Use of Barrier Material to Reduce Sodium Penetration to the Sub-Cathodic Lining of Electrolytic Cells

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Abstract

Cathode block heaving and cracking along the centreline in electrolysis cells have been observed in some EGA cells. These occur due to expansion of cathode blocks and bottom lining as a result of sodium penetration into these materials. The resultant stresses impact cell operation and cell life. The use of a barrier material placed directly underneath the cathode block was tested by EGA as part of cell lining improvements to reduce sodium penetration into the bottom lining. This paper discusses the results of using two potential barrier materials – graphite foil and steel. The conclusions are based on autopsies of two test cells, one for each barrier material.

Keywords: Aluminium reduction cell, Cathode block heaving, Sub-cathodic lining, Barrier materials, Sodium penetration, Cell autopsy.

1. Introduction

The integrity of the potlining materials is a crucial factor in reduction cell performance and operating cost. The cathode block, carbon materials and sub-cathodic refractories undergo extreme conditions during cell life, which affect cell operating condition, cell performance and cell life.

The potlining degradation is a combination of several factors, of which sodium penetration is a crucial mechanism. It can cause cathode block cracking or heaving, leading to potential increase in cathode block resistance, cell instability and early failures.

There have been many attempts to test different materials and design improvements, aiming to reduce the impact of sodium penetration in the reduction cell. EGA has undertaken controlled trials to test different materials as a protective layer underneath the cathode block. The paper discusses the main findings from the test cells using graphite material (Test I) and steel plate (Test II).

1.1 Sodium Penetration Through Potlining Materials

One of the main degradation mechanisms is sodium penetration into sub-cathodic materials as a result of the electrolysis process. Sodium migrates downward through the carbon cathode blocks into the sub-cathodic refractories by electrochemical driving force [1]. Sodium in aluminium will be in equilibrium with the melt species (NaF and AlF_3) as per Equation (1) and react further to sodium in carbon Equation (2) [2, 3].

$$Al_{(l)} + 3NaF_{(in\ cryolite)} \rightleftarrows 3\ Na_{(in\ Al\ )} + AlF_{3\ (in\ cryolite)} \quad (1)$$

$$Na_{(in\,Al)} \rightarrow Na_{(in\,Carbon)} \quad (2)$$

Sodium penetration occurs through the cathode block pores and cracks. It penetrates alumina and silica-based refractory materials and forms sodium aluminate and sodium silicate compounds, which can contribute to significant chemical and mechanical degradation of the lining materials [1, 4]. The increase in sodium penetration is influenced mainly by current density and some other factors, such as bath temperature and composition, and cathode material composition. The result is cathode block expansion and heaving, and degradation of sub-cathodic lining materials. While sodium penetration of the carbon lining materials is normal and unavoidable, excessive penetration may lead to decrease in the thermal insulation and significant contribution to cell failures.

Cracking of cathode blocks is an important factor that adversely affects the cell performance and cell life. Crack formation is mainly due to thermal stress, mechanical stress and electrochemical degradation [1].

Cathode block heaving can cause major disruptions to operations. Heaving occurs due to sodium infiltration and thermal expansion [3]. Sodium expansion of carbon blocks and bath penetration into refractory materials cause cathode block heaving and eventual cracking and spalling. Spalling detaches surface layers of the cathode blocks and exposes them to further erosion and degradation, which compromise the integrity of the entire potlining. Cracking provides infiltration paths for sodium and molten bath to the refractory lining and facilitates chemical attack of refractory lining materials [5].

2. Test I: Using Graphite Foil

A controlled test of bottom lining material was conducted at EGA to evaluate the use of graphite foil as a barrier protective layer to stop sodium penetration to sub-cathodic lining materials. A graphite foil of 0.5 mm thickness was used in the test cell. A double layer of the foil was placed on the top of firebricks, under the cathode block, throughout the cell, while keeping other materials with no change. Five test cell were built: three cells in CD20 technology and two in D20 technology.

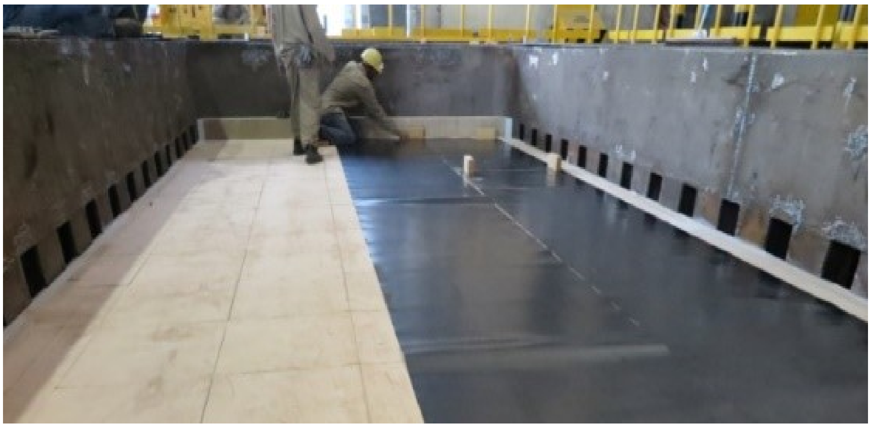

Figure 1. Cell construction using graphite foil.

2.1 Graphite Foil Performance

The trial cells were monitored closely. Trial cells had smooth operation and did not have any sign of abnormality due to the tested material. The cell performance was compared to control cells

4. Conclusions

Sodium penetration into carbon blocks and bottom lining occurs due to the aluminium electrolysis. Excessive sodium penetration can lead to cathode cracking or major cathode block heaving which can limit the cell life. The paper described testing of two different materials as a possible barrier to sodium penetration:

1) In test I, thin graphite foil under the cathode block did not show any benefit and did not prevent sodium penetration through the sub-cathodic lining.
2) In test II, the steel plate effectively stopped sodium penetration to the sub-cathodic materials. Even though, the cathode voltage drop was nearly the same as in control cells, major cracks in the cathode blocks were observed, but we have no proof that the cracks were related to the presence of the steel plate. Apart from the autopsied cell, which was an outlier, the life of other test cells was in the normal range for that technology. As a result, we believe that a steel plate barrier is a good option for further tests in other cell technologies.

5. References

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