

The Challenge to Replace the First Generation Pots Following a Rapid Successful Startup of a Large Number of Pots

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Abstract

Pot reconstruction on mature potlines is usually a relatively straight forward affair with a typical smelter having a range of from 240 to 750 pots. With an average life of approximately 5 years the average cut out rate is therefore 1 to 3 pots per week, with an occasional peak of say 4 to 5 pots per week. When starting new potlines, faster start-up rates are usually recorded as the pots are built in situ and therefore typically rate limited by availability of cut-in equipment and bath production and project construction progress. However how does one of the world's newest and largest smelters go about replacing 756 pots that were all successfully started over a 13 month period with no failures? This paper describes how Emirates Global Aluminium's (EGA) Al Taweelah smelter used human and plant resources to successfully and safely replace approximately 90 % of 756 pots in 24 months, peaking at 10 pots per week and included a major upgrade of the potshells during the pot turn around.

Keywords: DX Technology; cell lining, cell reconstruction.

1. Introduction

Emirates Global Aluminium's Al Taweelah smelter was built in two construction phases, the first being the startup of 756 pots using EGA's own DX Pot Technology over a 13 month period from 2009 to 2011 [1]. The second being the start-up of 444 pots using EGA's own DX+ Technology over a 9 month period from September 2013 to June 2014 [2]. This paper will focus on the replacement of the first generation pots from Phase 1, which is also the first industrialised installation of the DX Pot Technology.

The DX Technology for Al Taweelah Phase 1 was selected based on the successful performance of the 40 pot demonstration potline at EGA's Jebel Ali smelter, which was commissioned during 2008, which was itself built on the successful five demonstration pots in the Eagle section at Jebel Ali smelter.

The first DX pot was started on 2nd December 2009 and the last 756th pot on the 2nd January 2011 at an average of 1.9 pots per day, peaking at 6 pots per day (Figure 1). The start-up was very successful as not one pot failed or was required to be restarted. Adding to the highly successful start-up was that not one pot subsequently failed over the following approximately 4 years.

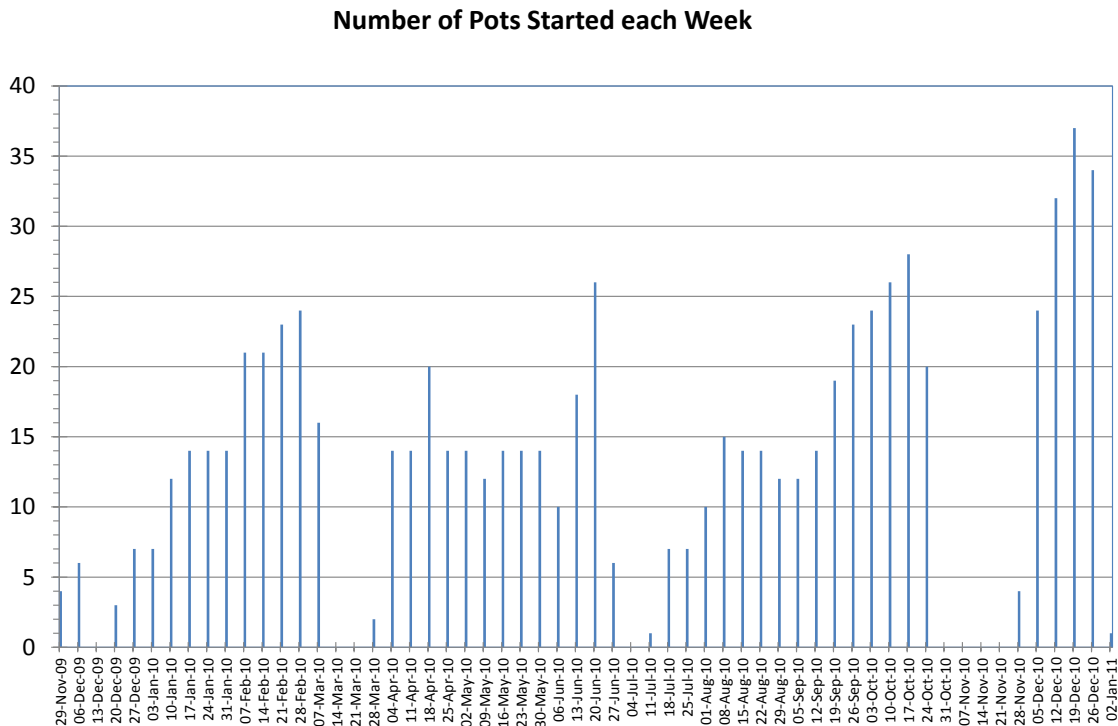


Figure 1. AT Taweelah Phase 1, number of pots started each week.

As the two DX potlines at Al Taweelah were the first commercialised potlines of EGA’s DX Technology and with the pot age of the demonstration potline still to reach end of life, the predicted age of failure for the technology was initially based on the Eagle pot autopsies undertaken on the five eagle pots which were shutdown at mid-life in January 2010, at ages from 1346 to 1432 days, to give place to five DX+ demonstration pots. With the potential for some differences in potlife due to higher operating amperage and design enhancement from the Eagle pots, EGA decided to selectively remove the first pot 2B002 at the age of 1560 days at then 380 kA, which was curtailed to enable a detailed autopsy. The purpose of the autopsy was to enable a snapshot of how the cathodes are aging and the performance of the lining in general.

2. The Problems with Successful large Scale First Generation Start-up

As demonstrated in Figure 2, a successful theoretical pot start-up with standard deviation of say 150 - 250 days in pot age would over time have declining and widening peaks in subsequent generations of pots due to randomization of pot age amongst the population. Thus the first generation pot replacement would require more resources to enable pots to be replaced without loss of pots in circuit days.

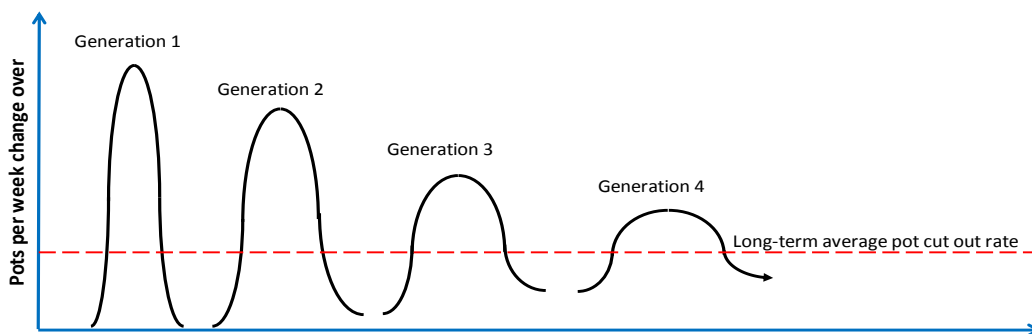


Figure 2. Theoretical pot generational replacement rate following successful start-up.

Thus without an elongated pot-startup, power outage or some other major disruption has impacted the potlife partially or fully in the potlines of a number of large new smelters in the last 10 years. A very successful large plant successful startup can be victim of its own success as a large group of pots will naturally fail in a short space of time and at a rates that potentially exceed the capacity of deline facilities.

For Al Taweelah, the pot start up rate was 1.9 pots per day, however the deline facility was designed for a long-term pot replacement of not just Line 1 and 2, but also Line 3 and potential future Line 4 with a name plate maximum pot replacement rate of 1 pot per day. As in the initial pot star-up, pots are built in situ by the project construction team, the initial pot start-up does not operate with the same physical constraint as operations for the ongoing pot replacement requirements through the deline facility.

Today, very few smelters have around 756 pots or more and those that do were typically built in stages over many years. Typical incremental expansion was one pot line at a time with a typical potline containing around 240 - 248 pots until the mid-1990's when the newer pot lines with amperages of 300 kA and above were being built with approximately 264 pots, later increasing to approximately 320 pots. During the 2000's some smelters in India and the Middle East were built with a single phase of approximately 640 to 1400 pots, however most of these plants suffered major outages or other constraints that prolonged the final start-up and thus provided a more spread-out pot life population than experienced by EGA's Al Taweelah Phase 1 smelter. Thus the peak in pot failures are typically within the capacity of deline facilities as most deline facilities can manage 2 - 4 pots per week as a minimum. Environmental standards preclude performing pot digout outside with excavators.

3. When to Actually Commence Pot Change-out?

As mentioned previously, all 756 pots of Phase 1 were started over a 13 month period at 13.3 pots per week. However, the deline facility was designed for 7 pots per week, hence the minimum time frame to replace the pots is approximately 25 months without any further investment, which was deemed both uneconomic and environmentally unviable.

Figure 3 demonstrates the shortest possible deline time frame of 108 weeks is nearly double the 56 week start up time frame. Hence waiting for pots to fail naturally may not be a viable option if pot turnaround time is to be kept to a physical minimum to minimize or ideally eliminate any loss of hot metal production.

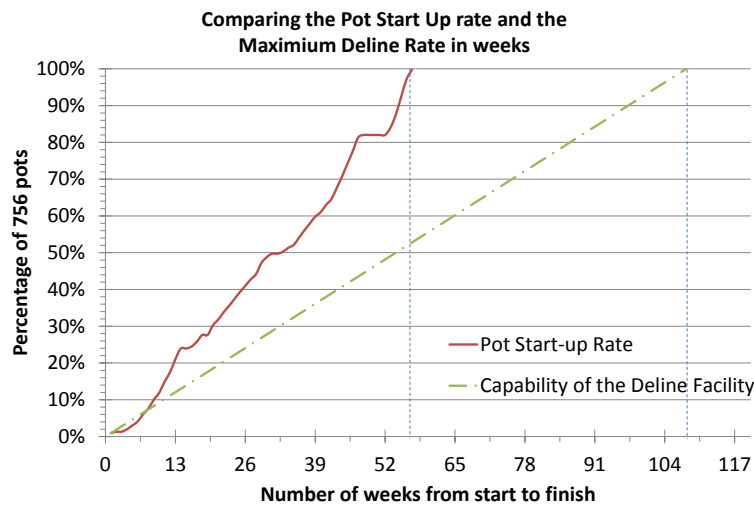


Figure 3. DX Demonstration Potline 1st Generation Failure S-curve.

In 2014, EGA, based on the Demonstration Potline performance revised the DX Technology pot life as follows;

- Minimum pot age - ~ 1650 days
- Average pot age - ~ 2000 days with a standard deviation of 190 days
- Maximum pot age - ~ 2200 days.

Based on this information, Al Taweelah developed a plan based on the youngest pot (last pot to be started) being cut out at the maximum predicted age of 2200 days. Al Taweelah then predicted that Phase 1 would cut out the last generation 1 DX pot in December 2016 with the first pot due to fail around June 2014, thus leaving a total window for deline operations of 130 weeks. As the theoretical minimum time frame for the untested deline facility is calculated at 108 weeks, this will provide 22 weeks buffer for commissioning of equipment and training of personal.

While Al Taweelah calculated there would be an approximate 22 week buffer, this buffer was insufficient to allow pots to operate to failure naturally as the buffer would more than likely be consumed in the first few months when the initial start-up rate was slow, leaving no space capacity for the latter half of the 756 pot population. Hence based on this information, pots would be cut out of production through selective culling, usually targeting poor performing pots and/or pots with known operational or performance issues. Where such pots were not available, pots would be removed from oldest to youngest in a sequence that prevents two pots being cut out within 14 days of each other such that the pot repair team would not be working alongside hot pots unnecessarily.

4. Adding Further Complexity to the DX Pot Change-out Program

While Al Taweelah is rising to the challenge of replacing one of the largest and most successful potline start-ups in the industry, adding to the challenge Al Taweelah would additionally be undertaking the technology providers recommendation to modify the pot shells in such as way the shells would be able to release an additional ~ 50 kW of heat. The greater heat loss would allow the DX pot technology to operate at higher amperage range of 380 – 400 kA, which is much more productive than the initial start-up amperage of 340 kA.

The shell modifications were quite extensive and involved cutting off the top half of the long side wall and cradle and rebuilding the existing standard “I” beam cradle with floating shell wall with two short fins to be replaced with an incorporated and fully welded shell and beam design with 5 620 mm long fins. Additionally the long end deck plate was removed and replaced with a grid for better air circulation and cooling.



Figure 4. Comparison between Generation 1 (left), Generation 1 Modified (middle) and Generation 2 shells.

The extensive fabrication work was undertaken by two contractors off-site and expected to take 12 days for the full turnaround, so that Al Taweelah was required to increase the shell inventory to 28 pots to accommodate the extra shell turn-around time.

5. Equipment Required for the DX Generation 1 Replacement Program

As part of the readiness for the first generation of pot replacements at Al Taweelah, the following equipment in deline building and infrastructure was acquired and constructed during 2012 - 2013. The lining facility including the automated 1200 cathodes / 42 pot sets per month casting facility and 7 lining pits was completed for initial construction of the Phase 1 pots.

The 420 m long lining and delining facility included the following major pieces of equipment:

- Two pot digout rooms (only one internally fitted out for Generation 1) with full dust collection and noise suppression. Designed to demolish a pot within 24 hours.
- One automated pot shell blasting room, capable of cleaning a pot in 8 hours.
- One pot rotator, designed to enable faster welding by moving the pot to the ideal position.
- One Pot Shell Straightening Machine
- One Cell Transport Crane
- Two Pot Lifting Beams designed to accommodate DX Original, DX Modified shells and DX+ for the new Line 3.
- One Superstructure Transport Crane
- One utility crane to lift the pot straitening machine
- Pot shell cooling area and other general repair areas
- Four Pot Superstructures
- 28 spare pot shells calculated as follows. Note that the new shells used a more advanced shell design that uses less steel and is hence overall cheaper, but stronger; this shell design was also applied to the DX+ and DX+ Ultra Technology.

Day																							
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Removal from pot line	Pot Cooling					Pot Digout	Pot Shell Clean	Pot Shell straighten	Pot shell Modification												Pot Construction	Inventory	Transport to Potline

Figure 5. Pot turn-around activity timeline.

The number of extra pot shells required was not a major concern as EGA has firm plans to extend the Phase 1 potlines to at least 800 pots and the excess shells left over from the modification project would be used in the extension.

The large investment into the deline facility was deemed viable on the basis that while the Phase 1 demand peak would progressively reduce with each passing generation to 2.9 pots per week longer, Al Taweelah was adding a further 444 DX+ Technology pots as part of the Phase 2 expansion. This further increased the long-term average deline rate of 5 pots per week.

6. Corporate Citizen Responsibility

While the Al Taweelah complex is some distance from the city of Abu Dhabi, it does however have a number of private land holders alongside the same boundary as the deline facility. Additionally Al Taweelah is in close proximity to a pristine estuary and the fragile coral reef ecosystem in the Arabian Gulf not far from the Al Taweelah beach. As such, Al Taweelah paid special attention to ensure there would be no process or noise pollution crossing the common

boundary or potential run off into the Gulf as well as protecting the Al Taweelah workforce and site in general. Hence the choice of pot digout and pot shell blasting technology focused on dust emission collection, noise abatement as well as the usual financial and general technical capabilities.



Figure 6. Al Taweelah aluminium smelter complex.

7. Preparing the People

The final and most crucial piece for the generation 1 deline program was training and preparing the people;

1. Operations 56 regular employees, 184 contractor employees with 7 quality control employees, mostly all on shift.
2. Regular on the job training as well as classroom training for safety, technical and manual activities according to trade and grade for both regular and contract employees.

While most of the labourers had limited experience, Al Taweelah was able to capitalize on the experienced leadership team at Jebel Ali and applied a streamlined single functional pot repair management structure for both sites. The success of using a functional management structure instead of site based was later used as the basis for the new EGA structure for all operations and support teams.

8. Actual Pot Replacement Performance

As this is the first industrialised use for the DX Technology, the predicted pot life was based on both limited information from the initial five Eagle Pots and later 40-pot demonstration potline at EGA Jebel Ali Smelter as well as modeling. Hence with no natural failures after 4 years of operation, in early 2014 the decision was made to cull pot 2B002 in the first week of April 2014 one of the oldest and deemed “representative” to undertake an autopsy to get better understanding how the pots are aging, confirm that the cathode wear rate is close to the predicted age of 2000 days, test the deline people and equipment and determine if the predicted relining start date of July 2014 was still appropriate to commence culling some of the older pots in lieu of natural failures.

Based on this information gained from the 2B002 autopsy, ATS confirmed that pot delining would commence in July 2014 at the rate of 2 pots per month and increase to 1 pot/week in August and continue to steadily increase each month to 7 pots per week. As Line 2 was started

prior to Potline 1 due to physical position on the site, the pot change-out would first commence in Line 2, room 2A. The first 19 pots in room 2B (oldest pots) would be preserved to allow natural aging to failure and thus provide a more detailed picture for future pot failures and planning of resources as generation 1 replacement progresses.

Figure 7 below shows the actual pot change-out rate per week and weekly average age. While the initial pots were selectively culled, driving a low pot failure age of 1600 - 1650 days, the first pots to fail naturally started to occur at 1720 days in December 2014.

Figure 7 also demonstrates that a total of 35 weeks exceeded the decline facility design of 7 pots per week. Of these 35 weeks, 18 weeks had pot failure rate of 9 or 10 pots per week. The peak occurred in March 2016 with a total of 14 pots failing. The bottleneck for the decline process was the single available digout room (2nd room was not fitted out until late 2017). However, the Pot Repair Team Leadership was able to optimise the performance from 24-hour turn-around to 16 hours with improving the skills of the machine operators, equipment modifications, changes in cell preparation prior to digout and just-in-time change out by the contractor for the SPL skips.

Overall the peak in pot failures occurred in the first quarter (Q1) of 2016, around the 500 pot mark which is also the period during which Phase 1 start-up peaked at 6 pots per day.

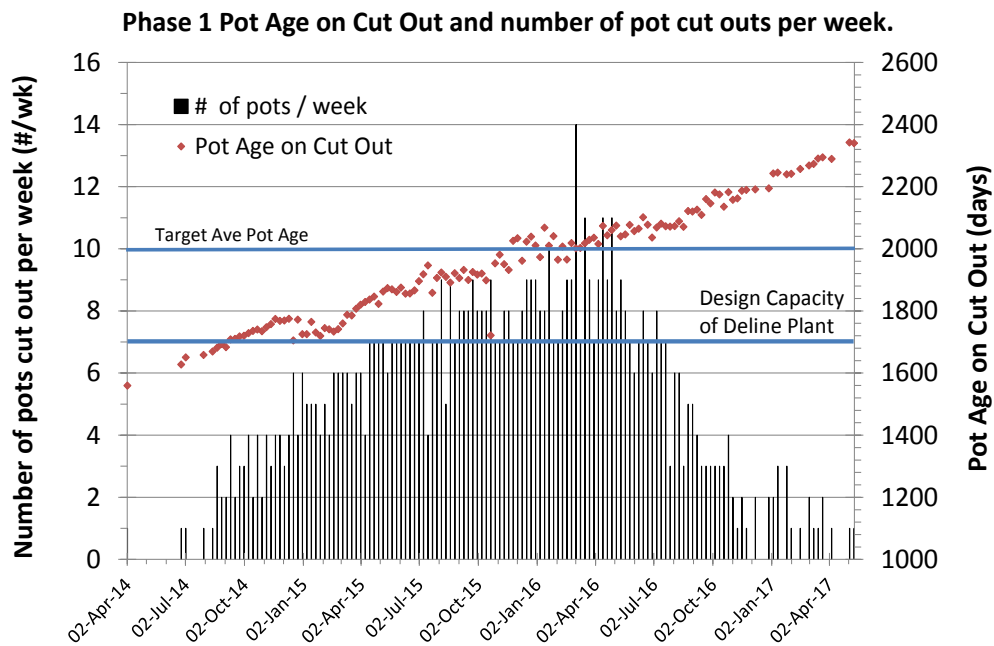


Figure 7. Number of pots per week cut out with weekly average at cut out.

A clear sign of the success of the Pot Repair Team rising to the challenge for pot failures exceeding plant name-plate deline capacity was the ability to sustain the pot turn-around time of 35 h/pot during the first quarter of 2016. Only four weeks failed to sustain an average pot turn around less than 45 hours. The pot turnaround times of 100 h and 80 h at the start were due to general equipment commissioning issues and minor modifications required.

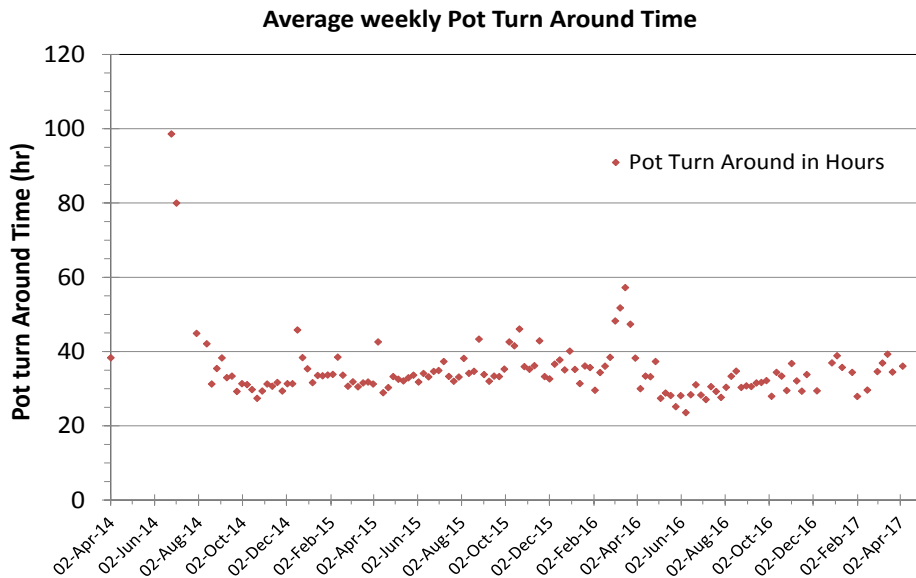


Figure 8. Average weekly pot turn around.

8. Summary of Pot Failure Statistics

- A total of 125 pots were selectively culled, most of which in Line 2 to prevent the pot failures exceeding the capacity of the delin facility.
- Seven pots tapped out, less than 1 % of the total population, with an average age of 1947 days.
- The oldest pots failed at 2342 days, failing in May 2017, 5 months beyond predicted.
- Seven pots were removed due to high cumulative silicon loss.
- No pots were removed due to mechanical or other issues from operations, superstructures, power outages, etc.

9. Conclusion

The overall average pot cut-out rate achieved was 5.1 pots per week with a peak of 14 pots. The average weekly pot turnaround time was 35 h/pot which included training and commissioning of the entire delining and pot handling equipment.

EGA Al Taweelah was able to demonstrate that not only was it able to undertake one of the industry's most successful single phase pot line start-ups with all 756 pots successfully started in 13 months, these pots continued to operate for a further 4 years without any failures. Additionally EGA Al Taweelah was able to take this level of success to the next level by replacing all 756 pots over a 35 month period with minimal loss of pot availability, with less than 1 % of the population tapping out and minimal number of healthy pots prematurely culled.

10. References

1. B.K. Kakkar et al, Commissioning of emirates aluminium smelter potlines, *Light Metals* 2012, 721-726.
2. Walid Al Sayed et al., World's longest potline start-up at EMAL, *Light Metals* 2015, 505-510.