Electric Furnace Off-Gas Cleaning Systems Installation at PT Inco

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ABSTRACT

PT Inco is a ferronickel smelter in Soroako, Sulawesi, Indonesia, which operates four electric smelting furnaces to smelt a ferronickel calcine prior to converting to nickel matte. The four electric furnaces operate continuously with calcine feed from five rotary kilns.

In 2003, WorleyParsons Gas Cleaning (formerly Gas Cleaning Technologies) performed a study to implement a new off-gas cleaning system on electric furnace #3 (EF3) at PT Inco. Proper combustion chamber design was critical to ensure complete combustion of the off-gas and to maximize combustion occurring within the furnace freeboard. Upon selection of a preferred combustion chamber and baghouse gas cleaning system design, the project was then carried through basic and detailed engineering in 2004. In 2005, the EF3 system was commissioned. The successful performance of the new system led to the design and implementation of similar systems on the other three electric furnaces. By the fall of 2007, all four electric furnaces had operating gas cleaning systems.

Prior to the start of the gas cleaning system project, off-gas from the furnaces exhausted directly to atmosphere via two chimneys without any gas cleaning. Today, all four furnaces operate with world-class emissions control. Furnace operation has also improved as a result of the optimum draft control provided by the off-gas systems.

This paper outlines the development of the project, key design considerations, and the results of implementing new gas cleaning systems on the four electric furnaces at PT Inco.

Background

PT Inco is a ferronickel smelter in Soroako, Sulawesi, Indonesia, which operates four electric smelting furnaces to smelt a ferronickel calcine prior to converting to nickel matte. The four electric furnaces operate continuously with calcine feed from five rotary kilns.

The four electric furnaces previously had no gas cleaning equipment installed to clean the furnace off-gas. Each furnace had two refractory-lined stacks with a combustion chamber and evaporative sprays. The combusted gases were then discharged directly to atmosphere. An electrostatic precipitator had previously been installed on one of the furnaces, but concerns over CO explosions led to that system being decommissioned.

In 2003, WorleyParsons Gas Cleaning performed a study to implement a new off-gas cleaning system on Electric Furnace #3 (EF3) at PT Inco. In addition to meeting particulate emission limits, the system was to be designed to meet the following key objectives:

- Minimize the explosion risks related to combustibles in the off-gas,
- Minimize maintenance requirements and associated downtime,
- Prevent sulphuric acid condensation in the off-gas stream and associated corrosion problems, and
- Provide sufficient capacity for the current and planned furnace operation and production levels.

Process Design

The electric furnace operation at PT Inco is a reduction process that generates process off-gases consisting primarily of carbon monoxide (CO) and hydrogen (H_2). Off-gas volume is therefore directly impacted by the carbon content and loss on ignition (LOI) content of the feed calcine. Small quantities of sulphur, carried over from the fuel oil used in the kilns, can evolve as sulphur dioxide (SO_2) in the off-gas as well. Analysis of historical calcine assays showed that carbon content typically ranged from 2 to 3 percent, and LOI content ranged from 1.2 to 1.6 percent. This variability translates into significant variation in process off-gas generation. A 30 percent variation in feed throughput also significantly impacts the process gas generation.

Freeboard gas analysis testing was performed at various calcine feed compositions to better characterize the resulting off-gas volume and composition. Benchmarking of other ferronickel furnace operations was also conducted.

The process gas of mostly carbon monoxide and hydrogen is highly combustible. In order to handle and clean the off-gas safely, the gas must be either rapidly quenched to suppress combustion, or the gas must be fully combusted in the furnace or combustion chamber. Fully combusting the gas is a much safer operation and allows for dry gas cleaning. This design can achieve much lower dust emissions than a wet scrubber-based system in suppressed combustion. Therefore, the full combustion approach is preferred and was selected for this application.

In a submerged arc furnace operation with covered bath, it is best to combust the process gas as much as possible within the furnace freeboard. This reduces the off-gas heat content and allows some of the combustion energy to be recovered by the calcine bed in the furnace. It also provides much easier temperature control in the off-gas system, reducing the risk of downstream explosions and dust sintering. Most importantly, this approach allows the furnace to be operated at a consistent slightly negative freeboard pressure of -4 to -7 mmwg. This draft setpoint allows the furnace to experience fluctuations in gas generation and still remain under slight suction, minimizing the puffing of fugitive carbon monoxide and hydrogen into the work area. The furnace has a much more stable operation at this freeboard pressure.

Moderate opening areas exist in the furnace roof between the roof bricks and at the electrode ports. This opening area and the freeboard draft allows infiltration air into the furnace freeboard. The air flow is more than sufficient to fully combust the process gases. Off-gas temperatures exiting the furnace are typically between 900 and 1000°C.

A combustion chamber is required at the exit of the furnace to combust any remaining combustible process gases. Proper combustion chamber design is critical to ensure complete combustion of the off-gas. A combustion gap was designed to allow combustion and dilution air to be drawn naturally into the combustion chamber. The air quickly combusts the residual CO and H_2 and dilutes the gas to 600 to 800°C, below the dust sintering temperature. The combustion chamber is refractory-lined to eliminate the risk of water leaks entering the furnace. The chamber is sized to maintain gas velocities in the range of 25 to 35 m/s to provide good mixing for complete combustion.

After the gas is fully combusted in the combustion chamber, it must be cooled for handling by the downstream equipment. A vertical evaporative spray chamber was designed to cool the gas to 370°C. This cools the gas enough to be handled by carbon steel ducting downstream without significantly increasing the gas volume as dilution would.

Furnace draft control is achieved using a louvered draft control damper located downstream of the spray chamber. The damper position modulates to maintain the freeboard draft at a setpoint between 4 and 7 mmwg.

A baghouse was selected to clean the off-gas. Baghouses on primary off-gas applications can consistently achieve 20 mg/Nm^3 outlet dust loading. Electrostatic precipitators can typically only achieve 50 to 100 mg/Nm^3. In addition, electrostatic precipitators present a real risk of explosion on combustible gas systems in the event that the gases are not fully combusted exiting the combustion chamber.

The baghouse is a 12-compartment, negative pressure pulse-jet baghouse and uses fiberglass bags with a PTFE membrane. These bags provide very high filtration performance and can withstand continuous temperatures up to 260°C. The baghouse is protected from acid condensation using powdered lime injection into the inlet gas stream. The lime coats surfaces and neutralizes any acid that might condense from the gas stream.

The 370°C primary off-gas exiting the spray chamber must be diluted to reduce the gas temperature below 260°C for handling by the baghouse. Instead of pulling in ambient air, several secondary emissions sources are tied into the baghouse system to dilute the primary off-gas. Exhaust from the furnace smoke hood, combustion gap hood, feed bin ventilation all tie into the baghouse system. A control damper in the main secondary gas duct is adjusted in steps to ensure the baghouse inlet gas temperature is maintained between 180 and 230°C. This ensures the baghouse is protected from high temperatures as well as from acid condensation due to low temperatures. The acid dew point for this system is estimated to be below 140°C.

The EF3 baghouse system capacity is 637,000 Am^3/hr and uses a single ID fan. The actual flow can be lower at lower calcine carbon and LOI content or at lower throughput. Therefore, the ID fan was supplied with a variable speed fluid coupling for reduced power consumption when operating at reduced capacity requirements. The ID fan discharges to a stack. Dust collected in the baghouse is transferred to a local dust bin via air slides and is then pneumatically conveyed to a large common dust bin for recycle to the process.

Project Execution

Upon selection of the preferred gas cleaning system design, the project was then carried through basic and detailed engineering by WorleyParsons Gas Cleaning in 2004. In May 2005, the EF3 system construction was completed and the new system was commissioned. WorleyParsons Gas Cleaning provided commissioning assistance to check system operation and to optimize performance. Key focuses of the commissioning work included optimizing the combustion gap size, damper positions and control set points, and optimizing the dust handling and conveying system operation.

The new system was successfully commissioned with only minor issues that were resolved during the commissioning process. Stack dust loading has been consistently below 20 mg/Nm^3. The system has now been operating successfully for nearly three years. The new off-gas system provides much better control of furnace draft, which has resulted in much more stable and reliable furnace operation.

Figure 1 shows a photo of the new EF3 baghouse installed at PT Inco.

Figure 1 – New EF3 baghouse at PT Inco

The successful performance of the new EF3 system led to PT Inco's decision to design and implement similar systems on the other three electric furnaces. Basic engineering on a new EF4 off-gas system was performed in parallel with EF3 detail engineering. Detail engineering was then conducted for EF4 in 2005, and basic engineering of EF1 and EF2 were conducted in parallel. Detail engineering of EF1 and EF2 systems was then performed in 2006.

For the EF4 system, two existing adjacent electrostatic precipitators were converted to a single pulse jet baghouse for gas cleaning. EF1 and EF2 have baghouses of similar design to EF3. The final three systems all have horizontal spray chambers located above the converter aisle instead of a vertical spray chamber adjacent to the furnace as with EF3. This change was made due to space limitations and a desire to have the final three furnace off-gas systems all have similar designs.

The new EF4 off-gas system was completed and successfully commissioned in February 2007 and has been performing very well. The EF1 and EF2 off-gas systems were completed and commissioned in the second half of 2007. By the fall of 2007, all four electric furnaces had operating gas cleaning systems. Today, all four furnaces operate with world-class emissions control.

Heat Recovery

Furnace off-gas heat content often represents up to 40% of the total furnace energy input, so finding ways to recover and use that heat can provide significant improvements in energy utilization and major reductions in operating costs. Smelting furnaces in particular have proven to be good candidates for heat recovery systems due to the stable gas conditions from the continuous furnace operation.

In parallel with the off-gas system design, WorleyParsons Gas Cleaning completed a study on heat recovery options for the electric furnace off-gas. For the PT Inco operation, a waste heat boiler was found to be the most effective option for recovering heat from the off-gas in terms of total heat recovered, capital and operating cost impact, and precedence. The detail engineering for the EF1, EF2, and EF4 off-gas systems included a provision for future installation of a waste heat boiler in parallel with the horizontal spray chamber for off-gas heat recovery.

Conclusion

The implementation of off-gas cleaning systems on the electric furnaces at PT Inco has been a true success. In addition to significantly reducing furnace emissions, furnace operating stability has been improved. The results have shown that taking a project through the conceptual, basic, and detail engineering phases to completion and commissioning provides the best approach to optimizing the system design, performance, and reliability.

This approach allows thorough process analysis in the early phases of a project to optimize process parameters and equipment sizing. This can include appropriate test work and modeling. The findings from the early phases together with experience from past projects can be incorporated into the later engineering phases to ensure the final design of a system is state of the art and highly reliable.

Finally, the approach shows that systems can be effectively designed for optimum emissions control performance while maximizing energy utilization.