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Advanced Selective Catalytic Reduction (ASCR)Technology- A Lower Capital Cost Solution for NO_x Reduction

FUEL TECH
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Agenda

- Introduction
- ASCR Project
- Results
- Future Projects

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

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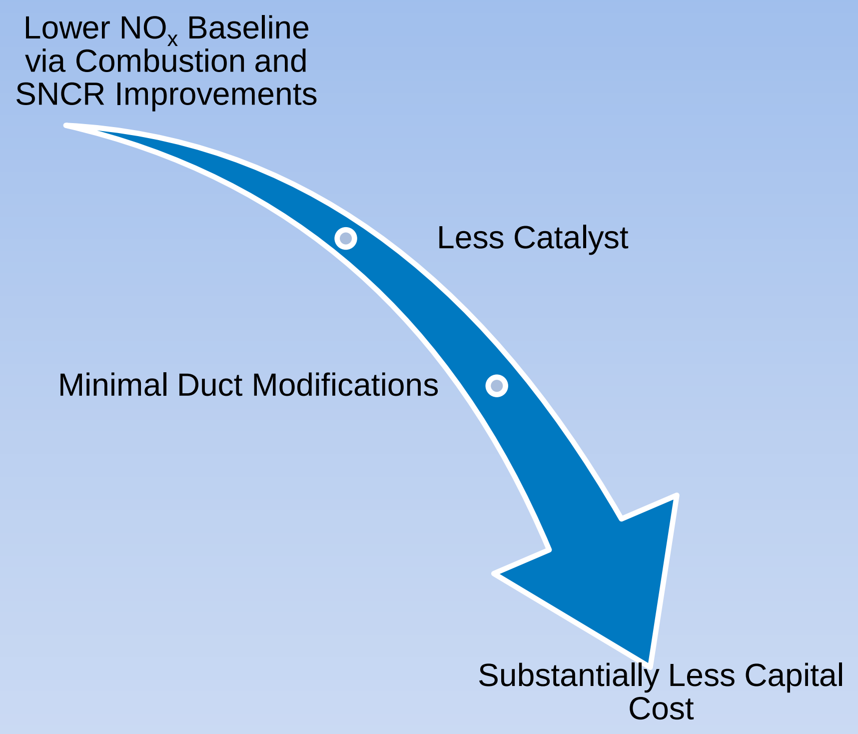
Present Challenges for Coal Energy

- 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.

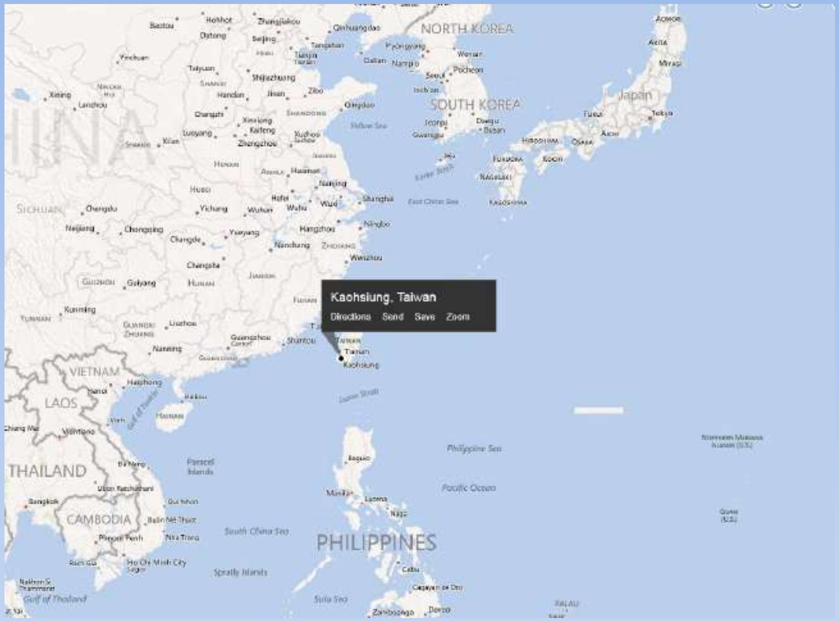
ASCR Design Principles

- Selective Catalytic Reduction (SCR) is the Best Available Control Technology for NO_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.



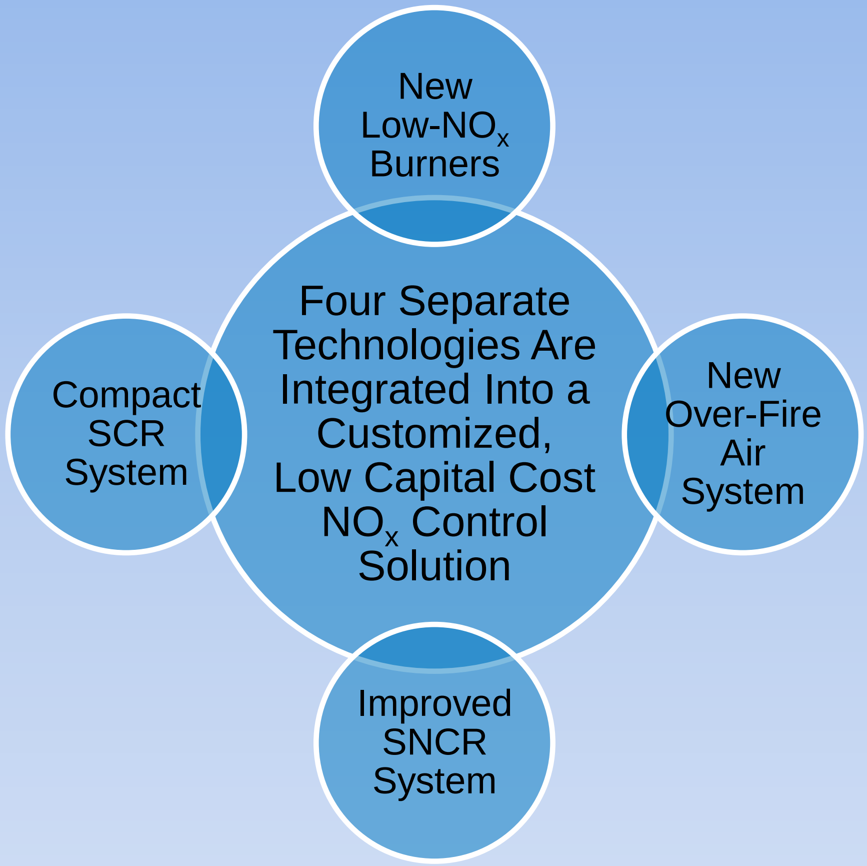
Project Site

- 50 MW T-fired boiler.
- Burns Multiple Fuels
  - Adaro Coal
  - Coke Oven Gas (COG)
  - Blast Furnace Gas (BFG)
- Located in Kaohsiung, Republic of China (Taiwan)



Project Background

- The plant needed to reduce NO_x emissions by >78% from a baseline of 230 ppm to below 50 ppm (dry basis @6% O_2).
- The unit had existing low-NO_x burners and an existing SNCR system.
- The project added:
  - New Low-NO_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

ASCR

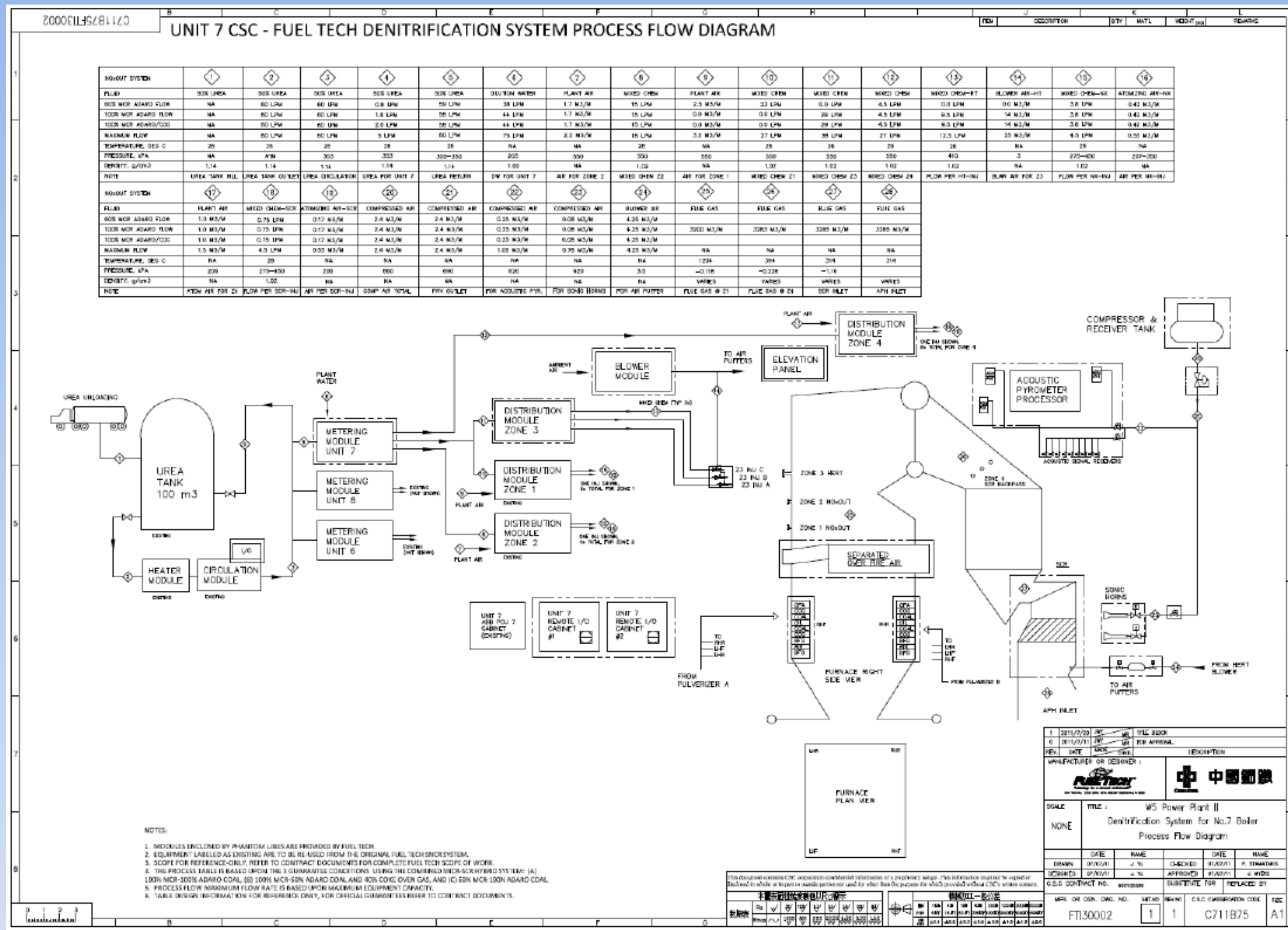
- The ASCR approach minimizes the NO_x reduction burden of the catalyst to approximately 29% (70 to 50 ppm).
- Requires only a single layer of 12 catalyst modules.
- Installation of all systems (OFA, burners, SNCR, and SCR) combine for an approximate cost of $5 million USD.

SCR

- A standalone SCR would need to accomplish the entire >78% NO_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.

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



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_x and CO.

SNCR

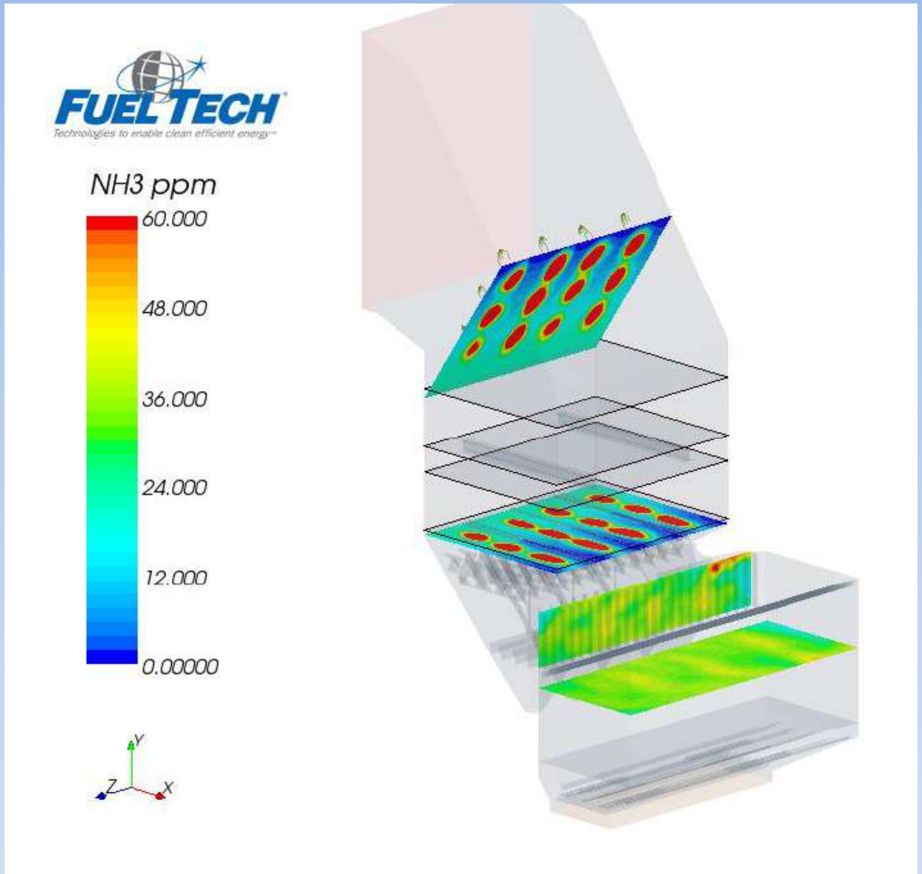
- High CO would decrease SNCR performance (less NO_x removal and greater NH_3 slip). This happens at local zones with high CO and/or if the boiler has high overall CO levels.
- Care had to be taken to achieve an even distribution of NH_3 and NO_x at the economizer.
- Final combustion NO_x affects final SNCR NO_x.

SCR

- NO_x/NH_3 maldistributions after the SNCR greatly affect SCR performance. Regions with elevated NO_x or NH_3 concentrations would reduce SCR performance.
- Final SNCR NO_x affects the final SCR NO_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 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.

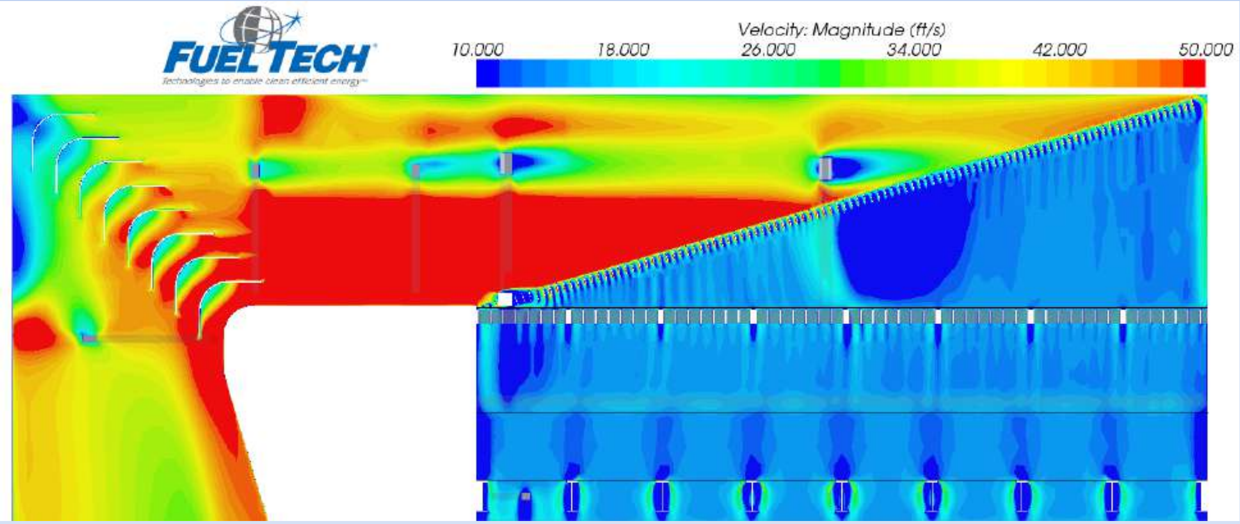


Design Challenges - SCR

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.

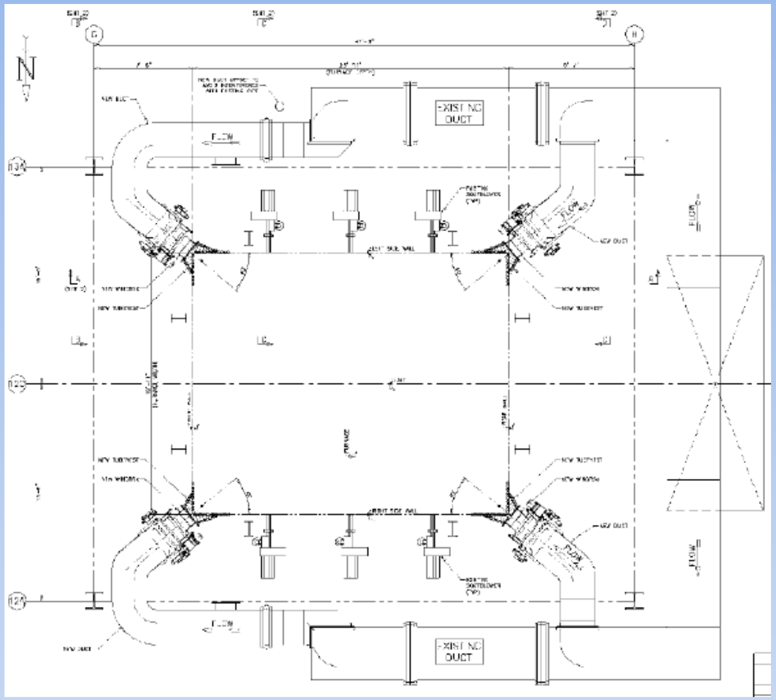
The solution to these challenges was the use of a patented graduated straightening grid (GSG).

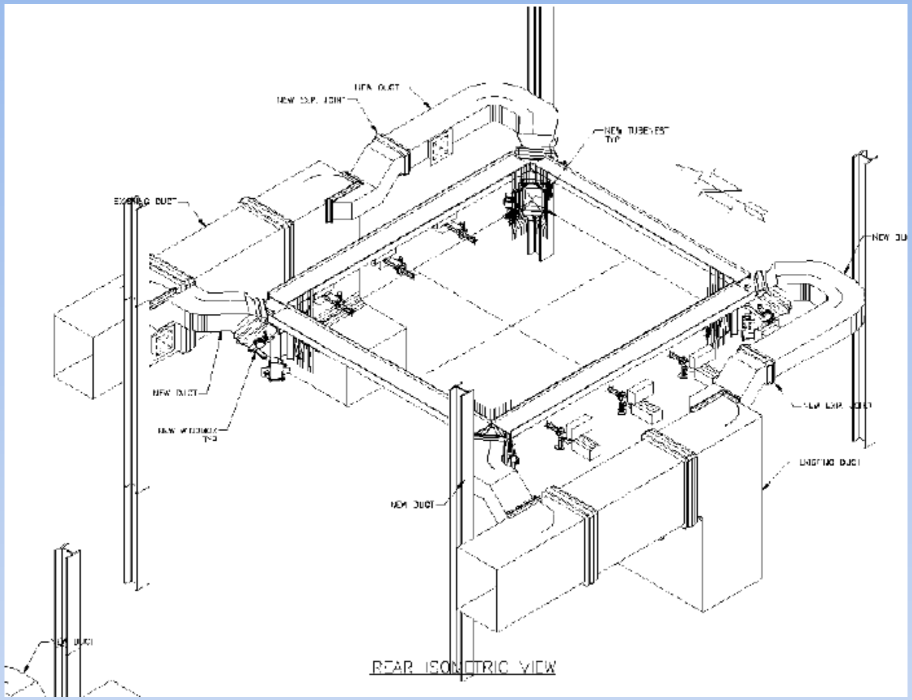


Project Design – Experimental Modeling

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



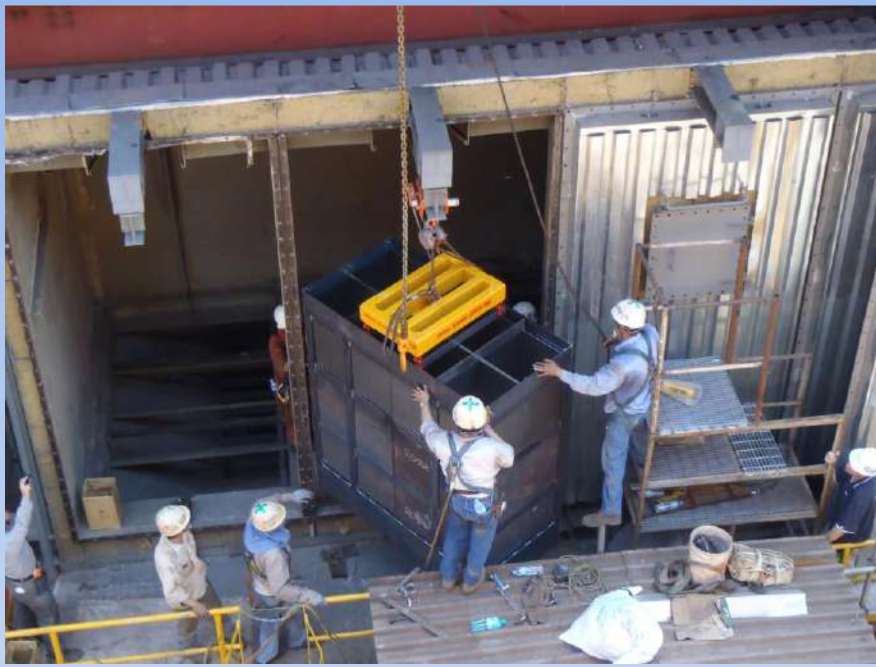


An over-fire air (OFA) system and new low-NO_x burners were included in the project. This reduced the baseline NO_x level for the SNCR system.

Site Duct Before and After

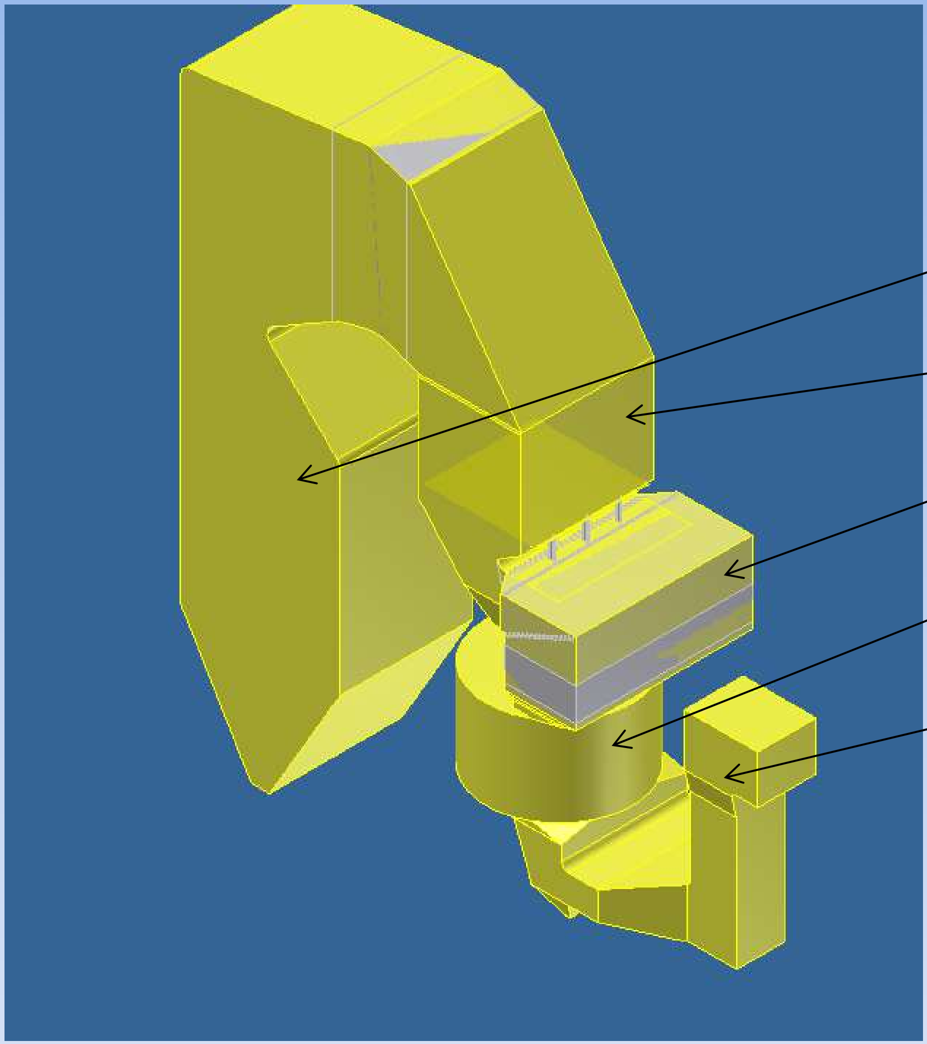
Since the SCR required a minimal volume of catalyst, the necessary duct changes were greatly reduced. This allowed most of the existing duct work to be used in the new design.

Catalyst Loading



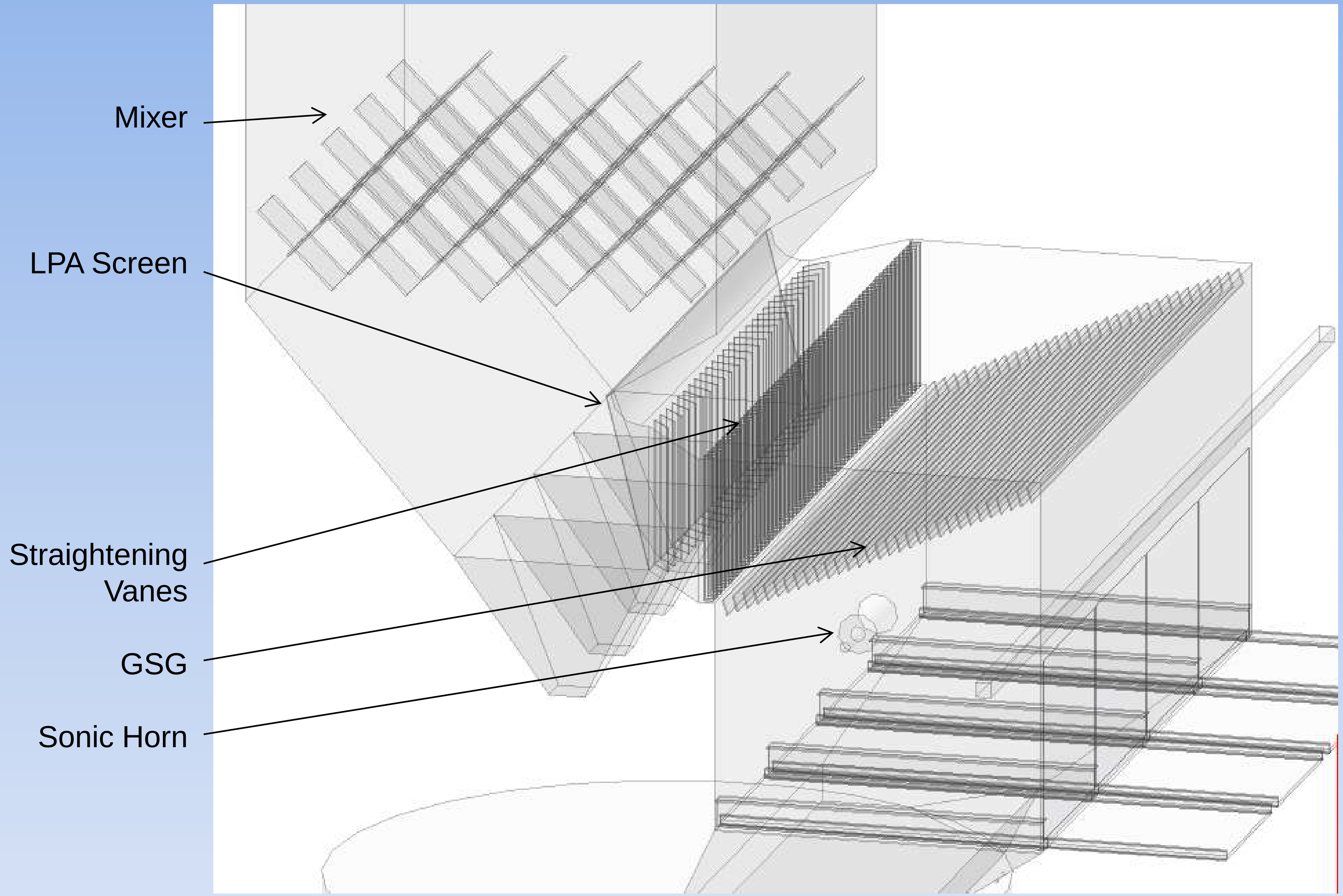
Because the design minimized the necessary catalyst volume, the catalyst install was able to be completed in two working days. This greatly reduced the time the unit needed to be offline for the installation.

Project – CAD Model



- Boiler
- Economizer
- SCR Reactor
- Air Heater
- ESP Inlet

Project – SCR CAD



Project – Catalyst

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 m^3.

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 NO_x

- 48 ppmd @6% O_2

NH_3 Slip at SCR Outlet

- 4.8 ppmd @6% O_2

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

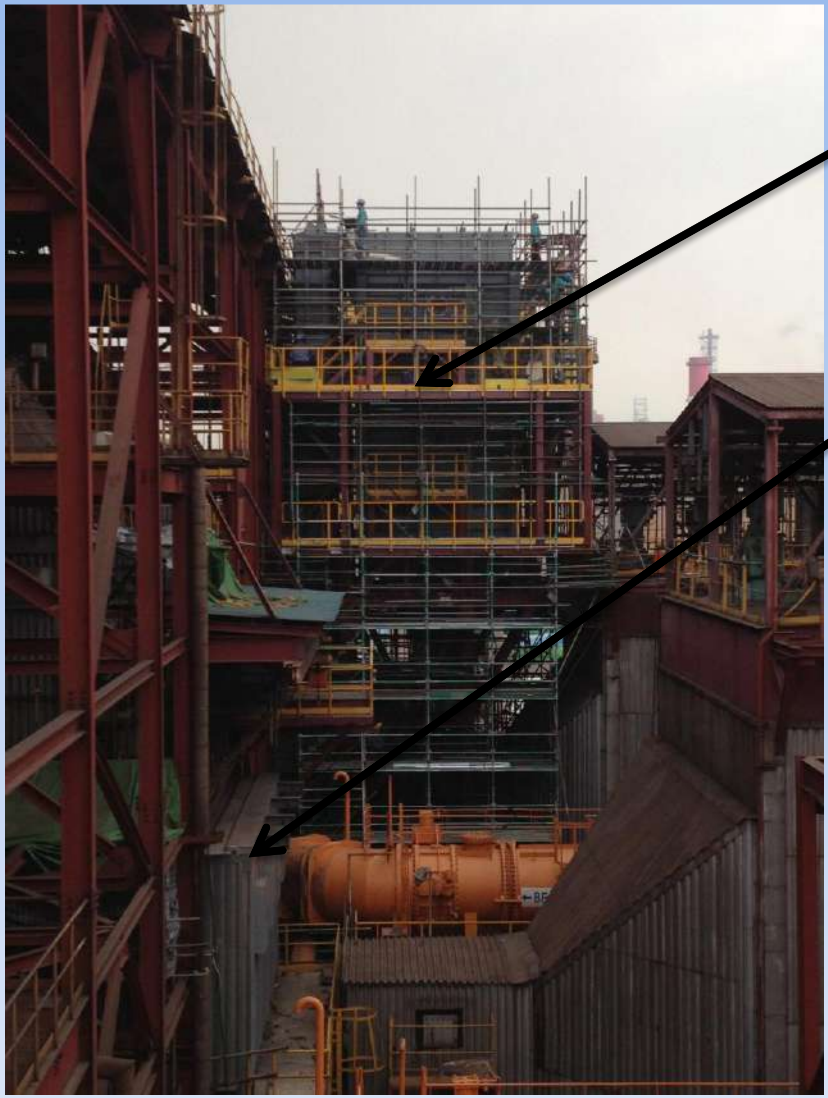
- First 4 Hour FAT Passed
- Second 4 Hour FAT Passed

New ASCR Project

- Upon successful completion of the first project the client requested additional ASCR for its two other identical units.
  - The new project required greater NO_x reduction down to 30ppm compared to 50ppm in the original project.
  - Fuel Tech increased the size of its SCR to 2 layers of catalyst to accommodate additional NO_x reduction.
  - Fuel Tech devised a new control philosophy designed to reduce operational costs at times when the outlet NO_x can be greater than 30ppm.
  - The startup and optimization for the first unit should be complete on or around October 2013. The second unit should be complete on or around March 2014.

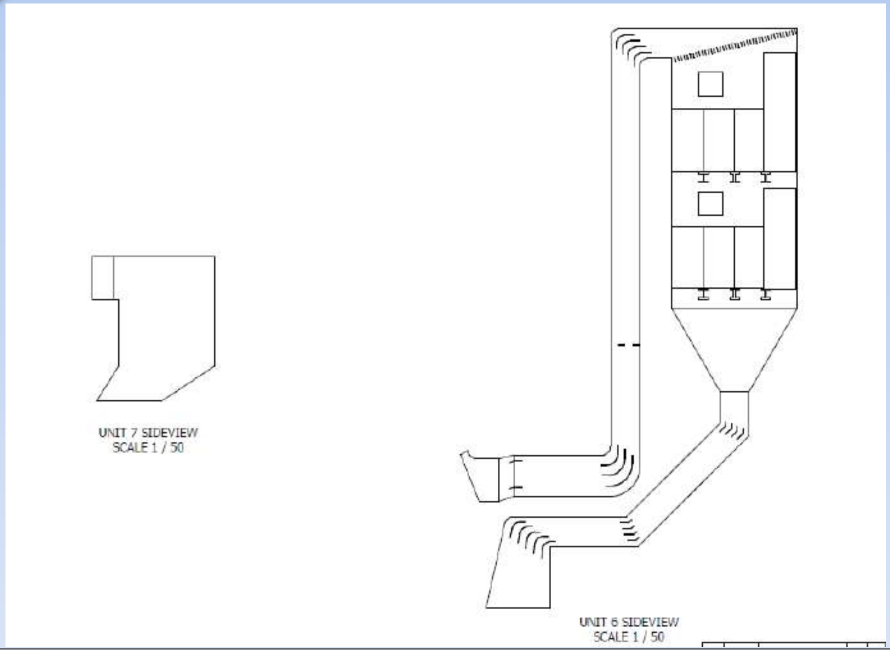
Original Project	Second Project
☐ 1 Layer of Catalyst	☐ 2 Layers of Catalyst
☐ 1 Unit	☐ 2 Units
☐ Standard Control System	☐ Advanced Control System

Size Comparison of the Two Projects



The SCR for the New Project

The SCR for the Original Project



Catalyst Required

- The New Project's ASCR approach required a total of 24 catalyst modules to achieve performance of 30ppmvd NO_x @6% O2.
  - The total cost was approximately $7 million USD per unit.
  - Less catalyst reduces the pressure drop of the ASCR causing a reduction in operational cost associated with running the ID fan.
  - The hybrid approach of an ASCR combined with a new advanced control system prioritizes the NO_x reduction system to first use the most efficient technologies first.
- A traditional SCR would have required twice as many catalyst modules to achieve a similar performance.
  - The total cost would be approximately $12 million USD per unit.
  - Additionally the substantial increase in catalyst would significantly increase the pressure drop of the SCR causing a larger electric load on the ID fan lowering operational cost.

Thank You Very Much

Questions?