# Design Options to Reduce Specific Energy Consumption in Aluminium Electrolysis Cells

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**Abstract**



The aluminium smelting industry is facing a period of economic challenge, where the aluminium price is down due to a supply-demand imbalance. The industry is now seeking ways to reduce costs in order to remain competitive. One of the few options that the aluminium smelters have is to reduce energy consumption, since it represents around 35 % of the production cost. Design options to reduce energy consumption by two ways are presented. One way is reducing the heat generated by Joule effect in the cathode and anode conductors, including an innovative design feature to reduce voltage drop in the anode. Another way is reducing the heat losses through the anode and cathode panel. These concepts can be used in existing technologies. Numerical models were used to predict the behaviour of these options and their impact on the cell thermal balance. Approximately 0.8 kWh/kg Al saving is predicted after implementation of all options presented in this paper.

**Keywords:** Aluminium electrolysis cells; energy consumption; anode design; cathode lining; thermal balance.

## 1. Introduction

The history of the aluminium smelter industry has shown a continuous decrease of specific energy consumption (SEC) in the reduction of alumina. It was a long road from the 30 kWh/kg Al consumption in the 1900's to the present world average of 13.5 kWh/kg Al, according to IAI [1]. Nevertheless, the reduction rate has stalled in the last 40 years. Only recently some initiatives towards less than 12.0 kWh/kg Al have been published by RTA [2] and Hydro [3].

However, as Barry Welch has pointed out [4] there are many constraints in the present technology, if one is seeking even lower values towards the theoretical minimum of approximately 6.3 kWh/kg Al. The main constraints are related to:

- The unavoidable energy wasted in the busbar used to link one cell to the next;
- The energy associated with the bath superheat required for alumina dissolution and for keeping a stable ledge protection, since there is no sidewall material that resists the liquid bath exposure;
- The preheating of gross carbon, cover, impurities and alumina;
- The inevitable heat losses associated with keeping the cell operating at high temperature.

Some of the typical strategies used to reduce SEC are: decreasing bath heat generation by lowering anode-to-cathode distance (ACD) [5], which requires a very stable pot regarding MHD; reducing the current density by increasing anode and cathode area while keeping the cell current constant; reducing anode bubbles voltage drop which may be achieved by using slots [6] and some latest ideas such as anodes with holes [7] to extract the gases. These strategies are not the focus of this paper, which will be on design options for anodes and cathodes seeking to reduce voltage drop and heat losses.

### 1.1 Reducing heat losses

The purpose of the anode cover, which usually consists of a mix of crushed bath and alumina, is to thermally insulate the top of the anode block, while preventing its oxidation. Its composition and thickness controls the heat losses through the cover but there are limits for both. Increasing alumina content reduces thermal conductivity but crust stability may be put at risk. In addition, there is a physical limitation to increase thickness related to the yoke position that cannot be covered to avoid its oxidation. The thermal conductivity of the anode cover material changes during anode life due to penetration of bath vapours that consolidates the bottom part of the loose layer in a hard portion [8]. This part has a much higher thermal conductivity and starts to become hard at around 725 ºC [9]. For this reason, the reduction of the thermal losses at the anode by increasing the thickness of the anode cover is limited.

Insulating the sidewall is not new in cell design [10], but should be employed carefully to avoid cell operation without enough ledge protection. There is a limit in heat losses reduction, which is related to limitations in space and the type of materials that can be used in cell construction.

### 1.2 Reducing voltage drop

Reducing voltage drop in anodes is found in papers [11] and patents such as: US7192508 B2, US5538607 and US6977031 B1. Some ideas of how to improve the contact between cast iron and carbon were studied. They are either related to stub hole design [12] or the one proposed by Berends [13] that uses multiple steel conductors driven into carbon and bonded into the cast iron.

There are many options regarding the reduction of voltage drop in cathodes. Increasing cathode block length decreases cathode voltage drop. Extra care should be taken with side lining insulation due to the reduction of the distance between sides of cathode block and the shell. Increasing collector bar section reduces voltage drop but the side effect is that it increases heat dissipation. Also, there is a limit related to increasing risk of cracks due to block strength reduction in the region around the bar. The use of graphitic and graphitized cathode carbon blocks also reduces voltage drop.

More recently, Feng [14] showed the results of the so called novel structure cathodes (NSC), which are being used in China with success in cells operating at around 12 kWh/kg Al of SEC.

An interesting option to reduce cathode voltage drop is the use of copper inserts in the steel collector bar. It has been tested by the industry since the 1970's (patent US3551319) with a strong renewed interest around end of 1990's (patents US 5976333, US 6231745 B1 and WO2001063014 A1). However, at the same time that copper collector bars reduce the voltage drop, they affect the cell thermal balance by extracting more heat due to the high thermal conductivity of copper. Therefore, it is very useful in a project employing higher current, but it should be used carefully in a project targeting lower energy consumption.

The main problem in reducing the electrical resistance of the conductors, such as anode or cathode, is that this always results in a decrease in the thermal resistance of the assembly. The electrode extracts more heat from the bath and, coupled with the fact that less Joule heat is generated, more heat generation by ACD is therefore required to keep the thermal balance of the cell. As a result, at the same cell current, the SEC increases or stays at the same value.

require modifying anode dimensions, preventing modifications in the rodding shop and baking furnace. The concepts can be used in existing technologies allowing the increase of energy efficiency at a low cost of implementation.

The low SEC anode together with the suggested cathode design results in a SEC gain of more than 800 kWh/t of aluminium with a minor impact on cell productivity.

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