Successful Start-up of the Fume Treatment Centre at Boyne Smelter Carbon Bake Furnace #4

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Abstract

At Boyne Smelters Limited (BSL) in Queensland Australia, a new carbon bake furnace was built as part of a AUD $337 million development program to replace two existing carbon bake furnaces. The carbon plant was to have a capacity of 200,000 tpy of anodes. It consisted of a Rio Tinto Alcan AP technology furnace, four (4) state of the art fire groups using natural gas, two furnace tending cranes, an anode handling system and a Fume Treatment Centre (FTC). The plant was commissioned in January 2012 and reached full capacity by April 2012. The FTC design incorporated several new features such as newly designed flow distribution system in the baghouse, microfiber filterbags which utilize lime pre-coat for improved filtration and a direct diesel driven emergency draft fan. Similar with the majority of startups there were some challenges to overcome, but the carbon bake furnace and FTC are both fully operational and have achieved operational and process performance guarantees.

Introduction

Boyne Smelters Ltd. (BSL) is located in Boyne Island, Central Queensland, Australia, just south of the township of Gladstone. In 2008 the Smelter underwent a major modernization to meet the latest environmental regulations for current and future operation. The joint venture of SNC-Lavalin Australia and Sinclair Knight Merz (SSJV) managed the project from the perspective of BSL. The tendering process for the FTC started in June 2008 and the first phase of the project was awarded in May 2009. Ironically, it was during the tendering phase for the FTC that the Global Economic Crisis (GEC) began. This had a worldwide impact on large capital projects and influenced how this project was to be staged in terms of cash flow and timing. During the first year following the initial award, critical engineering tasks were performed so as not to influence the overall project schedule. The final notice to proceed was not issued until March 2010 almost 10 months later, for the remainder of engineering services. The planned commissioning completion was scheduled for early 2012.

Due to the GEC, it was requested that cost optimizing measures be enforced to keep the project alive. Danieli Corus (DC) accepted this challenge and opted for foreign equipment supply and to import fabricated steel components from an offshore supplier. DC had extensive experience in overseas steel manufacture and understood that this method had potential for significant savings if managed correctly. This decision added to the complexity of building a state of the art FTC which incorporated the latest industrial developments in the field of dry scrubbing. When the installation contractor differs from the fabrication contractor there is potential for confusion and conflict of responsibility, even more so when the supply comes from overseas.

The objective of the FTC was to meet the client requirements in terms of ease of operation, high online reliability, maintenance friendly while performing acceptably to comply with the stringent local environmental legislations on airborne emissions.

The FTC Design

In the BSL FTC design, DC incorporated several new features as follows:

1. A more compact design occupying less footprint;
2. A safer and improved clean air plenum above the tubesheet
3. Modified arrangement to improve access to the cooling tower and exhaust stack platform;
4. An optimized flow distribution system at the entrance to the filter module;
5. A direct-drive diesel powered Emergency Draught Fan (EDF) located on the opposite side of the bake furnace;
6. The inclusion of microfiber filter bags that are pre-coated with hydrated lime

Compact Design

A new feature of the BSL FTC was the stack relocation and re-configuration of the ductwork where DC introduced a 180° bend in the clean air duct after the filter modules. The result was a significant savings in FTC footprint of approximately 7% as shown in Figure 1.

Further advantages include 1) the main exhaust fans could be installed beside the filter modules for clean and easy access, 2) the possibility of baghouse expansion without interference with alumina storage or mechanical equipment and 3) the stack and cooling tower could be installed adjacently for structural advantages.

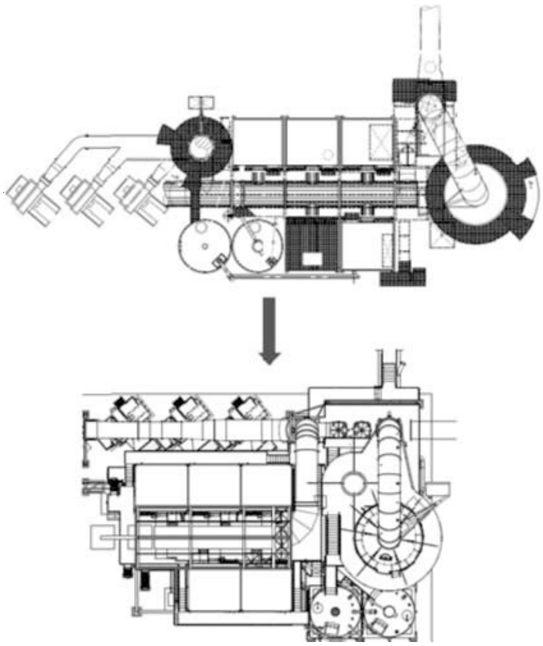

Figure 1. Reduction in FTC Footprint
as a Result of Stack Re-location and Duct Re-configuration

Clean Air Plenum Above the Tubesheet

The operators at BSL were used to the unique DC design walk-in clean air plenum above the tubesheet as it is installed at their Line 3 Gas Treatment Centre (GTC). The clean air plenum makes it very easy and convenient to replace the filter bags, however in recent years the rules and regulations defining confined spaces has become very stringent. Although not strictly classified as a confined space, the design had to consider the restrictions as well as the experience of the operators and maintenance crews.

The DC design features a walk-in plenum rather than removable lids and overhead cranes. The advantage of the walk-in plenum, Figure 2, 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. Furthermore, leaking bag identification can be done visually through the window in the entrance door on the clean side of the tube sheet. 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.

The recent FTC design now houses two full size man doors on opposite sides of the baghouse tubesheet. The doors provide easy access from multiple locations and promotes natural light and cross ventilation. These additional steps have de-classified the tubesheet to a restricted space, which requires fewer safety procedures to enter. It also simplifies inspection during operation and encourages cooling during bag change.

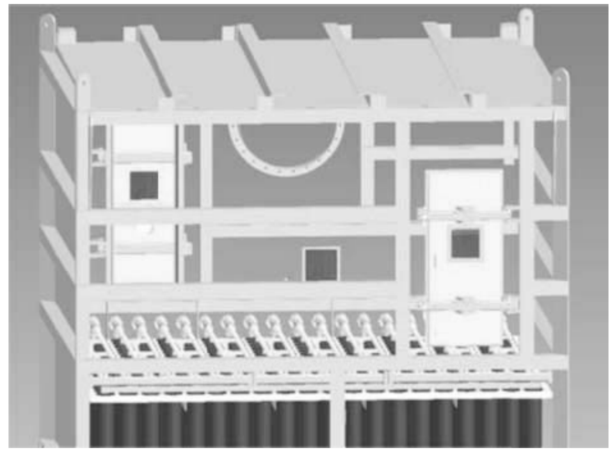

Figure 2. Double Full Size Access Doors
For Access to the Tubesheet

Access to Cooling Tower and Exhaust Stack Platform

The compact FTC design allowed the stack and cooling tower service platforms to be combined thereby saving on access stairs and additional steel weight. Recall that traditional FTCs had the cooling tower and stack at opposite ends of the FTC meaning duplicated stairs and platforms. As a result of the combination, a very spacious platform is present from which maintenance and gas measurements can be executed quite easily as illustrated in Figure 3.

Figure 3. Large Service Platform for
Cooling Tower and Exhaust Stack

Optimized Flow Distribution System

The use of CFD modeling during the early design phase has improved the understanding of the physics of the gas flow within the baghouse module. In particular close attention was given to the gas velocity in the hopper area, an area of the baghouse that previously received less consideration. If gas velocity reached critical values in the hopper, it could lead to alumina re-entrainment – meaning particles that already collected in the hopper could become picked up again. As can been seen in Figure 4, the flow distribution system acts to minimize the velocity across the bed of alumina in the bottom of the hopper and to distribute the flow evenly within the module cross section.

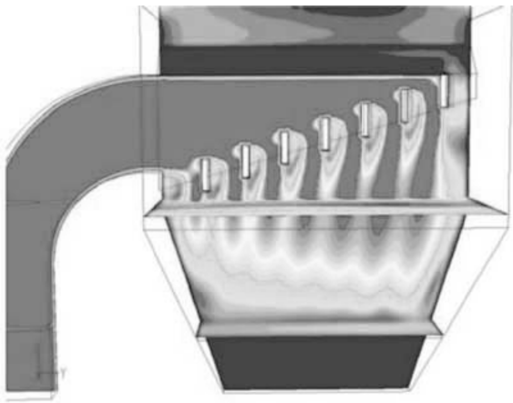

Figure 4. Computational Fluid Dynamic Model Illustrating Flow Distribution With Module Hopper

The overall result of the improved flow distribution system is:

- Reduced attrition of the alumina which is an advantage to the electrolysis process [1];
- Improved alumina disengagement in the hopper reducing the amount of alumina reaching the filter bags;
- Reduction in peak upward velocities toward the filter bags level out the range of these velocities.

<u>Direct Drive Diesel Powered Emergency Draught Fan</u>

As in most modern installations, the draft on the bake furnace should be maintained during operating excursions and upset conditions to avoid gas emissions within the Bake Oven. This performance criteria has led to the introduction of the Emergency Draught Fan (EDF) as shown in Figure 5.

Figure 5. Direct Drive Diesel Powered Emergency Draught Fan

The EDF is driven by its own diesel combustion motor, and is completely independent of the main exhaust fans. The EDF can operate during power failures to evacuate the bake furnace gases, a time when the FTC is stopped. In the past, this scenario was addressed by an emergency bypass over the FTC, e.g. natural draft ventilation directly from the ring main to the stack. But natural ventilation was insufficient to fully evacuate the bake furnace from fugitive emissions during an outage. There were some minor design and operational issues with the EDF as described in the commissioning phase that were related to starting and stopping the EDF itself, the physical location of the EDF on the furnace ring main relative to the FTC and the general control logic.

The concept of the diesel driven EDF was borrowed from the diesel driven firewater pump commonly used in the offshore industry. The main difference being the moment of inertia of a fan impeller is different of that of a pump. This was addressed during the engineering and resulted in a suitably sized motor, coupling and controlled the start-up sequence.

<u>Filterbag Selection</u>

Over the last ten years the performance of a FTC has changed as a result of the modifications in the upstream burner system in the bake furnace. Modern firing systems target the complete combustion of the pitch volatiles, which has affected the FTC particulate emissions in two ways:

1) The full pitch combustion results in fewer hydrocarbons in the exhaust fumes to the FTC. It is hypothesized that this in turn leads to unstable filter cake formation.

2) The particulate sizing is much smaller and particle concentrations in the fumes to the FTC are lower than traditional systems.

This results in a drastically reduced usage in Fresh Alumina (FA) consumption in the FTC freeing up more FA for the GTC where Fluorides are more prevalent. Additionally, the recycle rate could be lowered as well reducing material loading and alumina attrition.

Also standard homopolymer acrylic bags were struggling to meet the more stringent performance requirements due to upgrades in the bake oven. On the basis of trial runs with different types of bags at Alcoa Portland FTC startup, the homopolymer acrylic bags required a needlefelt microfiber top layer to reduce particulate emissions to acceptable limits [2].

On the basis of bag suppliers' experiences in other industries with a greater amount of particulate fines, the filter bags were pre-coated with hydrated lime prior to exposure to alumina and hot carbon bake fumes. This was the same procedure that was developed and successfully used in the Alcoa Portland FTC.

Modular Design

BSL is located in along the eastern coast of central Queensland, Australia. With the trades market highly dependent on the mining business in Western Australia and many major projects in the immediate area, the availability of local labour to erect the FTC was in short supply. As the manufacturing was done in an economical location outside Australia as a cost awareness measure, the local labour performing the erection was not the same company who completed the manufacture. Therefore, transportable parts from the point of manufacture were made as large as possible to suit land and sea transport. This approach had several benefits aside from the fabrication economics. Firstly, the parts or (semi-) modules can be built and conserved in a controlled environment in an economic country and shipped to the site (Figure 6).

Figure 6. Modular Design
Left Photo – Fully Fabricated Cooling Tower
Right Photo – Preassembled Baghouse and Stack Section

Works that could be performed within the fabrication shop as opposed to site are of better quality and performed at a more competitive labour rate. Additionally, by bringing large parts to the site, especially in an expansion project of an existing smelter, the traffic movements are reduced considerably. This enhances the safety condition of doing construction work in an operating plant. The large module delivery has a major impact on site labour requirements since there is less site welding and bolted splices to combine a series of smaller components. This type of modularization in combination with the split of responsibilities between manufacturing and the erection can only be accomplished with a detailed 3D model to avoid interferences on site.

3D Modeling

Modern construction projects rely heavily on construction documentation supplied by the Engineering firm to the fabrication and installation contractor as they include plans, details and information relevant to the successful installation. The BSL FTC was the first aluminium project that DC had completely modeled and represented in 3D in terms of structural members, pipe routing and cable trays. The model allowed several engineering disciplines to interact and visually see the final assembly before being built as shown in Figure 7:

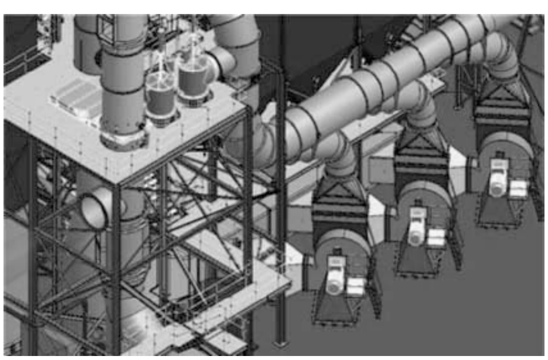

Figure 7. CFD Model of FTC

The 3D model incorporated all the details and data of a 2D model and allowed the designer to apply various alternatives and immediately analyze the impact. The result was an improved and efficient design. Benefits included:

- Minimum interference between structural, cable tray and pipe routing
- Improved visualization of concepts and layouts
- Optimum use of materials such as piping and cables
- Improved interaction between engineering disciplines

The last decade has witnessed a significant growth in use of 3D modeling in the Engineering and Construction projects.

Operating Environment

With construction activities nearly finished at the beginning of November 2011, the cold commissioning phase started shortly thereafter. The 1st phase comprised of pre-commissioning activities which involved cold commissioning of dampers, cooling system and rotating equipment. The 2nd phase involved cold commissioning of the alumina handling and baghouses. Whereas different parties were involved from this phase, a commissioning team was created and a meeting scheduled every morning. This meeting was led by SSJV before hand over of the plant and by BSL after hand over. The meeting was attended by SSJV, BSL, Innovatherm, Rio Tinto Alcan AP and Danieli Corus. This was a well-structured way to cope with construction, commissioning and safety issues. BSL was closely involved, including the phase where hand over had not taken place yet. This sped up the whole process as BSL took care of issues that could have led to delays.

Preparations

Commissioning Checklists

During the engineering phase of this project a commissioning manual was made and approved by SSJV and BSL. This manual was used as a guideline for this job. This included basic mechanical equipment checklists for construction completion and pre-commissioning. Process parameter tables such as pressure and amperage values were noted on the checklists as means of reference. During any future re-commissioning activities, the original parameters would be useful in re-establishing the successful operation. On site, these basic guidelines were refined with close cooperation of BSL and SSJV to develop the best hand over package to the owner. The documentation was used to evaluate the performance and for future reference.

Safety

As with every construction project, safety was given paramount priority. For every stage of the commissioning, a thorough checklist was made incorporating a complete and detailed safety analysis. All aspects of the safety plan were discussed with all contractors and trade disciplines and mutually agreed to comply with the project safety standards.

Cold commissioning

Start-up/cold commissioning is defined as the process of placing a system or portion of a system in operation for the first time under "live conditions" to ensure correct plant functionality. The cold start-up began when pre-operational testing activities are completed by the commissioning team. It was scheduled to minimize interference with bake furnace startup.

Main Exhaust Fans

There are three (3) main exhaust fans that are direct drive and fully instrumented in terms of vibration and bearing temperature monitoring. All fans were commissioned without difficulty and typical issues such as overheating bearings, variable frequency drive (VFD) control errors, excessive noise or vibrations were not observed.

Emergency Draught Fan

Despite the overall smooth start-up of the EDF, it suffered an initial setback. After the first run an inspection was made on the internals of the gearbox and it was evident that the mechanical gear had failed. The fan supplier and local technical experts were consulted on this issue and it was concluded that the inertia of the fan impeller stripped the gear on the fan shaft. The diesel motor shaft stopped immediately after stopping the diesel motor while the fan still contained inertia which kept it rotating, The fan supplier supplied a new gear in combination with a de-clutch mechanism which solved this issue. This was the first time a direct driven diesel fan was supplied for a FTC and this arrangement was re-engineered on the job in cooperation with the supplier and it operated successfully after this modification.

Poppet Damper Shaft

The FTC contains two bypass poppet dampers. One directs the flow directly to the main exhaust fans bypassing the conditioning tower and baghouse modules and the other one bypasses the entire FTC to direct the fume directly through the stack. During cold commissioning of the FTC the main exhaust fans ramped up to almost full speed and the damper was inadvertently in the open position. It is normally closed and should have been closed during the fan ramp-up. This poppet damper was designed for velocities around 5-10 m/s as it is only opened during emergency conditions. On this occurrence, the damper faced velocities reaching almost 75 m/s. As this damper was not designed for this extreme velocity pressure the shaft failed and the poppet disc ended up in the discharge duct. The broken damper was removed from the ducting and pieces were collected so as not to cause further damage to downstream equipment.

To ensure this failure would not occur again, the shaft was re-designed by DC in cooperation with the supplier and then discussed with BSL. The new shaft was substantially more robust and had a larger diameter with thicker welds. After modifying the poppet damper shaft it was mutually agreed to change-out the FTC poppet damper shaft as well to ease the concerns of the client that this would not happen with the other poppet damper in the future.

Alumina Handling

At the beginning of January 2012 the fresh alumina handling was commissioned. Initially, the filter bags were pre-coated with hydrated lime and alumina according to the procedure developed at Alcoa Portland a few years earlier. There were no major leakages noted in the alumina handling equipment which was a great relief as even a small deformation in the steel work used for the alumina handling equipment could lead to major alumina leaks and spillages. Alumina leaks are often difficult to rectify and could cause major commissioning delays.

First “Hot Fumes In”

The first two weeks operation of the new CBF4 was a dry out period to remove moisture from the refractory installation. During this period, the fume contained a high moisture content and no pollutants. The FTC provided draught and was operated in bypass mode. Initially one set of auxiliary burners was used for a week. A second set of burners was fired up after that week. After this period the temperature was high enough to start the first fire onto the first green anodes and the FTC was put into operation on two filter modules.

At the same time the first fresh alumina was fed towards the filter modules. As the fresh alumina was stationary for several weeks in the FA silo the extraction from the silo was troublesome. The ingress of some water during construction in the weeks before caused blockages of the silo outlet. A clean out of the FA silo solved this problem after which the FA flow to the filter modules was set to 2 t/hr.

After the system had time to stabilize, the carbon content of the reacted alumina was analyzed shortly after hot gas in. It measured approximately 0.5% indicating excellent pitch burning in the bake oven and a suitable amount of fresh alumina to address the carbon content.

Learning Curve During First Stage of Operation

After the first six months of operation the bake furnace is now running with all four fires at normal capacity. The installation runs in a safe, predictable way and operator attention is minimal. FTC bypass operation has been a rare occurrence, however during these first six months some other minor issues have occurred.

Wetting of Conditioning Tower Bottom

Not long into the FTC operation, it was observed that the discharge from the conditioning tower bottom was wet when it should be very dry under normal conditions. This was a serious concern and after a detailed analysis of the operational data by DC and BSL it became apparent that the compressed air control valve was not operating correctly under low flow conditions. This resulted in larger water droplets that were not evaporated before they reached the conditioning tower bottom. This issue was fixed by resetting the air control valve to a setting at which it allowed more air through which created smaller droplets. Since then, the conditioning tower bottom is running dry. This issue showed that the FTC conditioning tower cooling system is a very delicate piece of equipment which could result in serious problem if small issues such as the wet bottom are not addressed.

Unscheduled Deluge Trip

The FTC was equipped with thermal detection and fire protection in the collector and riser duct as well as the inlet plenum. During the first month of operation, the FTC tripped due to an unexpected activation of the fire deluge system in the inlet plenum. The temperature switches used for the deluge were set at a lower then required set point temperature, despite contradicting paperwork. The system reacted correctly and caused a FTC bypass operation for a short period. The cause was determined and the temperature switches were replaced.

Emission Guarantee Tests

In early June 2012, the FTC passed emission tests on particulates, fluorides, poly aromatic hydrocarbons (PAH's) and condensed tars with only one (1) tonne of alumina per hour and four fire operation, running on four baghouse modules. To create the best emission performance it is evident that the balance of the amount of alumina injected versus the recycle is very important. Too much alumina will increase the dust emission, too little will increase the fluoride emission. Despite passing the emission guarantee test, the emission parameters will still be closely monitored and optimized by fine-tuning the balance between the recycle and fresh alumina.

Conclusions

The startup of the FTC on BSL CBF 4 was successfully completed successfully to the satisfaction of all parties. The FTC incorporated new design features from Danieli Corus that enhance the safety and operability, maintainability and emissions performance. It was a clean startup with the new furnace, thanks to the close coordination of DC and BSL during hot and cold commissioning. There were minimal by-pass events which meant emissions were maintained even during the commissioning phases. The FTC continues to operate effectively and all parties consider the project a great success.

References

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