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UPDATE ON THE DEVELOPMENT OF D18 CELL TECHNOLOGY AT DUBAL

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Abstract

Dubai Aluminium commenced operation in 1979 with 3 potlines, each with 120 D18 technology cells. While more advanced cell technologies have since been developed and implemented at Dubal, the original D18 cell technology has continued to be updated and improved so that it remains a vital contribution to the overall smelter production.

This paper updates the progress[1] of the original D18 cell technology at Dubal over the past few years, and its contribution towards the plant total hot metal output of >1 million tonnes per year.

The four D18 potlines have been combined into two potline circuits, and additional busbars were added to all cells to reduce the external voltage drop and specific energy consumption. The original centre-break feeding design has gradually been replaced with a pseudo-point feeding design, and the anode size has been gradually increased so that it is now the largest for this technology. Other changes such as improved noise control logic, review of the anode set adder, and various changes to the alumina feed logic have enabled the D18 cell technology to reach the target amperage of 200kA and its subsequent stabilisation and optimisation at this milestone.

Introduction

Dubai Aluminium commenced operations at its Jebel Ali site in 1979, with the construction of 3 potlines of 120 cells each. The established Kaiser P69 cell technology was a prebaked, end-riser cell technology with the cells situated side-by-side. Initial operating amperage was 150kA with nominal design amperage of 155kA.

Significant modification and development where done over the years resulting in the development of the D18 cell technology.

An additional potline of 144 cells 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.

Along with the development of the CD20, D20, DX and DX+ cell technologies, there are now a total of 1573 cells in operation at Dubal's Jebel Ali plant.

Production History

Facilitated by various changes in the cell design and operation, the amperage in the D18 potlines has gradually been increased from an initial 150kA in 1979 up to the present operating amperage of 200 kA. Combined with improvements in current efficiency (from 80.5% in 1980 to 93.5% in 2011) and increase in the number of cells (from 360 to 520), the net hot metal production has grown to ~280 ktonnes per annum (Figure 1), or ~28% of the 1 million tonne hot metal output of the Dubal Jebel Ali plant (Figure 2).

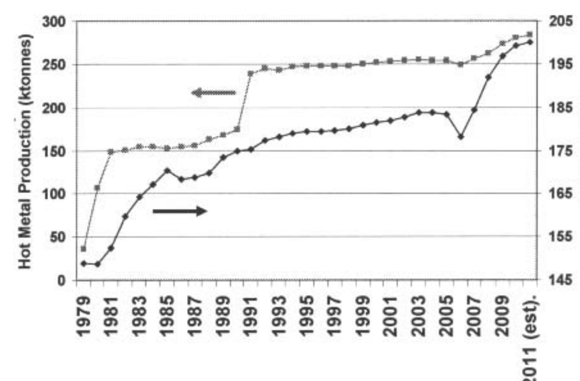

Figure 1: *Annual Hot Metal Production and Average Amperage*

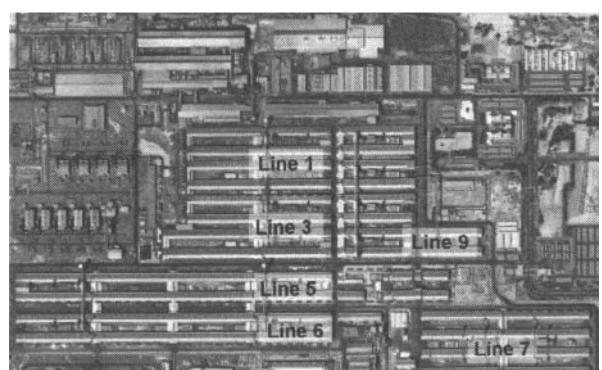

Figure 2: *Dubal Jebel Ali Plant (Lines 1 & 3 = D18)*

Due to the need for critical maintenance and eventual replacement of the original rectiformers, the amperage in the D18 potlines was reduced in the period from 2005 – 2007.

Concurrent with the project to replace the rectiformers, the four original potlines were connected into two pairs, reducing the effective number of potline circuits (and sets of rectiformers required) from four to two.

Also with the additional capability of new rectiformers, amperage increase resumed, with Line 3 reaching 200 kA, the highest potline the amperage ever achieved for the Kaiser P69 cell technology, in May 2009, followed by Line 1 in April 2010.

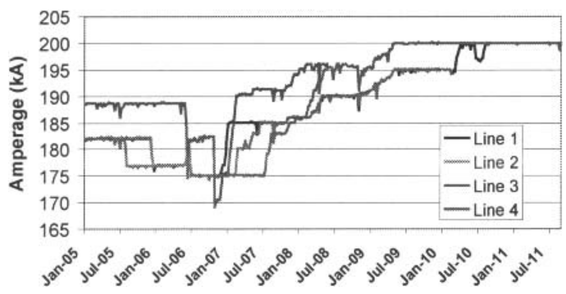

Figure 3: *Weekly Average Amperage in Lines 1-4*

While further increase in amperage is technically possible, lower incremental specific energy consumption in the other, newer Dubal cell technologies means that no further increase is planned beyond 200kA.

D18 Development

Busbar Modification

To decrease the current density and reduce the maximum busbar temperature and voltage drop, additional busbars have been implemented on the D18 cells. This additional busbar proceeded in two phases:

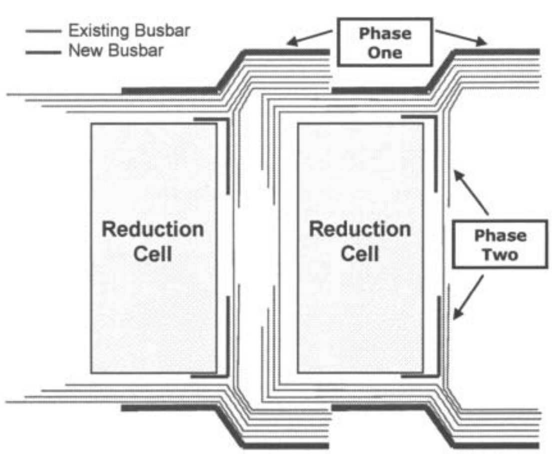

Figure 4: *Additional Busbar Schematic*

Phase 1: An extra busbar leaf of 100mm thickness was added to both the tap and duct ends (Figures 4 & 5)

Phase 2. Two pieces of 50mm thick busbar were added to the downstream cathode ring bus (Figure 4).

Figure 5: *Tap End Additional Busbar Leaf*

Due to the difficulty of welding in a magnetic field on live busbar, the additional busbar was bolted directly to the existing busbar (Figure 6). Measurement of the contact drop between the new and existing busbar has shown reasonably low resistance between the two.

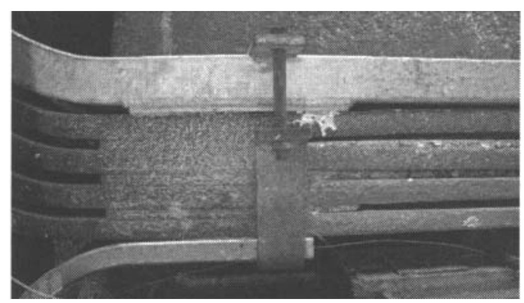

Figure 6: *Additional Busbar Bolted to Existing Busbar*

The tap and duct end external busbar (Phase #1) was started in April 2010, with eventually 2 cells per day completed. Full conversion (482 cells) was completed by May 2011. The additional cathode ring bus (Phase #2) is currently being added when the shell is removed during normal cell lining replacement. Currently 170 cells have been completed, and full completion is expected by 2015.

The combined voltage saving from the additional busbar was 60mV, or equivalent to 0.19 DCkWh/kg Al.

Noise Logic

The D18 noise control logic had a very high threshold before action was taken, with a noise value (peak to peak amplitude) of 0.90 $\mu\Omega$ required before resistance was added. This very high threshold resulted in manual intervention which required well before the noise logic took any action to stabilise a noisy cell.

The logic was modified to intervene at a much lower threshold (0.25 $\mu\Omega$), and to continue the normal alumina feed cycle until the noise prohibited accurate tracking (Table 1).

***Table 1**: Summary of New and Old Noise Logic*

		New Logic	Old Logic
Noisy Unstable	Stable Threshold	0.25 μΩ	0.60 μΩ
	Time required above Stable Threshold before logic activated	21 min	9 min
	Action	Add Resistance	Raise Alarm
	Noisy Threshold	0.45 μΩ	0.90 μΩ
	Action	Add Resistance & Fixed Feed	
	Time required for cell to be stable	60 min	21 min

Below is an example of the new logic intervening to add additional resistance to an unstable cell, allowing it to stabilise and properly search during underfeed and then eventually removing the additional resistance.

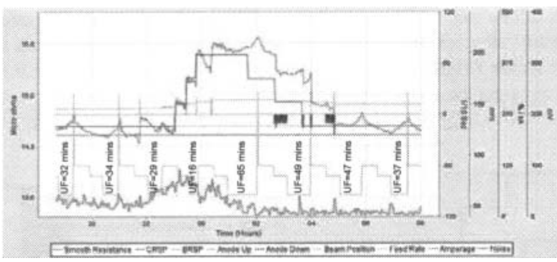

***Figure 7:** Noise Logic Intervening to Stabilise a Cell*

As well as improvements in average noise and current efficiency, a significant decrease (~40%) was also observed in the rate of manual interventions required for unstable cells (Figure 8).

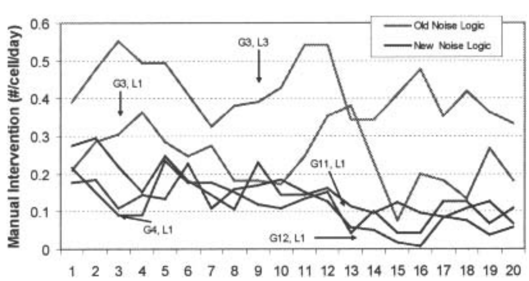

***Figure 8:** Rate of Manual Intervention of Noisy Cells*

<u>Cell Voltage Optimisation</u>

After setting of the cell base resistance set point (BRSP) at a constant value for new cells, the BRSP was often increased to mitigate chronic noise and instability, or reduced to decrease energy consumption. As the guidelines for this modification were not properly defined, this resulted in large variation in the BRSP across the potline.

To standardise the BRSP setting for the potlines, the BRSP for each cell was calculated based on a target bath voltage drop and the measured voltage drop of the other cell components (external busbar, cathode and anode drop etc.). Regular meetings were then held with both operations and potroom engineers to ensure that the overall cell performance supported the proposed changes, and that general consensus was reached when adjusting each cell gradually to the target BRSP.

Although this task was not technically challenging, it presented the opportunity for both the technical and operations personnel to work together to review the voltage setpoint for each cell, reduce unnecessary variation and optimise the overall energy consumption of the line (Figure 9).

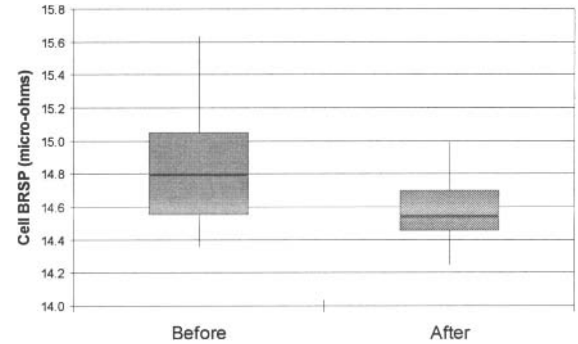

***Figure 9:** BRSP Distribution Before and After Optimisation*

<u>Alumina Feeding</u>

The original mechanism for alumina addition in the D18 design was centre-break (CB) feeding. Due to the performance limitations of feeding a large alumina mass (~100kgs) for every feed event, as with many other cell technologies of this age[2], the D18 cell technology has been gradually converted over to pseudo-point feed design (Figure 10).

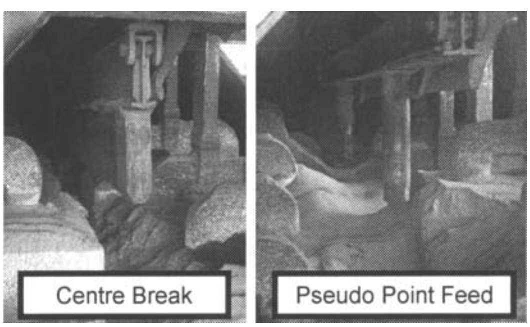

***Figure 10:** CB (left) and PPF (right) Alumina Feeding*

Successful conversion has been aided by the dual-breaker design of the CB cells, i.e. two independent breakers at the duct and tap end. The modification to pseudo-point feed with an alumina feed mass of 2 x 1.7 kgs per feed and better centre channel anode cover has substantially improved the energy efficiency and carbon consumption of the D18 cells:

***Table 2:** CB and PPF Performance*

		CB	PPF
Net Carbon	kg C/kg Al	0.460	0.425
Specific Energy	DC.kWhr/kg	15.47	14.90
Current Efficiency	%	92.28	94.33

After original inception in 2002, the number of point feeders has gradually increased, with full conversion achieved in 2010. A small number of centre break cells have also been retained to enable continued production of higher purity metal.

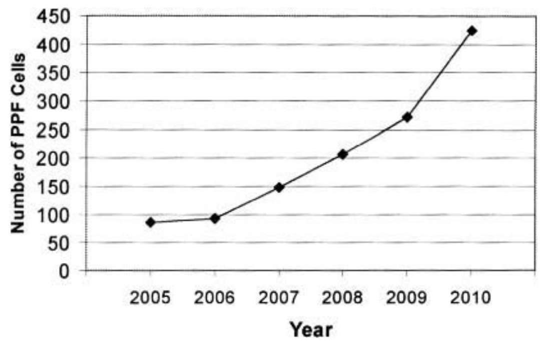

Figure 11: *PPF Conversion Rate*

As well as conversion to PPF, there have been continual refinement and improvement of the feed logic:

- Improvement of feed pattern after successful search.
- Optimisation of track scheduling.
- Optimisation of feed cycle after AE to prevent further relapse.

These changes have assisted in approximately halving the PFC emissions, despite the challenge of increased amperage over the past 6 years (Figure 12):

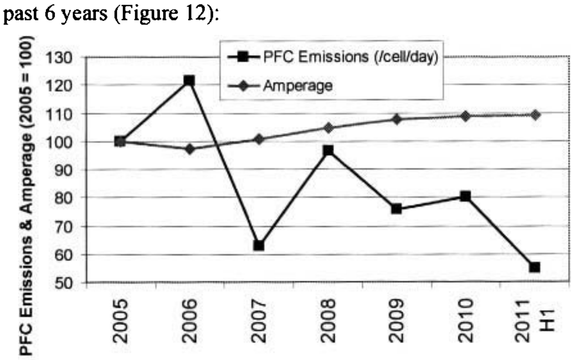

Figure 12: *D18 PFC Emissions & Amperage*

Anode Size

To increase the effective anode shadow area and reduce the anode voltage drop, the anode size has gradually been increased in the D18 cells, from an original length of 1130mm up to the current value of 1515mm (Figure 13).

In 2007, the anode backside was increased by a further 30 mm in all cells, bringing the baked anode length up to 1485 mm.

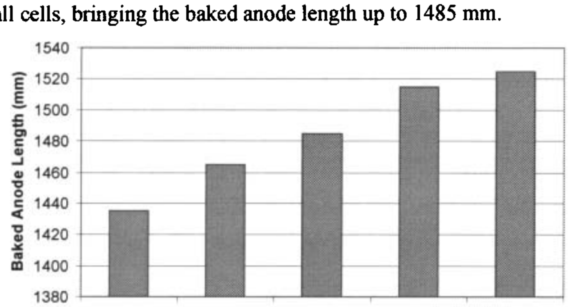

Figure 13: *D18 Baked Anode Length*

While the practical maximum anode size was reached in the centre-break cells at 1485 mm, with less need to avoid hindrance in the centre-channel, further increase to 1515 mm was made in the pseudo-point feed (PPF) cells in 2011. To facilitate this increase in anode size, various process changes were also made:

- Removal of the anode bottom chamfer and reduction in the target bath height to facilitate increase in the anode shift life with the longer anode
- Reduction in the overfeed rate and increase in the underfeed rate to reduce variation in the alumina concentration with the smaller liquid bath mass.
- Refinement of the BFT (break & feed time) auto-adjustment to better respond to variation in the alumina feed mass.

The anode set adder was also modified to increase ACD and stability after set, and to better match the thermal demands from a new anode (Figure 14). The cell BRSP was also reduced by 0.1 $\mu\Omega$ to offset the increase in setting resistance.

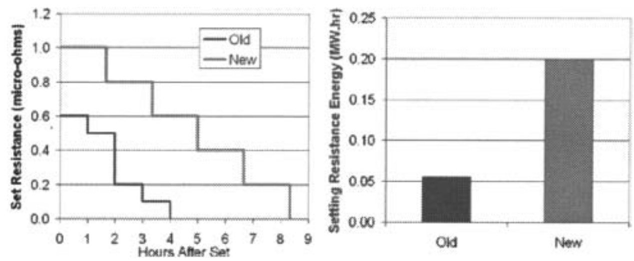

Figure 14: *Modified Anode Adder*

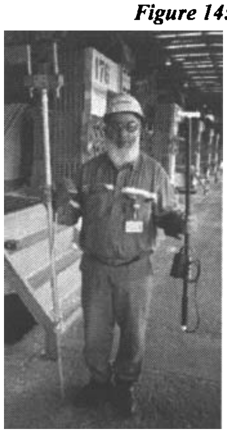

Figure 15: *New and Old CD Probes*

In conjunction with this change, the anode CD measurement tools were replaced with a lighter, less cumbersome and more accurate tool[3] (Figure 15) as well as a specific tool for clamp drop measurement.

Further and likely the final increment up to ~1525mm in anode length is anticipated in the PPF cells once the plant is able to produce this anode size after the carbon bake rebuild.

Connection of Potlines

With the relatively small size of the D18 potlines (~120-144 cells) and the need to replace the ageing rectiformers, the four potlines have now been connected into two potline circuits.

Lines 3 & 4 were successfully connected in May 2008, resulting in one potline of 272 cells operating at ~1300 volts at 200kA.

Lines 1 & 2 were similarly connected, with an additional 8 cells constructed at the north end of the potlines. Figure 16 shows a schematic of how they were connected to create one potline circuit.

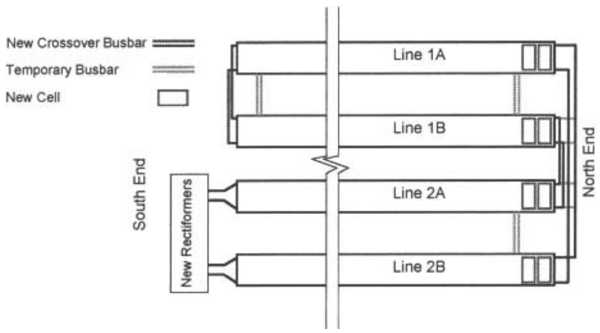

Figure 16: *Schematic of Connection of Lines 1 and 2*

Due to a longer procurement time for the new rectiformers, the connection of Lines 1 & 2 was carried out slightly different than for Lines 3 & 4, with a total of five phases:

- Energise temporary busbar at the north end of Lines 1 & 2 to allow construction of 8 new cells.
- Close temporary switches at the north end of 1B and 2A and open 1A/B & 2A/B temporary switches to allow cut in of new cells.
- Energise new PL21 rectiformers to Line 2 only.
- Energise the north end permanent busbar, remove 1B/2A temporary switches and energise the Line 1 south end temporary busbar (Figure 17) to connect both lines as one potline circuit.
- Remove switch from the south end temporary busbar and energise the permanent crossover busbar.

Lines 1 & 2 were successfully connected in February 2010, with a total of 248 cells operating at ~1160 volts and 200kA.

Figure 17: *Closure of Line 1 South End Temporary Switch*

<u>Alumina Distribution</u>

In conjunction with the company, Coperion Waeshle GmbH, a small trial of five cells has been in progress to validate the pneumatic distribution of alumina directly to the cell hoppers. Although this company has significant experience in material conveyance, this is their first experience with the distribution of alumina to a reduction cell. After satisfactory results with the five trial cells (Figure 18), this project is currently being extended to all 32 cells in the test section.

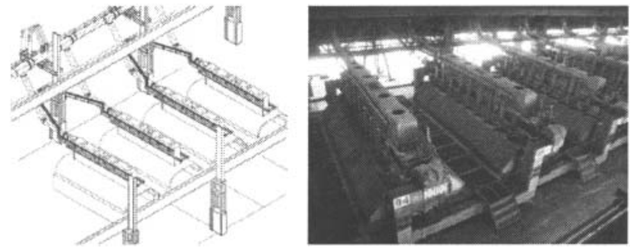

Figure 18: *Five Test cells of Coperion Alumina Distribution System in Line 1*

Future

The Smelter Optimisation and Major Projects teams are currently working on a complete upgrade of the D18 cell technology, designated D18+, to reduce the specific energy consumption to less than 13.2 DCkWh/kg Al. This revised design will incorporate the latest cell technology such as magnetic compensation and proper point feeders within the existing footprint of the D18 potline infrastructure.

Conclusion

Continual development of the original D18 potlines at Dubal has enabled them to remain economically competitive so that they continue to contribute to the growth and profitability of the company.

Acknowledgements

The effort and dedication of the Lines 1 & 3 Superintendents, Handerson Dias, Faisal Majid and their teams have been crucial for the recent accomplishments of the Dubal D18 potlines. Also, the invaluable work and support of Adam Sherrif, Mohammad S.W. Ali and the D18 Process Control team have been indispensable for the progress achieved over the past few years. Appreciation is also necessary for Abdulla Al-Jaziri and his hard working team for accomplishing ahead of schedule the PPF conversion and additional busbar projects. We are also thankful to Abdul Monem Bin Brek, Amer Al- Redhwan and associated team for the significant work that has been carried out by the Major Projects.

We are fortunate to be blessed with leadership that encourages and nourishes a culture of continuous improvement and achievement of excellence in all our cell technologies.

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