

AL05 - Critical Pots Index Report in EGA Potlines

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Abstract

Emirates Global Aluminium (EGA) is extensively pursuing the implementation of Industry 4.0 and its tools in potlines to monitor and improve the potline operation by identifying abnormal behaviour of individual pots. There are some common symptoms which are observed in sick and unstable pots, such as deviation in alumina dumps, anode quality leading to spikes, red potshell, increase in silicon content in the metal, change in pot super heat and internal heat etc. Generally, these symptoms are indicator for the operation/process team to flag pots with such behaviour as a sick/instable pot depending upon the severity of abnormal parameters. The sick or unstable pots are logged in the log book for corrective actions.

In order to automate the process of identifying the sick and abnormal pots, EGA technology developed critical pots index report using the Power BI software. The most common symptoms of abnormal pots were identified, and for each parameter deviation values and weightages were defined. A weightage was given for each abnormal parameter depending on the criticality of parameters such as, combined voltage drop (measured between the metal pad and the centre of downstream pot anode beam), silicon content in the metal, red potshell, bath temperature, noise, etc. Each pot is filtered for specified parameters, the weightage of parameters with the deviation is summed up, and the pots with weightage score above a specified limit are reported as sick or unstable. Pots with index score of 0-0.35 are declared as normal operating pots, pots with index score of 0.36 to 0.6 are declared as unstable and pots with index score 0.65 to 1.0 are declared sick pots. The score is 1 if all parameters on the list are out-of-range. This critical index report is configured in Smelter Analytics and is accessible to Potline Operation. The Critical Pots Index Report is configured separately for each potline to define the range of parameter deviations. This report is regularly used to track pots with abnormal behaviour, to provide rapid corrective actions and reduce the number of pots with abnormal operation.

Keywords: Critical Pots Index Report, DX+ technology, DX+ Ultra technology, Amperage increase, Cell performance.

1. Introduction

EGA is the world's leading 'premium aluminium' producer with business from mining and refinery to smelting and casting. In 2022, EGA produced 2.653 million tonnes of hot metal from its two production sites, Jebel Ali and Al Taweelah, and surpassed the milestone of 40 million tonnes of hot metal production since start-up in 1979. Potlines in both production sites comprise seven technologies (D18+, CD20, D20, D20+, DX, DX+ and DX ultra) with 2843 pots [1]. EGA is fully committed and focused to innovate the aluminum production process using Industry 4.0

and artificial intelligence tools in the operation areas to produce the metal with minimum impact on environment while maintaining highest industrial safety standards.

Microsoft Power BI based Critical Pots Index Report is one of the tools which is being implemented in EGA potlines to identify critical pots based on their latest performance data. Currently, this report has been configured for EGA Al Taweelah potlines (Potline 1, 2 and 3 operating 1266 pots) and is used by operation and process teams to track the critical pots and prioritise their actions depending upon the nature of pot abnormality.

Critical Pots Index Report has been also developed by EGA for ALBA Potline 6, which uses EGA's DX+ Ultra technology [2].

2. Traditional Method of Identifying and Handling Critical and Abnormal Pots

Aluminium production process faces multiple challenges which includes pot abnormality triggered by deviation in pot operating parameters with respect to set targets. Operation and process control teams work hand in hand to identify pots with abnormal operation and take corrective actions to restore normal pot operation by following the guidelines set to eliminate each pot abnormality. Pot abnormal/critical conditions include pot operation with high/low bath temperature, high instability, anode problems, heavy carbon dust, red potshell, high combined voltage drop, muck (sludge) on cathode blocks, high silicon, iron, copper content in the metal, alumina dissolution issue, high anode effect frequency, and pending routine activities. Each abnormal/critical pot is evaluated by operation and process teams to find root cause of the problem. A thorough investigation is carried out for abnormal/critical pots by reviewing the history of pot performance, recent events, and corrective actions taken.

After careful evaluation of pot performance, corrective actions are applied to restore normal pot operation from abnormal/critical condition. A list of abnormal/critical pots is continuously updated for the potline. The list of abnormal pots and the course of actions to be taken to remedy the abnormal operation condition of each pot is communicated to operation teams through traditional ways of communication which include white boards in the control room, log books and WhatsApp.

The existing method of pot evaluation required time to analyse the pot historical performance for the critical KPIs to find out the root cause of deviation and to determine which parameter triggered abnormal pot operation. Analysing and updating the list of abnormal pots manually on a regular basis is a tedious job with the possibility of miscommunication. Critical Pots Index Report is the solution to replace traditional methods; it identifies abnormal/critical pots, using Power BI by generating a system-based report of critical pots based on the latest pot performance data.

3. Development of Critical Pots Index Report – Out of Range Report Implementation in ALBA Potline 6

It is important to understand the evolution process of identifying the KPIs which were used to identify or declare a pot with abnormal/critical condition. At the beginning, an out-of-range pot performance report was developed by EGA's Technology Transfer Process Advisor at ALBA, using Power BI for ALBA Potline 6 during amperage increase. This report generated the list of pots continuously operating out of range with respect to critical KPI targets. The critical KPIs such as bath temperature, noise, anode effects, alumina dumps, silicon % in the metal, etc., were analysed for the previous 7 days. An out-of-range limit was defined for each KPI, and Power BI filters were used to filter the pots with repeated out of range behaviour. The pots which were operating continuously out-of-range for 4 days and more were filtered for each KPI. Then visually

the pots with KPIs most out of range were declared as critical/abnormal pots (highlighted in Figure 1) and operation and process resources were assigned to attend these pots with top priority.

A set of corrective actions was defined for such pots to restore their performance. This approach helped to identify the critical pots which required urgent attention. The same report was adopted by ALBA operation and process team and every morning a list of out-of-range pots was issued to operation superintendents who attended these pots. This was the first step towards the development of Critical Pots Index Report, now implemented in EGA potlines within Smelter Analytics (EGA’s comprehensive smelter analysis software), while in ALBA Potline 6 it is running as a stand-alone system in Power BI.

In Figure 1, the data of 424 pots in ALBA Potline 6 is filtered for the period from 8 November 2021 to 14 November 2021 (7 days). Filters are applied to identify the pots operated for 4 days or more. The filter of 4 days is applied for critical KPIs such as: Noise >25 mV, bath temperature <950 °C and pots operated with high alumina dumps >6000 dumps along with the list of pots having more than 1 anode effect (AE) in the last 7 days. Among the list of filtered pots, the pots which have more than 1 KPI out of range, such as pots E102, E211, E058, E101 and F013 were flagged for urgent attention to restore their normal operation. In Figure 1, Cell E102, 7 indicates that pot has been operating with noise level > 25 mV for last 7 days while the sum of anode effects indicates that there were 7 anode effects in last 7 days. This pot is declared abnormal/critical, requiring urgent action to stabilise the pot and decrease high AE frequency.

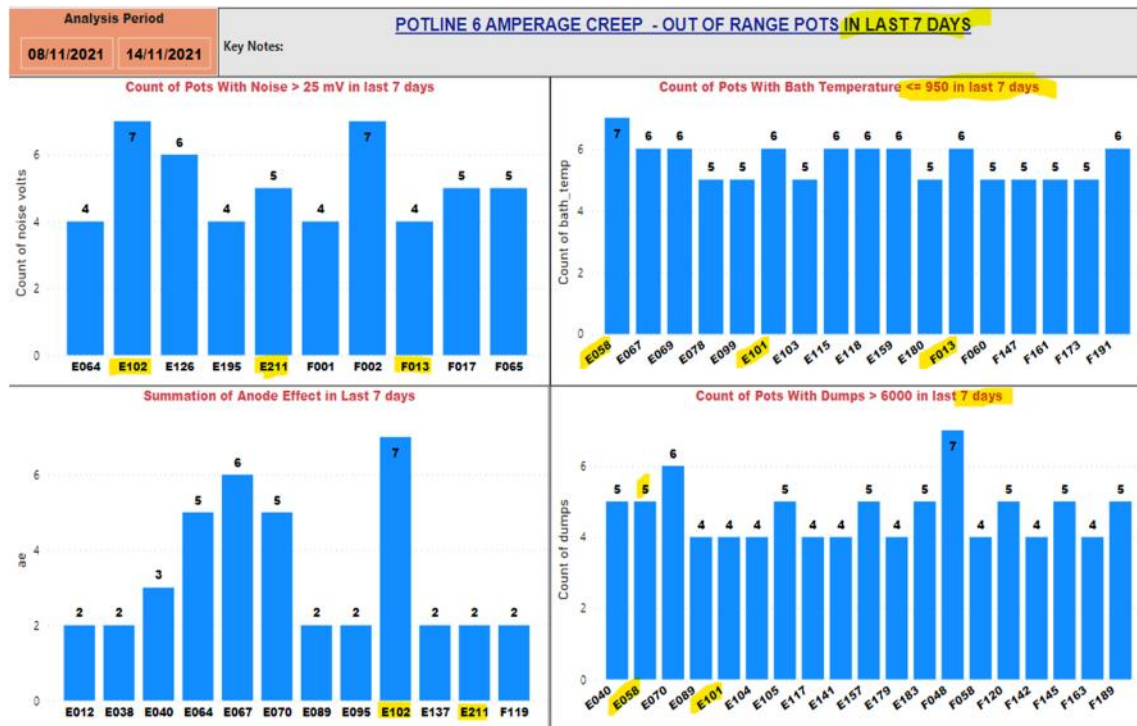


Figure 1. ALBA Potline 6 – List of pots with out-of-range KPIs. Dumps = alumina dumps.

4. List of Key Performance Indicators (KPIs) to Generate Critical Pots Index Report

Pots with abnormal behaviour were studied to identify the list of KPIs which are commonly the cause of pot abnormal operation: pots with various abnormal conditions like highly unstable, having anode problems, multiple anode effects, red potshell, high silicon and iron content in the metal, continuously high/low bath temperature, etc. Each pot abnormal condition was analysed separately, and KPIs before and after declaration of pot abnormality were analysed.

The change in pot behaviour and in individual KPIs was recorded to identify the relationship between the KPI deviations and their impact on pot performance. This study helped to understand and identify the values and deviations of most common KPIs when the pot is abnormal. A list of KPIs which were commonly observed during pot abnormal operation was prepared with the participation of operation and process team.

The target of each KPI during normal pot operation was identified along with an acceptable range (lower and upper limit). The ranges of acceptable values of KPIs were identified in the study of KPI behaviour during the transition phase from normal to abnormal pot operation. Table 1 shows the ranges for all KPIs.

Table 1. EGA Al Taweelah Potline 3 critical pots index report of KPIs.

Parameter	Range		Target	Comments	Index Score
	<	>			
Alumina dumps (Nos)	300	300	Daily average \pm 300 dumps	3 consecutive days	0.05
Bath temperature (°C)	950	978	962	If a pot is operating 3 consecutive days above or below range or one day above 985 °C or a jump of \pm 20 °C with respect to previous reading	0.10
		985	962		
Si (ppm)	-	600	Daily 500 ppm or increase of 100 ppm with respect to previous reading	Daily 500 ppm or increase of 100 ppm with respect to previous reading or 4 red shell observations in last 3 months	0.10
Fe (ppm)	-	1500	Daily 1500 ppm or increase of 500 ppm with respect to previous reading		0.05
Combined voltage drop		590	550	Previous available reading >590	0.15
Noise (V)	0.007	0.04	0.02	If pot is consecutively 3 days operating > 0.04 V or <0.007 V	0.10
AE (Nos)		3		Daily	0.05
Near AE (Nos)		5		Daily	0.05
Voltage adder (V)		0.07		Daily	0.10
Internal heat (Qin) KW		880		Daily	0.05
Superheat (°C)	5	14		Daily	0.05
Metal height (cm)		28		Deviation \pm 3 cm from target, target is defined in iRPMS	0.05
Spike		2		If 2 spikes are reported in last 3 days	0.05
Bath height	15	20	17 cm	If pot is operating \pm 3 cm from target for last 3 days	0.05
Total					1.00

An index score was assigned to each KPI when it is outside the range. Very critical KPIs like bath temperature, silicon content, red potshell, pot voltage adders and combined voltage drop were assigned higher index score of 0.10 or 0.15, while less important KPIs were assigned the score of 0.05. KPIs in normal range have no index score. Index scores for all out-of-range KPIs are added and the sum is classified. The higher the score the more critical the pot condition is, which means that more KPIs are out of range or more very critical KPIs. Pots with total score from 0.0 to 0.35 are normal and stable, pots with total score from 0.36 to 0.65 are unstable with potential to fall into category of sick pots, and the pots with total score of 0.7 to 1.0 are sick pots, and must be attended with top priority with additional resources since such pots have higher probability of failure and are operating in extremely critical condition. A pot has total score of 1 if all the KPIs in the report are out of range. More detailed explanation is given in Section 7. Table 1 gives an example of index scores for EGA Al Taweelah Potline 3.

5. Use of Power BI to Identify Critical Pots for ALBA Potline 6

Initially, the Critical Pots Index Report was designated for implementation in ALBA Potline 6 during amperage increase, aiming at 480 kA [3]. It was decided to use Power BI software to implement the critical pots KPIs index score table. In order to implement the Critical Pots Index Report, the support of EGA Information Technology (IT) team specialist for Power BI software was engaged. The IT picked up the concept of Critical Pots Index Report and the KPI ranges. The configuration of Power BI file to generate Critical Pots Index Report for ALBA Potline 6 was completed by EGA IT team in the third quarter of 2022. The report was generated from daily database of Potline 6 and was run as standalone system. For accurate results, multiple databases were updated manually prior to generation of the report.

The Critical Pots Index Report was shared with ALBA Potline 6 operations and based on the list of pots identified as critical by the Critical Pots Index Report, corrective actions were taken. The critical pots generated by the Power BI report were validated with actual pot operating condition in the potline and pots on the list generated by the Power BI. This list expedited corrective action, resulting in rapid restoration of pot normal operation.

EGA is the technology provider for ALBA Potline 6 and has access to daily data. The Power BI analysis for Critical Pots Index Report was run periodically on updated database. The list in Critical Pots Index Report was shared with ALBA Potline 6 operations via emails. The report helped to minimise the number of pots with abnormal operation by identifying KPIs with continuous out-of-range operation, indicated with red flag in the Critical Pots Index Report (Figure 2).

6. Implementation of Critical Pots Index Report in EGA Potlines

After evaluating the productive and positive results of critical pots index report in ALBA Potline 6, it was decided to implement Critical Pots Index Report in EGA potlines. EGA potlines are currently operating with seven different technologies (D18+, CD20, D20, D20+, DX, DX+ and DX Ultra) with 2843 pots at Jebel Ali and Al Taweelah sites [1]. The Critical Pots Index Report KPIs table will be defined and configured separately for each technology in consultation with operation and process teams responsible for the operation of each technology.

ALBA Potline 6 is operating with EGA DX+ Ultra Technology while EGA Al Taweelah Potline 3 is operating 444 DX+ pots and 14 DX+ Ultra pots [4]. DX+ and DX+ Ultra technologies are different but their operation and KPIs are similar. This is why it was decided to implement the Critical Pots Index Report at EGA Al Taweelah Potline 3 DX+ pots first.

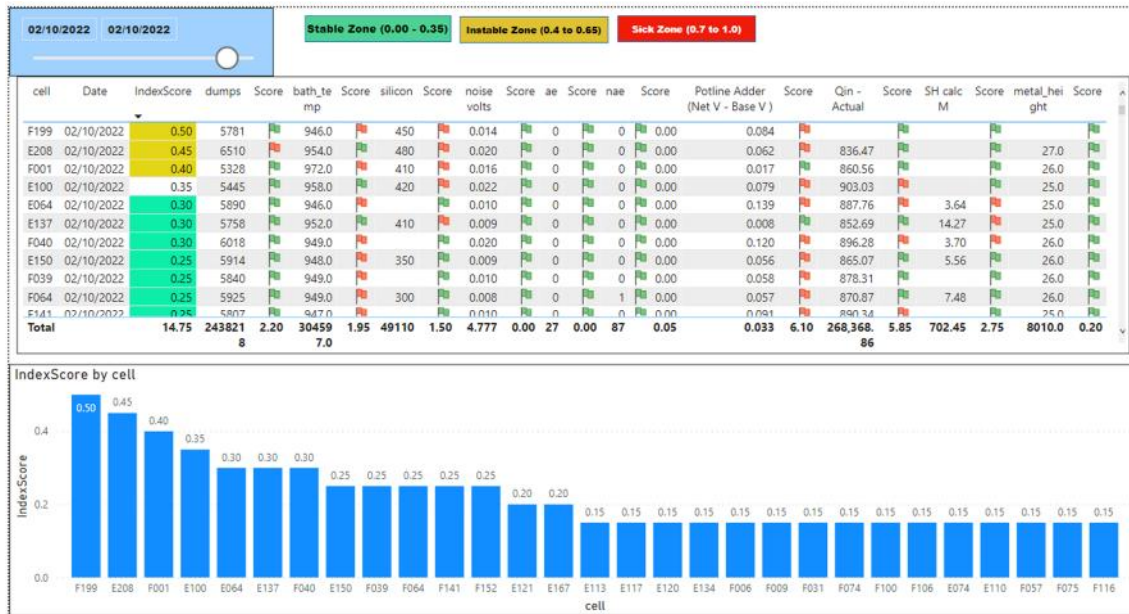


Figure 2. ALBA Potline 6 critical index report generated as standalone system.

The KPIs table implemented for ALBA Potline 6 was used as a reference in consultation with Al Taweelah Potline 3 operation and process team. The target and range of KPIs were defined for the operation of DX+ technology in Potline 3. EGA IT was designated for the implementation of Critical Pots Index Report. It was decided to launch the report through Smelter Analytics with a link to Critical Pots Index Report. The implementation at EGA has another advantage of direct connection of Power BI with multiple databases available in EGA servers. Thus, the report is updated automatically with the latest data from the server without the need to update daily data manually, which was the case in ALBA Potline 6.

7. Key Feature of Critical Pots Index Report

EGA’s IT configured the Al Taweelah Potline 3 as per the KPIs table provided by technology team and released it in Smelter Analytics in the 4th quarter of 2022. The Critical Pots Index Report is available through a link to all the employees that have access to Smelter Analytics.

This report filters all pots in the potline for all KPIs defined in Table 1. If any KPI is out of range, a weighted score is assigned for the out-of-range KPIs and the total score of all out-of-range KPIs is summed up for each pot. Pots with the highest index score are moved to the top of the list and the out-of-range KPIs are indicated with red flag with actual out of range value. Moreover, any KPI can be sorted individually for highest and lowest values as well. For example, if one wants to explore which pot in the pot list has high number of red potshell in a given period, you can simply click on the red shell and it will sort out the pots with the highest number of red shell observations with the number. The preview of the potline Critical Pots Index Report is given in Figure 3. The report is given in four pages, explained below.

7.1 Index Page

Index Page is launched through the link on EGA Critical Pots Index Report in Smelter Analytics. When this report is launched, Power BI automatically runs all the queries in the background to filter each KPI for each and every pot of the potline. Thus, this page of the report automatically filters the potline and populates the list of critical pots which need urgent attention. The pots with highest index score are placed at the top of the list, and index score background color is changed

according to its defined range. All predefined KPI values are also displayed in the row of each pot. Green and red flags are used to indicate if the KPI value is within the range or out of range.

The critical pots are also displayed with respect to index score at the bottom left of Index page in column bars (Figure 3). Moreover, the index score of operating pots is also averaged with respect to the operating pots distribution in potline in the sections to highlight which section has a greater number of pots with higher index score. The teams working in the section with highest index score are alerted to pay attention to pots with highest index score.

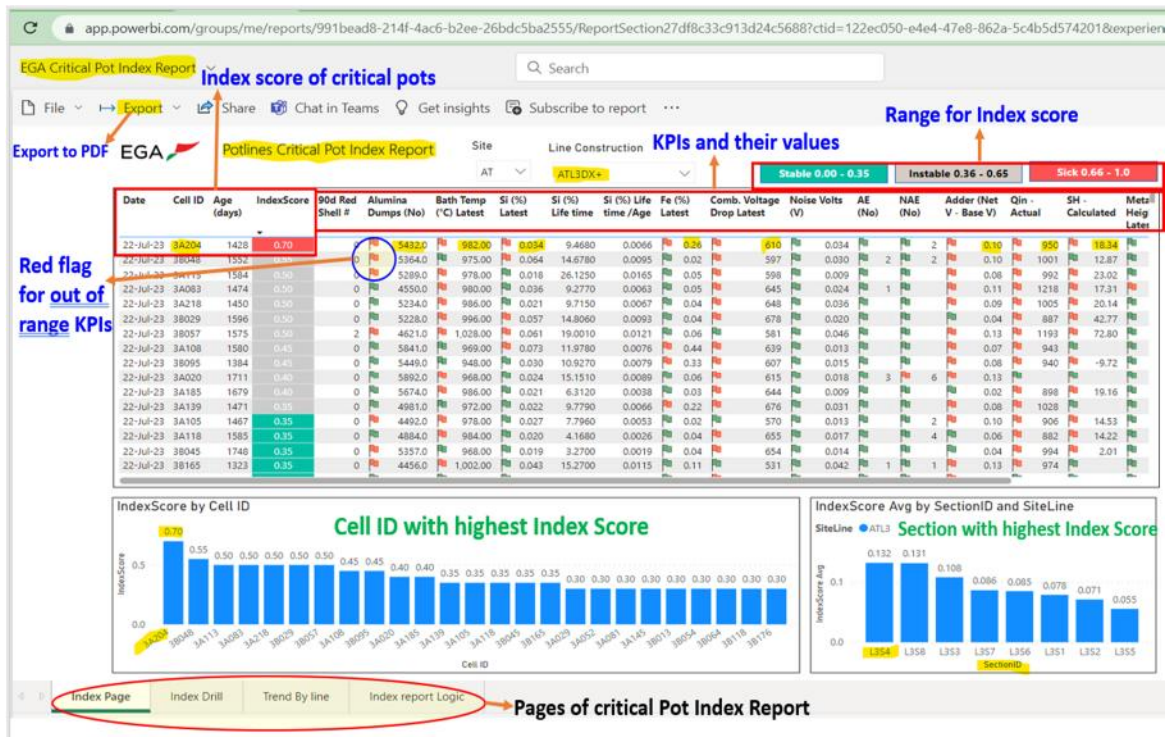


Figure 3. Index page with the list of pots with highest index score.

Another key feature of Critical Post Index Report is generation of critical KPIs performance analysis for the last one year or from the start-up of the pot until to-date. This analysis can be generated with one right click on the pot you wish to analyse by choosing the option of drill through (Figure 4). A right click on drill through will open the index drill page which contains the historical analysis of all KPIs of the pot.

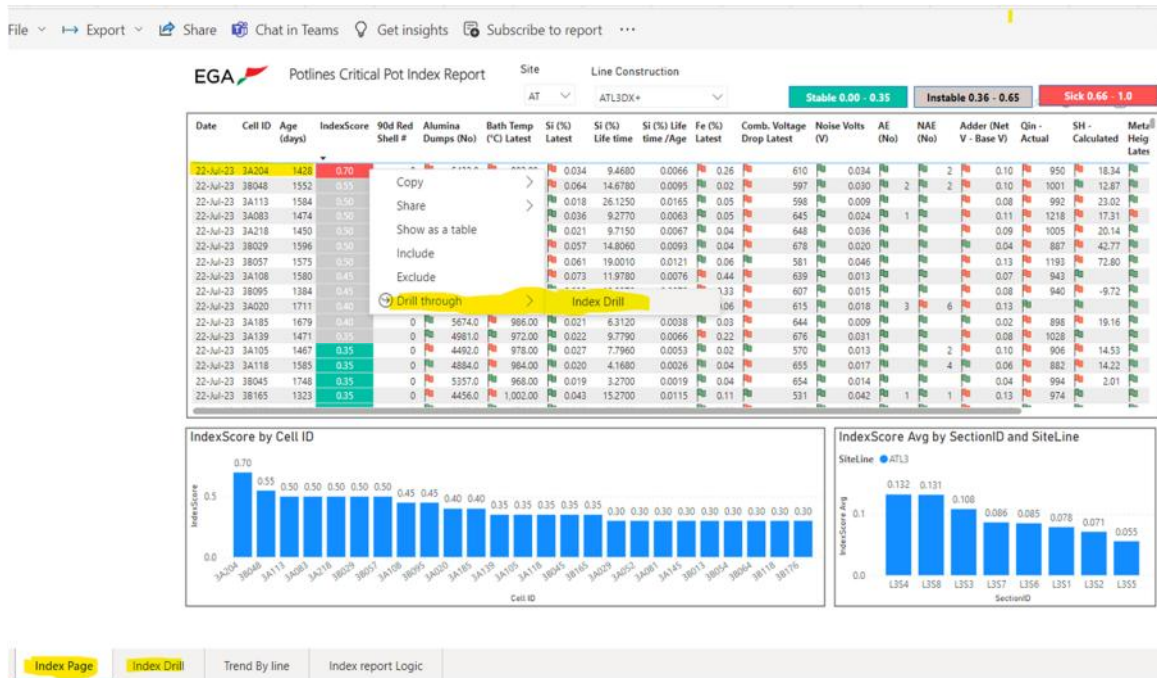


Figure 4. Drill through index drill for individual pot analysis.

7.2 Index Drill

Index Drill page provides the index score history for last one year or from the pot start up till to-date. The history of index score shows if pot performance has deteriorated recently or if historically this pot encountered abnormal operating condition again and again. This assessment is used to make short-term and long-term decision to maintain stable pot operation. In Figure 5, Cell 3A204 index score clearly indicates that this pot performance started to deteriorate in May 2023 and from mid-June the performance deteriorated further. Moreover, index drill page provides the graphical analysis for all the critical KPIs which are used for index score for the period of one year or from start up until to-date. In addition to predefined KPIs, data analysis of additional KPIs like cumulative loss of silicon, Fe, copper, red shell history and anode problems in the pot is also available.

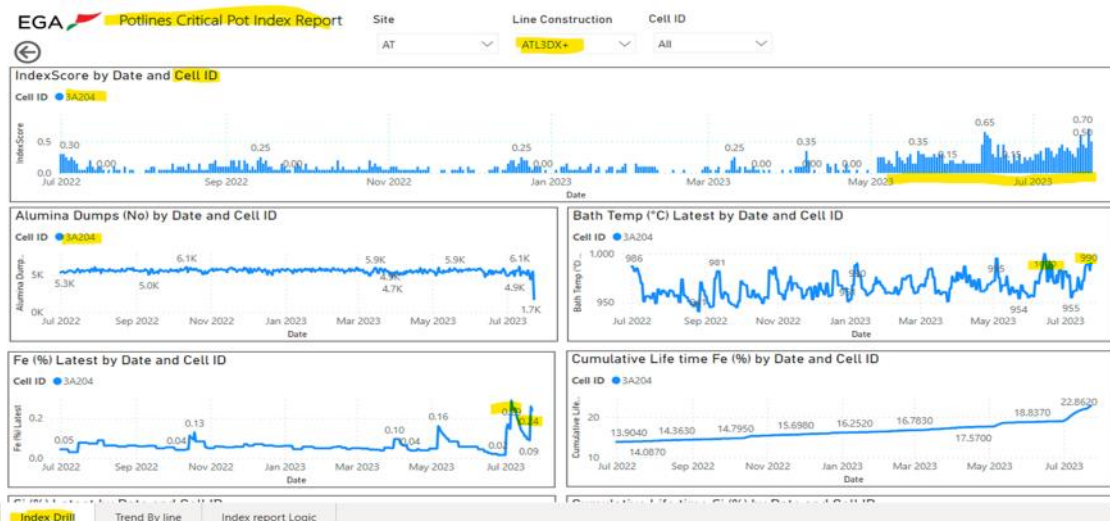


Figure 5. Index drill page preview – index score and KPIs analysis of the pot for the last one year.

7.3 Trend by Line

Trend by Line page contains the average index score of the potline which is driven as an average from individual pots index score. Potline index score indicates the overall situation of potline performance. Potline index score with increasing trend indicates that potline operating condition is deteriorating while potline index score with decreasing trend shows improving condition of potline. Potline 3 index score at the beginning of 2023 was high but it was better in July 2023 than at the beginning of the year.

Potline average trend also contains the KPIs used for calculation of index score. Thus, the whole picture of the KPIs performance is available on one page (Figure 6).



Figure 6. Trend by line page – index score and KPI analysis of the potline.

7.4 Index Report Logic

Index Report Logic page provides the key information about the KPIs table which is used to filter the potline and generate the list of pots with maximum index score. Refer to Table 1 describing target values along with the acceptable range and index score assigned. This information is useful to understand the logic working behind the generation of the Critical Pots Index Report.

8. Conclusions and Way Forward

The Critical Pots Index Report is used by EGA Al Taweelah Potline 3 operation team daily. The default setting of the report is configured for established pots (pots with age >56 days), but the pot age filter can be changed to pot early operation. The pots listed by the report are attended with top priority by taking the corrective actions for the deviated KPIs. This report is auto generated from latest datasets, hence accurate information is available in real time to make appropriate decisions to restore pot stability.

Moreover, this report also provides information about the potline operation trend which help the management to make decision for resource allocation in case of increasing index score. The Critical Pots Index Report was configured for EGA Al Taweelah Potlines 1 and 2 with DX Technology in July 2023. In the next phase, this report will be configured for Jebel Ali potlines.

9. References

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