Advanced Selective Catalytic Reduction (ASCR) System - Operating on a Coal Fired Boiler in Taiwan

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Fuel Tech

• Fuel Tech is a company engaged in the innovation and application of technologies for air pollution control, process optimization, and combustion efficiency. These technologies enable customers to operate in a cost-effective and environmentally sustainable manner.

• In addition to ASCR Fuel Tech’s air pollution control products include:
  – Flue Gas Conditioning
  – Graduated Straightening Grid (GSG)
  – Low-NO_x Burners
  – Over Fire Air Systems
  – SCR Systems, Equipment and Services
  – SNCR Systems
  – ULTRA Systems
Present Challenges for Coal Energy

- Coal-fired power plants are presently facing several challenges.
  - More stringent emission standards
  - Legislation requirements for renewable portfolio standards and carbon reduction
  - Abundance of affordable natural gas
- These challenges have forced energy producers to reduce coal consumption.
- This has resulted in a shift towards renewable energy with coal-fired power plants no longer being used for base load energy.
- These challenges require that NO$_x$ reduction systems be low capital cost in order to be economically feasible.
ASCR Design Principles

- Selective Catalytic Reduction (SCR) is the Best Available Control Technology for NO\textsubscript{x} reduction but limited in application due to high capital cost requirements and retrofit difficulty.
- The ASCR approach can achieve similar overall NO\textsubscript{x} reduction as a SCR but with a greatly reduced capital cost.
- An ASCR combines multiple low capital cost technologies including Low-NO\textsubscript{x} burners, OFA, and/or SNCR in combination with a compact SCR reactor.
- The ASCR reactor requires less catalyst, a smaller footprint and less duct modifications - all resulting in a greatly reduced capital cost when compared with a traditional SCR.
Project Site

• 80 MW T-fired boiler.
• Burns Multiple Fuels
  • Adaro Coal
  • Coke Oven Gas (COG)
  • Blast Furnace Gas (BFG)
• Located in Kaohsiung, Republic of China (Taiwan)
The plant needed to reduce NO\textsubscript{x} emissions by >78% from a baseline of 230 ppm to below 50 ppm (dry basis @6% O\textsubscript{2}).

The unit had existing low-NO\textsubscript{x} burners and an existing SNCR system.

The project added:
- New Low-NO\textsubscript{x} burners.
- New Over-Fire Air (OFA) System.
- Improved SNCR System
- Small SCR reactor between the economizer and air heater.
  » Single layer reactor with 12 modules of plate catalyst.
The ASCR achieves substantial capital cost savings. The reactor size necessary for a SCR only approach would require substantial duct modifications, civil engineering, and catalyst. For this example project, there was a 50% capital cost savings = approximately $5,000,000 USD.
The process flow diagram describes how the numerous technologies interact with one another.
Design Challenges

- All of the systems had to work together simultaneously. A problem or error in one system would cause problems in all systems downstream of it.

Combustion
- Strongly influenced by fuels.
- Different fuel combinations required different settings.
- Wet coal would produce greater CO.
- Mistuned and poor combustion settings would produce greater NO\textsubscript{x} and CO.

SNCR
- High CO would decrease SNCR performance (less NO\textsubscript{x} removal and greater NH\textsubscript{3} slip). This happens at local zones with high CO and/or if the boiler has high overall CO levels.
- Care had to be taken to achieve an even distribution of NH\textsubscript{3} and NO\textsubscript{x} at the economizer.
- Final combustion NO\textsubscript{x} affects final SNCR NO\textsubscript{x}.

SCR
- NO\textsubscript{x}/NH\textsubscript{3} maldistributions after the SNCR greatly affect SCR performance. Regions with elevated NO\textsubscript{x} or NH\textsubscript{3} concentrations would reduce SCR performance.
- Final SNCR NO\textsubscript{x} affects the final SCR NO\textsubscript{x}.
• This site required a complex control system capable of handling any fuel combination of coal, COG, and BFG. Depending on the fuel combination the NO$_x$ and temperature in the boiler varied significantly. This affected the OFA and SNCR systems.
• Designing duct modifications for the catalyst can be challenging:
  – Maintaining even NO$_x$/NH$_3$ distribution at the catalyst face.
  – Avoiding angled flow into the catalyst.
  – Avoiding excessive velocity into the catalyst.
  – Significant CFD is required to find a suitable design.
Design Challenges - SCR

• Fitting the SCR reactor into narrow section of ductwork can be challenging for numerous reasons.
• The gas must be turned and straightened with minimal space.
• Flow recirculation must be avoided.
• Care must be taken to avoid angled flow.
• The solution to these challenges was the use of a patented graduated straightening grid (GSG).
Part of the project involved the fabrication of a one-fifth scale physical model. The model underwent thorough testing for proper flow and ash accumulation.
An over-fire air (OFA) system and new low-NO$_x$ burners were included in the project. This reduced the baseline NO$_x$ level for the SNCR system.
Since the SCR required a minimal volume of catalyst, the necessary duct changes were greatly reduced. This allowed most of the existing duct work to be used in the new design.
Because the design minimized the necessary catalyst volume, the catalyst install was able to be completed in two working days. This greatly reduced the time the unit needed to be offline for the installation.
Project – CAD Model

- Boiler
- Economizer
- SCR Reactor
- Air Heater
- ESP Inlet
Project – SCR CAD

- Mixer
- LPA Screen
- Straightening Vanes
- GSG
- Sonic Horn
Plate type catalyst was selected for the project. Plate type catalyst was advantageous because it is more resistant to plugging than honeycomb catalyst and more robust so that it can handle greater flue gas velocities.

The catalyst pitch was 5.6 mm with a wall thickness of 0.8 mm. The total catalyst volume was 25.3 m³.
Project Results – Full Load Coal

CEMS NO$_x$
- 48 ppmd @6% O$_2$

NH$_3$ Slip at SCR Outlet
- 4.3 ppmd @6% O$_2$

Factory Acceptance Tests
- First 4 Hour FAT Passed
- Second 4 Hour FAT Passed
Project Results – Full Load COG and Coal

- **CEMS NOₓ**
  - 48 ppmd @6% O₂

- **NH₃ Slip at SCR Outlet**
  - 4.8 ppmd @6% O₂

- **Factory Acceptance Tests**
  - First 4 Hour FAT Passed
  - Second 4 Hour FAT Passed
Project Results – Low Load Coal

- **CEMS NO_x**
  - 45 ppmd @6% O_2

- **NH_3 Slip at SCR Outlet**
  - 3.1 ppmd @6% O_2

- **Factory Acceptance Tests**
  - First 4 Hour FAT Passed
  - Second 4 Hour FAT Passed
Questions?