Wireless and Automated Preheat Monitoring of Aluminium Reduction Cell

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Abstract

This paper discusses the transformation from a manual preheat monitoring system to a wireless automated one in the potlines at EGA's Jebel Ali site, improving the monitoring and control of aluminium reduction cell preheat. Aluminium is produced in reduction cells, where the cathode is made from a combination of lining materials and carbon. The cathode has a limited lifespan of 5–7 years and needs to be relined after its service life. Proper preheating of the cell is essential for both smooth operation and maximising the cell lifespan. Gradual and controlled preheating of the lining material and cathode carbon is necessary before adding liquid bath at approximately 960 °C. If cell temperature is too low when the bath is introduced, thermal shock may cause cracks in the cathode, which shortens the cell life. Traditionally, the temperature during the preheating process was measured manually. However, the conditions for measurement are challenging due to high heat and fumes, and manual temperature measurement is labour-intensive and prone to error.

This paper describes how EGA developed and implemented a wireless automated preheat monitoring system. The new system tracks the real-time temperature of the cathode and directly transfers the data into Pot Monitoring System (iPots) and allows live monitoring from the supervisor control room. The system can detect temperature deviations, check the uniformity of preheat temperatures across the cathode surface, and trigger alerts and voice alarms through EGA's Pot Control System. By measuring the temperature at a higher frequency than manual methods, the system can detect abnormalities in real time, enabling faster corrective actions. This not only increases the accuracy of the data but also reduces human error and the resources required for manual temperature measurement and data entry. Overall, the shift to an automated, wireless system has improved preheat monitoring and control, enhancing the efficiency of the potline and contributing to the longer lifespan of the cells.

Keywords: Cell preheating, Aluminium reduction cell, Wireless preheating monitoring, Potlife, Live preheat monitoring.

1. Introduction

Emirates Global Aluminium is the world's largest 'premium aluminium' producer and the biggest industrial company in the United Arab Emirates outside oil and gas, producing 2.69 million tonnes in 2024. The company operates a bauxite mine, an alumina refinery, two aluminium smelters and two aluminium recycling plants. In the two aluminium smelters, located at Jebel Ali and Al Taweelah, EGA operates seven cell technologies, developed inhouse since 1990, given in Table 1.

Table 1. EGA cell technologies and 2024 hot metal production.

Smelter and Location	Technology	No of Cells	Production in 2024
Jebel Ali, Dubai	CD20, D20, D18+, D20+, DX, DX+ Ultra	1577	1.13 Mt/y
Al Taweelah, Abu Dhabi	DX, DX+, DX+ Ultra	1266	1.56 Mt/y

An aluminium reduction cell has a limited operational lifespan of 5 to 7 years, after which it must be relined—primarily involving the replacement of the cathode—before being returned to service. Each year, approximately 15 % to 20 % of the total EGA cells undergo the relining, preheating, and startup process as they reach the end of their service life.

2. Preheating of Aluminium Reduction Cells

Aluminium reduction cell has to be preheated before start-up. The preheating stage slowly raises the cell materials from room temperature to operating temperature of 960 °C. Proper preheating of the cell ensures smooth transition from power-on to the normal cell operating condition to minimise the risk of an early cell failure caused by thermal stresses within the cathode materials [1–2]. Preheating and start-up of aluminium reduction cells have been estimated to contribute to about 25 % of all the factors that affect cell life [3]. The other main factors here are design, materials, construction, and operation.

EGA uses electrical preheat of cells where a coke or graphite resistor bed on top of cathode blocks generates the required heat [4] The quality of preheated cathode is evaluated by many factors, such as the final average cathode surface temperature, the final cathode surface temperature distribution, the vertical temperature gradients down through the cathode materials, the heat-up rate during the preheating and the anodic current distribution.

The duration and final temperature of the preheating are determined by the heat loss from the cell and the energy input to the preheating equipment. A significant portion of the input energy is typically lost as heat to the surroundings. By improving the cell insulation, the preheating time could be reduced by several hours with the same results and faster metal production.

2.1 Challenges of Manual Measurements

Traditional methods of temperature monitoring during aluminium cell preheating involve manual measurements taken every two hours from the start of preheat until bath-up. This process is labour-intensive, time-consuming, and exposes workers to health and safety hazards, including high temperatures and potentially harmful gases (Figure 1). Manual readings are also prone to several challenges such as misread values, misplaced data logs, and delays in data recording. These issues can result in inefficiencies, missed anomalies, and delayed corrective actions, potentially compromising the quality of the preheat process and the longevity of the cell.

2.2 Limitations of Wired Sensors

Wired monitoring systems, such as data logger-based devices used in EGA potlines, present several operational and safety challenges. These systems require an external power supply, introducing a significant risk of electrical hazards. Additionally, data must be manually retrieved and transferred to the reporting system, limiting real-time visibility from the control room. The process of routing cables from the cell to the data logger not only creates unsafe working conditions but also increases setup time, costs, and labour demands. Wired configurations also lack flexibility, making them less adaptable to evolving operational needs.

Figure 1. Manual temperature measurement during the cell preheating.

Continuous monitoring of cathode temperature throughout the cell preheating stage is highly desirable for ensuring optimal cell performance and longevity. However, the environment at the measurement points poses significant challenges. These include extreme heat, high levels of dust, exposure to harmful gases and electrical hazards. Such conditions demand robust and reliable temperature sensing solutions capable of operating safely and accurately under harsh industrial conditions.

3. Implementation of Wireless and Automated IoT Sensor Solutions

EGA is focused on implementing wireless and automated Internet of Things (IoT) sensor solutions, which digitally interconnects physical devices, to significantly reduce the need for manual temperature measurements during the preheating process. This transition not only enhances operational efficiency but also prioritises worker safety and environmental sustainability.

By automating the temperature monitoring process, the margin for human error is drastically reduced, ensuring accurate, real-time data collection. This shift leads to more data-driven decisions that are based on precise information, improving both the efficiency of the preheating process and the overall performance of the aluminium reduction cells.

Wireless sensor solutions offer a safer and more flexible alternative to traditional wired connections. These advanced sensors eliminate the risks associated with physical wiring, reducing potential safety hazards in high-temperature and hazardous environments. Additionally, wireless systems provide greater flexibility in terms of installation and scalability, making them a suitable fit for the dynamic needs of the aluminium industry.

4. Preparation and Installation of Wireless Preheating Monitoring System

One of the most significant advantages of wireless IoT sensors is their simplicity and speed of installation. Designed with user convenience in mind, these sensors can be deployed within minutes, eliminating the need for prolonged downtimes or complex setup procedures. Their wireless architecture allows for flexible placement in optimal locations, free from the limitations of traditional cabling. In addition to easy installation, these sensors are engineered for long-term reliability, offering a battery life of 4 to 5 years under continuous use. This minimises maintenance requirements and ensures consistent, uninterrupted performance over extended periods.

4.1 Thermocouple and Wireless IoT Sensor Installation

Before installation, the functionality of each thermocouple is verified by cross-checking with a Fluke meter. Thermocouples are prepared with extension cables of suitable length according to the installation location and attach male plug connectors. The thermocouples are then installed as per the Standard Operating Procedure (SOP) and secured with clamps as illustrated in Figure 2.

Figure 2. Installation of thermocouples and wireless sensors for cell preheat.

These devices are available in two configurations: one with a single thermocouple connector and another with four thermocouple connectors. The appropriate configuration is selected based on the number of preheat measurements required, as specified in Table 2 below.

Table 2. Preheat measurement and sensor configuration for EGA technologies.

Technology	No of measurements	Sensor configuration in Tap End	Sensor configuration in Duct End
CD20, D20, D18+, D20+	2 (T1, T2)	Single probe device (T1)	Single probe device (T2)
DX, DX+, DX+ Ultra	5 (T1, T2, T3, T4, T5)	Four-probe device (T1, T2, T3, T4)	Single probe device (T5)

Thermocouples T1, T2, T3, and T4 are connected to the tap-end sensors in their designated slots and T5 is connected to the duct-end sensor. These sensors are compact, enclosed units equipped with sockets for thermocouple pins and feature a magnetic base, allowing them to be conveniently mounted on any steel surface of the superstructure.

After connection, the sensors ere reset to ensure a proper functionality. The IoT-based sensors transmit accurate temperature measurements wirelessly, ensuring stable readings throughout the preheating process.

4.2 Device Assignment and Data Integration

After installation, the potline supervisor receives the sensor IDs along with the corresponding location details. The supervisor is responsible for assigning each sensor to the correct cell in iPOTS, including the location and cell number, at the time of cell cut-in, as illustrated in Figure 3.

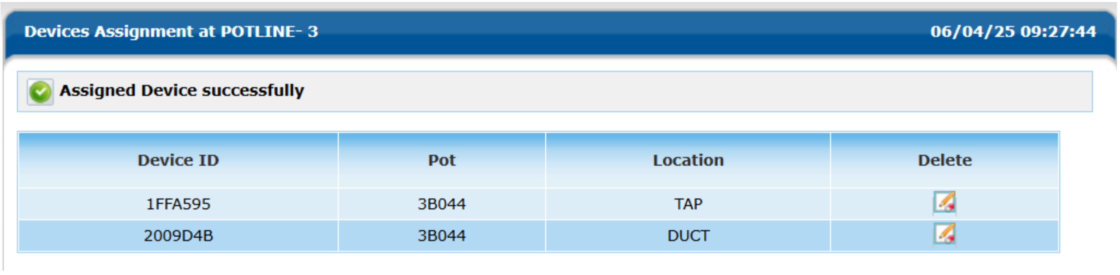

Figure 3. Wireless sensors assignment screen in iPOTS.

This assignment enables proper data integration and live monitoring of the preheat temperature. The system ensures that the cell is in the preheat stage before allowing device assignment and incorporates safeguards to prevent incorrect assignment to live or cut-out cells. Furthermore, the system automatically unassigns the sensors once the cell transitions to the bath-up stage. Before this transition, the preheat team disconnects the sensors from the thermocouples and stores them securely for future use.

5. Data Integration Architecture

The EGA Information Technology (IT) ensures that preheat temperature data collected from the field is seamlessly integrated into our software applications. Figure 4 illustrates the typical data integration workflow from IoT sensors to the end-user interface.

The wireless sensors transmit data to the Oracle Enterprise Manager (OEM) cloud, from where it is securely transferred to the EGA's cloud. The data is then routed to the EGA's central database and integrated with various industrial applications—such as iPOTS for real-time preheat temperature monitoring and iRPMS for automated report generation, including temperature-related calculations.

This end-to-end integration supports real-time analysis and data-driven decision-making, significantly enhancing operational efficiency across the organization.

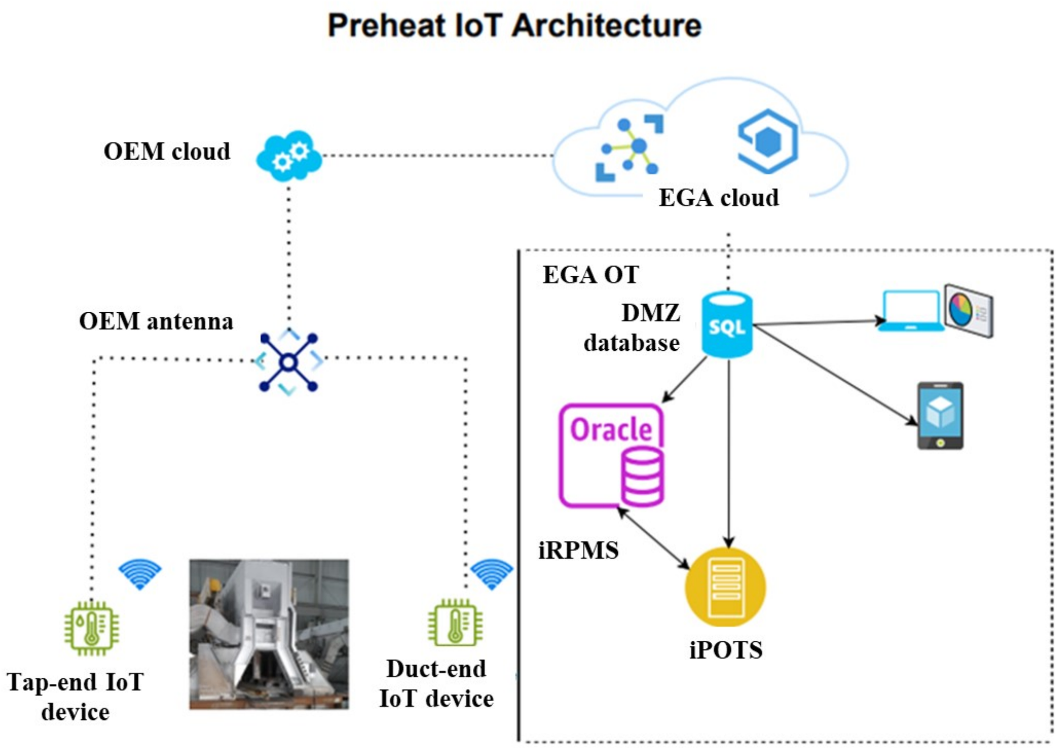

Figure 4. Wireless sensors data integration into proprietary software.

5.1 Live Preheat Monitoring Through iPOTS & iRPMS

Industrial software platforms such as iPOTS enable real-time monitoring of preheat temperatures by leveraging data from IoT-based wireless sensors. These systems provide continuous visibility into the preheating status of each cell, with live temperature feeds, alerts, and trend analysis seamlessly integrated into the existing cell resistance trace graph. This unified graph presents key parameters – including line amperage, resistance and preheat temperature – on a single screen, offering a comprehensive view of cell performance as illustrated in Figures 5 and 6.

Live temperature data is being captured in the iRPMS system in parallel with iPOTS, which provides detailed trends of the preheat rate and the temperature difference between both ends of the cell as illustrated in Figures 7 and 8.

Bath-up clearance will be issued based on the final preheat temperature. Preparation of the liquid bath in adjacent pots for the bath-up process is guided by the pot current preheat rate and the forecasted bath-up time.

Previously, during manual temperature measurements, there were considerable delays in the bath-up process even after the target preheat temperature had been achieved. This resulted in reduced productive pot availability.

With real-time temperature data now available, operators can monitor preheat rates accurately and plan the preparation of liquid bath from adjacent cells more effectively. This enables timely bath-up operations, reducing delays and enhancing overall metal production efficiency.

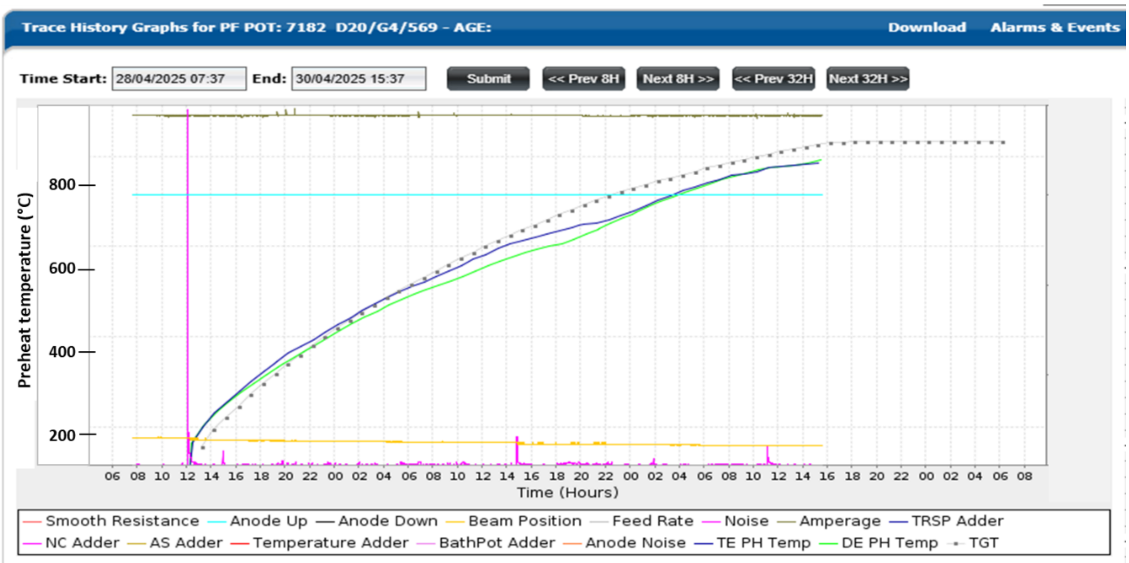

Figure 5. Wireless sensors data integration into iPOTS (2 Thermocouples #7182) – adjusted for preheat vertical scale. In the legend: TE PH Temp = Tap end preheat temperature, DE PH Temp = Duct end preheat temperature, TGT = Target temperature.

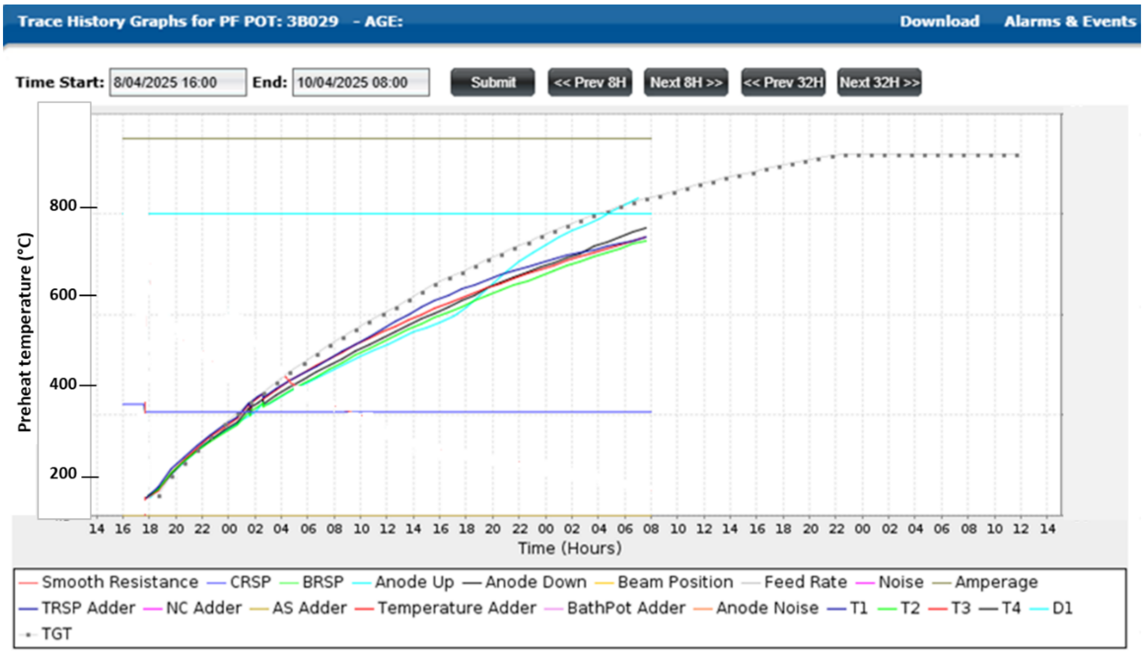

Figure 6. Wireless sensors data integration into iPOTS (5 Thermocouples #3B029) – adjusted for preheat vertical scale. In the legend: T1, T2, T3, T4 = Tap-end device preheat temperature, measured along cell centreline, D1= Duct-end device preheat temperature, TGT = Target temperature.

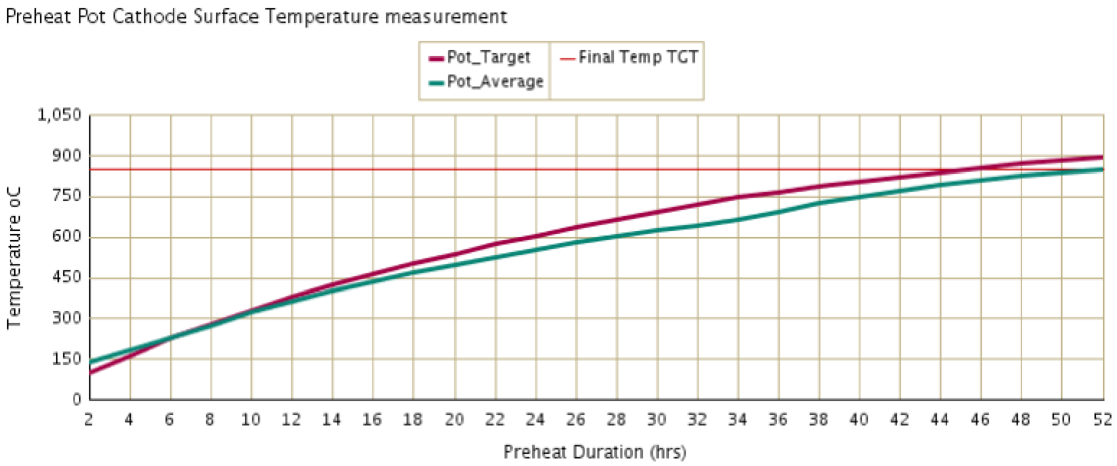

Figure 7. Preheat temperature integration into iRPMS (2 Thermocouples # 7182).

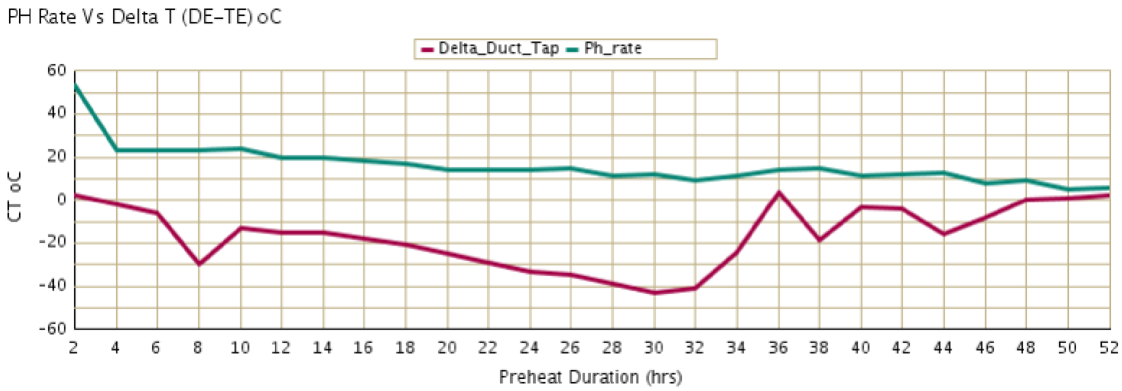

Figure 8. Preheat rate data integration into iRPMS. (2 thermocouples # 7182).

5.2 Abnormality Detection with Audio Alerts

Automated preheat temperature monitoring is continuously tracked through wireless sensors, with the target preheat temperature updated in the system throughout the preheat duration. If any deviation from the target value is observed at specific locations, whether on the high or low side of the target, the system triggers an alert for high or low preheat rates. Additionally, if a deviation is detected between the extreme ends of the cell, the system will alert for uneven preheat temperatures, allowing for timely corrective action.

These alerts are integrated with the shop floor audio announcement system and supervisory control room, ensuring immediate awareness and enabling quick response to prevent potential issues.

5.3 Automated Preheat Report.

The automated preheat temperature data were directly captured into the iRPMS report in real time. Technicians used to manually enter these data after the completion of preheat to maintain the cell preheat record in the system. This consumed many manhours. Along with that, related calculations were made manually in Excel and then transferred into the report, illustrated in Figure 9.

EGA **Final Preheat Report** iRPMS

RRQ019 Line : 9 Pot : 57 Cath ID :402284 Bathup Date : 19/01/2025 03:29 22/01/2025 12:03

Date	PH Duration	Amp (kA)	Volt (V)	PH Energy (kWh)	Temp TGT	Tap End o C	Duct End o C	Avg Temp	Delta (DE-TE)	PH Rate	Comments
17/01/2025 06:15	2	262	3.42	1792	100	130	134	132	4	49	
17/01/2025 08:15	4	262	3.24	3490	164	182	200	191	18	30	
17/01/2025 10:15	6	262	3.17	5151	228	234	266	250	32	30	
17/01/2025 12:15	8	262	3.25	6854	282	285	332	309	47	29	
17/01/2025 14:15	10	262	3.37	8620	332	340	398	369	58	30	
17/01/2025 16:15	12	262	3.33	10365	381	409	449	429	40	30	
17/01/2025 18:15	14	262	3.40	12147	425	479	504	492	25	31	
17/01/2025 20:15	16	262	3.44	13950	465	548	552	550	4	29	
17/01/2025 22:15	18	262	3.18	15616	502	604	614	609	10	30	
18/01/2025 00:15	20	262	3.08	17230	539	630	650	640	20	16	
18/01/2025 02:15	22	262	3.10	18854	576	655	666	661	11	10	
18/01/2025 04:15	24	262	2.98	20416	607	691	672	682	- 19	11	
18/01/2025 06:15	26	262	3.04	22009	638	724	739	732	15	25	
18/01/2025 08:15	28	262	2.86	23508	667	735	756	746	21	7	
18/01/2025 10:15	30	262	2.75	24949	695	742	770	756	28	5	
18/01/2025 12:15	32	262	2.98	26511	723	760	790	775	30	10	
18/01/2025 14:15	34	262	2.86	28010	747	778	809	794	31	9	
18/01/2025 16:15	36	262	3.00	29582	769	797	829	813	32	10	
18/01/2025 18:15	38	262	2.57	30929	789	815	845	830	30	9	
18/01/2025 20:15	40	262	2.68	32333	806	831	862	847	31	8	
18/01/2025 22:15	42	262	2.63	33711	825	847	879	863	32	8	
19/01/2025 00:15	44	262	2.94	35252	840	865	896	881	31	9	
Final/Avg	44	262	3.06	35252	840	865	896	881	31	19	

Figure 9. Automated preheat report on real time in iRPMS.

Now all the calculations are automated, and the trends are captured in the report. IT helps to maintain the accurate record by reducing error due to manual entries. Before it took a long time for report authorization and publishing the preheat report for a new cell; now this delay time has been reduced drastically.

6. Implementation and Usage Tracking

At EGA's Jebel Ali site, the wireless preheat monitoring solution was first introduced as Proof of Concept (POC) in the third quarter of 2023. Following positive results, the system was enhanced with additional features and scaled for full deployment across all Jebel Ali potlines. While the initial rollout encountered technical challenges and change management issues, these were effectively addressed over time, resulting in a more streamlined implementation process. As of now, the Jebel Ali site is nearing full implementation, with approximately 95 % of the potlines utilising wireless preheat monitoring as illustrated in Figure 10.

Building on this success, the deployment of the solution has now expanded to the EGA's Al Taweelah site. This new phase involves slight modifications in the system configuration to align with the specific cell design and construction requirements.

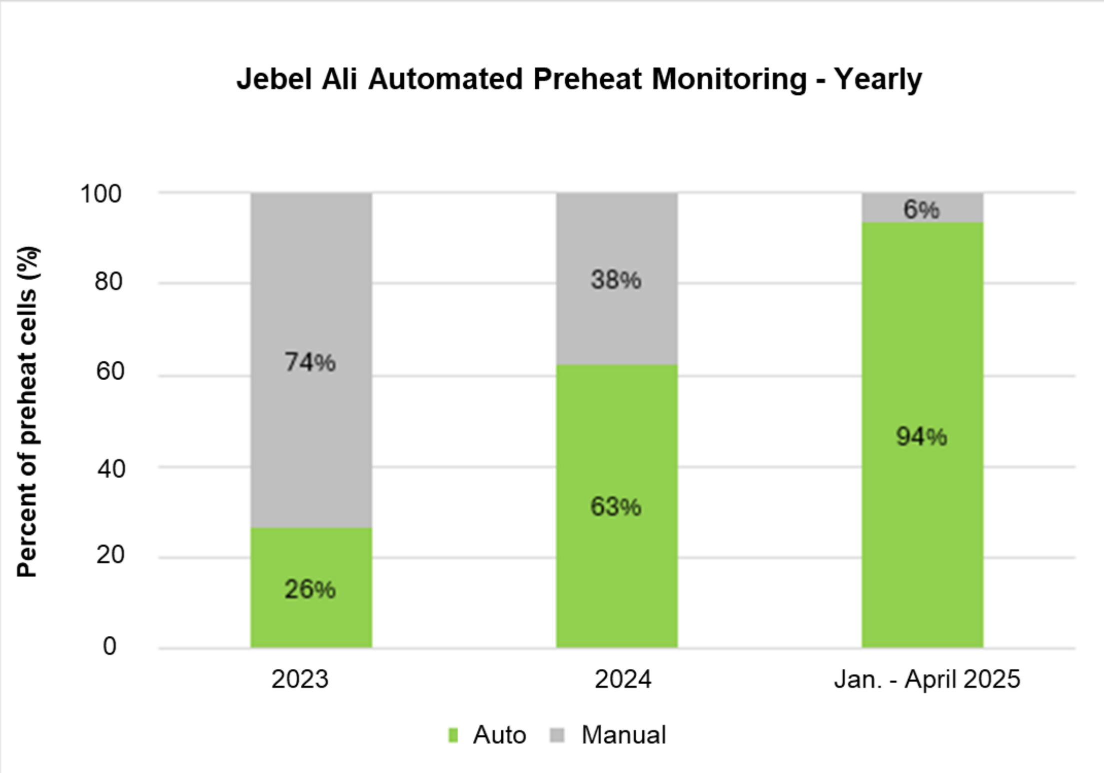

Figure 10. Wireless preheat monitoring implementation & usage at EGA Jebel Ali site.

7. Digital Transformation in the Aluminium Industry

Digitalization is now a necessity in the aluminium industry. Like many other sectors, the industry is embracing the digital revolution to optimise processes, reduce costs, and enhance product quality. The integration of new technologies, digital tools, and IoT systems enables aluminium producers to gather, analyse, and leverage data more effectively than ever before, driving greater efficiency and competitiveness.

8. Conclusions

The automated wireless monitoring system offers high-frequency, accurate preheat temperature measurements, surpassing manual methods. Continuous data collection establishes a strong foundation for optimising operations, with historical data supporting quality assurance efforts. By eliminating time-consuming and risky manual measurements, the system enhances safety, reducing potential health, safety, and environmental hazards.

Wireless sensors enable quick and easy installation, while direct integration into proprietary software systems such as iRPMS, iPOTS, and Smelter Analytics facilitates real-time monitoring of preheat trends. Early detection of abnormalities allows for prompt corrective actions, minimising material damage and production loss. The system also provides timely audio alerts, instantaneous quality evaluations of the cell preheating, and rapid report generation, all with minimal process time.

As EGA looks toward the smelter of the future, wireless sensor solutions will play a pivotal role. These innovations represent more than just technological progress—they embody EGA's deep commitment to innovation, operational safety, and environmental sustainability. By enabling real-time monitoring, predictive insights, and streamlined operations, wireless sensors are helping to create a more efficient, resilient, and future-ready aluminium industry.

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