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FROM D18 TO D18+: PROGRESSION OF DUBAL'S ORIGINAL POTLINES

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Abstract

Over the past four decades there has been continual development of the original D18 potlines at DUBAL to increase their efficiency and productivity. Amperage has increased by 37 % to 205 kA, the number of cells has increased by 44 % to 520 and individual cell production has increased by 47 % to 1549 kg/cell-day. Specific energy has also reduced from 15.96 to 14.79 DC kWh/kgAl and PFC emissions have reduced by 74% recently to 95 CO_2eq kg/t Al.

To make the next step in improving DUBAL's productivity and economic competitiveness, a completely new cell design, D18+, was developed to modernise the original potlines. After construction of seven D18+ test cells in 2012, the new design has achieved its key objectives with current efficiency of 95.1 %, specific energy of 12.64 DC kWh/kgAl and PFC emissions of 5 CO_2eq kg/tAl. Work has now begun for full implementation in the D18 potlines.

Introduction

DUBAL commenced operations with its first metal production in 1979 and eventual start-up of three potlines by the end of 1981. Consisting of 120 cells each, the three potlines, based on Kaiser P69 technology, initially operated at an amperage of 150kA.

Figure 1: Original D18 potlines at DUBAL.

In 1990, a fourth potline of 148 cells was constructed (Figure 1), utilising D18 cell technology and incorporating subsequent DUBAL improvements to the P69 design. In 2008 and 2010, an additional sixteen D18 cells were added, resulting in a total of 520 cells in the original DUBAL potlines [1].

Amperage Increase

Amperage has gradually been increased from the initial design capacity and then significantly to 205 kA from 2006 onwards after replacement of the original potline rectifiers (Figure 2).

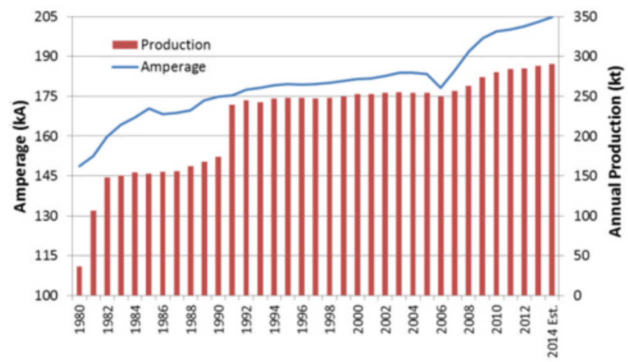

Figure 2: DUBAL D18 potlines amperage and annual production.

Along with improvements in current efficiency, the productivity of the D18 cells has increased by 47 % from an initial 1056 kg to 1549 kg/cell/day. This, together with the increase in the number of cells, has increased the total production of the D18 potlines from an initial 145 kt to an estimated ~290 kt in 2014.

Several initiatives have facilitated the significant increase over original design amperage to 205kA:

- Increased anode size,
- Revised lining design developed through thermal, electrical and mechanical modeling,
- Changing from 30 % graphitic to fully graphitic cathodes,
- Shell cooling fins,
- Additional busbar,
- Revised operational procedures and auditing,
- Assessment and regular monitoring of electrical busbar and connections.

Anodes

To increase the anode cross-sectional area, baked anode size has been gradually increased in the D18 cells from the original 1130 mm length to 1515 mm by 2011 (Figure 3). A proposal is being considered for 2015 to increase the baked anode length further to 1535 mm.

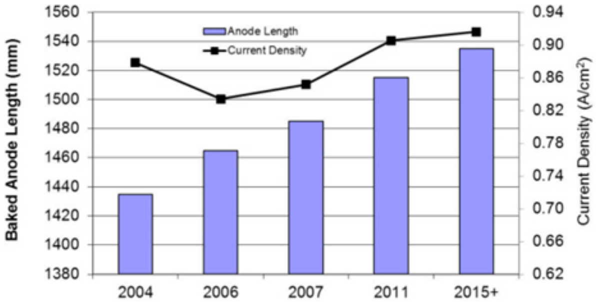

Figure 3: D18 anode length and current density.

The D18 cell has 18 prebaked anodes. In 2011, setting of two anodes consecutively, or 'double setting', was trialed and successfully implemented in Pseudo-point Feed (PPF) cells. Although the replacement of two anodes simultaneously is a greater disruption to the cell, this was compensated by:

- Less fugitive gaseous emissions
- Easier anode dressing
- Improved overall stability
- Reduced operator workload

To maintain anode performance and metal purity at higher amperage without decreasing shift life, the target bath height has gradually been lowered. The diligence and competence of the potroom operations to properly dress, as well as prompt diagnosis and action of problem anodes, has resulted in significant improvement in metal purity and gross carbon consumption despite the increase in amperage (Figure 4 and 5).

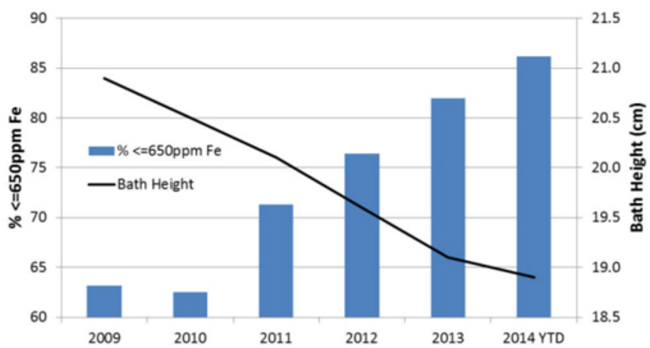

Figure 4: D18 metal purity and bath height.

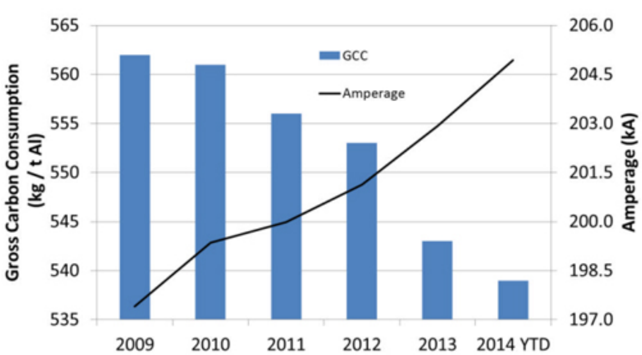

Figure 5: D18 gross carbon and amperage.

Perfluorocarbon (PFC) Emissions

The original P69 design was operated via centre break (CB) alumina feeding. Conversion to PPF was first initiated at DUBAL in 2002 on 15 trial cells. With increasing amperage, the performance advantages of PPF over CB operation increased significantly, resulting in expediting of the conversion to PPF operation [2].

To further improve the performance of the PPF feeders, and reduce their susceptibility to alumina fines, several changes were recently made to the feeder design:

- Stopper plate added to ore gate to avoid spillage of alumina outside of the feeding point,
- Ore control slot length increased,
- Ore deflector tray sealed / covered from the top to form a funnel, with an opening at the bottom.

These modifications resulted in > 50 % reduction in measured feeder dump weight variation both between different feeders and for the same feeder over time and with varying alumina qualities (Figure 6).

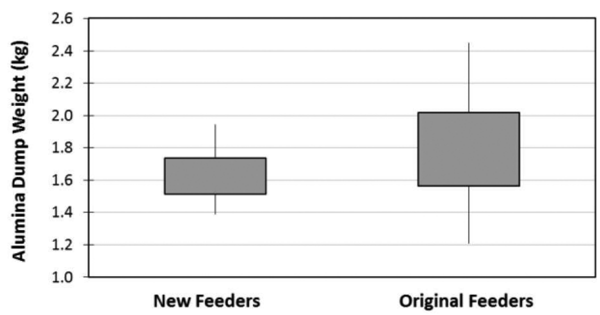

Figure 6: New and original alumina feeder dump weight boxplot.

This reduction in dump weight variation and improved resistance to fluctuation in alumina fines has resulted in significant reduction in Anode Effect Frequency (AEF) to 0.19 /cell/day compared to the average of 0.32 /cell/day with the older feeder design.

To reduce the AE duration (AED), the anode quench sequence was simplified to descend down and hold a lower anode beam position for the initial 28 seconds of the AE quench. Cycling of the beam was maintained but was postponed until after the average AE duration had passed (Figure 7).

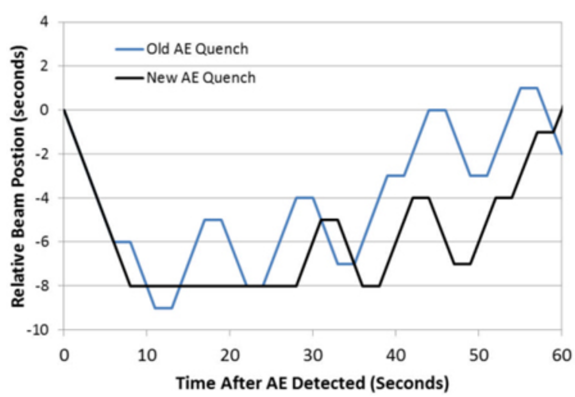

Figure 7: Old & New AE Quench Sequence.

Trial of the new AE quench sequence resulted in immediate reduction in the average AE duration, and after roll-out to all cells, a ~27% reduction in PFC emissions was achieved (Figure 8).

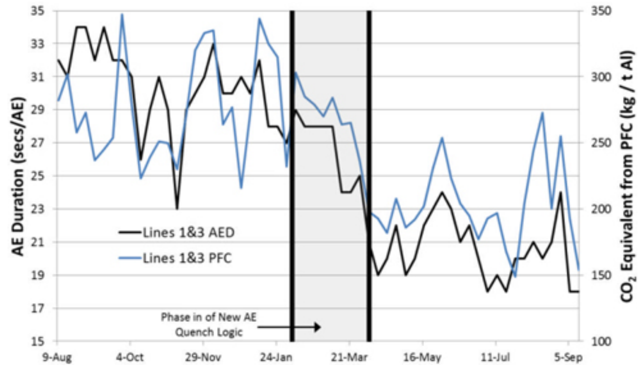

Figure 8: Reduction in AE duration and PFC emissions from new AE quench sequence

Additional Busbar

To reduce the external voltage drop between cells, additional busbar has been added [2]. This extra busbar was added in two phases, firstly as an additional busbar leaf at the tap and duct ends of the cells, and secondly as additional busbar inside the downstream cathode ringbus (Figure 9).

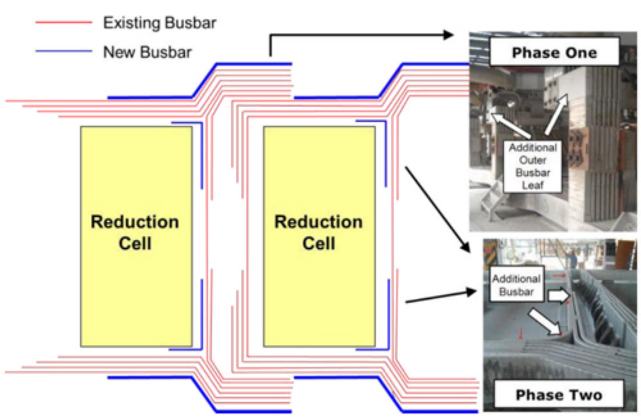

Figure 9: D18 additional busbar

Installation of the additional busbar has enabled energy savings of 0.20 DC kWh/kg.

Potline Connection

When replacement of the original rectifiers became necessary, a project was conceived to connect Lines 1 & 2 and Lines 3 & 4 to create two potline circuits, thus requiring only two new sets of rectifiers. In addition, two new cells were introduced to the end of each north potroom, resulting in 16 additional cells (Figure 10).

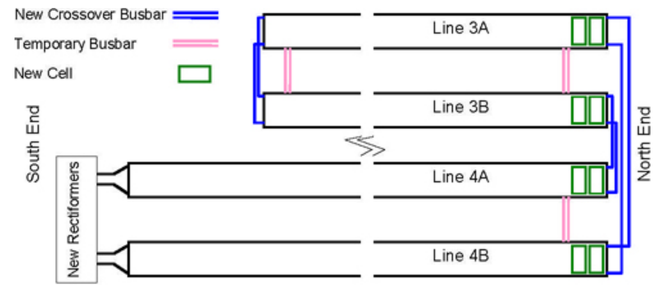

Figure 10: Schematic of connection of Line 3 and 4

Connection of Lines 3 & 4 (and re-designated as Line 3) was completed in July 2008, and with Lines 1 & 2 (and re-designated as Line 1) in February 2010. Both Lines are now successfully operating at 205kA and 1177 V (Line 1) and 1284 V (Line 3) respectively.

Cathode Lining and Shell

To prepare for the challenges of higher amperage and the change to PPF operation, the D18 cell lining was redeveloped. In addition to thermal and electrical modeling, thermo-mechanical modeling was performed to best design the cell lining so as to minimise stress and mitigate cathode cracking and deformation during normal operation (Figure 11).

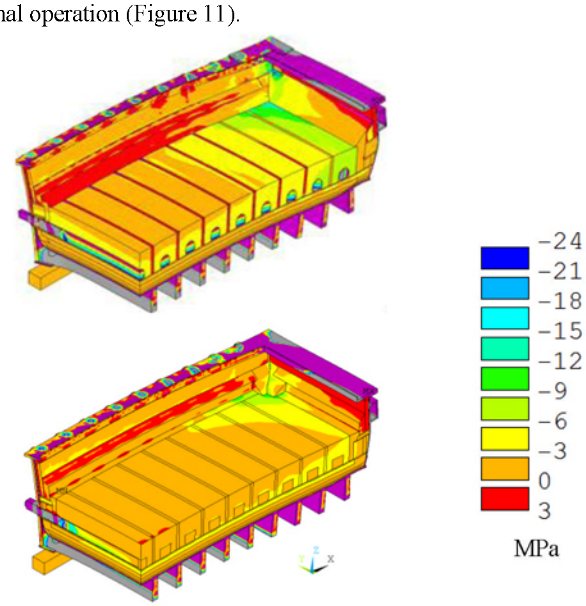

Figure 11: Calculated transverse stresses in old (top) and new (bottom) cell lining design

From 2010, the D18 cells have gradually been converted from 30% graphitic to fully graphitic cathodes. The primary benefit of this change is reduced cathode lining drop of 30 mV from higher electrical conductivity, equivalent to 0.10 DC.kWh/kg. The higher thermal conductivity also results in more uniform cathode temperatures and reduced risk of excess ledge formation on the cathode surface, and hence improved cell stability.

The collector bars in D18 cells have also changed from a round to a rectangular cross-section. As well as a 10 % increase in cross-sectional area the change to a rectangular profile has enabled a reduction in overall cathode height and consequent increase in cell cavity depth (Figure 12).

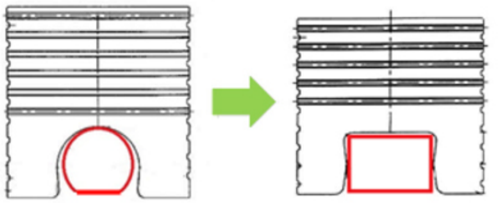

Figure 12: Change in collector bar shape from round to rectangular.

The D18 cells have also been changed to a split collector bar, with the benefit of greater room for expansion and reducing cathode heave, reduced material cost and reduced mechanical stresses to the pot shell (Figure 13).

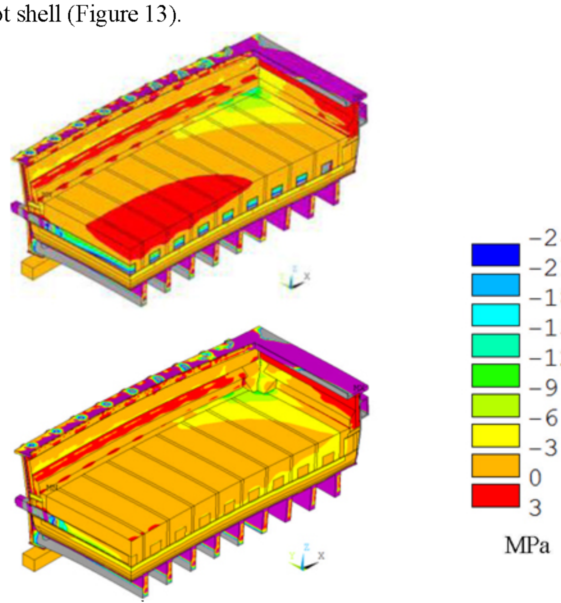

Figure 13: Calculated transverse stresses in new cell lining with single (top) and split (bottom) collector bars.

With higher amperage and consequently greater heat to be dissipated, cooling fins were added to the cell sidewall between the shell cradles from 2008 onwards[1]. With subsequent amperage increases, the cooling fin configuration from the DUBAL CD20/D20 design was adopted. This design featured three (vs. two) fins of greater size with ~3x the total area (Figure 18).

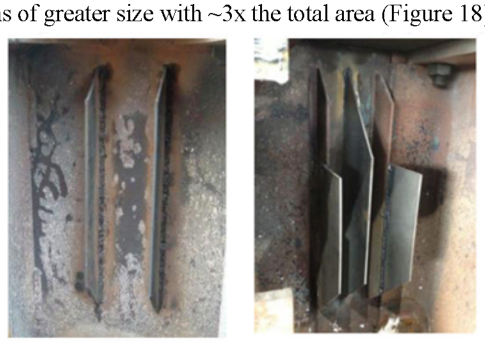

Figure 14: Original double and new D18 sidewall cooling fins.

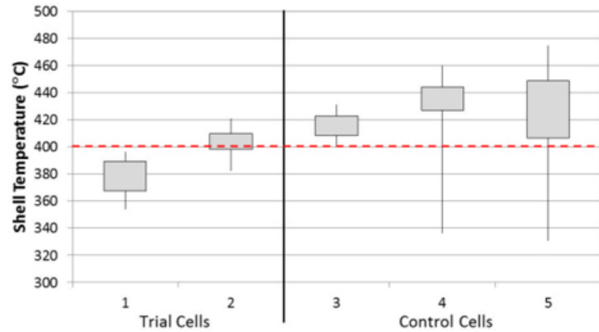

Figure 15: Measured shell temperatures of trial (triple-fin) and control (double-fin) cells.

The new fin configuration (Figure 15) yields a measurable decrease in shell temperature, mitigating potential shell deformation and sidewall exposure from lack of freeze at 205 kA.

D18 Performance

Through various initiatives to reduce both AEF and AED, PFC emissions have been able to be reduced by 73% over the past seven years (Figure 16). Specific energy has also been reduced despite a 13kA increase in amperage over the same period (Figure 17).

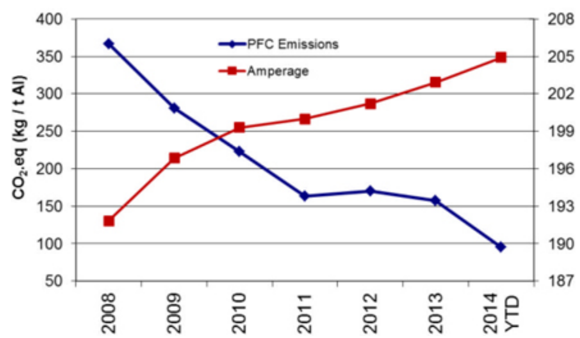

Figure 16: D18 PFC emissions and amperage.

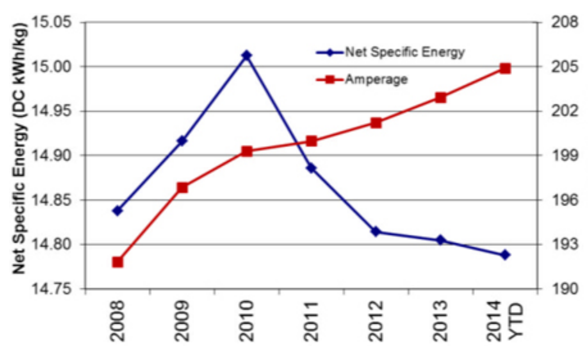

Figure 17: D18 net specific energy and amperage.

D18+ Technology

While further incremental advances in the D18 technology are possible, a complete revision of the cell technology has been undertaken to make greater advances in efficiency and productivity.

This resulting new cell design, D18+, incorporates major cell technology advances from other DUBAL cell designs, such as magnetic compensation and proper point feeding [3]. It has also been specifically tailored to the original D18 potrooms with the same inter-cell spacing, fume treatment plant (FTP) capacity and crane height. Table I summarises the main advancements of D18+ from the D18 design.

Table I: Comparison Between D18 and D18+ Technologies.

	D18	**D18+**
Busbar Configuration	End risers	Four side risers with under cell bus
Al_2O_3 Feeding	Pseudo Point Feed converted from dual centre breaking	Four point feeders with bath sensing breakers
AlF_3 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

After development and finalisation of the design by the DUBAL cell technology team, and completion of feasibility and economic analysis by the DUBAL Major Projects team, approval was given by the DUBAL board of directors to construct seven test cells to validate and test the new D18+ cell design (Figure 18).

Construction of the new cells commenced at the beginning of 2012. Seven D18 cells were replaced with the new D18+ design, utilising bypass busbar to enable uninterrupted operation of the existing potline.

Due to the exceptional efforts of the various smelter areas represented in the project team, the duration between cutting out the old D18 cells and energising the newly installed D18+ cells was significantly minimised to <30 days achieved without any injuries.

Figure 18: D18+ test cells.

The seven D18+ cells have now been operating for almost three years. All original design targets have been met and exceeded, with net specific energy now averaging 12.6 DC.kWh/kg and current efficiency of > 95 % at 205 kA (Figures 19-21 and Table II).

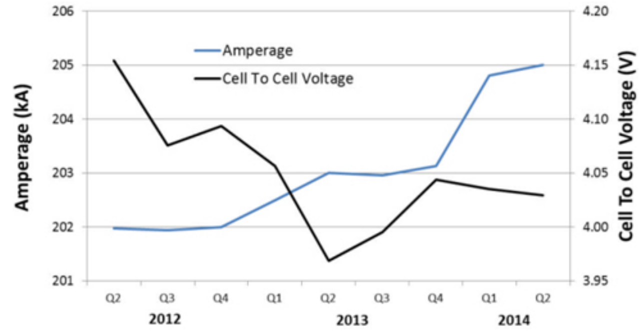

Figure 19: D18+ amperage and net voltage.

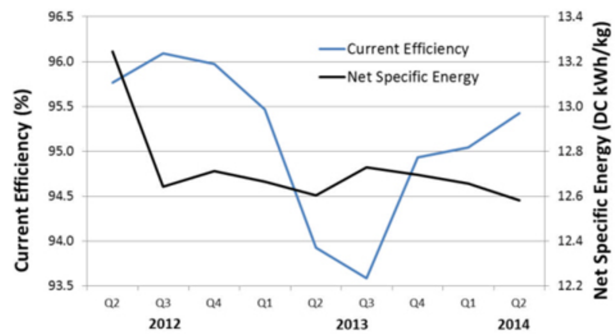

Figure 20: D18+ current efficiency and net specific energy.

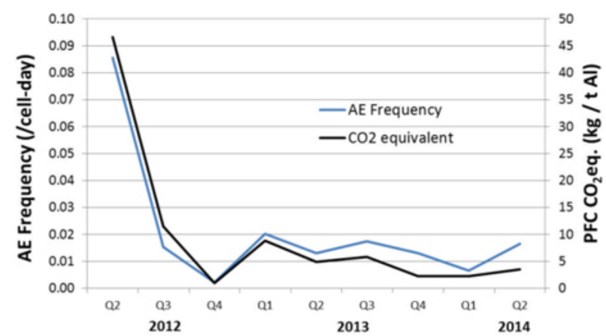

Table II: D18+ and D18 Performance Comparison (January – August 2014).

		D18 PPF	**D18+**	**Δ**
Net Voltage	V	4.66	4.03	-0.63
Current Efficiency	%	93.8	95.1	1.3
Specific Energy	DCkWh/kg	14.79	12.63	-2.16
Noise	mV	16	3	-13
Net Carbon	kg C / kg Al	0.430	0.420	-0.010
AE Frequency	#/cell-day	0.310	0.007	-0.303
AE Duration (>8V)	s	17	18	1
PFC Emissions	CO_2eq. kg/ t Al	95	2	-93

The D18+ design also incorporates the latest DUBAL cell control logic. The numerous improvements include:

- Anode effect prediction and prevention,
- Adaptive alumina feed cycle,
- Improved noise frequency monitoring,
- Revised voltage smoothening,
- New logic and interface for auxiliary routine operations (anode checking, dressing, height adjustment, bath tapping/pouring, etc.).

Online continuous monitoring of the anode current draw is also under development and trial, with live measurement of all 20 anodes at the rate of 1 Hz (Figure 24).

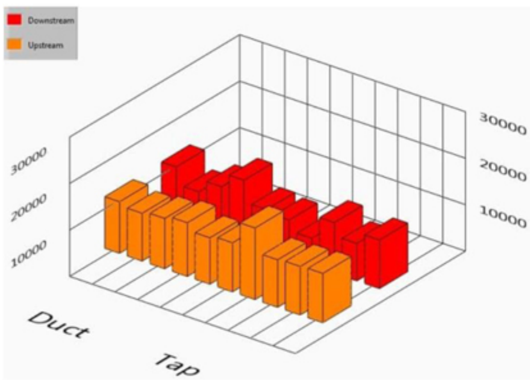

Figure 22: Real time D18+ individual anode current draw.

This level of anode monitoring opens new scope for cell control strategy, ranging from cell stability and anode spike formation to anode effect initiation and propagation. These capabilities will allow for significantly better process information and improved decision making.

As the current D18+ lining design is at the lower boundaries of its amperage operating window (205 kA), optimisation of the operating setpoint of the D18+ cells has been limited by the thermal balance. Although this has been mitigated by various actions such as increasing anode cover height, reducing cell draft and adding mechanical devices to limit natural ventilation on the sidewall, further reduction in cell voltage has been thwarted by low heat balance and subsequent spike formation and reduced current efficiency (Figure 23). Hence it is expected that further increases in amperage (to 230+ kA) will enable realisation of the full potential of the D18+ design.

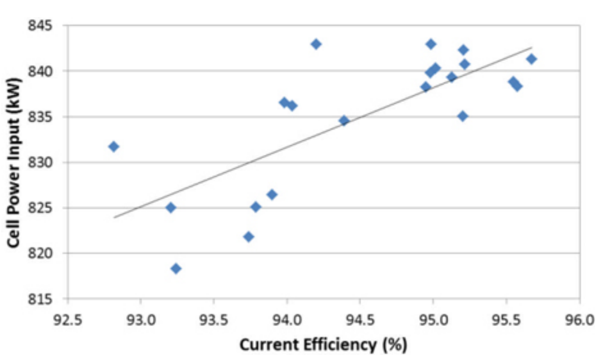

Figure 23: D18+ monthly power input and current efficiency.

With the D18+ cells now technically and financially validated, replacement of the remaining D18 cells will commence from March 2015. Although DUBAL has undertaken significant brownfield expansion over its history, this will be the first occasion where cells in an existing potline will be replaced with an entirely new technology. This poses new challenges:

- Converting D18 cells in batches of 30 cells, with bypass bus used to maintain operation of the remaining potline,
- Working with potroom operations to ensure uninhibited operation of existing cells as well as construction of new cells in the same potroom,
- Selection and management of newer D18 cells (when cutout for D18+ replacement) so that they can be restarted to replace ageing D18 cells elsewhere in the D18 potlines,
- Training of operations personnel to start and operate new D18+ cell technology while continuing to operate existing D18 cells within the same potline.

When the project is completed, the operating amperage of the D18+ cells will be increased from 205 kA to 230 kA. This will increase production by 40 000 tons per annum while utilising a similar amount of power as the existing D18 potlines.

Conclusion

Continuous development of the original D18 potlines at DUBAL has enabled them to continue to contribute to the growth and expansion of the company. The D18+ design will enable another significant step forward in increased efficiency and productivity, and reduced environmental footprint. This will enable DUBAL to maintain its competitive edge for the coming years.

Acknowledgements

The effort and dedication of the Lines 1 & 3 Operations, Handerson Dias, Faisal Majid and Jassem Mohammed and their teams has been critical for the achievements of the D18 potlines. Also, the invaluable work of Adam Sherrif, Mohammad S.W. Ali and the D18 Process Control team has been indispensable for the progress achieved over the past few years.

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