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F&GTC: COMBINED TREATMENT OF POT GASES AND ANODE BAKING FURNACE FUMES

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Abstract

Dry scrubbing technology is well known and used to treat either gases emitted by the reduction pots (Gas Treatment Centers) or fumes collected from the anode baking furnaces (Fume Treatment Centers). In fewer cases, the treatment of these gases and fumes has been realized by a common dry scrubbing system; fumes emitted by the furnaces are collected and mixed to the gases coming from the reduction pots. The mixed gases and fumes are then scrubbed together by a unique GTC designed and sized accordingly. This paper details the solutions implemented at Aluminium Dunkerque for Rio Tinto Alcan. Technical performances, investment costs and operation costs are detailed and compared with classical solutions, using a GTC and an FTC. Technical and organizational recommendations, necessary to guarantee the success of this solution are given as a conclusion to this paper.

Introduction

In the aluminium industry, the trend is toward not only a reduction of harmful emissions and particularly of organic compounds, some of which carcinogenic, but also the reduction of both capital (CAPEX) and operational (OPEX) costs associated to such treatment systems. In this context, both aluminium producers and suppliers of pollution control equipment have been looking at innovative ways to achieve these objectives.

One potential solution to optimise the CAPEX associated to the bake ovens fume treatment is to simply eliminate the dedicated Fume Treatment Center (FTC) and use the closest potline Gas Treatment Center (GTC) to treat the Anode Baking Furnace (ABF) fumes in a combined Fumes and Gases Treatment Center (F&GTC).

This paper details the solutions implemented by Solios Environnement at Aluminium Dunkerque for Rio Tinto Alcan in 1990. Technical performances, investment and operational costs are detailed and compared to a traditional solution, where ABF fumes are treated in a dedicated FTC.

Technical and organizational recommendations, necessary to guarantee the success of this solution are given as a conclusion to this paper.

The traditional layout

A Fume Treatment Center is designed for removing hydrogen fluoride and tars and Polycyclic Aromatic Hydrocarbons (PAHs) from fumes generated during anode baking. The process is based on the dry scrubbing technology. Fumes are exhausted from baking furnaces through a duct system, cooled down in an evaporative cooling tower, and conveyed to Venturi reactors. A mixture of fresh and recirculated alumina at an optimised ratio is injected into these reactors to be mixed with fumes. Most of the fluorides and PAHs contained in fumes are then adsorbed or condensed on alumina. The resulting charged alumina is trapped in bag filters and sent to the aluminium electrolysis process. PAHs are incinerated in the pot liquid bath, whose temperature exceeds 960°C. Treated fumes are then vented by exhaust fans through a main stack and to the atmosphere.

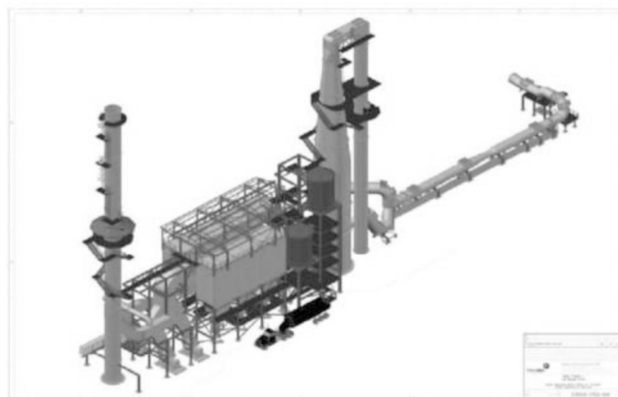

Figure 1 – Typical FTC layout

For a new typical smelter of 400,000 T Al/year capacity, a typical FTC will treat around 140,000 Nm^3/h of fumes from Anode Baking Furnace at 120 to 200°C.

A Gas Treatment Center (GTC) is designed for treating hydrogen fluoride and dust from gas generated by electrolysis pots. The process is similar to the FTC and involves dry scrubbing with alumina.

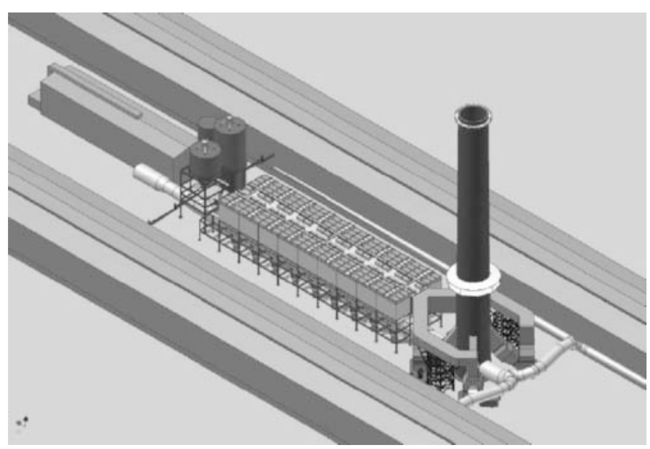

Figure 2 - Typical GTC layout

Gases are exhausted from each electrolysis pot through a duct system. They can be cooled down either by air dilution (if the gas temperatures are not too high) or by other cooling mean, such as a heat exchanger or water atomisation, and conveyed to venturi reactors. A mixture of fresh and recirculated alumina at an optimised ratio is injected into these reactors to be mixed with gas. Most of the fluorides contained in gas are then adsorbed on alumina, which is then used to feed the pots. Clean gas is then vented by exhaust fans through a main stack and to the atmosphere.

For a new typical smelter of 400,000 T Al/year capacity corresponding to 360 AP3X pots (up to 400 kA), there will be 2 GTCs each one treating around 1,800,000 Nm^3/h of gas at 140°C and up to 185°C at pot outlets in hot countries.

Combined treatment solution for both ABF fumes and pot gases

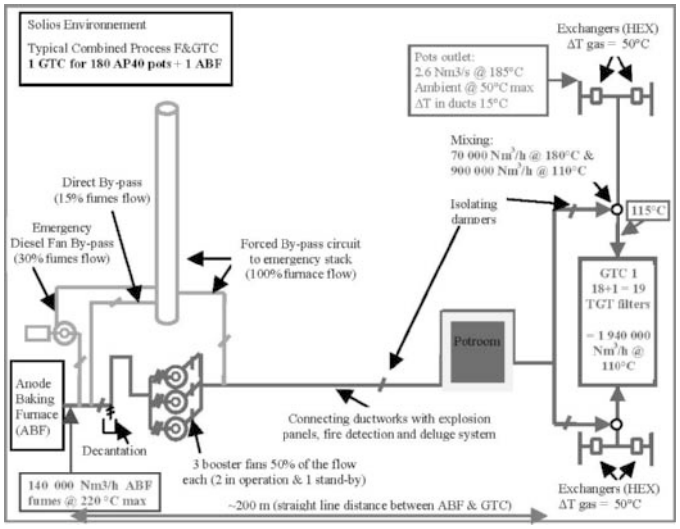

Figure 3 - Typical F&GTC process flow diagram

Figure 3 describes the combined solution for future projects where the standard FTC is replaced by a connecting duct from the ABF outlet to the GTC inlet ducts through the following steps:

- Pre-filtration: removes large particles from fumes by a cyclonic de-duster,
- Boosting fans: allow maintaining the requested negative pressure at the ABF outlet at one side and to boost the fumes to the GTC inlets at the other side,
- Connecting duct: to connect ABF outlet to GTC inlets and mix ABF fumes with pot gases,
- By-Passes to Emergency Stack:
    - Direct By-Pass: to ensure a natural direct draft from ABF outlet in case of fire,
    - Emergency Diesel fan By-Pass: to allow a minimum draft and under pressure at furnace outlet in case of power failure,
    - Forced By-Pass: to allow the ABF running at 100% without treating the fumes (during maintenance activities for example, for very limited durations),
- Fire detection, water deluge system and explosion panels to protect connecting duct,
- Additional Filter(s) on GTC: to treat the additional flow coming from ABF,
- Additional Gas Cooling capacity: to optimize the GTC's inlet temperature and achieve the F&GTC's performances.

The Aluminium Dunkerque experience

Since 1990, the West GTC of Aluminium Dunkerque is treating both fumes from ABF and gases from 132 AP30 pots. The process of the combined GTC is similar to the typical one above with a cyclonic de-duster close to the furnace, emergency stack, by-passes, booster fans and connecting ducts to GTC equipped with fire detection, deluge water system and explosion panels. This project does not employ heat exchangers upstream the GTC.

The gas flow from pots is 322 Nm^3/s @ 140°C max. and the average fumes flow from ABF is 23 Nm^3/s @ 180°C. The resulting temperature in the GTC is between 95 and 120°C (from winter to summer). The dilution ratio of ABF fumes is (322+23)/23 = 15. It means that one volume of fumes from ABF is diluted with 14 volumes of gases from pots.

PAH treatment performance

Regulations concerning PAHs are relatively recent and vary from one country (or even site) to another but tend to be expressed in maximum acceptable concentrations. Depending on the site and country, several lists of PAHs are applicable, which can sometimes make comparisons from one site to another difficult.

In the Aluminium Dunkerque case, the applicable regulation is based on both the OSPAR11 list (max. acceptable limit of 200 $\mu g/Nm^3$) and the Benzo(a)pyrene (max. acceptable limit of 0.20 $\mu g/Nm^3$). These limits are among the most stringent in the world, and are even more restrictive than the current European regulation based on the BREF2001 document [1].

PAH species	US-EPA	OSPAR
Naphthalene	X	
Acenaphthylene	X	
Acenaphthene	X	
Fluorene	X	
Phenanthrene	X	X
Anthracene	X	X
Fluoranthene	X	X
Pyrene	X	
Benzo (a) pyrene	X	X
Dibenzo (a,h) anthracene	X	X
Benzo (a) anthracene	X	X
Benzo (b) fluoranthene	X	X
Benzo (k) fluoranthene	X	X
Chrysene	X	X
Indeno (1,2,3 -c,d) pyrene	X	X
Benzo (g,h,i) perylene	X	X

Table 1 - Applicable PAH lists

The US-EPA PAH 16 list is used as a reference worldwide and even though Aluminium Dunkerque has no regulatory constraint based on this list, results are provided for international comparison purpose. **Table 1** summarises the PAH compounds included in each of these two lists.

The following charts show the results from the regulatory measurement campaigns organised monthly at the West F&GTC stack (from January 2011 to August 2012). Measurements are conducted in accordance with ISO11338-1 standard [2] and last for 2 hours.

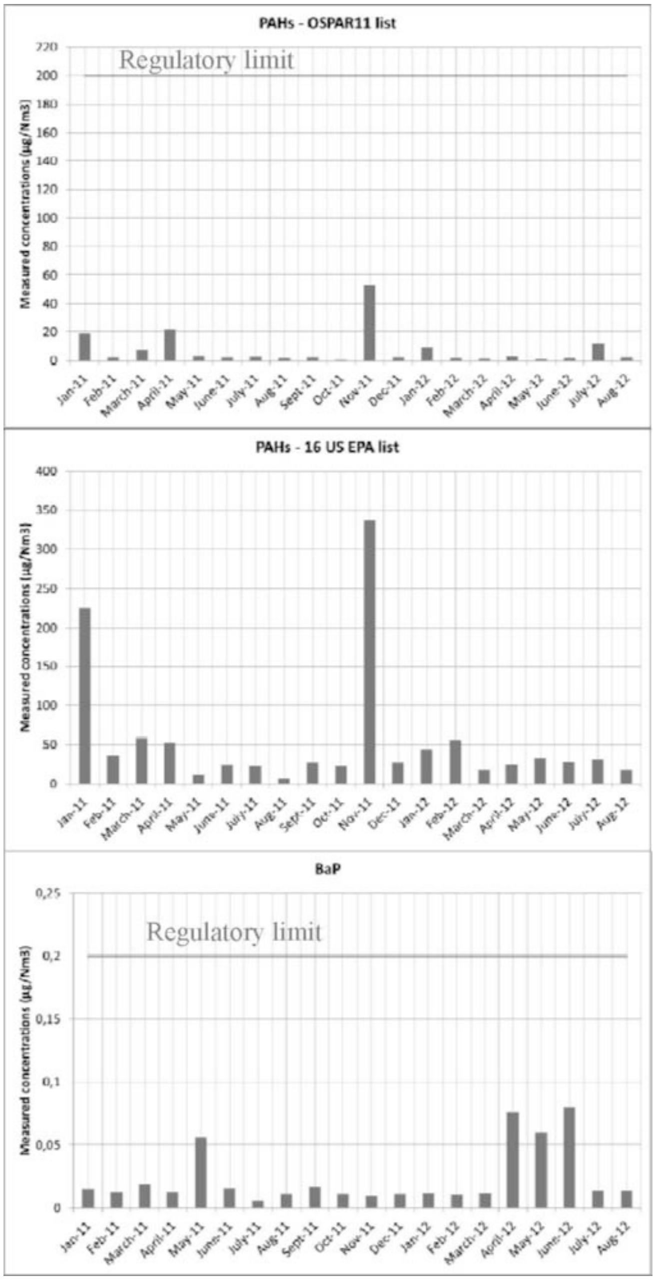

Figure 4 - AD PAH monthly monitoring results

Figure 4 shows that emissions remain well below the applicable regulatory limits; 80% of the values are below 10µg/Nm^3 for the OSPAR11 list, 90% below 0.02µg/Nm^3 for BaP and 75% below 50µg/Nm^3 for the US-EPA PAH 16 list. These results confirm that this process configuration reliably ensures the most stringent regulatory constraints are met. Peaks can typically be attributed to specific transitory ABF process operating conditions, such as fire changes.

These measurements cannot however be directly compared to the ones measured at a FTC stack. Indeed, fumes from the ABF are diluted with pot gases upstream of the F&GTC installation, which biases the comparison.

In order to evaluate the relative performance of a F&GTC versus a standard FTC, FTC concentrations have to be divided by the dilution factor calculated previously (15). The average F&GTC values will be compared to the one obtained from an extensive measurement campaign conducted on one recent FTC treating the fumes from an Aluminium Pechiney ABF comparable to Aluminium Dunkerque. These reference measurements were conducted in accordance with the same sampling standard and included six 2-hour samplings. Results were typical compared to what is reported for similar Rio Tinto Alcan installations. Inlet measurements were also conducted and confirmed the ABF outlet concentrations order of magnitude are similar.

In both cases, peaks related to fire changes will be unaccounted for, in order to ensure the comparison is made on a similar basis (the January and November 2011 results are not included in the calculation). **Table 2** provides the resulting numbers.

	Unit	**F&GTC**	**Reference FTC (*)**
OSPAR11	µg/Nm^3	4 / [0 – 22]	14 / [0 – 32]
US EPA 16	µg/Nm^3	30 / [7 – 59]	34 / [1 – 96]
BaP	µg/Nm^3	< 0.02	< 0.01
Average / [Range] (*) Measured concentration divided by dilution factor			

Table 2 – Summary results

One should be extremely cautious in drawing precise conclusions on the relative performance of these two technologies from these numbers, considering not only the uncertainty related to the sampling procedure and the variability observed between the measurements, but also the fact that these measurements have obviously been conducted in different conditions (two different furnaces, climate…).

Nevertheless, these numbers show that the average and ranges are comparable. With respect to BaP, more than 60% of the F&GTC measurements are below the detection limit (typically around 0.01µg/Nm^3). A more accurate comparison between these two technologies regarding BaP would require measurements to be conducted with a lower detection limit.

HF treatment performance

The analysis of HF measurement results at Aluminium Dunkerque shows that they are around 20% higher at GTC West than at GTC East (0.53 mg/Nm^3 at GTC West vs. 0.43 mg/Nm^3 at GTC East as mean value for 2011). These values are good and remain lower than the applicable regulation of 0.70 mg/Nm^3. Monthly monitoring is conducted in accordance with ISO15713 [3].

This difference of performance is at least partially attributed to a different ratio of treated gas over injected fresh alumina between the two GTCs. Indeed, the fresh alumina flow rate is equally split between both GTCs whereas GTC West treats a higher flow rate (same pot flow rate but an additional 23 Nm^3/s coming from the ABF). Nevertheless, this situation is similar to the one where enriched alumina from a standard FTC is sent by dense phase system to a single GTC silo.

In a future Greenfield F&GTC this unbalance could be easily corrected by a fresh alumina distribution done in accordance with the global treated flow. A controlled lower gas temperature, obtained thanks to the installation of a cooling device such as a HEX, would also contribute positively in achieving similar performance.

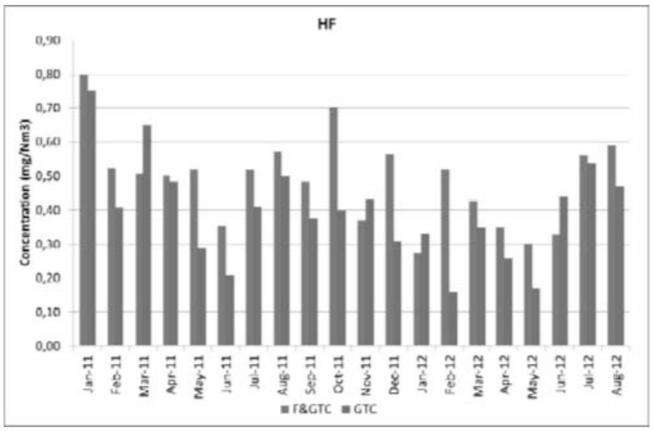

Figure 5 – AD HF monitoring results

<u>Operation & Maintenance</u>

Since Aluminium Dunkerque's ABF upgrade in 2001, the furnace operation has been stable. As a result, by-passes account for typically less than 10 to 20 hours per year, which is comparable to a traditional FTC. It is to be noted that most of these by-passes are unrelated to the F&GTC operation, but are linked to the ABF process.

The connecting duct to the GTC was never cleaned and the fire protection system was rarely solicited since that period (in 2012 the ABF was by-passed for only 6 hours for minor problems). The booster fans (2 in operation and 1 stand-by) are operating without any major issue even if they handle dirty fumes containing tars. Their rotors are cleaned once a year with high pressure water without stopping or by-passing the system. Overall, there is no significant difference between F&GTC West and GTC East from an operation point of view. Routine inspections mainly include a daily 1-hour visual inspection of the booster fans area.

As for maintenance, and contrary to the FTC design, there is no need for an annual or bi-annual shut-down for cleaning in an F&GTC due to the absence of cooling tower and dedicated filters.

Investment & operational costs comparison

Due to its simplified layout (there is no cooling tower, no dedicated silos and alumina handling systems and filters/reactors), the F&GTC requires significantly less CAPEX than the corresponding FTC.

On the other hand, there will be a longer connecting duct and one or two additional filters (depending on fumes flow) in the corresponding GTC as well as an additional 10°C extra cooling capacity on gas for the GTC Heat Exchanger (only applicable if the smelter is located in a hot country).

Based on the above data for a typical smelter in the Gulf area with 1 potline of 400,000 T Al/year capacity corresponding to 360 AP3X pots, there will be 2 GTCs each one treating around 1,800,000 Nm^3/h of gas at 140 and up to 185 °C at pot outlets and 1 ABF generating 140,000 Nm^3/h of fumes at 120 to 200 °C.

Table 3 summarises the result of our comparison between the CAPEX on turn-key basis of 1 FTC + 1 GTC and of 1 F&GTC based on the above hypothesis.

The F&GTC system brings an estimated CAPEX saving equivalent to 50% of a dedicated FTC CAPEX.

	FTC + GTC		**F&GTC**	
	1 FTC	1 GTC	1 ABF (*)	1 GTC
CAPEX	32	100	11	105
Total CAPEX	**132**		**116**	
(*) Inc. connecting duct & accessories				

Table 3 – Relative CAPEX between the two solutions (100 = CAPEX from 1 GTC)

It is thought that the OPEX related to a F&GTC installation is also lower compared to the "1 FTC + 1 GTC" configuration. Though the gain is difficult to estimate to-date, it would be related to the following beneficial items:

- No requirement to transport fresh / charged alumina from the FTC to the GTC area (typically by trucks or dense phase),
- Lower number of filter bags, which are all made out of polyester whereas FTC filters are traditionally made out of acrylic (about typically 100% more expensive). Indeed risks of bags hydrolysis and acid attacks are drastically reduced as fumes from ABF are diluted with pot gases by a factor 15. Aluminium Dunkerque's experience confirms that bags life time are the same for both GTCs,
- No cooling tower (no maintenance associated).

As for utility consumptions (water, compressed air and electricity), the F&GTC configuration has a slightly better figure than the FTC+GTC one: 10% lower compressed air consumption, no water consumption (due mainly to the absence of cooling tower) and same level of electrical consumption.

Conclusion

The main advantages of a combined F&GTC are the CAPEX and OPEX savings. Opportunities exist to increase these benefits by further integrating the F&GTC in the smelter layout.

These savings are brought while ensuring that the strictest environmental regulations can be met. Available data suggest that the PAH treatment efficiency of an F&GTC is comparable to the one observed on the most recent FTC. Additional measurements would however be required to compare accurately the difference between the two technologies with respect to BaP.

As for the security of operation, the main risk is fire propagation to the F&GTC through the long duct connecting it to the ABF, which has never materialised in Aluminium Dunkerque in 22 years of operation. This suggests fire control measures implemented are adequate. New Greenfield installations could nevertheless benefit from recently developed fire protection systems, which would reduce even further the risk.
Operation and maintenance tend to be easier compared to a FTC, due mostly to the absence of alumina handling systems and cooling towers.

Specific attention must be paid should this technology be considered in hot countries where the gas temperature upstream a typical GTC in summer time is between 125°C and 135°C while the optimum PAH treatment temperature is 105°C to 110°C. This situation can be addressed by the installation of heat exchangers on the pot gas circuit for example. Heat exchangers will allow maintaining the gas temperature below 115°C with no additional cost compared to the air dilution solution. In these conditions, the expected environmental performance of an F&GTC will be similar to the one obtained with a FTC, and is compatible with known current regulations.

Overall, this configuration, already implemented in three smelters worldwide, including the one by Solios Environnement at Vlissingen for Pechiney Nederland N.V. (shut down recently, but was operating satisfactory for many years), is an interesting alternative to the traditional design that could be considered for future new Greenfield projects.

References

[1] Integrated Pollution Prevention and Control (IPPC) – Reference Document on Best Available Techniques in the Non Ferrous Metals Industries – December 2001

[2] ISO11338-1, Stationary source emissions – Determination of gas and particle phase Polycyclic Aromatic Hydrocarbons – Part 1: Sampling

[3] ISO15713, Stationary source emissions – Sampling and determination of gaseous fluoride content