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THE TRANSITION STRATEGY AT ALOUETTE TOWARDS HIGHER PRODUCTIVITY WITH A LOWER ENERGY CONSUMPTION

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Abstract

The Alouette aluminium smelter at Sept-Iles, Quebec was commissioned in 1992 with a nominal capacity of 215,000 tonnes per year based on AP30 cells operating 264 pots at 300 kA. Since that time, the plant has expanded considerably, and in 2005 a new potline of 312 pots was added plus an 18 pots test section. The cells currently operate slightly over 370 k Amp with plant capacity now at 600,000 tonnes per year. In the quest for higher productivity and profitability, Alouette is planning a transition to 400 kA based on the use of new, high-amperage, low-energy (LE) AP cells, referred to as AP40LE. In designing this new cell, certain lining, rodding procedures and materials of construction were modified. The main performance objectives and the development steps towards introducing the AP40LE pots and plans for bringing all production lines to 400kA are described in this paper.

Alouette in Perspective

Commissioned in 1992, Alouette is a joint venture between Austria Metall, Hydro Aluminum, Investissement Québec, Marubeni and Rio Tinto Alcan. With an original capacity of 215,000 tonnes per year the plant went through several improvement steps, plus a major expansion in 2005, such that plant capacity is now rated at 600,000 tonnes per year.

The reduction plant is based on Pechiney AP30 technology, with carbon anodes produced directly on site at the anode plant. This anode facility includes a VAW/KHD paste plant and four Pechiney, open-pit anode baking furnaces, with each unit connected to a Solios fume treatment center. At the casthouse, molten aluminum is cast in one of three, low-profile sow casters, producing 750 kg sows. The off-gases from both the potroom and anode baking furnaces are cleaned by contacting the off-gas with fresh alumina. An 18 pots test section has enabled Alouette to achieve rapid on-site technology development and implementation. A more complete description of the process plant was recently published[1].

A major asset at the plant is the outstanding relationship developed with the work force. This is an on-going feature at Alouette. In addition, the human resource department and all plant managers, for example, pay special attention ensuring that any new candidate being considered for employment meets Alouette's five basic values: progressive attitude, team work, communication, professionalism and versatility.

The Alouette plant operates under quite specific conditions in terms of fixed energy availability. Thus, an original fixed energy contract at 395 MW was awarded in 1992 (also referred to as Phase I) while a second similar energy contract of 500MW was awarded in 2005 (Phase II). The operation under such a fixed energy contract, where an increase in aluminium production is achieved only by a reduction in specific energy consumption (S.E.C) is quite rare in the industry. At several sites around the world where additional energy may be available, a production increase is instead obtained by increasing amperage and allowing for an increase in pot heat losses, a situation which often leads to an increase in S.E.C. The Alouette operation under a fixed power contract led the Company to develop its technology and related operational practices, leading it to outstanding performances.

Strengths and Limitations of Current Pot Design

In the past 10 years, Alouette concentrated in maintaining its specific energy consumption to the lowest level of the AP3X family while at the same time increasing plant productivity and environmental performances. Figure 1 illustrates the trend in S.E.C achieved during this period. The S.E.C. initially trending upward, due to aging of line 1 and then being lowered to the best values in 2006-2007. Since then, it has been maintained at fairly steady levels in the range 12,700-12,800 kWh/t. Given this flattening out in S.E.C. in recent years, and given that Alouette's target is to remain in its leading position with low energy consumption, a step change at the plant was considered required.

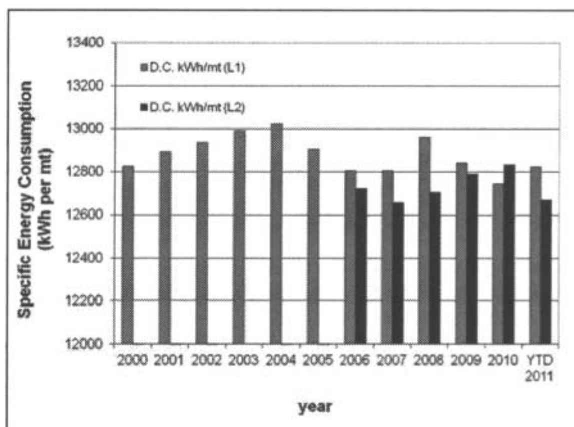

Figure 1-Specific Energy Consumption at Alouette during the last 10 years[2]

A recent paper on the Alouette plant[2] described some of the limitations of the present pots in service. Line 1 was originally built with 264, AP30 pots, while Phase 2 (since 2006) consists of 312 AP30 pots in Line 2, plus an 18 pots test section added as an extension of line 1, for a total of 594 pots (including the test section). The 18 pots test section consisted of two, sub-sections of 9 pots each (test section A and test section B). Out of the 576, AP3X commercial pots in operation, there are approximately 526 pots of the so-called "standard design" (STD) and the remaining

50 pots are "low heat loss" pots (LHL). It is noted that none of the LHL or STD pots use forced air convection to help remove excess cell heat. Alouette philosophy has been to operate at higher cell amperage with constant or lower specific energy consumption (S.E.C), thus obviating the need for such forced air cooling.

Thus, Alouette has had an history of increasing cell amperage and reducing heat losses up to the point that a limit would be found in terms of the lowest anode-cathode distance (ACD) at which the pots could be stably and efficiently operated[2]. As noted, Alouette is now leading the AP3X family in terms of both low ACD and low S.E.C. Lower ACDs are often related to a reduction in current efficiency, but ultimately, it is not so much the current efficiency (C.E.) which is important at Alouette, but the specific energy consumption (S.E.C), hence it is considered that the plant could afford a small reduction in C.E. and still maintain or improve the S.E.C. Nevertheless, when the ACD is overly "squeezed", pot instability or the bypass current can reach a certain level which prevents a reasonable C.E. to be obtained, leading to an increase in S.E.C. It is noted however, the STD and LHL pots at Alouette have not yet reached this critical ACD.

It is recognised however that the LHL and STD pots "as is" are not likely to be operated efficiently at 400kA. It is possible nevertheless that modifications to the STD design, combined with improved operational practices could allow such an improved design to run at 400kA, such improvements are investigated in the test section at Alouette since 2006.

The "Bridging" Concept during a Transition Period

Between 1992 to 2001, it could be said that the Alouette team was initially more focused on operating the plant at the highest efficiency, and at the same time, transitioning from lower to higher conductivity cathode blocks to allow for operations at the forthcoming higher cell amperage. The amperage was raised from 315kA to 330kA during this period.

Figure 2 shows the trend in the increase in amperage for Lines 1 and 2 at Alouette over the last 10 years. Larger anodes and also the slotted anodes were introduced in early 2000; it is considered that these were major "enablers" in allowing subsequent ramp-up in amperage as shown in Figure 2.

A steady progression to higher current levels is seen in Figure 2 between 2004 and 2008, corresponding to the Phase II period plus the transition to the larger anodes. As a result of the Phase II energy contract and of numerous aforementioned improvements, it was possible to increase amperage and pot production. Even though some losses in current efficiency were observed due to the reduction in anode-cathode distance (ACD), the metal production per pot was raised and the specific energy consumption remained between 12,700 and 12,800 kWh/tonne. In other words, Alouette was able to produce more tonnes using the same pots without losing on overall energy efficiency.

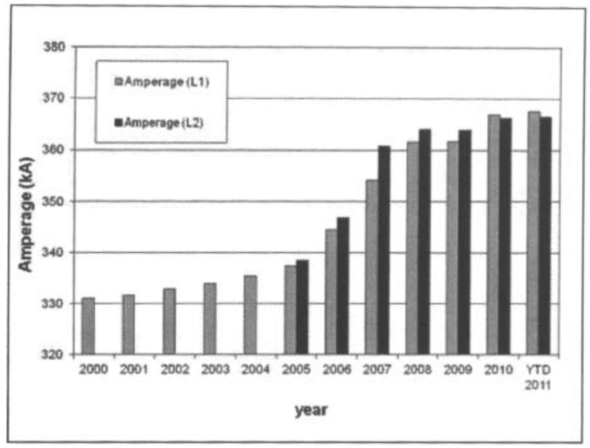

Figure 2 - Amperage Profiles in Alouette Lines 1 and 2 during the last 10 Years

Since 2008, the energy contract has essentially been maximised, and the progression towards slightly higher amperage (Figure 2) occurred by leaving more pots out of operation so as to allow the remaining pots to operate at a higher amperage. This strategy allowed Alouette to keep raising the amperage at the plant even though no additional energy overall was available. It is noted that operating at a lower ACD requires the development of high quality operating practices. Such a route to lower ACD was advantageously taken by Aloutette and preparatory for additional energy availability.

In early 2011, another limitation arose for increasing amperage. At nearly 370kA, with a given anode density, the amounts of carbon left under the anode stubs was getting too low, and higher amperage could not readily be reached without affecting the metal quality. This limitation has since been resolved by changing the anode cycle, thus permitting higher amperages at the end of 2011. The present Alouette strategic plan also includes step changes to reach higher amperages, hence, significant design modification were required to realize the strategy.

During the transition period from the lower to a higher cell amperage, a middle situation exists whereby the new pots which would be designed for a higher amperage would be operating alongside the older ones (at lower amperage), and hence each type would likely operate at a non-optimal amperage. The time required at Alouette to replace all production line pots with a new design will take between 5 and 7 years. Before say 80% of the pots would be replaced by the new technology, the amperage would have to be maintained within the upper limit for the older design, thus dampening productivity. Further, during the transition period, the blended SEC (weighted average of new and old design) must respect that in the strategic plan.

In the case of Alouette, the forthcoming new technology will allow operations at +400kA and also allow to operate at the lower limit of 380kA, while the current design is considered optimal in the 360-370kA range, but is considered to have the ability to reach 380kA incurring only minor losses in energy efficiency and potlife. This latter amperage level is believed adequate for the transition period as illustrated in Figure 3. The Alouette team has therefore been carefully investigating strategies for this transition period (amperages between 368 and +400kA) over the last two years.

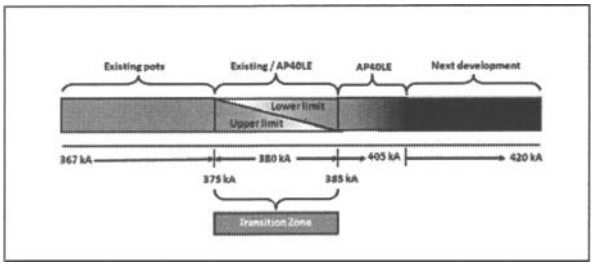

Figure 3: Schematic Diagram Illustrating the Transition between the Present Amperage and that with New Technology.

In this investigation, the upper limit of the STD pots was first identified. This included operating and modelling the behaviour of the STD pots at 367 and 380kA and then extrapolating the behaviour to that at higher amperage. The ACD, the S.E.C. and the thermal balance of the pots were determined and presented in the form of an "operating window".

While the new AP40LE design requires 400kA (optimal level), still, a number of questions were raised with respect to successfully achieving the transition to this level and beyond. Firstly, for example, how could each technology achieve a balance so as to maximise the revenue for Alouette, and how best to position the company for the future? Secondly, what will be the "bridging" strategy to allow the highest production at the lowest cost and risk during the transition period?

The company having challenging objectives, the need for accessing expertise in the fields of pot lining, thermo-electrical and thermo-mechanical modelling was recognised and Alouette has opted for an alliance with Rio Tinto Alcan (RTA) in 2009. This alliance thus allowed access to the expertise developed at other RTA plants so as to fast track development of the proposed new cell, the AP40LE. This cell would operate at high amperage and low specific energy consumption and without convective forced air. The expertise from RTA and Alouette would be pooled so as to meet Alouette's strategic goals.

The main tasks set for the team were as follows:

- Find the maximal amperage for the present technology and evaluate the risk of operating the pots at this amperage (S.E.C, potlife, pot stability, anode effect rates, etc.) during the transition period.
- Design a new pot allowing Alouette to realise its strategy (+400kA) and low energy.
- Prepare a transition strategy and evaluate the plant performance from the present condition through the full transition of the plant to 400kA.

Pot Development Cycle

With the agreement between Alouette and RTA, the AP40LE prototype was developed in a fast track mode. In order to fit with the strategic plan at Alouette, the initial goal was that the new design would operate at 400 kA and with a specific energy consumption of 12,000 kWh per tonne. An initial meeting between RTA and Alouette technical staff was held in the fall of 2009 where a mapping of all possible ideas which could attain the goal was developed. A screening of ideas was then made to eliminate those deemed overly costly, or considered too risky for the situation. Based on this, it was found that the initial goal could be reached, but economical and risk considerations led the team to a pot design operating at 400 kA, but achieving less than 12,600 kWh per tonne. The stepwise project development cycle as developed by RTA is presented in Figure 4.

The development project commenced with an on-site measurement campaign on the standard pots (STD) at 367kA and 380kA. The measurements were then incorporated in a new thermoelectrical model to be subsequently used in the evaluation of how far the STD design could go in amperage while maintaining acceptable energy efficiency and pot performance. The on-site measurements plus the resulting thermoelectrical model allowed the RTA team to evaluate different component packages (anode, cathode, bricks, rodding,etc.). Out of the many possible combinations, the most promising were then evaluated in greater detail to finally arrive at a pot design which would be applicable for relining all the Line 1 and Line 2 pots at Alouette during the next potlining wave starting at the beginning of 2013.

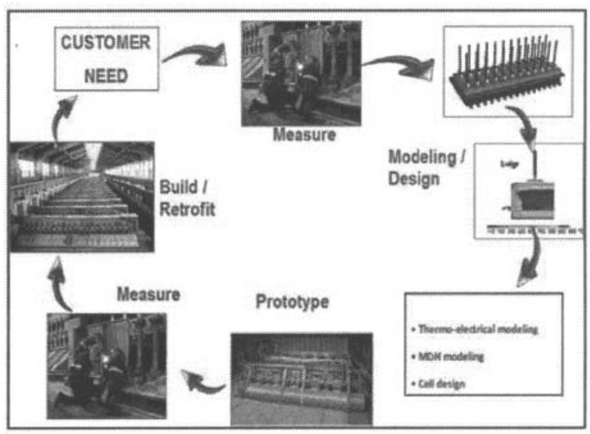

Figure 4 - Pot Development Cycle used by the RTA Development Team

Four prototypes were designed and installed in early 2011 in Alouette's B test section. These new pots have been performing to expectations during the last 6 months at 380kA. In the fall of 2011, a measurement campaign was performed on the above four pots to compare the performance with initial specifications (heat losses, ledge profile, cathodic and anodic resistance,...). It is noted that only minor differences were observed between the engineering design and the measured process values obtained in the field on the four new pots. From these results, it was concluded that the new AP40LE is likely to reach the design performances at 400 kA. At the end of 2011, Alouette is planning to install 3 additional AP40LE pots in the B test section, thus providing 7 pots converted to the new design (out of the section's 9 pots). At this point, it is planned to raise the amperage in the B test section to +395kA. Operation at a higher amperage will confirm whether AP40LE design adjustments are required prior to the implementation.

Figure 5 illustrates a simplified project timeline showing how the team moved from brainstorming (end of 2009) through to the anticipated validated prototype at 400kA expected at the end of 2012. This "fast track" development cycle is thus intended to be completed in slightly more than two years. It is to be noted that such a fast development cycle could only be obtained with the full commitment of the people at site and with access to several components that were tested previously internally or at other plants.

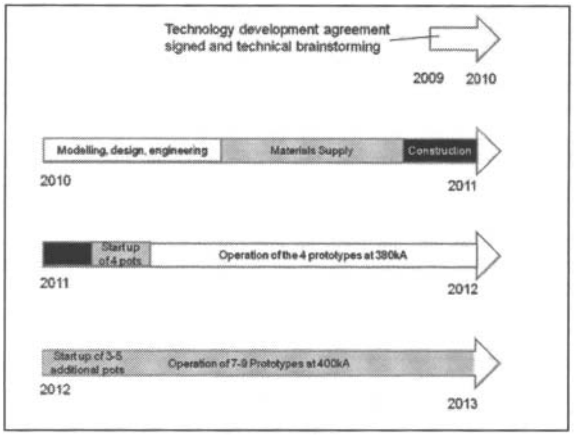

Figure 5 - Development and Commissioning Schedule of the AP40LE Trial Pots

Conclusions

As the Hall Heroult Process is getting closer to what is considered the theoretical limit for energy efficiency in practice, future gains become more and more difficult to attain, and require testing of a number of alternative ideas which can be both costly and time consuming. In order to reach Alouette's strategic goals related to energy efficiency, environmental performance and profitability, alliances with technology and materials providers have been found to be very beneficial. Amongst ingredients for success in process and technology development, the following aspects are considered essential:

- A systematic approach, with stage gates, including the use of continuous improvement techniques.
- Full involvement and "buy in" of the whole work force, including operating staff, technical staff and managers.
- Strong operational experience, incorporating best practice and results from trials developed at other industrial sites.
- Highly skilled process modelling team able to perform on-site measurements for model testing/validation, coupled with the ability to identify both the strengths and weaknesses of the developed models (and make the necessary adjustments).

Within the present alliance between Alouette and RTA, Alouette is sharing its experience in pot design and operating experience at low ACD and low energy consumption, while RTA is sharing its pot design and modelling expertise, its technical resources and its experience acquired at other plants. Alouette is now the elected test site for the new AP40LE which was designed to meet Alouette's strategic goals. This alliance is considered to be a "win-win" situation and all are confident that the anticipated future results will confirm the success of this enterprise.

Depending on the outcome of this project, RTA may offer this new pot technology on the market for greenfield and brownfield projects where high productivity at low energy consumption is required. A site with the AP30 pots could proceed, for example, with such a conversion to AP40LE at a reasonably low capital investment.

Acknowledgments

The authors acknowledge the contributions of the entire Alouette team in reaching the present excellent performance at the plant by continuously improving the AP30 pot design and by improving plant practices. The Company's success flows from their excellent efforts. Acknowledgement is also given to the RTA team, which included outstanding individuals from a number of plants, coupled with those at research and development centres, and for its contribution in the ongoing developments at Alouette. Thanks are also given to Dr. Phillip Mackey of P.J. Mackey Technology Inc. for his assistance in editing this paper.

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