

Inspection methodology and upgrade options for Anode Bake Fume Treatment Centres

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Abstract

Fume Treatment Centres (FTC) are essential for the operation of anode baking furnaces and for keeping emissions within environmental limits. Many FTCs in operation today have exceeded their initial design life and experience severe operational and maintenance issues. This paper presents a structured methodology and risk-based approach which is used for assessing fit for service. Considering the uncertain future of carbon plants, smelters often seek to extend the safe lifetime by a given period. When addressing these challenges, a strategic choice must thus often be made involving building new, upgrading, refurbishing, or a combination. A key piece of equipment, where failures are critical, is the cooling tower. Repairs can often not keep up with deterioration, so it must either be replaced entirely or substituted by the AHEX (anode heat exchanger). The AHEX solution does not only provide gas cooling but also upgrades the reactor where alumina is mixed with gas upstream the filter house.

Keywords: Fume Treatment Centre, Cooling Tower, Corrosion, AHEX, Inspection.

1. Introduction

REEL provides solutions for the aluminium industry, alumina handling from port to pot, cranes, anode handling equipment, as well as Gas and Fume Treatment Centres (GTCs and FTCs) through its dedicated Environmental Control Solutions activity. For close to 50 years, REEL ECS has delivered more than 25 Fume Treatment Centers (FTC) around the globe, treating fumes from Anode Baking Furnaces (ABF). The REEL ECS team provides existing aluminium smelting plants with services relating to modernization, replacement, or capacity increase operations. Over the years, improvements have been made in technology mainly around dry scrubbing and cooling towers with water, and more recently the AHEX heat exchanger that omits water injection and enables energy recovery.

2. Aging of FTCs and ABFs

The installed base of FTCs is getting older and this paper focuses on the challenges of aging plants, specifically the ones that are 25–40 years old and have surpassed their intended service life. It aims to explain some common challenges, the causes and how they can be addressed short term, and the possible upgrade options for more long-term operation.

Operation of the FTC and ABF are closely linked. After two to three decades, it is often observed very high fumes flow (Nm^3 gas per hour), due to leakages, and it is then not only time to rebuild

the furnace but also to assess the state of the FTC. As the furnace is aging and refractory condition worsening, the demand for flow is indeed increasing.

In the meantime, the performance of the FTC must thus be kept up, by measures such as, monitoring the pressure drop across the plant, internal cleaning, increasing rate of bag filter replacement [1]. Constant suction from the FTC is vital for combustion efficiency and safety in the ABF [2]. Failing to maintain the performance of the FTC can cause loss of draft, quality excursion in anode production, and even lost aluminium production due to lost in-house anode production and difficulties with sourcing anodes from elsewhere.

3. Failure Modes

As all other technical installations, FTCs are subject to normal wear and tear in both electrical and mechanical equipment. As they get older, the maintenance frequency will increase. Smelters often observe a growing backlog of maintenance up to the point where the plant's reliability is at obvious risk. This article focuses on the gas treatment process and corrosion-related failure modes, especially those putting the gas conduit at risk. This is because failure of the ductwork will lead to loss of draft and in worst case be a risk to the structural integrity.

3.1 Acid Dew Point Corrosion (Internal to Gas Conduit)

Gases from the ABF contain various combustion products, refractory dust, coke dust, and tars, including PAH, SO₂, SO₃. Together with water weak and strong acids can be formed. The main protection of the duct is the insulation. Insulation is vital to ensure that all internal duct surfaces are maintained at around 100 °C especially where alumina is not present to reduce the acid concentrations. Lack of insulation can not only jeopardize the duct locally but also downstream equipment. Once holes in the ductwork start to develop, either through the steel walls or around expired expansion joints, cold ambient air enters, causing not only the draft capacity to decline, but also the process temperature to drop. The result is a vicious cycle where more air entering and the temperature dropping, loss of acid dew point margin, and accelerated degradation.

Another high-risk area is the cooling tower. It is critical that all the injected water is evaporated before reaching the bottom of the conditioning tower, if not the condition will quickly deteriorate from acid attack [2].

Major concerns arise when it is found that the loss of material in the gas conduit turns in to a risk to structural integrity. It is often found that problems in the plant are linked to the operation of the process. The risk for acid dew point corrosions varies with the temperature and SO₃ concentration in different locations of the plant (Table 1). Stagnant areas in ductwork, such as dead legs, are at higher risk. Understanding acid dewpoint corrosion is key to grasping the varying risk levels in different parts of the plant.

The sulfuric acid (H₂SO₄) dew point can be evaluated by correlations. Industry recognized ones are Okkes [3], Verhoff [4], and ZareNezhad [5]. The sulfuric acid dew point, a temperature, is a function of H₂O and SO₃ concentration in the gas. The reader should keep in mind that the ABF is operated with a high excess air, so fume and moisture concentrations are much lower than that found in power plants or other combustion processes, but challenges can still arise in the FTC.

Representative values for process temperature, moisture content, SO₃ concentration, and calculated acid dew point are shown in the column of table 1. Aim is to have a margin, where the steel wall temperatures are well beyond the predicted acid dew point temperature. In an insulated duct, wall temperature is close to that of the process temperature. If insulation is removed,

sometimes done to mend the ductwork, the steel wall temperature is normally mid-way between the gas and ambient temperature.

Table 1. Typical operating conditions and acid dew point in FTC gas duct.

Area / Zone	Process Temperature °C	Moisture content Vol% H ₂ O	SO ₃ concentration mg/Nm ³ *	Acid dewpoint °C	Comment
1. Inlet duct and riser	120-240	2-4	10	110	Low to moderate risk
2. Cooling tower downstream spray	105-115	4-7	10	120	Extreme corrosion attack possible
3. Downstream dry scrubber fans (C.T.)	100-110	4-7	0.1	70	Moderate to high risk if not insulated well
4. Downstream dry scrubber fans (AHEx)	100-110	2-4	0.1	60	As above, better margin with less water
5. Dead legs w/o flow	< 60	4	10-0.1	60-100	High risk

*) SO₃ concentration fumes FTC inlet measured to 10 mg/Nm³ is in agreement with 400–800 mg/Nm³ SO₂ and 1–5 % conversion to SO₃. The dry scrubbing is effective at removing SO₃ and values < 0.1 mg/Nm³ have been measured.

In the inlet duct, the temperature is high, so a good acid dew point margin exists. A critical area exists downstream the cooling tower spray lances. Increasing the water content in the gas, at the same time lowering the temperature, is removing the margin completely. An internal lining is mandatory to protect the steel. Organic linings can be damaged by fires. By upgrading with the AHEx, Zone 2. in the table will cease to exist. The dry scrubbing process is measured to be excellent at lowering SO₃ contents. It is still easy to appreciate the value of the AHEx, since Zone 4 has lower moist content and hence better acid dew point margin than Zone 3. All downstream parts of the plant benefit from a dryer gas.

Another cause of internal wear in aging plants, distinct from corrosion, is erosion by alumina particles in the gas flow. This applies to the reactor in particular, but also the bag-filter hopper, as charged alumina from the dry scrubbing process is very abrasive.

3.2 Corrosion Under Insulation (External to Gas Conduit)

One purpose of the insulation is to maintain the steel surface temperature above water and acid dew points. Problems can over time arise if the state of the external protective clad is not maintained. With winds and weather rain – and if coastal, seawater spray – can enter the clad. Usually in the vicinity of the FTC rain contains sulphur from the chimney and industrial dust. Water entering under the insulation brings contaminants inside, dries up due to the heat, and over time the impurities accumulate. The result is a very corrosive environment. This mechanism is often referred to as CUI (Corrosion Under Insulation). An example is shown in Figure 1.



Figure 1. Example of corrosion under insulation.

State of the aluminium clad covering the glass wool insulation will deteriorate with time due to wind, snow, ice and more. The risk of CUI tends to be higher in cold and humid climates. Ideally, the clad should be maintained as the roof of a house. In practice, leaks are hard to detect, likewise is access to do repairs.

It is important to understand the different mechanisms to effectively address problems in aging FTCs. It is also clear good inspection methods are required to correctly assess the plant condition. Challenges in a plant varies the same way climate, fume gas, and process operation varies.

4. Inspection Methods

With the challenges both internal and external to the ductwork, it is clear good inspection methods are required. Some of the methods REEL ECS uses during inspections are:

- Drone with both photo camera and aerial passive infrared thermography inspection.
- Removal of clad and insulation in a prioritized areas for wall thickness measurements.
- Measurements of pressure, temperature, and gas flow to detect blockages or leaks.
- Calculation of plant pressure drop and comparison with actual measurements.
- Thermodynamic modelling of cooling tower and comparison with actual data.
- Evaluation of actual plant performance and emissions compared to design specification.

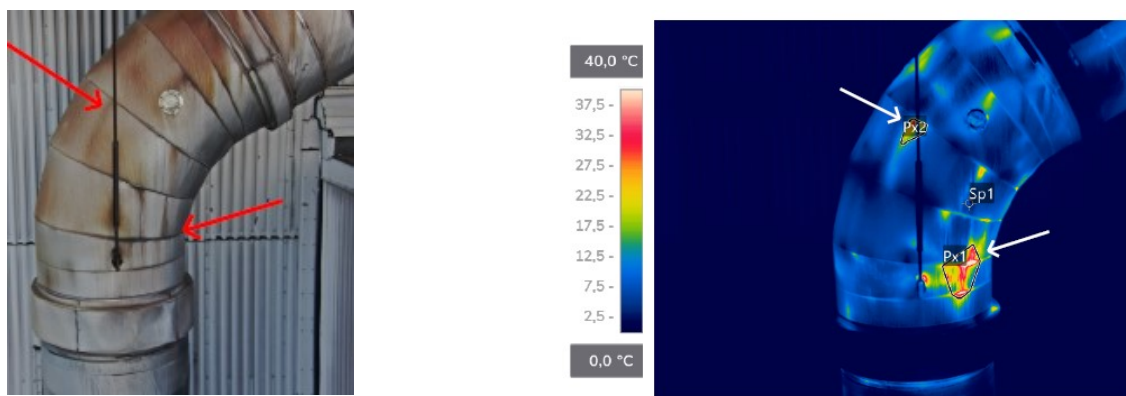


Figure 2. Drone photo and thermographic inspection.

Figure 2 shows thermal image taken from drone. Interpretation is key, and there is no direct indication. Water in insulation usually shows up hot, while leaks are seen as cold plate joints.

All the above is combined with the process knowledge, corrosion risk and wear, deposits, internal to the ductwork. The result of the analysis is presented as a fit for service and remaining lifetime assessments type report. It is then possible to create a refurbishment program pointing out the areas that requires attention including:

- Ducts and structural integrity
- Dampers and plant general control
- Material handling system
- Bag filter and pulse system
- Cooling tower water spray lances and associated control system

The assessment is based on a structured approach. The plant is broken into sub-systems according to the equipment list or piping and instrumentation diagram tag list. For each item, a score or condition grade is given based its useful remaining life. Rating can also be done for probability for failure and consequence. The risk associated with each item can then be used to create a risk-based maintenance program where actions are prioritized according to urgency. Getting an overview of the overall condition of the FTC is a major outcome of such study.

5. Upgrade Options – AHEx Implementation

Smelters always seek to find the best outcome at lowest cost. The upgrade path depends much on 1) the remaining useful life in existing equipment or prospect of repairs and 2) the outlook for operation of the ABF in question in years, which can typically be 5 to 25. If budget allowed, a new FTC is always desirable, but in practice it can be hard to find space for the footprint.

It is often found that the cooling tower is the critical piece of equipment in aging FTCs. Root cause is often in a combination of aging technical equipment (spray lances, water and air supply systems) and the structure itself (corrosion in the cone under spray lances or bottom of tower). The FTC gas cooling must usually be upgraded in combination with refurbishment of filters. On the other hand, it can be found remaining lifetime in equipment such as inlet duct, dampers, main fans, stacks, silos and auxiliaries. These items are less exposed to harsh conditions or are better understood and more frequently followed up by maintenance crews. The outcome is that combining upgrades with a refurbishment program is found more attractive than a new FTC. It is also important to choose a solution that respect constraints in footprint and keep production downtime to an absolute minimum.

An alternative to the conventional large cooling tower structure is the REEL AHEx. It is a shell and tube heat exchanger module that combines gas cooler and alumina injection [6]. This solution can be considered as an advantageous alternative to the refurbishment or replacement of the existing cooling tower.

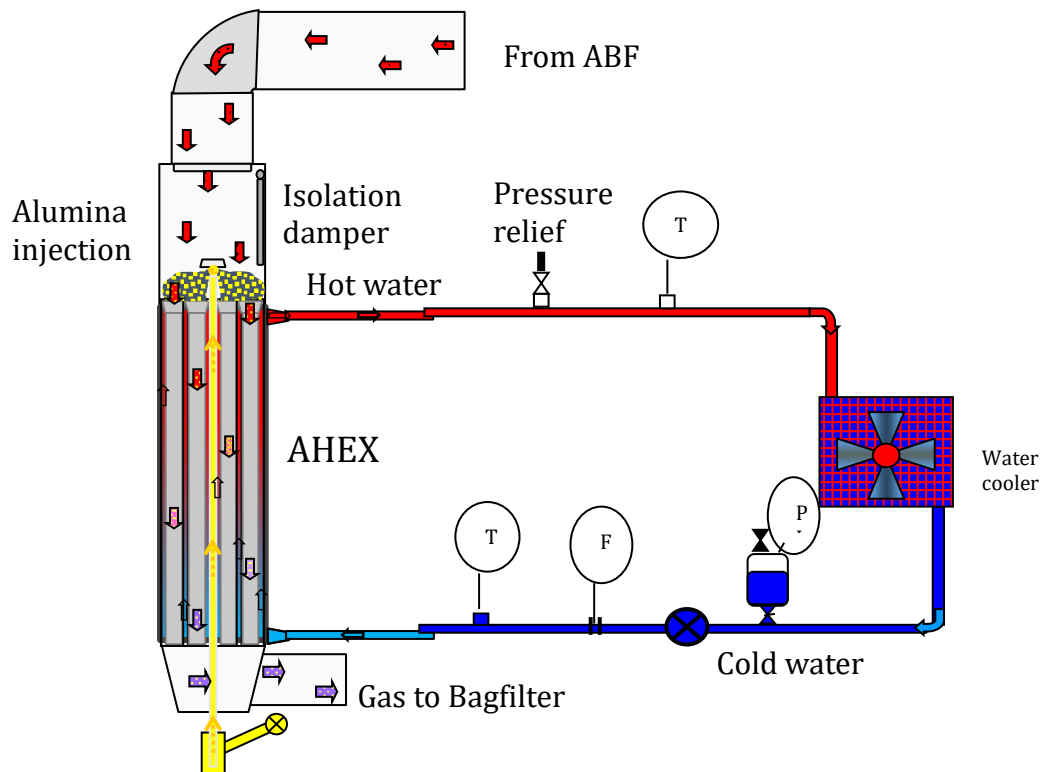


Figure 3. AHEX schematic diagram [7].

The AHEX [7] Figure 3 normally operates with water temperatures 60 °C in an 80–90 °C out. It handles a wide range of gas temperatures in while maintaining 90–100 °C gas temperature out.

Upgrading with the AHEX is desirable for several reasons.

- It is a heat exchanger enabling energy recovery;
- It is not adding any water so downstream equipment is at a much lesser risk of corrosion;
- It is also an upgrade of the reactor where alumina is mixed with the gas, providing for reduced stack emissions - superior performance has been demonstrated and documented [6];
- The configuration is one AHEX per bag filter giving N-1 redundancy, as opposed to a cooling tower where an outage will lead to dry scrubbing bypass mode and uncontrolled emissions, a significant advantage for practical operation and maintaining yearly emission targets;
- Size and location more convenient for maintenance or replacement than cooling tower.

An example of an AHEX installation is shown in Figure 4. Note there is no cooling tower.



Figure 4. Three AHEX modules installed at TRIMET Hamburg [6].

6. Conclusion

FTCs are critical equipment, as they directly impact the quality, availability and safety of the anode production process. The condition of aging FTCs should therefore be assessed, and remedial actions implemented to prevent what can easily become major operational disasters. With this in mind, REEL ECS has developed a structured methodology to assess FTC condition, including both the process aspects as well as its structural integrity. Such assessments can then be used to prioritize areas to be addressed and select the most relevant approach between refurbishment or replacement of the affected equipment, in full or in part. Cooling towers representing the main area of concern, their replacement by AHEX – a heat exchanger-based solution developed by REEL ECS – can advantageously be considered.

7. References

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