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ALUMINUM REDUCTION TECHNOLOGY

Cell Design and Performance

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PREPARATION AND START-UP OF ARVIDA SMELTER, AP60 TECHNOLOGICAL CENTER

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Abstract

A new milestone for the reduction technology has been reached with the startup of the Arvida Smelter, AP60 Technological Center in Jonquière (Canada). The Arvida Smelter, AP60 Technological Center establishes a new industry benchmark – the most cost-effective, energy-efficient and environmentally friendly smelting technology commercially available. The first phase has delivered 38 first generation AP60 cells with an annual production capacity of 60,000 tons of aluminum. Starting from the development of the first prototype AP60 cells, this article presents the construction, commissioning and startup of the new smelter in 2013. (Note: At the time this paper was written, potline start-up was still in progress and 19 out of 38 AP60 cells had been started)

Introduction

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; and a low energy cell with APXe.

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

	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, laddles,…)	Common	
Builiding	Common	

Table 1 – AP60 and APXe configuration

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 Smelter, AP60 Technological Center enables the full validation of the cells and equipment in industrial conditions.

AP60 will operate at 600kA with 13.0 kWh/kg energy consumption. APXe operates around 500kA with an energy consumption close to 12kWh/kg (see figure 1).

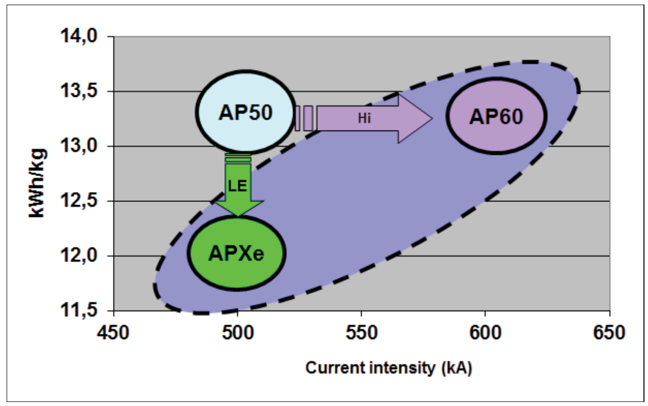

Figure 1 – Operating regions of new AP cell technologies

In addition to energy efficiency and cost-effectiveness, AP60 and APXe comply with Rio Tinto Alcan's demanding HSE standards. With the validation of AP60 at the Arvida Smelter, AP60 Technological Center (Quebec, Canada) and the APXe cell at the LRF, these two technologies enable Rio Tinto Alcan to stay in the vanguard of reduction technology for the benefit of its own pipeline of internal growth projects, and of the projects of its partners and customers.

Taking advantage of the numerous AP30 potlines and cells, a large number of the technology innovations used in the cell design have already been optimized and tested on AP30 technology. For example, the design of the low resistance cathode has been tested on hundreds of AP30 cells. This capability to test technology innovations on several cell technologies (AP18, AP30, P155) has sped up and strengthened the AP60 cell development.

Development of AP60

The development of the AP60 technology started 4 years ago at the Rio Tinto Alcan - LRF installation in France. Reducing Full Economic Cost (FEC) using new knowledge developed in Rio Tinto Alcan R&D centers was the key driver that pulled up the development of AP60 over formally proposed AP50 technology [2, 3].

The economic advantages of AP60 technology

In comparison with AP40 and AP50 cells, the AP60 cell design uses longer anode blocks, and a different superstructure and busbar network allowing for better techno-economic performance. The productivity of AP60 technology (tpy /Full Time Employee) is 25% higher than AP40 when comparing the full potline case for each technology. AP60 productivity is also 15% higher than AP40 when comparing plants at equal energy blocks between 750MW to 1,100MW.

AP60 can be described as a compact technology (high current density and low CAPEX). With 9.62 t/y/m^2 of building area, AP60 is 24% more efficient compared to AP40 at 7.74 t/y/m^2.

A comparison of Full Economic Cost (FEC) and Net present Value (NPV) shows the clear advantage of AP60 (at 570 kA) over AP40 vs. power block size and plant capacity (figures 2 and 3).

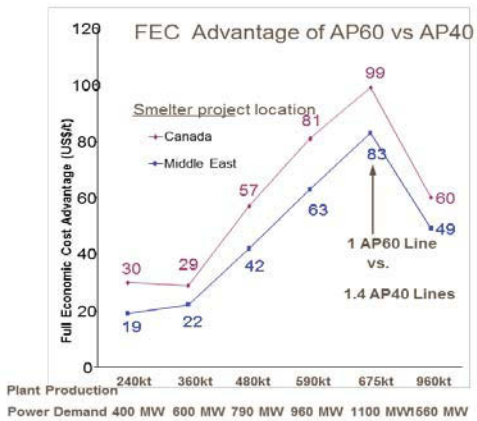

Figure 2 - Full economic cost advantage of AP60 over AP40 for two smelter location.

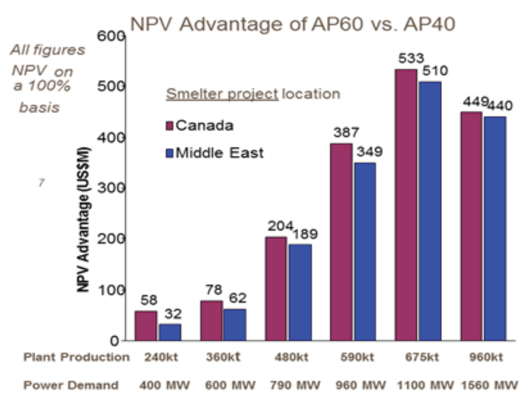

Figure 3 - Net present value advantage of AP60 over AP40.

The resulting increased intensity of AP60 over AP50 allowed also for a reduction in the number of cells (from 44 to 38) to be built for the same capacity of 60 000 Mt/y at the new Arvida Smelter AP60 Technological Center.

Key Development steps of AP60 technology at prototype level

AP60 was designed using in-house RTA specialized thermo-electrical, MHD and thermo mechanical models. After the design phase, it was decided to build one cell at the St-Jean de Maurienne LRF facility in France in order to test the performance of the technology at prototype level while at the same time starting the construction of the new Arvida Smelter, AP60 Technological Center in Saguenay.

An AP60 prototype cell was started in December 2011. Due to LRF substation limitations at that time, the target intensity of the prototype was set at 550 kA. Table 2 shows performance results achieved with the cell over a 6 month period.

Key indicator	Results
Intensity (kA)	550
Current efficiency (%)	94,2
SEC (kWh/t)	13260

Table 2 - Performances of AP60 prototype cell over 6 months

The differences between the prototype cell and the cells at the Arvida Smelter, AP60 Technological Center include; anode height, cover material composition, magnetic fields and exhaust gas flow rate. These differences explain that the LRF prototype cell operate at 550 kA. The Plan of the Arvida smelter AP60 Technological Center is to operate the AP60 technology at 570 kA during the first phase. The remaining 30 kA intensity increase (to operate at 600 kA) is to be done during industrial development of the technology in 2014.

Key aspects of the Arvida Smelter AP60 Technological Center construction.

The notice to proceed for construction of the 38 cell plant was awarded in December 2010. The substation was built in order to sustain a future expansion to a full line smelter.

The rigorous Rio Tinto Alcan process of technology package transfer was a key element of the strategy to build the Arvida Smelter AP60, Technological Center (figure 4). This methodology ensures that all engineering phases are done with carefully controlled information. Emphasis was put on quality control by technology experts for the most important aspects of the new technology. Prototypes of busbars, superstructures, shell and lining were built by sub-contractors and approved by Rio Tinto Alcan experts before going into full scale production for construction.

Figure 4 - Arvida Smelter, AP60 Technological Center.

Project management was done efficiently and integrated very high HSE standards using Rio Tinto's management system.

As the new plant will be the platform for future developments of the AP60 technology, strategic R&D equipment were integrated into the package at the construction phase. A booster section, complete with exhaustive instrumentation for cell monitoring, will be used by RTA R&D teams with expertise in modeling, measurements, cell design, and operation to develop the full potential of the technology.

The commissioning of the technology

At the end of the construction phase, the plant was turned over to the operations team who began a series of tests to commission the new equipment. Among these tests were some more specifically related to the ability of busbars to handle 600 kA of current intensity. Measurements of temperature, displacement of the busbars and short circuit equipment testing were done at different current intensities allowing development of an in-depth knowledge of this critical subject.

The short circuit tests were followed by magnetic field testing of potroom equipment. One needs to know that the level of amperage of the AP60 technology leads to the development of very high magnetic fields (greater than 600 gauss). It was identified early on as a technology risk that the magnetic field may cause malfunction of potroom equipment. Well before the start-up phase, many components were tested in high magnetic fields and mitigation plans were put in place. Even with all this early testing, it was still found that some equipment had to be modified. For example, some forklifts were unable to move at certain locations in the potroom and positioning the tip of the metal crucible was not possible and series of corrective actions were put in place to address these and other specific issues.

During this time, more general potroom equipment testing was also being performed. This phase allowed operators to be trained and get used to the new equipment and operating procedures. This also allowed operating people to interact with internal technology experts dispatched on the site to increase local knowledge of the new AP60 technology.

Cells start-up

At mid-October 2013, the first 19 cells of the smelter have been started. Each AP60 cell required the addition of up to14 MT of liquid bath.

Before adding the liquid bath to the cell, the preheating phase was critical to limit the risks of infiltration. This phase was carefully controlled using specialized thermocouples on the cathode surface and other measurement techniques. It was important that final temperature of the cathode surface reach a minimum target temperature. As shown on Figure 5, the final temperature before pouring the liquid bath was reached after 36 hours.

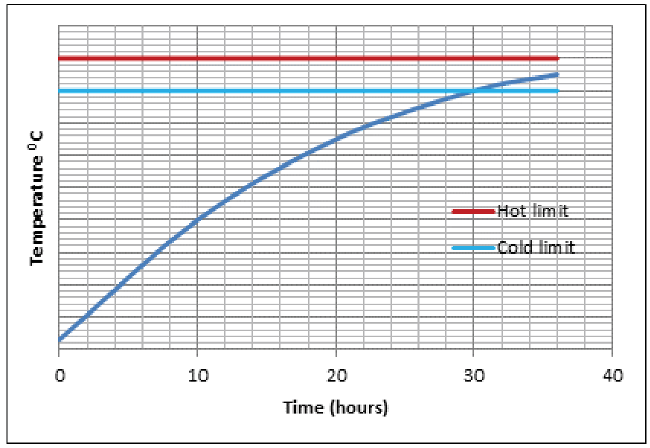

Figure 5 - Surface temperature before bath addition at start-up.

One of the cells was used to develop a new dry start-up methodology. This way of starting the cell is important as it provides a method for starting the first cell of a greenfield smelter.

An important parameter to follow after start-up is the measurement of the cathode current distribution. This information is used to determine if some infiltration took place during early life of the cell. For all the started AP60 cells, the cathode distribution measurements show no sign of infiltration, confirming the robustness of the cell design and start-up method.

For all 19 cells, an extensive measurement campaign was performed to provide data on mechanical behavior of the shell, superstructure and busbar at start-up and during the stabilization phase. Among the measurements done were the dynamic deformation of the shell and superstructure (figure 6). The measured values were compared with the modeled ones and the deviations were analyzed. The results will be used for further development of the technology.

Figure 6 - AP60 superstructure (photo)

Cell stability

One key element of the AP60 technology is the Magneto Hydro Dynamic (MHD) balance of the cell. The first AP60 cell tested in the LRF facility has demonstrated a very good stability. A comparison was made with the AP30 cell (The AP30 cell stability is already very good and has already demonstrated its capability to operate at low ACD on thousands of cells).

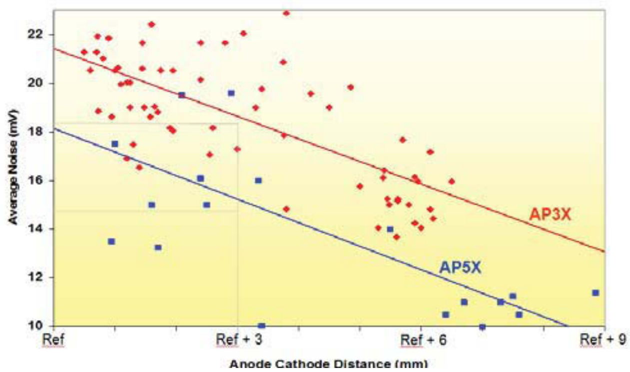

Figure 7 - Comparison of cell noise between AP60 and AP30 cells

Cell noise (measured in mV) of industrial AP30 cells has been compared to the noise of the AP60 cell at LRF. The comparison has been made at different ACDs (in mm) and the results are shown in figure 7. Lower voltage noise indicates greater stability of the metal-bath interface for the AP60 technology (improved current efficiency) and a better ability to operate at lower ACD. Operational results confirm that AP60 technology is inherently more stable than AP3X (by ~20%) due to its very innovative busbar network. This can be further exploited to achieve superior performance.

In addition, the MHD modeling software has evaluated the bath metal interface of LRF cell and for the Arvida smelter cells. At LRF each cell operates at different amperage in the workshop, creating an unfavorable MHD situation. Figure 8 shows that the Arvida smelter cells will have a flatter interface than the LRF cell, opening the way for very promising results.

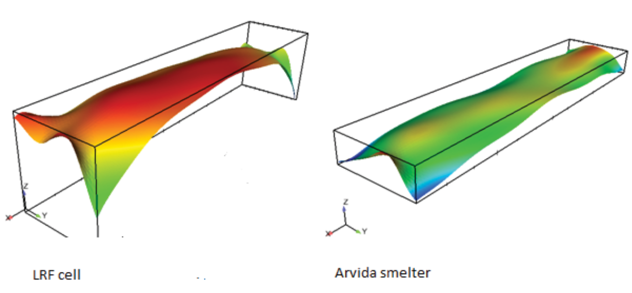

Figure 8 - Bath metal interface of AP60 cell at LRF and Arvida Smelter, AP60 Technological Center (same scale in the two figures)

This prediction has been confirmed by the start-up of the first cell at the Arvida smelter. After a few days of operation, the cell stability is very good. The cell's instability (WRMI) was less than 40 Nano-Ohms (Figure 9).This unique cell stability is to be used for further development of the AP60 technology.

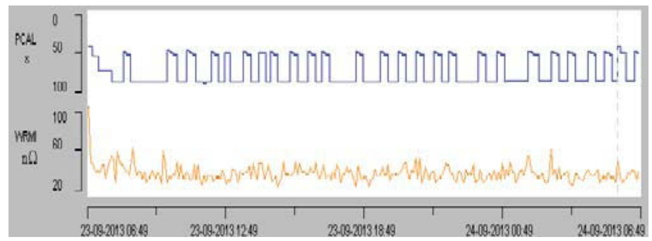

Figure 9 - Stability of AP60 cell

The next step of the technology development

A specific test will be done to assess the industrial performance of the technology. Local technology experts will closely monitor longer term performance of cells as well as mechanical behavior of equipment to continuously improve the technology.

Table 3 shows the targets for the AP60 technology.

	AP60 technology performances
Intensity (kA)	**600**
SEC (kWh/kg)	**13.0**
Production (t/day)	**4.51**

Table 3 - Targets of AP60 Technology

The Arvida Smelter, AP60 Technological Center will be the future platform for development of this technology up to and beyond 600 kA. The platform will also be used to develop new environmental technology as well as operational automation development. With the Arvida Smelter, AP60 Technological Center, Rio Tinto Alcan has developed and validated a new benchmark for cell technology with the AP60 validated in industrial conditions. In parallel the APXe cell, using the same framework (shell, superstructure and busbar) operates at low energy and is ready to be used in industrial conditions.

Conclusion

At the time this paper was written, 19 AP60 cells had been successfully started in the new Arvida smelter AP60 Technological Center. This represents an important milestone for the aluminium industry as AP60 dramatically increases cell productivity over previous technologies. As demonstrated, AP60 cell is 25% more productive than AP40 (tpy /Full Time Employee).

Since APXe (low energy) and AP60 (high productivity) share the same optimized framework (busbars, shell, superstructure and operating equipment) the industrial validation of AP60 at Arvida Smelter, AP60 Technological Center allows Rio Tinto Alcan to stay in the vanguard of reduction technology for the benefit of its own pipeline of internal growth projects, and of the projects of its partners and customers. The new industrial platform is already equipped with a booster and will be the basis for future development of the technology.

The authors would like to thanks all of the pioneers involved in the development, construction and demonstration of the AP60 technology from France and Canada.

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