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START OF AN ALUMINUM REDUCTION CELL WITHOUT LIQUID BATH

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Abstract

A successful trial was conducted at Century Aluminum's Kentucky smelter to determine the best method to start an aluminum reduction cell when liquid bath is not available, as it happens when an idled smelter is restarted. Materials, equipment, and methods critical to the successful dry start are discussed. A newly-lined cell was resistor-baked to target temperature, and dry crushed bath pushed onto the heated cathode surface. The cell voltage decreased over the next 24 hours until the cathode surface temperature stabilized. Ten to 15 centimeters of liquid bath could be seen between the anodes. The anode beam was raised to increase the voltage and heat and melt more dry bath. Eight hours after beam raise, the cell was operating at target voltage and had 35 centimeters of liquid bath. Four hours later the liquid bath reached the metal-addition target temperature, and molten aluminum was added to the cell to complete the dry start.

Introduction

In preparation for a possible restart of an idled aluminum smelter, Century Aluminum in Hawesville, Kentucky tested a method for restarting an aluminum production cell using only dry tapped bath. A team from the technical and production areas of the Hawesville smelter tested a method similar to that of Reek, *et al.* [1] to obtain liquid bath for the first cell started in an idled smelter by melting dry bath in the cell after pre-heating it.

Materials

Materials considered critical for the dry start process were optimized for the trial (Table 1). These included a cell superstructure meeting quality specifications, a flat cathode surface, resistor granules for baking the cell, insulation for baking, dry crushed tapped bath for melting into liquid bath, best-quality anodes, and air-cooled anode assembly iron-aluminum transition joints.

Method

Cell Preparation

After the cell superstructure was verified to be working properly, the anodes were placed into the cell by first hanging them one inch above the resistor bed (Figure 3). When all the anodes were clamped into place, each anode clamp was manually loosened to allow the anode to slide slowly down to the resistor bed. No anodes were dropped onto the resistor material, and no compression of the resistor bed occurred. Care was taken to align the anode rods perpendicular to the anode bus. Wooden spacer bars were used to create equal spaces between the anodes so dry bath could be pushed into the spaces after pre-heating the cathode.

The cell was insulated for pre-heat, or bake, by wrapping the top and sidewall side of the anodes with foil-backed insulation (Figure 4). A strip of insulation was placed down the center of the cell over the center channel. The strips were cut to allow individual sections to be removed or pulled back to view the channels. In addition to holding heat, the insulation served to keep crushed bath off the cathode surface until the end of the bake cycle.

After the cell was insulated, crushed tapped bath was added to completely fill the area between the anodes and the sidewalls and endwalls (Figure 5). The same material was added to the tops of the anodes and spread to a thickness of about 5 cm.

Critical Materials	Important Properties
Superstructure	Proper operation of all mechanical functions, including anode clamps, beam jacks, and ore gates. Beam sanded at anode rods. Alumina ore bin not filled until a few hours before beam raise.
Cathode surface	Transverse seams between cathodes cut level with surface, so cathode surface is flat across cell. Thermocouples installed around perimeter of cell.
Resistor	Coke resistor material size: 0.5 to 4 mm in diameter (Figure 1). Thickness of resistor bed: 40 mm across entire cathode surface except in center channel.
Insulation	Foil-backed insulation used during bake to hold heat in and dry bath out.
Crushed tapped bath	Size range: 0.5 to 15 mm in diameter (Figure 2). Installed between sidewall and anodes, and on top of anodes to about 5 cm in height.
Anodes	Best-quality anodes used, with attention to baking furnace time and temperature, non-lamination, best rodding quality, no missing pieces, and perfect thimble holes Cast iron composition checked before rodding. Thimbles filled to within 5-6 mm of the rim. Wire-brushed anode rods at anode beam contacts.
Transition joint air-cooling	Weld between iron yoke and aluminum rod susceptible to failure at high temperature. Air-cooling built with 25-mm dia. aluminum pipes with holes drilled to match transition joint spacing. Pipes hung from superstructure, and ends fitted with high-temperature steel hose to cross deckplate.

Table I. Materials considered critical to a successful dry start.

Figure 1. Resistor material (mm).

Figure 3. Anodes placed carefully in cell on resistor bed.

Figure 2. Crushed tapped bath (mm).

Figure 4. Insulation between anodes.

<u>Cell Energized and Pre-heated</u>

The cell was energized, and the cell lining pre-heated to 800 ºC. During the 32-hour pre-heat time, process engineers and technicians provided 24-hour coverage, recording cell voltage, anode rod voltages, cathode thermocouple and surface temperatures, transition-joint temperatures, collector-bar temperatures, and general observations.

Observers also coordinated with supervision and directed specially-assigned operators in adjusting individual anodes which were judged to be in danger of overloading. Adjustments were made with care, generally consisting of small lateral shifts of the anode rod, to avoid introducing dry bath material under the anode.

The bake cycle was basically standard for the Hawesville smelter, except for an increase in the height of the resistor bed and air-cooling of the transition joints. Air-cooling was activated soon after the cell was energized. The air-cooling design can be seen in Figures 6 and 7.

Figure 5. Crushed tapped bath in sidewall and on top of anodes.

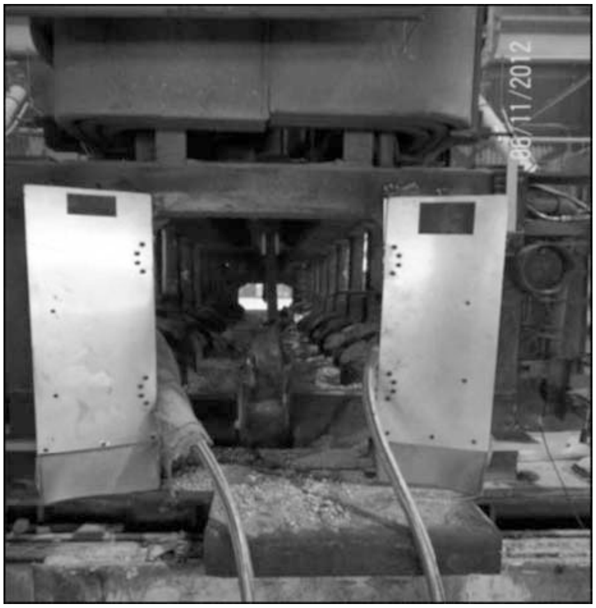

Figure 6. Center channel at end of bake cycle. High-temperature steel hoses connect aluminum pipes to air supply.

Making Liquid Bath

When the cathode surface reached a temperature of 800 °C, the bake cycle was complete. The bake insulation was removed to expose the center channel (Figure 6) and the spaces between the anodes. Dry crushed tapped bath was pushed into the spaces between the anodes, a small amount at a time, by crews working the cell (Figure 7).

The process was repeated at 15 to 20-minute intervals. As the solid bath between the anodes melted, dry bath was pushed into the liquid bath and more solid bath pushed into the space between the anodes. When the solid bath melted, it first formed a pasty sludge. This sludge appeared within a few hours. After about five hours, true liquid bath first became visible between the anodes.

Figure 7. Dry bath pushed between anodes to melt. Note air-cooling pipes on anode assembly.

It is important to note that the process of adding dry bath was done slowly, in order to closely monitor the amount of liquid bath as it developed. The dry bath was added only in between the anodes, and not in the center channel, so the center channel was clear to receive liquid bath if it was deemed necessary to abort the test.

The process of working the solid dry bath into the melting bath was repeated for 24 hours. At intervals over the 24-hour period, crushed dry bath was added to the anode tops and cells sides to replenish the material pushed in between the anodes.

Raising the Anode Beam

After 24 hours of adding crushed tapped bath to the cell, 10 to 15 cm of liquid bath was visible between the anodes. During the same period, the cell voltage decreased as the resistor material was consumed. Figure 8 shows the voltage decay.

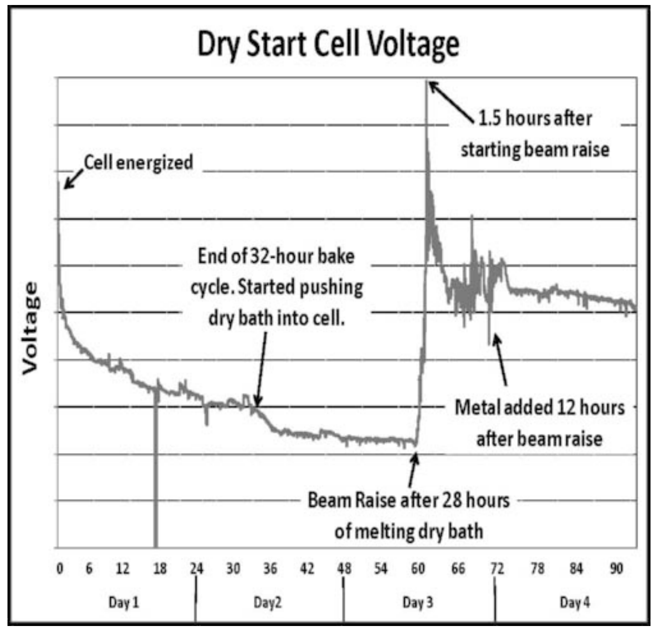

Figure 8. Cell voltage during dry start.

Cathode temperatures, as measured by thermocouples around the cell perimeter, became more uniform as bath melted in the cell (Figure 9). Thermocouples in the corners of the cell read much lower temperatures than thermocouples along the sides.

Voltages of the corner anodes (#1, 9, 10, 18) were among the lowest of the anodes before and after the beam was raised (Figure 10). It is likely little or no bath melted or stayed melted under the corner anodes. Collector bar and transition joint temperatures were stable throughout the bake cycle and beam raise.

At 24 hours after the start of melting bath, the cathode temperatures had leveled off and started to decrease. To continue the dry bath start, it was necessary to raise the anodes off the cathode surface, to increase cell voltage and generate more heat. A four-hour notification of beam raise was given to all production, technical, and rectifier personnel.

At the designated time for beam raise (60 hours after the cell was energized), all personnel were removed from the catwalks, and the anode beam was raised in the smallest increments possible, to allow the liquid bath to flow under the anodes. In between raises, crews went onto the catwalks to push more dry bath onto the cathode surface for melting. As the voltage increased, the heat increased, and more dry bath melted. About 2 hours after the initial beam raise, the cell voltage was stable.

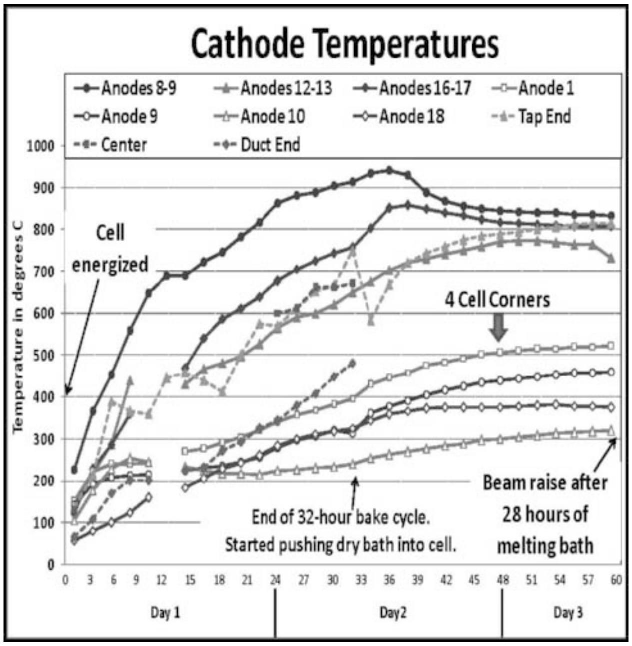

Figure 9. Cathode thermocouple temperatures from cell energized to initial beam raise.

Eight hours after the initial beam raise (68 hours after cell was energized), the cell had 35 cm of liquid bath. Soda ash was added at about three hours after beam raise. When the liquid bath reached the target temperature for metal addition 12 hours after beam raise (72 hours after energize), molten aluminum was added to the cell for a successful completion of the dry bath restart trial.

Conclusion

It is possible, with attention to critical materials and processes, to start an aluminum reduction cell without liquid bath, and therefore, to restart an idled smelter when no liquid bath is available. Specific knowledge with respect to voltages, temperatures, materials, time, and crewing was gained from this successful trial of a dry bath restart at Century's Hawesville, Kentucky smelter. Another trial of a dry bath restart using pure cryolite in place of the crushed tapped bath is under consideration.

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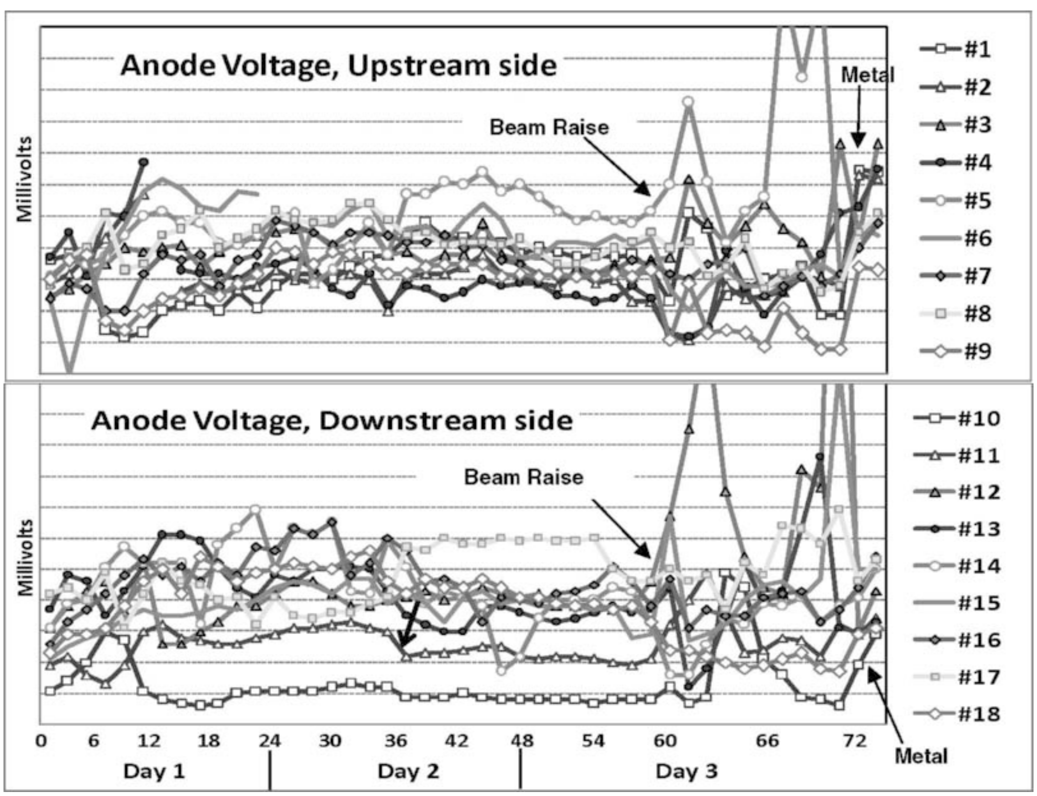

Figure 10. Anode voltages during bake, beam raise, and metal addition.