ARVIDA ALUMINUM SMELTER - AP60 TECHNOLOGICAL CENTER, START-UP PERFORMANCE AND DEVELOPMENT OF THE TECHNOLOGY

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Abstract

The 38 cells of the Arvida Aluminum Smelter-AP60 Technological Center were started at the end of 2013. This successful start-up has established a new benchmark for the primary metal aluminum industry in terms of productivity, robustness, environmental performance and CAPEX/OPEX benefits. The cell start-up methodology was fine-tuned using process data analysis and specific R&D instrumentation. An in-depth measurement activity was performed during the different phases of cell start-up to characterize the mechanical behavior of shells, superstructures and busbars, thus allowing characterization of the robustness of the mechanical cell design. In parallel, measurements were taken to evaluate the cell lining performance and cell stability. After six months of operation, the robustness of the cell technology and the operational and environmental results have opened the way for improved performance and amperage increase.

Introduction to AP60 Technology platform

In response to market demands, RTA has developed a strategy based on a common platform able to deliver high performance cells: a high amperage cell with AP60 (fig 1); and a low energy cell with APXe.

Figure 1 : AP60 pot line during start-up

As seen in Table 1, the two technologies have been developed using the same optimized framework (busbars, shell and superstructure) and equipment to operate the cells. Specific elements, such as cathodes, anodes, and shell ventilation differentiate the two cell designs in order to operate at high amperage (AP60) or low energy (APXe).

Table 1 : AP60 and APXe configuration

Technology	AP60	APXe
Busbar	Common	
Shell	Common	
Superstructure	Common	
Alumina feeding device	Common	
Anode assembly	High productivity	Low energy
Cathode and lining	High productivity	Low energy
Shell ventilation	High productivity	Low energy
Gaz flow	High productivity	Low energy
Pot control system (Alpsys ™)	Common	
Equipments (Pot Tending Assemblies, vehicles, ladles,…)	Common	
Builiding	Common	

The first prototype cells have been tested and validated since 2010 at the LRF (Laboratoire de Recherche des Fabrications, Saint-Jean-de-Maurienne, France) [1]. The new Arvida Aluminum Smelter-AP60 Technological Center (Quebec, Canada) enables the full validation of the cells and equipment in industrial conditions.

As shown in Figure 2, the AP60 development platform will operate at 600 kA with 13.0 kWh/kg energy consumption, while the APXe development platform operates at around 500 kA with energy consumption close to 12 kWh/kg.

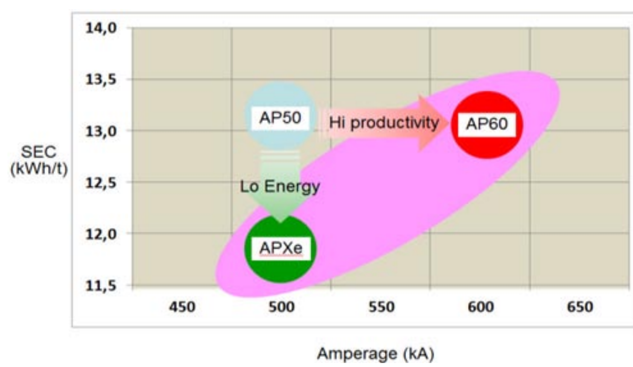

Figure 2 : Operating regions of new AP cell technologies

AP60 technology is a high productivity technology designed to operate at current densities close to 1 Amp/cm2. It is also a technology that uses a lower mass of bath per kA when compared with other cell technologies as shown in Figure 3. This can be achieved using the results of advanced R&D work in process control technology done in the last ten years.

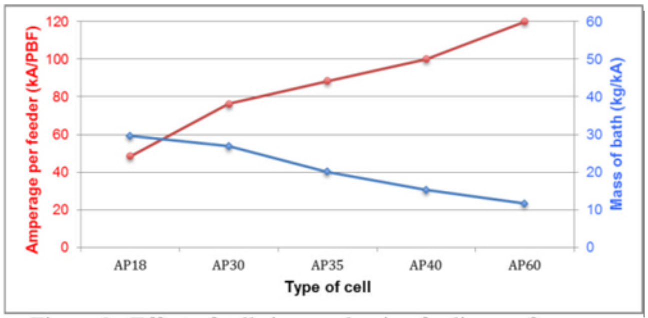

Figure 3 : Effect of cell size on alumina feeding performance (PBF=Point Breaker Feeder)

Smelter Start-up

Following extensive pre-operational verification, including high magnetic field testing of the equipment, the 38 AP60 cells were started. R&D and operation people finalized the start-up methodology of the new technology. The first cells were started using hot bath from the nearby Arvida smelter. Then, cells were started using generated bath from new operating cells. Some of the 38 cells were used to develop a new dry start-up methodology. This approach is important as it provides a method for starting the first cell of a Greenfield smelter.

Specific measurements were taken on each cell to validate the start-up methodology performance. Some cells were extensively equipped with internal thermocouples to monitor the temperature evolution in the lining. The 38 cells were successfully started, and no metal or bath infiltration was detected.

Mechanical Validation of the Technology

To validate the behavior of the cell components, a number of measurements were taken on the cells during start-up and during stabilized operation. This is the first time that industrially manufactured versions of the mechanical components were tested.

Cell Components under Start-up

The start-up period of the cells is always very stressful for the components. The shells and superstructures undergo their maximum temperature exposure and their highest transient conditions. The extreme temperature values and gradients impose mechanical deformations on the components through thermal expansion. Mechanical loads on the superstructure and the expanding lining also contribute to component deformation and material stress.

Each of the 38 cells was measured at four different phases of the start-up. "Cold" phase measurements were taken prior to putting the cell on-line. "Bath+2h" measurements and "Metal+2h" measurements were taken shortly after raising the anode beam during bathup and after adding molten aluminium, which was done about 24 hours after bathup. "On-line+200h" measurements were taken about a week after the cell start-up.

Principal deformations were measured during each phase. These include the vertical upheaval of the sidewalls, the superstructure ceiling, the anode beam, and the anode beam mechanism axles. Additional deformation and displacement measurements were taken on seven cells to include intermediate phases and additional measurement points. During construction, these cells were also equipped with numerous temperature and displacement sensors, enabling the continuous observation of the thermo-mechanical behavior during start-up.

The principal deformations showed the general behavior of the components and enabled comparisons between each started cell. Differences in the deformation patterns were observed based on the adjustments to the start-up parameters, such as in a dry start-up. These differences were more apparent in the superstructure, as it is more exposed to temperature variations of the cell. A typical deformation pattern was determined for the AP60 cell, corresponding to the specified start-up protocol.

The vertical deformation of the AP60 shell can be characterized by the lengthwise upheaval of the structure. The measurements for each phase are presented in Figure 4. These measurements show very progressive deformations along the length of the shell. The center rises while the heads go down. The maximum upheaval was measured at Metal+2h, and this value is similar to what is commonly experienced on AP3X cells.

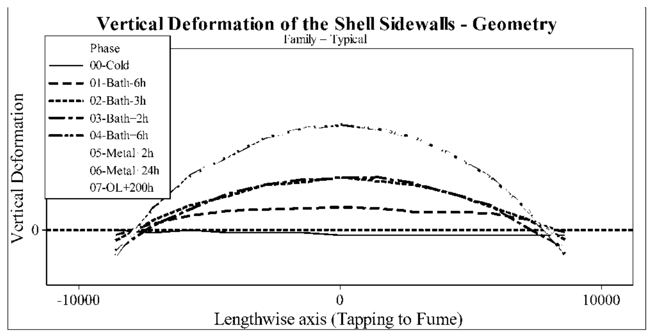

Figure 4 : Shell lengthwise upheaval

The measurements of the anode beam orientation for each phase are presented in Figure 5. Usually, these measurements show two straight beams, with an orientation that varies from positive to negative during the start-up. The final orientation is slightly negative, but presents no impact on cell operation.

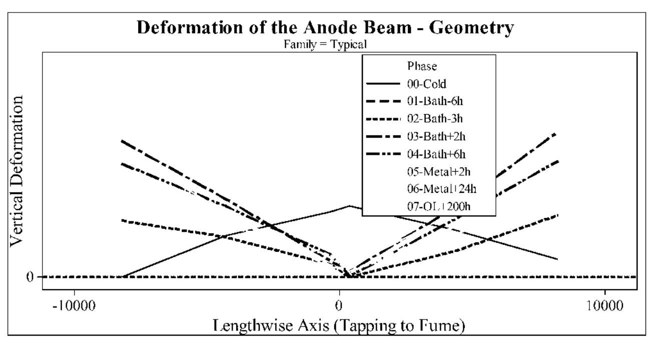

Figure 5 : Anode beam orientation

Principal and additional measurements were compared to the thermo-mechanical modeling results, as well as to available measurements on the prototype cells at LRF. The results show the same deformation behavior, with slight amplitude variations. These variations are the result of minor differences in the component design, the start-up parameters, and the thermal patterns, and are essentially due to the transition from a prototype environment to an industrial environment [2].

The measurements taken, in conjunction with quality and structural integrity observations, validate the component design of the AP60 cells. Additional verifications are scheduled to observe the shells and superstructures during stabilized operation as well as during the first relining campaign.

Busbars in Stabilized Operation

Once all the cells were started and operations were stabilized, a measurement campaign was taken on the cell busbars and on the transition busbars. Current distribution was measured where parallel busbars were present. These showed no signs of irregularities. Voltage drops were measured on the cell-to-cell busbar network and was confirmed as corresponding to design criteria. The quality of the electrical contact in the short-circuiting wedges was evaluated and proved satisfactory. The measurements and analysis results validate the design and construction of the busbars.

The behavior of the cell components (shell, superstructure, and busbars) has demonstrated a very satisfactory performance over the start-up period and the first months of operation of the plant. Some minor improvements opportunities have been identified and included in the design for future constructions. These improvements include adjustments to start-up fuse dimensions and to superstructure end panel deformation behavior.

Cell Performances

Following the plant start-up completion and the mechanical validation of the AP60 technology, the amperage was raised to reach the target of the first phase at 570 kA, in June 2014, as shown in Figure 6.

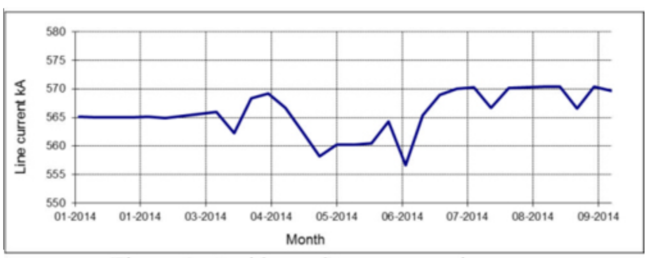

Figure 6 : Arvida smelter amperage increase

During the 6-month period of amperage increase, technological validations were made at different levels: equipment, alumina feeding, thermal regulation, operation practices, process and scrubbing parameters. After the first month of operation at 570 kA, some key performance indicators were confirmed, especially pot stability, bath temperature and anode effect frequency.

As shown in Figure 7, the cell's instability (WRMI) was around 70 nano-Ohms after plant start-up completion. Through the amperage increase and technological optimizations, the WRMI decreased over the months to reach a stabilized level at 30 nano-Ohms, in June 2014. These results confirm that AP60 design is inherently more stable than that of the AP3X, with voltage noise about 20% lower. This can be further exploited to achieve superior performance.

Figure 7 : Arvida smelter instability

This result confirms the optimized MHD situation evaluated by modeling [2] and is very promising for operation at very low ACD.

The cell thermal condition was also confirmed during this period with a stabilized bath temperature of around 960 °C, presented in Figure 8.

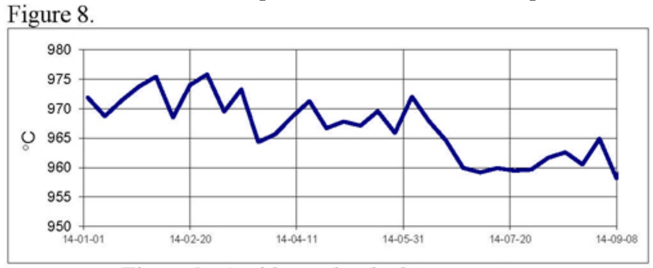

Figure 8 : Arvida smelter bath temperature

As for the anode effect frequency, the results were very unsettled at the beginning of the year, mostly due to the transition phase from the plant start-up mode to the operational mode. However, as the process and operation teams got used to the full line operation and the technological validations made, the anode effect frequency was decreased from 0.4 ae/p/d to 0.02 ae/p/d in August 2014, as presented in Figure 9.

Figure 9 : Arvida smelter anode effect frequency

This result reaches a new benchmark for AP Technology and confirms the potential to realize a very good stable cell performance.

Achieving outstanding environmental performance is one of the main design objectives for the AP60 technology. Indeed, this new generation platform now achieves excellent fluoride emissions at the Arvida Aluminum Smelter-AP60 Technological Center, as shown on the following graph, depicting the pot line roof vent total fluoride emission.

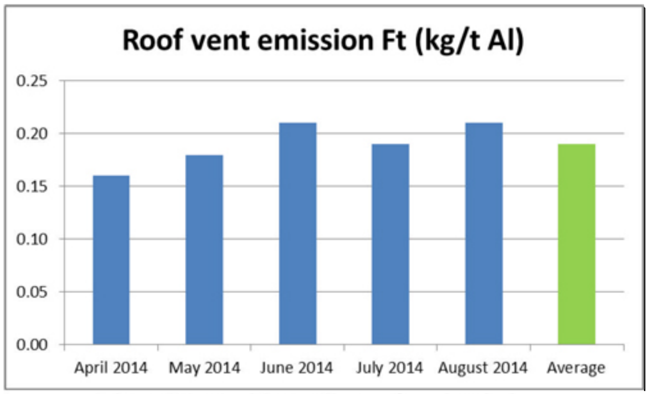

Figure 10 : Arvida smelter roof vent emissions

The performance of 0.19 kg Ft/t Al, achieved over the last five months after plant start-up and operational stabilization, was the combination of the innovative design of the pot gas collection system within the superstructure, specific pot tightness improvements made compared to previous cells generations, the very stable cell behavior and, of course, high work quality. This result was obtained at the lowest possible CAPEX as the plant is not equipped with over-suction system or anode butt boxes, and during the summer period, which is known as being slightly unfavorable. With this 5-month period result, an annual performance of 0,17 kg Ft/t Al can be expected, to be confirmed as results are accumulated over a full year period.

The last step to confirm the cell performance after the plant start-up and the full-scale operation was to realize a specific test to assess the industrial performance of the AP60 technology. During this test, many process and environmental key indicators were strictly monitored, as well as the operation practices and the metal production. In August 2014, the test was managed during a period of 30 days, and the results are presented in Table 2.

Table 2 : Results of the AP60 performance testing during August 2014

Key indicator	Result
Metal production (kg/p/d)	4407
Amperage (kA)	570.7
Current efficiency (%)	95.9
Potline specific energy consumption (kWh/kg Al)	13.090
Net carbon consumption (kg/t)	408
Anode effect frequency (AE/p/d)	0.02
Roof vent fluoride emissions (kg F/t Al)	0.21

For all the key indicators, the results are outstanding and assess very well the industrial performance of the AP60 technology. Local technology experts will continue to monitor longer term performance of cells and pot life, as well as mechanical behavior of equipment to continuously improve the technology.

The Next Steps of the Technology Development

The Arvida Aluminum Smelter-AP60 Technological Center is the platform for technological development up to and beyond 600 kA, as well as new environmental technologies and operational automation.

In parallel with the AP60 technological validation, some cells are operating in Arvida beyond 570 kA on a dedicated development platform. These AP60 cells will be raised up to 600 kA in the coming months to develop the next technological step in industrial conditions and validate a new benchmark in the aluminum industry for cell operation.

In complement, some work is also being done to prepare the AP60 lining next generation in order to lower the energy consumption at this level of amperage as well as to operate significantly above 600 kA.

Conclusions

At the time this article was written, the 38 cells of the Arvida Aluminum Smelter-AP60 Technological Center were in operation, and the AP60 technology was validated at 570 kA. Industrial start-up procedures were developed and successfully demonstrated. Start-up and operational equipment capacity to operate safely in high magnetic field was also demonstrated, as well as mechanical behavior of shells, superstructures and busbars. After the stabilization phase, cell stability was demonstrated and very good operating and environmental performances were measured and confirmed by the specific 30-days test in August 2014.

The results obtained since the plant start-up have established a new benchmark for the primary metal aluminum industry in terms of productivity, robustness, environmental performance and CAPEX/OPEX benefits. With the AP60 technology, Rio Tinto Alcan demonstrated its leadership in the development of efficient reduction cells for the benefit of its own pipeline of internal growth projects as well as for the benefit of the projects of its partners and customers.

References

1. Martin, Olivier et Al. “Low Energy Cell Development on AP Technology TM”, Light Metal 2012, 569-574.

2. Gariépy, René et Al. "Preparation and Start-up of Arvida Smelter, AP60 Technological Center", Light Metal 2014, 797-801.