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ALUMINUM REDUCTION TECHNOLOGY

Environment I

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Reduction in HF emission through improvement in operational practices

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Abstract

In a prebake aluminium reduction cell, hydrogen fluoride is generated due to the continuous electrochemical oxidation of the hydrogen entrapped in the carbon anode matrix leading to formation of HF emission. Additionally, presence of moisture content in alumina or due to electrochemical generation in anode leads to HF formation due to the following reaction:

$$2AlF_3 + 3H_2O \longrightarrow Al_2O_3 + 6HF$$

Emissions are known to have adverse impact on human and urban environment. Hence, Dubai Aluminium has adheres to strict performance standards in order to reduce HF emissions via investment in high efficiency Fume Treatment Plants (FTP) which are capable of capturing more than 98% fluoride emissions and revising operational job practise. In D20 technology potline, a reduction in roof HF emissions 30-50% was accomplished after reviewing operational practises. This paper describes the initiatives implemented to reduce roof HF emissions.

Introduction

Hydrogen fluoride (HF) is a hazardous gas, therefore as part of corporate social responsibility Dubai Aluminium is committed to reduce HF emissions to meet stringent environmental performance standards.

The aim of this paper is to describe how hydrogen fluoride (HF) emissions have been reduced without installing additional scrubbing equipment in the flue gas line. Understanding the generation of HF and its escape mechanisms are therefore important.

In potlines, hydrogen fluoride is generated mainly by to the reaction of alumina with the available atmospheric moisture

$$2AlF_3 + 3H_2O \longrightarrow Al_2O_3 + 6HF$$

The reaction is endothermic in nature. Other sources of heat, such as hot bath and hot anode act as a catalyst and aid in the formation of hydrogen fluoride.

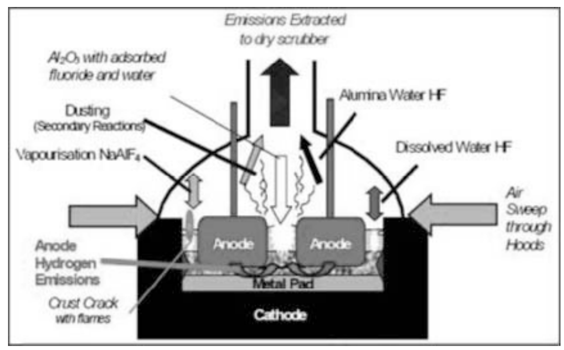

Figure 1: The important aspects of fluoride generation in an industrial aluminium smelting cells, ref [9]

A significantly higher percentage of HF escapes from the pots when the pot hoods are opened for routine anode replacement – an activity that is more frequent as the potline amperage is raised. The situation of controlling and minimizing HF emissions is therefore both challenging and intriguing.

Figure 2: Evolution of amperage in Dubal Potroom, ref [10]

Analysis and measurement of HF Emissions

More than 42% of the roof HF emissions have been reported to in the routine anode setting activity, figure 3.

The information provided a direction to prioritize the actions to control the fugitive emissions.

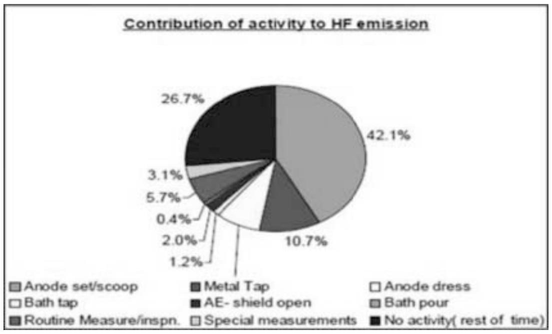

Figure 3: Contribution of various operational activities to the total HF emissions in Dubal. Ref [7]

Boreal made HF Gas Analysers have been installed and operating in most of the potlines at Dubal. It measures gas concentration over open paths, as shown in figure 4.

Figure 4: Boreal HF gas analyser used in Dubal potlines

It consists of a rack-mounted integrated transmitter/receiver, the Central Control Unit (CCU) and remote heads. The setup is illustrated in figure 5.

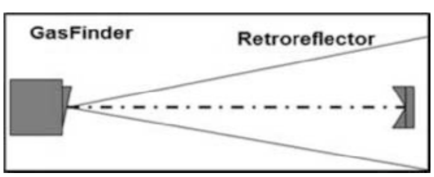

Figure 5: Schematic of Boreal HF gas analyser

In the cells hydrogen fluoride is generated from the fluoride based bath of electrolyte in gaseous form and in solid form.

The solids are formed in the vaporisation process from the exposed electrolyte and the entrainment of particulate materials from bath, alumina feed and crust during the evolution of gases.

Hydrogen fluoride has several generation mechanisms in electrolysis cell. One of the mechanisms is attributed to hydrolysis when alumina enters and dissolves in the bath. As the adsorbed moisture content reacts with the aluminium fluoride and leads to formation of HF emissions following the below reaction, ref [9]:

$$NaAlF_4 + 3H_2O \rightarrow Al_2O_3 + 3Na_3AlF_6 + 6HF$$

Another mechanism is the hydrogen content in the anodes which could react with fluoride based electrolyte leading to HF formation.

$$Na_3AlF_{6\,(l)} + 1.5\,H_2 \rightarrow Al_{(l)} + 3NaF_{(l)} + 3HF_{(g)}$$

Formation of Hydrogen fluoride drops exponentially at lower temperature, figure 6.

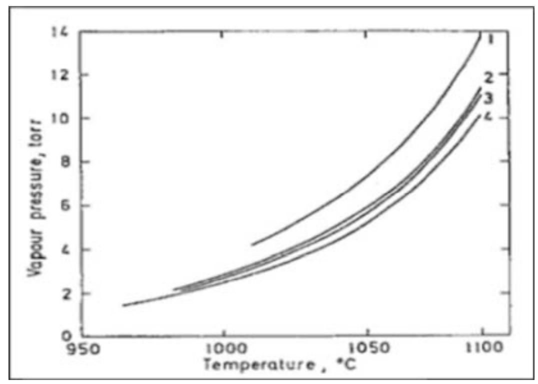

Figure 6: Total vapour pressure of system of Na_3AlF_6-Al_2O_3-CaF_2 Vs Temperature. ref [3]

Improvement in operational practises

A series of initiatives were taken to lower the HF emissions from the potlines. A 41% reduction in HF emissions has been achieved in the D20 technology potlines, figure 7. The success was achieved by optimising work practices and re-designing tools and equipment. The important changes have been discussed and presented.

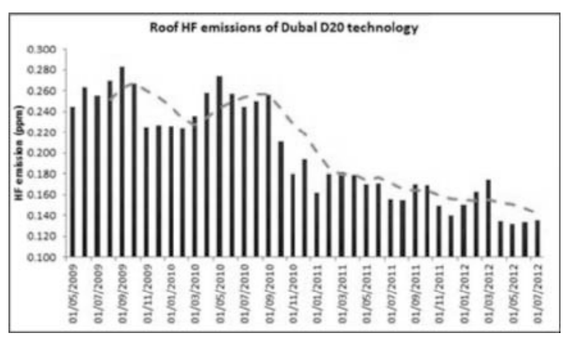

Figure 7: Reduction of roof HF emission in D20 technology, ref [11]

1- Anode Replacement Activity

Anode setting is considered as the most common manual routine operation practise in a prebake aluminium reduction cell. Anode setting activity comprises a number of steps which contribute to HF emissions such as:

- Removing the hot butt and placing it on an open tray.
- Placing cavity scoop skimming material in open hopper containers.
- Keeping the cell cavity open until setting the new anode.

In order to minimise the evolution of hydrogen fluoride during anode setting activity, the following improvements have been implemented:

a. Restricting only two cell hoods removal per cell just before removal of the butt.
b. Introduce cavity scoop material container cover tray as illustrated in figure 8.

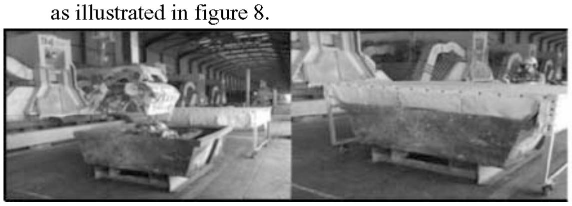

Figure 8: Mobile cavity scoop material cover tray

c. Increasing cell draft rate to maximum level during anode setting automatically.

The impact of the above practice changes on HF emissions was tracked and shows a 27% reduction in Hydrogen fluoride emission during an anode setting shift as illustrated in figure 9.

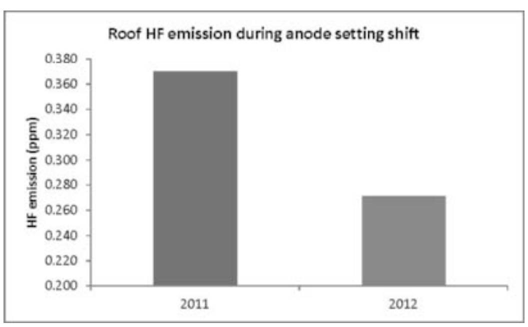

Figure 9: Reduction in roof HF emission during anode setting shift

2- Bath up of a New Cell

A number of steps contributing to HF emissions were identified during a cell bath up activity:

- Pouring hot liquid bath from the crucible into an 'open' pouring launder to reach the cell cavity.
- Following the bath up, skimming of resistor coke from the 'open' back-walls of a cell.
- Hydrogen fluoride emission from the gap between the rod and the gas-skirt.

The initiatives were:

a. Changes over from CP coke to graphite as the resistor bed for cell preheat. The practice also enabled a 90% reduction in the quantity of the resistor material. Consequently, the practice of back-wall skimming following a bath up has been discontinued.
b. Adopted the practice of complete hooding during bath up.
c. Seal the gap between anode rod and gas-skirt.
d. Establish the usage of customised new cell bath up door as illustrated in figure 10.

Figure 10: Usage of new cell bath up door

e. Customise the bath pouring launder with complete sealing in order to avoid direct HF emission to the environment.

   A 38% HF emission reduction was achieved following the implementation of the above initiatives.

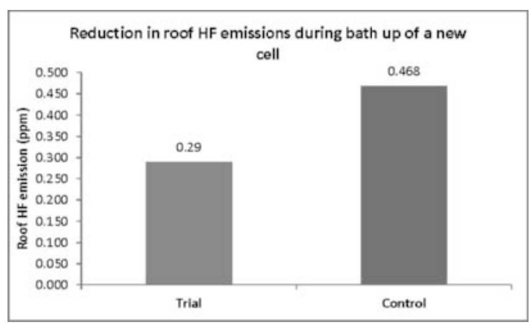

Figure 11: Reduction in roof HF emissions during bath up of a new cell

3- Fumes generated during metal and bath tapping

During the metal tapping operation, the molten metal is siphoned directly into an insulated cast iron crucible by the use of an air-ejector system. The compressed air ejector then produces a suction of the metal into the crucible.

Bath tapping is done in very much the same way as metal tapping with siphoning bath from the cell into a special bath tapping crucible.

The cruce lid aspirator was re-designed in order to angle the aspirator towards the cell thus drafting the gas to the gas treatment centre.

A reduction of 65% in HF emissions was achieved during the tapping activities as illustrated in figure 12.

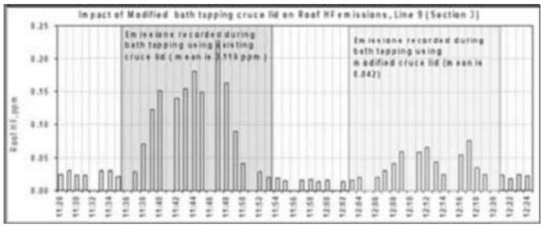

Figure 12: Reduction in roof HF emission due to diverting of bath tapping cruce lid, ref [11]

4- Cell cut out practice

During cell cut out and removal of all liquid from the cell, the damper in the ventilation duct is now opened fully to reduce the emissions and cool down the anodes as illustrated in figure 13.

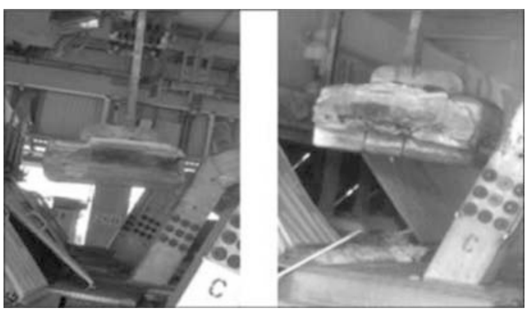

Figure 13: Old practice of removing hot anode and new practice of removing anodes once cold

5- Miscellaneous

Cell hooding and tap door sealing efficiency was improved by the following practice changes:

a. Introduced a stopper at the end of the cell quarter plate to avoid shield displacement, figure 14.

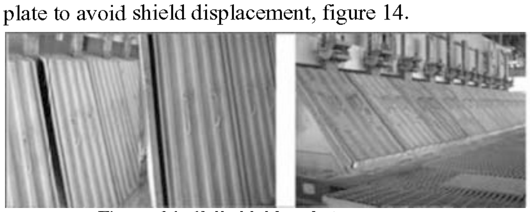

Figure 14: Cell shield end stopper

b. Introduced a systematic audit and repairing sequence of shields.

c. Faster methodology of charging metal crucible skimming material to the cell to minimise tap door opening time.

d. Enhance cell tap door bottom sealing, figure 15.

Figure 15: Fixing a light aluminium sheet at the bottom of cell door

Conclusion

Despite the harsh Gulf climate and the amperage creep, Dubal has made great strides in controlling the HF emissions to a current level of 0.158 kg/t of Al roof HF emission. The paper focuses on simple, but effective techniques designed to further lower the HF emissions into the potrooms.

All design changes were conceptualised and carried out in-house. Minimal capital expenditure, low maintenance and simplicity of design are the outstanding features of the changed practices adopted.

Change in the work practices and in the HF reductions have been sustained for the past 12 months and are being rolled out to all of the Dubal potlines.

Acknowledgment

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