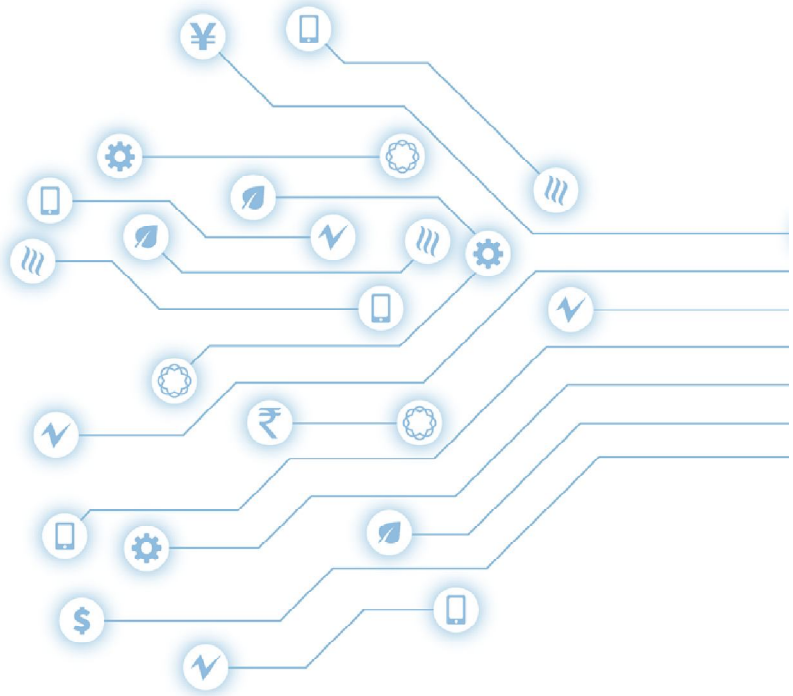
Boiler Emission Control - NOx



Sunil Chauhan, GE Power India Ltd.

NOx Generation During Combustion

During the combustion of fossil fuels, nitrogen oxides (NO and NO_2) collectively referred to as **"NOx",** are produced in and around the high temperature region by two primary reaction processes

THERMAL NOx – formed through oxidation and combination of N2 & O2 in combustion air

20 – 40% of the total NOx

FUEL NOx – formed from the organically bonded nitrogen contained in the fuel

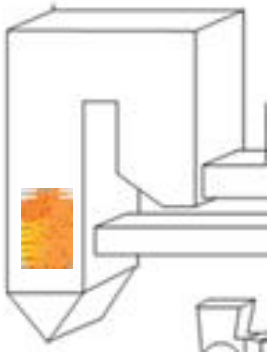
60 – 80% of the total NOx

Prompt NOx – 'Near flame envelop'

Options for NOx Reduction

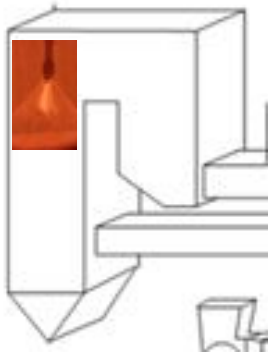
During Combustion (Prevent NOX Formation)

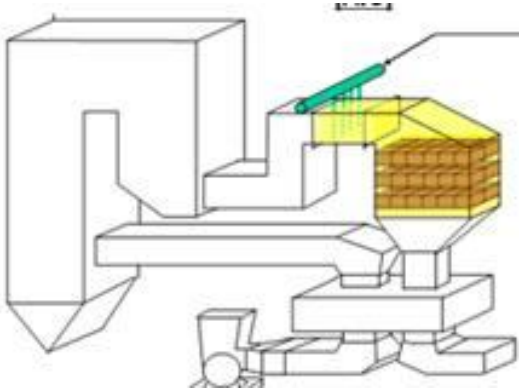
- Tangentially Fired
- Wall Fired



Post Combustion (Reduces the NOx)

- SNCR
- SCR





NOx Control During Combustion (Prevent NOX Formation)

THERMAL NOx

- Formation is very sensitive to both temperature and oxygen.

- Increases exponentially with temperature.
- Proportional to the square root of oxygen content.

- To reduce Thermal NOx.

- Reduce the **Peak flame temperature**.
- Reduce the **oxygen** concentration in the region of the maximum temperature zone.
- Reduce the **residence time** of the combustion gases at the peak temperature.

FUEL NOx

- There is a weak correlation to fuel nitrogen.

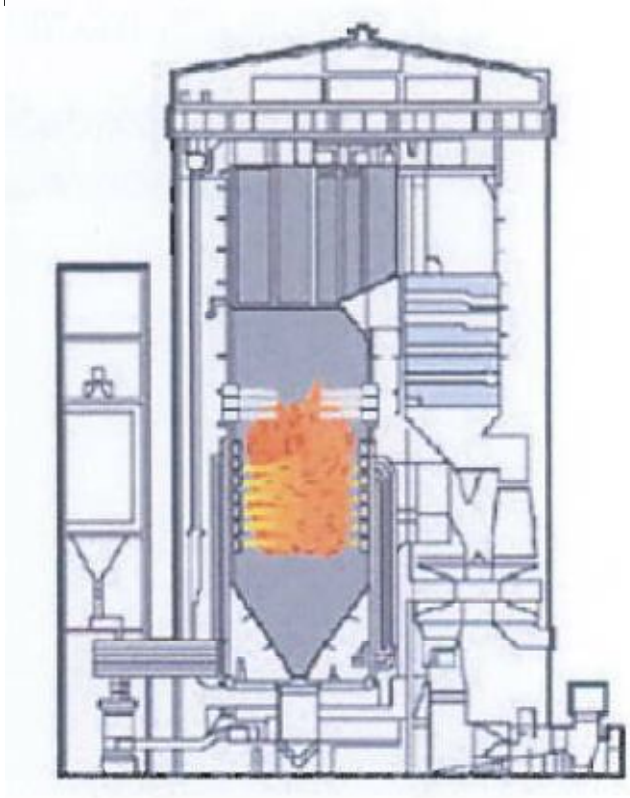
- Depends on fuel O_2 / Fuel N_2 ratios
- Lower the ratio ,lower will be the NOx produced

Fuel NOx can be minimized by.

- Controlling quantity of air permitted to mix with the fuel in the early stages of combustion.

Quantity of NOx generation

- Coal properties
- Fuel Oxygen /Nitrogen ratio
- Heat release rates in the furnace
- Furnace size and geometry
- Firing system Design
- Excess air
- Residence time



NOx Reduction During Combustion – LNCFS ™

TFS 2000™

-Reduces available O2 during critical early phase of combustion in the main burner zone to maximize time at sub or near stoichiometric condition

- Staging air to CCOFA and SOFA
- CFS™ Secondary air nozzle tips
- Flame attachment coal nozzle tips

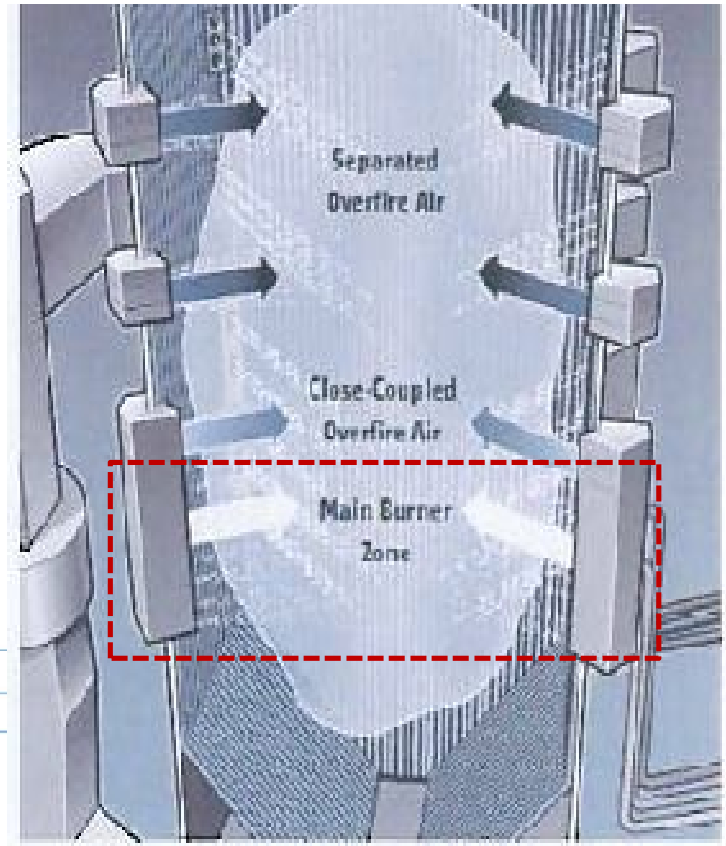
- Also uses a finer coal grind that allows for more aggressive staging

- < 1% on +50 mesh, > 75% - 200 mesh

  Finer grind increase surface area

  Allow less O2 in burner zone

- Helps control both Fuel & Thermal NOx



Advantages & Limitations

- Proven Technology since early 1980s
- Low Capex
- No Opex
- Low shut down time for implementation
- No additional Aux. power
- No impact on boiler operation
- No impact on boiler operating parameters

- Increase in UBC losses due to firing zone sub stoichiometric condition but can be addressed by improving the coal fineness by mill classifier re-design
- Limitations to reduce the NOx up to 50%

Post Combustion (Reduces the NOx by Chemical Reaction)

Basic Chemistry for Post Combustion NOx Reduction

$$NO_x + NH_3 \longrightarrow N_2 + H_2O$$

FURNACE ZONE

High Temperature 850 Deg.C to 1100 Deg.C

SELECTIVE NON CATALYC REDUCTION (SNCR)

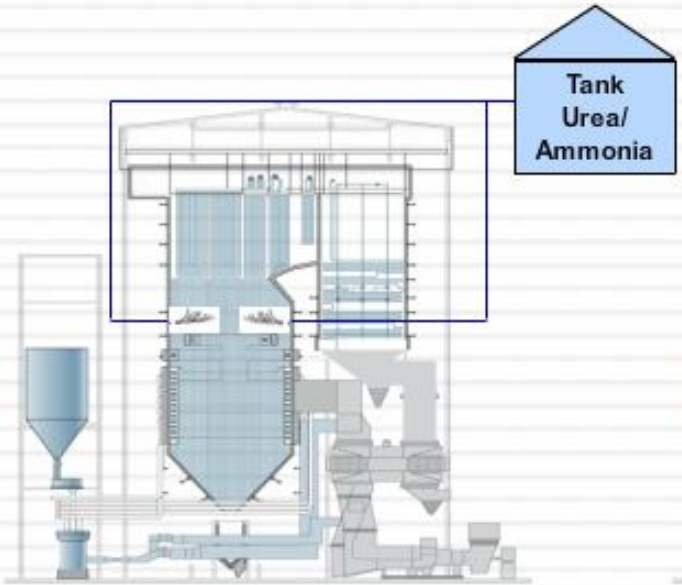
$$NO_x + NH_3 \longrightarrow N_2 + H_2$$

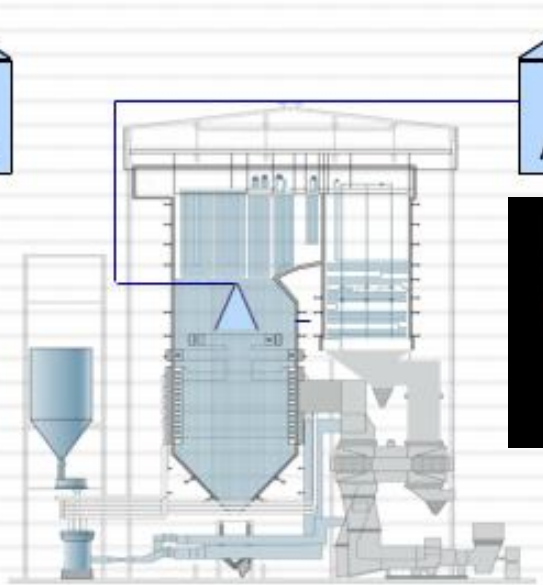
ECONOMIZER OUTLET

Presence of Catalyst & Temperature 350 Deg.C to 450 Deg.C

SELECTIVE CATALYC REDUCTION (SCR)

Types of SNCR





Traditional SNCR

- Uses lances to inject urea
- Limited effectiveness in boilers >400 MW because of jet penetration

GE Power Umbrella SNCR

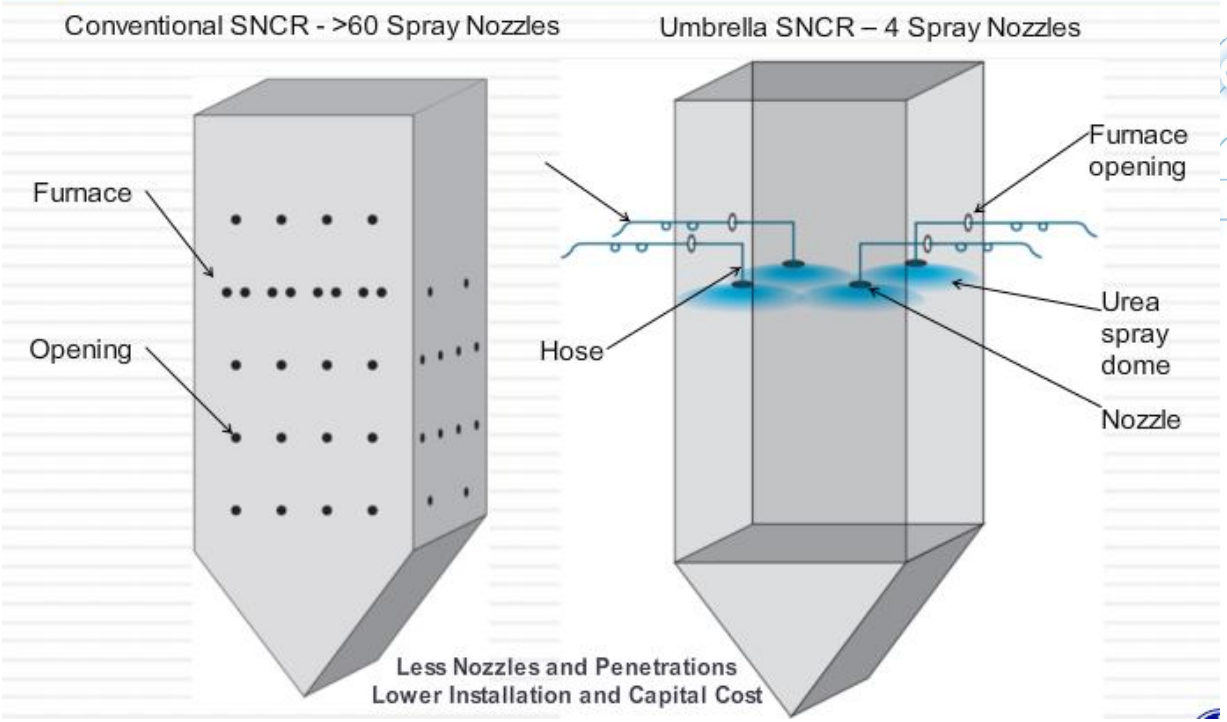
- New Patented method of injecting Urea
- No limitation on boiler size

Umbrella SNCR

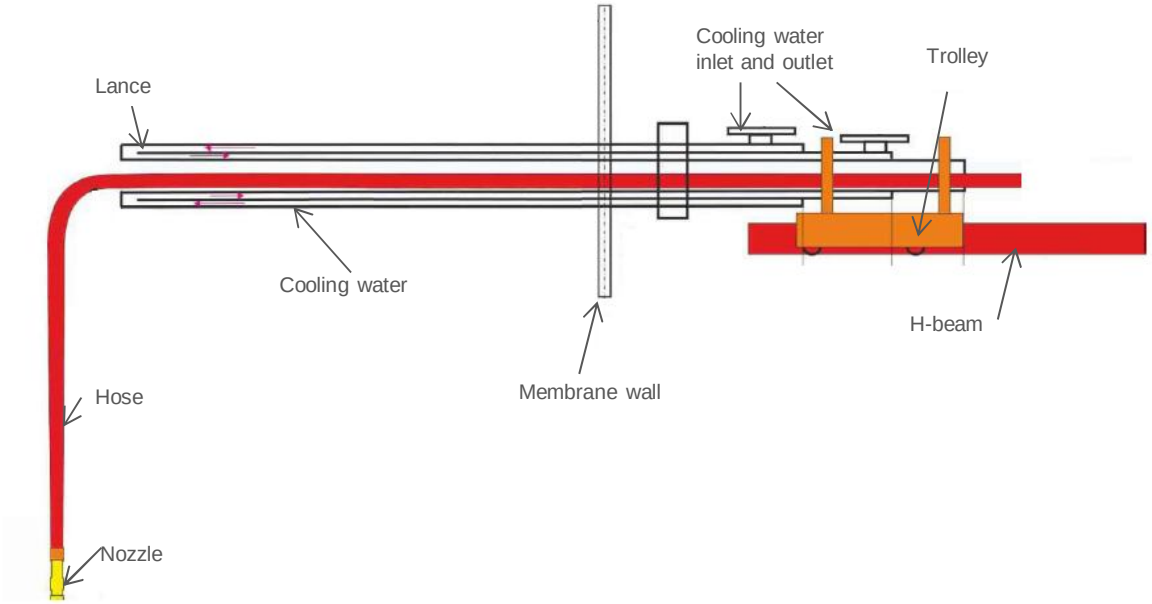
- The Umbrella SNCR is a new application of the SNCR process.
- The Umbrella SNCR has been successfully demonstrated in multiple power plants in Europe. NOx reduction up to 60%
- Superior to other SNCRs:
  - Better gas mixing from top
  - Larger droplets allows high gas temperatures
  - No need for real time temperature mapping
  - Easier and more flexible installation
  - Applicable at large boilers

USNCR™ (Umbrella SNCR)

Urea Nozzle Locations Comparison



Umbrella SNCR Lance assembly



Advantages & Limitations - SNCR

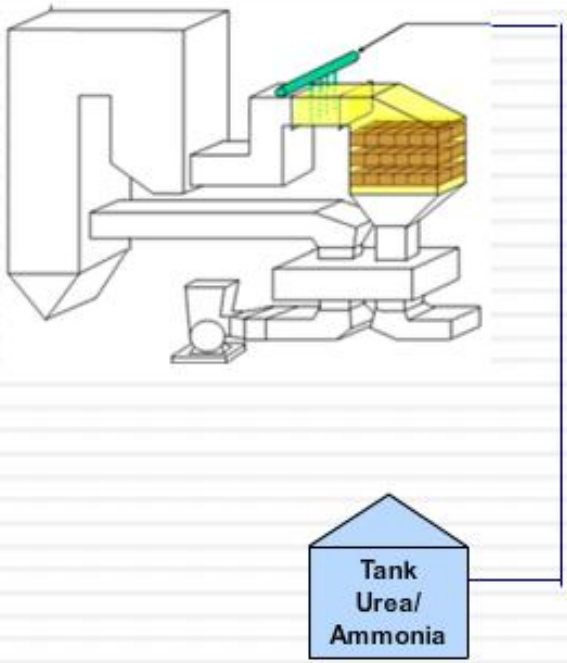
- Proven Technology
- Low to moderate Capex
- Very Low shut down time for implementation
- No impact on boiler operation
- No impact on boiler operating parameters

- Requires reagents like Ammonia or Urea
- Water Consumption
- Auxiliary power (very low)
- Limitations to reduce the NOx up to 50%

NOx Reduction - SCR

Selective Catalytic Reduction - SCR

- NOx reduction achieved with chemical reaction between NOx and ammonia as flue gases pass through a catalyst in a reactor
- 85% to 90+% NOx removal



Advantages & Limitations - SCR

- Proven Technology Globally
- Very High NOx reduction (upto95%)

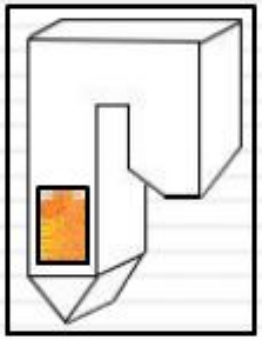
- Very High Capex
- Long Shut down for retrofit (Civil & Structural work)
- Requires reagents like Ammonia or Urea
- Auxiliary power due to ID Fan loading
- Periodic Replacement of costly Catalyst
- Performance of Catalyst yet to be proven for high ash erosive Indian coals
- Difficult to retrofit in existing boilers due to space constraints
- Limitation during boiler low load operations

Boiler Emissions Norms

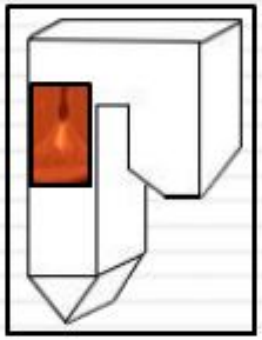
Installation Date	NOX (mg/Nm^3)	SOx (mg/Nm^3)	Particulate (mg/Nm^3)	Mercury (mg/Nm^3)
TPP's installed before Dec 31, 2003	600	600 (units < 500 MW) 200 (units ≥ 500 MW)	100	Nil (units < 500 MW) 0.03 (units ≥ 500 MW)
TPP's installed after Dec 31, 2003 – Dec 31, 2016	300	200 (units ≥ 500 MW)	50	0.03
TPP's installed from 1st Jan, 2017	100	100	30	0.03

Options for NOx Reduction

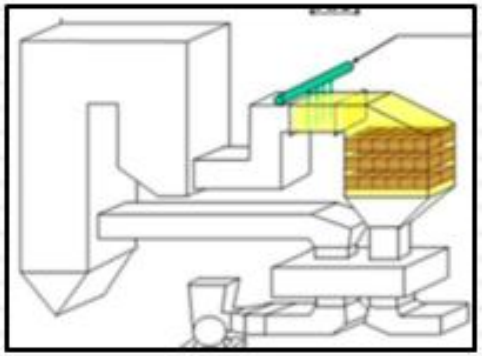
Which one is Best?



Boiler

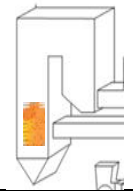
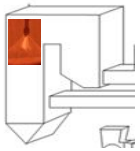
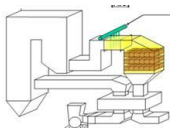


SNCR



SCR

Selection Of Technology

Installation Date	NOX (mg/Nm^3)	Recommended Technology
TPP's installed before Dec 31, 2003	600	 Low NOx Firing System only
TPP's installed after Dec 31, 2003 – Dec 31, 2016	300	  Low NOx Firing System + USNCR
TPP's installed from 1st Jan, 2017	100	  

Advanced Controls for Boiler efficiency and NOx reduction

GE / NeuCo BoilerOpt®

Typical Results

Optimal Control of Boiler through Load range. Allows a 0.5% to 1.50% improvement in heat rate (saving fuel)

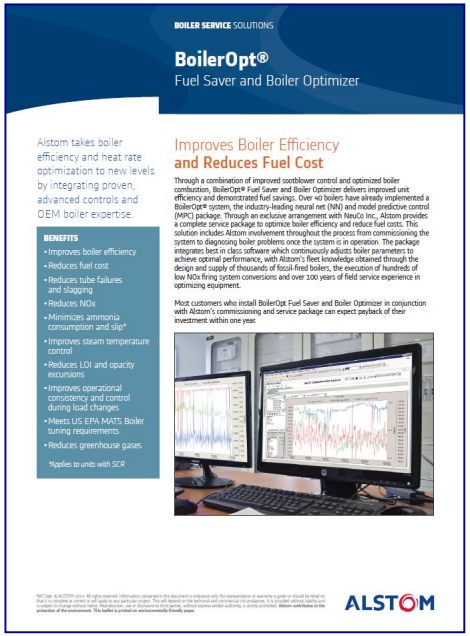
Reduces steam for sootblowing by up to 1/3, resulting in fewer outages for tube failures caused by sootblower erosion

Reduces Steam temperature variations

- Close control of superheat and reheat to achieve full or increased power output without subjecting tubes to over temperature and creep damage

Controls fuel / air ratio and soot blowers to minimize Particulate, NOx and CO emissions. Typical reduction of 5-15%

Optimizes the Ammonia flow in SNCR and SCR



BOILER SERVICE SOLUTIONS

BoilerOpt®

Fuel Saver and Boiler Optimizer

Alstom takes boiler efficiency and heat rate optimization to new levels by integrating proven, advanced controls and OEM boiler expertise.

BENEFITS

- Improves boiler efficiency
- Reduces fuel cost
- Reduces tube failures and slagging
- Reduces NOx
- Minimizes ammonia consumption and slip*
- Improves steam temperature control
- Reduces LOI and opacity excursions
- Improves operational consistency and control during load changes
- Meets US EPA MATS Boiler tuning requirements
- Reduces greenhouse gases

*Applies to units with SCR

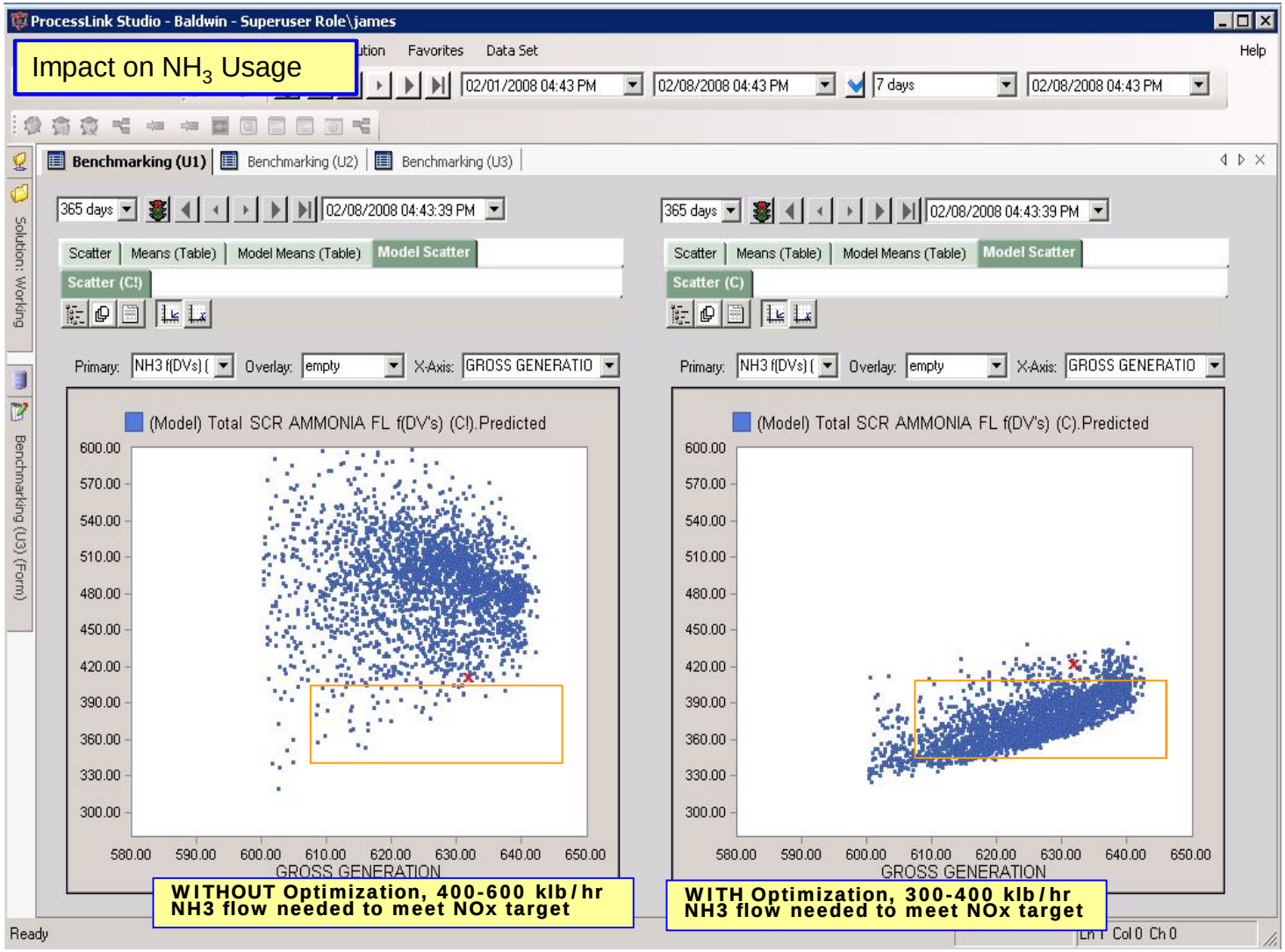
Improves Boiler Efficiency and Reduces Fuel Cost

Through a combination of improved sootblower control and optimized boiler combustion, BoilerOpt® Fuel Saver and Boiler Optimizer delivers improved unit efficiency and demonstrated fuel savings. Over 40 boilers have already implemented a BoilerOpt® system, the industry-leading neural net (NN) and model predictive control (MPC) package. Through an exclusive arrangement with NeuCo Inc., Alstom provides a complete service package to optimize boiler efficiency and reduce fuel costs. This solution includes Alstom involvement throughout the process from commissioning the system to diagnosing boiler problems once the system is in operation. The package integrates best in class software which continuously adjusts boiler parameters to achieve optimal performance, with Alstom's fleet knowledge obtained through the design and supply of thousands of fossil-fired boilers, the execution of hundreds of low NOx firing system conversions and over 100 years of field service experience in optimizing equipment.

Most customers who install BoilerOpt Fuel Saver and Boiler Optimizer in conjunction with Alstom's commissioning and service package can expect payback of their investment within one year.

ALSTOM

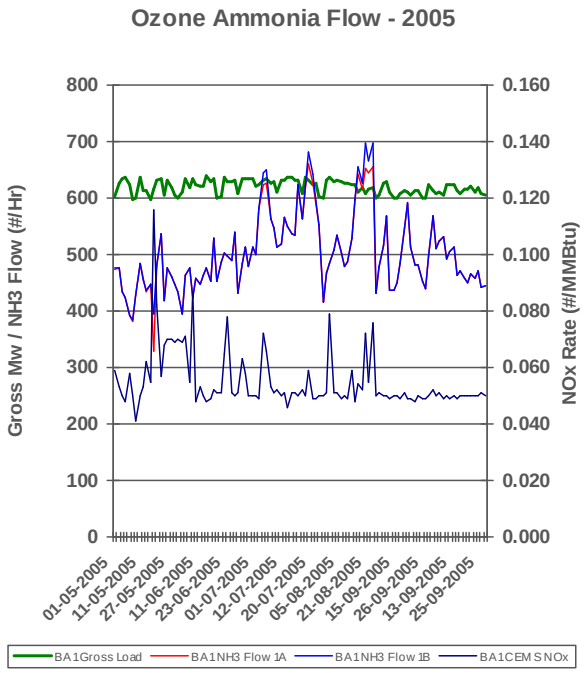
Impact on NH_3 Usage

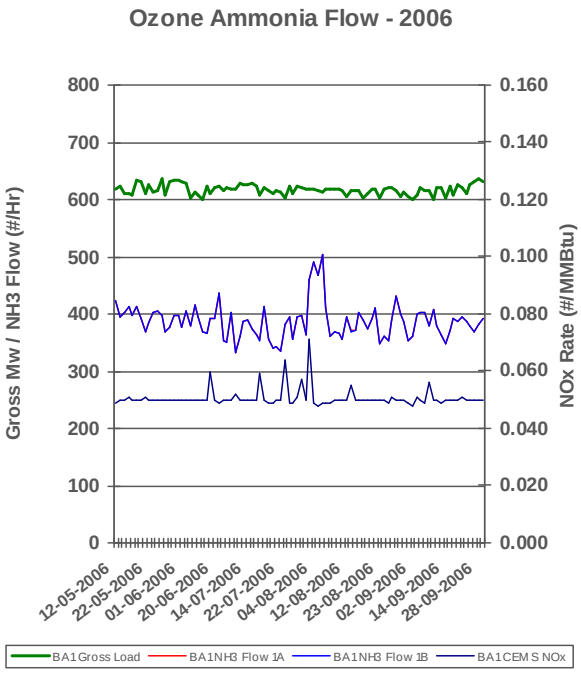


WITHOUT Optimization, 400-600 klb/hr NH3 flow needed to meet NOx target

WITH Optimization, 300-400 klb/hr NH3 flow needed to meet NOx target

CombustionOpt Ammonia Reduction





Spruce 1 BoilerOpt
KPI Summary

Spruce Unit 1					
KPI	**Units**	**OFF**	**ON**	**Delta (ON - OFF)**	**Delta (%)**
Gross MW	MW	571.15	564.57		
Heat Rate	Btu/kWh	9661.32	9556.74	-104.58	-1.08%
Blr Eff	%	83.99	84.77	0.78	0.93%
NOx	#/MMBtu	0.127	0.121	-0.006	-4.72%
CO	ppm	107.06	123.06	16	14.94%
O2 Avg	%	2.277	1.912	-0.365	-16.03%
RH Temp E	degF	1003.64	1003.88	0.24	0.02%
RH Temp W	degF	1002.96	1003.33	0.37	0.04%
RH Spray	klb/h	91.43	87.54	-3.89	-4.25%
SH Temp E	degF	1003.26	1004.12	0.86	0.09%
SH Temp W	degF	1000.16	1003.84	3.68	0.37%
SH Spray	klb/h	14.9	21.89	6.99	46.91%

Summary

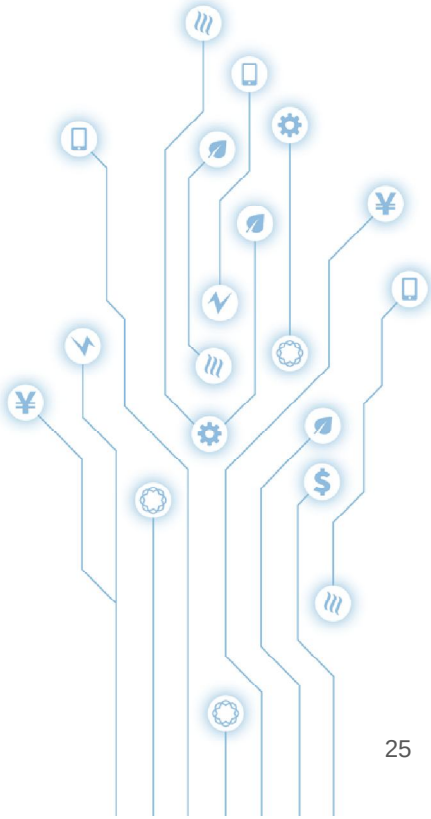
Required NOx can be reduced by limiting NOx production during combustion and/or by post combustion equipment

Cost and complexity rises with increased removal requirements

- 600 mg limit achievable in most boilers with Low NOx firing system
- 300 mg limit achievable in most boilers with Low NOx firing system and in some cases SNCR
- 100 mg limit achievable with Low NOx firing system with SNCR+ SCR

GE equipment for firing systems, and post combustion technologies in operation at hundreds of power plants globally

Questions ?



Thanks