New Generation Anode Baking Furnace: a Breakthrough Technology Increasing Productivity and Sustainability

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Abstract

The anodes used for aluminium production are baked in order to reach the resistivity, mechanical resistance and reactivity adequate for the electrolysis process. The anodes are baked in pits that are usually separated from each other by fluewalls and headwalls made of dense refractory material. In 2017, an industrial prototype of the new generation anode baking technology was installed at the Bell Bay smelter with 6 sections converted to this patented technology. The headwalls were partially removed to allow a productivity increase by 15 % and gas consumption reduction by 30 %. The operation and maintenance of this breakthrough technology has raised some challenges which have been overcome with the development of new tools and operation/maintenance procedures, as well as some design improvements that have been implemented during the rebuild of this zone in 2021, after 82 rounds of fire. As a second and a third zone are planned to be built on the Bell Bay furnace in 2022, this paper reviews the exceptional performance of the first industrial prototype, as well as the issues and challenges related to the deployment of this technology on a complete furnace.

Keywords: Anodes in aluminium electrolysis, New Generation anode baking furnace, Rio Tinto Bell Bay.

1. Introduction

In an open-type Anode Baking Furnace (ABF), anodes are placed in pits separated by hollow fluewalls, through which hot gases flow during the baking phase and air flows during the cooling phase. Sections are separated by headwalls through which flue walls in the same row are linked between one section and the next, thereby forming individual flue wall lines extending along the entire furnace.

The headwalls constitute 20 to 25 % of the dense refractory mass installed in the furnace. They are heated and cooled during each fire cycle, which requires a large amount of gas and limits the ability to rapidly cool the anodes. The sealings between the fluewalls and the headwalls need regular maintenance, during which refractory maintenance operators enter the confined space of the pits and renew the fibers under difficult conditions: high temperature, working at height, presence of dust and fibers. Based on those considerations, a concept of New Generation (NG) anode baking furnace was proposed [1, 2].

After several developments and the installation of a pilot zone in one of the furnaces at Grande-Baie plant, the implementation of this technology on six sections of the Bell Bay Aluminium (BBA) furnace was realized in 2017 [3].

The purpose of this article is to review the performance of the first generation of the New Generation design implemented in BBA after nearly five years of operation and to detail the improvements integrated in the current and future works.

2. New Generation Anode Baking Furnace concept

2.1 Concept of the New Generation (NG) Technology

The concept of the NG patented technology [1, 2] is to remove totally or partially the headwalls as presented in Figure 1. It is applicable to both furnace revamping and new projects. For existing furnaces, it allows to increase the volume available for anode baking inside the pits. The number of headwalls to be removed should be selected depending on the anode dimensions to accommodate either an extra set of anodes or an increase in anode dimensions.

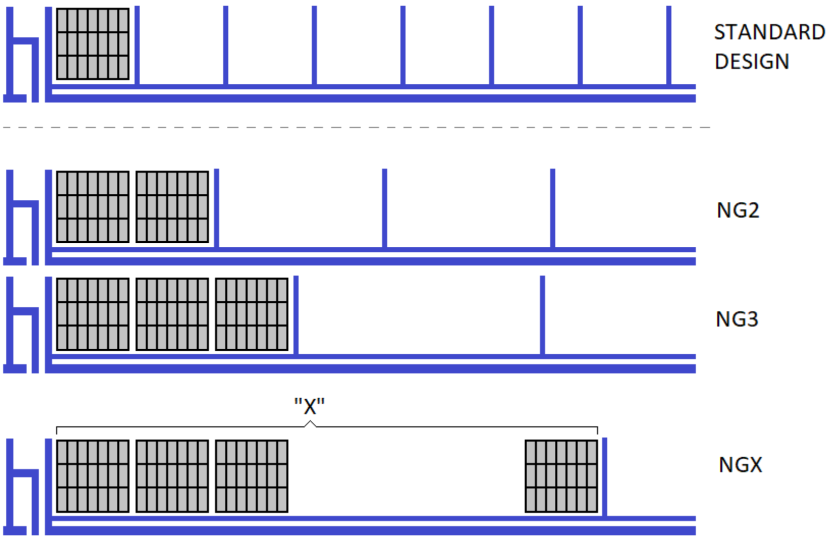

Figure 1. Concept of the New Generation Technology.

2.2 Headwall functionalities and challenges with their removal

The key role of the headwalls in the standard ABFs is the following:

- Allow for thermal expansion of the fluewalls
- Mechanically support fluewalls when pits are empty
- Separate sections (delimitation for operation sequence)

As the headwalls are removed in the NG design, it has been necessary to develop technical solutions and to adapt operational practices to assure the above functions. In particular, the NG design should allow the accommodation of the fluewall for thermal expansion which is usually allowed via the expansion gaps located at the junction between the headwall and the fluewalls in the standard design (see upper part of Figure). As headwalls are no longer present, the internal design of the fluewall was modified so that the expansion and contraction can be handled by the fluewall itself through dedicated zones, called “breathing zones” (see lower part of Figure). The design of bricks used in these areas has been modified so that relative movements between bricks is less inhibited in these locations compared with the rest of the fluewall.

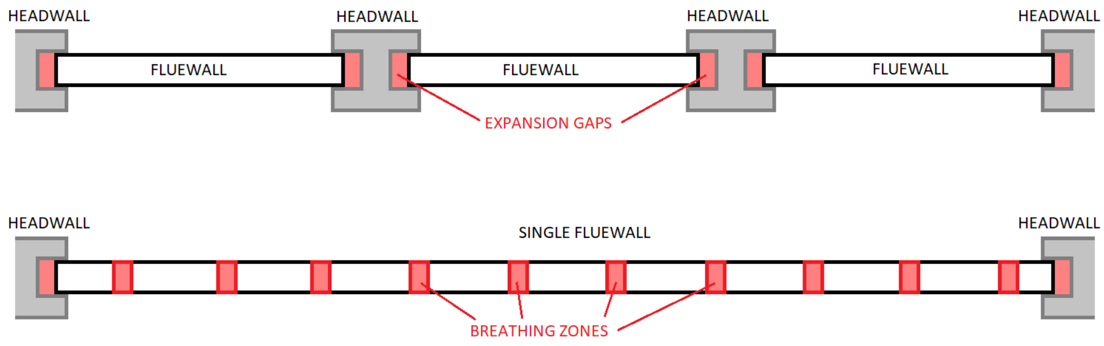

Figure 2. Classical design (top) vs. NG technology (bottom).

2.3 Six Section Trial at Bell Bay Aluminium

The anode baking furnace at BBA was constructed in 1989: the furnace has 3 fires with 48 sections, and 7 pits per section. Each pit is stacked with 7 layers of 4 anodes (horizontal loading).

With the necessity to rebuild some sections in the furnace in 2017 and the need for BBA to increase the anode production, an opportunity arose to use the NG design on one zone of this furnace.

At that time, the NG design had been under trial since 2013 in Grande-Baie plant and several modelling activities had shown the potential for BBA to merge 6 sections into one [4].

The following benefits were expected:

- Increased anode production (for no change in fire cycle) by providing pit space to fit a seventh anode pack into the six sections pit (see Figure 3),
- Health and safety improvements from reduced refractory maintenance and sealing required in the pits,
- Reduced material cost for refractories and labour costs for refractory installation (due to the absence of headwalls),
- Reduced gas consumption,
- Reduced refractory maintenance costs.

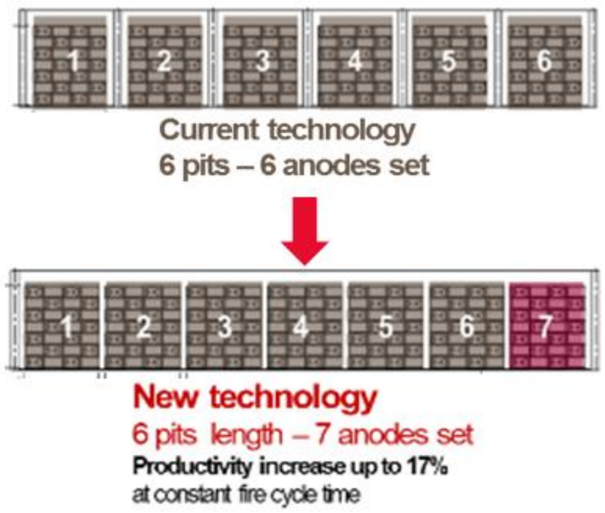

Figure 3. Anode loading pattern in BBA furnace with current and NG Technology.

The first zone was installed in December 2017 with the support of Smelter Technical Support - Pacific Operations (Brisbane, Australia) and Aluminium Technology Solutions (Voreppe, France) teams.

3. Performance Achieved for the First Industrial Trial at Bell Bay Aluminium

3.1 Safety

The first pilot zone installed in BBA was operated from December 2017 until October 2021. Over this period, no significant incident was reported during the installation, the operation or the routine refractory maintenance carried out on the zone. The suppression of five headwalls allowed to reduce the sealing maintenance by 80 %.

3.2 Refractory Condition and Maintenance

A key measure for the success of the project is the lifetime of the fluewalls. For the first generation of the pilot in BBA, a lifetime of 82 fire cycles was achieved versus a usual fluewall life of 120 fire cycles obtained on standard sections. Examples of the NG refractory condition are shown in Figure 4.

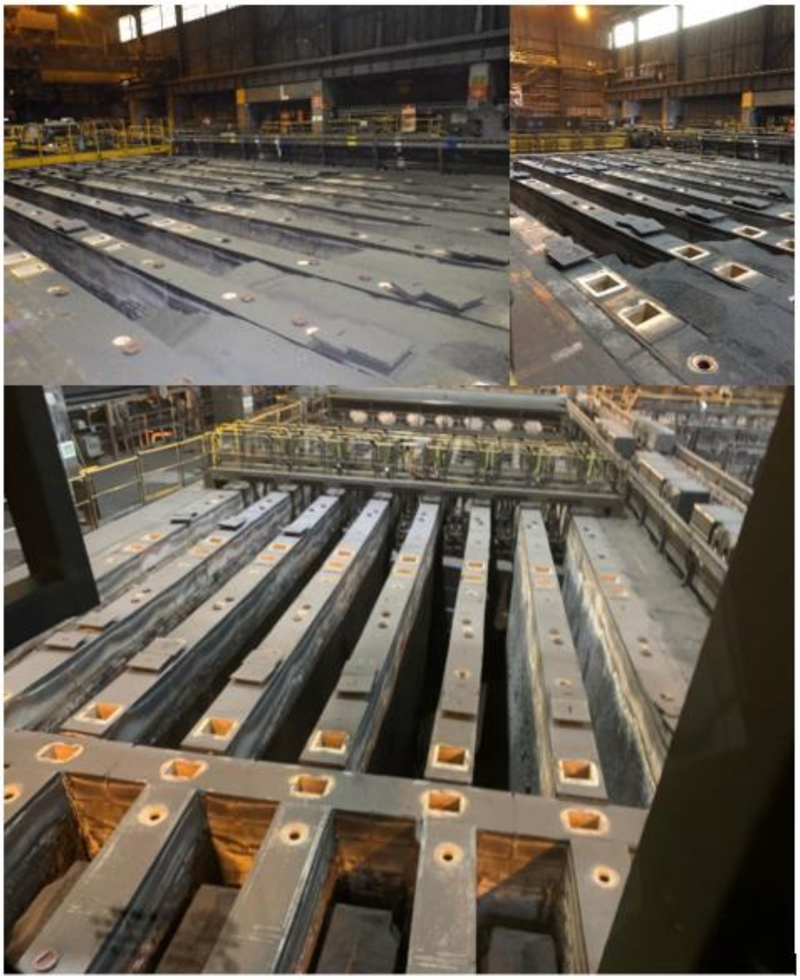

Figure 4. View of the NG zone after 21 rounds of fire (upper left), 41 rounds of fire (upper right) and at 75 rounds of fire shortly before the demolition (lower).

If it is considered that an extra set of anodes was baked in each pit at each fire cycle, the weight of anode baked for each ton of refractory laid was 17.4 for the NG versus 18.9 tba/t of refractory for the standard sections. This achievement was beyond expectations and considered an excellent performance for a first industrial prototype. An accurate follow-up with regular measuring and auditing campaigns has been realized over the full life of the pilot zone to monitor and understand the deterioration mechanisms. The main mode of degradation of the 33 m-long fluewalls was the bending. The bending began from the first fire cycle and was already critical after 20 fire cycles, with pits width varying from 630 to 910 mm instead of the nominal 750 mm (see Figure 5).

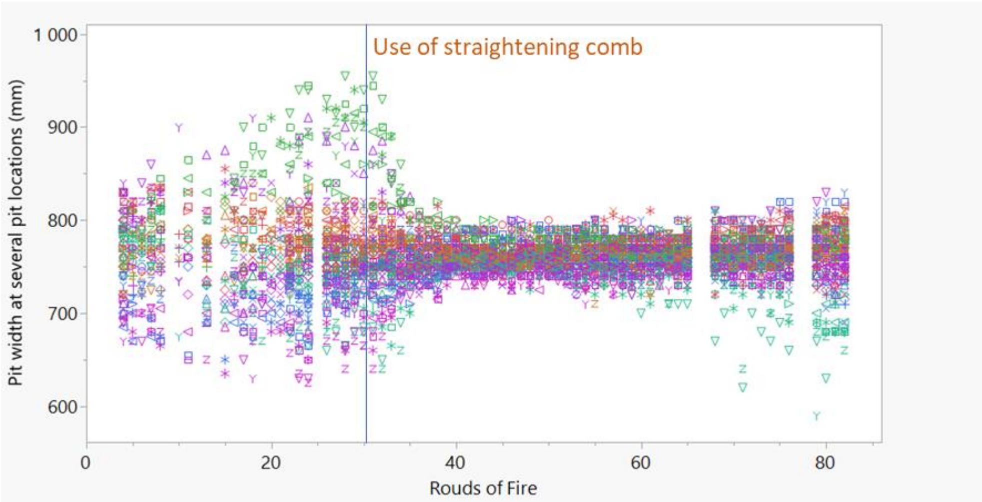

Figure 5. Measurements of pit width in several locations over the life of the NG zone.

A new tool has been developed to mitigate this effect (Figure 6): ramps equipped with hydraulic cylinders have been used at each fire cycle to straighten the fluewalls on a regular basis after the 30th fire cycle. These tools allowed a rapid return to pit width variation comprised between 730 and 800 mm.

Figure 6. View of the straightening comb during its transportation.

In parallel the emphasis has been placed on the loading/unloading procedures such that the narrow pits are loaded first and unloaded last in the sequence of operations (this procedure is a recommendation on standard sections as well, but it becomes even more necessary in the NG design with high sensitivity to bending). After 60 fire cycles, some pinching was observed under the gas injection peepholes. A campaign of V-shape repairs was carried out between two fires (with no production loss) (Figure 7). The area has been reinforced with additional tie bricks for the future rebuilds.

Figure 7. V-shape repairs being carried out to restore pinching below gas injection peepholes.

The main source of deterioration which triggered the rebuild of the NG zone was the heavy bending of the fluewalls in some areas, where some sets of anodes could no longer be unloaded. The early straightening of the NG fluewalls with the straightening combs for the next generations as well as some design modifications should extend the life of the next generation.

3.3 Anode Quality

Anode quality was assessed using the carbon crystallite size of the anode (L_c) measured on core samples. The baking level of the core samples (NG GROUP) were compared with that of a standard section of the same age (CONTROL GOUP). The comparison of the baking level of the two populations (520 core samples) shows that the distribution is similar, with the NG GROUP having a slightly higher baking level than the one of the CONTROL GROUP (Figure 8).

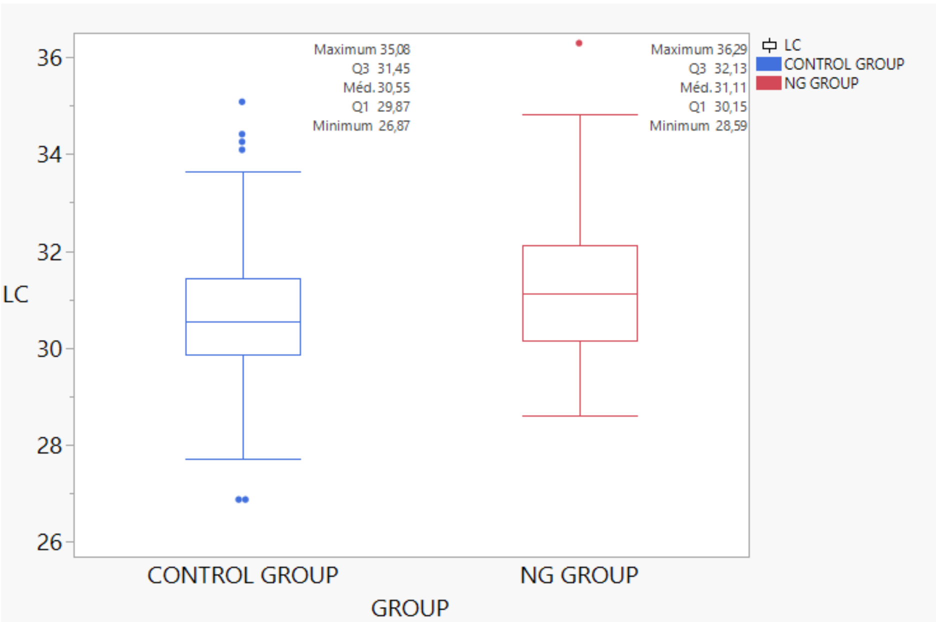

Figure 8. Box plot for the populations of core sample of the CONTROL GROUP (left) and that of the NG GROUP (right).

3.4 Gas Consumption

Gas consumption was evaluated by comparing the gas usage of the NG GROUP, which was located at the outlet of one crossover, with the sections located on the outlet of the other crossover and that had a similar age (CONTROL GROUP). The results show that 18 % less gas was injected in the NG GROUP sections than in the CONTROL GROUP over the full lifetime (Figure 9). Given that an additional set of anodes was baked in the NG group, this brings gas consumption savings to a level of 30 % if the energy per ton of baked anode is considered.

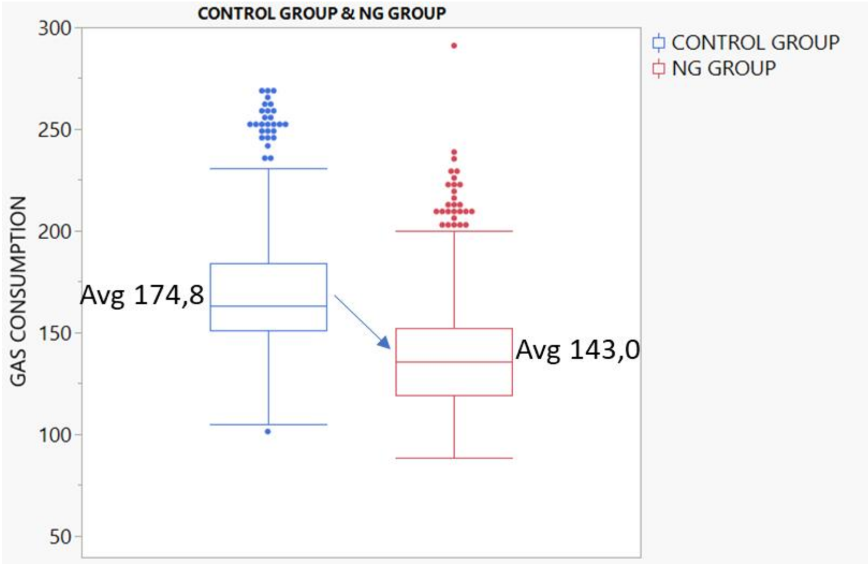

Figure 9. Box plot for gas consumption of the CONTROL GROUP (left) and that of the NG GROUP (right).

3.5 Process

No major changes have been put in place to manage the fire progression in the NG sections in comparison with the standard ones. Only minor adjustments were required to maintain a satisfactory control level on the process. The degassing front of NG sections was more active and tended to be further ahead in comparison with other sections due to the higher quantity of pitch provided by the additional set of anodes. The use of alternative preheating regulation methods [5] allowed control of the degassing front while using a higher draft. The temperature measurements of anode sets during unloading showed that the unloading temperature was reduced by 50 °C. The absence of headwalls with significant thermal inertia allows faster cooling.

3.6 Operations

Due to BBA's requirement for a higher productivity of the furnace, the nominal fire cycle time was maintained despite the additional set of anodes to be baked in the NG GROUP. The absence of headwalls to separate each section required a higher workload at the start of loading and at the end of unloading the NG zone. This creates an unevenness in the operations that must be managed with a thorough methodology of change management. The experience showed that the NG technology is less flexible with respect to operating deviations. Lasers were placed on the furnace tending assemblies to help the operators define the position of the anodes to be loaded in the absence of headwall demarcations.

4. Conclusion and Perspectives

The overall performance of this first 6-sections wide NG zone was beyond expectations.

Over the lifetime of 82 fire cycles, the NG zone allowed:

- 17 % of productivity increase (+ 8 759 anodes over the lifetime of the zone)
- 14 % reduction of CAPEX
- A gas consumption reduction by 30 % (equivalent of 613 kAUD gas savings)
- 2 654 t CO_2 savings for 1 / 8th of the furnace converted
- 80 % less sealing maintenance

The NG Technology has proven to be an appropriate solution for a productivity increase of existing anode baking furnaces; i.e. in the same furnace casing. It also provides an option for the reduction of the gas consumption/CO_2 emissions. This validates the technical and economic viability of this new breakthrough technology. However, the business case associated to this technology has to be evaluated for each plant (possibility to have an extra set of anodes, plant's need for higher productivity, storage capability, etc.).

As a result of this success, BBA has decided to rebuild the zone with the NG technology in October 2021. It has also decided to extend the NG technology to 5 other NG6 areas on the furnace by 2025. A major step was reached in July 2022 with the prefabrication of the 33 m long fluewalls in 12 lifts/fluewall, which were built in situ in the 2017 and 2021 installations. This represents an opportunity to significantly reduce the construction time, with less production loss.

5. References

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