Light Metals 2011 *Edited by: Stephen J. Lindsay*
TMS (The Minerals, Metals & Materials Society), 2011

PASTE QUALITY IMPROVEMENTS AT ALCOA POÇOS DE CALDAS PLANT

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Keywords: Soderberg, Fines, Mixing.

Abstract

Alcoa Poços de Caldas Soderberg Carbon Plant began its operation in 1965 and after a series of upgrades including a mixer heating system upgrade in 1989, fines control in 2000, mixing temperature optimization in 2004 and installation of coke preheaters in 2009, the plant now has twice the original production capacity with near world-class paste quality. The benchmark paste quality characteristic is 1.55 g/cc of baked apparent density (BAD), while Poços results are about 1.45 g/cc. The Paste Plant is now challenged to meet Potroom requirements for anode performance (higher loads and dry anode top technology).

This paper describes the enablers chosen to improve the baked properties, which includes the optimization of fines production, mixing process, and recipe. The quality management system which includes a carbon laboratory with Soderberg baking furnace, sample preparation, and baked analysis (BAD, Air Permeability, CO_2 Reactivity and Electrical Resistivity) are also described.

Introduction

Different from a Prebaked Plant, the Poços Smelter operates with Soderberg technology which requires additional control from the potroom area to form and bake the anode using the Electrolytic pot. Anode top control is needed with plasticity and leveling as a requirement for stubbing operation. In the Paste plant a control of paste flowability is needed with continuous adjustments on aggregate pitch demand.

The paste production process can be divided into three different areas: dry aggregate, mixing, and extrusion processes.

Dry Aggregate:

Incoming coke consists mostly of coarser particles, with which it is not possible to produce a dense anode due to the high level of inter-particle porosity. Classifying, crushing and milling the incoming coke will result in different particle sizes capable of forming a denser aggregate and consequently a denser anode [1]. This step consists of separating the material into three fractions: coarse, intermediate, and fine in order to produce the densest packing (Figure 1). The number of fractions depends on the plant facilities (number of sieve decks and tanks) and the particle size for each fraction is obtained through a ternary diagram that takes into account, among other things, raw material quality and the particle size.

Upon receiving and characterizing, the coke is unloaded and sent to the Vibrating Screens where it is separated into three products: oversize (over 0.5 mesh), coarse (between 4 and 0.5 mesh) and intermediate (under 4 mesh). Oversize particles go to the Hammer Mill and return to the screens while coarse and intermediate particles go to the designated storage tanks. The coarse tank overflow goes to the Hammer Mill and consequently to the Vibrating Screens again. The intermediate tank overflow goes into the tank used to feed the Ball Mill (Figure 2).

The Ball Mill is the equipment responsible for producing the fines fraction, where, according to the feed rate and air classifier adjustments, it is possible to produce a different fineness. In Poços, the feeding rate is adjusted according to the power necessary to rotate the Ball Mill. As the mill empties, the force required for rotation increases, consequently increasing the feed rate. When the mill is overloaded, the force required drops, and the feed rate either decreases or is manually interrupted when there is evidence clogging. Having consistent Ball Mill operation is fundamental in order to produce a fines fraction that has consistent sizing. Dust collected in the plant is added in the Ball Mill outlet at an established rate according to the dust tank level (measured twice per shift).

Fines particles are the most important coke fraction because [2]:

i. It must not be in excess which will require additional pitch to coat the increased surface area;
ii. It fills the spaces between coarser coke particles to produce a maximum dry bulk density;
iii. It fills the open pores, resulting in a denser anode.

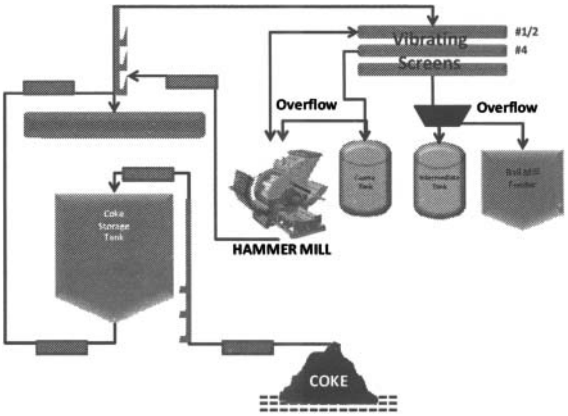

Figure 1. Dry Aggregate Flow

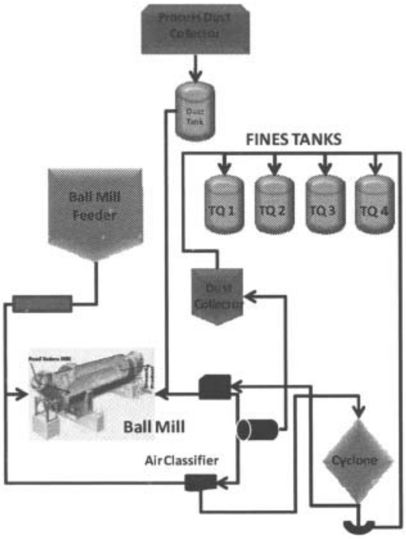

Figure 2. Ball Mill Flow

Mixing Process:

The Mixing process can be divided into three steps: weighing, preheating, and mixing.

Each fraction is fed individually to the Preheater where it is weighed (22% coarse, 35% fines and 43% intermediate respectively).

Since 2009, Poços has used a preheating facility where, after weighing the batch, the coke is heated through electrical induction.

After the preheating process, the aggregate is transferred to the mixer. Poços has three Preheaters and consequently three Batch Mixers working in parallel (Figure 3). The mixers are heated with thermal oil (kept at around 200°C), which guarantees that the coke will not lose temperature while the dry aggregate is mixed [3]. After 6 minutes, the total programmed pitch is added. The paste continues to be mixed until the final temperature reaches 188°C and with a minimum of 45 minutes of total time mixing. Each batch is equivalent to 3.6 tons of paste.

Pitch wets the surfaces of all particles, fills pores in and between the particles, and is added in liquid form (at around 185°C). Optimized pitch content is necessary in order to avoid cracking and poor strength, with a minimum of air permeability.

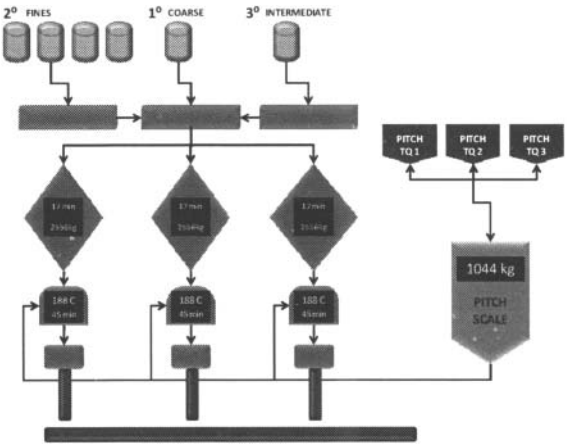

Figure 3. Mixing and Extrusion Process Flow

Extrusion:

After mixing, the paste is transferred to the extrusion box and extruded. Cooling the briquettes is necessary after extrusion to ensure they do not deform or stick together.

While the paste is not completely cooled, binder (pitch plus fines) is still soaking into coke pores.

Pasting on Anode Top:

The briquettes are loaded every 48 hours in each of the 288 pots using a special vehicle, respecting a time frame between the stubbing and tapping operations.

After a daily top condition inspection, three different briquettes can be added with the aim of keeping anode top plasticity under control: wetter (around + 1.0% pitch), dryer (around -1.0% pitch) or typical.

Solution Approach

The strategy of working with higher pitch content in the paste attends to the anode top requirements and gives good operational conditions for anode formation, but impacts negatively the anode quality. An anode with a higher pitch percentage shows higher porosity, permeability and reactivity, causing higher dust generation and anode consumption in the potrooms. Based on this restriction and consequences to the potroom, training seminars were held involving the entire team in search of practical solutions.

In order to pursue paste quality improvements, a step by step action plan was developed in Paste Plant in Poços de Caldas:

i. Fines production optimization;
ii. Mixing process optimization;
iii. Recipe optimization.

This approach was established based on the following theory:

i. Having fines enough to fill open pores;
ii. Use of a higher mixing energy, to force binder (fines plus pitch) into coke pores;
iii. Formulation of a recipe containing a minimum quantity of coarser material (more porous material) and still

keeping the strength characteristic necessary for the anode operation.

Experimental approach

Fines Production Optimization:

This strategy refers the best fit fines fraction; in other words, it works with a fines target with the highest Blaine* number sustainable, using the smallest fines fraction generating a denser baked paste [4]. * Blaine equipment is an indirect measure for fineness of fines, by measuring dry particle air permeability. It is a technique widely used in the cement industry.

The main objective of this test was find the best configuration for pitch content and fines fraction running with 4500 Blaine, ensuring paste quality improvements.

The tests were arranged as follows:

Test 1: Evaluate impact of each change (increasing fineness, decreasing fines fraction, decreasing pitch content).
Test 2: Assess Paste Plant productivity capacity and stability;
Test 3: Practical application (potroom results).

Test 1 (November/2009):

i. After ensuring Blaine machine calibration, four recipes were produced and sampled following the typical Paste Plant set up.
   Fines Fineness regular target = 4000 Blaine.

ii. Keeping the same pitch and coke supplier, 25 recipes were produced while the fines fineness was adjusted through increasing the air classifier speed from 22% to 29%. The Ball Mill product was sampled and analyzed each cycle and followed (4500 ± 200 of Blaine number). While the results on the weigh belt feeder had not reached 4500 (sampled each 2 hours), all the produced batches were considered as transitional material and were not analyzed.

iii. Following the configuration below, 25 recipes have been produced in order to evaluate the gains from each change, see the explanation below:
   - Test A: keeping the old recipe (22% coarse /35% Fines /43% Intermediate), increasing fines fineness (from 4000 to 4500) and keeping the original pitch content (27.7%);
   - Test B: adjusting the recipe (22% coarse /32% Fines /46% Intermediate), increasing fines fineness and keeping the pitch content;
   - Test D: adjusting the recipe and pitch content in order to reach flowability target (131%) and increasing fines fineness;
   - Test C: keeping the pitch found on test D and fines fineness, but using the old recipe.

The test set up are further summarized in Table I.

Table I. Test 1 set ups.

Test	Pitch Content (%)	Fines Fraction (%)	Intermediate Fration (%)	Blaine Number
Typical	27.7	35	43	4000
A	27.7	35	43	4500
B	27.7	32	46	4500
C	27.6	35	43	4500
D	27.6	32	46	4500

The baked analysis results from each test are shown in Table II.

Table II. Test 1 results.

Test	Baked Apparent Density (g/cc)	Air Permeability (nPm)	Eletrical Resistivity (µΩm)	CO2 Reactivity - Residue (%)	CO2 Reactivity - Dust (%)	CO2 Reactivity - Loss (%)
A	1.476	2.166	69.217	88.527	2.437	9.037
B	1.484	2.063	79.660	73.105	9.005	17.715
C	1.489	2.143	88.560	80.675	6.363	12.955
D	1.486	3.599	70.905	84.405	4.055	11.540

Test 2 (December/2009):

During 2 days, the Paste Plant was run with the set up developed in Test 1 D. A total of 90 batches were produced with no operational instability.

Test 3 (April/2010):

After a flowability test to ensure top plasticity and to find the pitch target, 24 pots received briquettes produced with 4500 Blaine for 3 months. These briquettes were produced at the beginning of the month during 2 or 3 days, and as a safety factor, 30% of total production scheduled was produced with plus or minus 1% pitch for top correction. Comparison of a typical month's data with test data is presented in Table III.

Table III. Test 3 results.

Month	Baked Apparent Density (g/cc)	Air Permeability (nPm)	Electrical Resitivity (µΩm)	CO2 Reactivity - Residue (%)	CO2 Reactivity - Dust (%)
Typical Paste April-10	1.448	1.738	86.11	72.94	16.790
Test Blaine 4500 April-10	1.453	4.645	77.39	75.28	9.980
Typical Paste April-10	1.454	1.671	79.49	75.94	7.640
Test Blaine 4500 April-10	1.456	5.785	82.40	77.68	9.580
Typical Paste July-10	1.460	3.795	61.10	92.85	0.878
Test Blaine 4500 July-10	1.463	-	65.83	94.24	0.190
Average Test Blaine 4500	1.457	5.215	75.203	82.397	6.583
Average Typical Paste	1.454	2.401	75.568	80.577	8.436
Difference	0.003	2.814	-0.364	1.820	-1.853

Mixing Process Optimization:

Using the same mixer and aiming to increase the mixing energy, the strategy adopted was to simulate what happens during the prebaked paste mixing process.

By adding part of the total pitch scheduled, the mixer blades found it more difficult to promote the aggregate mixing, consequently mixing energy was raised (measured by monitoring the mixer amperage) and forcing the fines penetration into the open coke pores.

Pitch addition is made in one step, 6 minutes after the beginning of the mixing process. In the new strategy, this addition was made in two phases, where the first occurs at 6 minutes, with 70% of the total mass, and the second phase after about 30 minutes of mixing, adding the remaining 30%.

Therewith, the first phase will work to promote the binder penetration (pitch plus fines) and the second phase will guarantee the flowability characteristic necessary for the stubbing operation. This new way to manage this process has been named as the New Mixture Strategy (NMS).

The test was arranged as follows:

Test 1: Evaluate the operational strategy;
Test 2: Develop the NMS control logic;
Test 3: Test the NMS control logic;
Test 4: Evaluate paste quality gains with the new logic.

Test 1 (February and March/2010):

Based on Paste Plant production flow, the operability of this strategy was tested manually by the operating team.

As Poços has only one pitch scale, there was an observed delay on the total mixing time when at the same time different mixers require pitch addition.

For process safety, there were some conditional circumstances to transfer the paste for extrusion when the team was developing the new mixture control strategy program:

i. Both phases completed;
ii. Minimum of 15 minutes mixing in phase 2;

Tests 2, 3 and 4 (from April to August/2010):

Four tests have been completed with one, two, and three mixers respectively to evaluate the new program and the operability of this approach.

After testing the program, there was a flowability test to find the optimum flowability target. Three different briquettes were produced with 130%, 143% and 150% flowability targets respectively. A total of 6 batches were produced for each recipe and added into three different groups of pots (4 pots per group) within a week.

During this test, the typical paste had 29.0% pitch and a flowability of 143%, while the briquettes produced with the NMS optimum condition had 28.4% pitch and 143% flowability.

The test results are compared with a typical month paste results in Table IV:

Table IV. Test results.

Month	Baked Apparent Density (g/cc)	Air Permeability (nPm)	Electrical Resitivity (µΩm)	CO2 Reactivity - Residue (%)	CO2 Reactivity - Dust (%)
Typical Paste March-10	1.443	1.314	84.36	85.76	5.453
Test NMS March-10	1.438	3.037	86.83	89.26	3.050
Typical Paste April-10	1.454	1.671	79.49	75.94	7.640
Test NMS April-10	1.459	1.718	85.46	67.19	15.160
Typical Paste June-10	1.454	3.863	67.76	91.95	1.035
Test NMS June-10	1.484	4.809	60.71	92.61	0.660
Typical Paste August-10	1.450	5.286	66.02	91.66	1.425
Test NMS August-10	1.455	6.805	71.40	91.41	1.205
Average Test NMS	1.459	4.092	76.10	85.12	5.019
Average Typical Paste	1.450	3.033	74.41	86.33	3.888
Difference	0.008	1.059	1.693	-1.211	1.131

Recipe optimization

In both strategies presented, the recipe configuration and adaptations were essential to make the quality improvements possible.

Results and Discussion

Fines production optimization

Table II demonstrates the test data resulted from each change (increasing fines fineness, adjusting recipe and adjusting pitch content). Tests A and B were not applicable due to dry top plasticity. While Test C showed slightly higher baked apparent density, Test D showed better CO_2 Reactivity Residue and Dust, while keeping top plasticity under control. Due to that Test D was taken as the standard for the subsequent tests.

Compared to typical paste results (Table III), there was a potential to increase CO_2 Reactivity Residue by 1.82% and BAD by 0.003 g/cc. During almost all tests, there was no necessity to add briquettes to correct the top plasticity (> 95% under control), showing higher top plasticity stability.

Mixing process optimization:

Table IV shows the mixing strategy test results compared to typical paste results. There was a potential to reduce pitch by 0.60% while the baked apparent density increased by 0.008 g/cc.

Connecting both strategies

During an excursion of low coke quality (from 0.940 g/cc to 0.910 g/cc of Vibrated Bulk Density), the need to increase pitch content in the typical paste arose in order to recover top plasticity (more than 20% of pots with dry top condition). Instead, the Process Team has opted to use the potential savings of the NMS and Fines Fineness to improve top condition.

Introducing the NMS gave an opportunity to reduce pitch by 0.6% and the increasing Fines Fineness provided top plasticity stability, thereby improving paste quality.

The first step, in September 2010, was to change the mixing strategy, and the second step in October 2010was to increase the Blaine number from 4000 to 4500. Even with these strategies, in order to recover top plasticity, pitch content had to be slightly increased from 29.0% to 29.4%.

A further increase in mixing energy and maintenance of constant paste temperature was required to best mix the dry aggregate with binder. The preheating time was increased from 17 minutes to 19 minutes and the thermal oil reduced from 295°C to 255°C. The final results are provided in Figures 4, 5, 6 and 7.

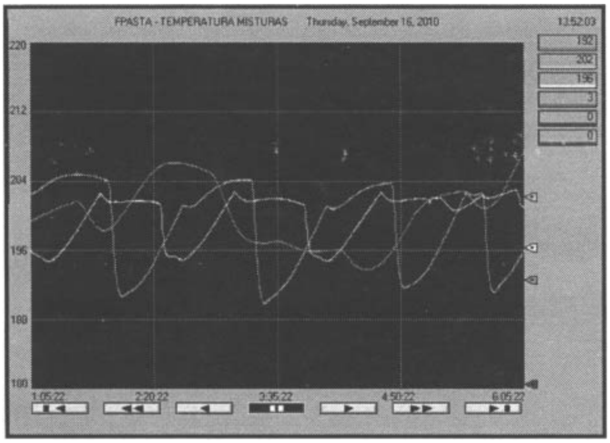

Figure 4. Temperature (°C) during mixing process before changes. September 2010. (red line: mixer 5, green line: mixer 6 and white line: mixer 7).

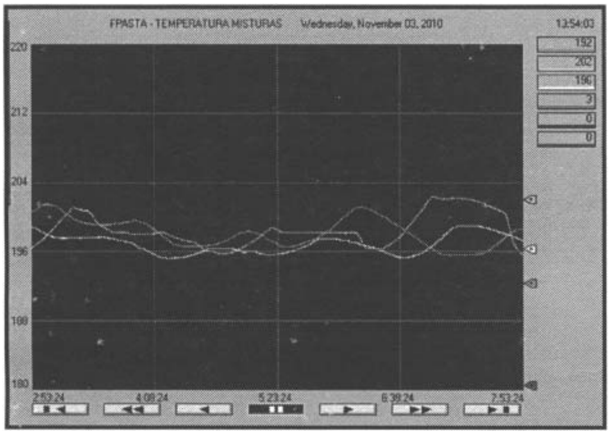

Figure 5. Temperature (°C) during mixing process after changes. November 2010. (red line: mixer 5, green line: mixer 6 and white line: mixer 7).

As shown in Figures 4 and 5, comparing temperature standard deviation there was a significant reduction after the change were implemented.

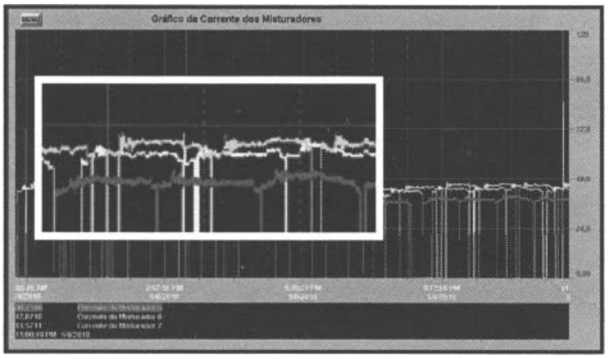

Figure 6. Mixers Amperage (A) before changes. August 2010. (red line: mixer 5, yellow line: mixer 6 and blue line: mixer 7).

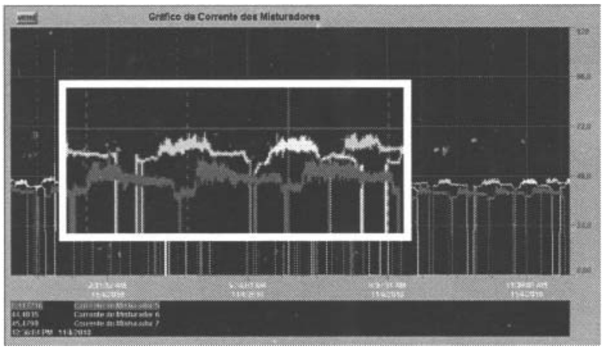

Figure 7. Mixers Amperage (A) after changes. November 2010. (red line: mixer 5, yellow line: mixer 6 and blue line: mixer 7).

By increasing coke temperature, reducing thermal oil temperature and expanding the NMS, the mixer amperage increased approximately 3.67 amperes, with no change on paste flowability (Figures 6 and 7).

According to previous experiences in the plant, reducing 0.040 g/cc on coke vibrated bulk density it was expected to decrease baked apparent density by 0.030 g/cc.

Looking for paste quality evolution on Figure 8, paste quality, as measured by BAD:

- Decreased at first by 0.038 g/cc due to the low coke quality (from 1.445 to 1.407 g/cc throughout September);
- Increased by 0.015 g/cc (from 1.407 to 1.422 g/cc), after the NMS and fines fineness strategy implementation;
- Increased by 0.022 g/cc (from 1.422 to 1.445 g/cc), after reducing the thermal oil temperature and increasing the coke temperature.

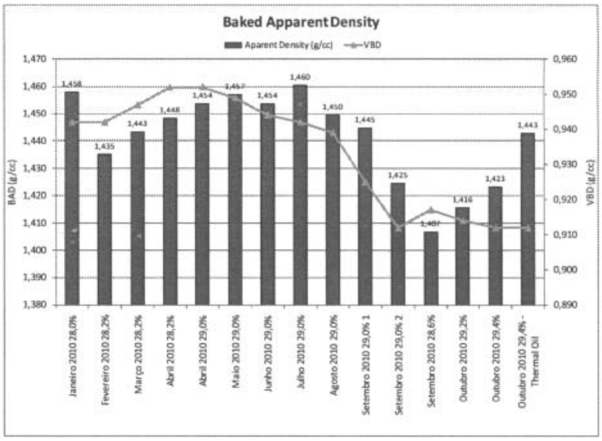

Figure 8. Baked Apparent Density compared with Vibrated Bulk Density (VBD) evolution in 2010.

Other baked paste analysis evolution during 2010, can be seen in the following Figures:

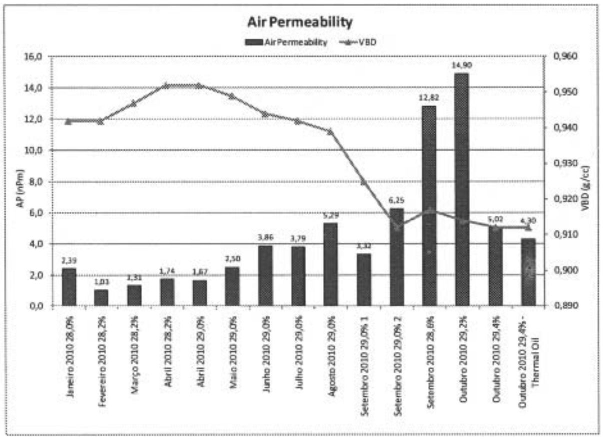

Figure 9. Air Permeability compared with Vibrated Bulk Density (VBD) evolution in 2010.

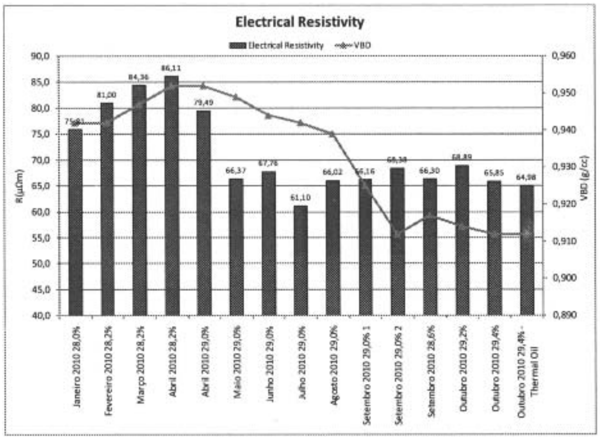

Figure 10. Electrical Resistivity compared with Vibrated Bulk Density (VBD) evolution in 2010.

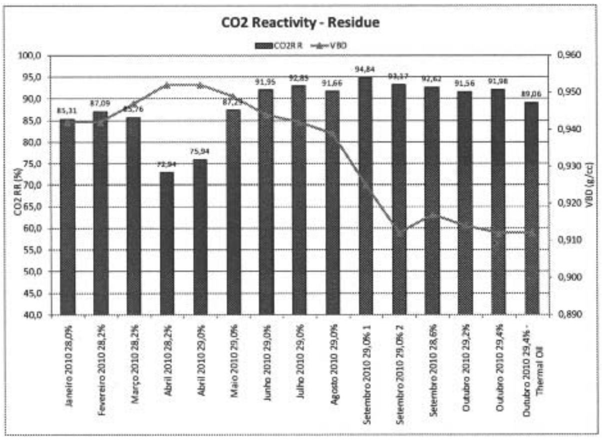

Figure 11. CO_2 Reactivity Residue compared with Vibrated Bulk Density (VBD) evolution in 2010.

Due to the more porous coke (lower VBD) the most impacted parameter since September was Air Permeability (Figure 9), even so, initial results have already shown that the adopted strategy is a good way to minimize coke impacts.

Higher mixing energy (mixer amperage) provides a more homogeneous mixture, due to the filling of coke open porosity and better mixing of the dry aggregate. For Batch technology it is even more important to combine both approaches to be able to capture the gains and not to dry the paste.

Conclusion

Baked results have demonstrated that combining the New Mixture Strategy with Fines Production Optimization was an excellent strategy to produce higher paste quality (mainly higher BAD and CO_2 Reactivity Residue) while reducing pitch consumption.
These strategies are a good approach to minimize the negative impacts caused by lower coke quality on baked properties and anode condition. Future data will prove whether it was possible to fully compensate for coke quality gaps using preheater and thermal oil changes, or whether some additional adjustments are necessary.

Acknowledgments

Paste Plant Staff at Poços de Caldas were involved in making this project a success and their commitment was essential to the project completion. Special thanks to Chin Woo and Ciro Kato for contributing with their ideas and knowledge.

References

1) Kirstine L. Hulse, *Anode Manufacture* (Sierre, CH: R&D Carbon Ltd, 2000), 77 – 156.

2) Woo, Chin, "Fines Control" (Paper presented at Green Mill Training in Deschambault, Québec, 14 September 2009), 26.

3) Kirstine L. Hulse, *Anode Manufacture* (Sierre, CH: R&D Carbon Ltd, 2000), 207 – 236.

4) Woo, Chin, "Fines Control Initiative" (Paper presented at the 1st Paste Plant Workshop, Poços de Caldas, Minas Gerais, 28-29 January 2010), 16.