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EXPERIENCES IN FTC DESIGN, OPERATION AND DEVELOPMENT

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Abstract

Over the past decades, emission control has consistently been a major issue for the developed, aluminium consuming world. Environmental facilities like Fume Treatment Centres have been retrofitted to paste plants and carbon bake furnaces throughout the world. The emerged countries have seen a great increase in aluminium consumption and for all greenfield smelters, the addition of FTC's has been mandatory. Danieli Corus's experience in FTC's extends from retrofit projects in e.g. the EU and Australia up to LSTK projects in developing countries such as the Middle East and India. This article describes how existing FTC's have performed over the past decades in terms of environmental performance and maintenance requirement. For recent projects, specific circumstances of execution in greenfield situations are discussed. In addition, developments in FTC technology and future prospects are presented.

Introduction

Since 2007 Danieli Corus has 8 fume treatment centres for Anode bake furnaces on order. The projects involving these FTCs are under various stages of execution within our organization, ranging from Basic Engineering from recently acquired projects, to construction and start-up and operation. Whereas these projects give a representative overview of the latest trends of FTC design, we would like to present these and try to identify current and future design trends.

Experiences in Design

An FTC for an Anode Bake Furnace is a mature type of equipment of which a lot is known and written about. In most projects the specification for the unit is defined to a high level of detail by the technology supplier of the bake furnace leaving limited design parameters to be optimized by the FTC supplier. One out of the eight projects was designed based on a true functional specification.
The design of the FTC focuses on two issues:

1) The cleaning of the exhaust fumes, e.g, the environmental performance and
2) the reliability of operation of the unit as such and therefore the Bake Furnace as a whole.

With respect to the environmental performance, much relies on the dry scrubbing process itself. The principle process has not changed over the years.

In order to meet the current Anode Bake Furnace capacity under construction today, the most common FTC configuration yields a 5 module scrubber although 3 and 6 module designs are considered. The DC design FTC employs a traditional high pressure pulsing system. The high scrubbing efficiencies are ensured through the use of the patented Vertical Radial Injector (VRI) technology. A single, generously sized cooling tower with redundant temperature controls ensures optimum hydrocarbon condensation while maintaining a dry bottom operation.

From recently started Bake Furnace using full control Pitch burning firing systems [1], the initial performance values showed successful results on all environmental performance parameters with the exception of particulate capture. An investigation soon eliminated all of the most probable causes of the particulate emission and a study was initiated into the cause of the emission source in conjunction with the client and industry specialists.

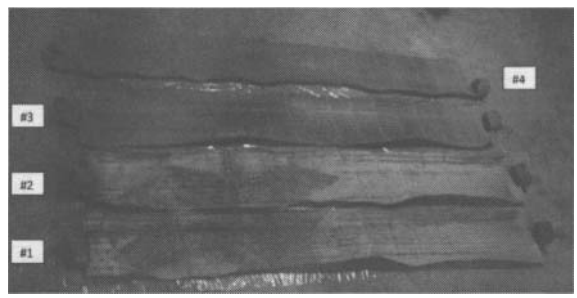


Figure 1: Particulate Investigation study

In the following months of gathering information and performing trials, it was decided to perform a series of inlet gas tests to determine the composition of the fume.

This information along with the results of the study led Danieli Corus to formulate a theory to explain the particulate emission which revolved around two observations:

1) The full pitch burning results in fewer hydrocarbons in the exhaust fumes. This in turn leads to stable filter cake formation
2) The particulate concentrations in the fumes are lower than can be expected based on the design specification and also the particulate size was much smaller.

The above was confirmed . The measurements of the inlet concentration of TOC (Total Organic Compounds), Coal Tar Pitch and Particulate Matter were in a range of less than 5-10% of the specified maximum value

As a result of the above observations , the amount of Alumina in the system for both the fresh as well as the recycle flow was reduced significantly to avoid unnecessary high dust loading and generation of fines in the system..

Stack emissions showed immediate improvement with the initial steps and continued to show improvement which would appear to validate the current theories explaining the high particulate count.

After now having established the actual operating point of the FTC, the filter bag material needed to be reviewed and tested to the new situation. . A trial using 6 different filter bags of different suppliers has been held. Each of the supplied filter bag types were installed at different locations in the filter modules for a 6 week trail. After this period the bags were removed and sent to an independent lab for testing and analyses. The results are summarized the table below:

Sample	Material	Air Permea-bility	Dust Penetration	Physical properties
A	Polyester	Average -	100%	Good
B	PAN membrane with PTFE coating	High	0%	Good
C	PAN	low	50%	Good
D	PAN with Imide P84 microfiber	Average +	100%	Good
E	PPS with PTFE coating	Average	50%	Good
F	PAN with Imide P84 microfiber	Average	50%	Good
PAN: Polyacrylonitride PPS: Polyphenylenesulfide				

Table 1: Results first field trails filterbags

Based on the above results, the Sample B would be the best solution, however as Membrane filter bags are more difficult to install and have a lower Permeability (in clean condition) than other filter bags, this solution was not taken, but further testing was done with Polyacrylonitride bags with other microfiber materials over a 5 months trail period. The results are presented in table 2:

Sample	Material	Air Permeability	Dust Penetration	Physical properties
1	Polyester / PAN Mixture, PTFE Coated	Low	40-80%	Good
2	Polyester / PAN microfibre	Average	60-90%	Good
3	PAN microfibre needlefelt, senged oil and water repellant	Average	30-60%	Good

Table 2: Results second field trails

On the basis of the above results the Polyacrylonitride (PAN) filter bags with microfiber were selected and installed. During the subsequent performance test of the re-bagged installation the particulate emission guarantee (5 mg/Nm^3) was met. [2]

It is now apparent that the challenge lies in providing a plant design that is capable of achieving emission targets with a much broader range of inlet concentrations produced by a new generation of high efficiency firing systems.

A more comprehensive adjustment to process parameters is required than previously considered and must be formulated according to the measured or expected inlet conditions.

Reliability and operability

Lately the focus on FTCs is moving from the process performance towards the operational performance such as reliability and the operability.

Maintaining the furnace draught in all situations, including upset situations, has become the main focus.

The furnace draught is typically provided by 3 exhaust fans (2 duty + 1 standby) and is controlled by variable speed drives to provide accurate draft control while ensuring energy efficiency and reducing operating costs.

In most modern installations the draught should be maintained also in up set conditions to avoid lifting of the flue gas covers of the furnace ring main and associated gas emission within the Bake Oven. This has led to the introduction of the so-called Emergency draught fan or EDF. The EDF is contrary to the main exhaust fans driven by a diesel engine to cope with power failures which would stop the FTC. In the past this was overcome by an emergency bypass over the FTC, e.g. directly from the ring main to the stack. The design issues with the EDF are related to starting the EDF itself, the location of the EDF relative to the FTC on the furnace ring main and the control logic.

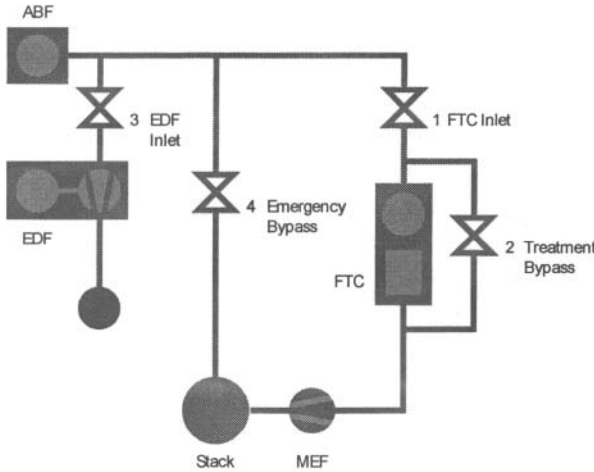
The main issue in selecting an EDF was how to the start the Fan. The idea for the EDF has been copied from a diesel driven firewater pump, commonly used in the offshore industry. The only issue is that the moment of inertia of a fan is different of that of a pump and that due time and consideration needs to be given to the sizing of the motor, the coupling and the start-up sequence. For one location this has resulted in a diesel generator driving an electric motor driven fan, while at another location a direct driven fan is installed.

The second point is the location of the EDF relative to the FTC on the ring main. There are two possibilities: on the opposite side of the ring main, or next to the FTC. The first option has the advantage that the system is totally independent of the FTC, the second has the advantage that no separate stack and dampers are required.

The control of the EDF has resulted in lengthy discussions during the engineering phase, but the following table explains the operation at best:

Fume Temperature	**Valve Position (Open /Close)**				**MEF**	**EDF**
	1	**2**	**3**	**4**		
< 185°C	O	C	C	C	RUN	STOP
185°C	O	O	C	C	RUN	STOP
220°C	O	C/O	O	C	RUN	START
250°C	C	C/O	O	C	STOP	RUN
350°C	C	C/O	O	C	STOP	STOP
400°C	C	C	C	O	STOP	STOP
No Power	C	C	O	C*	STOP	START
EDF Failure	C	C/O	O	O*	STOP	FAIL
* Fail open on EDF power failure						

Table 3: Cause and Effect Diagram FTC operation



1. FTC B/C valve
2. FTC treatment bypass
3. EDF B/C valve
4. FTC Emergency bypass

Figure 2: Fume flow schematic

Note that the EDF has its own independent control system which senses the under pressure in the ring main.

If the ABF must be able to run for extended periods of reduced anode production, the system must to be able to cope with large turndown capability. Extended periods of lower production can result in an FTC with baghouse modules of varying filter "on gas" time and therefore the system must be able to address the likelihood of managing gas flows through filters of varying pressure drop. The variable pressure drops through the filters requires the controls to measure and balance the gas flows through the various baghouses to avoid high filter velocities caused by preferential flow paths.

The Danieli Corus scrubber can be designed with a closed loop control system which measures and manages the flow into each individual module as an automatic function or manual operation via the operator's control panel.

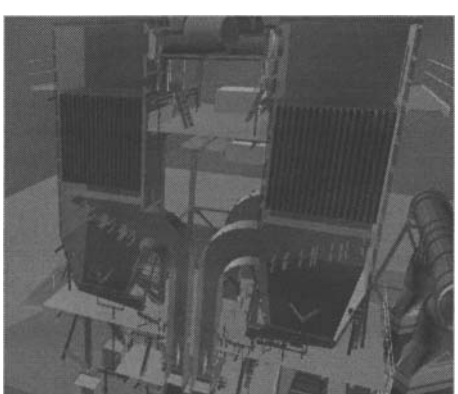


Figure 3: Walk- in Plenum

The Danieli Corus design features a walk-in plenum rather than lids. The advantage of the walk-in plenum (see figure 3) is that a leaking bag can be replaced quickly, typically in less than one hour after detection, without the use of an overhead crane, jigs etc. Also the detection which bag is leaking can be done visually through the window in the entrance door on the clean side of the tubesheet. This feature will become more and more important in cases where particulate emissions becomes more stringent and one leaking bag may cause the limits to be exceeded.

Nowadays health and safety requirements however qualify the walk-in plenum as a confined space with all the requirements associated with that. By modifying the design by adding an extra door on the opposite side, an emergency exit has been created and the confined space issue has been resolved. Whereas most new installations of the FTC are located in a warm climate, the second door also provides additional ventilation of the walk-in plenum during the bag change, lowering the temperature in which the operators work.

Experiences in Execution/ Construction

The projects are executed in such a way to meet the project objectives with respect to quality, time and cost, or in another way of putting it: timely build and cost effective, safe installation meeting the environmental performance. In order to meet the criteria for quality we rely on our proven Pleno –IV design, which has a track record of 40 years. Health and Safety has become more and more an issue today, and with the use of modern software it has led to a new design approach based on 3D modeling. The module allows for reviews to ensure health and safety, constructability, maintainability and ease of operations. A Walk-Through model review has become a standard milestone in the engineering and design of a modern FTC.

In order to reduce cost, as large as transportable parts of the plant are being produced at the manufacturer's place and shipped to the construction site. This approach has several benefits: the parts or (semi-) modules can be built and conserved in a conditioned environment in a low cost country and shipped to the site.

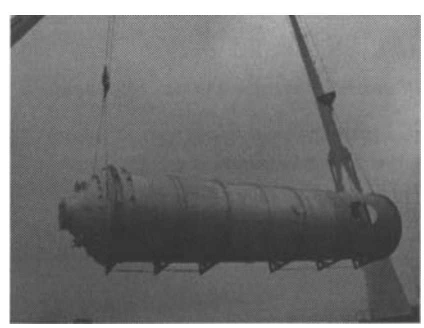


Figure 4: pre-assembled Conditioning tower

By bringing large parts to the site, especially in a expansion project of an existing smelter, the traffic movements and the required site labour is reduced considerably and therefore enhancing the safety condition of doing construction work in an operating plant. This type of modularization in combination with the split of responsibilities between manufacturing of steel modules and the erection can only be done with a detailed 3D model to avoid clashes on site.

Figure 5: FTC modules during Shipment

The use of CFD modeling during the design phase has resulted in a better understanding of the physics of the gas flow and in particular the gas flow with entrained Alumina particles. This has resulted in an improved design of the FTC, mainly in the reactor and in the designating area (figure 6). The overall result of this process is reduced attrition of the alumina, which is an advantage to the electrolysis process [3], better disengagement in the hopper bottom and adjustment of the Alumina injection depending on the unit capacity.

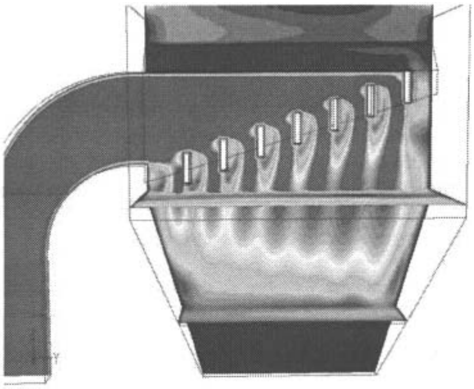


Figure 6: CFD optimized alumina disengagement

Experience resulting in new development

Further areas of FTC development are a controlled recycle to further improve the performance of the dry scrubbing process by applying the DC patented Volumetric feeder to control the recycle flow of Alumina to the reactor. This would allow the FTC to be better equipped to meet future emission targets to 2 mg/Nm^3 for particulate.

<u>The VRI</u>

The Vertical Radial Injector (VRI) creates an excellent contact of the alumina particles and the furnace gas, obtaining more than 98% HF removal efficiencies at the VRI followed by the remainder of the HF removal at the filter bags Air is used to fluidize the alumina inside the VRI and the alumina will overflow through the holes as shown in figure 7. Due to the intensive contact of the alumina particles in the gas, the recycle rates will be relatively low, reducing attrition of the alumina and abrasion of the filter bags. The alumina plume can be observed by removing the inspection hole in the riser duct. By controlling the fluidization air, the alumina coverage (plume) in the gas can always be set optimal, even when the gas volume rises. This feature guarantees the removal efficiency at different load conditions. CFD models were used to investigate the influence of the fluidizing air and the shape of the plume.

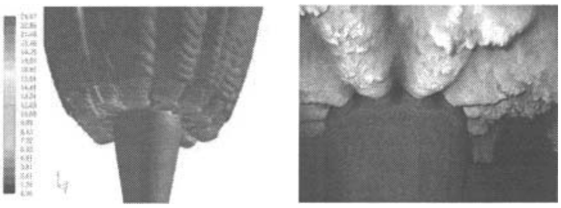


Figure 7: VRI operation; CFD model versus actual operation

<u>Spark detection.</u>

The full Pitch burning in the bake furnace has changed the properties of the tar coming from the furnace to the FTC. The concentration of liquid pitch or pitch droplet which drop out in the collector duct is becoming less and less. However, the pitch deposits in this ducting was and still is a potential risk for duct fires for which the FTC is equipped with deluge systems. The presence of so called "dry" sparks or glowing ambers flying by in the collector duct and riser duct can cause a fire when they get into contact with the pitch deposits. A spark detection system will detect the glowing matter at the inlet of the duct and will give a controlled dose of water in the duct to extinguish the spark and avoid a potential fire [4]. This system will further enhance the availability of the FTC and improve overall average emission levels by avoiding bypass time due to fires.

Conclusion

The design and construction of FTCs has changed over time. Advances in Full Pitch Control have changed the feed to the unit considerably and has provided new challenges to meet the ever stringent emission legislation worldwide. The increasing awareness for health and safety has impacted the design of the unit and led to cost increases and complexity of design and operation. The economic impact of the changes are mitigated by optimal design of the installation with modern design tools such as, but not limited to 3D computer and CFD modeling and higher degree of modularization.

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