

Pot Integrated ABART (PIA) Gas Treatment

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Abstract

A novel dedicated pot gas treatment unit, Pot Integrated ABART (PIA) concept is reviewed, and initial test results are shown.

In the Gas Treatment Centres (GTCs) the fluoride components contained in the pot gas are captured and returned to the electrolysis cell with the enriched alumina. This not only recovers the valuable fluoride back to the electrolysis process, but also minimizes the emissions of hazardous fluoride components to the atmosphere. The new PIA concept differs from conventional centralized GTCs in that each pot will have its dedicated mini gas treatment process. This ensures that the same amount of fluoride will be collected and recovered back to the same pot. Among other benefits, this is expected to result in improved pot stability due to less fluctuations in the electrolyte composition.

An early version of the PIA process has been tested in parallel with the central GTC at Alcoa Mosjøen with promising results that are presented in this paper. Currently, fabrication of a larger test unit to be installed on one pot is ongoing, and the paper will also discuss the challenges expected for individual pot operation, maintenance and modular fabrication. This new test unit will allow further investigation of the impact on the pot stability, as part of a joint R&D program between REEL, Alcoa and SINTEF.

Keywords: Gas treatment center, Pot Integrated ABART, Alumina, ABART.

1. Introduction

Particulate and gaseous fluorides are emitted from the pot with the pot gas, and the corresponding concentrations and fluoride mass flows will be quite different from one pot to another, due to different pot process settings and heterogeneous crust and cover qualities.

On individual pots, long-term temporal variations in gaseous fluoride evolutions (from a few hours to several weeks) can also be significant due, for instance, to changes in the same process parameters and crust integrity, as well as variations in ambient conditions (humidity) and alumina properties, to list only the most important parameters. But fluoride evolution will also vary over the short-term (a few minutes). Typically, high HF concentrations are observed during alumina feeding and a lower background level in between as also described in [3], [5], [7]. Overall, in high amperage pots the average gaseous HF concentration measured may be in the range of 200-300 mg/Nm³ with peaks of 500-600 mg/Nm³, corresponding to typically 15-30 kg F_g/t Al.

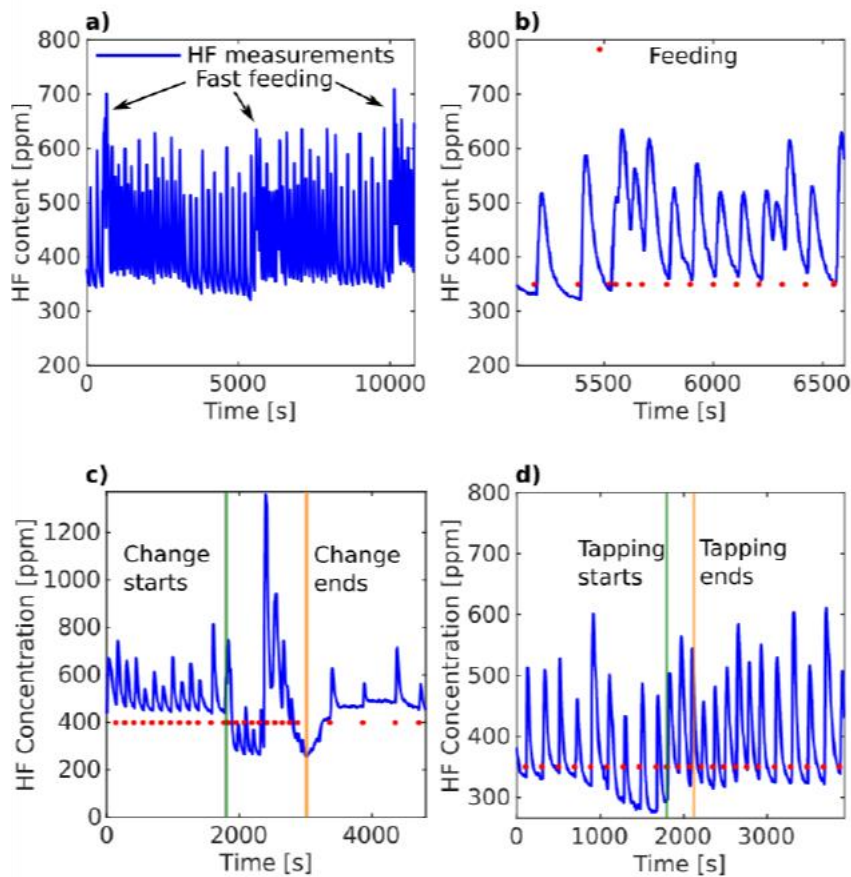


Figure 1. HF variations during pot feeding (a and b), anode change (c), and tapping (d) [3].

The temporal variations in particulate fluoride quantities are not so well documented but are expected to be influenced by the same parameters as gaseous fluoride, including the crust integrity. However, higher humidity will initially increase the fraction of particulate fluoride which further down the process can hydrolyze into HF, therefore increasing the ratio gaseous fluoride over particulate fluoride [6, 9].

Traditionally, pot gas is treated in large centralized GTCs consisting of several REEL ABART compartments. A description of this process can for instance be found in [4]. In this typical arrangement, GTCs treat the combined fumes from a group of pots, which can reach up to 200 in the largest installations.

As an alternative to the traditional GTC configuration, a dedicated Pot Integrated ABART (PIA) gas treatment module for one pot is proposed [1]. This novel concept enables a one-to-one fluoride recovery for each pot, and is illustrated in Figure 2.

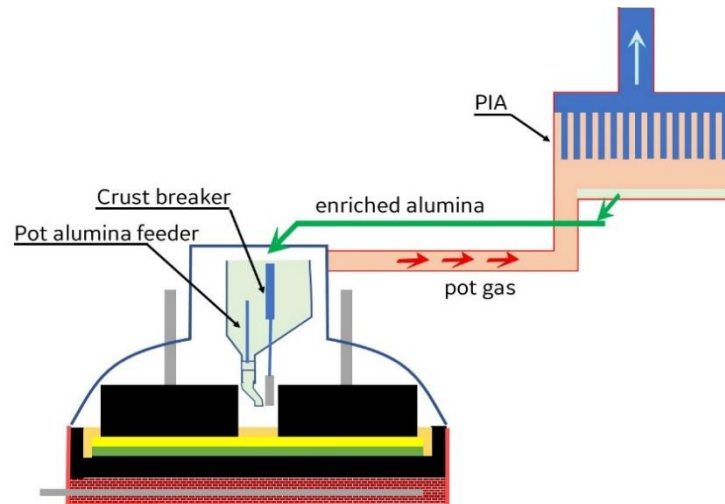


Figure 2. Gas treatment with the REEL patented [2] Pot Integrated ABART concept, PIA [1].

In this arrangement the fluorides emitted from a single pot will be collected and returned to the same pot with only a short delay corresponding to the consumption of the enriched alumina from the pot hoppers. The PIA is designed to collect more than 99.8 % of the emitted fluorides, an efficiency at least equivalent to the state-of-the-art standard, centralized, GTCs. This will ensure that close to the exact amount of fluoride lost from a particular cell through the pot gases will be returned shortly after to the same pot, independently of the temporal variations in the fluoride generation from the respective pot. Overall, a much more stable fluoride content in the bath is expected when compared to centralized GTCs and this can provide significant pot process benefits, including a higher current efficiency and/or a reduced specific electricity consumption.

Mainly to compensate for the sodium content in the alumina, aluminium fluoride (AlF_3) is added to the pot to maintain the required acidity in the bath. This represents a significant cost for the aluminium production. A better control of the fluoride balance of the individual pots should also improve the acidity level over time, and therefore possibly reduces the overall AlF_3 consumption. For instance, a 10 % reduction in the AlF_3 consumption reduces overall cost in the range of 3 USD /ton aluminium. However, the most significant impact is expected on the current efficiency. These parameters will be closely monitored in a joint research program between Alcoa, Sintef and REEL based on a PIA demo plant that is currently being installed at Alcoa Mosjøen.

In addition to providing major process advantages the proposed concept is also expected to be economically attractive both for greenfield and brownfield projects due to its modular nature.

2. PIA Concept Description

The main principles governing dry scrubbing of the pot gas with alumina have been refined over the past 50 years since the first GTCs were installed on the aluminum electrolysis cells. The principles of the REEL ABART 2-stage injection is known from several previous publications, for instance [4].

The PIA dry scrubber design is based on past experiences, but a significant step change in the overall design has been achieved by making this concept compact container sized and modular. In particular, the mass fabrication of multiple units has been emphasized including a significant simplification in the control of alumina through the system by utilizing the pot feeder as the main alumina feeding device through the entire system. This is described in the alumina-by-demand principle for which a patent application is filed [2].

2.1 Integration of Multiple PIA Modules

As shown in Figure 3, primary alumina is fed to the individual PIA modules typically from a central silo through an integrated transport airslide that feeds one section of pots (typically 30-50 pots). In the PIA module, the alumina is mixed with the HF laden gas from the pot. After separation, the enriched alumina is fed to the pot through a dedicated airslide (see Figure 4). It should be noted that the short transport loop of enriched alumina minimizes any scaling that can take place within such transport loops/ducts containing enriched alumina. Another advantage is that the segregation effects between the pots in long enriched alumina transports and silo systems are eliminated.

A PIA module consists of an integrated heat exchanger HEX, reactor, alumina hooper and a filter compartment. The pot exhaust gas first enters the integrated HEX where it is cooled before it enters the PIA reactor. Downstream of the PIA, on the gas side, individual stacks/fans can be installed or otherwise the clean gas can be collected into a centralized fan/stack. It is also an option that the clean gas can leave the potroom via the roof ventilator where it can be mixed with the potroom diffuse emissions. This may be of a particular interest for efficient mixing and dispersion of the SO₂ contained in the pot gas. This may potentially also add more draft to the potroom by impulse mixing of the gas flows, and/or by increasing the temperature of the plume exiting the potroom. The PIA module may, however, also include separate SO₂ treatment steps to abate the SO₂ emissions if required.

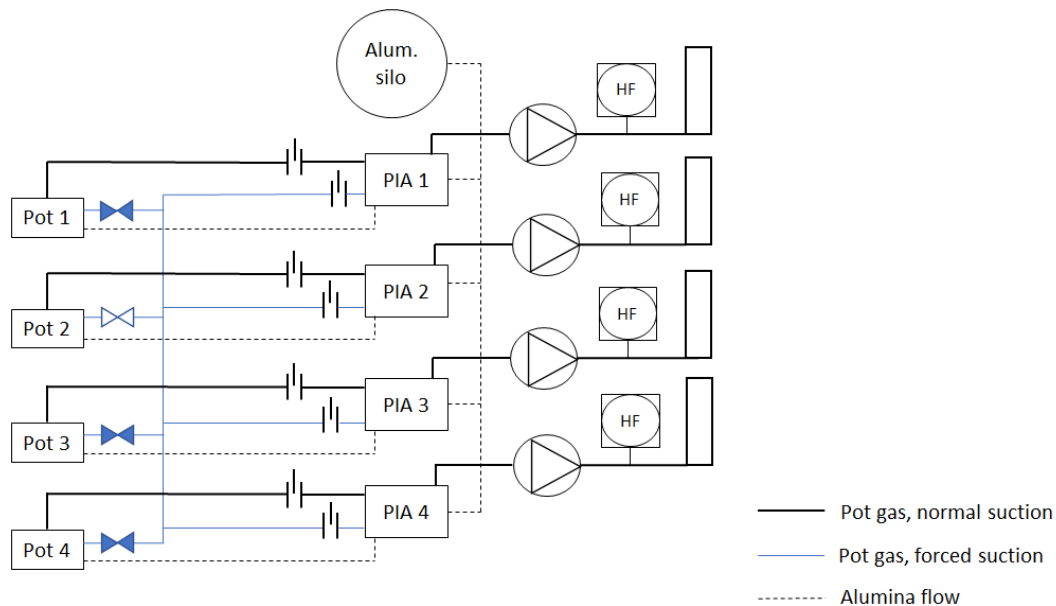


Figure 3. Simplified Process Flow Diagram from [1].

In Figure 3, the diagram also shows a dual duct network to provide for high draft ventilation. In normal operation, the forced draft damper is closed as indicated, and it only opens in forced suction mode to enable additional suction from a single pot (ref pot no 2 in the figure) during anode changes, for example. The dual duct is connected to the other PIA modules to enable additional suction from the pot. Also indicated are blind plates that can be closed in case the PIA module must be taken out of service - for instance for filter bag change. In this case the forced draft damper is also opened to maintain the normal suction from the pot and keep the PIA module in bypass mode.

2.2 Alumina Handling Process and Control

As with all parts of PIA, synergies and integration with the existing pot facilities are sought after including utilization of the pot feeder and control as the main alumina dozing device through the entire system. An alumina-by-demand concept ensures that the primary alumina feeds into the PIA when it is needed to allow for efficient capture of the HF peaks following the feeding into the pot, as described in the patent application [2]. To optimize the capture of HF, additional “boosters” are included (as discussed in the patent filing [2]) to ensure that the optimal mixing of alumina and HF takes place within the PIA module. In addition, each PIA module is equipped with HF monitoring (HF sniffer [8], indicated on Figure 3) to ensure that all parts of the PIA are working as intended, or providing alarm for the operator to take action otherwise.

2.3 Modular Prefabrication and Integration to the Potline

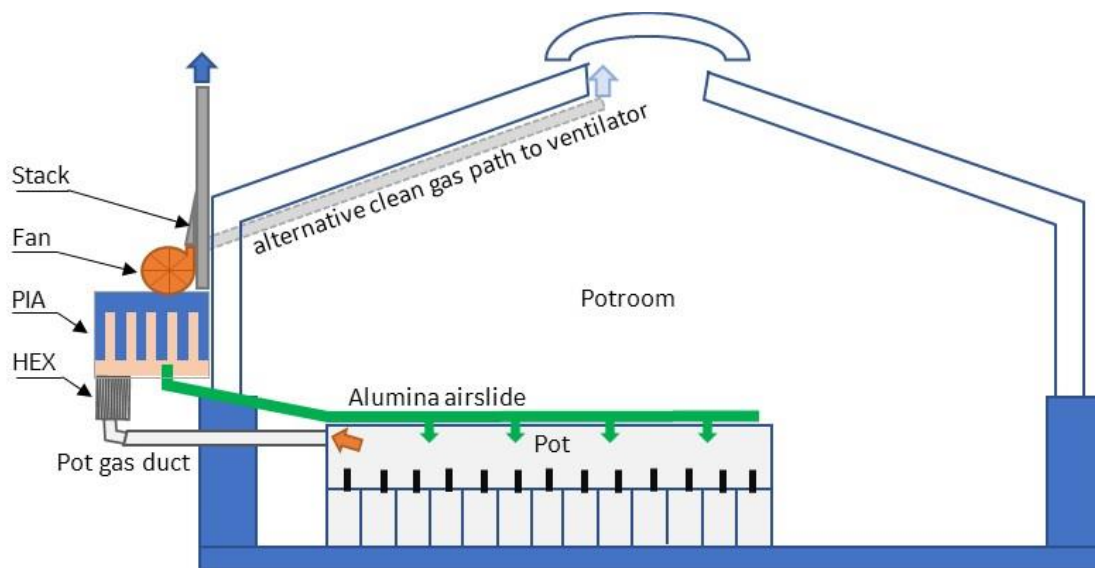


Figure 4. Gas treatment with the REEL patent filed [2] PIA concept [1].

The PIA unit is designed to fit standard container sizes and may arrive to site in fully modular prefabricated units for quick assembly onto the potroom columns. This modular design is the main idea behind the concept and allows for manufacturing using automatic fabrication facilities assuring flexibility in production rates and delivery to site. With a few adaptations to allow for the different pot technologies, a parametric design tool will enable low degree of specific engineering from case to case. Early pot startup can be considered due to quick and flexible fabrication rates that for instance easily can match the pot startup rates in greenfield projects.

Due to the small compact size the PIA concept can also be particularly interesting for smaller expansion projects where space is congested.

The relatively small size of the PIA module also enables easy maintenance without heavy parts. All wear and maintenance points are designed to be accessible from outside, and only in extreme cases the module must be taken out of service using the forced draft damper and blind flange as described in section 2.1.

3. Experimental Prototype Validation

To develop and validate the PIA concept, several iterations of design, CFD, lab tests, and prototype tests on site have been performed.

The lab tests were conducted in 2019 on the prototype shown on Figure 5 to confirm the stable flow of alumina through the system demonstrating the alumina by demand principle. In addition, air was introduced into the PIA to simulate reactor dispersion and mixing efficiency with the alumina.

The next paragraphs will focus on the results achieved from the initial prototype tests on site that so far have been successful. At the end are discussed the next steps of validation, including the test connected to an actual pot.

3.1 Prototype Initial Site Test Results

The objective of the initial tests with the PIA concept was to validate the HF removal efficiency with “real” pot gas. For this purpose, a small prototype size PIA was shipped to Alcoa Mosjøen and installed in parallel with an existing GTC as shown in Figure 5.



Figure 5. PIA Prototype Initial Site Test Installed at Alcoa Mosjøen.

Useful experience was gained with regards to alumina recirculation and alumina control effect on scrubbing efficiency. As discussed earlier, the pot feeder is intended to be the main control device for the alumina flow through the system. To simulate this, suitable batches of alumina were taken out manually in buckets during the 8 h tests that were performed. In addition, manual settings inside the PIA allowed adjustments to the alumina recirculation rate to different levels, corresponding to different reactor pressure drops.

When plotting the reactor pressure drop against outlet fluoride concentration for this case, it is seen that dry scrubbing efficiency improves with higher reactor pressure drop as expected since this is correlated with more recirculation of alumina. Gas flow rate remains constant during the complete test at approximately 3 000 Nm³/h.

As shown in Figure 6 the HF emissions stabilized at approximately 0.1 mg/Nm³, which is considerably lower than typical regulatory requirements of 0.5 mg/Nm³. The results suggest that optimum scrubbing efficiency is achieved at a reactor pressure drop of less than 400 Pa.

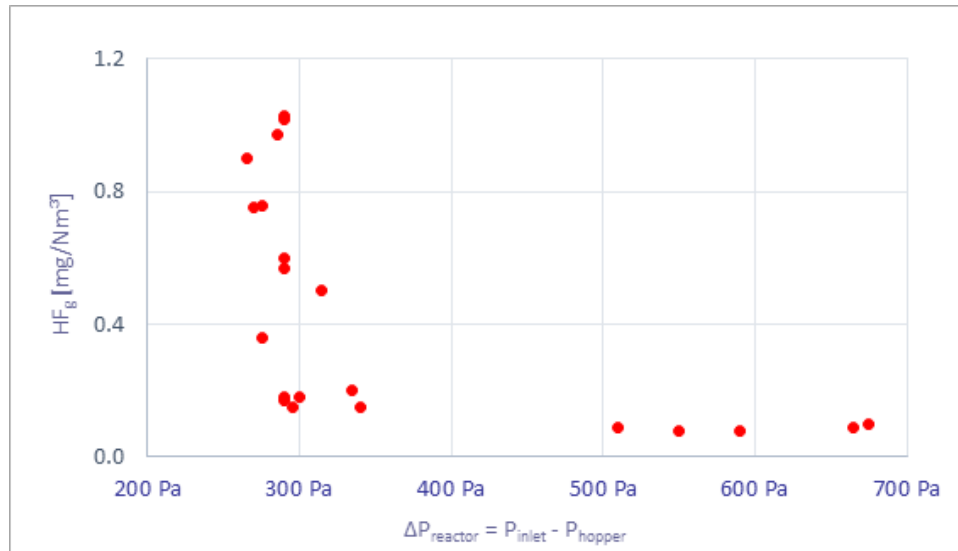


Figure 6. PIA Prototype Initial Site Test Results.

4. Conclusions

The novel PIA alumina-by-demand concept is expected to improve the fluoride balance for the pots, with corresponding improvements in current efficiency and possible reductions in the AlF₃ consumption. It would also provide additional process benefits, such as less segregation and attrition of the alumina is expected due to the short transport distances of enriched alumina from the GTC to the pots.

It is designed to be mass produced in container sized modules to minimize overall fabrication and erection time on site. This allows for short installation times and helps to enable early startup of pots one by one – a valuable benefit both for greenfield and brownfield projects.

The small size of the PIA components provide for easy maintenance. And when multiple PIAs are connected together with a forced suction network, this configuration provides for good redundancy in case a unit has to be placed in bypass mode.

The concept has been demonstrated in the laboratory and in initial tests on site that have been successful. The next step will consist of a full-scale demonstration on one pot at Alcoa Mosjøen, which will allow validating the design as well as the positive impact on the pot process. These tests will be conducted in collaboration with SINTEF and Alcoa.

5. Acknowledgements

Most illustrations in section 1 and 2 have been previously published and the authors wish to acknowledge and express their gratitude to the original publications as indicated.

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6. References

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