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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[3].

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(2) that COF_2 precedes the anode effect and, as originally predicted by Calandra (3).

The equivalent reaction:

$$3C + Al_2O_3 + 3NaAlF_4 = 3COF_2(g) + 4Al + Na_3AlF_6$$

$$\Delta G_{960\,C} = 632\ J / mol\ COF_2 \qquad (1)$$

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

$$2COF_2 + C \rightarrow CF_4 + 2CO \qquad \Delta G_{960\,C} = -45.8\ J / mol\ CF_4 \quad (2)$$

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 0.3volts above the minimum voltage in the cell alumina modulation curve – this compares with the normal thermo dynamically predicted value of almost 1volt.

Navarro(4) 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(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.

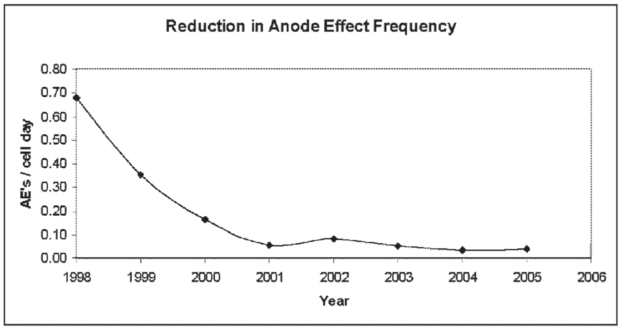


Figure 1: The reduction in AEF with improved practice and control at Nordural

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 930oC) 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

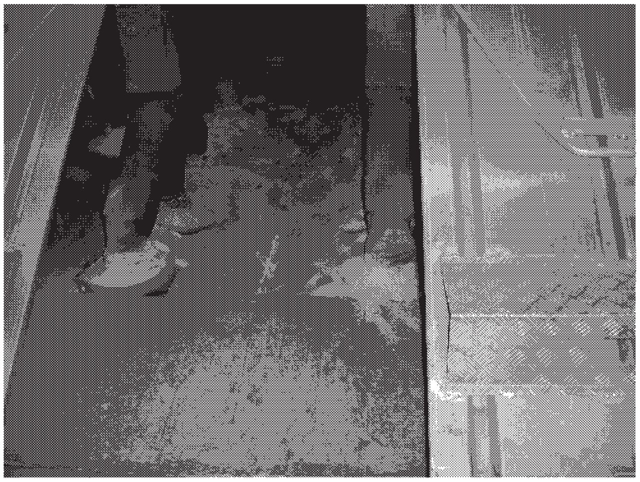


Figure 2: Illustrating the typical cell preparation for preheat – cell is ready for bath-up

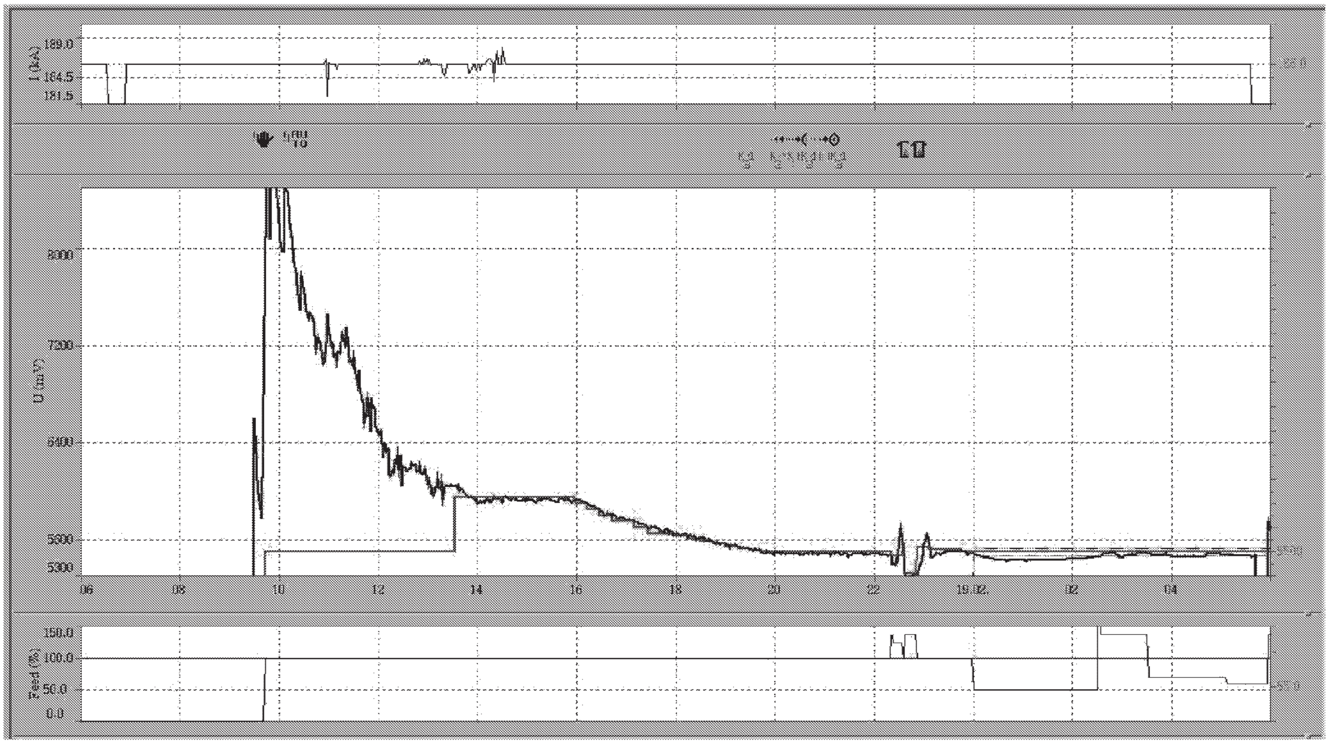


Figure 3: A typical cell feeding and voltage response during the first 20 hours following bath-up

During bath-up, each cell was given four crucibles of bath, each crucible being approximately 1.5 tons. The following were additional procedures:

- During the pouring of the bath, two alumina shots were added from each feeder as the bath passed down the centre channel. The purpose of this was to ensure the operation of the feeders was as expected and the cell was in the full state of preparedness. It also ensured good mixing of alumina around the cell so that the chances of anode effects were minimised.
- When the target depth of bath reached 10cms at the opposite end during the pour, the supervisor would start raising the anode beam towards the target inter-electrode spacing of 7cms.
- The total amount of bath transferred during the start-up was targeted to give a total liquid depth of 25cms, although there was a pause between the fourth and subsequent transfers.
- The cell voltage was monitored during the beam raising and bath transfer to ensure the rate of beam raising controlled so that the voltage did not exceed the mandatory eight volts.

Once all bath had been transferred, the cell was put in a special feed strategy to ensure that anode effects did not occur.

The temperature and cell voltage were monitored at regular intervals during this and the subsequent settling period.

- When the voltage had dropped to a new stable value (approximately 5.5volts for the cell preparation and anode/cathode distance) and the temperature started to increase without additional ACD/ voltage, the cell cathode surface was clear of freeze, excepting under some of the side packing.
- If necessary, in order to stop the temperature of the bath going outside the target temperature range of between 970°C and 995°C, manual adjustments to the set point voltage were made.
- Approximately 12 to 16 hours after bath-up, with the cell being within the target voltage band and target temperature band, the cell was ready for metal transfer. Typically approximately 8 tons of metal was transferred in order for the cell to start approaching the target combined depth for metal and bath.
- After bath and metal transfer, the cell was put into normal process control mode (demand alumina feed) and the target resistance/ voltage reduced to within 250millivolts of final target value. This target voltage was subsequently slowly adjusted down towards the final target value within the next five days.

Practically, during the first 12 hours after bath-up and prior to metal transfer, little alumina was added to the cell via the automatic feed strategy, most of the oxide supply coming from the extra bath volume and the reaction of the soda mixed with the side packing crushed bath.

The associated voltage and control feeding of a typical cell start-up is illustrated in Figure 3. In this graph, some of the “noise” reflects the bath transfers.

Since sufficient soda was packed in the sides, based on experience with the cathode blocks, the cells seldom required further soda additions in the first week, and subsequent soda adjustments were rarely made. They were only added if the chemical analyses (which were initially performed at a more regular interval than normal) moved out of the target band.

At the end of the first week, the cell settling had the voltage at the normal target control band and the chemistry towards the lower limit of the normal operating band. This was allowed to self-adjust further until it reached the mid-point and the cell was operated normally thereafter.

The benefit of the anode effect free startup procedure has also shown up in the long term cell performance figures. As shown in the following table, the long term efficiencies of the cells has increased and, presumably through less cathode damage, the energy consumption has also been reduced through lower cell voltages.

Table 1: Performance analysis of cells using the new restart practice

Cell Group	Startup	DC kWh /t Al	CE%	AE's/cell day
Semi Graphitic	Traditional	13.66	94.2	0.069
Semi Graphitic	"No AE's"	13.38	95.5	0.055
Graphitic	"No AE's"	13.14	96.3	0.05

Pot Line Startup

The objective of the pot line startup was to get the first 100 cells in operation and their stable condition as quickly as possible, whilst not interfering with the operation of the other pot line or the continued construction and commissioning that was going on in other expansion phases of the smelter. The following were features of the startup plan:

1. Four cells per day were to be started, all sequentially over a two hour period starting at a fixed time each day. This sequential approach was decided on because:
   i. The bath transfer crucibles were hot.
   ii. The overall smelter work could be planned so this occurred at the time there was minimum likelihood of demands on cranes and routine operations in the other pot lines was at a low activity level.
2. A normal work crew was used but this was always led by the Shift Supervisor/Leader.
3. Whilst normal preheat time was 60 – 70 hours, the new pot line was preheated for 72 hours in order to give better control, lower risk and enable remedial action to be taken if an emergency had occurred.
4. Four sets of bath transfer pouring stands were made, with these being positioned ready for the startup each day.
5. Three bath transfer crucibles were used, each having bake capacity of 1.5 tons.
6. A total of 20 sets of specially designed flexibles were used. The design of these was to enable quick removal from the cells about to have bath-up and quick relocation to the next cell that they were to be used on.
7. The transfer of flexibles was by a modified attachment for the anode jacking frame to support the transfer.
8. The cells started during the previous four days were used as a source for making and supplying new bath. At the end of the four days the baths had been settled towards the normal target masses.

Figure 4: One of 16 anode flex sets being removed with aid of adapted transfer assembly

<u>Differences In Cell Preparation Practice</u>

Four cells adjacent to the last ones put onto preheat were prepared using the flexibles from the cells that had been cut-in during the previous shift with the preparation being in the normal manner. This included:

- Laying the coke–graphite resistance bed.
- Using sidewall packing of crushed bath mixed with powdered sodium carbonate. This avoided the risk of high concentration pockets.
- Thermo couples for temperature monitoring were positioned in the centre channel of the cell. .
- Anodes were isolated from the clamping point using insulating paper but positioned ready for quick clamping when being bathed-up.
- Insulating fibre and some cover material was applied to the cells and the hoods positioned.

All the preparation work was performed by a crew of 7 operators during the shift following the cut-in of the bath-up and activation of the last set of cells as well as monitoring cells on preheat.

The cells were cut-in for preheat at approximately the same time each day . This was important since the practice necessitated the line current being put to zero before cut-in.

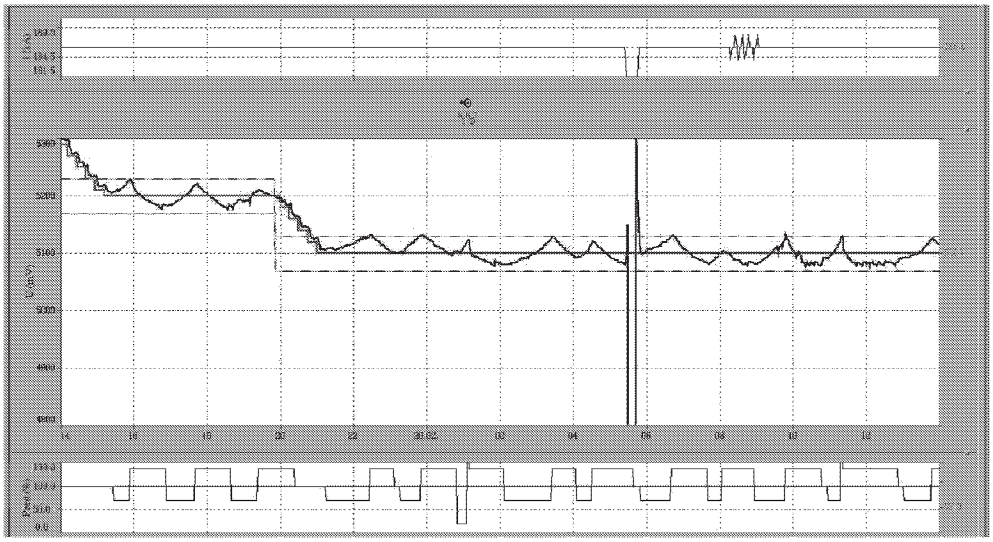


Figure 5: The energy management and control of a cell during its use for making bath (days 2 &3)

Figure 5 above shows the operating control curve of one of the early startup cells in its second and third day. During this period it is being used for bath production and consequently the cell voltage is higher and the underfeed times less consistent. However the anode effects are being avoided.

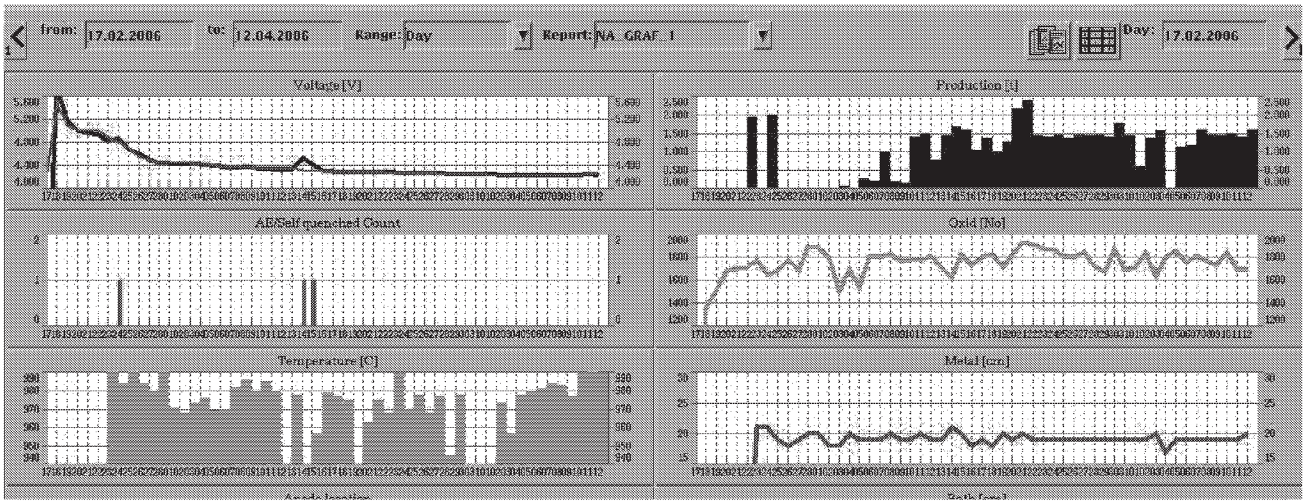
Results for the Startup of the First 100 Cells

The startup of the larger new pot line involved a total of 240 cells. However it was necessary to stage these as completion of the potline and other support services (such as anode covering material, hot metal treatment at the cast house etc) was staged. As with any new pot line, new equipment and electrical hardware is also involved and these are usually more sophisticated, and in themselves, have greater teething problems. However, for the first 100 cells, the smelter had the backup of equipment from the existing pot line and therefore the impact of these teething problems was minimised.

The following features for the startup of the first 100 cells however show the benefit of the new procedures introduced and the minimization or elimination of anode effects.

- The average anode effect frequency was less than 0.09 anode effects per cell day over the first 50 days
- The average operating voltage after settling the cells was 4.25volts, which was 0.03volts less than previously achieved.
- The total man-hours per cell started that can be attributed to the total cell preparation, preheat and startup procedure was less than 40 m-h per cell

The problems of commissioning a new line are illustrated in Figure 6 which is the daily summary from a cell started in the first week. While it only had three AE's in that period (AEF<0.06 / cell day) the two AE's in mid March were at a time control software was being upgraded.



from: 17.02.2006 to: 12.04.2006 Range: Day Report: NA GRAF 1 Day: 17.02.2006

Figure 6: The first 2 months of operation of a new cell

Subsequent to this stage (first 100 cells), delays in satisfactorily commissioning some of the key support services and debugging of the new equipment resulted in the need to reduce the pot line current and adapt actions as we attended to the other issues.

Consequently long term performance figures at the target operations have not been able to be achieved – partly due to inexperience in optimizing the operation and control of the cells at the low amperage..

However the preheat and startup practice for the new pot line has been satisfactorily established.

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