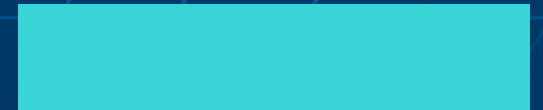


SCR Technology

Riley Power, Inc.

SCR Technology

- Catalyst requires proper temperature, homogeneous NO_x/NH₃ mixture, homogeneous temperature, and uniform flow distribution at its inlet to perform properly

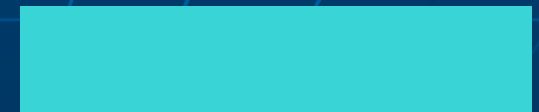


Proprietary Delta Wing System

- Results in homogeneous NO_x/NH₃ concentrations entering SCR catalyst
- Accommodates variations in flue gas conditions
- Provides mixing for NH₃
- Greatly reduces injection points (typically 3 to 8 pts)
- Minimizes nozzle plugging by ammonia salts
- Simplifies tuning / shortens commissioning



BPI consistently meets its NO_x reduction and NH₃ slip guarantees across load range and operating conditions

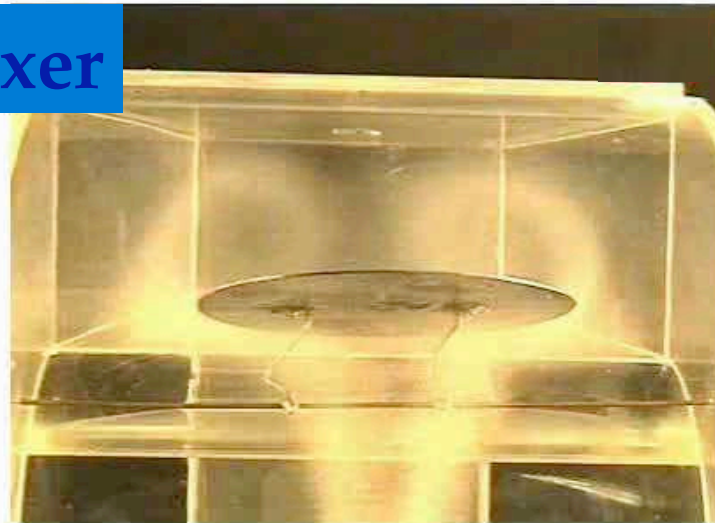
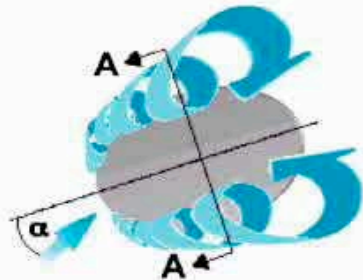


Flue Gas Mixing Technology

Delta Wing Mixer

SGM for mixing of gas:

- concentrations
- temperatures
- volume flows



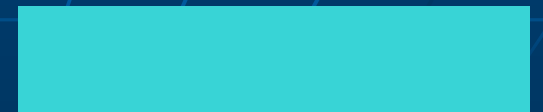
Section A - A
Vortices generated on plate edges

Working principle:

leading edge vortices created by gas flows arriving at shaped plates under an angle of attack generate turbulences for mixing purposes

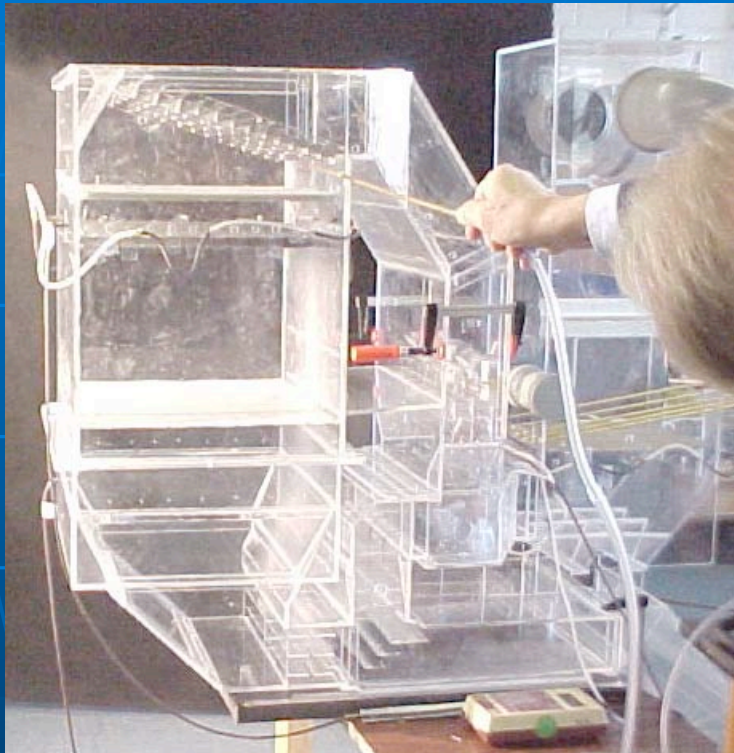
Energy through Synergy

Delta Wing Static Mixers



Flow Models

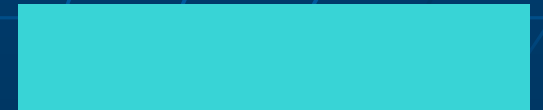
- **1:40 scale flow model**



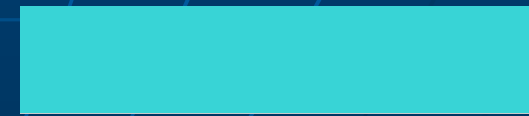
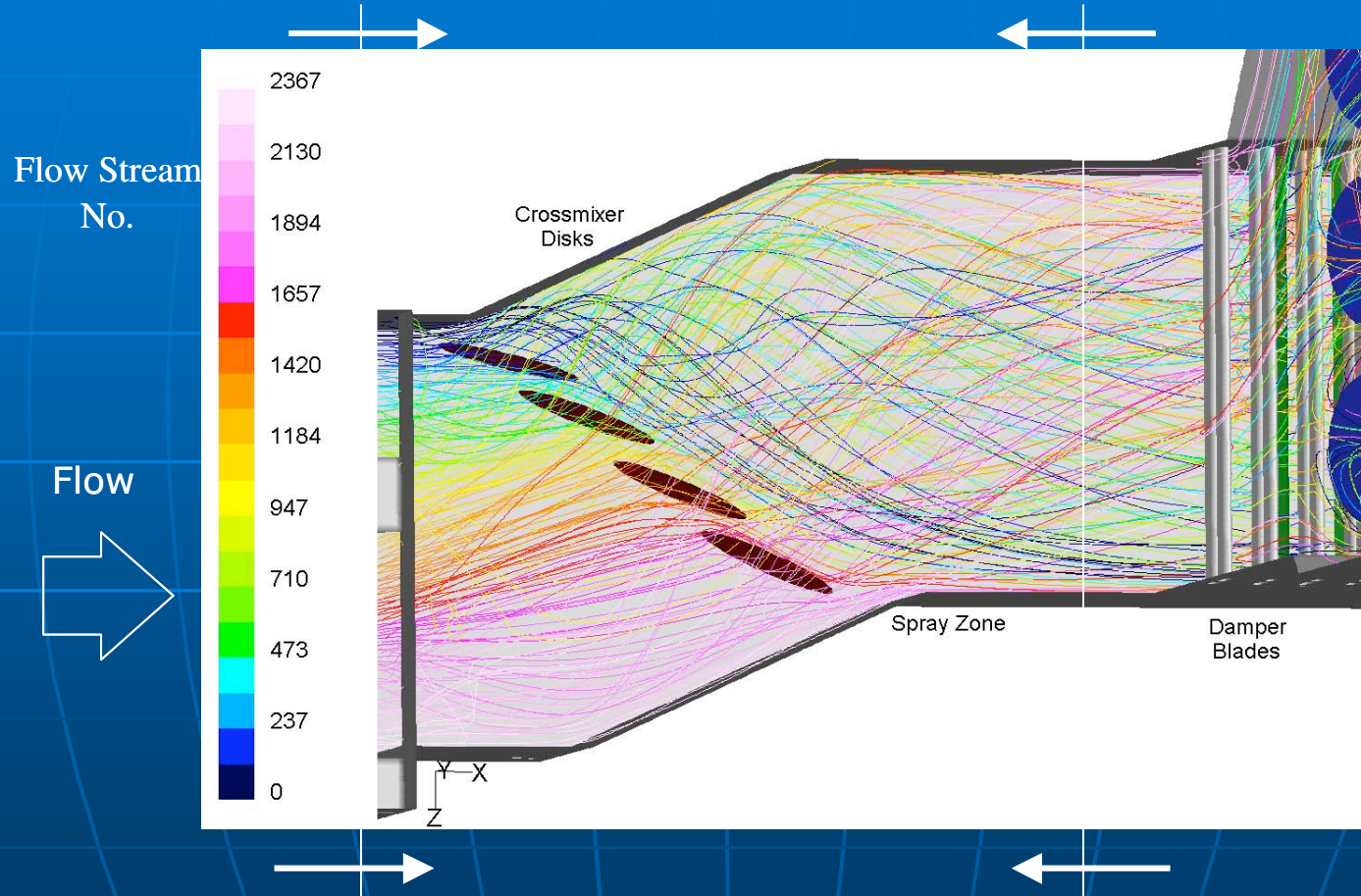
BPI makes extensive use of flow modeling to guide designs and to ensure proper distribution



- **1:15 scale dust model**



Cross Mixing Flow in Econ Out / SCR Inlet Plan View



Value of 'Full Duct Mixing'

- High NO_x Efficiency over Entire Operating Range
 - Boiler Load, Firing Systems, Mills/Burners
 - Economizer Outlet Temperatures
 - Split Back passes
- Minimal NH₃ Slip
- Suitable Conditions for Air Heater
 - Temperature and Flow Distribution
 - Avoidance of Pluggage
- Low Pressure Drop and Impact on Fans
- Maximizes Catalyst Life
- *Enables High Performance from an In-duct SCR Reactor*

Delta Wing vs. Grid NH3 Injection

Delta Wing vs. Injection Grid

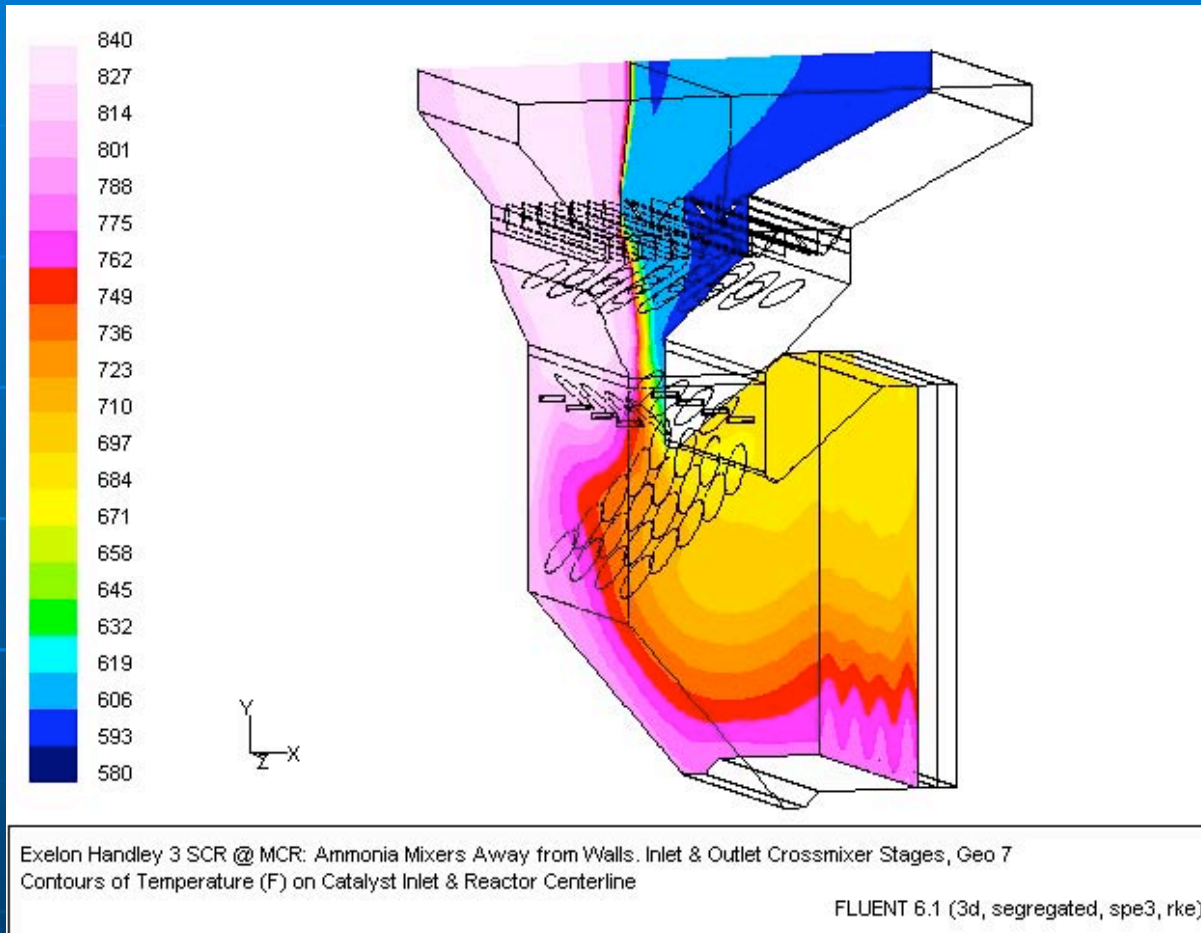


Order of Magnitude or Greater
Reduction in Number of Valves

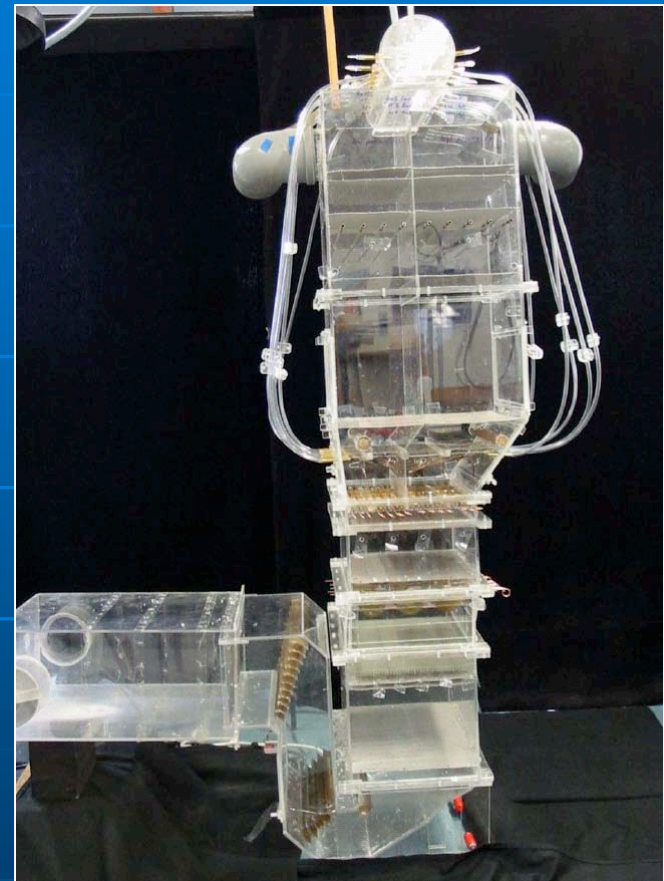
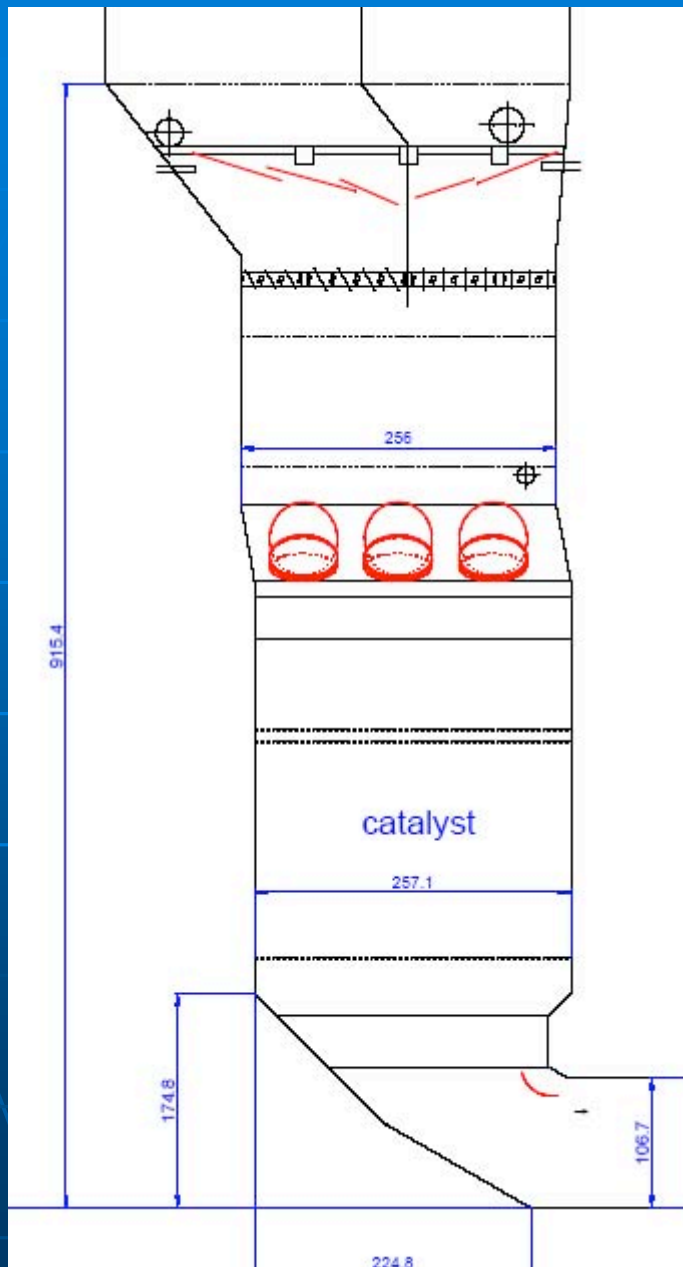


- Reduced Startup Time
- Simpler Operation
- Reduced Maintenance

In Duct SCR



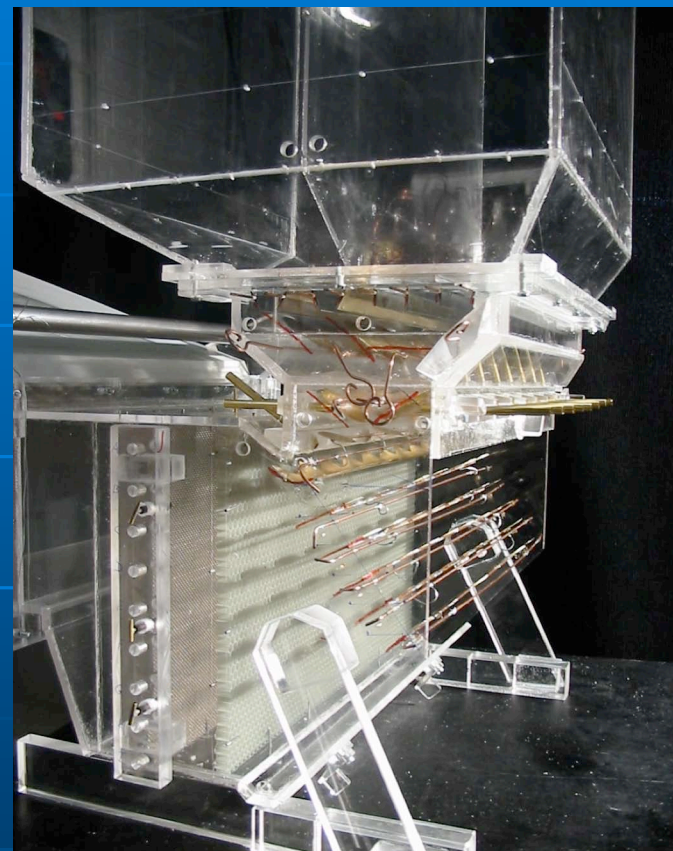
Compact in-duct SCR Coal-fired Boiler



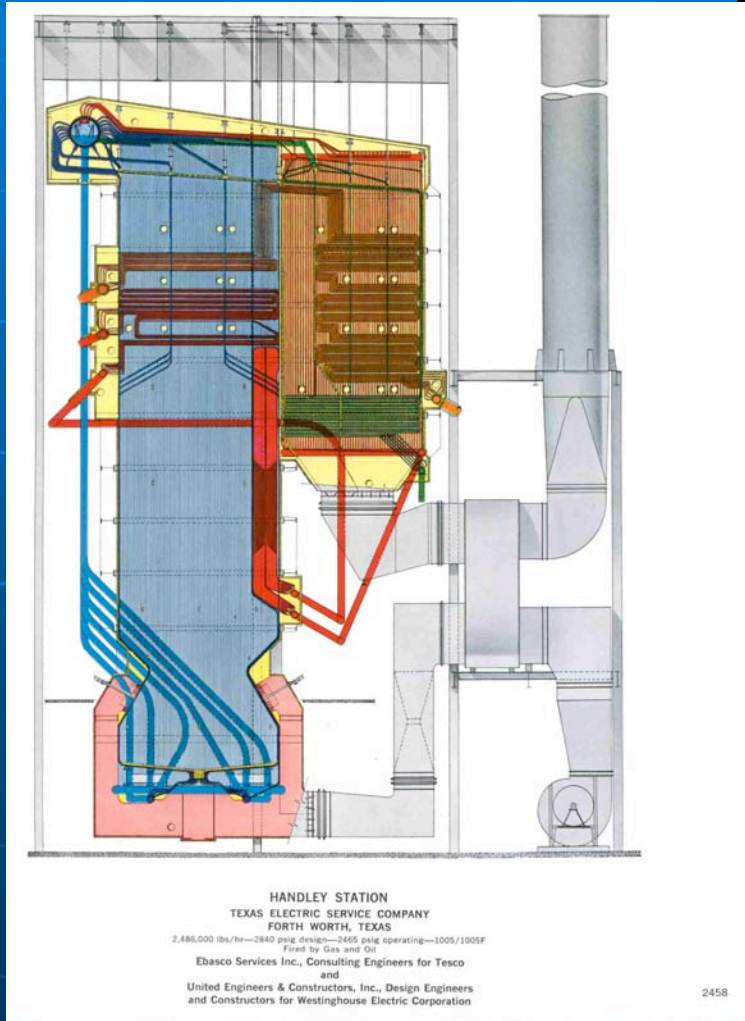
Compact In-duct SCR

Excelon Handley Unit 3

- **Turbo Boiler**
- **94% NO_x Removal SCR**
- **In-duct Reactor Arrangement**
- **Delta Wing Mixing System**
- **Aqueous Ammonia**
- **Honeycomb Catalyst**

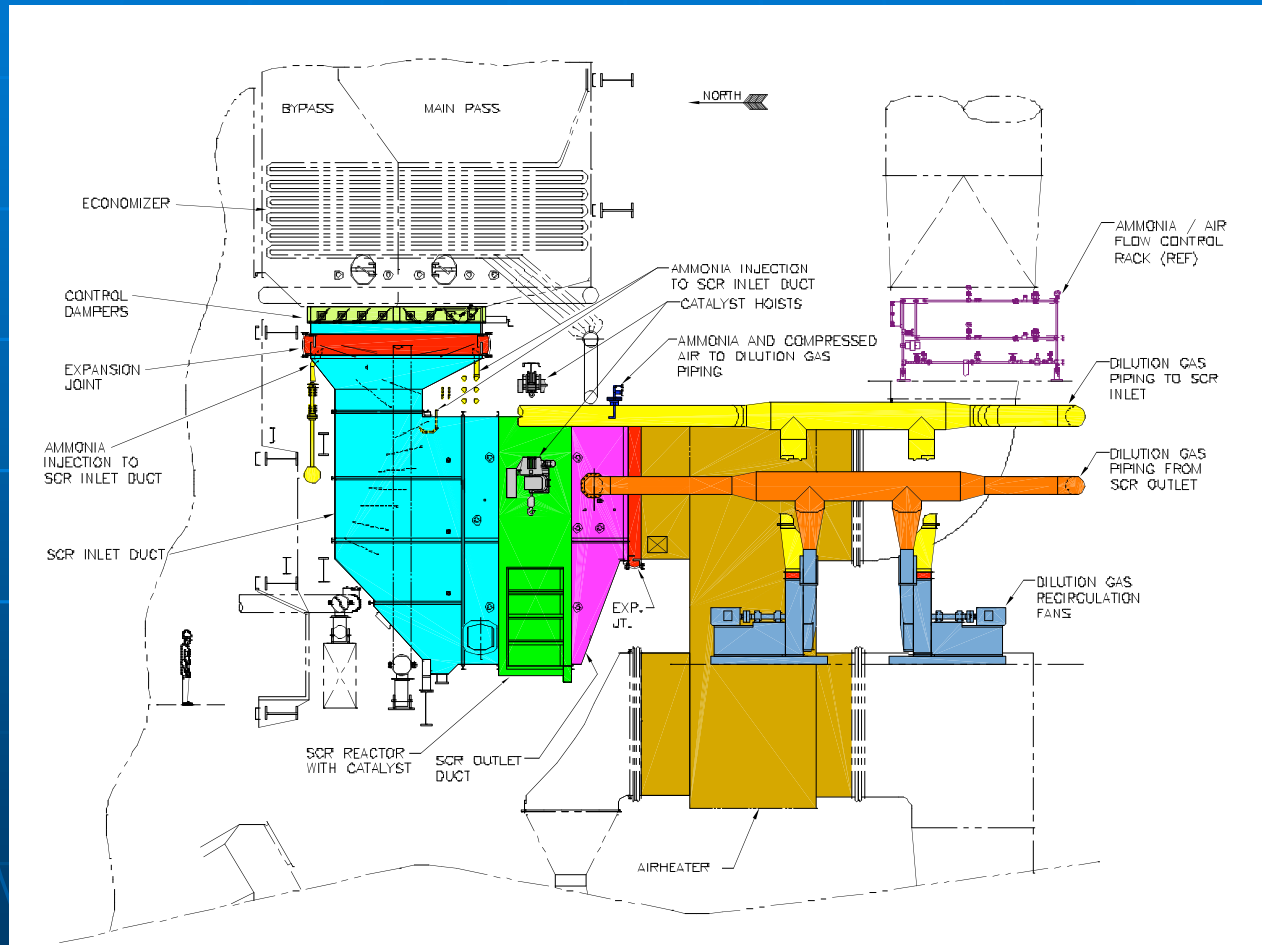


Handley Station Unit 3



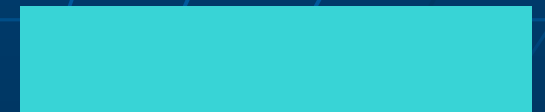
- 400 MWe Gas-fired Boiler
- Turbo Fired Furnace
 - Pressurized Design (2) FD Fans
 - 24 Directional Flame Burners
 - IFGR, SFGR, Burner Mods
- Two Pass Boiler
 - Main Pass(Reheat)
 - Bypass
- Reheat Control Dampers

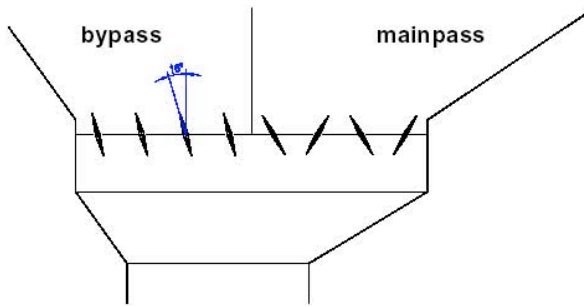
Handley SCR System Design



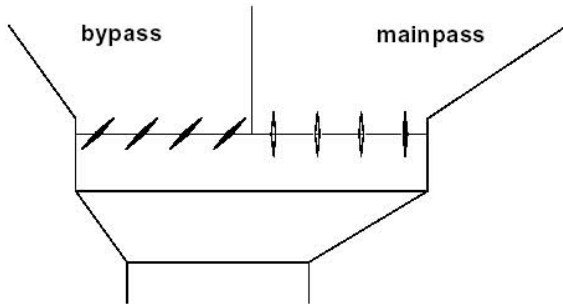
Design Challenges

- Catalyst Performance
 - space limitation
 - pressure drop constraint
- Short Mixing Length
- Reheat Control Damper Location
- Temperature Distribution
- Schedule

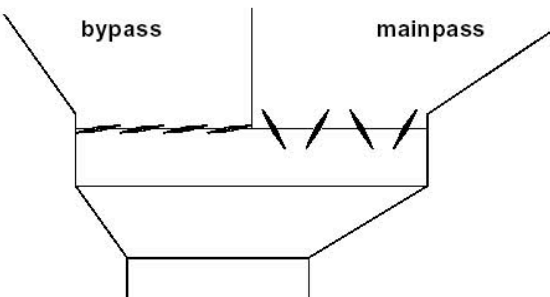




Damper position for 100% load

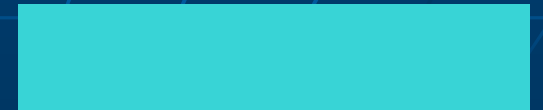


Damper position for 60% load



Damper position for 40% load

Reheat Control Damper Operation



Flow Model Objectives

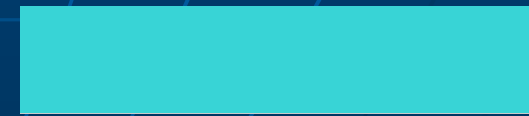
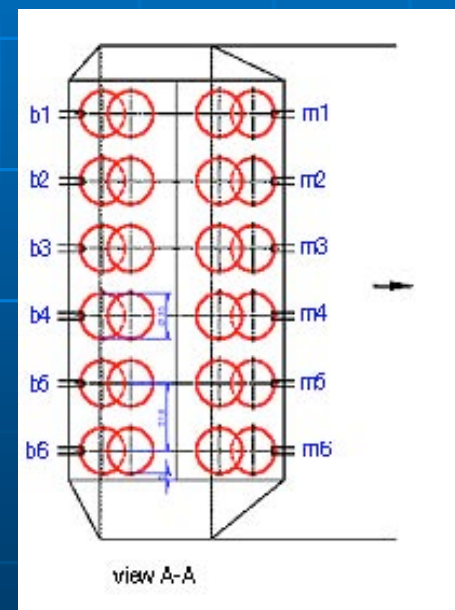
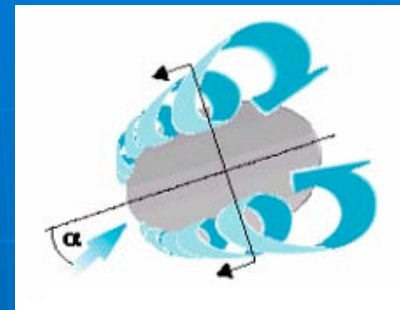
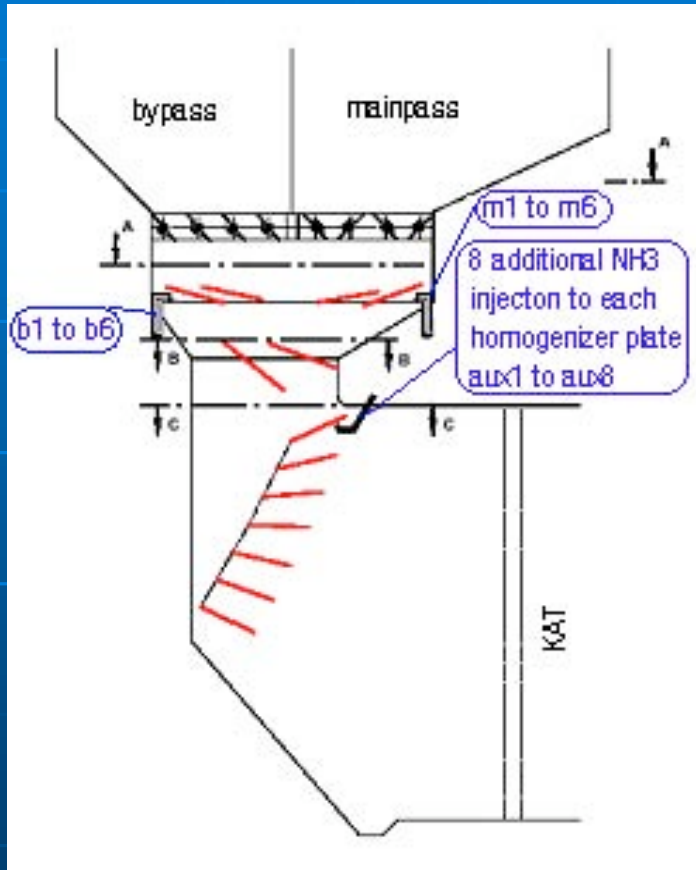
- NH_3/NO_x distribution @ 1st layer
- Gas velocity distribution
- Temperature distribution
- System pressure loss
- Control for performance at low load
- Streamline Optimization Process
 - Reduce number of injection nozzles
 - Initial NH_3 settings

Distribution Criteria

100% Catalyst Surface

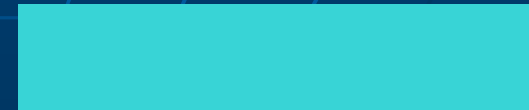
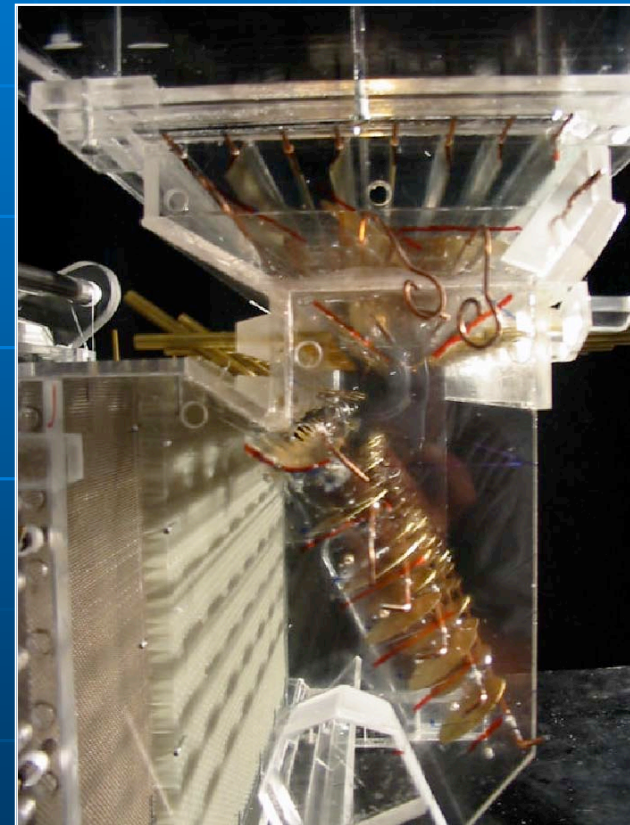
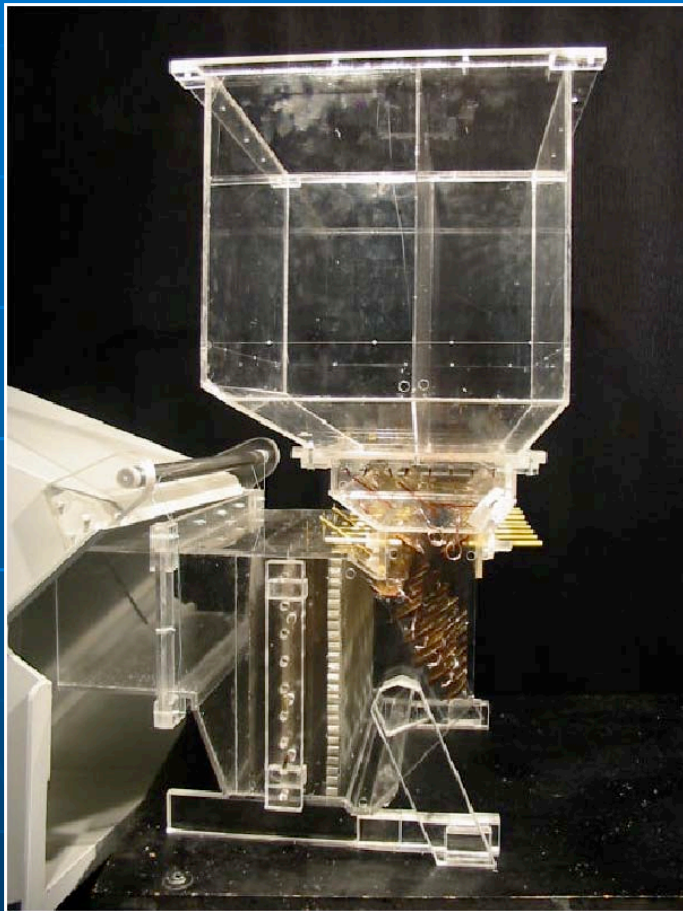
Load	%	100	75, 50, 25
Temperature	°F	+/- 50	+/- 50
Gas Velocity	% RMS	15	15
NH₃/NO_x	% RMS	6	15

Delta Wing → Static Mixing Devices

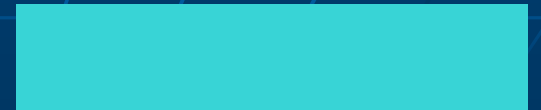
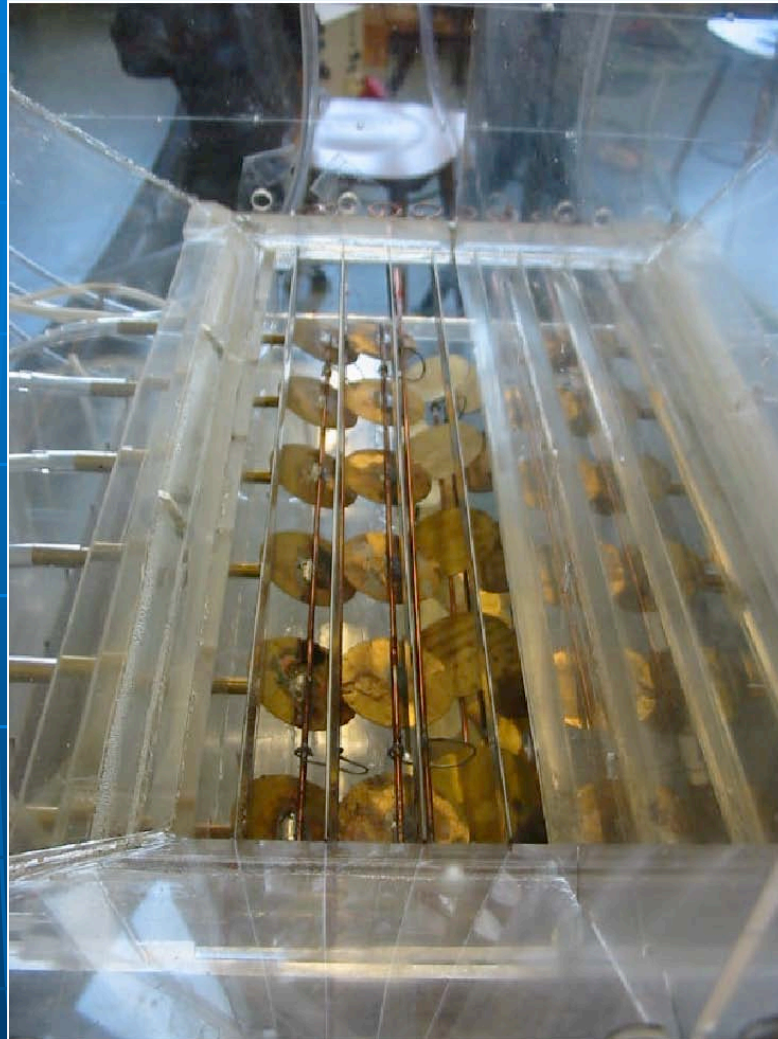


Handley SCR Flow Model

Scale 1:25

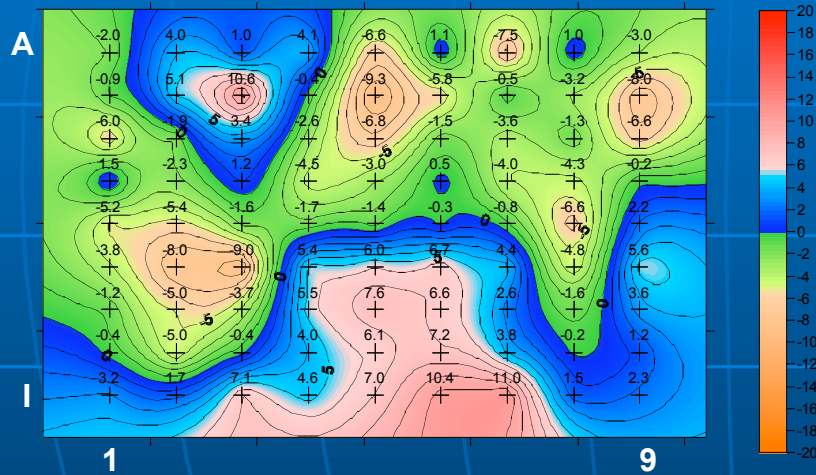


Ammonia Mixers



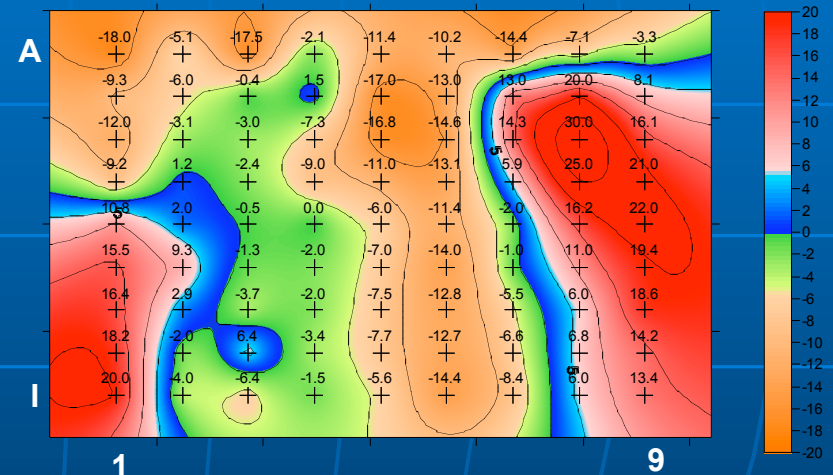
Handley SCR Flow Model Ammonia Distribution

100% Load

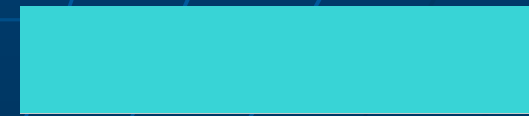


$$\sigma / c_{\text{avg}} = 4.9\% \quad \max \Delta c / c_{\text{avg}} = \begin{matrix} + 11\% \\ - 9.3\% \end{matrix}$$

40% Load

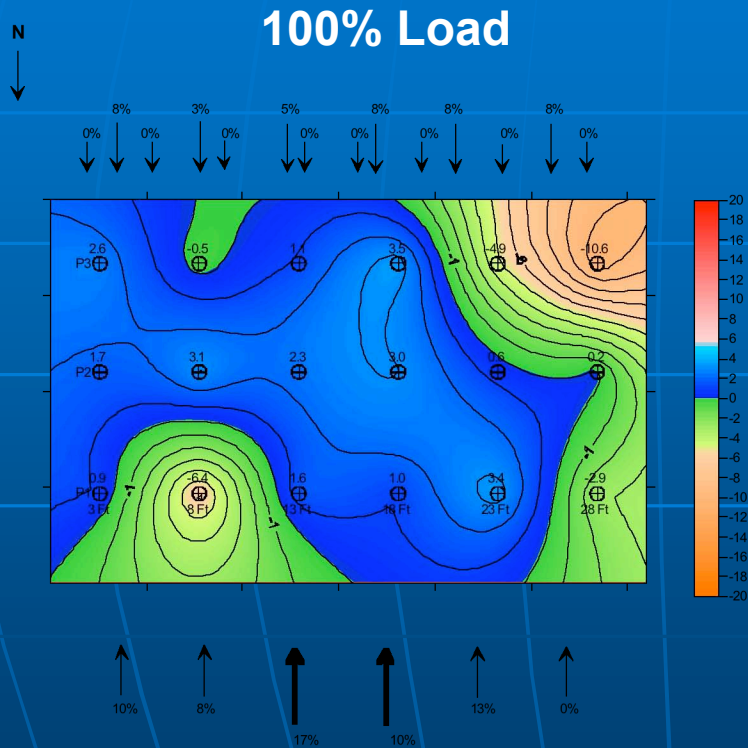


$$\sigma / c_{\text{avg}} = 11.7\% \quad \max \Delta c / c_{\text{avg}} = \begin{matrix} + 30\% \\ - 18\% \end{matrix}$$

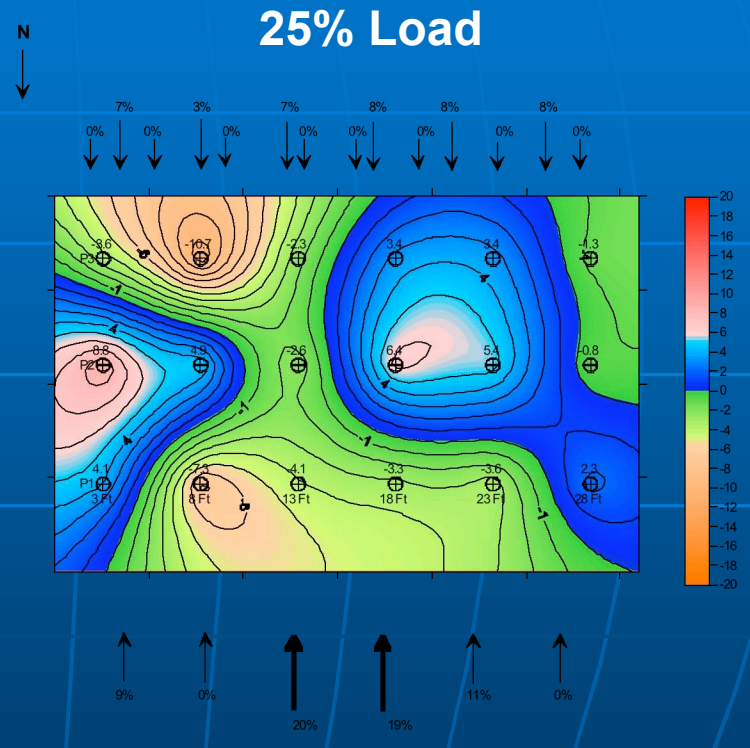


Handley SCR NH₃/NO_x Test Results

Reactor 3A



$$\sigma / c_{avg} = 3.8\%$$



$$\sigma / c_{avg} = 5.5\%$$



SCR Performance

Unit Load	MW	410	307	200	104
Inlet NOx	Lbs/MBtu	0.35	0.27	0.18	0.15
Outlet NOx	Lbs/MBtu	0.02	0.01	0.01	0.01
NOx Reduction	%	94.3	96.3	94.4	93.3
NH₃ Slip	ppm	<u><3</u>	<u><3</u>	<u><3</u>	<u><3</u>
Pressure Loss	iwg	9			

Summary

- 94 % NOx Reduction / 3 ppm slip
- 8 months design/commissioning
- Compact design / short mixing length
- No relocation of major equipment
- 12 Injectors with Delta Wing[®] mixers
- Full and part load operation
- 10 days initial operation to acceptance