POTLINE STARTUP WITH LOW ANODE EFFECT FREQUENCY

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Abstract

Nordural has had a policy of continuous improvements, including reducing the total carbon dioxide greenhouse gas equivalents by lowering anode effect frequency, gross and net carbon to the level where the smelters total attributable emissions (including allowance for anode baking) is less than 1800 kg CO₂ equivalents / tonne of Al. The technology and work practice changes to achieve the improvements have been described elsewhere.¹

For the start up of the second potline, further modifications were carried out to the cell pre-heat and start-up work practice to ensure a rapid, but manageable, potline commissioning using the existing work force. Four cells were started up in quick succession each day. Despite the normal problems associated with the commissioning new plant and equipment, during the start up of the first 100 cells the anode effect frequency, as counted from the time of bath-up of each cell was less than 0.09 anode effects per pot day with the average duration being similar to that of the established potline.

The Paper describes the design improvements, work practices and operating strategy used to achieve this smooth commissioning with a low demand on the work force.

Introduction

As part of Nordural’s continuous improvement strategy, work and control practices to reduce per fluorocarbon emissions from cells has been a priority. Nordural has had sustained periods of operation of pot lines with anode effect frequencies below 0.05 anode effects per pot day as a consequence of this. The detailed strategy and approach used have been described in detail elsewhere.¹

Because of their relevance to the approach and strategy for pot lines startup, key features of the general AE minimization methodology developed are described here. Changes made included:

- A greater emphasis on limiting the magnitude of the voltage rise above a minimum in the alumina concentration/resistance curves.
- Optimizing the magnitude of over feeding used to terminate the anode effect.
- Ensuring the maximum percentage of the alumina introduced to the cell electrolyte comes from the point feeders rather than indirectly through crust and cover spillage (and hence sludge/muck baked feeding).
- Rapidly lowering the current density and obtaining good mixing during the termination of the anode effect to minimize the time when anode effects occur.
- Using more detailed analysis of the normal cell feeding resistance versus time curves including adding special feeding modulations so that there was early detection of deviation from normal work practices or other mechanical causes of feeding irregularities within the cell (including blocked feeder holes, empty ore bins and failure of crust breakers etc).

The first of these changes was motivated by the earlier confirmation that COF₂ precedes the anode effect and, as originally predicted by Culandra.⁶

The equivalent reaction:

\[
3C + Al_2O_3 + 3NaAlF_6 \rightarrow 3COF_2(g) + 4Al + Na_3AlF_6
\]

\[\Delta G_{900\text{C}} = 632 \text{ J/mol COF}_2\] (1)

occurs at a potential well below that normally predicted for carbon tetrachloride evolution. The carbon tetrachloride formation arises from a secondary chemical reaction leading to the high proportion of carbon monoxide being co-evolved as per the reaction

\[2COF_2 + C \rightarrow CF_4 + 2CO \quad \Delta G_{900\text{C}} = -45.8 \text{ J/mol CF}_4\] (2)

this depolarizes the potential/voltage at which the CF₄ is formed.

Depending on the process variables in the cell, especially the chemistry, temperature and operating current density (hence anode potential/polarization), the initiation of an anode effect will occur at anode potentials less than 0.3vols above the minimum voltage in the cell alumina modulation curve – this compares with the normal thermo dynamically predicted value of almost 1volt.

Navarro⁶ has shown that fast extinguishing of anode effects can occur simply by appropriate lowering of anode current densities and emphasizing the mixing and his approach had similarities to steps introduced in order to efficiently extinguish the anode effects without heavy feeding.
Many cells have considerable alumina concentration gradients in them\(^{5,6}\) and, in this work we found that the gradients could be minimised by improving the reliability of the equipment, and reducing the opportunities for muck and sludge to form. This was achieved by changing the anode setting pattern to one that enabled better anode coverage but less spillage\(^{2,7}\).

**Some of Nordural's Experience in Reducing the AEF**

As the AEF (anode effect frequency) was reduced, the greatest proportion of multiple anode effects due to mechanical failures in the transfer of alumina from the ore bin into the electrolyte increased. Accordingly, more sophisticated analysis of the curves was also introduced in order to obtain early detection of these problems although they could only be resolved by subsequent inspection of the cells. The overall benefit of these approaches is illustrated in the following curve – the success being achieved over a number of years.

![Reduction in Anode Effect Frequency](image)

**Figure 1: The reduction in AEF with improved practice and control at Nordural**

**Restart Cells and Smelter Anode Effect Frequency**

As the anode effect frequency was reduced, the anode effects associated with the restart practices became a significant contribution to the total. The restart practices that were being used were consistent with those used in other smelters with the occasional strong AE which generated considerable heat.

In the re-examination it was found that there was no need for excessive heat generation after adding bath if the surface had been adequately preheated while eliminating the AE was found to reduce localized differential expansion stresses.

Likewise the need for an AE to clean the cell bottom of oxide to ensure an absence of sludge, was also found to be unnecessary because of the quality of modern control which could be implemented immediately after bath-up. Accordingly a modified demand feed logic was developed to help eliminate start-up AE's while ensuring all normal target conditions were met.

**Key Features Of Nordural’s Preheat And Re-start Practice**

Some of the general features of the preparation and preheat practices are listed below. The key goals were to ensure uniformity in temperature cathode block temperature within the cell (although gradients up to 80° between corners and centre could occur) and the final heat-up temperature being sufficiently high that freezing would not occur during the bath transfer for bath-up.

1. A graphite + coke resistance bed was used covering the full cathode surface. Its resistance, granulometry and bed thickness were adjusted to give the target total heating rate (as measured by the total megawatt hours input and calculated from a model) and achieve the target temperature (of greater than 930°C) within the desired time.

2. The cell preparation involved using a retaining material around the periphery of the anodes and packing the gap around the edge of the cell with a mixture of crushed bath and powdered soda. This combination ensured minimum risk of airburn of the cathode blocks whilst delaying the rate of baking of the sidewall.

3. The prepared cell had the top of the anodes covered with an insulating fibre plus a limited amount of normal cover material. Hoods were positioned in place in the normal manner.

4. Full line current from cut-in, but using flexes between the anode rods and anode beams at all times.

5. During pre-heat the current through individual anodes was monitored at regular intervals.

6. Individual anodes were isolated if the target current through them exceeded a given value for the routine monitoring. The anodes were isolated for a fixed time prior to cutting back in. The isolation was by simply releasing the clamp between the floating end of the flexible and the anode beam.

7. The temperature of the thermocouples in the centre channel was monitored at regular intervals to ensure uniformity and compliance with the target heating rate.

If the cathode temperature had not achieved the target value 12 hours before the expected bath-up, remedial action was taken to ensure and increase in heat-up rate. This could involve removing some of the insulating material and allowing the bottoms of the anodes to airburn.

![Illustrating the typical cell preparation for preheat - cell is ready for bath-up](image)