Advanced Selective Catalytic Reduction System Operating on a Coal-Fired Boiler

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AGENDA

• Introduction
• ASCR™ Advanced SCR Project in Taiwan
• Field Results
• Fuel Tech is a worldwide leader in the development and commercialization of advanced technologies designed to enable more efficient and environmentally acceptable combustion of a wide range of solid and liquid fuels, primarily in boilers and furnaces.

• 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.

• With its strong tradition of customer focus and proprietary, cost-effective engineering solutions, Fuel Tech is experiencing accelerated growth as it benefits from ever-tightening global air pollution control requirements, as well as, market-driven shifts to lowered costs, and often more problematic fuel sources, which demand innovative combustion optimization solutions by utility and power generators.
Typical Power Plant

**Fuel Tech Technologies**
- **ASCR™**: Advanced SCR: System that combines LNB + OFA + SNCR + AIG + GSG™ + Catalyst
- **AIG**: Ammonia Injection Grid
- **GSG™**: Graduated Straightening Grid
- **HERT™**: High Energy Reagent Technology™
- **LNB**: Low NO, Burners
- **NOxOUT™**: SNCR system using high momentum injectors
- **OFA**: Over-Fire Air
- **ULTRA™**: Safe Ammonia Generation System
- **SCR**: Selective Catalytic Reduction
- **SNCR**: Selective Non-Catalytic Reduction
- **SCR Services**: Selective Catalytic Reduction services which include: optimizing process design, catalyst selection, and improving the overall performance of SCR
- **Static Mixer**: Equipment used to mix temperature, velocity, and NOx to optimize SCR performance ahead of the AIG
- **TIFI® Targeted In-Furnace Injection™**: Chemical injection programs used to target slag control, SO₃ mitigation, and fuel flexibility

**Non-Fuel Tech Supplied**
- **Baghouse**: Controls particulate matter (PM) from flue gas
- **ESP**: Electrostatic precipitator for PM control
- **Wet FGD**: Scrubber to maximize SO₂ removal using Flue Gas De-Sulfurization (FGD)
- **Dry FGD**: Scrubber to remove SO₂ with less water than Wet FGD
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.
Selective Catalytic Reduction (SCR) is the Best Available Control Technology for NO\(_x\) reduction but limited in application due to high capital cost requirements and retrofit difficulty.

The ASCR approach can achieve similar overall NO\(_x\) reduction as a SCR but with a greatly reduced capital cost.

An ASCR combines multiple low capital cost technologies including Low-NO\(_x\) 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.

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**ASCR Design Principles**

- **Lower NO\(_x\) Baseline via Combustion and SNCR Improvements**
- **Less Catalyst**
- **Minimal Duct Modifications**
- **Substantially Less Capital Cost**
Project Site Details

- 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.
Capital Cost Savings

Compared to SCR Only

**SCR**
- A standalone SCR would need to accomplish the entire >78% NO\textsubscript{x} reduction (230 to 50 ppm).
- The standalone SCR would require >3x the catalyst volume and about 4x the construction footprint.
- Approximate cost is $10 million USD.

**ASCR**
- The ASCR approach minimizes the NO\textsubscript{x} reduction burden of the catalyst to approximately 29% (70 to 50 ppm).
- Requires only a single layer of 12 catalyst modules.
- Installation of all systems (OFA, burners, SNCR, SCR) combine for an approximate cost of $5 million USD.

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.
Project – Process Flow Diagram

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}.
Design Challenges

• This site required a complex control system capable of handling any fuel combination of coal, COG, and BFG. Depending on the fuel combination the NOx 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 NOx/NH3 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.
• 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 GSG™ Graduated Straightening.
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.
Combustion Modifications

An over-fire air (OFA) system and new low-NO\textsubscript{x} burners were included in the project. This reduced the baseline NO\textsubscript{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\textsubscript{x}:
- 48 ppmd @6% O\textsubscript{2}

NH\textsubscript{3} Slip at SCR Outlet:
- 4.3 ppmd @6% O\textsubscript{2}

Factory Acceptance Tests:
- First 4 Hour FAT Passed
- Second 4 Hour FAT Passed
Project Results

Full Load COG and Coal

CEMS NO\textsubscript{x}
- 48 ppmd @6% O\textsubscript{2}

NH\textsubscript{3} Slip at SCR Outlet
- 4.8 ppmd @6% O\textsubscript{2}

Factory Acceptance Tests
- First 4 Hour FAT Passed
- Second 4 Hour FAT Passed
Project Results

Low Load Coal

CEMS $\text{NO}_x$
- 45 ppmd @6% $\text{O}_2$

NH$_3$ Slip at SCR Outlet
- 3.1 ppmd @6% $\text{O}_2$

Factory Acceptance Tests
- First 4 Hour FAT Passed
- Second 4 Hour FAT Passed
Next Projects

- China Steel Units 6&8
- Same Inlet Design Data
- Outlet NO$_x$ 30 PPM
- Double Reactor Size to Accommodate Biomass Co-Firing
Questions?