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D18+: POTLINE MODERNISATION AT DUBAL

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Abstract

Dubai Aluminium commenced operation in 1979 with three potlines utilising Kaiser P69 cell technology. Upgraded to D18 technology, the original potlines have been constantly improved to increase their efficiency and productive output, with amperage increasing from 150 to 202kA.

In order to make further significant progress in the original potlines, DUBAL has initiated a project to completely revise and modernise the cell technology. Designated D18+, the new in-house design incorporates the latest cell technology such as magnetic compensation and proper point feeders within the existing footprint of the original D18 potline infrastructure.

Seven D18+ cells were constructed and started-up in March 2012 and are now successfully meeting their key design targets with net specific energy consumption of 12.75 DC kWh/kg Al and anode effect frequency <0.02 /cell/day. The test cells are now currently being fully evaluated before implementing throughout DUBAL's D18 potlines.

Introduction

Dubai Aluminium (DUBAL) commenced operation in 1979 with 360 reduction cells in three potlines utilising Kaiser P69 technology (later D18 technology) with prebaked anodes, end risers with cells situated side-by-side. An additional potline of 144 cells, utilising the D18 technology, was constructed in 1990, bringing the total number of cells to 504. Additional cells were added in 2008 and 2010, bringing the total number of cells to 520.

Significant modification and development has been achieved over the years to the D18 technology, including conversion pseudo-point feeding, additional busbar, modification of the cell lining design, increased anode size and cell control logic improvements. This has facilitated increase in amperage, improved current efficiency and reduction in specific energy consumption and PFC emissions[1].

Figure 1: DUBAL D18 Cells.

With the antiquity of the D18 technology however, further significant advances in operating performance are limited mainly by poor magnetic stability, alumina and AlF_3 feeding control and high anode current density. A new cell design, D18+, has been developed to modernise the original DUBAL D18 potlines and improve their performance and economic competitiveness.

Development

Several options were considered before electing to develop the new D18+ cell technology.

The original D18 busbar has already been modified with additional busbar. Further modification with the addition of side-risers and re-designed cathode ringbus to increase MHD stability and reduce the ACD was modelled, with an estimated improvement of ~260mV or ~ 0.8 DC kWh/kg estimated. Keeping the original superstructure with the same number of anodes however would not have resolved the limitations of current density and alumina feeding.

The CD20/D20 design is a proven technology[2], with 1,008 cells in operation at the DUBAL Jebel Ali Plant, and implementation of the design in the D18 potlines was a low risk option. Although the D18 & CD20/D20 cell design have the same shell width, the inter-cell spacing is greater at 6.10 vs. 5.34 metres for D18. The greater spacing would lead to a reduction of ~60 in the number of cells, or ~23 kmt/year less production. Other issues such as FTP (fume treatment plant) capacity, and differences in crane & floor height would have also necessitated modification to the D18 potrooms.

Hence, to incorporate the advantages from the CD20/D20 technology while maintaining the same number of cells to ensure that the brown field project was economically viable, a new cell design had to be developed within the below constraints:

- Same cell-to-cell distance to maintain the same number of cells to sustain and improve metal productivity.
- Maintain the existing top elevation of the D18 cell in order to utilise existing critical equipment (multifunctional cranes, AlF_3 charging vehicle etc.).
- Keep the amperage availability limits with the existing rectifiers.
- Maintain the existing fume treatment plants (FTP's).

In order to satisfy these criteria the decision was made to develop a new D18+ cell design. The D18+ technology is a complete revision of the original D18 cells and incorporates the major advances of reduction cell technology that has occurred since start-up of the original DUBAL D18 potlines.

Table I compares summarises the main differences between the D18 and D18+ cell technologies:

Table I: Comparison between D18 and D18+.

	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	Dense Phase System
Number of Anodes	18	20
Anode Beam Control	Pneumatic	Electric
Number of cathode blocks	17	19
Collector Bar - Flexible Connection	Bolted	Welded

The end-risers of the D18 design along with the significant increase in amperage over the original nominal target have resulted in inferior metal pad stability. The magnetic compensation from the side-risers and under cell bus of the D18+ has allowed for substantial reduction in maximum metal pad heave from 15.6 to 7.2 cm, and metal pad velocity from 17.1 to 11.0 cm/s (Figure 2 & 3):

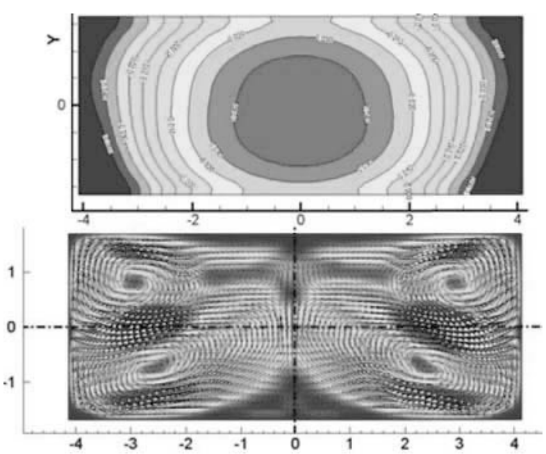

Figure 2: D18 Metal Pad Heave (top) & Velocity (bottom).

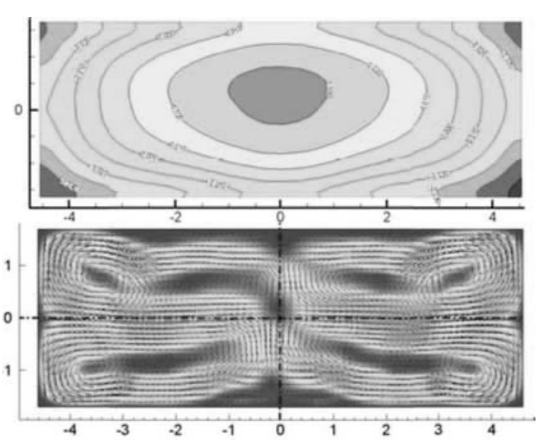

Figure 3: D18+ Metal Pad Heave (top) & Velocity (bottom).

The replacement of the reduction cell with a new design while still keeping the existing footprint of the original potline presented several challenges:

- Cell Spacing: In order to fit the D18+ cell within the existing footprint and cell spacing, the side risers and busbar had to be designed to fit in the space orginally occupied by the end riser D18 cells. Despite the limited space, the D18+ cell design team were able to successfully engineer the D18+ busbar so that it fitted within the existing cell to cell space without limitation to anode setting activities.

- Remote Cell Controller Display: The cell controller for the original D18 cells was placed at the duct end of the cell. The D18+ cell controller utilises a substantially updated design which enables greater data input/output and overall functionality for operations. As activities are normally conducted at the tap end of the cell, it was imperative that access be improved. Hence a remote controller input and display was developed by the DUBAL Information Technology and D18+ teams that was able to be installed at the tap end of the D18+ cell superstructure (Figure 4).

Figure 4: D18+ Remote Display.

- In order to fit within the limitations of the existing potline infrastructure, the superstructure design has been developed based on the experience gained from D20 and DX+ technologies, making the D18+ superstructure the shortest and most economical design.

- The D18 shell design was very robust with good mechanical characteristics, therefore the existing D18 shells were reused and extended by two cathode blocks to minimise the capital cost.

- Floor Level: With the installation of undercell busbar, the D18+ shell was elevated by ~20cm when compared to the existing D18 cells. To ensure that this did not hinder access to the cell for operational activities, the tap end floor level was raised by ~20cm with the addition of a concrete pad.

- The new D18+ superstructure and hoods were designed to substantially minimise the cell gaseous emissions compared with the older D18 cells, both to lower the potroom HF emissions and maximise their recycling to the FTP's.

Construction, Start-Up and Stabilisation

After development and finalisation of the D18+ design and completion of the feasibility and economic analysis, approval was given to construct 7 test cells to validate and test the new cell design.

Besides cell design constraints, one of the main challenges to the brown-field project was to minimise the production losses during the construction while the existing cells are out of circuit.

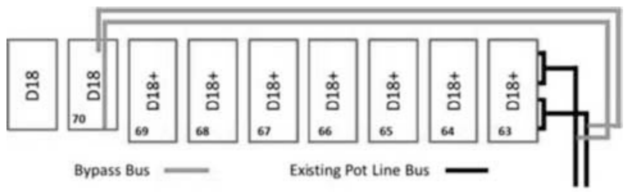

Figure 5: Schematic of D18+ Cells with Temporary Bypass Bus.

Due to the exceptional efforts of the various Smelter areas that comprised the project team, the duration between cutting out the old D18 pots and energising the newly installed D18+ was significantly minimised. The conversion was also completed without injuries. This was possible due to careful and detailed planning, risk assessment of all activities during the project, strong, effective coordination and follow up within the multidepartment team and contractors.

The seven test cells were constructed in the northern end of Room B, Potline 1. After cut out of one D18 cell (#70) on the 8th of February 2012, bypass bus installation (Figure 5) commenced on the duct end of the construction area to enable the necessary civil works, bus bar installation and installation of the seven new D18+ cells. Seven D18 cells (63-69) were also cut out from February 12th to 15th, upon which the bypass bus was connected to enable construction of the seven D18+ test cells (Figure 6).

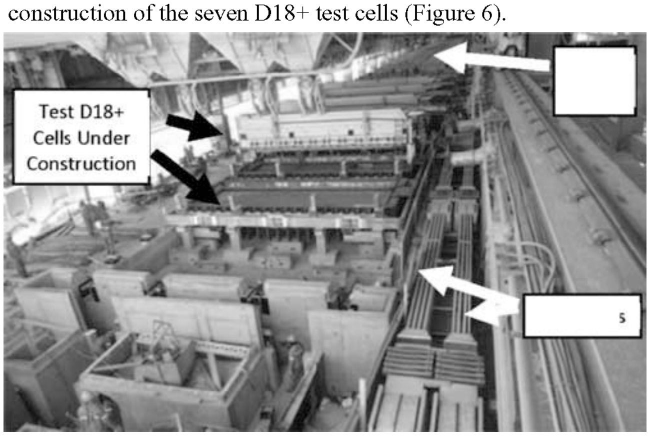

Figure 6: D18+ Cells Under Construction.

On the 14th of March, or 28 days after the start of construction, the bus bar of the D18+ cells was energised and the bypass bus was removed. The first D18+ cell was then cut in for pre-heat on the following day and bath up of all seven test D18+ cells was completed by March 20th (Figure 7 & 8).

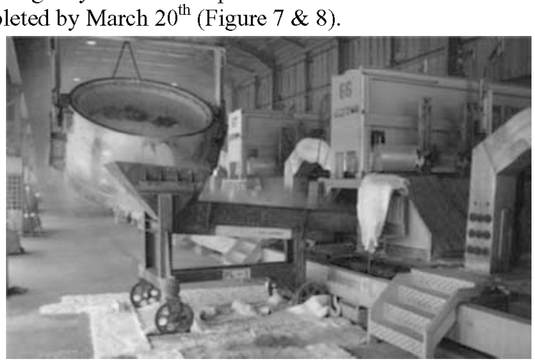

Figure 7: Bath Up of First D18+ Cell.

Figure 8: Completed Seven D18+ Test Cell.

The D18+ cells were started at an amperage of 205kA. A reduction in Line 1 amperage to 202kA in the weeks after start-up however resulted in the need for optimisation of the D18+ heat balance at the lower amperage. Actions taken to stabilise the D18+ thermal balance included:

- Anode cover height increased.
- Gas suction target rate reduced.
- Metal height optimised following modification of breaker tips.
- Temperature resistance adder modified to be more responsive.
- Anode set adder increased.
- Corner grill replaced with solid plate to limit sidewall convection and heat loss (Figure 9).
- External insulation added to sidewall at cell corners.

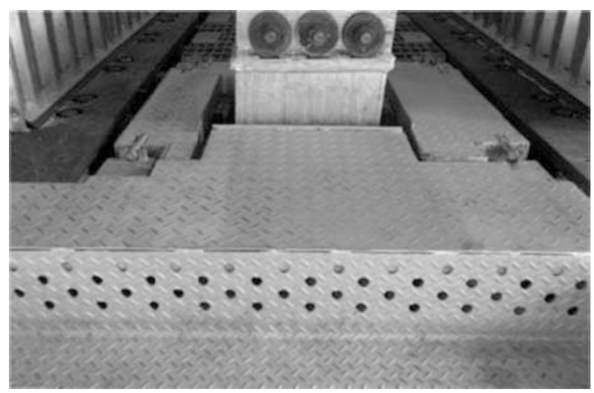

Figure 9: Solid Plate at Cell Corners.

These changes along with the exemplary operation and control by the Line 1 team resulted in the D18+ test cells quickly stabilising in the first few weeks of operation (Figure 10 & 11).

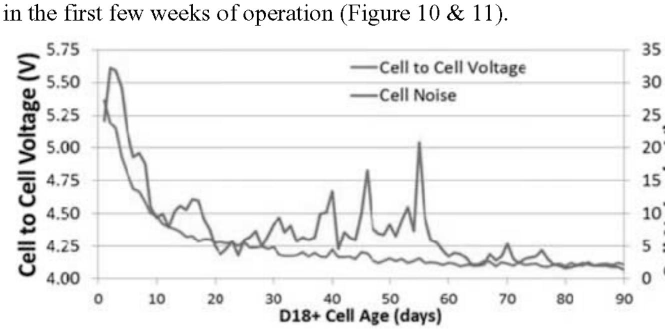

Figure 10: D18+ Voltage and Noise for Initial Operation.

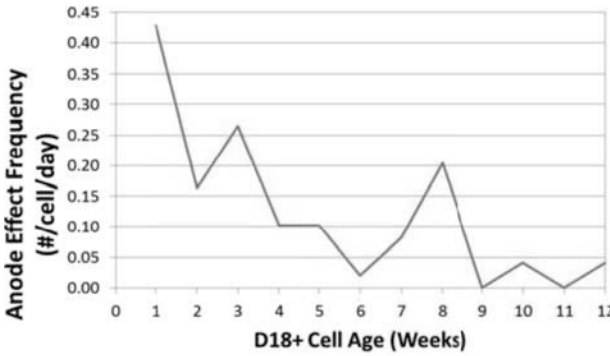

Figure 11: D18+ Anode Effect Frequency for Initial Operation.

Performance

After initial stabilisation, the voltage set point of the D18+ cells was successfully lowered to its design target, and is now averaging <4.1 volts with average noise of <5mV (Figure 12).

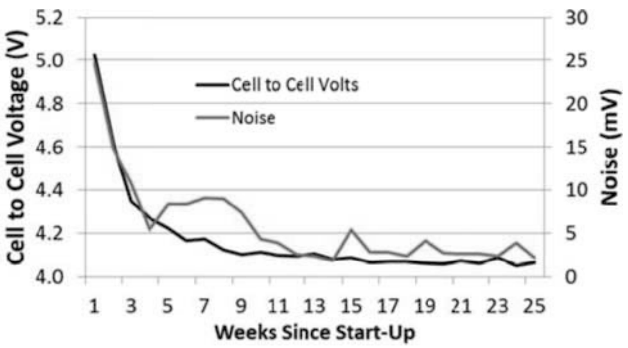

Figure 12: D18+ Net Voltage and Noise.

After adjustment of the metal height target, the current efficiency has become stable at >95%, resulting in the net specific energy now consistently <12.8 DC kWh/kg (Figure 13).

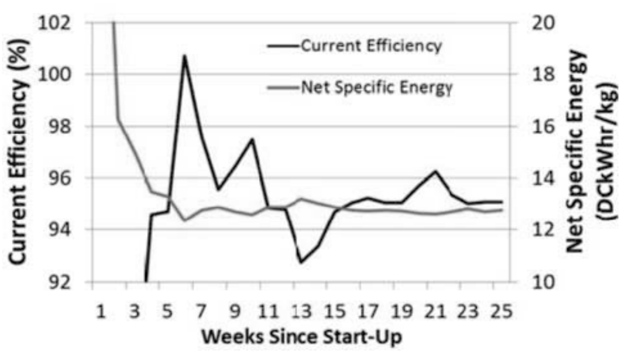

Figure 13: D18+ Current Efficiency and Specific Energy.

After adjustment of the thermal balance, the bath temperature and AlF_3 concentration are now stable and on target.

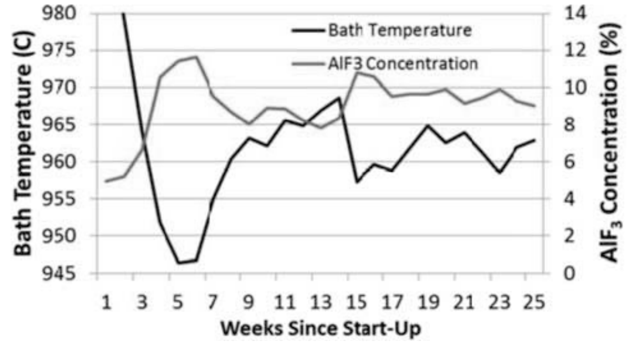

Figure 14: D18+ Bath Temperature & AlF_3 Concentration.

Utilising the latest iteration of the DUBAL cell control logic, the anode effect frequency has successfully reduced to <0.02 /cell/day.

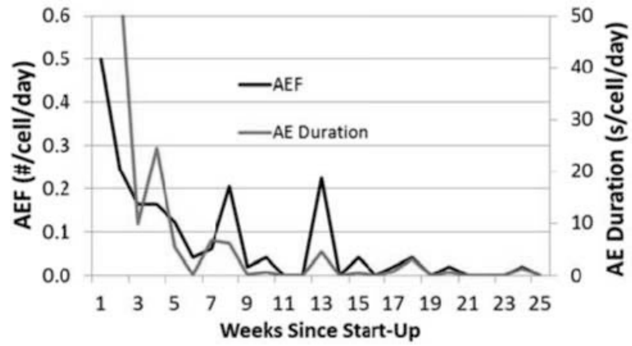

Figure 15: D18+ AEF & AE Duration.

The performance of the D18+ cells have now exceeded the original design targets resulting in significant improvement over the existing D18 cells (Table II):

Table II: D18+ & D18 Performance Comparison.

		D18+	**D18**	**Difference**
Net Voltage	V	4.065	4.689	-0.624
Current Efficiency	%	95.10	92.34	2.76
Net Specific Energy	DCkWhr/kg	12.74	15.14	-2.40
Noise	mV	3	17	-14
Net Carbon	kgC / kgAl	0.420	0.446	-0.026
Anode Effect Frequency	#/cell/day	0.015	0.44	-0.43
Anode Effect Duration (>8V)	seconds	57	31	26
PFC Emissions*	CO_2eq. kg/mt Al	16	247	-231

* CO_2 equivalent is calculated as in reference [3], using the Tier 2 method and SAR (Second Assessment Report).

Conclusion

The successful test and validation of the D18+ cell technology has proven that it is both technically and practically possible to update and replace the cell technology within an existing operating potline. Study of the feasibility and optimal engineering pathway is currently in progress to enable replacing the remaining 513 D18 cells with the D18+ technology in Lines 1 & 3 at DUBAL.

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