NZAS BAKING FURNACE REBUILDS – 20 YEARS OF MULTI-SECTIONAL REBUILD METHODOLOGY

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Abstract

New Zealand Aluminium Smelters (NZAS) operates two anode baking furnaces. Each furnace is rebuilt during operation (i.e. “on the run”) when required based on flue wall condition. The methodology employed involves replacement of up to five adjacent sections and is unique within the Pacific Aluminium group. A fire group is temporarily removed from operation to provide access to a large part of the furnace. Flue wall and head wall pieces are pre-built outside of the furnace then lifted into the furnace and joined in-situ. The installation process is typically repeated ten times over the course of the rebuild which has a total duration of 20 to 24 months. The methodology has been successfully used at NZAS in the two rebuilds of each furnace since 2002. The process is explained with discussion of advantages and disadvantages compared to alternate rebuild methodologies.

Key words: refractory, CBF, ABF, rebuild, multi-section

Introduction

Carbon anodes at New Zealand Aluminium Smelters (NZAS) are baked in two open baking furnaces, CBF1 and CBF4. Each baking furnace contains a network of hollow flue walls through which hot gases flow to provide heat to bake the anodes (Figure 1). Head walls separate the furnace into manageable sections for operational activities (including loading, baking and unloading of anodes).

CBF1 was originally constructed as a 60-section Kaiser furnace in 1971, while CBF4 was originally constructed as a 48-section Alesa furnace in 1996. Subsequent rebuilds of each of the furnaces have incorporated significant design changes, particularly to the head walls, and over 1997-1998, CBF1 was converted to a 48-section furnace [1]. Both furnaces operate three fire groups at various cycle times to meet the anode requirements of the Reduction Lines. Fire cycle times typically vary between 24 and 30 hours in CBF1, and between 27 and 32 hours in CBF4.
The condition of the refractory flue walls deteriorates over time as the walls are repeatedly fired and cooled, to a point where standard maintenance practices cannot keep up with the deterioration. Flue walls then need to be demolished and replaced with new walls. Refractory deterioration can be accelerated by various factors, including high sodium content in anodes, poor quality materials or installation, excessive heat, short fire cycle times, sub-optimal operational practices and insufficient or ineffective refractory maintenance. Flue wall service life varies considerably, but is typically in the range of 100 to 200 fire cycles (approximately five to ten years).

A number of factors are considered when determining the method of furnace refractory renewal, including the maintenance strategy and the baking furnace production capacity. The following outlines these factors and details the rebuild approach used at NZAS.

**Furnace Rebuild Strategies**

There are two main strategies for replacing flue walls employed within the industry:

- Continual replacement, and
- Campaign-style rebuilds

**Continual Replacement**

Under a continual replacement strategy, individual flue walls, and sometimes pairs of adjacent flue walls, are demolished and replaced as part of an ongoing program. The top parts of the headwall (“pillars” or “piers”) are often replaced as part of this program. This strategy can be sustained for about five or six generations (approximately 25 years). After this time, a full refurbishment is required to replace the side and floor insulation (item 7 in Figure 1), and to completely replace the head walls. All flue walls are replaced as part of this refurbishment.

An advantage of the continual wall replacement strategy is the relatively steady workload and the corresponding demand for labour resources. There are also no significant peaks in capital expenditure until the full refurbishment event, which is dictated by condition of the head walls and insulation. In this way, the maximum life of the headwalls is realised, however there is a loss of value in the final generation of flue walls with most being replaced at less than their maximum potential life.
The main disadvantage of continual wall replacement strategy is that the condition of an old flue wall can negatively impact the condition of an adjacent, younger flue wall, via pressure from the packing coke in the pit between them and from anode loading difficulties. Deformation of the aging head walls can also have a negative impact on flue life.

Campaign-Style Rebuilds

A campaign-style strategy involves replacement of all flue walls as a defined project (the “rebuild”). In the period between rebuilds very few, if any, flue walls are replaced. Within Pacific Aluminium, the duration of each rebuild is typically around two years; however in recent years, rebuilds of between eighteen months and three years duration have been completed. The rebuild may be either a full rebuild or partial rebuild. In a full rebuild, all flue walls and head walls are replaced, whereas in a partial rebuild, the scope may be limited to the internal flue walls and the head wall pillars. In this case, the subsequent rebuild would likely be a full rebuild.

The campaign-style strategy has the advantage of enabling more rapid changes in pit dimensions, which may be required to accommodate anode size changes at the smelter. With a full rebuild, there is also the benefit of fully restoring the expansion gap between the head wall and flue wall, via reinstating the correct head wall positions. Disadvantages include the peak in capital expenditure and the need for project management and mobilisation/demobilisation of labour resources.

Campaign-style rebuilds often involve the replacement of one or two adjacent sections in the space between the operating baking equipment (fire groups). Hence, there is little, if any, reduction in the quantity of anode production during the project. NZAS has the advantage of spare anode baking capacity and can remove a fire group from the furnace being rebuilt to enable access to a larger group of adjacent sections. The ability to build, store and transport a large number of flue wall and head wall pieces is another enabler for the multi-sectional approach at NZAS.

**History of Multi-Sectional Replacement at NZAS**

NZAS has the longest history of multi-sectional rebuilds within the Pacific Aluminium group. Table 1 details the timing, distinguishing features and some of the improvements implemented in NZAS rebuilds over the last twenty years.

The complex project of re-configuring CBF1 from a 60-section furnace to a 48-section furnace has been previously reported [1]. The basis of the current methodology for NZAS rebuilds has not varied significantly since 2002. This methodology will be detailed in the following section, together with photographs from the 2011-13 CBF4 and 2016-17 CBF1 rebuild projects.
Table 1: Summary of NZAS Multi-Sectional Rebuilds since 1997

<table>
<thead>
<tr>
<th>Rebuild Date</th>
<th>Furnace</th>
<th>Maximum Number of Adjacent Sections Replaced Together</th>
<th>Distinguishing Feature / Improvement Implemented</th>
</tr>
</thead>
<tbody>
<tr>
<td>1997-8</td>
<td>CBF1</td>
<td>5</td>
<td>Conversion from 60-section to 48-section furnace</td>
</tr>
<tr>
<td>2002-3</td>
<td>CBF4</td>
<td>5</td>
<td>Pre-built head wall pieces used for the whole head wall for the first time within Pacific Aluminium</td>
</tr>
<tr>
<td>2005-6</td>
<td>CBF1</td>
<td>4</td>
<td>Pit width increased to match CBF4 via the use of thinner side insulation</td>
</tr>
<tr>
<td>2011-13</td>
<td>CBF4</td>
<td>5</td>
<td>Flue walls installed in two pieces (previously three pieces)</td>
</tr>
<tr>
<td>2016-17</td>
<td>CBF1</td>
<td>5</td>
<td>Furnace raised by one brick course; Reduction in the number of head wall pieces per head wall</td>
</tr>
</tbody>
</table>

NZAS Rebuild Methodology

Project Schedule

The rebuild is conducted in five distinct campaigns. Within each campaign, ten sections of flue walls and head walls are pre-built outside of the furnace and then installed in two separate groups of five adjacent sections. The exception is the first campaign when only eight sections are required, enabling a lower workload for the start of the project as the team are becoming accustomed to the process. Each pre-build phase takes approximately nine weeks and is followed by eight weeks of installation in the furnace. Each installation phase is separated into two parts, Part (a) and Part (b) in which four or five adjacent sections are demolished and installed. The team then return to pre-building walls for the next campaign. The total duration of the project is approximately twenty-two months, which includes a month of setting up and training at the start of the project.

Figure 2 shows the layout of the campaign areas for the 2011 CBF4 rebuild. Part (b) of each campaign is separated from Part (a) by the distance that the largest gap between the fire groups has moved in the time that Part (a) has been installed. This gives rise to a distinct pattern of flue ages following the rebuild. The maximum value of the flue walls is achieved by following the same replacement pattern in subsequent rebuilds, replacing the oldest walls first and achieving a narrow distribution of flue wall replacement ages.

Anode stock management

Fundamental to the NZAS rebuild strategy is the ability to remove a fire group for the installation phases. This provides the space between the remaining two fire groups to access groups of five adjacent sections. The removal of a fire group is possible at NZAS due to a level of spare baking capacity. Even so, an enabler for the project is to ensure sufficient baked anode stocks for the duration of the fire group removal. Prior to the project, baked stock levels are usually maximised, and during each pre-building phase, anode production is increased via shorter fire cycle times. If necessary, the fire group can be returned to operation during the pre-building phase and removed again just prior to the next installation phase.
Figure 2: Layout of Campaigns

Figure 3: Pre-built wall pieces

Pre-building Phase

The multi-sectional rebuild strategy relies on the ability to pre-build and store ten sections of flue wall and head wall pieces. The building utilized for this previously housed a Riedhammer furnace, which was shut down and demolished in 1997. The building was subsequently set up to house the Off-line Cell Reconstruction Facility in one half, and the CBF Pre-build and Storage Area in the other half. The original furnace overhead crane was modified to handle the pre-built wall pieces. Figure 3 shows the CBF Pre-build and Storage Area full of wall pieces at the end of a pre-building phase.

Three purpose-built platforms for pre-building wall pieces are situated such that they take up a minimum footprint in the storage area and allow overhead crane access to remove the pre-built wall pieces. The work area of these platforms is elevated so that the wall piece can be lowered as the piece is built up, keeping the working surface at an ergonomically comfortable height for the brick layers.

Pre-sorted pallets of refractory bricks and skips of pre-mixed mortar are transported to the platforms using a 3-tonne forklift. Two of the platforms are set up for flue wall pre-building with the third set up for head wall pieces. Four bricklayers/trowel-hands work on each flue wall platform and three bricklayers work on the head wall platform. Management of the large quantity of bricks and mortar used daily on the platforms requires an additional four people. Each flue wall piece requires four pre-sorted pallets to be stacked by hand and approximately four tubs of mortar. To meet the schedule, each flue wall platform needs to produce one complete flue wall (~60 courses) per day and the head wall platform needs to produce approximately half of a head wall.

Flue walls are built in two pieces, each approximately 2.5m high x 5m long. Historically, two or four main pieces and seven or eight separate pillars were pre-built to construct each head wall. An improvement in the 2016-17 CBF1 rebuild was to include the pillars on the
two upper pieces of the head wall, reducing the total number of pieces per head wall to four, and consequently reducing the number of crane movements during the installation phase.

In CBF4 there are 384 full flue walls and 46 internal head walls which equates to over 950 individual pieces. Each piece is individually lifted using purpose-built lifting tongs, and undergoes four moves before it is in its final position in the furnace:

- From the wall build platform into the storage area,
- From the storage area onto a purpose-built trailer,
- Transported to the furnace building and lifted off the trailer onto the floor, and,
- Lifted from the floor into the furnace.

Demolition

Demolition of the five sections takes approximately 5 days. In preparation, the precast flue wall tops are removed while the pits are still loaded with baked anodes prior to the start of demolition. This assists with the cooling of the walls. A device called a “muncher”, suspended by the CBF crane, is used to demolish the upper parts of the internal flue walls, shown in Figure 4. After a section of the internal flue walls have been reduced by about half their height, an excavator is lifted into the space to demolish the remaining walls and to transfer the brick rubble into skips for removal from the furnace. This process is shown in Figure 5. The skill of the excavator driver is paramount to achieving an efficient demolition without damaging the underlying side and floor insulation.

The final clean out has a manual component during which the workers remove any remaining bricks and sweep clean the floor surface.

![Figure 4: The Muncher](image1.png)  ![Figure 5: Excavation](image2.png)

Installation

The furnace floor is leveled, if required, before the new refractory is installed. This is done so that the flue wall and head walls have a stable, level base and their tops will be level with the top of the concrete tub to within +/-5mm when installed. This usually involves filling in recesses in the insulation, particularly under the head wall. Figure 6 shows strips of a monolithic refractory (“castable”) laid out at the correct level. The castable is poured and screeded between and around the strips to complete the floor, as shown in Figure 7.
The level surface is marked out for correct placement of the new walls using a surveyor’s report and permanent reference points on the top of the concrete tub which mark the head wall centres. Head wall positions are critical so that all sections fit back into the concrete tub and so that the expansion joints between flue walls and head walls are restored to design dimensions. The old flue walls in the section next to the group of five sections being replaced may need to be trimmed to accommodate the new headwall.

A small amount of in-situ brickwork is required to provide a base for the headwall pieces in the marked locations. The head wall pieces are then lifted into the furnace. The pieces are joined by in-situ brickwork to complete the head wall. Two stages in this process are shown in Figures 8 and 9.

External flue wall pieces are lifted in (both lower and upper halves) before the lower half of the internal flue walls are lifted in.

Floor tiles are laid in the pits and the joints between the head walls and the flue walls are sealed. Anodes are then loaded to provide a working platform for installation of the upper pieces of flue wall and sealing the upper joints. Figure 10 shows workers laying mortar on the
top course of the lower half of an installed flue wall in preparation for lifting in the upper half.

Figure 10: Preparation for installation of upper half of flue wall

The old flue walls in the section next to the group of five being rebuilt usually need some re-bricking to align the flue wall ports with the head wall ports. Figure 11 shows the interface of old and new sections following re-bricking of old flue walls into the new head wall positions. This work on the old-to-new interface is variable and time-consuming. It is one of the advantages of the multi-sectional methodology that the number of such interfaces is reduced compared to single sectional replacement.

Finally, the precast flue and head wall tops are installed and the group of five sections is completed, as shown in Figure 12.

Figure 11: The interface of old and new sections

Figure 12: Completed group of five sections

Safety

Over the last twenty years of NZAS baking furnace rebuilds, there has only been one lost time injury. This occurred during the 1997-8 CBF1 reconfiguration from 60 sections to 48 sections. During the 2011-13 CBF4 and 2016-17 CBF1 rebuilds, two minor First Aid injuries were sustained over the ~120,000 hours worked.
A large number of safety improvements have been implemented over the years. Some of these are detailed below.

Ergonomics

The pre-build phase involves a high degree of manual handling. To reduce the potential for strains, the frequency of handling large bricks (20-25kg) has been significantly reduced through design. Pre-task warm-up exercises and regular stretching pauses are an important part of the task and attention is paid to the positions of people for particular tasks. Numerous improvements to practices, tooling and lifting systems have improved both safety and operability.

Stabilisation of Old Walls

A safety measure added in the CBF1 2016 rebuild was the stabilization of the old flue walls in the section next to the group being demolished. These walls are without a head wall at one end between the demolition of the old head wall and the installation of the new head wall. To provide temporary structural support, a simple support system was designed and installed prior to the demolition. Figure 13 shows the support system in place (photo taken after demolition of the 5-section group). Old walls may also be supported with anodes and wooden wedges; however this option was not suitable at NZAS due to a lack of clearance between the anodes and the head wall piece lifting tong.

Blue Lights on Forklifts and Cranes

Congestion increases in the pre-building area as the storage area fills with wall pieces. There is a requirement for extensive forklift movements to manage the materials required for wall building. Blue lights were fitted to the front and rear of the forklift to indicate its position. The blue light system was also trialed on the furnace overhead cranes used for lifting wall pieces into the furnace. Figure 14 shows the light as a visual indicator to a person working around the crane to indicate where the cranes tools, which are considered a suspended load, are in relation to the person.

Figure 13: Stabilisation of old flue walls

Figure 14: Blue light indicating crane tool position (suspended load) to Operator working 6m below. There is a 1m exclusion zone around the “blue dot”. 
Conclusion

Anode baking furnaces are typically maintained by either continuous flue wall replacement or a campaign-based strategy. New Zealand Aluminium Smelters employs a campaign-based strategy, and is unique within Pacific Aluminium for its long history of multi-sectional rebuilds. This methodology has served NZAS well over the last twenty years, delivering excellent results in terms of safety and installation quality.

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References: