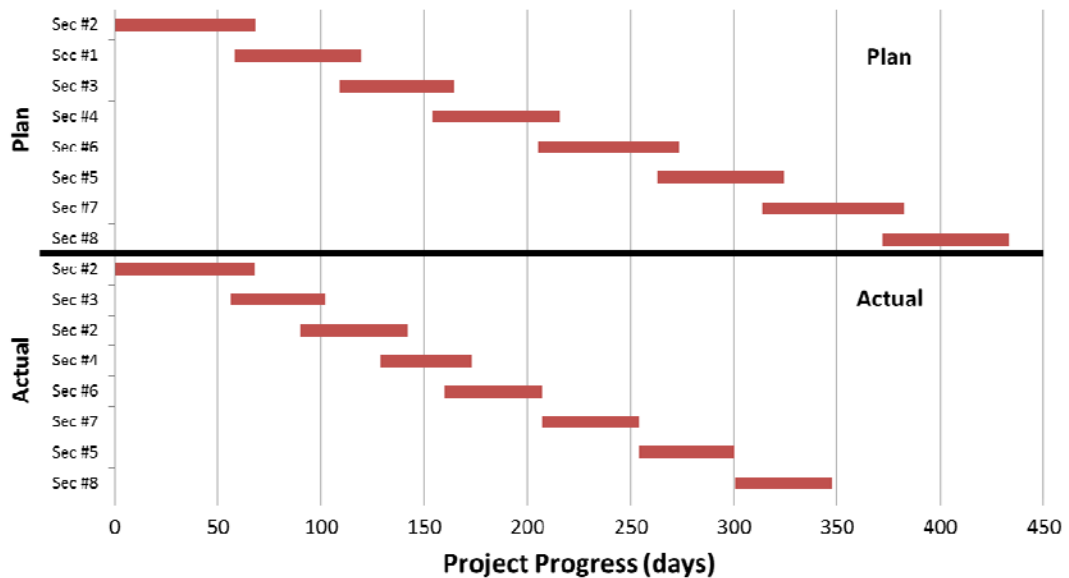


Figure 10. Potline 1 D18+ project schedule.

2.6. New cell control logic training

The new D18+ Technology also incorporates the latest EGA cell control system. Based on a Programmable logic Controller (PLC) controlling up to 10 cells, the system is operated by a new touchscreen human-machine interface (“HMI”) (Figures 11 and 12).

1023 POT CONTROLLER 1024					
28/07/2016 09:29:11					
4.062V 10.93 $\mu\Omega$		219.9kA		4.077V 11.07 $\mu\Omega$	
6 / 14 mV		219.9kA		11 / 19 mV	
31.3 / BF / -1			15 / 17 cm		
959 / 12.0			0.060 / 0.020 %		
29.4 / U1 / 2			13 / 16 cm		
974 / 7.6			0.037 / 0.018 %		
PL 1	ROUTINE	SUPV.	PL 1	ROUTINE	SUPV.
POT 023	OPTN'S.	FUNCTIONS	POT 024	OPTN'S.	FUNCTIONS
LOCKOUTS	DATA		LOCKOUTS	DATA	
	ENTRY			ENTRY	
CELL INFO	FLAGS	CALL	CELL INFO	FLAGS	CALL
		SUPERVISOR			SUPERVISOR
HISTORICAL	TRENDS	ALARMS	HISTORICAL	TRENDS	ALARMS
DATA			DATA		

Figure 11. D18+ HMI Overview screen.

1023 CELL INFORMATION					
28/07/2016 09:29:33					
4.054V 10.93 $\mu\Omega$		219.9kA		4.081V 11.07 $\mu\Omega$	
6 / 14 mV		219.9kA		8 / 19 mV	
Base Feed 28/07/2016 09:06 (00:23:03 ago)					
Beam Pos.: 99 mm.		Remaining Time: 6 min, 56 sec.			
1.2 sec.		1.2 sec.		1.4 sec.	
1.1 sec.		1.1 sec.		1.1 sec.	
BFT: 31.3 sec.		BRSP: 4.092 V		AVG NOISE: (3hrs) (30mins)	
Feed Rate: 99 %		PrDeltaV: -1.0 mV		Full: 25 27	
AE Freq: 0.033 /30days		CRSP: 4.092 V		MHD: 8 8	
		11.10 $\mu\Omega$		Anode: 14 15	
CELL	DATA	RESISTANCES		AIF3	NEW CELL
INFORMATION	ENTRY			DUMPS	CONTROL

Figure 12. D18+ HMI Cell Information screen.

The introduction of the more sophisticated control logic and interface meant additional training of the operations personnel. This was initially done in a classroom environment with the aid of a simulator that fully resembled the new control logic interface. This was then followed with familiarisation in potrooms on the first new D18+ Technology cells.

2.7. D18+ Technology start-up

On 8 October 2015, the Section 2 (the first section converted to D18+ Technology) was formally handed-over by the project team to Potline Operations. Cell 31 was the first cell cut-in (Figure 13), and after 52 hours of pre-heat it was successfully bathed-up on 11 October. The Section 2 cells were then gradually cut-in at the rate of four per day, while the final cell in the section was bathed-up one week later on 18 October (Figure 14).



Figure 13. Section 2 under preheat.



Figure 14. Bath-up of first D18+ Technology cell in Section 2.

The same procedure was followed in subsequent sections, with four cells cut-in per day and all cells cut-in after 8 days.

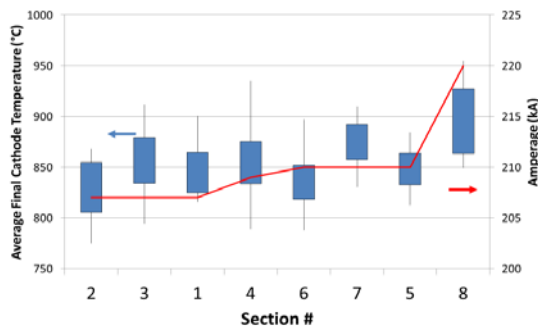


Figure 15. D18+ final pre-heat cathode temperature and amperage.

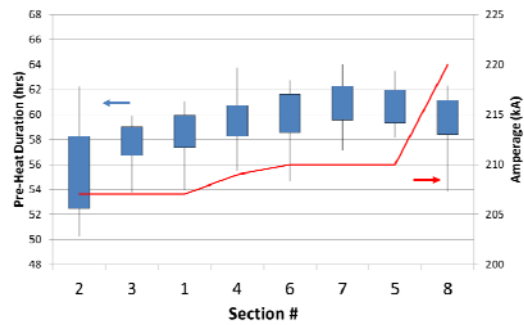


Figure 16. D18+ pre-heat duration and amperage.

The first D18+ Technology section started-up had lower than expected final cathode temperature, with an average of 826 °C. This was gradually improved by altering the resistor template, increasing duration and higher amperage (Figures 15 and 16).

The operations team also invested considerable effort to minimise anode effects after bath-up and during subsequent metal pouring. This resulted in a reduction of anode effect frequency (“AEF”) during the first 48 hours from 0.70 /cell/day to 0.03 /cell/day (Figure 17). The number of cells high in voltage (> 8 V) immediately after bath-up also gradually reduced to zero.

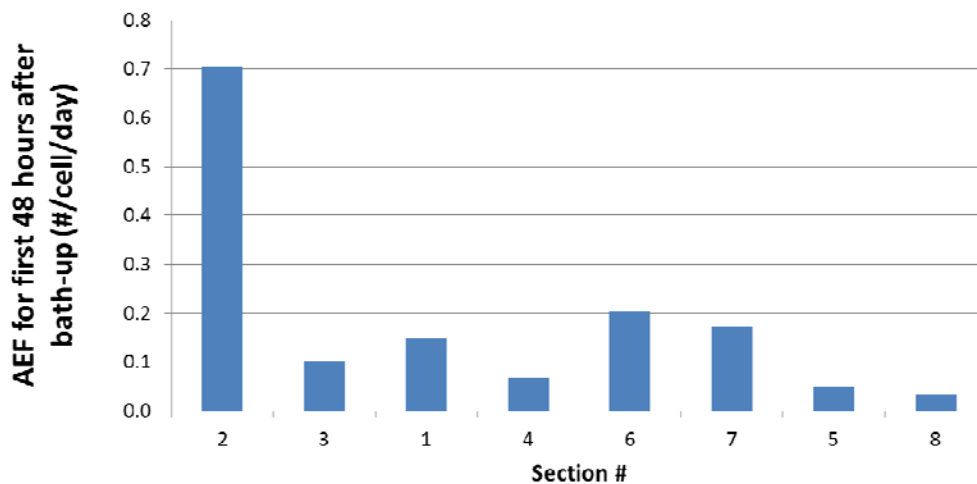


Figure 17. AEF for first 48 hours after bath-up.

2.8. Amperage

One of the challenges during the upgrade process was that the D18 Technology cells were near their upper limit for amperage, while conversely the D18+ Technology cells were near their lower limit. At the start of the project in September 2015, the amperage in Potline 1 was 207 kA. This was gradually increased to 210 kA by February 2016 (Figure 18).

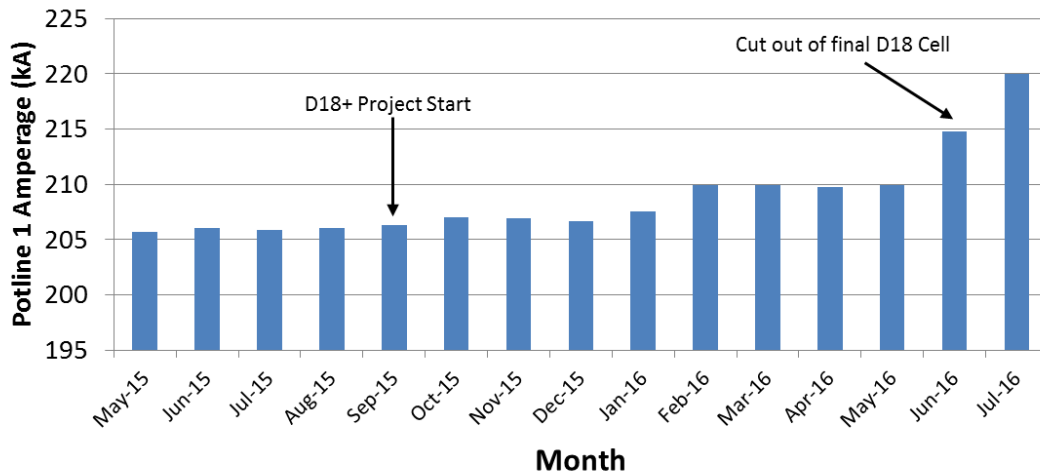


Figure 18. Potline 1 amperage increase.

At 210 kA, the anodes of the D18 Technology cells were close to their limit, with the butt thickness close to the minimum size possible. To mitigate this, anodes were closely monitored and raised if they were at risk of being too thin and causing stub wash. Airburn and other anode problems also required more frequent replacement with a plethora of mid-rota anode butts available due to the D18 Technology cell cut-outs.

The D18+ Technology cells are well magnetically compensated cells though they are also susceptible to low superheat and associated problems despite the low metal height target, very high anode cover, low gas draft and other steps taken to conserve heat within the cell. After careful consideration, the base resistance set point of D18+ Technology cells was set to an equivalent 70 mV higher until the project was completed and the amperage could be increased.

Upon cut-out of the final D18 Technology cells, Potline 1’s amperage was gradually raised to 220 kA. Further amperage increases are limited by the current fume treatment plant (“FTP”) capability. Once upgrade work on the FTPs is completed (by the end of 2016), the amperage will be increased further to 235 kA.

2.9. Performance

Figures 19 and 20 illustrate the average section voltage for the first 100 days (excluding Section 8 as it had just been started up). The time to reach target voltage was reduced from 40 days to 26 days. Average noise was less than 20 mV three weeks after start-up and is now averaging 10 mV after 100 days.

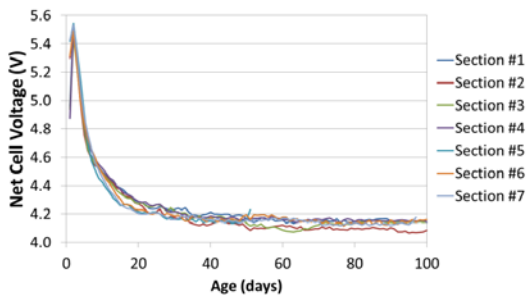


Figure 19. D18+ Technology net cell voltage.

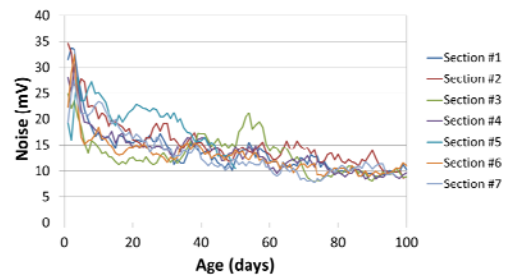


Figure 20. D18+ Technology noise.

Figures 21 and 22 show the average section current efficiency and net specific energy for the first 100 days. The first three sections started (1, 2 & 3) show higher initial current efficiency (as tapped) due to higher metal heights. For subsequent sections, the first metal tap was done earlier, reducing the need for larger corrective taps to reduce the metal height to target. At approximately 60 days in Section 3, there were issues with the cell alumina conveying system, which negatively affected the AEF, bath temperature and current efficiency. This was subsequently remedied, however, and the section quickly returned to stability.

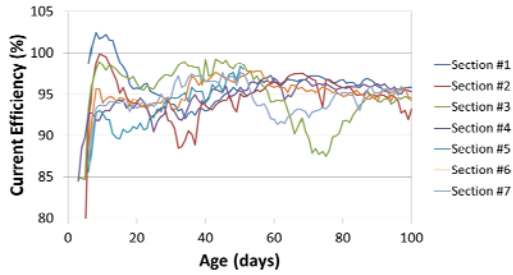


Figure 21. D18+ Technology current efficiency.

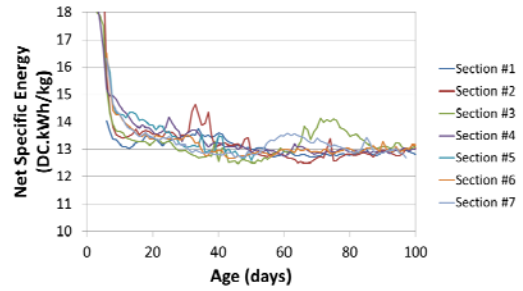


Figure 22. D18+ Technology net specific energy.

Figure 23 and 24 depict average D18+ Technology metal and bath height. As per the cell start-up procedure, the metal height target of 15 cm and bath height of 16 cm were gradually reached after 30 days of operation and with minor variations thereafter.

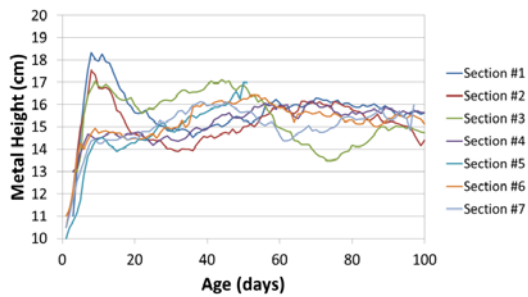


Figure 23. D18+ metal height.

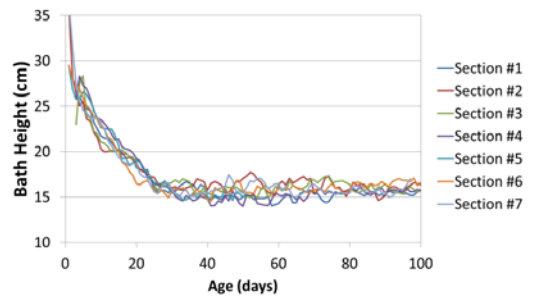


Figure 24. D18+ bath height.

Figures 25 and 26 show the average D18+ Technology bath temperature and electrolyte (AlF_3) concentration. For the initial sections, the bath temperature was above target and AlF_3 concentration was below target for the first 30 to 40 days. This was successfully mitigated by gradually reducing the target net cell voltage during the same period (Figure 14).

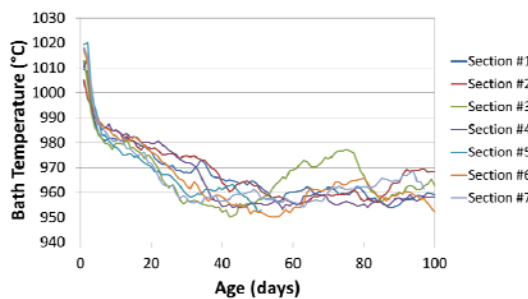


Figure 25. D18+ Technology bath temperature.

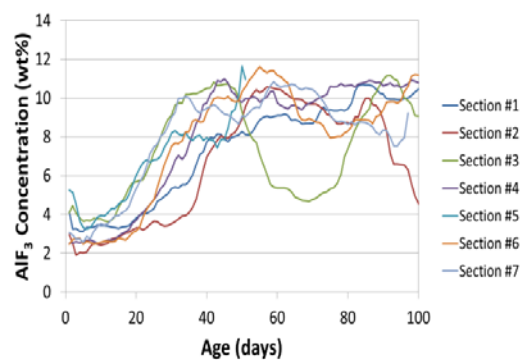


Figure 26. D18+ Technology AlF_3 concentration.

Figures 27 and 28 show the average D18+ Technology AEF and anode effect duration (“AED”). Despite the high AEF in Section 6, both the AEF and AED quickly reduced during the start-up period and continue to remain at low levels.

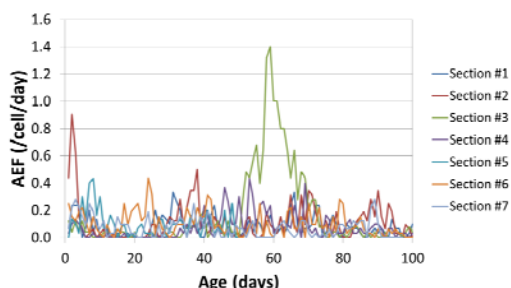


Figure 27. D18+ Technology AEF.

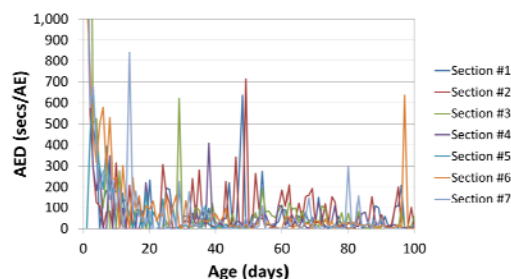


Figure 28. D18+ Technology AED.

Table 2 shows the initial 21-day performance of Potline 1 D18+ Technology after stabilisation at 220 kA. Net specific energy is less than 13 DC.kWh/kg Al and current efficiency is on target at 94.80 %. The cells remain stable with an average noise of 12 mV and perfluorocarbon (“PFC”) emissions are at a low level of 29 CO₂eq. kg/t Al.

Table 2. D18+ Technology performance at 220 kA.

Parameter	Unit	D18+
Net Voltage	V	4.132
Current Efficiency	%	94.80
Net Specific Energy	DCkWh/kg Al	12.99
Noise	mV	12
Net Carbon Consumption	kg C/tAl	420
Anode Effect Frequency	#/cell/day	0.04
Anode Effect Duration (> 8 V)	seconds	30
PFC Emissions	CO ₂ eq. kg/t Al	29

2.10. Way Forward

With the last Potline 1 D18+ Technology section started-up in July 2016, the operations and process control teams will continue to work on stabilising at 220 kA and optimising performance for maximum efficiency, before increasing the amperage further to 235 kA in 2017.

Pre-work has already begun to convert the 272 D18 Technology cells in Potline 3 at EGA Jebel Ali to D18+ Technology. Drawing on the experience and skills learned from the Potline 1 conversion, it is expected that Potline 3 will be completed by October 2017, resulting in a total of 520 D18+ Technology cells at EGA Jebel Ali.

3. Conclusions

The Potline 1 D18+ Technology implementation commenced in 2015 to convert all 248 cells to the new D18+ Technology. Full conversion was achieved ahead of schedule without incident or injury on 24 July 2016 with the bath-up of the final cell. During the same period, the amperage of Potline 1 was increased from 207 kA to 220 kA. Upon completion of the FTP upgrades at the end of 2016, the amperage will be increased further to 235 kA, increasing EGA's hot metal production capacity by more than 23 kt/year. The experience gained from the Potline 1 conversion will be applied for during conversion of 272 cells in Potline 3, which will begin in September 2016. The D18+ Technology project will reduce the energy consumption of EGA Jebel Ali's original potlines by a targeted 2 kWh/kg Al while also significantly reducing the environmental footprint.

4. Acknowledgement

The effort and dedication of Potline Operations, Jassem Mohammed and Faisal Majid and their teams has been crucial for the successful conversion of Potline 1 to D18+ Technology. Also, the invaluable work and support of Mohammad S W Ali, Adam Sherrif, Maitha Faraj and the D18 Process Control team have been indispensable for the smooth conversion to the new D18+ Technology.

We are also thankful to Amer Al Redhwan and the EGA Capital Projects team, and Alexander Arkhipov, Syed Fiaz, Konstantin Nikandrov and the EGA Technology team for the significant work carried out for the design and implementation of D18+Technology.

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