Update on the Abart Gas Treatment Center Technology

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Abstract

The Abart (Aluminium Best Available Recovery Technology) is well known in the Aluminium industry and more than 1000 gas treatment modules have been installed worldwide. In some cases up to 34 modules have been assembled into large centralized gas treatment centers (GTCs). Since the first installations the technology has continued to evolve including new step changes in gas cooling technology (HEX), alumina distribution (Alfeed) and the compact Abart-C technology. Abart- C provides more flexible solutions that can be especially beneficial for retrofit and expansion projects, and can include an integrated SO_2-scrubber. The paper will focus on the various technologies involved such as integrated silos for alumina handling, fan integration, gas and alumina distribution, and gas cooling. Scaling and erosion are challenges within the GTCs, and can affect the performance of the individual components and modules comprising the GTC. In addition, although more rarely, upset conditions within individual modules can occur if there are mechanical issues with, e.g., air fluidization devices. A new method for gas sampling and detection of upset process conditions will be discussed including a patented early warning detection system based on SO_2 gas sampling from the individual Abart modules.

Keywords: Gas Treatment Center; Abart; Alfeed alumina distribution; HEX gas cooling technology, Sniffer.

1. Introduction

Gas Treatment Centers (GTCs) today recover almost all (except a small fraction) of the HF gas emitted from electrolysis pots using the Hall-Heroult process for aluminium production. The HF gas is removed from the raw gas in the GTC dry scrubbing stage where the raw material to the pots, alumina, is brought into contact with the gas. Typically the fraction of HF in the raw off gas is in the order of 2 - 400 mg/Nm³, while the outlet clean gas from the GTC can contain less than 0.5 mg/Nm³ which gives an HF removal efficiency of more than 99.7 %. High removal efficiency protects the environment around the plant from potentially harmful emissions, and since the fluoride is recovered back to the pot (see Figure 1) the consumption of the costly AlF_3 is reduced significantly.

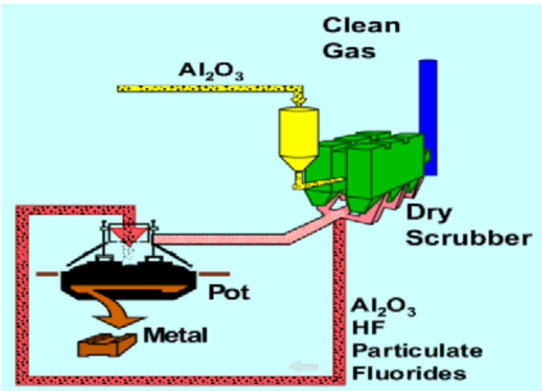

Figure 1. The alumina HF recovery loop.

In Figure 2, the main components in a large GTC 2 x 17 centralized Abart modules single line dry scrubber located in the Middle East are shown. This shows the preferred layout in the industry today. Each pot superstructure is connected to the branch duct via the electric isolator piece into the potroom ducting and finally into the GTC inlets. Also shown are the primary alumina silo storage, enriched alumina silo, main fans, stack and alumina distribution systems. In some cases as a part of the GTC, SO_2 is removed with a wet scrubbing stage either using sea water or sodium hydroxide solutions as absorbent. The wet scrubber is typically located between the main fans and the stack (see also Section 7 on SO_2 scrubbing).

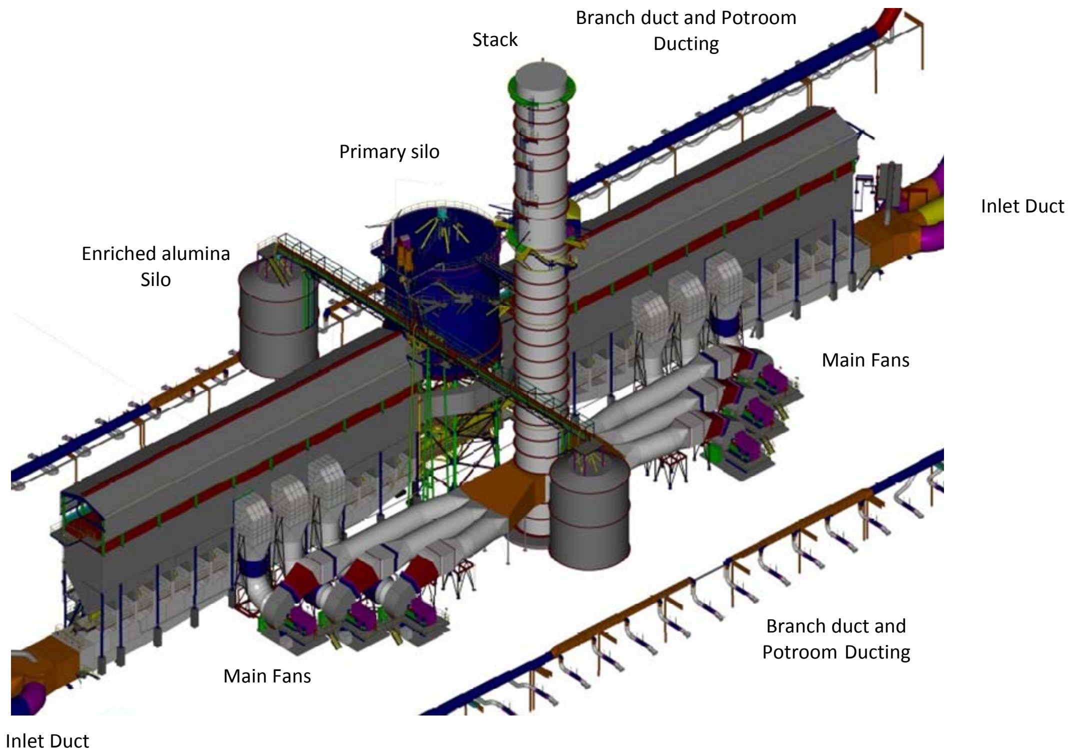

Figure 2. Large centralized GTC.

In the following sections the main principles and new developments in the Abart system will be described.

2. The Abart Principle

The high specific surface of alumina together with its high affinity to HF helps to capture the HF molecules contained in the raw gas from the pots and is a decisive factor that allows for the HF adsorption to take place. In addition the GTCs must be designed to reliably mix the alumina and the raw gas as efficiently as possible without causing too much attrition to the fragile alumina particles. Retention times, mixing lengths, concentration and flow profiles etc. must also be favourable to achieve optimal adsorption. In addition erosion and scaling must also be under control, as well as minimum energy consumption.

Within all of the above restraints, the Abart GTC technology has proven to be very reliable over time and more than 1000 Abart dry scrubbing modules are now in daily 24 hours, 7 days per week operation worldwide. The main characteristics of the Abart dry scrubbing system are shown in Figure 3.

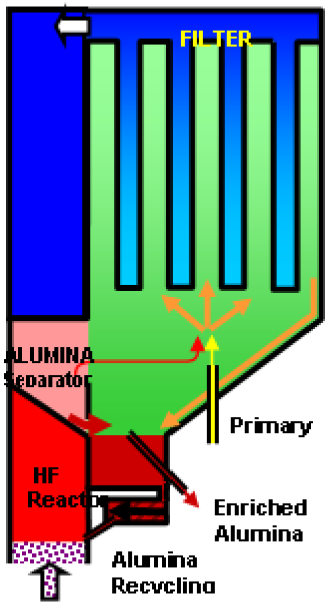

Figure 3. Characteristics of Abart system.

The Abart (Aluminium Best Available Recovery Technology) from GE Power is based on a two-stage, counter current cleaning technology where primary alumina is injected into the filter to polish the remaining HF in the pot gas after the main portion of HF is recovered in the reactor as shown in Figure 3. In the reactor, the alumina from the hopper is recirculated into the reactor to adsorb the main bulk of HF and enrich the alumina as much as possible. In the last stage the primary alumina with the highest adsorption efficiency is injected directly onto the filter bag surface to remove the last HF fraction remaining after the gas has been treated in the reactor stage. This two–stage counter current adsorption system secures very low emissions.

The mechanical recirculation feeder in the Abart reactor allows for a unique optimization, control and measurable recirculation rate that can be adjusted remotely from the control room. The HF emission requirements can therefore be met without too high recirculation rate thereby reducing the pressure drop in the filter, and attrition of the alumina. The recirculation feeder is also designed to break down scaling lumps that otherwise could obstruct the passages of alumina into the reactor etc. over time.

3. Gas Cooling and Waste Heat Recovery

One of the main challenges especially in hot and humid climates is that the emission increases with temperature, and as shown in [1] a 10 °C increase in gas temperature can increase HF emissions by 50 %. One explanation for this is that particulate materials containing fluorides such as NaF_4 from the bath react with humidity in the air and cause HF emissions inside the dry scrubber filter bag material [2].

Various means of gas cooling has therefore been developed over the past years. Each method of cooling has its benefits and drawbacks and adds more or less cost. Proven gas cooling systems are now available such as the heat exchanger (HEX) technology shown in Figure 4, and discussed extensively in [3 - 5]. The main benefit of the HEX technology is that no dilution air is needed to reach acceptable temperatures during summer. Addition of dilution air requires added dry scrubber modules, and diluting the gas stream before abatement reduces the efficiency of HF adsorption. In addition the HEX technology allows for heat recovery of the large quantities of waste heat presently lost to the atmosphere.

Figure 4. Heat exchanger for pot gas cooling.

The recovered heat can be used for e.g. heating of buildings etc. through a district heating network, power production, and in hot climates desalination and chillers are main alternatives for waste heat utilizations as discussed in [6] and [5].

The Abart can be equipped with external heat exchangers as shown in Figure 4. The heat exchanger shown in Figure 4 is designed for high gas temperatures and cools the gas 3 MW [5], thus improving the HF recovery. However, for new Abart installations, we recommend integrated heat exchangers (IHEX) where the IHEX is directly integrated with the filter. This reduces the costs of installation by removing the need for foundations, bypass duct and dampers.

4. The Abart-C

In the traditional layout the GTC modules are located at a centralized location, and in some cases 2 x 17 modules have been assembled together as indicated in Figure 2. One rationale is that large units such as large main fans and large stacks, sea water scrubbers etc., are less costly than several smaller units for a given total gas flow. The Abart-C concept challenge this idea since it is a fully standardized and modularized concept where individual silos, fans, heat exchangers and SO_2 scrubbers are adapted to fit the standard Abart dry scrubber module size as shown in Figure 5. This concept will be particularly beneficial for smaller expansions, i.e. “plug and play”. In general however the Abart-C concept gives a high degree of freedom, and more or less compartments can now be located where it is most suitable to e.g. to reduce ducting lengths and pressure drop e.g. by dedicating 3 - 4 modules for each section of 30 - 50 pots, allowing also for early start-up of the pot line sections.

Other main benefits with the Abart–C concept are as pointed out in [7]:

- Less footprint since the large fans, ducting, SO_2 scrubbers, stacks etc. are integrated in the module
- Higher fan efficiency since the N-1 solution for the traditional main fans very often gives low efficiency.
- High degree of standardizing of fans etc. reduce the cost

The integrated silo in the Abart-C module is located higher than the pot, and allows for alumina transport by gravity flow directly to the pot (as shown in Figure 6) without the use of airlifts or intermediate silos etc. This allows for a safer and more robust system since there are fewer components that can break down. The standardized Abart-C concept will still contain more than 24 hours of alumina storage depending on the plant’s consumption.

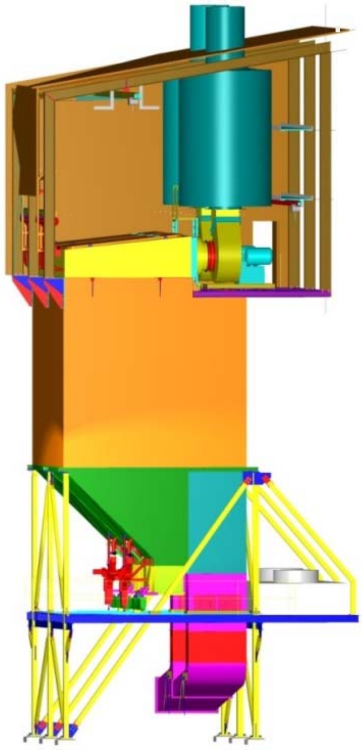

Figure 5. Abart C-308.

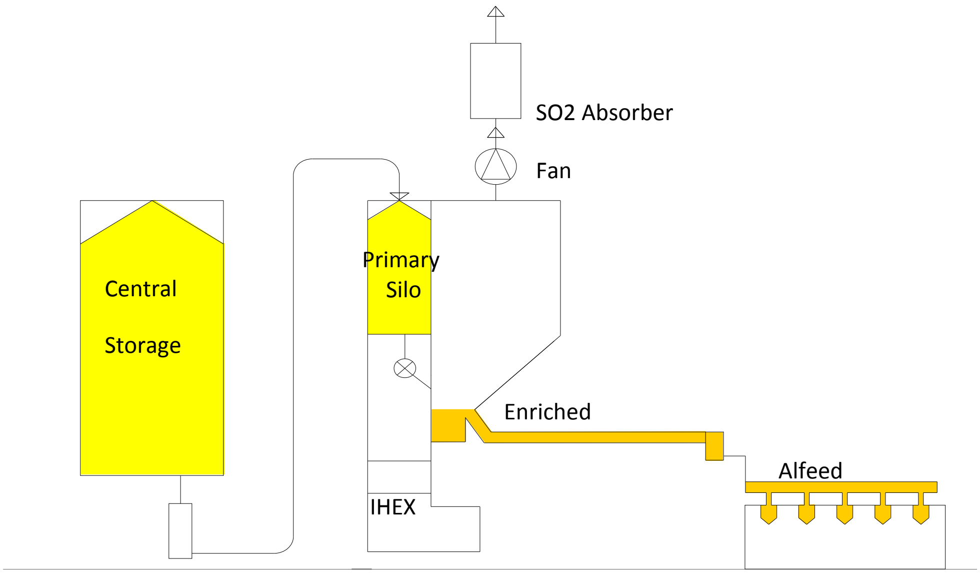

Figure 6. Alumina handling from port to pot with Abart-C.

5. Extractive Sampling – HF Sniffer

As the GTC size grows, the need to keep control of the large number of compartments grows as well. Each Abart compartment is equipped with pressure sensors and other sensors to monitor different aspects of the process. What has been missing (or rather too expensive) is the opportunity to verify the emission from a single compartment. Abnormal operation of a compartment may not be visible when it is part of a mega-GTC with 30+ compartments.

Measuring emission of HF is normally done in the stack, and will provide an average measure of the GTC efficiency. In order to be able to measure the HF emission from each compartment it has been assumed that each compartment would need its own HF sensor. However laser instruments are expensive and also need regular maintenance.

GE has developed a system that makes it possible to measure the emissions from single compartments with only one laser. This is done by extractive sampling from each compartment and a shared HF monitor. Figure 7 shows the prototype of the HF "sniffer". A tube collects gas samples from each compartment of the GTC one compartment at the time into one HF sensor.

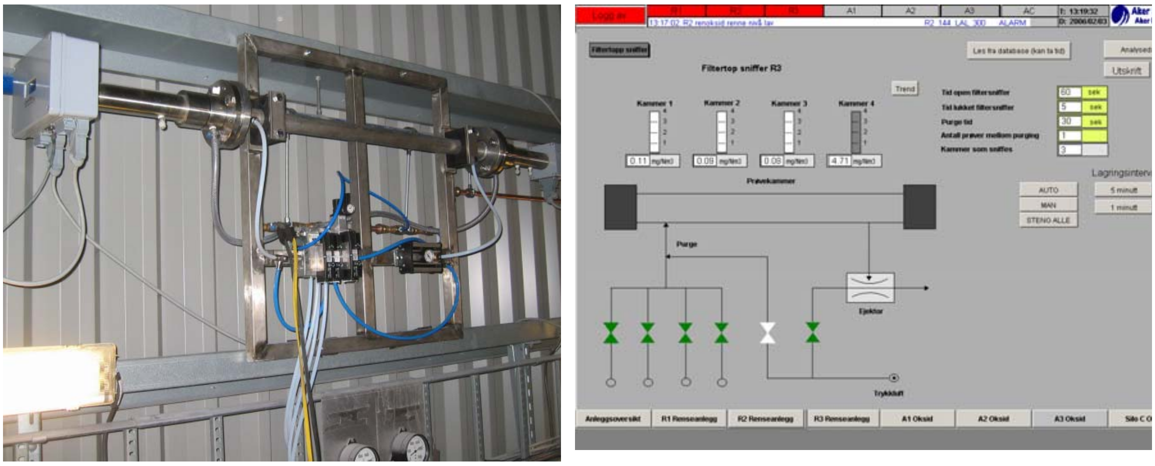

Figure 7. HF extractive sampler.

Figure 8 shows raw data of HF from the sniffer. The HF emission levels are low, but there are distinct differences between the compartments. Such data can be used to verify the "health" of individual compartments and to simplify the search for emission spikes, as shown in Figure 9.

In Figure 9, the injection of primary alumina to a filter compartment was blocked by purpose verify the sniffer. The GTC continues to operate normally for more than 2 hours on recycled alumina. Eventually though, the HF emission increases. Both the stack based HF monitor and the extractive sampler shows increased emission. In this case, the operator would immediately know which compartment is faulty, and can direct a maintenance crew to the correct spot. In conventional systems, the maintenance crew would need to conduct an extensive search of the GTC in order to find where the problem is located.

Data from the experiment were also coupled with measurements of SO_2 emissions. They showed that when primary alumina feed was shut off, SO_2 emissions immediately increased as shown in Figure 10 (see light grey stapled curve indicating that the primary alumina feed rate is shut of at 08:00 h, and the corresponding increase of SO_2 emissions shown with the stapled light green curve). This is explained by desorption of SO_2. Alumina has higher affinity towards HF than SO_2, and SO_2 molecules are "kicked off" the surface by the HF molecules. As shown above, it takes hours before HF emissions are noticeable on an HF instrument. Measuring the change in SO_2 emissions from the GTC therefore provides an early warning system for detection of any fault before they lead high HF emissions.

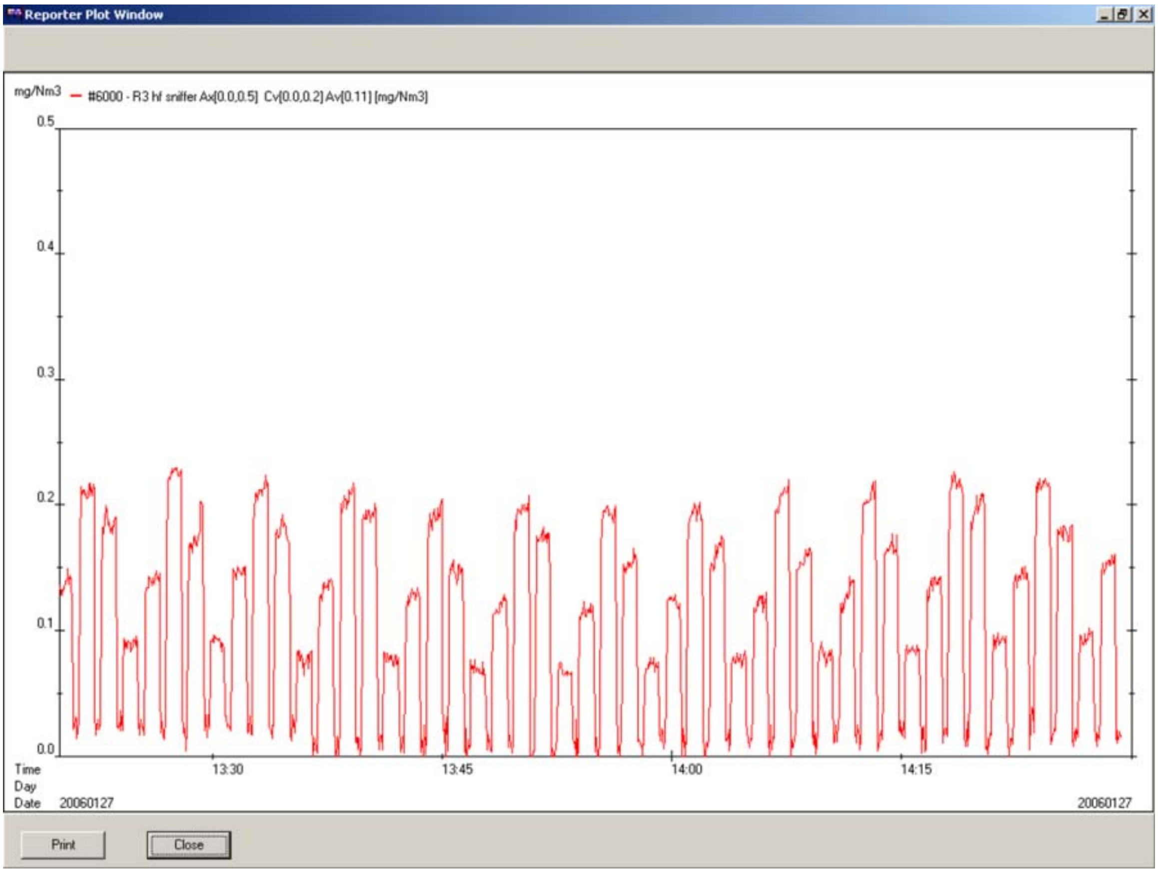

Figure 8. Emission levels (Raw data) for a 4 compartment GTC.

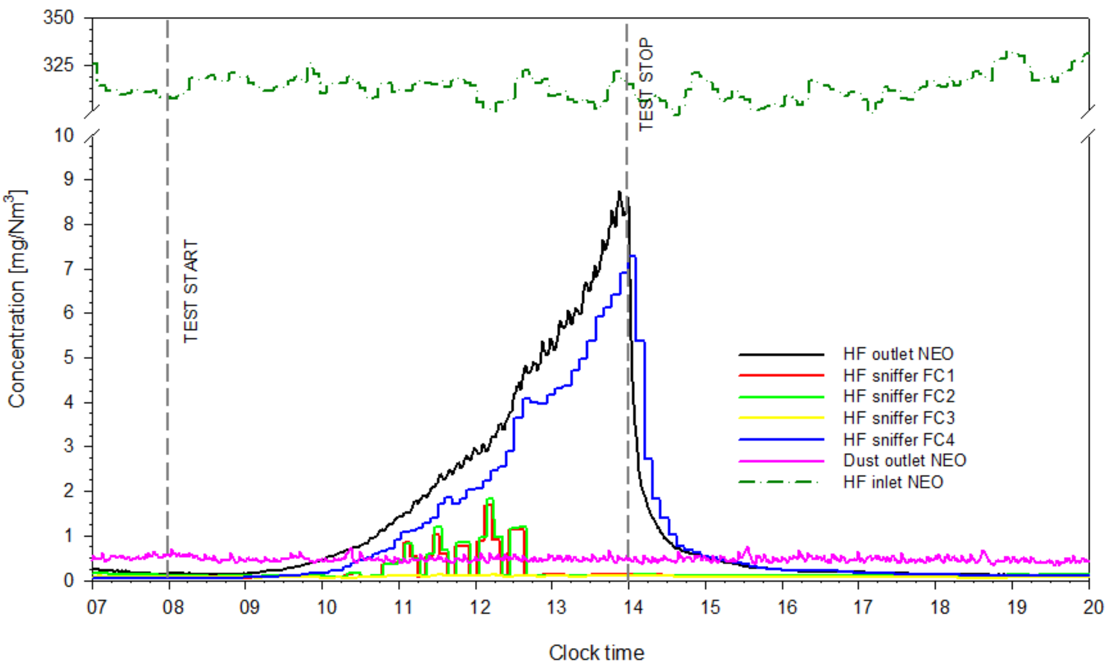

Figure 9. 100 % blocking of alumina injection to a filter compartment. Both the stack based HF monitor and the extractive sampler show a problematic emission. However, with extractive sampling, the problem can be pinpointed to the exact compartment.

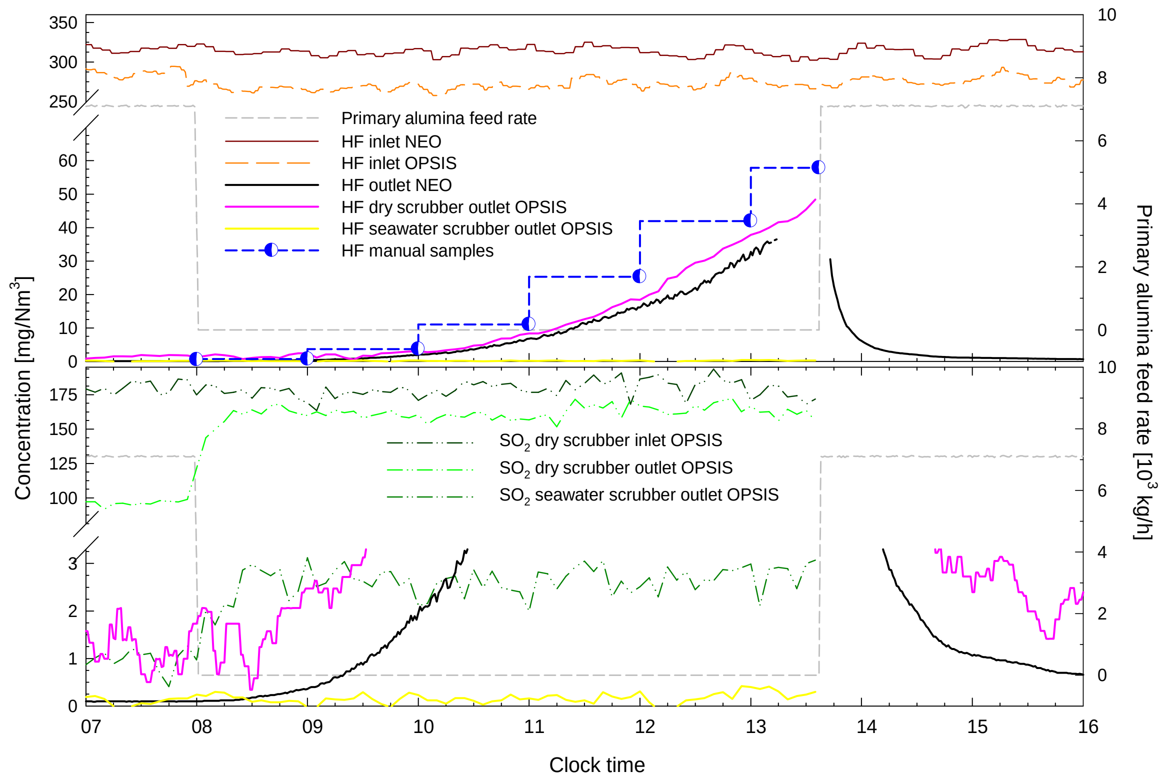

Figure 10. Early warning detection system(GE patent).

6. Automatic Alumina Feeding to Pots Using Alfeed

GE's portfolio to the aluminium industry includes pot feeding through our Alfeed system. Alfeed is based on well proven air slide technology and is installed on several aluminium smelters. It can be efficiently integrated with the Abart–C, feeding enriched alumina by gravity directly into the Alfeed system. This eliminates the need for a separate enriched silo and additional alumina transports. Alternatively, Alfeed can be fed from the enriched alumina silo. The basic outline of the system is shown in Figure 11. Alfeed is based on two different kinds of airslides:

- Horizontal distribution airslide
- Pot feeding airslide.

A fully fluidized horizontal distribution airslide is used to distribute alumina to a potline section, normally 20-50 pots. The distribution airslide is normally fed from the upstream enriched alumina silo, though it can be connected directly to the GTC. The distribution airslide operates as a fluidized bed well above minimum fluidization velocity. This serves to homogenize alumina in the bed, but it also keeps larger particles in suspension, moving them around in the bed. The distribution airslide also operates as a reservoir of alumina, and the height of alumina in the bed is normally kept at 30-40 cm. The level is kept constant by the use of a rotary feeder, and signals from the level transmitter.

At every pot, alumina flows from the distribution airslide down to the pot airslide. At these points, the fluidization air is vented through a cyclone to the gas duct. The fine particles are separated by the cyclone and returned to the pot airslide, and mixed with the alumina. With this system, the amount of dust from the potfeed system in the GTC duct is minimised. High dust levels in the pot gas can seriously affect the performance of a GTC.

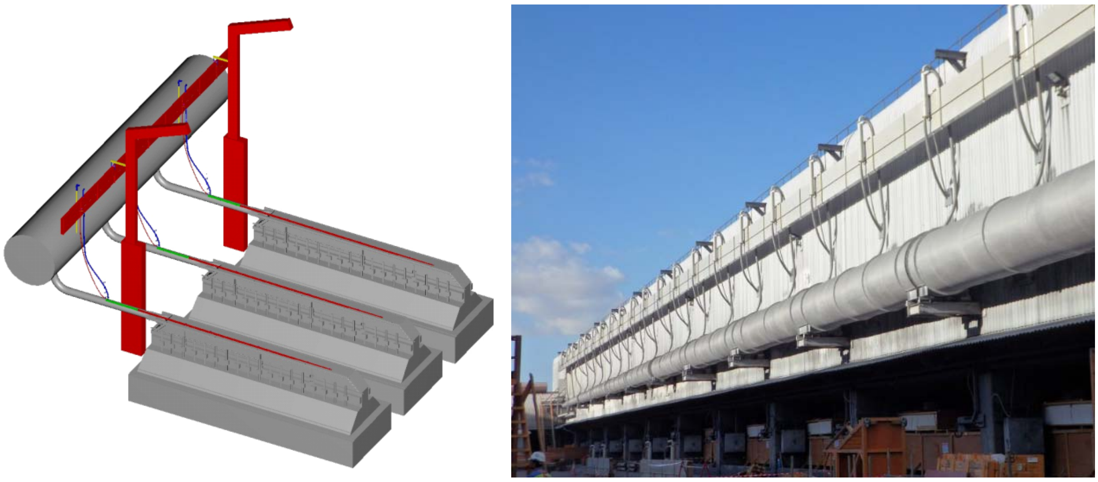

Figure 11. Basic of Alfeed. The distribution air slide hangs on the pot room wall and feed pot airslides.

A flexible hose transports alumina from the cyclone to the pot airslide. A similar hose connects the air chamber of the distribution airslide with the air chamber of the pot airslide. A hose is easy to route to the pot. The pot airslide is adapted to the specific pot, with filling points where the pot technology demands them. The pot airslide is a potentially fluidized system which main priority is to keep the pot silos filled at all times. When the pot consumes alumina, the pot airslide will automatically top-up the pot internal silo.

7. SO_2 – Emissions

The main emission focus of aluminium smelters is HF and dust. However, aluminium smelters are also a source of SO_2 emissions. SO_2 is the main source of “acid rain” and fish death, and the main sources used to be coal fired power plants. Power plants are now usually equipped with desulphurization units, and “acid rain”, mostly history. Aluminium smelters are locally a big source of SO_2 emissions, although the SO_2 emission levels are low compared to power plants. The origin of SO_2 in the smelters is from Sulphur contained in the carbon anodes. In several countries, aluminium smelters are required to include desulphurization units.

Figure 12. Centralized GTC with seawater desulphurization (SWFGD) scrubber.

GE has developed several solutions for desulphurization of the pot gas. The comparatively low SO_2 level vs. power plants means not all solutions for power plants are suitable. GE can supply both alkaline (soda) and sea water scrubbers for SO_2 cleaning. GE have installed SO_2 cleaning on more than 10 aluminium plants over the world.

7.1 The Integrated SO_2 Scrubber

The conventional way for SO_2 removal is to place the SO_2 scrubber after the dry scrubber as a standalone unit as shown in Figure 12. This requires comparatively large space on the ground, and construction of several big concrete modules. However, to suit the newly developed Abart-C with its modular approach, we have developed a standalone wet scrubber to be included on the filter top above the fan as a separate unit. The scrubber is shown in Figure 13. The first full scale installation of this scrubber was commissioned in May 2013. Such SO_2 scrubbers are installed as standard modules and can easily be retrofitted on top of the fan.

Each scrubber is sized for and treats the gas from one filter compartment (i.e. one fan) giving full N-1 operation. The scrubber is made of lightweight GRP (Glass fiber Reinforced Plastic) and is installed directly above the fan, suspended from the roof structure. The advantages of the new scrubber are multiple compared to the traditional scrubber:

- No need for extra space or special concrete structures,
- Can be used with any kind of liquid like NaOH (soda) or seawater,
- Easy to transport and install,
- Based on a modular design and integrates with the filter within the space allocated,
- Reduced costs compared with traditional wet scrubbers,
- Reduced fan power compared with traditional wet scrubbers,
- No extra ducting,
- No corrosion issues as it is made of GRP.

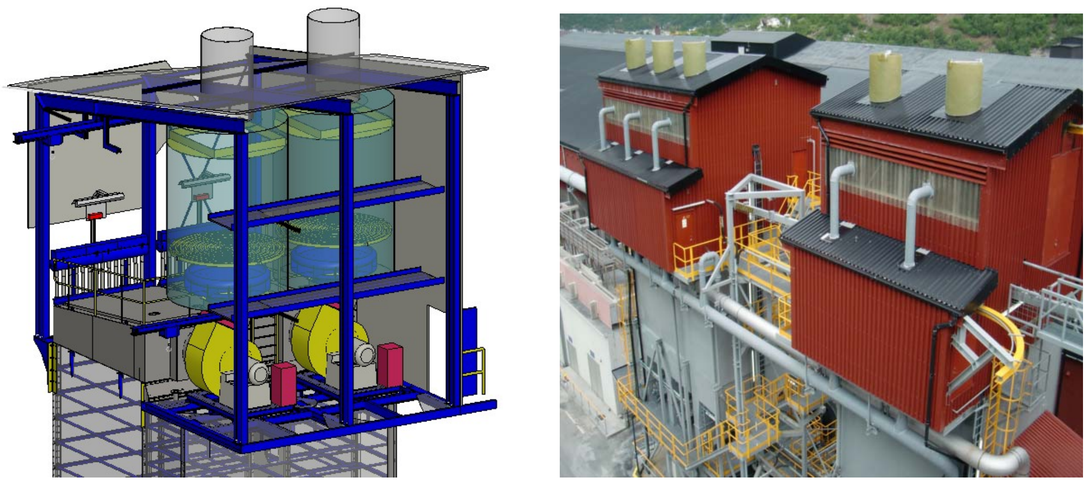

Figure 13. Abart C wet scrubber installed on filter top.

8. Conclusions

Even if GTCs have been around for a long time and is now by many considered a mature technology, several new ideas, products and developments are implemented as discussed in the above. The development is driven by the desire to optimize the GTCs into more modularized and standardized systems that allow for less cost and faster start-up of the potlines. Another driver is the increasing size of the pots themselves with higher temperatures and more concentrated gas requiring new gas cooling systems including heat exchangers and waste heat recovery systems that now are in operation several places in the world.

SO_2 gas scrubbing is not always required depending on the local regulations and SO_2 load, but the trend is probably that this will be mandatory in more locations in the future, and retrofits of existing GTCs may be necessary. In this case the new Abart-C retrofit is particularly interesting as it does not require any added footprint on the plant, and the modularized and standardized SO_2 scrubber can be easily lifted into the existing penthouse.

The sniffer system pinpoints the location of abnormal operation, eases the maintenance and troubleshooting, and can also predict the emissions with the patented early warning system. The sniffer also allows for multiple stacks (one for each Abart-C module) to be implemented with less cost, and allows for easier optimization and balancing of the large GTCs.

9. References

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