Influence of Hooding Conditions on Gas Composition at the Duct End of an Electrolysis Cell

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Abstract

Aluminum smelters are known to be important producers of perfluorocarbons (PFC). These gases are generated when the localized overvoltage in the cell exceeds the threshold necessary to electrolyze the cryolite, hence generating an anode effect. When it remains localized, this event is difficult to identify and it can generate only a small amount of PFC for several hours. Under these conditions, the cell behavior is almost undisturbed and no action is initiated from the cell control system to correct the situation. To understand this phenomenon, it is common to extract the gas from the duct end of specific cells - where dilution is minimal - and measure the gas composition continuously using a Fourier-transformed infrared spectrometer (FTIR). However, air infiltration can affect the measured PFC concentration, and the gas flow rate in the duct of the cell. In this study, a tracer gas was injected into the cell under multiple scenarios to assess the impact of the hooding conditions on the flow rate and concentration of the measured gases. This investigation quantified the uncertainty associated with the measurements of the gas composition for six specific scenarios compared to optimal hooding conditions.

Keywords: Aluminum electrolysis; perfluorocarbon emissions; low voltage anode effect; hooding condition; FTIR measurements.

1. Introduction

During primary aluminum production, massive emissions of gas are produced as the result of numerous chemical reactions occurring in the reduction cells. For technologies using carbon anodes, carbon dioxide (CO_2) is the primary component of these emissions. Nonetheless, other gases can be present in the output flow depending on the electrolysis conditions. Some of these secondary gases include carbon monoxide (CO), sulfur dioxide (SO_2), hydrogen fluoride (HF), bath vapors ($NaAlF_4$, Na^+) and perfluorocarbons (CF_4, C_2F_6)

As most of the chemical reactions occurring during the production of these gases are well known [1], identifying the output composition of an electrolysis cell can offer relevant and instantaneous information about the cell behavior (current efficiency, net carbon consumption, etc.). For this reason, some studies [2 - 7] investigated the evolution of the gas composition directly at the duct end of an electrolysis cell. This methodology has become particularly relevant in recent years along with studies investigating the occurrence of low voltage anode effects (LVAE). LVAE are also known as non-AE emissions or background PFCs. These emissions of CF_4 and C_2F_6 occur under conditions that are not completely understood, hence the multiple and recent studies on the subject. Analysis of the gas collected directly at the duct end of the electrolysis cell limits the dilution of the gas stream to a single cell, allowing the detection of the gas precisely when the concentration of the studied component exceeds the noise level of the measuring instrument.

This paper investigates if gas samples collected at the duct end represent well enough the ensemble of gas mixture emitted by the electrolysis cells. Using a tracer gas, the effects of the hooding conditions and the position of the gas collection within the cell are investigated in order to understand the limitation of this methodology.

2. Experimental Setup

2.1. Cell and equipment specifications

Experiments were performed under industrial conditions on a prebaked AP40LE reduction cell, using point-feeders at Aluminerie Alouette Inc. The cell was operating above 390 kA for the entire duration of the test. A stainless steel sampling probe was inserted at the duct end of this specific cell to sample the gas flow and route it to a Fourier-Transformed Infrared Spectrometer for analysis of the gas composition. The FTIR used was a GASMET™ DX-4000, equipped with a Peltier cooled mercury-cadmium-telluride detector (sample cell path: 9.8 m, volume: 0.5 L, resolution: 7.8 cm^{-1}). The gas was continuously directed towards the analyzer at a volumetric rate of 2 liters per minutes (LPM). The gas stream was sent sequentially through a 15-micron filter, desiccant, activated alumina, a 5-micron filter and finally a 2-micron filter to remove dust, traces of water and hydrogen fluoride for the protection of the measuring equipment. The gas was preheated at 120 °C before entering the FTIR and concentration measurements were performed at a rate of 10 scans per second. Average values for five-second periods were recorded. The background spectrum was redefined once a day before the tests using high purity nitrogen.

Gas collection within the cell is designed to be volumetrically uniform between five different inner ducts within the cell superstructure (listed A to E on Figure 1). None of these gas streams is mixed until they reach the main duct at the extremity of the cell. From this point, there are approximately three feet of conduct before the stainless steel sampling probe. Due to restriction from the surroundings, this is the only sampling point available to collect gas from a single electrolysis cell.

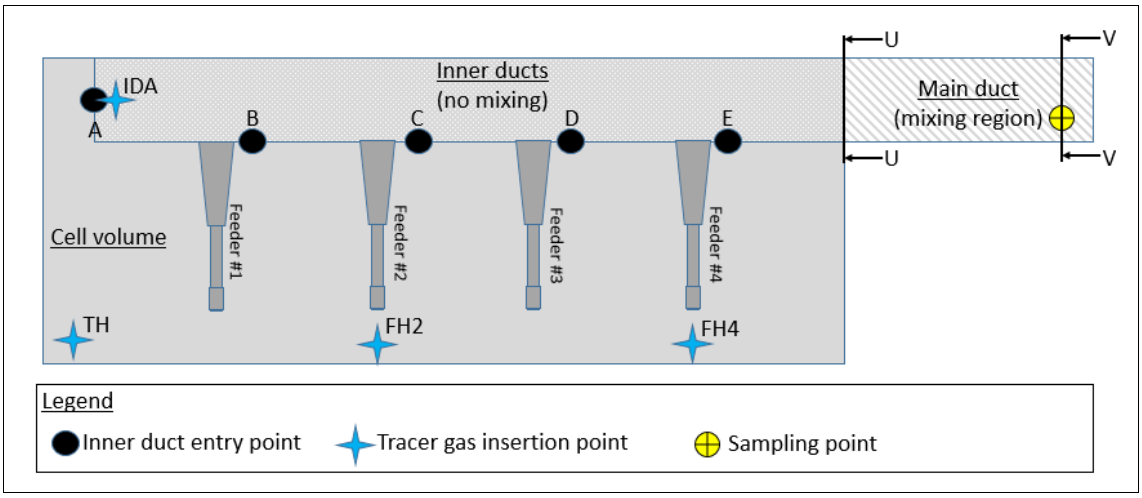

Figure 1. Schema of gas collection within the test.

Finally, this paper clearly demonstrated that measurements of the composition of gas extracted at the duct end of an electrolysis cell could be adequate for qualitative studies. However, the accuracy of such a method is influenced by too many factors and is inadequate for quantitative measurements of localized emissions. Refinements are required to investigate such phenomenon. Such refinements could include a change in the structure of the main duct to ensure an adequate mixing of the gas coming from the five inner ducts before it is extracted and sent to an FTIR for analysis.

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6. References

1. Lukas Dion, *Bilan de matière dynamique pour une aluminerie*, M. Eng. Thesis, Département des sciences appliqués, 2014, Université du Québec à Chicoutimi, Chicoutimi, Canada. p. 116.
2. Lukas Dion, et al., Using artificial neural network to predict low voltage anode effect PFCs at the duct end of an electrolysis cell. in *Light Metals*. 2016, 545-550.
3. Lukas Dion et al., Prediction of low voltage tetrafluoromethane emissions based on the operating conditions of an aluminium electrolysis cell, *JOM*, (2016), Vol 68, Issue 9 (to be published).
4. Li Wangxing et al., On continuous PFC generation unrelated to anode effects, *Light Metals*, 2011, 309-314.
5. Xiping Chen et al., Investigation on formation mechanism of non-anode effect related PFC emissions from aluminum reduction cells, *Light Metals*, 2013, 877-881.
6. David S. Wong, and Jerry Marks, Continuous PFC emissions measured on individual 400 kA cells, *Light Metals*, 2013, 865-870.
7. Eliezer Batista et al., Sustainable reduction of anode effect and low voltage PFC emissions, in *Light Metals*, 2016, 537-540.
8. Neal R. Dando et al., Non anode effects PFC : Measurement consideration and potential impact, *Light Metals*, 2015, 551-555.
9. Air_Liquide, *Gas Encyclopedia*, 2013 [cited 2016 07-19]; Available from: http://encyclopedia.airliquide.com/Encyclopedia.asp?