AN ANODE PLANT IN URBAN AREAS: FICTION OR REALITY?

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ABSTRACT

To avoid conflicts between settlements and industrial areas, a buffer zone is usually provided. All too often it can be observed that urban areas are expanding faster and further than expected. Such a development may create problems for the plants involved.

Anode plant emissions consist partially of pitch and tar fumes, composed of Polycyclic Aromatic Hydrocarbons (PAH's). These emissions can create an offensive smell and are to a certain extent carcinogenic. 'State of the art' off gas cleaning through dry adsorption is not adequate for *volatile* pitch and tar fumes abatement. Today, with the 'Regenerative Thermal Oxidation' (RTO) process a new technology is available, destroying condensed *and* volatile PAH's as well. After two years of successful operation on an anode bake furnace, results have shown that it is possible to reduce the harmful emissions by at least a factor of ten. A new design which is able to cope with the bake furnace and with the paste plant emissions in *one single* RTO unit will be presented, simplifying significantly the anode plant off gas cleaning. With this approach the anode plant emission problems will be settled once and for all.

1. ANODE PLANT EMISSIONS CONFLICT POTENTIAL

There are many good reasons to design industrial areas in the neighbourhood of settlements. Availability of housing, utilities, sub-suppliers and traffic systems are just a few arguments to build plants in a populated area. Buffer zones will usually be arranged between urban areas and industrial complexes to avoid possible conflicts caused by industrial emissions. In real life however, the pressure to develop the buffer zone is often irresistible. It can be taken for granted that after a certain time the inhabitants will complain about the industrial emissions. In the framework of this paper, anode plant emissions will be discussed. Considering the total emissions of aluminum smelters this is justified by the fact that paste plant and bake furnace emissions to air consist of Polycyclic Aromatic Hydrocarbons (PAH's) which are carcinogenic, can create an offensive smell and visual hindrance. As a consequence, anode plant emissions to air present a significant conflict potential with inhabitants in the neighbourhood.

2. STATE-OF-THE-ART EMISSION CONTROL

Figure 1 shows an anode plant with all their key components. In figure 2 the process block diagram of such a plant is presented.

Besides the 'critical emissions' liquid and solid waste as e.g. spills from the paste plant and refractory bricks is generated by an anode plant. This issue has been discussed in the document 'WASTE MATERIALS IN ANODE MANUFACTURING; AN OVERVIEW [1]. Sulphur dioxide emissions of anode plants are negligible compared with the SO_2 emissions of aluminum smelters.

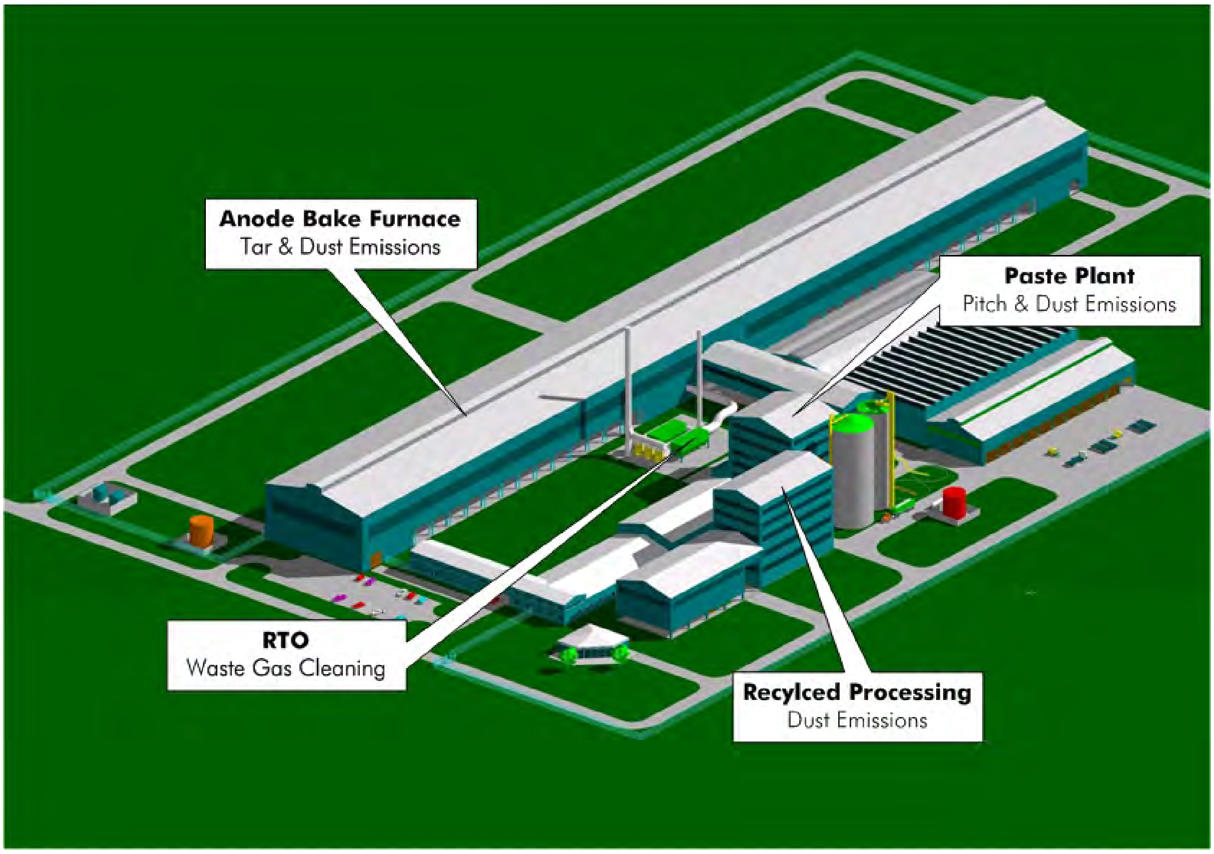


Fig. 1: Artist's impression of a state-of-the-art anode plant

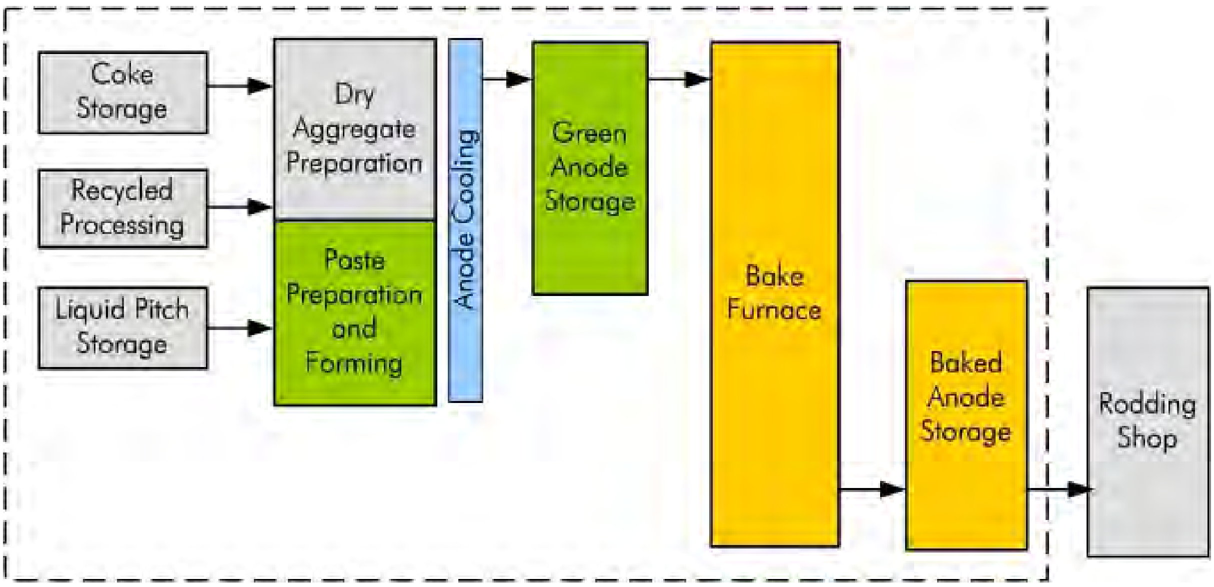


Fig. 2: Anode plant process block diagram

Today, smelters are designed with a production capacity of up to one million tons of aluminum. For such smelters, anode plants with a capacity of 500'000 tons per year and more will be required. The absolute quantity of (carcinogenic) emissions for such plants is in the order of magnitude of 200'000 kg per year. Most of the tar and pitch components in the plant off-gas consists of volatile matter (i.e. is *not* condensed). Dry adsorption units are unable to cope with these *volatile* emissions. Dry adsorption is therefore inadequate and just not good enough to avoid conflicts with neighbours and to comply with reasonable health standards. A totally new approach is therefore required.

3. A NEW APPROACH FOR ANODE PLANT EMISSION REDUCTION

An anode plant optimized for minimum emission differs in three aspects from a 'typical' situation as defined above:

- Unloading of Petroleum Coke by a vacuum unloader instead of by crane.
- Latest generation of bag filters equipped with high quality bags, able to guarantee dust emission concentrations as low as 10 mg/Nm3 for PM 10 dust, i.e. for fine dust with particle sizes in the range of 0 – 10 μm and virtually no coarser dust at all.
- Pitch and tar fume abatement for paste plant, anode forming and anode bake furnace, by means of a 'Regenerative Thermal Oxidation' unit instead of by dry adsorption units.

3.1 Obtainable Results in Dust Emission Reduction

For many years, with 'standard' bag filters, a dust concentration of 50 mg/Nm3 (PM 10 dust) has generally been the accepted level. With properly designed bag filters of the latest generation an emission concentration of ≤ 10 mg/Nm3 for PM 10 dust can be attained. In substituting a crane-to-hopper unloading system by a vacuum unloader, uncontrolled dust emission to air is reduced to virtually zero. Emissions by crane to hopper unloading result in coarse dust emissions. Although coarse dust is not harmful as far as health aspects are concerned, it creates visual hindrance. Vacuum unloading solves this problem. Latest generation bag filters as well as vacuum unloading is considered 'proven technology', so no undue risks are involved in applying these abatement methods. Vacuum unloading of petroleum coke has often been questioned due to the potential risk of petroleum coke grain destruction. It has since been proven that grain fragmentation is limited and mainly restricted to grains that would anyway be crushed during dry aggregate preparation. In applying the abatement methods described, the dust emission will be reduced by a factor of 10. It can therefore be considered that the dust emission problem has been solved.

3.2 PAH Emission Reduction through Regenerative Thermal Oxidation (RTO)

Experts in the early eighties of the 20th century were already aware of the fact that incineration of the pitch and tar fumes would be the correct way to go [2]. However, at that time it was not possible to tackle all technical problems related with energy recuperation as the technology was simply not available. Without recuperation it was estimated that the energy required for the combustion of the tar and pitch fumes would equal two to three times the energy required to produce the anodes. With such a high energy demand, combustion was not viable as an abatement method.

Since then, significant progress has been made regarding material technology. Even so, successful implementation of after burner technology with energy recuperation has been quite challenging. In a typical anode plant the bake furnace is responsible for the emission of 80% – 90% of the total tar, i.e. consisting of the condensed and volatile components. Liquid pitch storage, paste plant and anode forming are responsible for the remaining tar emissions.

The first successful application of a regenerative combustion system has been reported from paste plant and anode forming off gas cleaning [3, 4]. The first attempts to handle bake furnace off gasses were unsuccessful due to technological difficulties. These problems have since been solved. At the time of writing, an 'Autotherm' installation based on the 'Regenerative Thermal Oxidation – principle (RTO) [5, 6] has already been in successful and continuous operation for a period of two years, cleaning bake furnace off-gasses from an open top ring type furnace with a capacity of 100'000 tons per year, controlled by the proven Bake Furnace Process Control System supplied by R&D Carbon Ltd.

3.3 Description of the Regenerative Thermal Oxidation Technique

Combustion of the pitch and tar fumes is the only feasible approach to successfully remove the harmful emissions. Incineration of these components as such is straightforward. Problems are created by the fact that the off gas quantity is significant, the temperature level of the gas low and the calorific value of the impurities negligible. For a proper incineration, a temperature of approximately 800 °C is required. As a consequence, a simple combustion process would result in energy cost of unbearable proportions.

In the Regenerative Thermal Oxidation (RTO) process, the energy stored in the hot gasses after incineration of the impurities is used to heat up a heat exchanger. The combustion chamber is directly linked to two heat exchange chambers filled with a stack of ceramic elements as shown in figures 3 and 4.

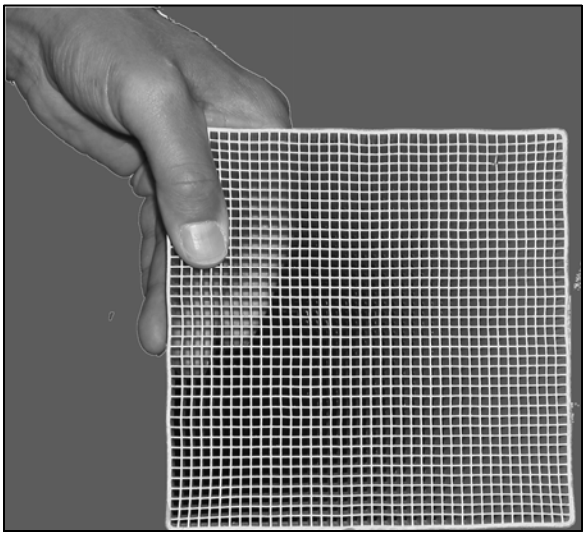


Fig. 3: Ceramic element as applied in a ‚Autotherm' RTO heat exchanger.

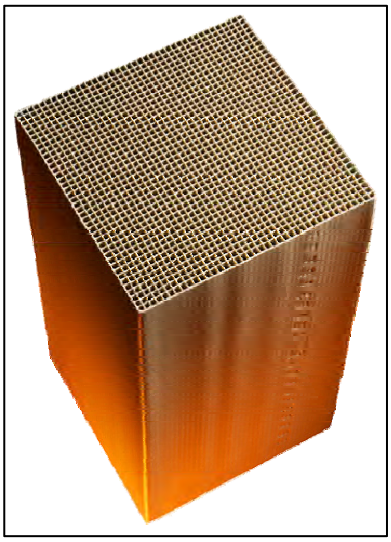


Fig. 4: Stack of ceramic elements as shown in figure 3.

By stacking identical elements a laminar flow with a low aerodynamic resistance is attained. The high surface guarantees an efficient heat transfer. As mentioned above and as shown in figure 5, the combustion chamber is directly connected to two identical heat exchangers. The gas flow direction in the combustion chamber is reversed in short intervals of typically two minutes as shown by the arrows marked ① and ②.

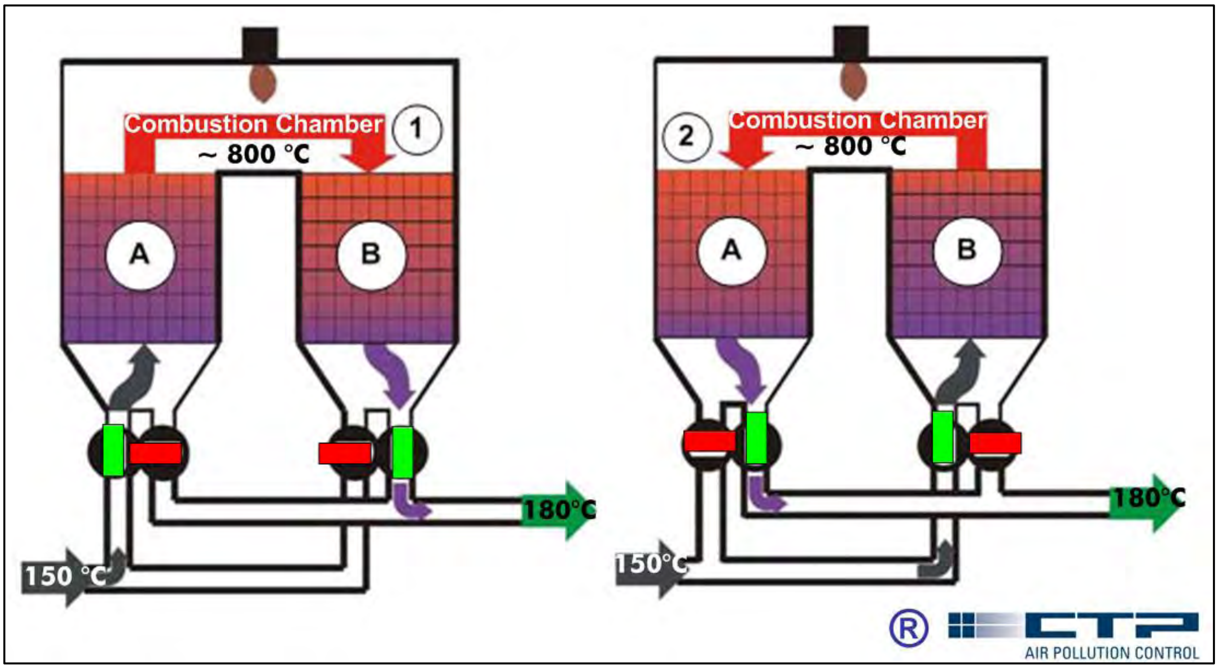


Fig. 5: RTO combustion chamber with heat exchangers A and B.

At the left side of the drawing the raw gas from the furnace flows through the heat Exchanger 'A'. The cold gas is heated by the hot ceramic elements. After incineration of the impurities the cleaned gas enters the heat exchanger 'B' (arrow ①) and heats up the heat exchanger 'B'. Now, the cleaned and cooled down gas is released to the HF absorption unit (not shown). Typically, two minutes later the valves below the heat exchanger operate in such a way that the raw gas then enters the heat exchanger 'B' (right side of figure 5). The gas is then passed through the combustion chamber as shown by the arrow ② and heats up the heat exchanger 'A'. After two minutes an identical cycle will re-start. For capacity and redundancy reasons a number of e.g. three or five such units can be operated in parallel.

HF removal is performed on limestone in a dry absorption unit downstream of the RTO. From this unit the off gas is released to the atmosphere through a stack.

In the case of a high load of condensed tar, a pre-filter may be required where tar droplets are captured on ceramic elements. The pre-filters are cleaned by burning out the filters at regular intervals.

3.4 RTO Application for the Treatment of Paste Plant and Anode Forming Off-gasses

In paste plants, the off-gas temperature is even lower than in a bake furnace, resulting in pitch fume condensation in the piping. Pre-heating this gas with separate heaters has been tried. This is however a complicated and inefficient approach. To avoid the need of separate off-gas heating, a new approach has been patented [7]. According to this approach, hot off-gas from the bake furnace RTO is used as carrier gas for the 'cold' off-gas from the green anode production. The off-gas amount of the green anode production is much less than the bake furnace off gas quantity. This creates the possibility to mix the off gas from the green anode production with the off gas from the bake furnace. All the off-gasses loaded with PAH's will then be treated in *one* combined RTO or 'Combined Fume Treatment Plant', as shown in figure 6.

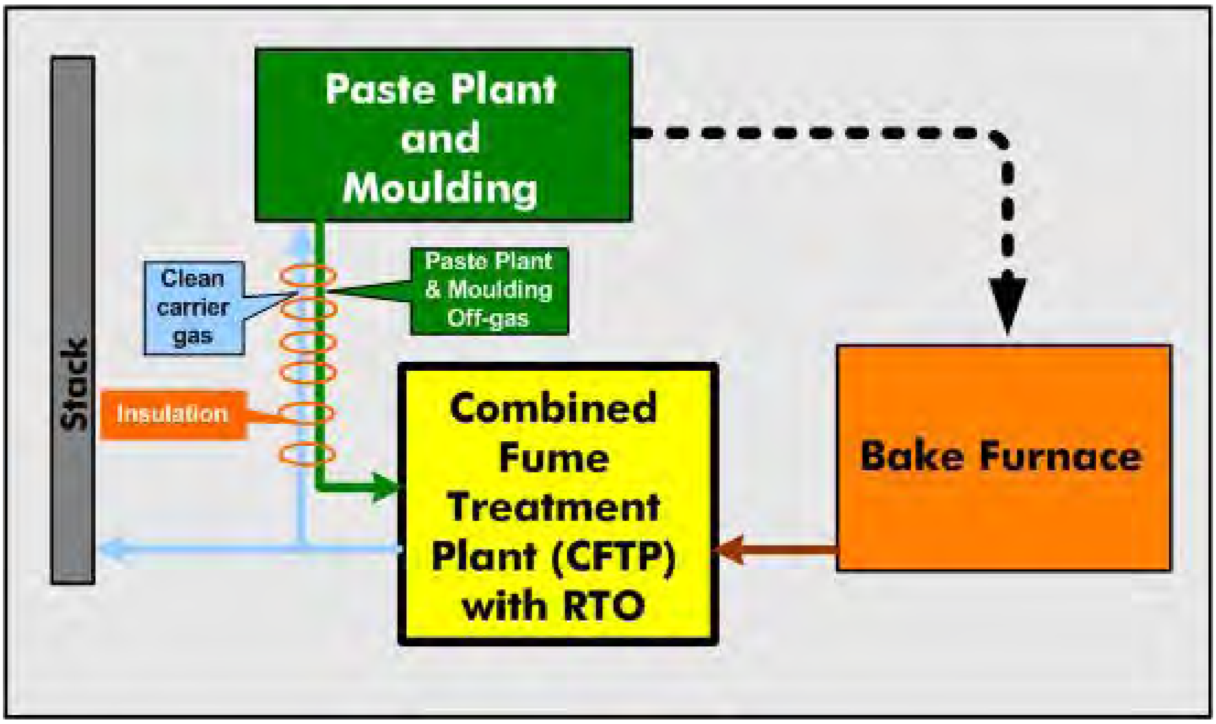


Fig. 6: Combined Fume Treatment Plant (CFTP) for Bake Furnace and Paste Plant

An indication of the gas quantities and the total emission of hydrocarbons (i.e. the total tar) in an anode plant with an annual capacity of 500'000 ton is shown in figure 7.

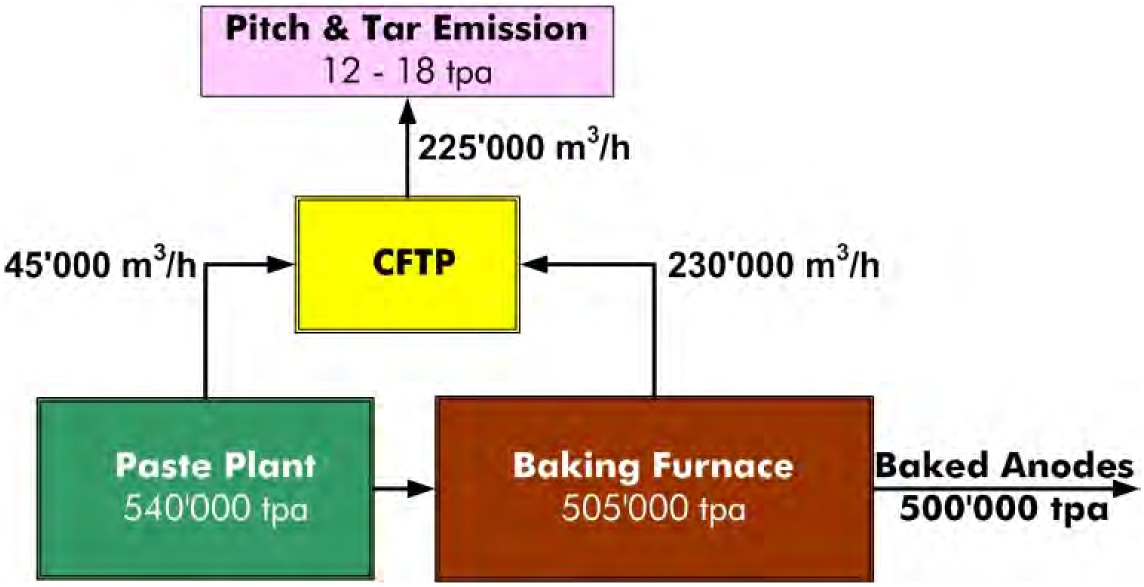


Fig. 7: Indication of gas quantities and total tar emissions for an anode plant with a capacity of 500'000 ton/year.

4. BOUNDARY CONDITIONS FOR MINIMUM EMISSION OPERATION

For minimum emission a decent plant design, proper maintenance and sound operation practice is required. The following examples give an indication of conditions required for minimum emission operation:

- Bag filters operating without defective bags and equipped with proper quality bags.
- Bake furnace equipped with state-of-the art bake furnace process control system for optimum tar fume combustion.
- Regular emission monitoring.
- Training of production and maintenance people regarding awareness of minimum emission operation.

5. CONCLUSION: RTO, THE ULTIMATE APPROACH REGARDING ANODE PLANT TAR EMISSION ABATEMENT

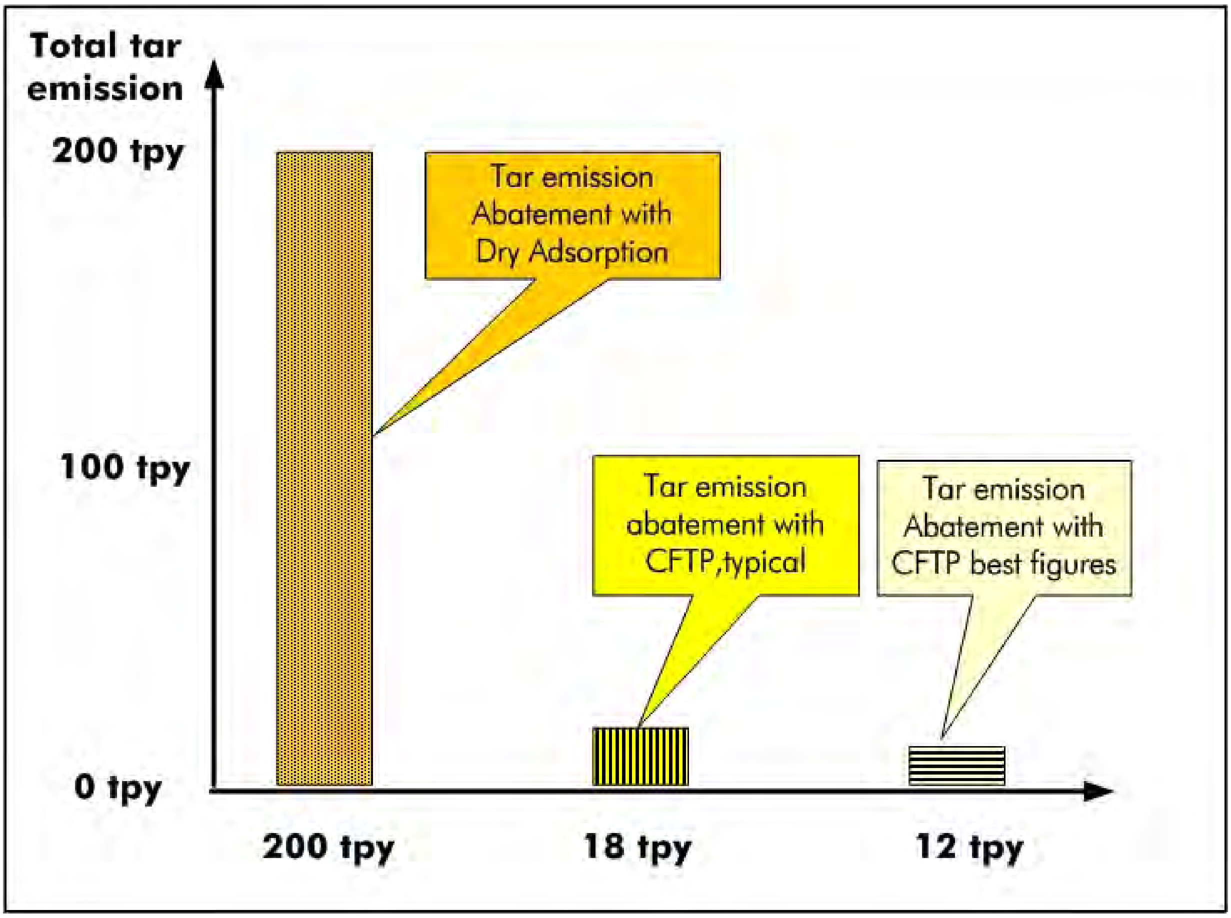
Pitch and tar fumes generated in green anode production and in anode baking represent by far the most critical emission problem in anode production. Dry adsorption as considered ‘State of the Art’ today is unable to capture volatile components and to reduce pitch and tar emissions to acceptable levels. As shown in table 1 and in figure 8, substitution of dry adsorption by Regenerative Thermal Oxidation (RTO) techniques reduces emission by a factor 10 or more with bearable emission abatement cost. With the RTO approach, the remaining emissions are negligible. It can therefore be concluded that the problems created by anode plant emissions have now been solved.

Source	Material	Typical plant abatement method	Typical anode plant; total emission	Modern plant abatement methods	Modern anode plant; typical total emission
Coke & butts unloading & storage	Coke dust	Bag filters	150 t/y	Bag filters	15 t/y
Paste plant & Pitch storage	Pitch & tar fumes	Dry adsorption	26 t/y ①	RTO	2.5 t/y ①
Anode forming	Pitch & tar fumes	Dry adsorption	4 t/y ①	RTO	0.5 t/y ①
Bake furnace	Pitch & tar fumes	Dry adsorption	170 t/y ①	RTO	15 t/y ①
Bake furnace	Fluorides	Dry adsorption	1.5 t/y	Dry absorption on lime	1.5 t/y

①Total tar; i.e. condensed tar and volatile matter.

Table 1: Emission comparison for typical and ‘modern’ anode plants with a capacity of 500’000 t/year

Fig. 8; Anode plant for 500’000 t/year; pitch and tar fume abatement through dry adsorption (left) and Regenerative Thermal Oxidation (RTO) (centre and right).



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