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WORLD'S LONGEST POTLINE START-UP AT EMAL

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Abstract

EMAL started up the first cell of Potline 3 on 11 September 2013. Several challenges had to be overcome for the technology transfer from five DX+ demonstration cells at DUBAL to a Potline of 444 cells starting up at 440 kA. Among these were: first time implementation of plant-wide PLC based control system, management of large Gas Treatment Centers with capacity greater than 2 million Nm³/h and management of the longest Pot Feed System. Separate teams were organized for pot preparation and preheat, bath-up and early operation and normal operation. The last cell was started up on 13 June 2014, completing the start-up at an average rate of 11.26 cells per week with an impeccable safety record and no pot failures. Several process improvements during the start-up were made in preheat, bath-up; early operation and alumina feed control. This paper describes the challenges faced and improvements made during Line 3 start-up

Introduction

Emirates Aluminium (EMAL), a group company of Emirates Global Aluminium (EGA), completed its green field Phase I (Ph-1) start-up in January 2011 and soon after commenced its major expansion project, termed as Phase II (Ph-2), to increase production capacity by 40% reaching 1.3 million tons per annum. This project consisted of building Potline 3 (PL-3), a new anode plant, a new power generation block, a new bank of six rectifiers and expansion of existing casting facilities.

Start-up commenced about 3 months ahead of schedule and was safely completed in 9 months without any lost time injury (LTI) or pot failure incidents.

<u>Description of PL-3 and associated major equipment</u>

PL-3 is a 1.7 km long Potline having 444 DX+ cells and twelve sections. PL-3 is constructed in east-west orientation, similar to Ph-1 (Potline 1 & 2). Rectifier bank is located at the west end with current entering 'Room B' and exiting 'Room A'. In each potroom two sections at either end have 36 pots each and two middle sections have 39 pots each. Inter-potroom temporary linkage bus bars are constructed under the 2nd and 4th passage ways enabling possibility of 4 or 8 sections short circuit. Permanent linkage bus bars connect cells 3B222 and 3A222 at the east end, between the potrooms.

A total of 50 Programmable Logic Controllers (PLC) are used to control the Potline, two of them dedicated for amperage signal control. Each PLC is connected to a minimum of 6 pots and a maximum of 10 pots. A total of 224 Integrated Pot Control Panels (IPCPs) are connected to the PLC system, with each IPCP housing controls for two pots typically with one Human Machine Interface (HMI) screen.

Two gantries are used for Pot Tending Machine (PTM) transfer, one in the center passage and the other in the East end passage. A central PTM maintenance shop serves the 15 PTMs deployed.

Two Gas Treatment Centers (GTC) using dry scrubber technology, located in the courtyard between the two potrooms, one each in east and west halves serve the entire potline. Each GTC is serviced by one alumina tanker unloading station for primary alumina supply to the silo. Reacted alumina is supplied to the pots by two independent Pot Feed Systems (PFS) for either halves of the potline using air slide conveying system. Recycled Anode Cover Recycle Material (ACRM) is transported to potroom roof top silos by dense phase conveying from Bath Processing Facility (BPF) located adjacent to Anode Plant.

Selection of Cell Technology

Dubai Aluminium (DUBAL), a group company of EGA, has been in the field of high amperage cell technology development for more than a decade. Following the success of DUBAL's DX cell technology in Ph-1, EMAL opted for their next generation DX+ cell technology for its PL-3 project. Demonstration scale operation of five DX+ cells at DUBAL commenced in July 2010 and achieved stabilization by end of November 2010 at design amperage of 420 kA. After successful validation of the cell design by numerous measurements [1] at 420 kA, the amperage of DX+ demonstration pots was increased to 440 kA. Excellent performance at 440 kA during 14 months, confirmed the possibility of starting up EMAL PL-3 at 440 kA [2]. After this, DUBAL continued amperage increase in demonstration pots and operated successfully at 450 kA for 8.5 months, until the shutdown in order to install new generation of pots, DX+ Ultra [3].

EMAL DX+ potline is designed for an operating range of 420 – 460 kA. The pots use 36 four–stub anodes, and are operated with a life cycle of 72 – 76 shifts. PLC based pot control system with a user friendly HMI was developed and proven in the five DX+ demonstration pots at DUBAL. Pot shell, superstructure, bus bars, shell supports and potroom building designs were optimized to minimize capital costs without compromising quality and safety of operation [2].

Work and Team Organization

An optimized work organization was developed for PL-3 in which considerations were given to minimize interferences between hot metal traffic and anode transportation. By this design, tapping and anode changing activities were isolated into either east or west halves, whereby mobile fleet interference was minimized. Also, uniform work load for all the four shift-groups was achieved. However, to enable this work organization to function, occasional PTM transfer between A and B rooms is necessary.

A new Senior Manager role was created to lead the start-up process and was supported by separate area teams namely, start-up and early operation team; normal operation team; preheat team; process control team; maintenance team; automation team and services team. In addition, a team of shift advisors and process specialists from DUBAL actively supported the start-up.

Core Start-up team

In addition to potline operation, core start-up team comprised of dedicated members from all related areas and supported by a full time technical team from DUBAL. An effective five-stage work structure model was successfully employed by EMAL during the Ph-1 green field start-up [4]. Similar approach was adopted in Ph-2 defining the start-up process into five stages;

- Pre-commissioning,
- Pot preparation and preheat,
- Start-up (Bath-up and voltage stabilization),
- Early life (including bath generation for new pots),
- Normal operation.

This model was implemented successfully with suitable modifications to cater to brown field start-up.

Challenges Expected

DUBAL started five demonstration pots at 420 kA and, after proving successful performance, steadily raised amperage to 440 kA. The challenge of establishing the 440 kA start-up was taken up by DUBAL team. Some of the support systems were also being implemented on large scale for the first time, necessitating the start-up team to be prepared for new challenges, such as:

- Differences in pot gas exhaust characteristics between the potline and DX+ demonstration section at DUBAL,
- First time full potline implementation of PLC based Pot Control System (PCS),
- Interfacing with Ph-1 and hot bath transfer from PL-2 to PL-3 for the first pot bath-up,
- GTC commissioning and longest Pot Feed System (PFS) commissioning alongside pots start-up.

Additional challenges from other areas were also expected in terms of their readiness to support an ahead of schedule start-up.

Start-up

By short circuiting the first temporary linkage bus bar, PL-3 circuit for the first 4 Sections (1, 2, 11 and12) was energized for short circuit test (SCT) on 20th August 2013. The test continued for three days until 22nd August 2013; during the test, the amperage was increased to 500 kA for 16 hours to assess bus bar circuit capability. In addition, a series of measurements were made to assess circuit integrity, wedge voltage drops, linkage cross over voltage drops, concrete support and basement integrity, and earth leakage status. All the results were within the expected design values and the test was successfully completed, followed by de-energizing.

On 6th September 2013, PL-3 was re-energized and the first pot was put on preheat on 9th September. This pot was started on 11th September 2013 after 48.6 h on preheat, using liquid bath transferred from PL-2.

Preheat Results

After a few trials and modelling, one template for graphite resistor preheat, which showed the best results in terms of preheat quality was chosen for the rest of preheats. Details of the trials and model evaluations are described in a separate paper [5]. Preheat results of all pots against the pots with final template are shown in Figures 1 and 2. In these figures, as well as in Figures 3 and 4, the average value of the variable shown is given as well as the first and the third quartile values. 25% of the values are below the first quartile and 75% of the values are below third quartile value. The bottom and the top of the vertical bar show the minimum and maximum values, respectively.

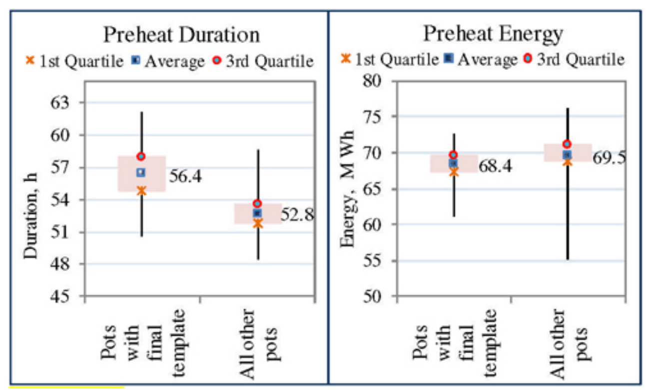


Figure 1. Comparison of preheat duration and energy input.

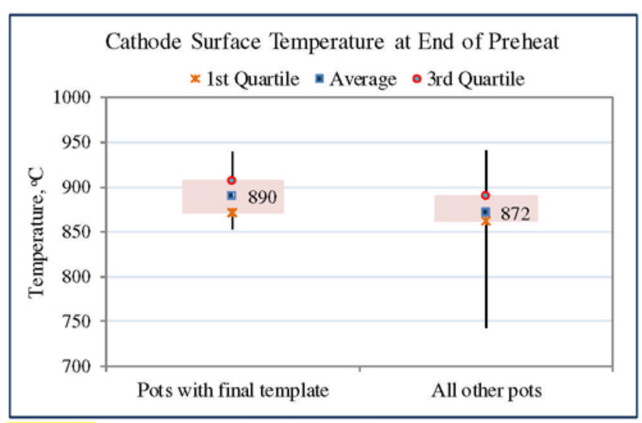


Figure 2. Comparison of cathode surface temperatures, average of measurements on pot center channel at tap, center and duct end.

During the start-up, amperage was increased in two stages from 440 kA to 444 kA and the improvements to preheat process listed below were implemented.

- Preheat energy was displayed in HMI,
- Preheat energy target range was increased to 65 – 70 MWh.

Bath-up and early operation

Some of the operational problems encountered are discussed in the following sections.

<u>Break and feed performance</u>

Hard crust formed soon after bath-up, resulting in poor breaker performance. Anodes were covered with crushed bath during pot preparation, which made the crust very hard to break after start-up. Reacted alumina being very lean in fluorination during start-up also added to the problem.

For maximizing anode usage in the first anode change cycle, 'anode saving plan' was implemented. As a result, there was no anode changing in newly started pots for 7 – 8 days. This practice was also thought to make the crust hard to break.

The following mitigations were put in place to tackle hard crust.

- Anodes covering during pot preparation with ACRM instead of crushed bath,
- Anode saving plan was discontinued,
- Bath sensing module was disabled after bath-up.

<u>Energy balance during early operation</u>

Improvements to energy balance and feed control were done in stages. Based on the progression of changes, three categories of pots are defined here; Trial group (first 23 pots), Revision 1 (next 14 pots) and Revision 2 (next 64 pots).

Energy requirement after bath-up reduced significantly for Rev-2 pots, as shown in Table I. This could be attributed to improvements in preheat process.

Table I. Energy input after bath-up.

Average pot voltage during 1 hour after bath-up, V			
	Trial	Rev-1	Rev-2
1st Quartile	7.0	6.8	6.7
Average	11.3	7.0	7.4
Minimum	6.4	6.0	6.3
Maximum	19.1	7.5	12.0
3rd Quartile	16.3	7.3	7.3

Typically after 24 hours from bath-up, metal pouring was done by adding 12 to 14 tons of liquid metal to the pot. Energy control from bath-up to metal pouring is analyzed in terms of pot voltage. Figure 3 shows a comparison of pot voltage in Trial, Rev-1 and Rev-2 groups. As can be seen, consistency achieved for Rev-2 group is better than the other groups. For the rest of the pots started, the same control parameters were used with suitable fine tuning to accommodate the amperage increase (from 440 to 442 and to 444 kA). Figure 4 compares Rev-2 with the rest of the pots.

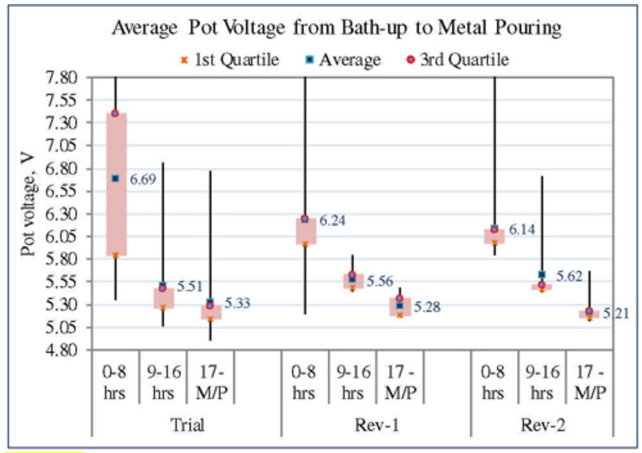


Figure 3. Comparison of pot voltage until liquid metal addition for the three groups.

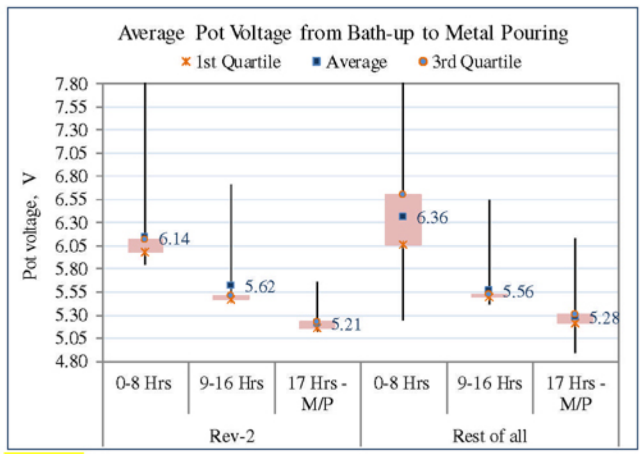


Figure 4. Comparison of pot voltage until liquid metal addition of all subsequent pots against Rev-2 pots.

<u>Anode effects and feed logic improvements</u>

Use of non-slotted anodes during the start-up adversely affected AE performance. To overcome this, slots were cut in about 7000 anodes. Maintenance team designed and installed a slot cutting unit, which could cut 6 mm wide slots. Two such units operated for about three months. This change made a significant contribution to reducing anode effects.

Bath donor pots had the automatic anode effect (AE) quenching disabled, but sometimes this caused long duration anode effects. Typical liquid levels were 60 – 70 % of the cavity depth making it risky to enable automatic quenching. A standard procedure for handling such long AEs was established after several trials. The steps included raising anode beam to stabilize metal oscillation, holding to allow natural decay in voltage while accelerated break and feed was going on, followed by normalizing the anode beam position to original. At the same time, for controlling high bath temperature, lump bath additions were made and shell compressed air cooling was used.

Alumina feeding strategy was also modified for reducing AEs. Feed logic changes were done to over feed (OF) rate, under feed

(UF) rate and base feed time (BFT); these are shown in Figures 5 – 7.

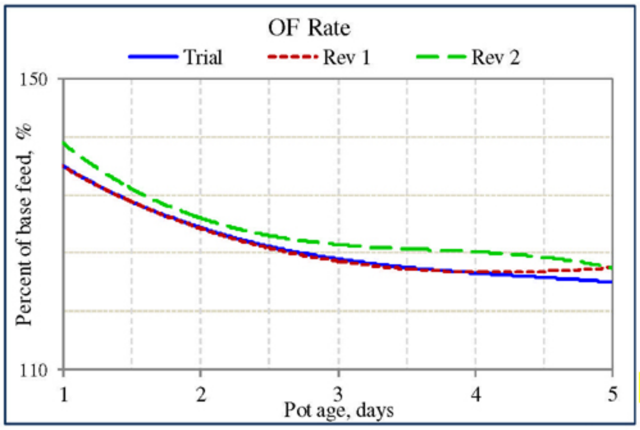


Figure 5. Comparison of OF rate between Trial, Rev-1 and Rev-2 groups.

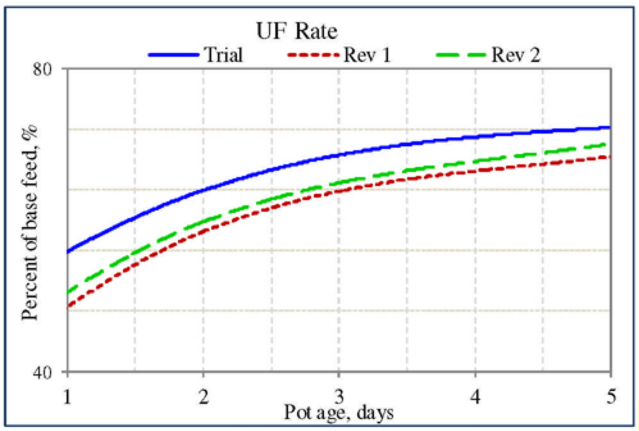
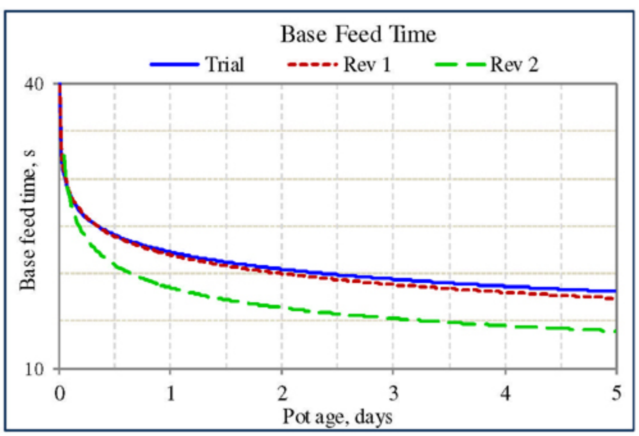


Figure 6. Comparison of UF rate between Trial, Rev-1 and Rev-2 groups.



Improvement achieved in controlling anode effects is shown in Figure 8 as AE-minutes per pot day (anode effect frequency × anode effect duration in minutes) for five days after bath-up. Rev-2 pots performed better than the other two groups.

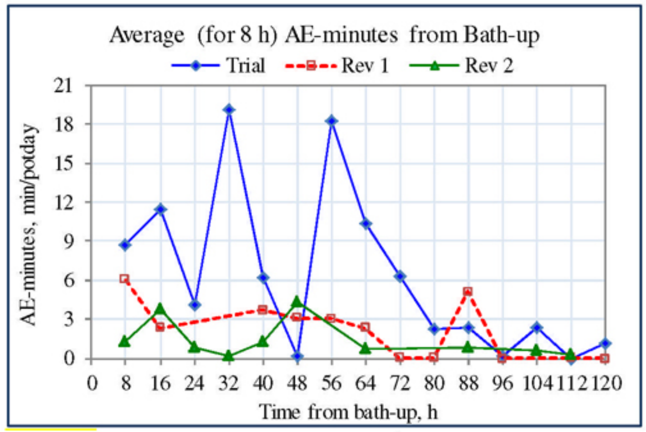


Figure 8. AE-minutes (8-hrly average) after bath-up.

Cathode heaving, shell deformation and anode beam sagging

Maximum of 6 cm cathode heaving was measured at the center during preheat. Figure 9 shows the measured cathode heaving while anodes were connected to a flexible frame during preheat.

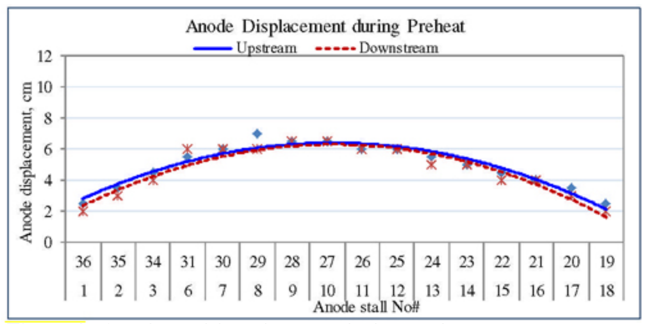


Figure 9. Anode positions in a pot during preheat.

Shell heaving and beam sagging were measured for some pots, typically on the 2nd day from pot start-up. Figure 10 shows a combined effect of heaving and sagging.

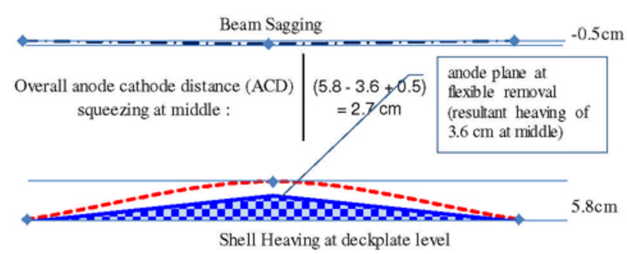


Figure 10. Measured cathode heaving and beam sagging.

The blue shaded plane shows anodes bottom at end of preheat due to cathode heaving. The red dotted line just above the shaded area shows measured shell upward heaving. Resultant is 2.2 cm due to cathode heaving after bath-up. Similarly, beam sagging was measured as 0.5 cm as shown by the top blue broken line. Overall effect is approximately 2.7 cm lowering of anode cathode distance (ACD) at the middle.

As a result of this, middle anodes were subject to more adjustments for abnormal current distribution, and also more anode problems were reported for middle anodes. To overcome this effect, following improvements were applied during bath-up;

- Ensure a minimum of 7.5 cm ACD during bath-up,
- Raise selected center anodes by 1 to 2 cm soon after bath-up.

These measures yielded excellent post bath-up stability for all the pots started from then onwards.

Pot Feed System (PFS) performance

In each of the two pot feed systems per potroom, feed enters from the mid-point of three sections and travels approximately 400 m to either side to reach end pots.

The following challenges were faced:

- As start-up was taking place at the west end, PFS had to transport alumina through the entire length for filling the started pot hoppers causing loss of material through the vents (vent domes) to GTC duct,
- Material fall-over into GTC duct from alumina hoppers inside the pot superstructure, resulting in hoppers getting empty,
- As the sections completed start-up, particle size distribution of alumina across the length of the conveyor was found varying (refer to Figure 11), resulting in variability in fluorination level of alumina.

As part of commissioning, the first two challenges were overcome by adjustments to conveying pressure and by close monitoring of performance of PFS along with start-up progression.

Work on PFS is continuing by way of vent dome design modification to minimize particle size segregation within conveyor and to reduce material loss to GTC duct.

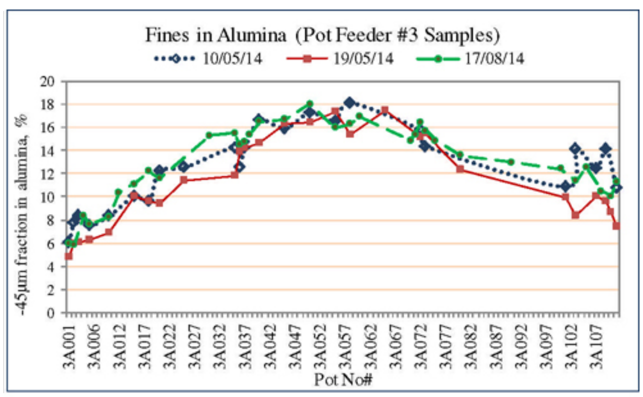


Figure 11. Alumina fines distribution along one branch of PFS.

Thermal balance of pots during early operation

Thermal balance of pots during early operation was affected by several factors such as pot voltage, excess AlF_3, basement ventilation conditions, input material properties, and issues with pot feed system. As shown in Figures 12 and 13, at target bath temperature, excess AlF_3 was below target.

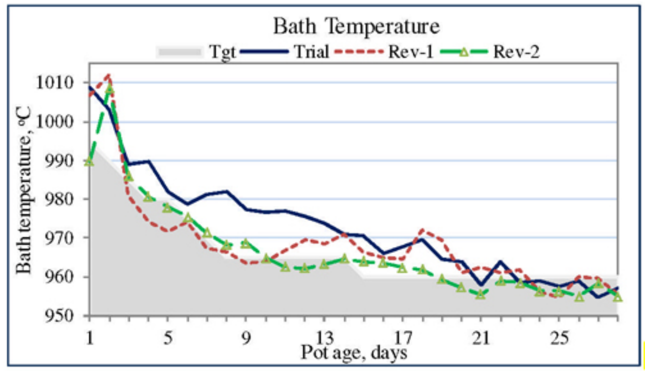


Figure 12. Bath temperature, early operation trend for the three groups against DX+ target.

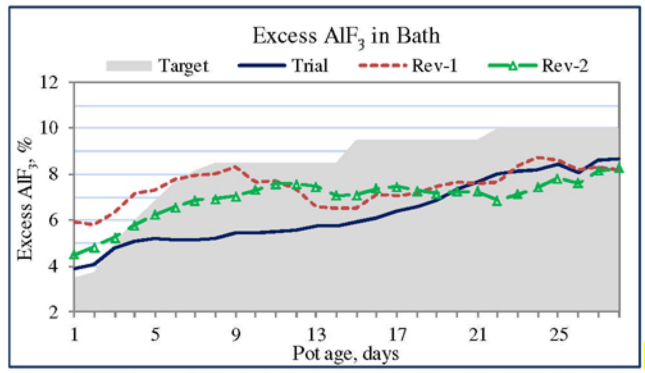


Figure 13. Excess AlF_3 in bath, early operation trend for the three groups against DX+ target.

As start-up progressed, thermal balance and material properties improved resulting in better operation of the pots.

Work re-organization

After starting up the first eight sections, original work organization required some changes. A complete re-organization of work pattern was implemented as shown in Figure 14.

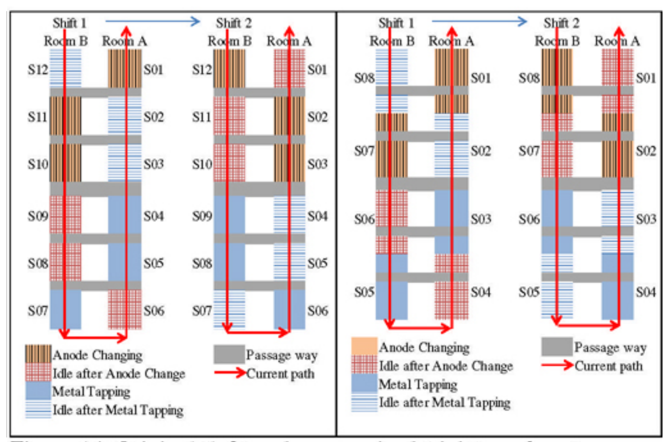


Figure 14. Original (left) and re-organized (right) work pattern.

In the new pattern, hot metal movement and anode pallets movement did not conflict as they were separated to either half of the potline.

For continuation of start-up at the required pace, this change proved to be a key success factor. In the long run, this work pattern would avoid need for PTM transfer from one potoom to the other.

Start-up summary and Overall Performance of PL-3

Figure 15 shows daily number of pots started compared to the plan. The long pause from 8th November 2013 to 23rd December 2013 was due to delay in power generation.

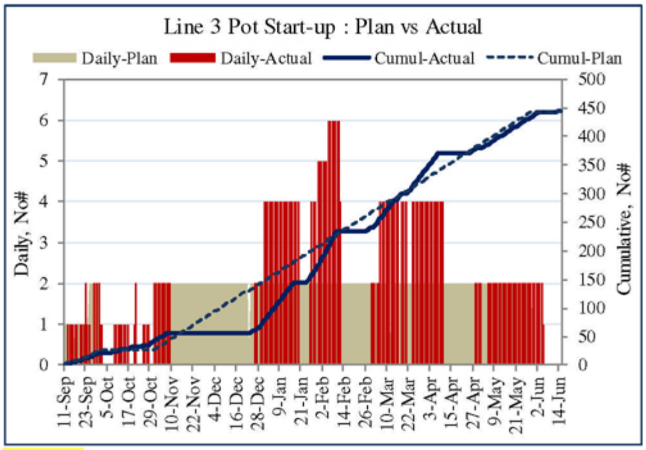


Figure 15. Pot start-up plan vs actual from 11 September 2013 to 13 June 2014.

Accelerated start-up during 28 January to 10 February 2014, resulted in starting up 76 pots within two weeks. Experience gained by start-up team in controlling early operation and changes made to shift working pattern allowed to achieve this feat.

Overall performance

In spite of a number of challenges encountered during start-up of PL-3, an impressive performance in terms of productivity and energy efficiency is demonstrated as shown in Table II.

Table II. KPI of normalized pots (>56 days), as on 14 Sep 2014.

KPI	Unit	August 2014	YTD-2014 as on 14th -Sept
Amperage	kA	448.4	445.6
Current Efficiency	%	95.6	95.7
Metal Production	kg/pot-day	3453	3435
Volts per Cell	V	4.248	4.251
DC Specific Energy	kWh/kg Al	13.24	13.24
Net Carbon	kg C/t Al	411	427
Fe in metal	%	0.0411	0.0414
Si in metal	%	0.0237	0.0248
AE Frequency	No/pot-day	0.14	0.18
AE Duration	s	10	21

Line amperage was increased to 444 kA during the start-up and reached 450 kA within two months from completion of start-up. AEF < 0.10 per pot day and AE duration of 10 s was reported for DX+ technology at 440 kA [2]. Work is currently underway to achieve similar performance at 450 kA for DX+ pots in EMAL Potline 3.

As of September 2014, the best numbers achieved are AEF of 0.073 per pot day and AE duration of 5.8 s for a section of 54 trial pots over two consecutive weeks at 450 kA.

Conclusions

The longest potline in the world was safely and successfully started at 440 – 444 kA, with impressive results on key performance indicators. Critical success factors were;

- An experienced start-up team with able leadership, and working hand-in-hand with DUBAL technical team.
- PLC based pot control system and HMI.
- Introduction of slotted anodes from preheat.
- Effective treatment of long AEs in bath generation pots.
- Relentless process monitoring, data analysis, trials and resulted process improvements.
- Mitigations implemented for cathode heaving.
- Continued support from Ph-1 in supplying liquid bath and other resources whenever needed.
- Work pattern re-organization.
- Stable operation of the power plant.

Acknowledgement

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