NOx Emission Reduction in Kiln-5 at ALBA (Aluminium Bahrain)

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Abstract

The anode baking process is highly energy-intensive, requiring approximately 2 GJ/t of baked anodes. In this process, refractory walls are heated by direct gas injection from the top of the furnace to bake the anodes. However, combustion emissions, particularly nitrogen oxides (NOx), have become a significant concern in industries that rely on fossil fuels. NOx generation in kilns results from a combination of thermal NOx, fuel NOx, and pitch volatiles combustion efficiency. Thermal NOx are formed during combustion of gas and air mixture at high baking temperatures (> 1 170 °C) inside the flue. ALBA Kiln-5 had been experiencing high NOx levels (> 250 mg/Nm^3) since its inception, which was a major issue. Under the Environmental, Social, and Governance (ESG) initiative, reducing NOx emissions was a top priority for ALBA. This paper presents the experiences of ALBA in successfully reducing NOx emissions from >250 mg/Nm^3 to below 100 mg/Nm^3 consistently. This achievement was made possible through various in-house trials and optimization of baking parameters, and the installation of ultra-low NOx burner nozzles in all fire groups. The introduction of specially designed low NOx burner nozzles resulted in a significant reduction in NOx emissions without compromising the baking process, anode quality, or thermal homogeneity inside the flue wall.

Keywords: Carbon anodes, Baking kiln, Thermal NOx, Low NOx burners, Fuel combustion.

1. Introduction

Aluminum Bahrain (ALBA), is the world's largest single-site aluminum smelter outside of China, with an annual aluminum production capacity of over 1.6 million tonnes, is renowned for its technological advancement and innovative strategies. ALBA's Kiln 5 was commissioned in 2019 as part of the ALBA's Line 6 project. This kiln consists of 68 sections and 4 fire groups, operating on a nominal fire cycle of 24 hours. Waste gases are treated with alumina in the Fume Treatment Centre (FTC) to reduce fluorides and other contaminants, and clean gases are released into the environment via the stack. The FTC is equipped with three Induced Draft fans to create adequate draft to run the fires, a cooling tower to cool down the gases, 8 bag filters, and silos for fresh and treated alumina. The nominal gas flow to Kiln-5 FTC is 115 000 Nm^3/h. Natural gas is used as fuel and is injected into the flue walls through burner nozzles installed on burner ramps to achieve anode baking level (Lc) close to 34 Å.

2. NOx Emission at ALBA Kiln-5

NOx has a detrimental impact on both human health and the environment, causing respiratory diseases and contributing to the formation of acid rain when it reacts with the atmosphere. Since inception, Kiln-5 NOx emissions from the FTC stack were in the range of 280–300 mg/Nm^3 (Figure 1). In 2023, ALBA management decided as part of environmental continuous improvements to reduce the NOx emissions limit to 150 mg/Nm^3.

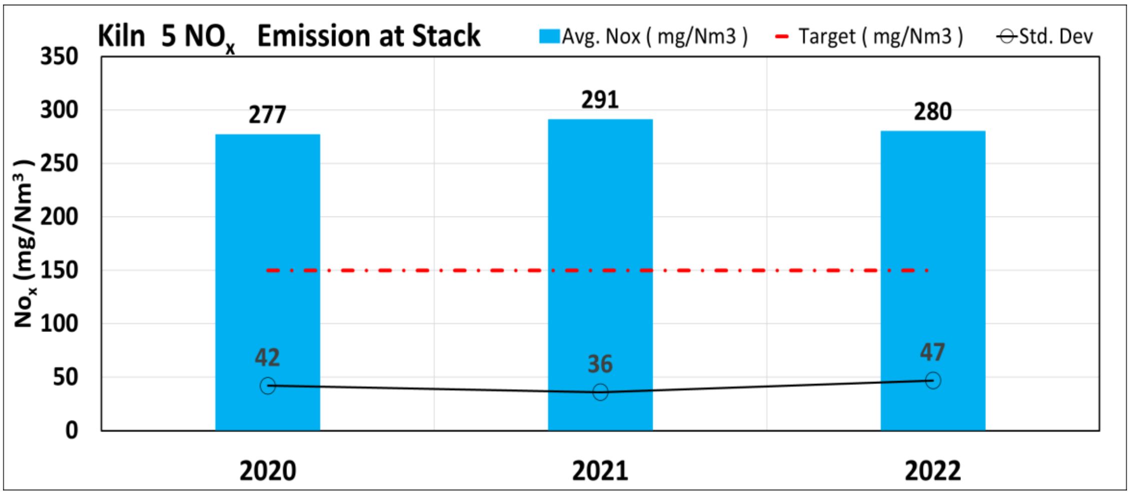

Figure 1. NOx emission from kiln 5 (blue) and target (red).

In kilns NOx generation is a result of a combination of thermal NOx, fuel NOx, and pitch volatiles combustion efficiency. Nitrogen oxides (NOx) are primarily generated by the firing control system, and there is no simple method to reduce them at the stack level. Therefore, NOx formation to be reduced at source to reduce stack emission.

3. NOx Reduction by Process Optimization (Initial Trials)

Thermal NOx is formed at high flame temperature combined with high air concentration. Initial trials were done to reduce thermal NOx formation during firing, by optimization of process parameters and fine tuning of gas injection into the flue walls:

- Burner pulse duration was increased from 0.4 s to 1.2 s to increase flame volume and reduce heat flux density.
- The fuel gas nozzle tip was retracted from 30 mm to 50 mm away from the burner tip to reduce average velocity of the fuel gas jet to reduce flame peak temperature.
- Improved sealing of the burner nozzle by inserting ceramic wool between nozzle base plate and the top of the peep hole cover to prevent air ingress during pulsing.

After implementing above changes in the firing system, the average NOx content measured at the FTC stack was reduced from 282 to 252 mg/Nm^3 (Figure 2). However, the target value of 150 mg/Nm^3 was not achieved. Another trial was conducted by reducing gas peak temperature by 10 °C, NOx emission reduced slightly but baking level dropped significantly, so trial was reverted immediately. ALBA objective was to reduce NOx emissions below local legal limits without compromising on anode quality and performance in pot rooms.

Table 1. NOx reduction project summary: KPI Evaluation.

Parameter /observation	Before NOx Reduction Project	After NOx Reduction Project
NOx Emission level (mg/Nm^3)	250–300 (Std.Dev. 39)	75 (Std.Dev. 18)
Burer's nozzle service life (Month)	9	9
Baking process	Stable, complete pitch burn	Stable, complete pitch burn
Anode Baking Level(Å)	> 34 (Std.Dev. 1.1)	> 34 (Std.Dev. 0.9)
Refractory temperature (°C)	93 % reading < 1 370 °C, No hot spot	96 % reading < 1 370 °C, No hot spot
Gas Consumption (GJ/t BA)	1.80	1.75

6. Conclusions

To comply with the new stringent environmental regulations, ALBA has adopted latest low NOx burners nozzle technology. NOx emission from stack reduced by two thirds with the implementation of new generation burner nozzles and fine tuning of process. With the successful completion of the NOx reduction project, ALBA has set a precedent by demonstrating its commitment to environmental protection, a key ESG goal. The kiln operation is now running smoothly and safely with the new burners. ALBA achieved reduction in NOx emission below local stringent emission limits with no negative impact on baking process, anode quality, flue wall life and gas consumption.

7. References

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