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EXPERIENCES ON ANODE RECONSTRUCTION PROCESS IN SØDERBERG TECHNOLOGY

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Abstract

Anode construction is a challenging process for Søderberg Cells. In order to reestablish the full plant capacity at Alcoa Pocos de Caldas, located in the southern part of Brazil, it was necessary to develop a new process to bake anodes within the potrooms environment. Using reduced amperage as baking element and controlling the current passing through each of fifty stubs, it was possible to assembly new anodes with quality and proper condition for optimum cell operations. This paper describes the sequence of activities applied for bake-in of new Søderberg anodes, the techniques implemented to monitor and control the baking process and finally the outcome after pot start-up.

Introduction

Søderberg anode principle was patented in 1918 and it has been used in the aluminum industry since 1923. The bottom surface of the anode (Figure 1) reacts during the electrolysis process, and in the upper part (top anode) addition of "green" anode paste briquettes gradually replaces the anode material that is consumed at the bottom surface. The heat from the electrolyte constitutes the main source of baking energy, giving the bottom of the anode its final physical properties

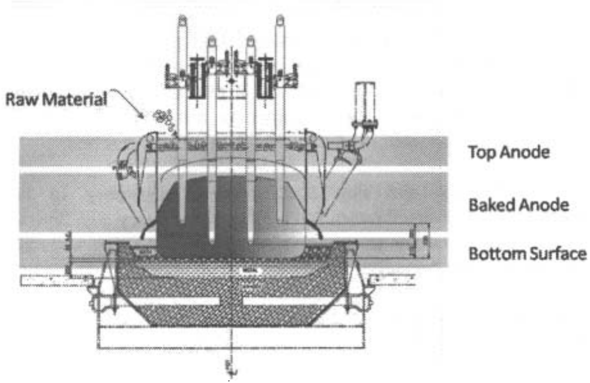

Figure 1: sketch of Søderberg cell design

One major concern for Søderberg anodes is related to polycyclic aromatic hydrocarbon (PAH) emissions from the coal tar pitch binder, which are considered to be environment and workplace hygiene pollutants and as such subject to government regulations in most countries [1,2].

The Alcoa Pocos de Caldas facility is located in the southern part of Brazil. Bauxite mining, alumina refinery, Søderberg smelter and an aluminum powder plant are all integrated. Søderberg cells are divided into three potrooms with the total capacity of 96,000ton/year.

In the first quarter of 2011, 4.5% of pots were out of operation due to poor anode condition. In order to reestablish the full smelter capacity, it was necessary to develop a process to demolish poor anodes and build and bake-in new ones within the potrooms environment. This process had not been applied since the late of 1970's in this facility, when the third potline was put into operation. Due to the lack of information and no present in-plant experience on that, technicians and engineers were challenged to create a procedure to manufacture Søderberg anodes.

This paper describes the sequence of activities applied for assembling new Søderberg anodes, the techniques implemented to monitor and control the baking process and finally the outcome after pot start-up.

Experimental Procedure

The dimensions of Søderberg anode at Alcoa Pocos de Caldas are 7.6m x 2.2m x 1.65m (length x width x height). The total weight of an anode (including casing, stubs, anode superstructure is about 60ton. A multi-task team with process and mechanical engineers, technicians and skilled operators was created to assembly new anodes. The main sequence of events is listed below:

<u>Anode Demolition</u>
This step consists on removing all stubs, the anode bus bar, gas manifolds and finally the anode casing. The remaining carbon material is then dug out and the material delivered to Paste Plant to be recycled.

<u>Anode Casing Repair</u>
In this step, anode casing surface, thickness and flatness is checked and any abnormality fixed. After that, the casing structure is assembled and all parts tightened. In order to guarantee good electrical contact between anode bus bar and stubs, it was also decided to repair the anode bus bar connections and change all old clamps with new ones.

<u>Cathode Preparation</u>
Most of the cathodes were fully relined and placed in the stalls. A ~5 cm thick layer of petroleum coke (intermediate fraction from paste plant) was spread over the cathode surface to level briquettes and help on load distribution after starting the baking process. A steel bottom template was inserted on top of the coke layer.

<u>Anode Preparation</u>
The anode superstructure was placed on the cathode and the anode bus bar and flexible connections positioned. The next step was to insert the stools (cylindrical carbon-blocks) just above the steel bottom template on cathode (Figure 2).

Figure 2: stubs being sited on carbon stools.

A total of nine thermocouples were installed at different locations in the anode, all at the level of the bottom of the stubs. Figure 3 shows the position of each thermocouple in the anode, with the position of the stubs as reference.

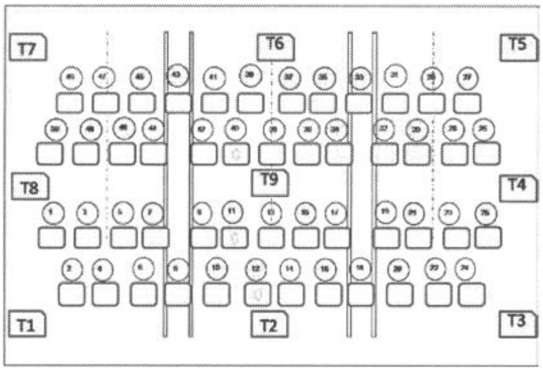

Figure 3: thermocouples position in anode (T1-T9), using as reference the number of stubs.

The cathode deck plate was covered using a refractory paper and metallic covers. After that, about 50ton dry-type briquettes (less 1% pitch compared to regular briquettes formulation) were added to the top of the anode superstructure. It was also decided to install shunt bus-bars to run the baking process at lower amperage. The amount of shunt bus-bars varied from 3 to 4 according to line load. It represented -15 to 20kA when compared to line amperage.

Baking Start-Up:

A check-list form was used to evaluate critical items such as stub alignment, shunt condition and level of briquettes on anode top. It was necessary to divide the crew as follow:

- One group dedicated to remove the metallic by-pass, connect shunt bus-bars in the circuit and cut in the pot;
- One group to measure the current pick-up in each stub and cathode current distribution after cutting in the pot;
- One person to evaluate when it was possible to gradually increase the line load;
- One person in the control room to increase the line load following the instructions.

Before starting the baking process, all stubs were disconnected from the bus bar and the anode was gently bumped down (2 downward movements) to guarantee good stub-to-stool contact. After that, all stubs were tightened again in anode bus bar.

A log-book was also created to record all current pick-up measurements in stubs and anode temperature, as well as any action to balance current distribution during the baking process.

As a rule of thumb, a stub should be disconnected, using a dielectric paper between the stub and anode bus bar every time there is a preferential path for current passing through stubs. In this case, it was used as reference values higher than 14 (typical reading was about 5-7). A preferential path for current can cause an uneven baking process and ultimately non-baked zones that could collapse at the end of the baking process. Another possibility was to insulate a certain stub to force the current to flow through neighboring stubs with lower load pick-up.

Using temperature readings during the baking process, it was possible to either electrically insulate or connect stubs to respectively reduce or increase the temperature rate. It was also decided not to insulate more than 20% of the total number of stubs. This would cause over loading in some stubs that could be detrimental to cathode lining.

The baking process can be enhanced by burning wood or charcoals in peripheral area (side and end-walls) on cathode rammed bevels. In order to do so, it is extremely important to protect bevels from direct fire using solid bath.

The anode is now ready to bake. The load pick-up and cathode current distribution measurements must be done every time load is increased.

The line load must start at the minimum the power substation can provide (60kA). During this period, it was necessary to monitor the pot voltage to not exceed 10V. If measurements were OK and no abnormalities were found, amperage was raised by 5kA and the procedure repeated till the line load target was reached.

After achieving the line load, it was necessary to take measurements every 2 hours and make the necessary adjustments. It was also necessary to compress the briquettes using a metallic pole against the briquettes.

The flames coming out of the anode top is quite common during the first hours of baking. Fire must be extinguished, preferably using air.

Monitoring and Control

During Anode Baking Process:

1. *Current Pick-up*: it refers to current (amps) passing through each stub. The current pick-up should be measured every time the load is increased. After that, technicians can measure every two hours till the end of baking. Figure 4 shows the load pickup measurement and the operator insulating one stub.

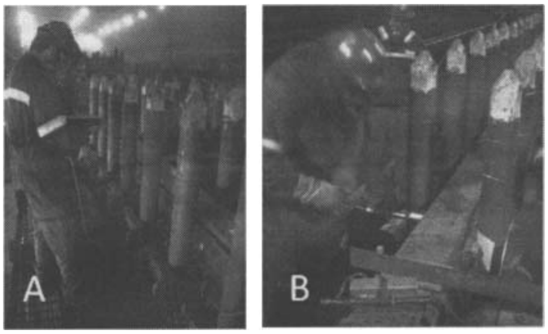

Figure 4: current pickup measurement in each stub (A) and operator insulating one stub with dielectric paper (B).

2. *Anode Temperature*: it was measured together with current pick-up. As a rule of thumb, final temperature at different anode areas should be higher than 500°C to minimize the risks of unbaked regions that can collapse after raising the anode to cut in the cell. The individual temperature should not exceed 1100°C to avoid rapid pitch de-volatilization and thus deteriorate the anode quality. Added to that, it may cause excessive thermal stresses in the cathode blocks with block cracking as a result. If temperature remains low, it is necessary to add an external source of heat (as example burn woods or charcoals) on cathode bevel. This procedure will help on anode baking process.

3. *Cathode Bus Bar Current Distribution and Temperature*: it is measured after baking start-up, when the load target is reached and it should be continued at least once a day till the end of baking. Cathode bus bar with temperature higher than 180°C should be cooled using compressed air. For cathode bus bar with high temperature (> 200°C), it is necessary to either install compressed air to cool it or disconnect any stubs that are carrying too much current in a region close to the high-temperature collector bar.

4. *Available Paste*: This measure refers to the total height (cm) of unbaked anode in the anode top area. It is measured from the top to the bottom by inserting a ruler into the anode (Figure 5). It is important to control available paste to guarantee proper condition for stubbing operation and thus avoid anode problems.

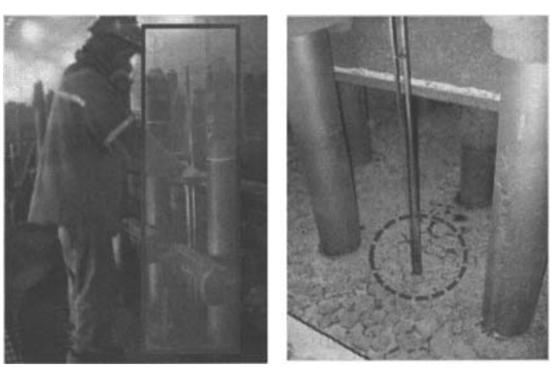

Figure 5: available paste measurement activity. A non-baked anode is measured by this technique.

Another good practice is to compress the top of anode in a regular basis by using a steel pole to help on the anode densification process. Keep the amount of briquettes on the top as leveled as possible – during baking step it is necessary to add more briquettes to compensate the gas release/ anode forming process. At the end of baking, all stubs must be connected to the anode bus bar.

The baking process will be considered completed if:

- Anode temperature reaches 450°C minimum;
- Available paste is less than 100mm (at the ends) and less than 60cm (at the center);
- Minimum baking time at 4 days (5 days preferable).

After completing the baking process, it is necessary to remove the bottom and side steel templates to avoid iron contamination in metal.

After that, liquid electrolyte is poured into the cell, the anode-cathode distance is adjusted and the pot is cut in. During the soaking time (period where pot is in operation only with electrolyte bath), temperature and voltage are controlled every half hour. Throughout this period, the briquettes level is closely monitored and adjusted if necessary.

After completing the soaking time (16-20h), liquid metal (7ton) is added to the pot and parameters adjusted accordingly. Stubs pulling operation is started after 48h of pot operation.

<u>After Pot Start-up with Electrolyte:</u>

1. *Anode Voltage Drop (AVD):* AVD is one of the pot voltage components. Less voltage than a pot requires can turn into anode problems and mucky pots with a negative consequence on current efficiency. AVD refers to electrical losses between the anode bus bar (central point) and two different regions on the bottom part of anode). Reference: < 0.580V.

2. *Anode Bubble Noise*: This is an indirect measurement of anode quality. It refers to the gas covering portion of anode bottom. The bubble layer under anode plays an important role in the operation of aluminum cell. The understanding of this impact is based on theoretical analysis and speculative models. According to Perron et al. [3], bubbles contribute to induce flow in the cell. This flow is important for the thermal balance and also for the distribution and dissolution of alumina. However, bubbles increase the voltage of the cell and causes deformation along the cryolite-molten aluminum interface. As a rule of thumb, the higher bubble noise the less defects in anodes bottom surface, as per example cracks (horizontal and verticals). Typical value in Alcoa Pocos de Caldas is about 40 to70 micro-ohms.

3. *Anode Problem*: This refers to amount of any carbon (chunks, slabs, points, etc) removed from pot. It causes a detrimental effect on current distribution, with negative effect on anode baking process and cathode life (high temperature excursions). Reference: anode problem/per pot: one occurrence per year.

Results and Discussions

During the first hours of baking process, pot voltage was gradually decreased from 9V to less than 3V. The baking time varied from 93 to 125.5h. The baking time was completed when both available paste and baking temperature achieved the minimum spec requirements.

Looking at the final anode temperature in different anode regions, it was found that areas closer to the ends became colder (e.g. T1, T3, T4, T5) if compared to the center of anode thermocouples. In order to increase the temperature, it was necessary to reduce the height of stools placed in the ends by 10cm and also burn charcoal on top of the rammed cathode bevel. Figure 6 shows the box plot chart of nine thermocouples installed at the different locations in the anode. In descriptive statistics, a box plot (also known as a box-and-whisker diagram or plot) is a convenient way of graphically depicting groups of numerical data through their five-number summaries: the smallest observation (sample minimum), lower quartile (Q1), median (Q2), upper quartile (Q3), and largest observation (sample maximum) [4].

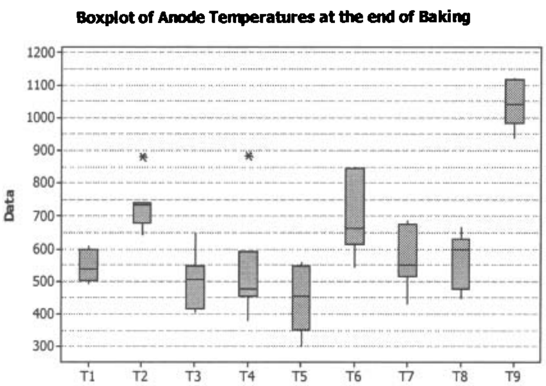

Figure 6: anode temperature at the end of baking.

As a part of learning process it was also necessary to develop a gas exhaust system to minimize the PAHs release during the baking process. A temporary solution was developed, consisted on a steel container partially filled with water and two layers of polyurethane. The flexible piping was installed inside the pot and connected to this container and the gases pulled using a venturi system. After that, the PAHs released to environmental reduced substantially (Figure 7).

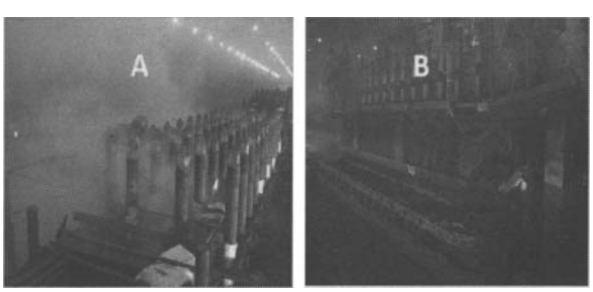

Figure 7: PAHs emissions before (A) and after (B) installing the exhaustion system during anode baking.

After ending the baking process, the contaminated water was delivered to treatment station and the polyurethane to be incinerated.

After Cell Start-Up/ Early Operation:

After completing the anode baking process, the cell was cut out and all metallic templates removed. The bottom part of anode showed few minor cracks on the sides and good flatness. Figure 8 shows an overview of bottom part of anode just after removing the metallic templates.

After this step, liquid cryolite (about 10-12ton) was poured into the cell, the current bypass removed and the cell was started.

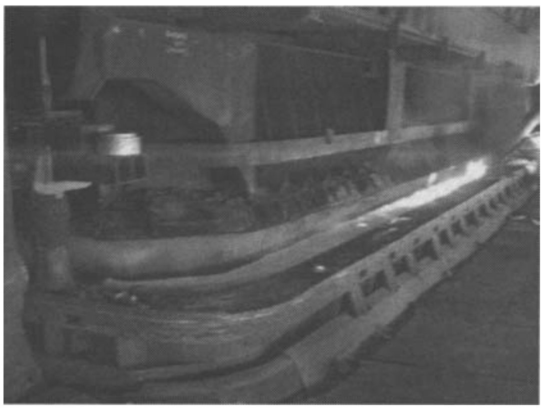

Figure 8: an overview of anode surface just after ending the baking process. Few cracks and good flatness observed.

The overall results were very positive: AVD of pots with new anodes achieved 0.577V (±0.106V) whereas reference pots 0.634V (±0.121V). Analysis of variance (ANOVA) showed that data is statistically different.

Comparing anode bubble noise, pots with new anodes achieved 71.81 μΩ (±27.25). Reference pots achieved 46.85 μΩ (±16.38). ANOVA showed that data is also statistically different.

No anode problem was reported during the first 30 days of cell operation. The main parameters during baking process and after 30 days of cell operation are summarized in Table 2.

Table 2: Main parameters during baking and after 30 days of cell operation.

	Parameter	Average	Stdev	Min	Max
During Anode Baking	Pot Voltage at Baking Start-up (V)	9,09	2,19	5,39	12,49
	Total Baking Time (h)	107,11	13,74	93,00	125,50
	Final Baking Temperature (°C)	618,99	34,86	577,78	669,78
	Available Paste (cm)	68,61	5,78	56,60	76,90
New Cell (30 days of operation)	Anode Voltage Loss (V)	0,577	0,106	0,357	0,712
	Bubble Noise (micro-ohms)	71,81	27,25	38,83	114,47
	Anode problem	none			

Conclusion

Looking at the overall anode results, it is possible to conclude that the anode baking process developed for Søderberg cells at Alcoa Pocos de Caldas was successfully concluded due to the following aspects:

No incidents were reported. All safety equipment was applied to avoid any injury throughout different activities.

- Good planning was crucial to guarantee good anode properties. All anodes was continuously monitored and controlled.
- The PAHs release was minimized and controlled using a non-costly exhaust system.
- The continuous improvement methodology was applied for each anode assembled. By doing that, results became more predictable.
- The anode voltage drop was better in pots where anode was assembled if compared to regular pots.
- Another parameter, anode bubble noise, also was better in pots where anode was assembled if compared to regular pots.
- The learning and sharing experiences allowed more people to perform this activity. The operators and technicians commitment was crucial to achieve the goals.

Acknowledgments

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References

[1] Boenigk, W. et al *Production of Low PAH Pitch For Use in Søderberg Smelters* – Light Metals 2002, pp. 519-524.

[2] Pedersen, T.B.; *The Søderberg Cell Technology - Present Performance, Challenges and Possibilities* - TMS 2001, pp. 489-495.

[3] Perron, A.; Kiss, L.I.; Poncsák, S.; *Regimes of the Movement of Bubbles Under the Anode in an Aluminum Electrolysis Cell* – Light Metals 2005, pp. 565-570

[4] http://en.wikipedia.org/wiki/Box_plot