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AP35: THE LATEST HIGH PERFORMANCE INDUSTRIALLY AVAILABLE NEW CELL TECHNOLOGY

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Abstract

Pursuing the goal of designing high performance, high productivity and low capital cost cell technology, Aluminium Pechiney re-engineered its well known AP30 reduction cell to create an advanced cell operating at about 350 kA and called AP35. Following the avenue opened with the re-engineered smaller sister cell AP21 [1], the AP35 design integrates the latest development in lining design, anode assembly and sidewall ventilation.

Several test pots have been operating for four years, with the last 18 months at 350 kA, at the Saint-Jean de Maurienne smelter, allowing for extensive industrial trials of various designs and material variations. Technical performances are presented and discussed.

The new cell technology is also available for retrofitting current AP30 potlines, providing extra production output (compared to an average operation at 325 kA) with modifications depending on the technical limits of the existing facilities.

1 – AP35 technology

The goal of the AP35 project was to re-engineer the AP30 technology, in order to maximise the production per pot, i.e. significant increase in amperage, without any decrease in technical performances (current efficiency etc.) and potlife duration.

To determine the design of robust pots working at maximum amperage, all available variables were studied, from lining to anodic equipment, including pot shell, sidewall ventilation, and process control.

However, we only took into account modifications that could be implemented at low cost and without any potline stoppage, so that this new technology could also be used for retrofitting existing AP30 pots.

1.1 – Design method

The AP35 technology is the result of an optimisation process that lasted more than five years (including design). The main steps are detailed below:

1.1.1 Feasibility and lab studies using numerical simulation tools and lab trials.

All possible modifications being listed, we used numerical models to determine and optimise the more promising configurations.

These tools include:

- a thermo-electrical model to compute the impact of each modification on the thermal balance of the pot and to forecast the amperage
- a magneto-hydrodynamic model to check the metal pad behaviour
- a thermo-mechanical model to evaluate the impact of modifications on the pot shell thermal loads and on the pot shell mechanical behaviour
- electrical and mechanical models to estimate the consequences of the increased loads on the busbars and the superstructure.

We practised lab trials on materials and specific equipment to determine exact characteristics and to test reliability.

We also took into account Aluminium Pechiney's past experiences in pot retrofitting and boosting to select the most appropriate modifications. For instance, we took advantage of experience on the AP21 and AP50 projects.

1.1.2 Industrial optimisations

6 trial pots were converted from AP30 to AP35 in the Saint-Jean G-Line in 1996. Two more adjacent pots followed in 1998.

Amperage was initially set to 330 kA and was increased in late 1999 to 350 kA. These increases in amperage have been the results of a continuous optimisation of the anodic equipment, pot shell ventilation, process control, etc.

The major changes enabling the conversion from the AP30 to the AP35 technology are:

1.2 – Anodic equipment

An increase in anode surface area lowers the electrical resistance in the bath pad, thus allowing an increase in amperage to maintain the thermal balance of the pot.

The limitations of the enlarged anode surface area are linked to the volume of liquid bath: larger anodes mean less liquid bath available for alumina dissolution and an increase in the pumping effect of bath with anode beam displacement.

A further amperage rise is accomplished by increasing the anode pin dimension to increase the rate of thermal dissipation through the top of the pot.

1.3 – Lining

Lining design is a powerful tool for increasing pot amperage. The extra amperage is the result of an increase in heat dissipation through the bottom and the side parts of the pot.

Compared with a standard lining, the AP35 advanced design gave a significant extra-amperage by using:

- Graphitised cathode blocks, with high thermal conductivity,
- Re-engineered sidewalls to increase the heat transfer and to control the ledge profile. Resistance against bath erosion and air oxidation was taken into account.

1.4 – Pot shell and ventilation

Some extra amperage was also obtained through improved pot shell ventilation, increasing the heat flow evacuated through the side lining. Furthermore, this improvement ensures a reduced thermal load on the pot shell, and thus better mechanical behaviour and less maintenance.

Pots shell modifications were implemented in order to provide perfect thermal contact between the side lining and cradle wall, with the use of stiffeners.

1.5 – Process control

4 AP35 trial pots have been equipped with the new Aluminium Pechiney ALPSYS process control [2]. All parameters were optimised for the AP35 technology, leading to excellent pot control: technical results are presented in §2 for current efficiency, alumina regulation, instability and anode effect control.

AP35 technology and the ALPSYS process control lead to very high levels of aluminium production performance, in terms of current efficiency and power consumption.

2 - Technical performance of the trial pots

2.1 – Description of the AP35 trial

The industrial AP35 trial was implemented on 8 adjacent pots in the G-Line of the Saint-Jean de Maurienne smelter, with a 50 kA booster.

Operating such trial pots in a potline gave us the opportunity to:

- benchmark the technical results of these trial pots with those of a well-established reference.
- test the robustness of the technology, by operating the pots in real industrial conditions.

From the beginning of the trial, a group of 5 pots of same age was selected in the G-Line, as a reference, to compare technical results of AP35 and AP30 pots.

2.2 – Specific operations

The trial was organised so that the pots could be operated in the same way as the rest of the potline, without any additional human resources, other than R&D technicians to monitor performance and provide advice on operational adjustments.

However, some operations were adjusted to account for the specificity of AP35 pots:

- The bath tapping table was adjusted because the AP35 have less bath volume than the AP30 due to the larger anodes.
- The anode change cycle has been shortened by 8 8-hours shifts to adapt to the higher current density on AP35 pots, without changing the anode height.
- The metal tapping operation required double tapping per cycle due to the size of the tapping ladles used by the G-Line. This double tapping per cycle is not ideal for smooth operation of the pot, but the AP35 pots did not show any adverse reaction to this particular point.
- The parameters for AP35 thermal regulation and alumina feeding process control have been adapted to optimise the AP35 performance. Both the ALPSYS regulation and the Saint-Jean de Maurienne standard regulation were studied because of the differences between the two systems. The ALPSYS regulation parameters were optimised to take full benefit of the parabolic slope calculation and other improvements. For standard regulation, the parameters were adapted from those of the rest of the potline to take into account the increase in amperage, low bath volume, etc. But these changes were partially limited by the 15 year-old central computer in the Saint-Jean G-Line, which is unable to provide individual values for some operating parameters.

2.3 – Preheat and start-up

All AP35 pots were started up using the standard Pechiney electrical resistance preheat method over 48 hours. We experienced several start-ups, at amperages varying from 330 kA to 350 kA, without any problems.

We designed new AP35 shunts for start-up at high amperage. Excepting this specific equipment, the procedure was not any different from the AP30 pot preheat. We closely monitored cathode temperature during preheat to adapt the removal schedule of the shunts and to achieve the programmed temperature increase in the cathode, with liquid metal added to the pots after 32 hours. All the operations went smoothly without any incidents.

AP35 pots were stabilised and fully operational about 1.5 month after start-up. Figure 1 gives the typical evolution of excess AlF_3 in the bath for an AP35.

2.4 - Technical results

Technical results are given below in table I for AP35 and AP30 reference pots. The values are 6 month averaged (from March 2000 to August 2000).

The AP30 reference pots were lined in 1996 with semi-graphitic cathode blocks.

The alumina regulation, pot instability, ledge profile measurements and graphitized cathode wear are discussed in the following section.

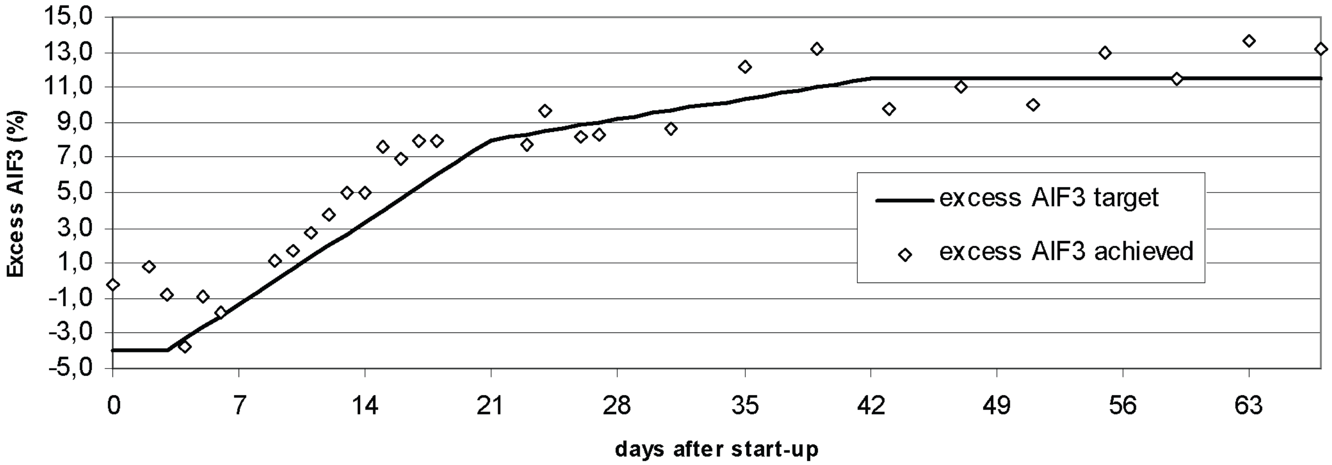

Figure 1: Excess AlF_3 content in the bath for an AP35 pot

Table I: Comparative Technical Results

		AP35 pots	AP30 reference pots
Amperage	KA	349.5	300.9
Current Efficiency	%	94.8	93.3
Pot Voltage (micro-computer)	Volts	4.261	4.151
Power Consumption	KWh/t	13 645	13 475
Pot Resistance	Micro-Ohms	7.47	8.31
Instability	Nano-Ohms	47	61
Bath Temperature	°C	955	953
Excess AlF_3	%	12.2	11.9
Cathode Resistance	Micro-Ohms	0.87	1.04
Anode Effects (ALPSYS for AP35)	Number/pot/day	0.24	0.22

Amperage on the boosted section is now at the maximum booster capacity, but we consider that the trial pots may be able to take some more amperage via small thermal adjustments.

Adjustment of the thermal regulation makes it possible to reach target values for bath temperature and excess AlF_3, despite the low volume of liquid bath available in the pots.

Difference in cathode resistance features the cathode block type: graphitized for AP35 and semi-graphitic for AP30 reference.

2.5 – Subjects of interest

2.5.1 – Alumina regulation

One major challenge during the AP35 trial was the small volume of liquid bath available due to the larger anodes: about 2.5 tonnes less than for a standard AP30, which means less alumina dissolved in the bath whereas the alumina consumption is theoretically 17% higher.

However, optimisation of ALPSYS regulation leads to high performance in alumina feeding.

Tracking duration is 6 minutes shorter for AP35 than for AP30, as expected with the higher alumina consumption.

2.5.2 – Pot instability

An initial objective with the AP35 project was to verify that these pots could operate with an amperage increase of 20 %, and still be well balanced magnetically.

The results shown in figure 2 demonstrate a significant improvement (by -14 nano-Ohm) which proves the excellent stability behaviour of the AP35 pots.

The stability enhancement is partly linked to the slotted anodes implemented on the trial pots. This impact can be seen on figure 2, with AP35 stability decreasing at the end of April 2000, once pots were fully equipped with slotted anodes.

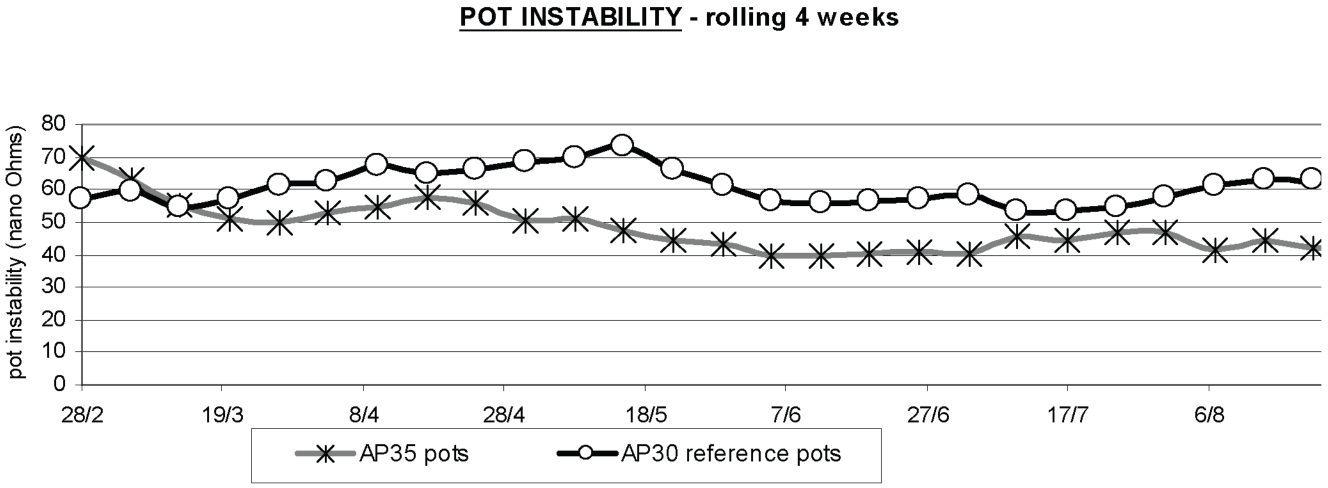

Figure 2: Comparison of pot instability.

2.5.3 – Pot ledge profile

The pot ledge profiles are measured on a regular basis to evaluate the protection of the side lining.

Figure 3 presents average ledge profiles on the upstream and downstream sides for AP35 pots and AP30 reference pots at the age of 4 years approximately.

The use of an advanced side lining design, in conjunction with improved pot shell ventilation, provides very efficient side protection for 4 year-old pots: there is almost no attack on the side lining compared with AP30 reference pots.

This good protection suggests that the cathode pot life duration will not be affected by sidewall wear.

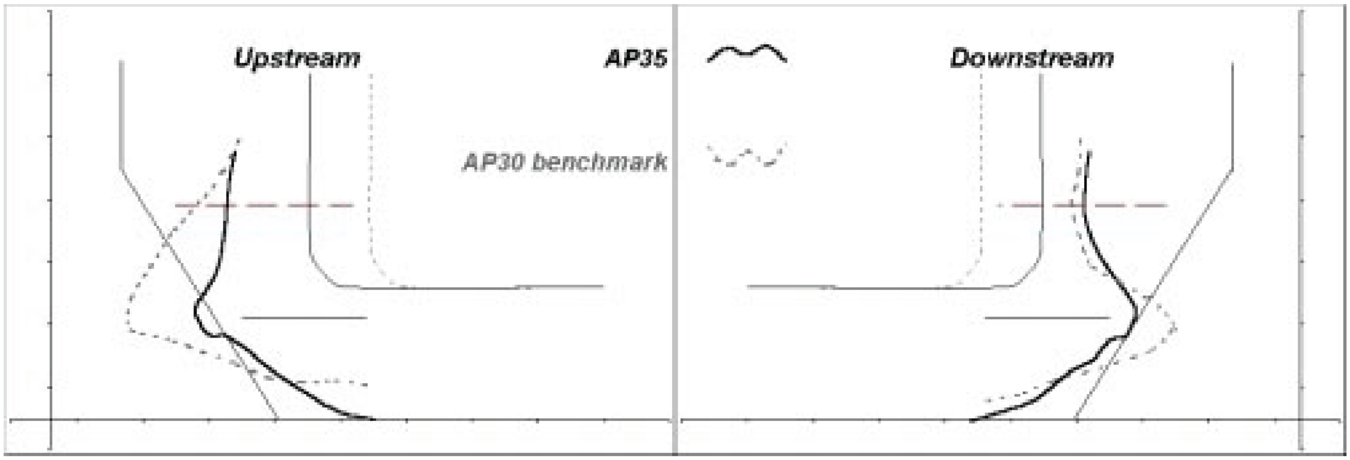

Figure 3: Comparison of pot ledge profile.

2.5.4 – Cathode wear

Side lining protection being assured, another concern about the AP35 potlife duration was the graphitized cathode wear [3].

Apparent wear rate (not corrected for cathode heave) is regularly measured on AP35 trial pots.

Figure 4 gives average and maximum wears per pot for different ages. The wear rate calculated on the maximum wear measurements is about 53 mm/year.

This figure corresponds to average wear rates measured and calculated on standard AP30 pots, which means that there is no increase in graphitized block erosion with the increase in amperage.

This result allows us to forecast a life duration of about 65 months, or about 2000 days, for AP35 pots.

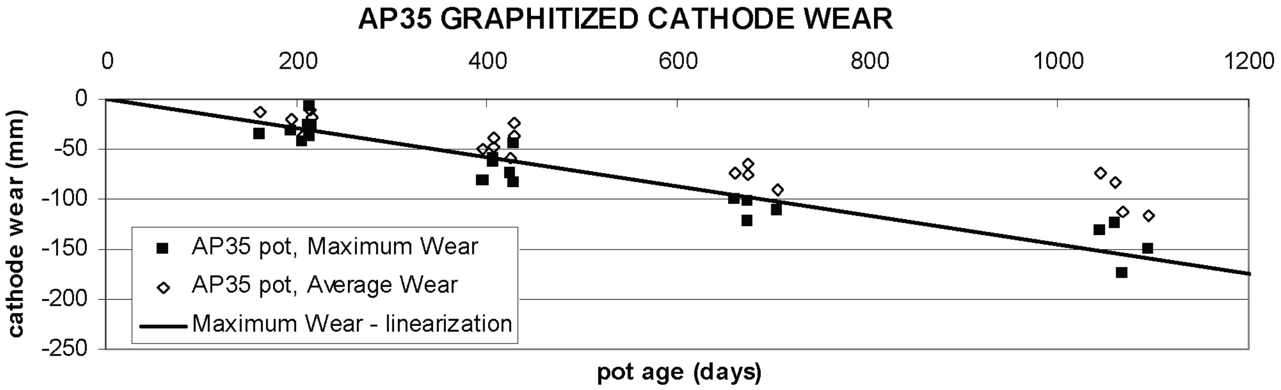

Figure 4: AP35 graphitized cathode wear

2.5.5 – Conclusion on technical performances

The AP35 trial pots in the Saint-Jean de Maurienne G-Line have proved their robustness and high level of performance.

The optimised design being implemented and validated, the main issue was to adapt the pot feeding parameters to the increase in alumina consumption and to the decrease in liquid bath volume. Optimisation of the pot thermal balance and the fine tuning of both the ALPSYS regulation and the standard G-Line regulation systems resulted in very satisfying results.

Furthermore, potlife duration is very promising, as estimated from the side ledge profile and cathode wear.

These results, achieved in an industrial environment, make AP35 pots an efficient technology industrially available to date.

3 – Economical considerations

An AP30 smelter operating at 325 kA (such as Aluminium Dunkerque) is considered as the reference in the following sections.

Two cases are detailed: retrofitting of an AP30 plant and construction of a Greenfield plant.

3.1 – Retrofitting

The marginal investment costs for the additional production depends very much on the technical limits of the existing facilities. Major modifications may for instance be required in the substation to deliver the extra-power or in the carbon plant to produce and bake longer anodes.

In comparison, modifications in the reduction department may be very limited. For instance, the AP35 trial facilities validated busbar capabilities at 350 kA as well as the pot emission draft compatibility with the Saint-Jean de Maurienne dry scrubbing system. Consequently, the main modifications may involve only some pot tending facilities (tapping ladle, anode trailer, etc.).

Depending on the technical thresholds of the existing facilities, the estimated marginal investment costs are about 650 US$ per tonne for the additional production.

However, the AP35 technology can be customised to optimise this marginal investment cost to the target of a specific project.

3.2 – Greenfield

The significant increase in production using AP35 technology compared to AP30 results in a reduction of the total investments cost per installed tonne.

Plant investment costs increase by only 1.5 %, whereas the production is increased by more than 9 % (higher amperage and better current efficiency), leading to a minimum 7.5 % reduction in investment costs per tonne.

4 – Conclusion

After 4 years of operation and optimisations in the Saint-Jean de Maurienne G-Line, this new technology is proving its high efficiency and robustness.

The trial pots have been running for the last 18 months at 350 kA. Their industrial operation has confirmed that our design tools and methods were well calibrated.

AP35 technology can be used either for retrofitting AP30 plants or for Greenfield projects.

Aluminium Pechiney has completed feasibility studies to implement this technology in its AP30 plants in the coming years.

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