

## Gas Treatment and Improvements for More Than 40 Years at the Hamburg Trimet Smelter

Elmar Sturm<sup>1</sup>, Lorenz Struck<sup>2</sup>, Anders Sørhuus<sup>3</sup>, Sivert Ose<sup>4</sup> and Eivind Holmeffjord<sup>5</sup>

1. Former Potroom Manager HAW, Consultant

2. Project Engineer THH- TRIMET Aluminium SE

3. Product Technology Manager

4. Technical Lead development projects

5. Senior Process Engineer

GE power, Centre of Excellence -Aluminium , Oslo, Norway

Corresponding author: anders.sorhuus@ge.com

### Abstract

The dry scrubber installed at the Reynolds Aluminium Smelter in Hamburg 1973 by Fläkt marked one of the first alumina injection type dry scrubbers installed world-wide for the capture of HF gas from the aluminium electrolysis process. Even if both companies have changed names and owners since 1973, a successful relationship has continued during more than 40 years of joint development and technology sharing that has resulted in many smaller and larger improvements that are implemented on daily basis, and that will be summarized in the paper including:

- Impurity stripper (1984),
- Pre-reactor (1999/2010),
- Impulse duct development (2004),
- Ongoing first of kind Fume Treatment Center (FTC) Heat Exchanger System (AHEX), AHEX-FTC (2017).

The impurity stripper helps producing high purity metal in the forefront of current efficiency. The pre-reactors have enabled the existing dry scrubber from 1973 to achieve state of the art performance. The impulse duct enables smelters all over the world to operate Gas Treatment Centres (GTCs) with less energy requirements. The ongoing first of kind AHEX-FTC project marks a new beginning for the anode bake furnace fume treatment technology as a first industrial implementation more than 40 years after the first dry scrubber was installed.

**Keywords:** Gas Treatment Centre (GTC), impurity stripper, impulse duct, Abart, AHEX-FTC

### 1. Introduction- Improvements over 40 Years- Timeline

Over the past 40 years the aluminium primary smelter located in Hamburg commissioned by Reynolds Aluminium in 1973 have seen several name changes and owners/consortiums such as HAW owned by Alcoa, Amag, Hydro and finally today Trimet. Svenska Fläkt, later ABB, Alstom and today GE was invited to install their first of kind dry scrubber for HF capture and recovery to meet the environmental challenges at the time the smelter was built. The successful application of the dry scrubber gas treatment technology at Hamburg was instrumental for the introduction of this technology that still today dominates the gas treatment of the aluminium electrolysis pot gas worldwide.

The basic principle of dry scrubbing the HF gas on alumina in the injection type dry scrubbers implemented in Hamburg in 1973 is still the preferred basic method for HF pot gas removal and recovery back to the pots. However, over time many innovations and improvements in the dry scrubbing technology has evolved. With each step in dry scrubber technology innovations, the Hamburg smelter has been quick to install upgrades in order to always be in the forefront environmentally, and this remains today with the GE's first of kind AHEX-FTC technology under

construction in Hamburg to achieve the lowest possible emissions, and energy recovery from the anode bake plant.

This paper will summarize the main joint developments and upgrades implemented in Hamburg including the pre-reactor two stage Abart retrofit, impulse duct to reduce the pressure drop, and the impurity stripper installation to remove undesirable elements such as  $P_2O_5$  and Fe from the recycled alumina, and finally the expected results for the AHX under construction.

## 2. The Trimet Hamburg Smelter

Figures 1 - 3 show the Trimet Hamburg smelter, the GTC and the impurity stripper. A total of 270 pots in 2 potlines produce 135 000 t Al/year. Each pot has a normal suction of 4900 Nm<sup>3</sup>/h, and the pots are equipped with dual position dampers able to increase the suction by 30 % during pot operation. The total gas flow of 1.5 million Nm<sup>3</sup>/h is treated in 4 gas treatment plants; SF1, SF2, SF3 and SF4, each with two clean gas stacks located as shown in Figure 2. All four plants are retrofitted with pre-reactors (SF1 and SF2 in 2011, and SF3 and SF4 in 1999/2007).



Figure 1. The Trimet smelter.



Figure 2. Gas treatment plant (SF3).



Figure 3. Impurity stripper (SF4).

SF1 and SF2 treat 90 pots each from potline 1 and are each equipped with 24 filter compartments (see Figure 4) and are currently operating with 240 star shaped bags per compartment since 2015 (filter to cloth ratio approximately  $0.54 \text{ Nm}^3 / \text{m}^2 \text{ min}$ ). In addition, one new Abart compartment with 600 polyester needle felt bags was installed in parallel to increase the overall suction from line 1 in 2003.

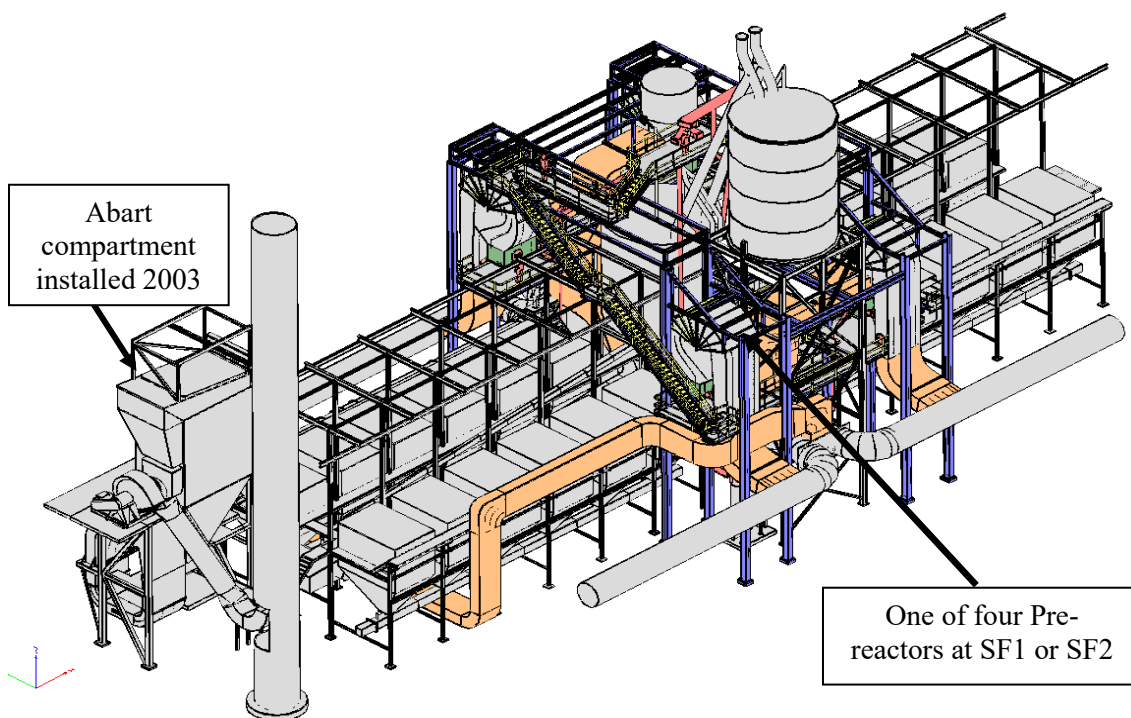


Figure 4. SF 1 and 2 with four Pre-reactors and extra Abart compartment.

### 3. Drivers for Improvements in the GTCs

#### 3.1. Legislation/Emissions

Over the 43 years of operation the raw gas concentration has increased from about  $80 \text{ mg HF/Nm}^3$  to more than  $300 \text{ mg HF/Nm}^3$  due to amperage increase, introduction of point feeder technology and changes in bath chemistry. With the increased raw gas HF concentrations, the GTCs had to be improved accordingly.

Over the same time the legislation for emissions has continued to set improved standards in Germany (TA Luft) as shown in Table 1. The current emission limits for each of the four SF-plants in the Hamburg smelter are measured continuously and classified in half hour values. The total mass flow of HF (roof and stack) emission limit is  $7.2 \text{ kg/h}$ .

Table 1. Development of emission limits in Germany.

		TA Luft 1974	TA Luft 1986	TA Luft 2002
HF gaseous (Potroom)	$\text{mg/Nm}^3$ $\text{kg/t Al}$	- -	1 0.5	1 0.5
F total	$\text{kg/t Al}$	1	-	-
Dust (Potroom)	$\text{mg/Nm}^3$ $\text{kg/t Al}$	120 20	30 5	10 2

Measured emission values are for the stacks: 0.3 to 0.9 mg HF/Nm<sup>3</sup> which is equivalent to 0.7 kg HF/h, or 0.05 kg/HF/t Al (average). This gives an efficiency of the scrubber in the range of 99.8 %. For the pot room diffuse emissions a total of 4.8 kg HF/h (equivalent to 0.31 kg HF/t Al on average) is measured. These world class emission levels are achieved by continuous improvements and upgrades of the GTCs to the latest available technology and secures that the legislative levels are adhered to with good margin.

### 3.2. Energy Consumption GTC and Emissions to Potrooms

Apart the energy used for the electrolysis process the energy needed for the GTC has been focused on more over the last years. The main power consumer in the GTC is the main fans. Therefore, a KPI has been defined that describes the specific fan power needed in MW per Nm<sup>3</sup> of gas volume:

$$KPI = \frac{MW \text{ (fans)}}{\frac{Nm^3}{h} \text{ (total gas volume)}} \quad (1)$$

Figure 5 shows the specific power consumption. The strong improvement is realized by introduction of impulse ducts, frequency steered fan motors, star shaped bags, optimizing bag pulsing etc.

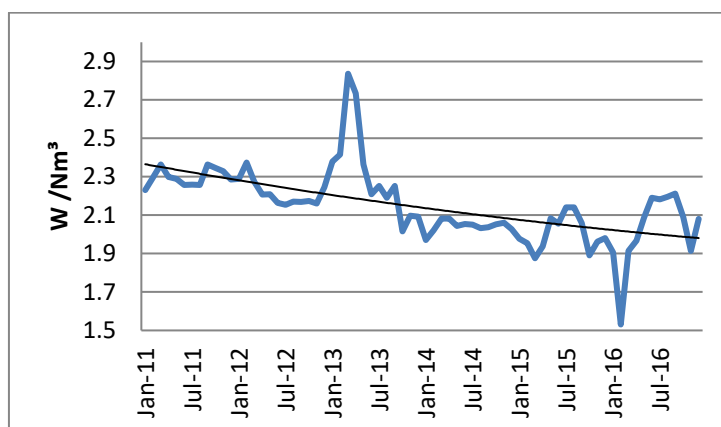
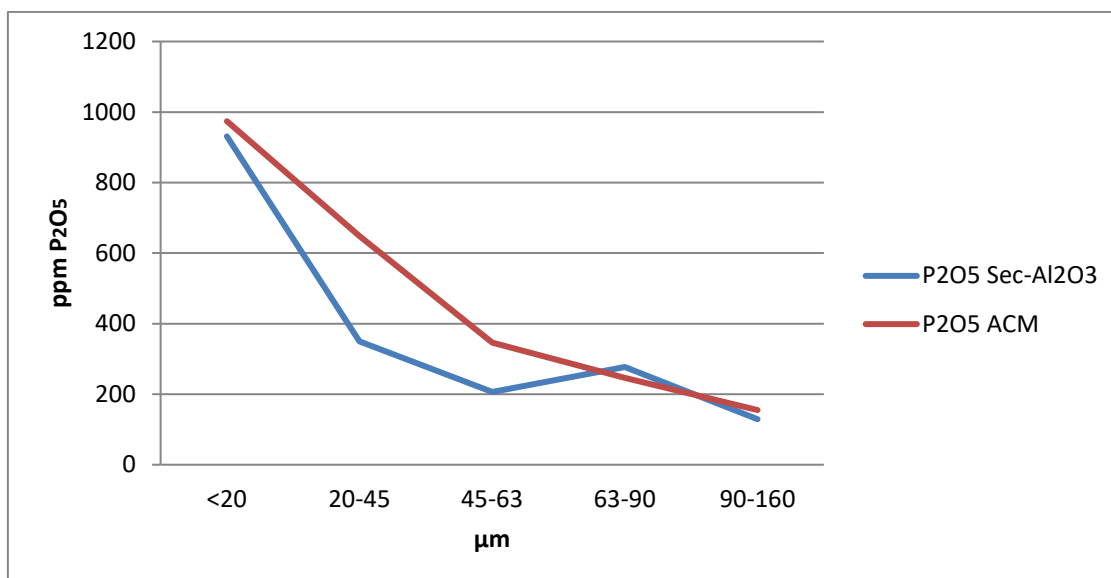


Figure 5. Specific power consumption for main fans, THH GTC.

### 3.3. Metal Purity- Impurity Stripping

Almost no emissions are lost to the atmosphere in modern high efficient dry scrubbers, and the HF evolving from the pots is almost 100 % recovered back to the pots with the enriched alumina. An undesirable side effect of this is that trace elements tend to accumulate in the system, and eventually leave the system as impurities in the metal.

The impurities tend to accumulate in the fine fraction of the enriched alumina and anode cover material (ACM) as exemplified with P<sub>2</sub>O<sub>5</sub> shown in Figure 6.



**Figure 6. Relation between grain size of enriched alumina, ACM and content of impurities.**

The  $P_2O_5$  originates mainly from the raw materials dissolves into the bath in a range up to 200 ppm and find an equilibrium with the metal of roughly 1:10 [3]. When the oxides are dissolved in the bath they may take place in the electrolysis process and consequently reduce the overall current efficiency for the aluminium production.

The impurity stripper (see Figure 3) can remove the fraction of  $P_2O_5$  and other impurities leaving the pre-reactor back to the pot with roughly 33%. This will therefore improve the metal quality corresponding, as well as improving the current efficiency of the aluminium electrolysis process.

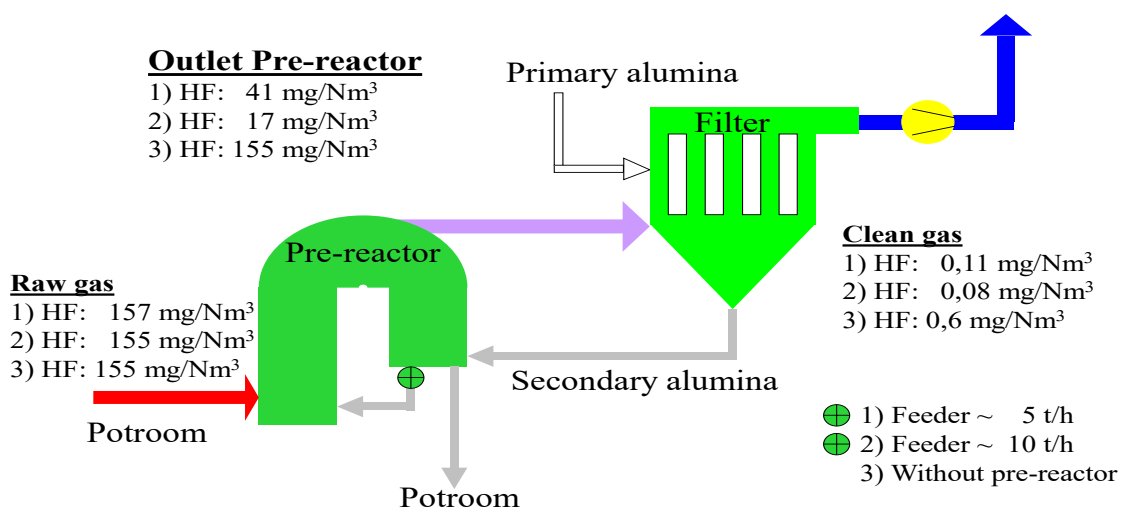
Several versions of impurity strippers have been tested, and the ability to separate a sharp cut of fines containing the impurities from the main bulk of enriched alumina is one of the most important performance parameters and are influenced both by the impaction and classification stages of the impurity stripper [3]. The fine fraction residue represents also a cost since it still contains a high fraction of alumina mixed with the impurities. Ongoing work on the impurity stripper has shown that it is possible to improve the cut size and enrichment factors of impurities further, and for certain conditions the corresponding loss of alumina was up to three times less.

High processing capacity with minimum energy consumption is also important.

The removal efficiencies of phosphorus and iron and other impurities have been proven in long period potroom operations. The number of pots with a metal quality better than 99.85% has been increased by 20 % and the current efficiency has been increased by more than 0.5%

#### **4. Pre-Reactor Retrofit Technology**

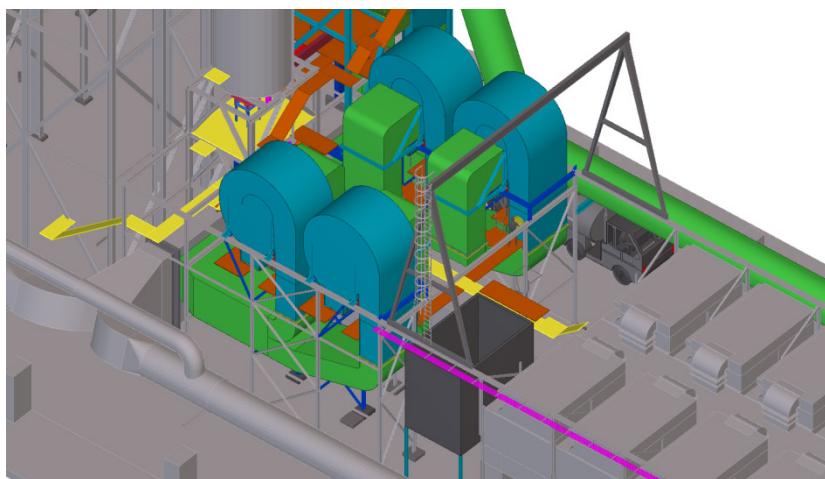
The first set of prereactors were installed in Hamburg in 1999 for SF3 and in 2007 for SF4 for a gas volume of 230 000 Nm<sup>3</sup>/h prereactor. As shown in Figure 7 approximately 90 % capture of the HF is achieved in the prereactor stage with the relatively low inlet concentration of approximately 150 mg/Nm<sup>3</sup> [1].



**Figure 7. HF Concentrations for Dry Scrubber with Pre-Reactor at SF3 and SF4 [1].**

In 2011 SF1 and SF2 were also fitted with the pre-reactor technology. In this case the inlet HF gas concentration was measured to 250 mg/Nm<sup>3</sup>, and again HF removal efficiencies in the range 85 – 92 % could be confirmed.

As can be seen from Figure 7 very low stack emissions (< 0.1 mg/Nm<sup>3</sup>) can be measured due to the efficient Abart two stage injection system upgrading the dry scrubber originating from 1973 into the forefront of what is possible to achieve even with the most modern GTCs installed today. In comparison, the first of kind single injection dry scrubber technology without recycling of alumina installed elsewhere in the 70<sup>th</sup> and 80<sup>th</sup> could see up to 20 mg/Nm<sup>3</sup> HF stack emissions – far beyond the legislative emissions today.



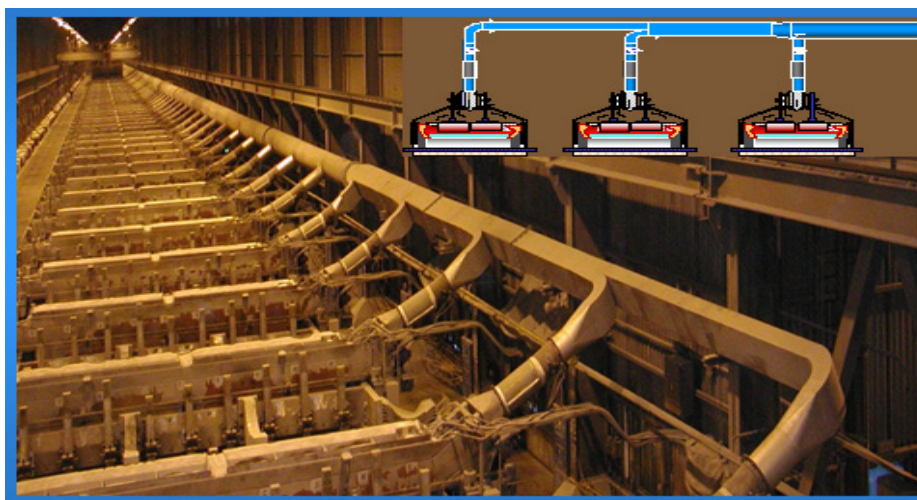
**Figure 8. Pre-reactors currently under commissioning at DUBAL Potlines 1 - 3.**

With the pre-reactor installations in Hamburg, GE has got a basis for emission prediction of future projects including pre-reactors. In 2016 the first pre-reactors at Dubal Lines 1 - 3 were installed and are currently under commissioning and startup.

## 5. Impulse Duct

Figure 9 shows the patented [5] impulse duct developed and tested in Hamburg. As described in [2] the retrofitted impulse duct reduced the pressure drop in the ducting with 812 Pa (down by 64 %).

The reduced pressure drop is based on ideal acceleration of the gas from pot number one combined with acceleration of the gas downstream pot one into the main gas collecting duct. This principle can remove the requirement for throttling the gas flow at the individual pot outlets to balance the flow and thereby avoiding the associated irreversible pressure drops in conventional balancing systems.

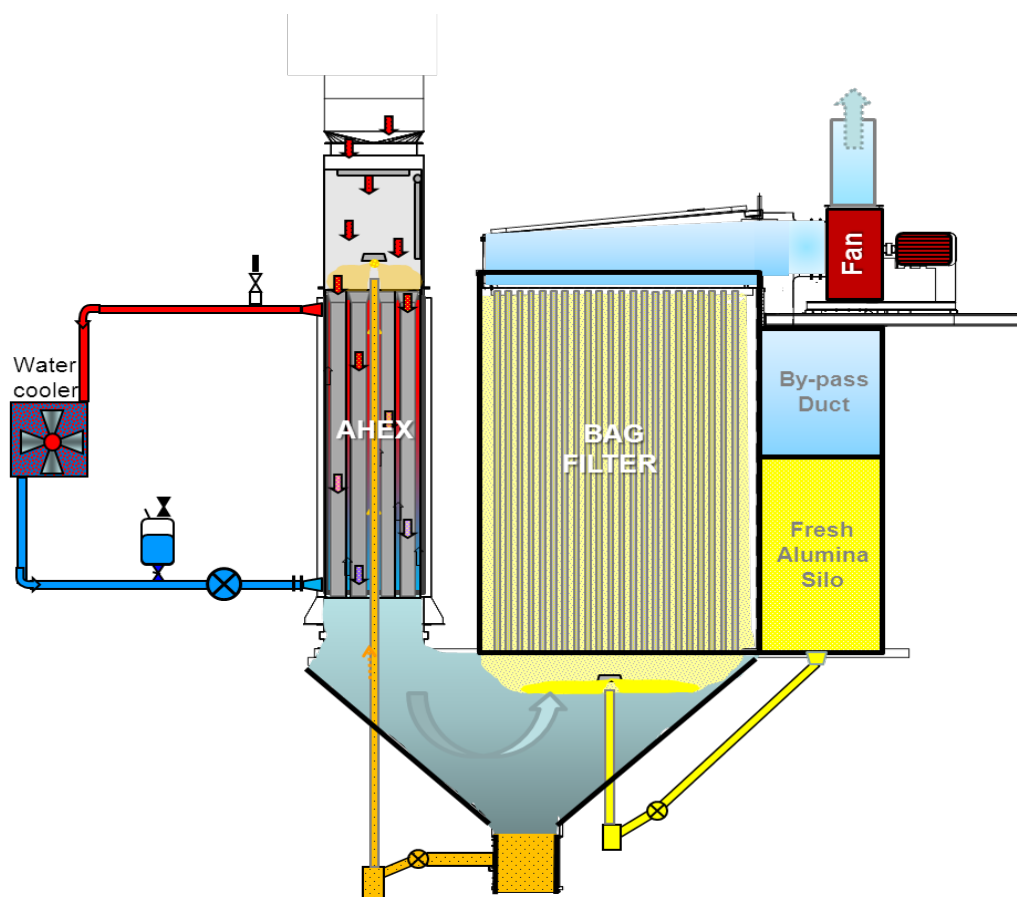


**Figure 9: Impulse duct installed in Hamburg [2].**

The impulse duct is later installed at many smelters worldwide due to the potential to reduce the pressure drop and corresponding energy consumption for the main fans with more than 10%. For retrofits the ability to increase the suction in existing plants with minimum interventions can be seen as even more attractive feature of the system.

## 6. The First of Kind Full Scale AHEx-Fume Treatment

The traditional method for anode baking furnace fume cooling and treatment is to use evaporative cooling in large water cooling/conditioning towers followed by a dry scrubber with alumina injection. It is well known that this method has numerous operation and maintenance challenges. GE has developed [4] a new method for the cleaning of anode baking fumes using heat exchangers (AHEx) as shown in Figure 10. The method has been tested in full scale at Alcoa Mosjøen, and Trimet in Hamburg is the first smelter to install all compartments with AHExs.



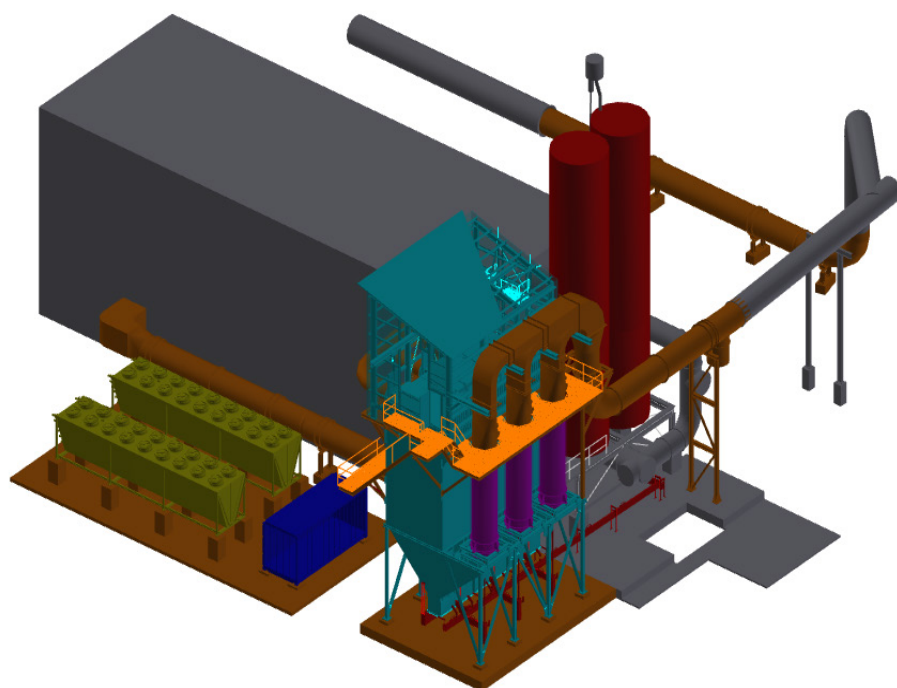
**Figure 10. Principle of AHEX with Abart Bag Fiter.**

In the AHEX the gas is cooled with heat exchanger and the process is completely dry. Problems with corrosion and deposits due to water condensation is removed, and the gas can be cooled below the traditional 110°C to condense more of the organic components in the raw gas onto the alumina surfaces.

Emission measurements of the new AHEX system shows equal or better emissions of PAH and HF compared to the traditional cooling tower technology [4].

The AHEX system at Trimet will replace the existing RTO (Re-generative Thermal Oxidiser) and filter. The AHEX system for Trimet will consist of 3 AHEX and filters as shown in figure 11. The existing fans and silos will be reused, reducing the installation costs. Construction starts in autumn 2017 and commissioning/start-up early 2018.

The hot water (80 – 90 °C) from the AHEX will be used to generate electricity using an Organic Rankine Cycle - ORC machine. In the ORC, an organic liquid with low boiling point is used instead of water. This makes it possible to generate electricity using the classic Rankine cycle. The installed capacity of Trimet ORC is maximum 250 kW electrical.



**Figure 11. AHEx project at Trimet Hamburg.**

## **7. Conclusions and Further Work**

The impulse duct, the impurity stripper, and the pre-reactor technology are examples of more than 40 years of cooperation and technology sharing between the smelter in Hamburg and the Aluminium competence center in Oslo. This cooperation continues today from the GE Center of Excellence – Aluminium with ongoing projects at Trimet such as CFD-optimisation of bag houses, of pot superstructure gas suction, waste heat recovery projects with the GE heat exchanger (IHEx) , and continues improvements of the existing GTC and impurity stripper systems.

The first of kind AHEx will be commissioned in Hamburg next year, and represents a new breakthrough technology for the anode bake plants, and is in some way analog to the first of kind alumina injection type dry scrubber for pot gas installed more than 40 years earlier at the same site.

Not only Trimet takes benefit from the innovations developed, but all over the world smelters operate with alumina dry scrubbers modelled after the first installation in Hamburg in 1973, pre-reactors are currently under commissioning at Dubal and the impulse ducts are installed in multiple locations in the world. The impurity stripper will most likely see increased interest over time as the impurity levels in the raw materials tend to increase, and proven results of the first of kind AHEx under commissioning in Hamburg is anticipated by smelters world wide.

## **8. Acknowledgement**

The culture of continuous improvements and joint sharing of technology is one of the factors contributing to the success of both companies over the more than 40 years of cooperation and for the years to come. The authors are grateful for the opportunity to present some of the many examples of successful technology innovations over this long period of time.

## 9. References

- 1) Elmar Sturm, Geir Wedde, E. Holmefjord, High Performance and Cost Efficiency of Dry Scrubbers, *Light Metals* 2001, 379-383.
- 2) Michael Sahling, Elmar Sturm, Geir Wedde, Odd Strand, Improvements of pot gas collecting efficiency by implementation of Impulse Duct System, *Light Metals* 2004, 351-355.
- 3) Dr. Elmar Sturm, G. Wedde, Removing Impurities from the Aluminium Electrolysis Process, *Light Metals* 1998, 235-240.
- 4) Anders Sørhuus, Sivert Ose, Geir Wedde, Ahex - A New, Combined Waste Heat Recovery and Emission Control System for Anode Bake Furnaces, *Light Metals* 2013, 1323-1328.
- 5) Odd Strand, Odd Bjarno, Lars-Eric Johnasson, A process and a device for transport of gas, *WO 2003001106 A1*, January 3, 2003.