REINHOLD ENVIRONMENTAL Ltd.

2016 NOx-Combustion-CCR Round Table Presentation

February 1 & 2, 2016, in Orlando, FL / Hosted by OUC

Mitsubishi Hitachi Power Systems Americas

DeNOx Technologies

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Aftermarket Product Manager

February 2, 2016

Synergies of MHI/Hitachi Merger for Solid Fuel Applications

MITSUBISHI HEAVY INDUSTRIES, LTD.

Technologies:

- T-fired Boilers
- Boiler Performance Model
- T-fired Coal Burners
- Hot Gas SCRs
- Honeycomb Catalyst
- Pulverizers
- Mercury Controls (ORP)

HITACHI
Inspire the Next

Technologies:

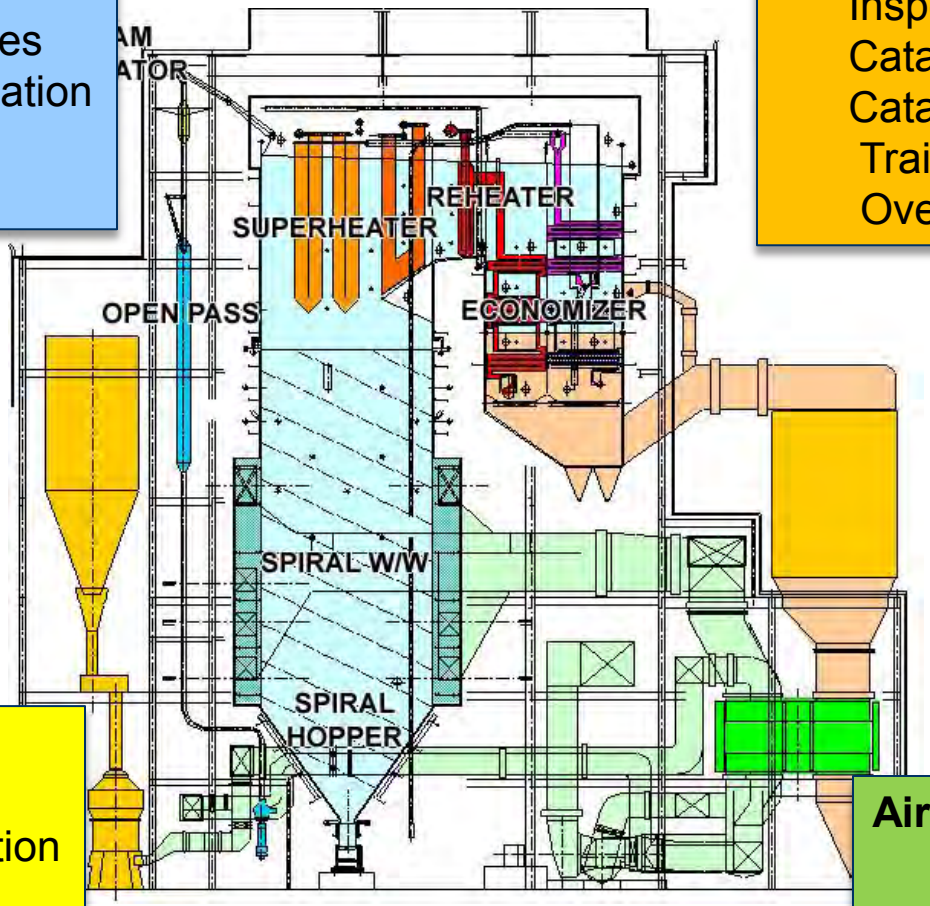
- Wall-fired Boilers
- Boiler Performance Model
- Wall-fired Coal Burners
- Coal SCRs
- Plate Catalyst
- Pulverizers (MPS)
- Mercury Oxidation

Integrated solutions and services for any operating unit across an entire Utility's fleet

Field Engineering Services

Boiler:
- Combustion Tuning
- Inspection
- Engineering Studies
- Operational Evaluation
- Training
- Outage Support

SCR:
- AIG Tuning
- Inspection
- Catalyst Testing
- Catalyst Life Management
- Training
- Overhaul Advising



Pulverizers:
- Inspection
- Operational Evaluation
- Training
- Overhaul Advising

Air Heater:
- Inspection
- Operational Evaluation

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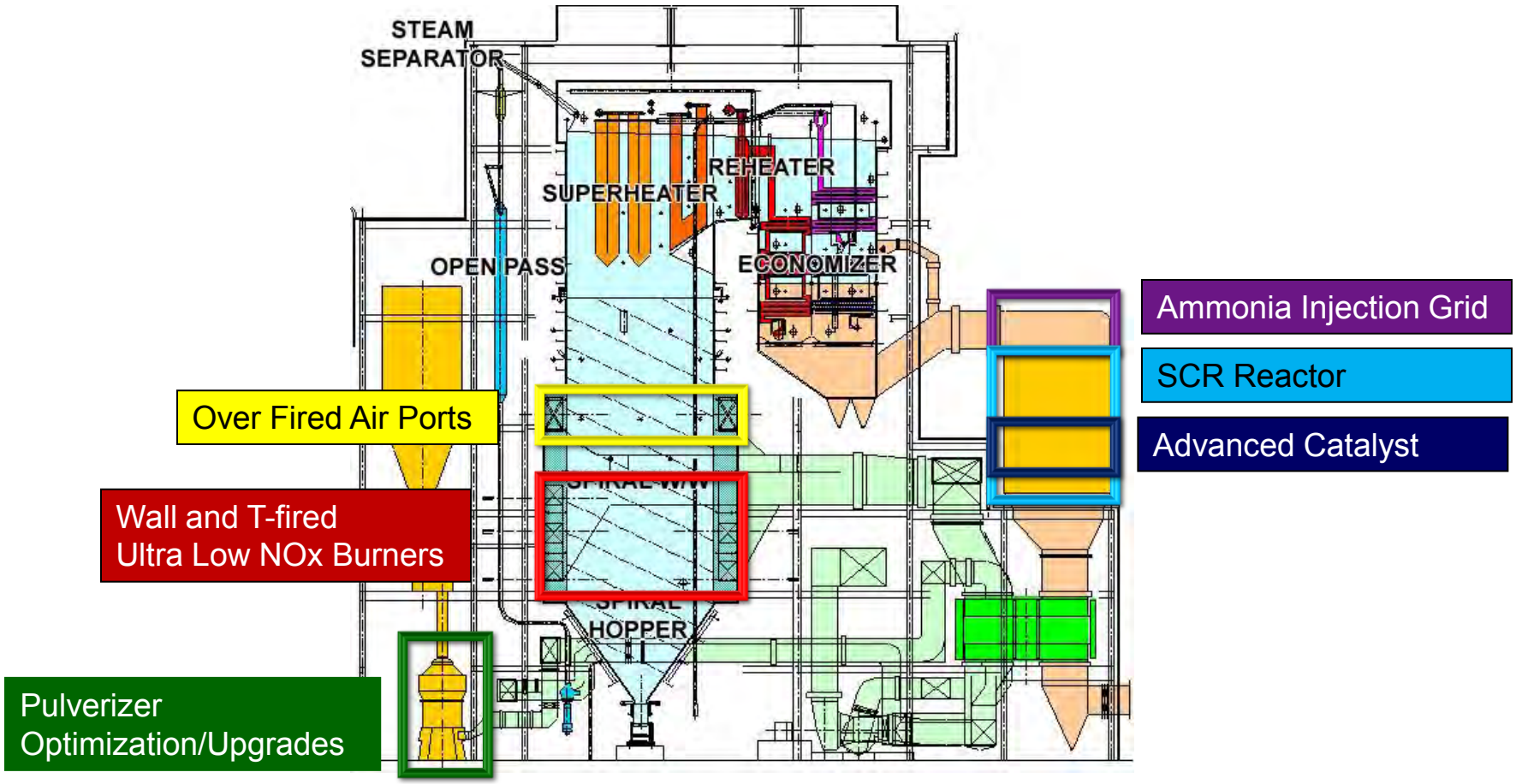
MHPSA DeNOx Technologies



MHPSA has extensive experience in all aspects of DeNOx Systems

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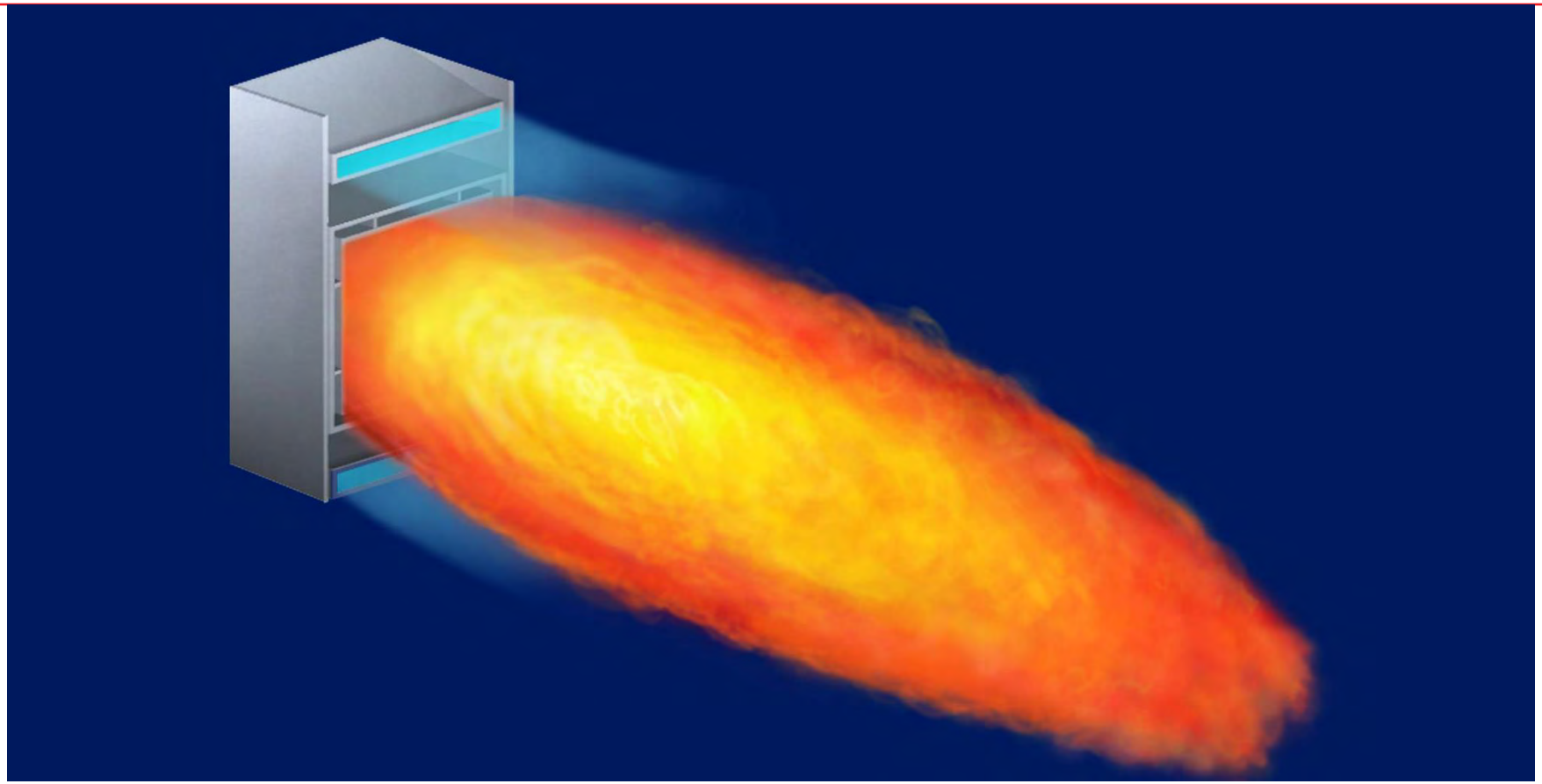
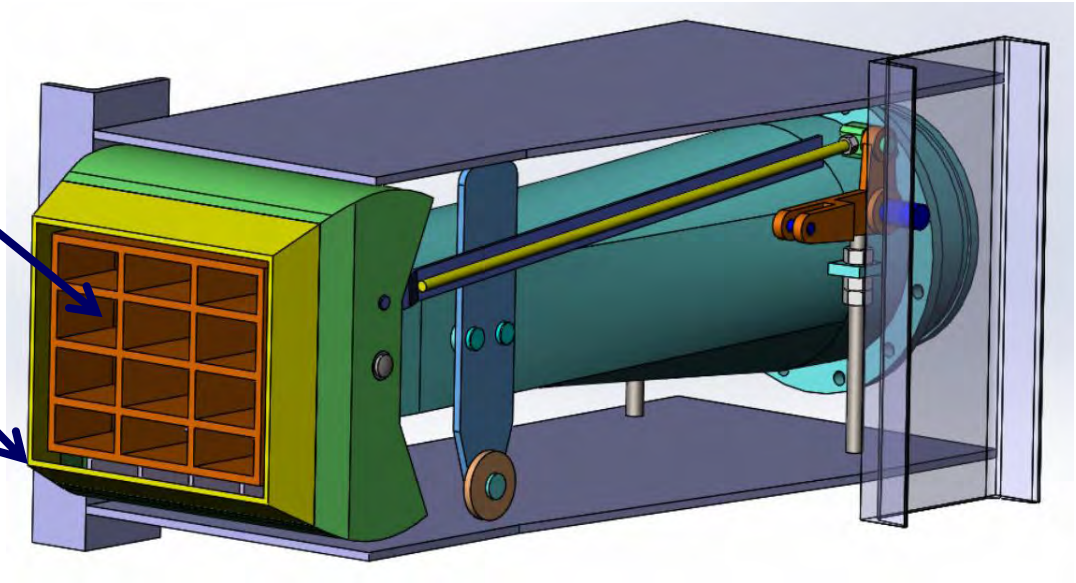
Introducing the NEW Ultra-Low NOx Corner-Fired M-PM Burner



Introducing the New T-Fired Ultra Low NOx Burner

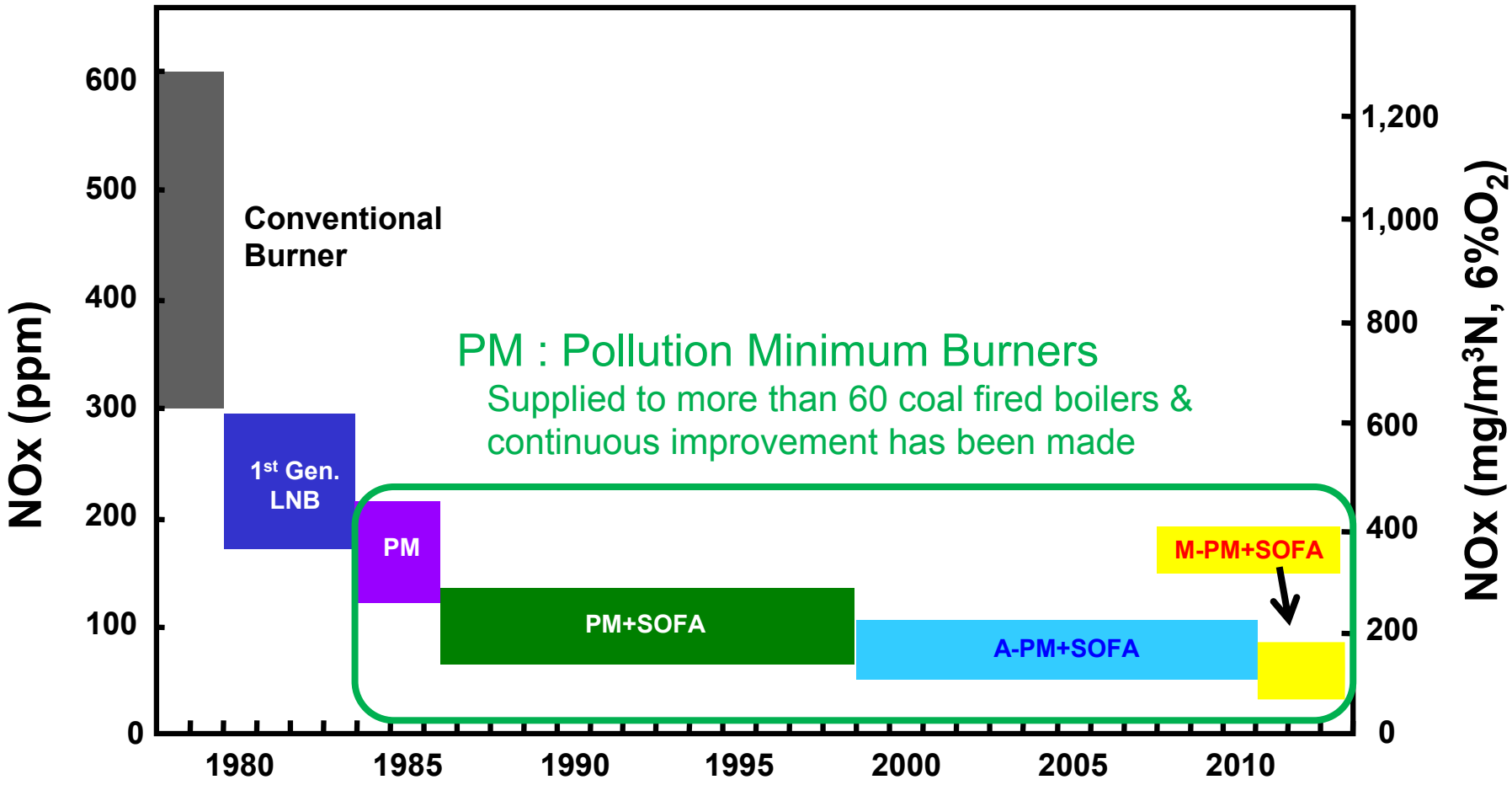
Design Advantages:

- Patented Design reduces NOx by splitting the flame into two separate fuel rich and fuel lean flames
- Multiple material options for high durability on all wear parts
- Ability to burn all fuel types including PRB, bituminous, lignite, and Illinois basin
- Capable of achieving Ultra-Low NOx while maintaining a low Unburnt Carbon level



Can achieve Ultra Low NOx emissions while maintaining low Unburnt Carbon levels

MHPSA's NOx Reduction History for T-Fired Boilers



PM : Pollution Minimum
A-PM : Advanced PM
M-PM : Latest version of A-PM
SOFA : Separated Over Fired Air

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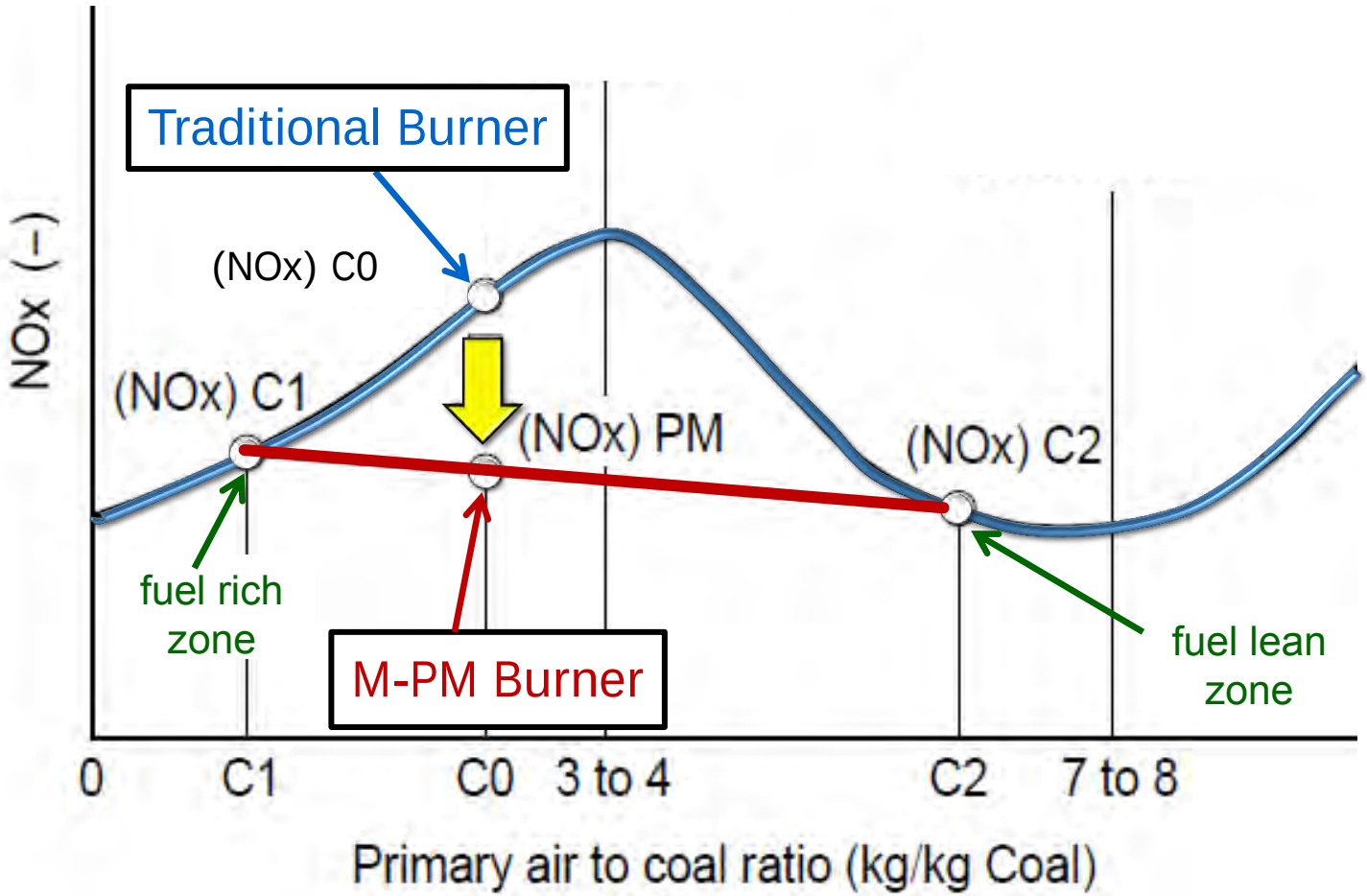
M-PM Burner: How Does it Work

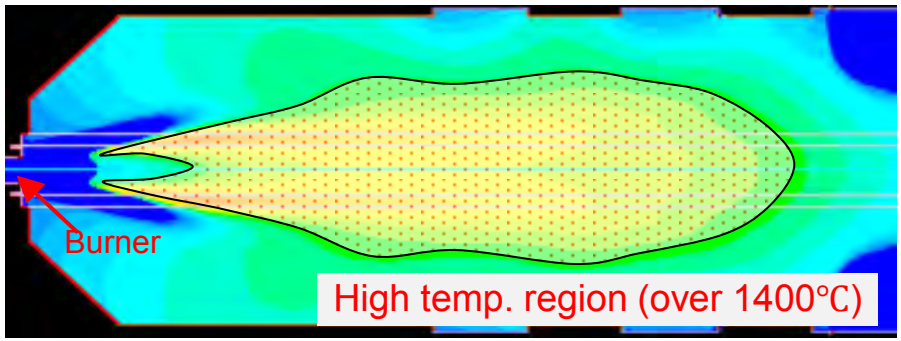


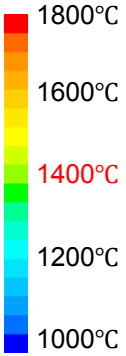
Patented technology drastically reduces NOx by splitting the flame into two zones

CFD of Traditional Burner

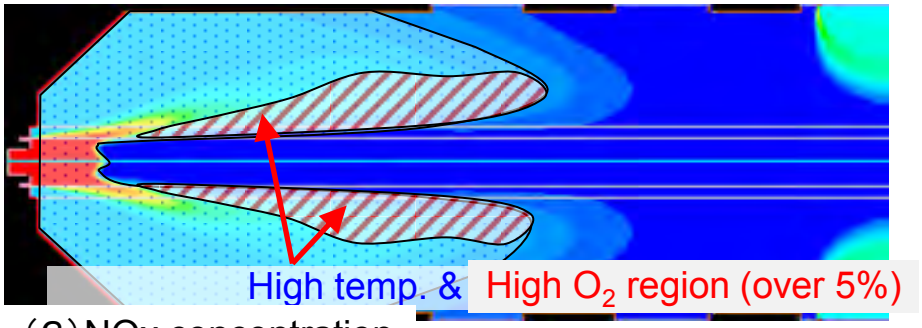
Traditional Burner

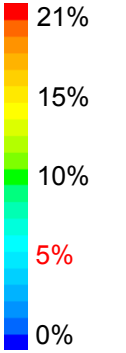
(1) Flame temperature



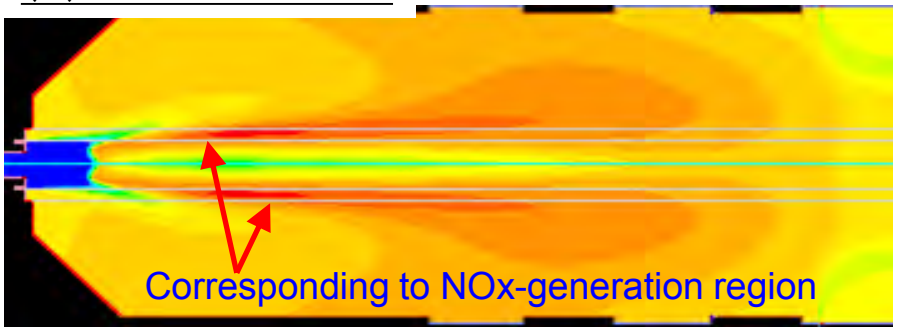


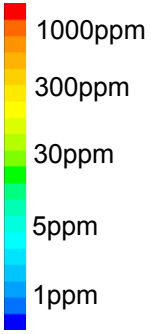
(2) Oxygen concentration





(3) NOx concentration





High Temperature & O2 region corresponds to High NOx region

This region must be minimized to reduce NOx

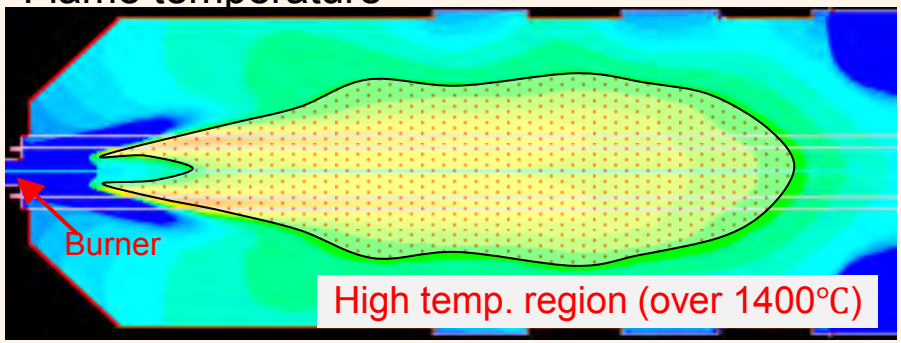
Burner Ignition Characteristics must be optimized

Comparison of Traditional and M-PM Burners (CFD)

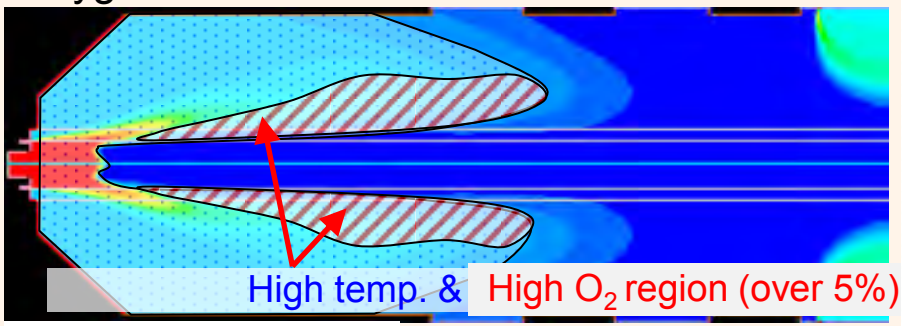
＜Traditional burner＞

NOx generated at the high temp.& high O_2 region

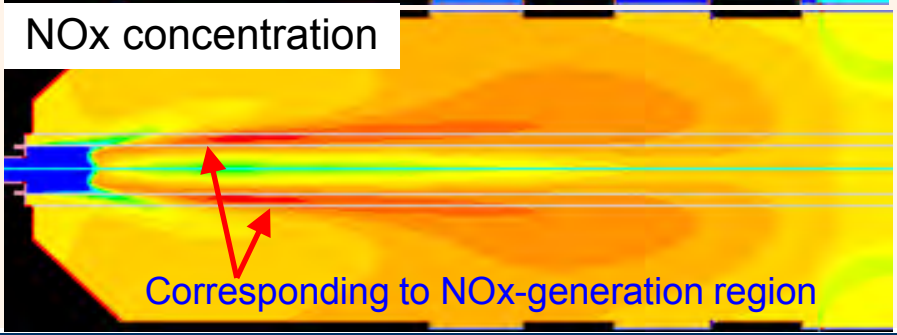
Flame temperature



Oxygen concentration



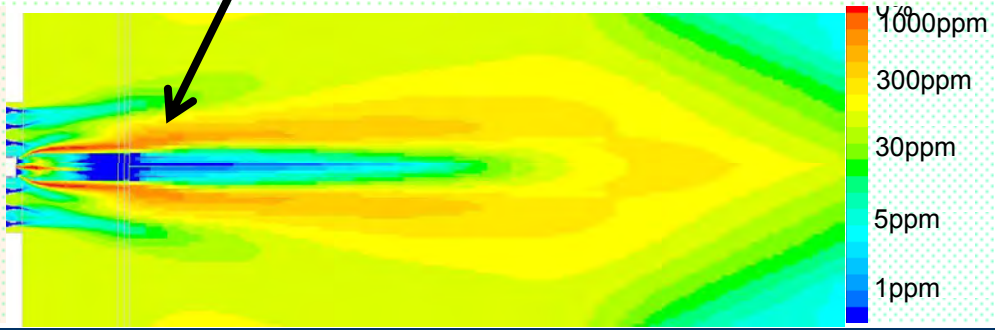
NOx concentration



＜M-PM burner＞

NOx reduced by the temperature control of outer flame

High NOx generation area at the outer flame is reduced



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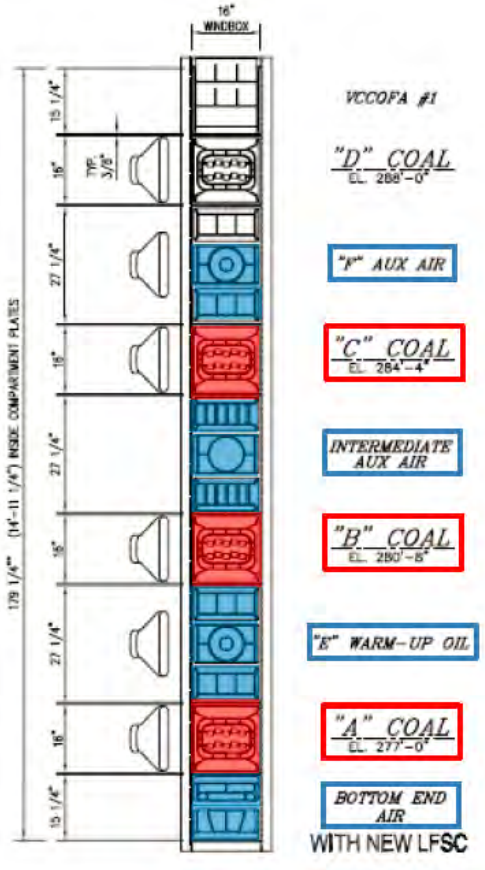
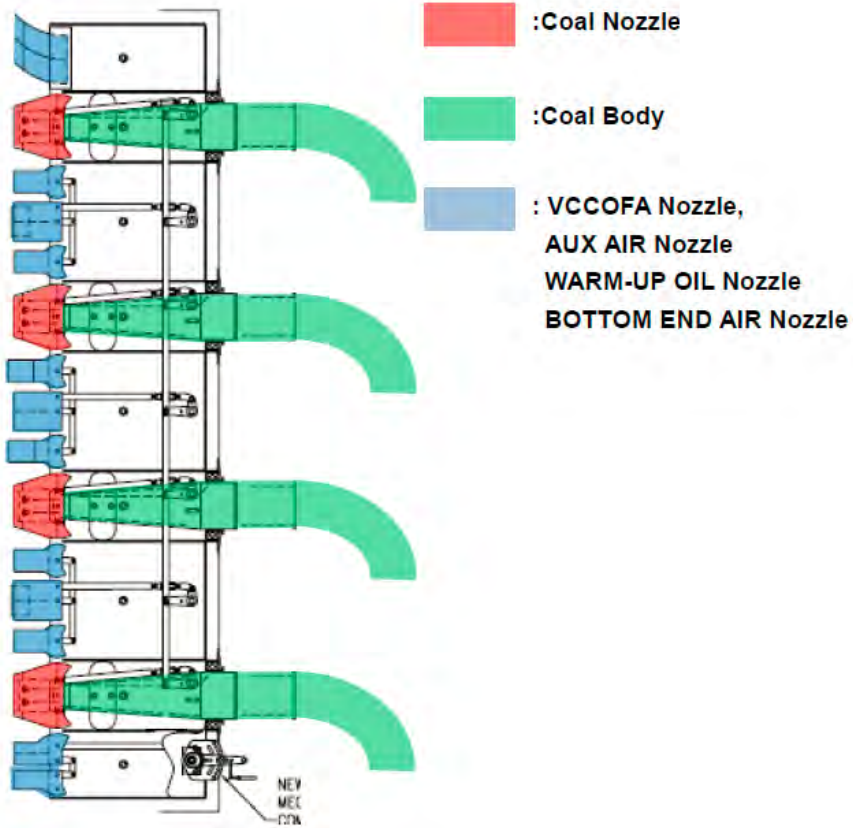
Typical Modification Scope

Modification Area

- Modification of all burners nozzles is required
- Aux Air may or may not need to be replaced based on existing condition
- Coal Body may or may not need to be replaced based on existing condition





Recent Retrofit Operating Experience

Plant	Houfu Unit 5 (Japan)	Carbon2 Unit 2 (Mexico)	Zhuhai Unit 1 (China)	Zhuhai Unit 2 (China)	Baoshan Unit 3 (China)	Hirono Unit 5 (Japan)	Norgener Unit 1 (Chile)	Norgener Unit 2 (Chile)
Output	25 MW	350 MW	700 MW	700 MW	350 MW	600MWe	132 MW	132 MW
Burner Elevations	2	5	6	6	5	6	4	4
Separated Overfired Air	Yes⇒Yes	No⇒No	No⇒Yes	No⇒Yes	No⇒Yes	Yes⇒Yes	No⇒No	No⇒No
Existing NOx	178 ppm	275 ppm	175 ppm	175 ppm	158 ppm	150 ppm	197 ppm	199 ppm
Retrofit NOx	125 ppm	220 ppm	68 ppm	65 ppm	65 ppm	108 ppm	143 ppm*	111 ppm
NOx Reduction	30%	20%	62%	64%	59%	30%	27%	44%
Retrofit Year	2012	2013	2013	2013	2014	2014	2014	2015

M-PM Burner has provided significant NOx reduction on multiple Units

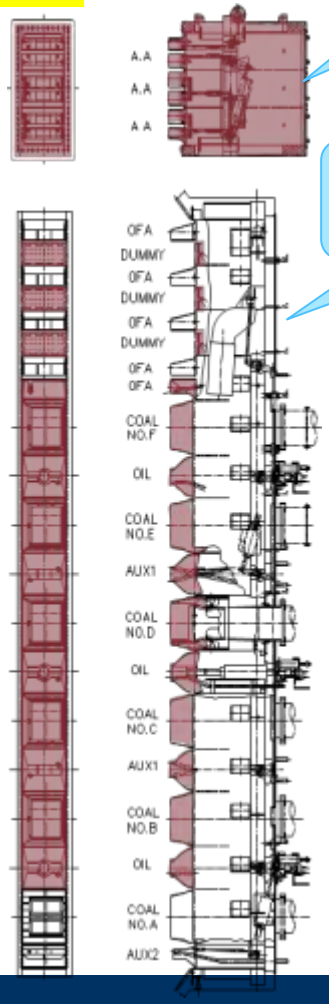
Zhuhai - Unit 2 (China) Effect of Modification

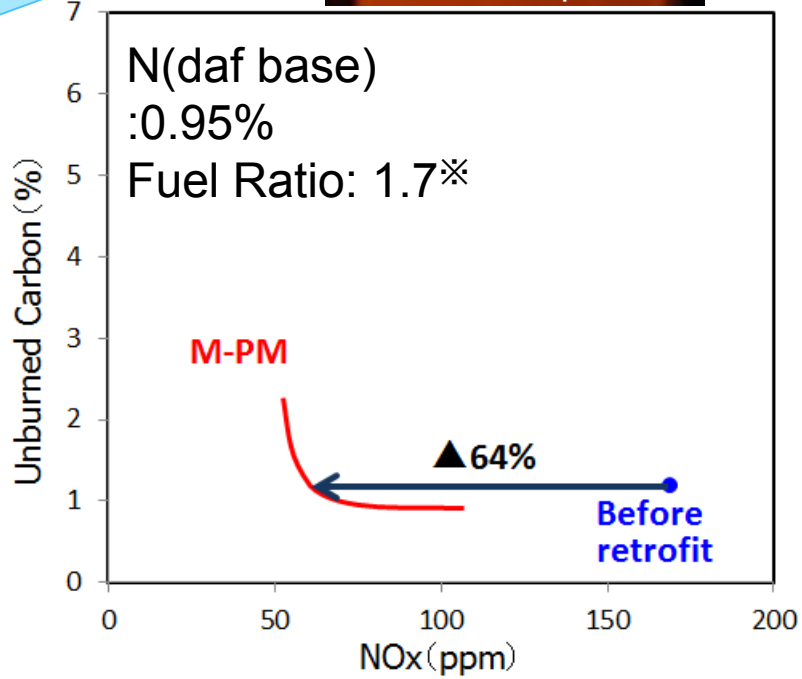
All burner nozzles replaced and SOFA installed

- 64% reduction in NOx emission

Items	Specification
Unit output	700MW
Number of burner level	6 levels
Boiler type	Forced circulation boiler
Combustion type	4 corners, corner firing
Modified part	(1) Changing of burner nozzles (to M-PM) (2) Addition of SOFA

※Fuel Ratio: Fixed carbon／Volatile matter
（Index of combustibility）



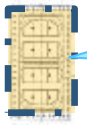


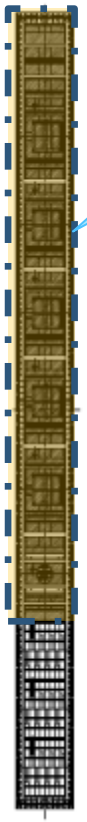
Baoshan - Unit 3 (China) Effect of Modification

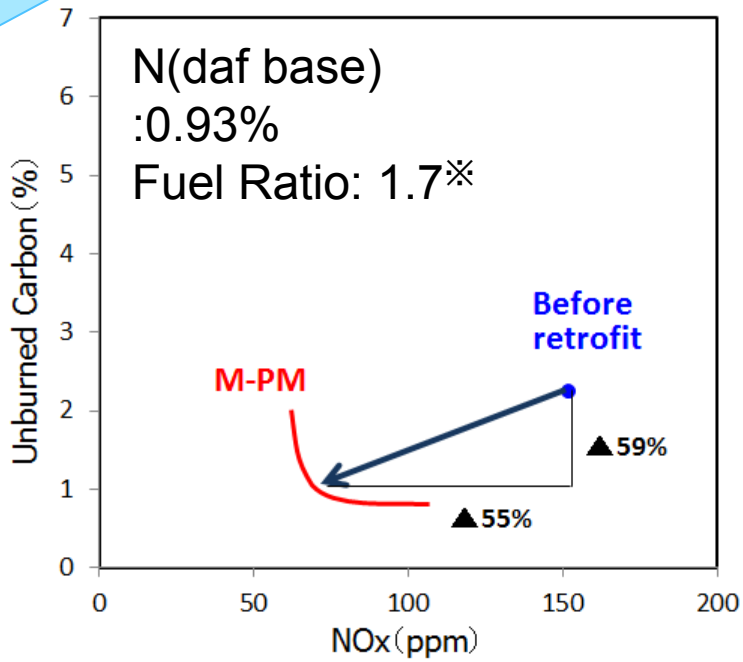
All burner nozzles replaced and SOFA installed

- 55% reduction in NOx emission
- 59% reduction in unburned carbon

Items	Specification
Unit Output	300MW
Number of Burner Elevations	5 elevations
Boiler type	Forced Circulation Boiler
Combustion type	4 Corners, Corner firing
Modification parts	(1) Changing of burner nozzles to M-PM (2) Addition of AA (Aditional Air)







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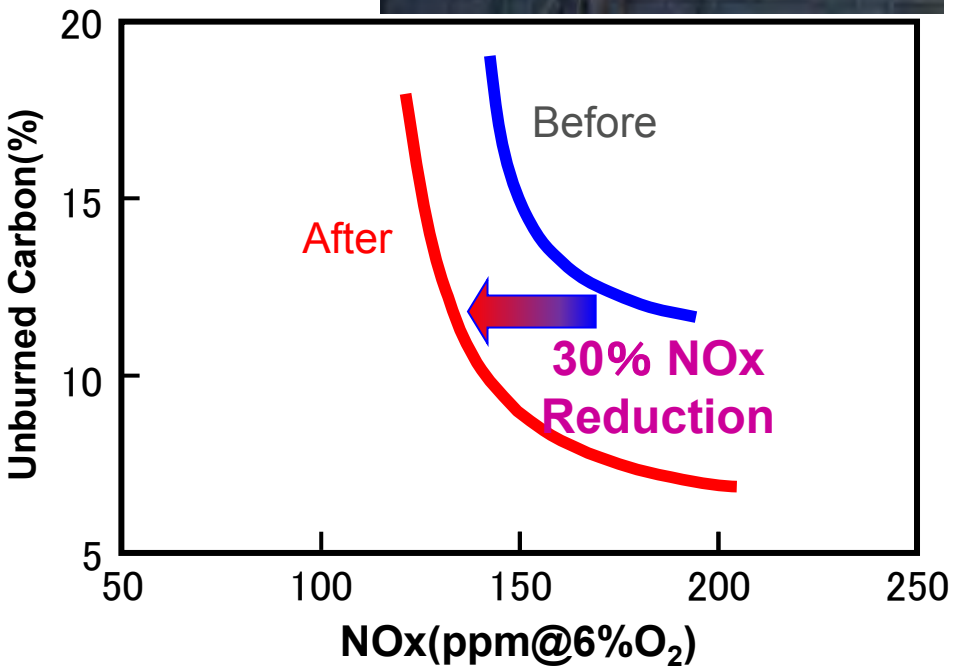
Houfu - Unit 5 (Japan) Effect of Modification

NOx was decreased by 30% from the existing PM burner with the same Unburned Carbon (UC).

Item	Specifications
Boiler Output	25MWe
No. of Burner Elevation	2 Elevation
Steam Temp.	543℃
Modification Contents	PM ⇒ M-PM （All Nozzles Replacement） SOFA was originally installed and no change was made
Process	Burner Retrofit：Sept. 2012 Combustion Test：Nov. 2012



Carbon - Unit 2 (Mexico) Effect of Modification

NOx was decreased by 20% compared with the existing burner (without SOFA)

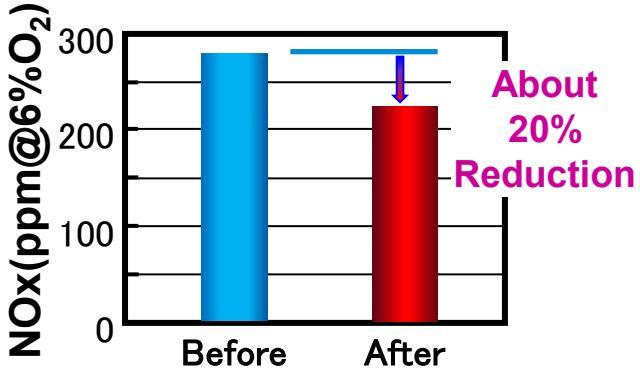
Item	Specification
Boiler Output	350MWe
No. of Burner Stages	5 elevation
Steam Temp.	541℃ / 541℃
Modification Contents	Only coal nozzles replacement SOFA has not been installed
Schedule	Burner Retrofit: Dec. 2012 Combustion Test: Feb-Mar 2013

Normal Operation (100%Load)

4 elevation operation

Only coal nozzles were replaced and 2ry air nozzles were not replaced, the Nox reduction effect was rather small

NOx Before/After Modification (100%Load)

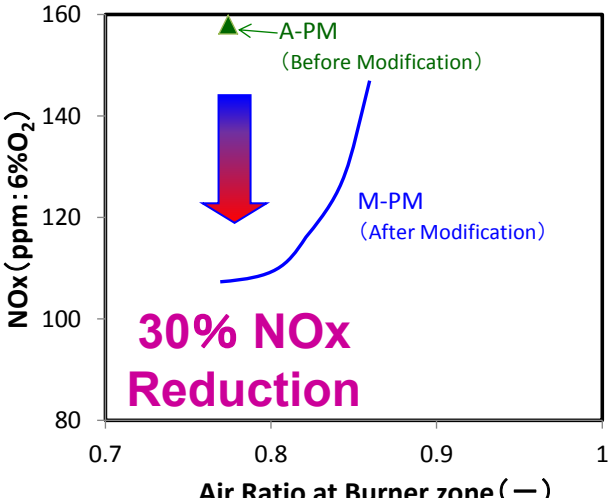


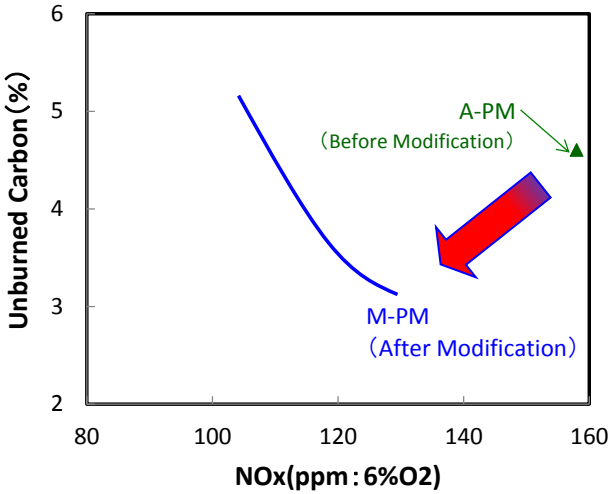
Hirono - Unit 5 (Japan) Effect of Modification

A-PM burner was replaced to M-PM burner

- 30% reduction in NOx emission at same air ratio at burner zone
- Improvement of NOx-UB characteristic

Item	Specification
Boiler Output	600MWe
No. of Burner Stages	6 elevation
Steam Temp.	600℃ / 600℃
Modification Contents	A-PM ⇒ M-PM （All Nozzles Replacement） SOFA was originally installed and no change was made
Schedule	Burner Retrofit：Mar.~Jun. 2014 Combustion Test：Jul. & Oct. 2014

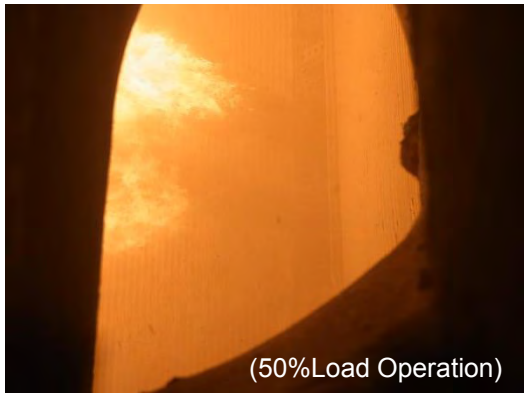




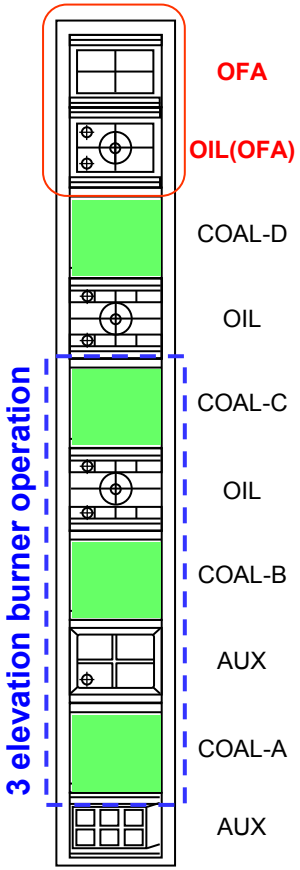
Norgener - Unit 2 (Chile) Effect of Modification

NOx was decreased by 44% compared with the existing burner (without SOFA)

Item	Specification
Boiler Output	132.4MWe
No. of Burner Stages	4 elevation (3 elevation burner operation)
Steam Temp.	SH:540℃ / RH:540℃
Modification Contents	All nozzles replacement Modification to OFA AA has not been installed
Schedule	Burner Retrofit：Mar.-Apr. 2015 Combustion Test：Jun. 2015

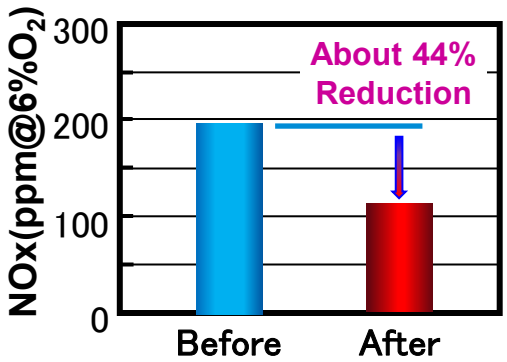


Guaranty Operation (100%Load)



- Upper oil burner: Modification to doubles as OIL and OFA (Over Fire Air)
- Upper Compartments: Modification to OFA
- Tilt mechanisms of OFA nozzles: Modification to separate from other nozzles
- All coal burners: Replace to M-PM
- All burners able to adjust tilt

NOx Before/After Modification (100%Load)



Recent US Utility Evaluation for M-PM Burner Applications

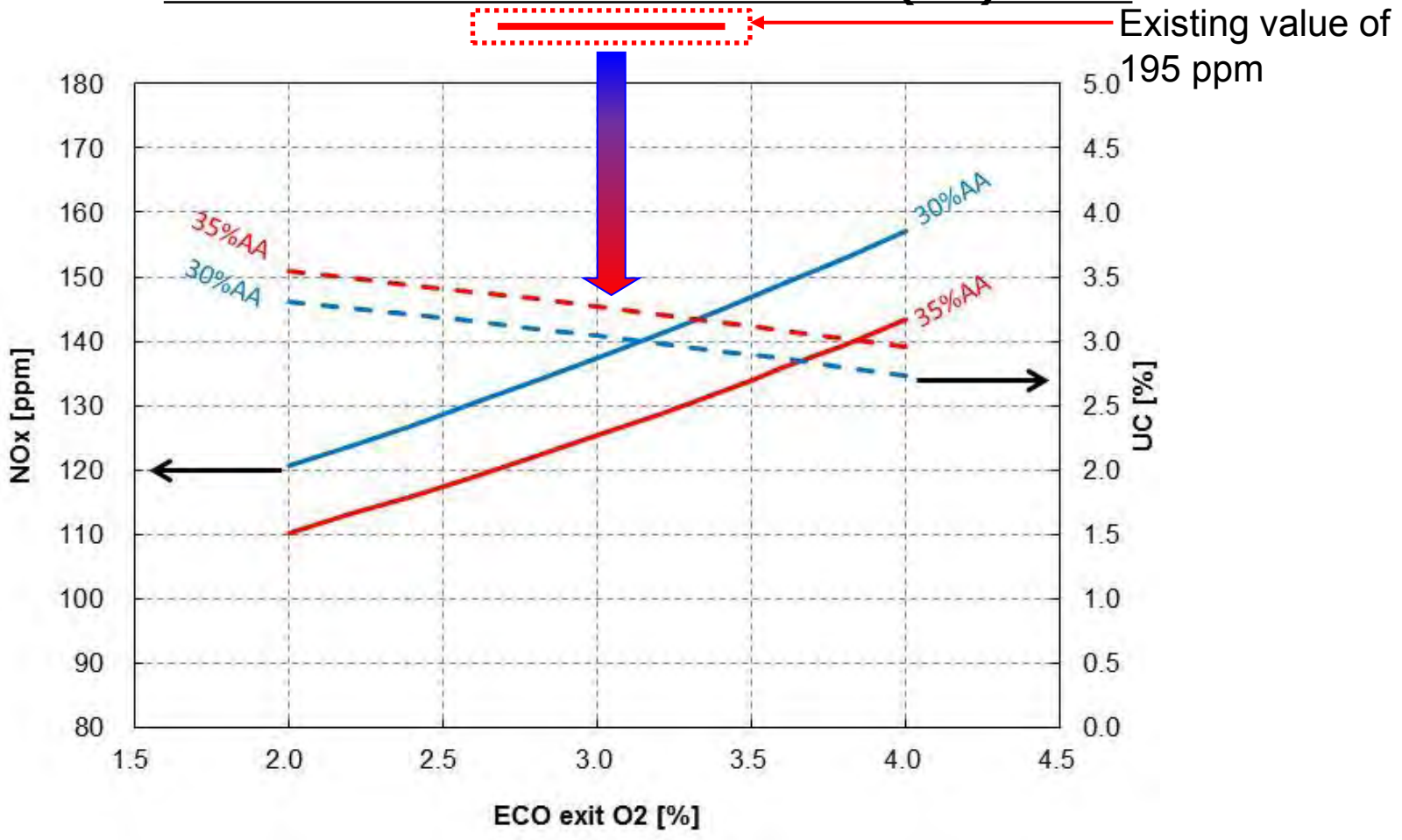
State	Unit MW size	Existing NOx	Predicted M-PM NOx	NOx Reduction	Coal
Maryland	167	0.26	**0.18**	**31%**	Eastern Bit
Kentucky	282	0.30	**0.17***	**43%**	Illinois Basin
New York	167	0.33	**0.20**	**39%**	Bituminous
Texas	917	0.25	**0.14**	**44%**	Lignite
Virginia	424	0.29	**0.21***	**28%**	Eastern Bit
Iowa	726	0.18	**0.12**	**33%**	PRB

* - Separated Over Fire Air was added

Supported multiple Utilities burning various fuels: Predicted an average NOx Reduction of 36%

Result of Case study for 282 MW Boiler

Predicted NOx-Unburned Carbon(UC) value

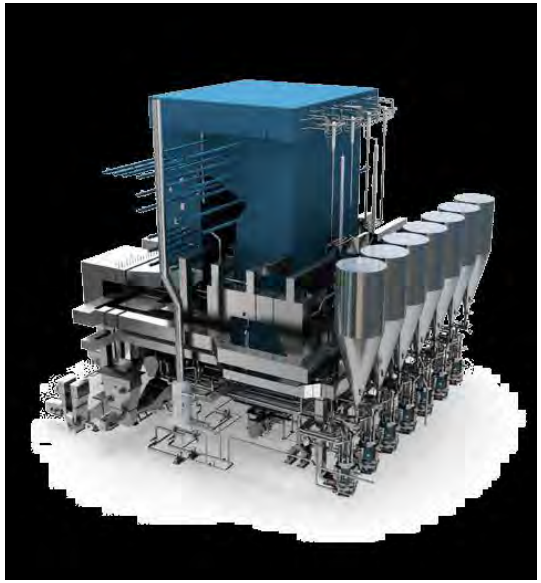


Design can accommodate customer preference for NOx vs UBC

Introducing:
"Long Term NOx Reduction Service Agreement" (LTNSA)

Long Term NOx Reduction Service Agreement for O&M Savings

- O&M costs for SCR systems are greatly impacted by inlet (combustion) NOx levels
- DeNOx System LTSA Approach:
  - Replace existing burners with Ultra LNBs
  - Optimize SCR ammonia consumption
  - Reduced catalyst replacement cycles
  - Lower mercury emissions
  - Reduced SCR minimum operating temp



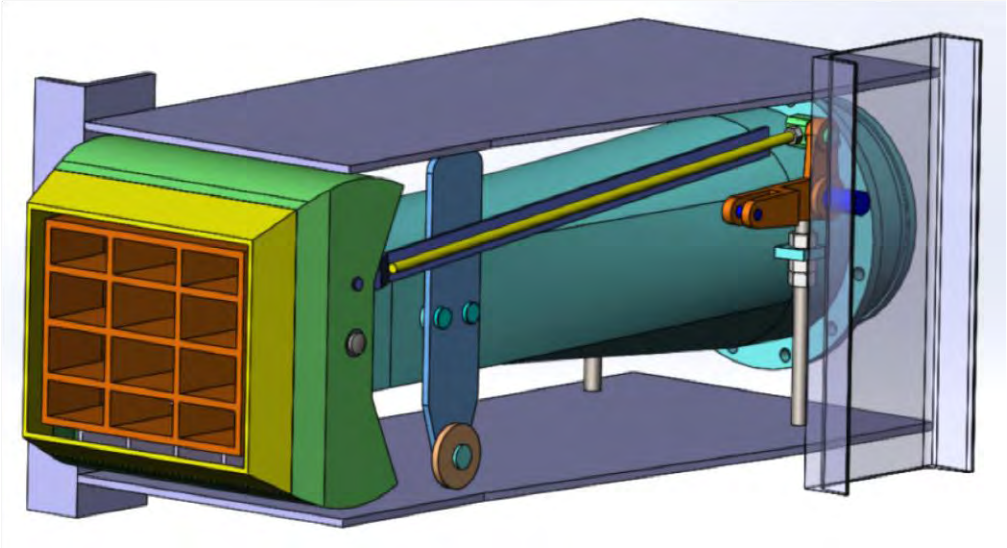
- 500 MW T-fired boiler
- Bituminous Coal
- 3 Layer SCR

As a LNB, SCR and catalyst supplier, can provide long term guarantees on O&M savings

Step 1: Burner Improvement

Existing Burner Conditions:

- NOx emissions - 0.28 lb/MMBtu with Separated OFA
- Unburned Carbon - 3%



Utilizing MHPSA Advanced LNB

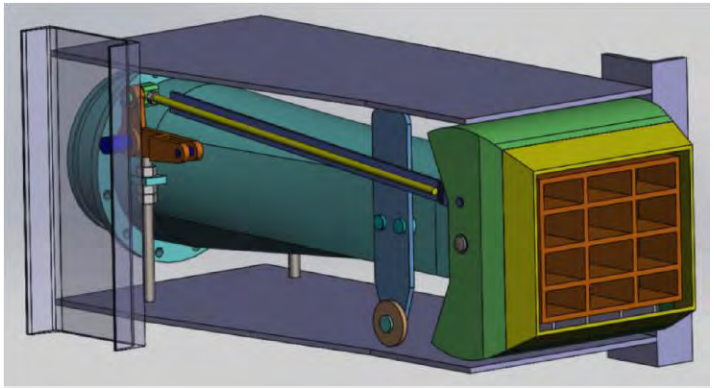
- NOx emissions - 0.17 lb/MMBtu ↓
- Unburned Carbon - <3%
- No changes to the Separated OFA
- Installed cost of LNB - $3.5M

Burner replacement results in NOx emission reductions of 39%

Step 2: Ammonia Consumption Reduction

Existing Ammonia Injection Conditions:

- Ammonia Injection - 450 lb/hr at full load
- SCR NOx reduction - 0.23 lb/MMBtu
- Annual Ammonia cost - $1.85M



Ammonia Consumption improvement by Utilizing Advanced LNB

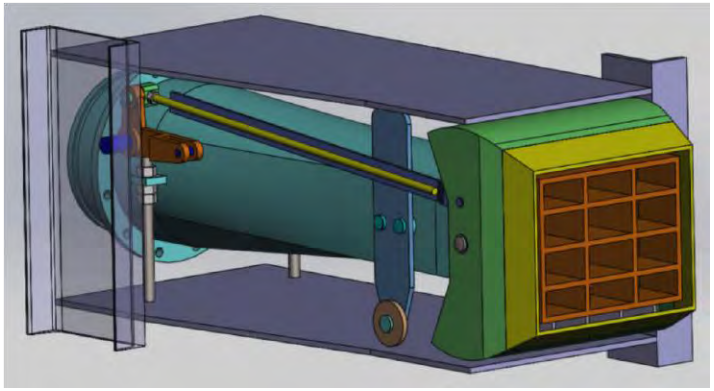
- Ammonia Injection - 234 lb/hr (48% less) at full load ↓
- SCR NOx reduction - 0.12 lb/MMBtu ↓
- Annual Ammonia cost - $0.95M ↓

Annual Ammonia savings is $0.9M

Step 3: Catalyst Life Extension

Existing Catalyst Conditions:

- Catalyst activity potential required – 3.2
- Catalyst Life - 24k hrs
- Annual Catalyst cost = $0.4M + installation = $0.17M

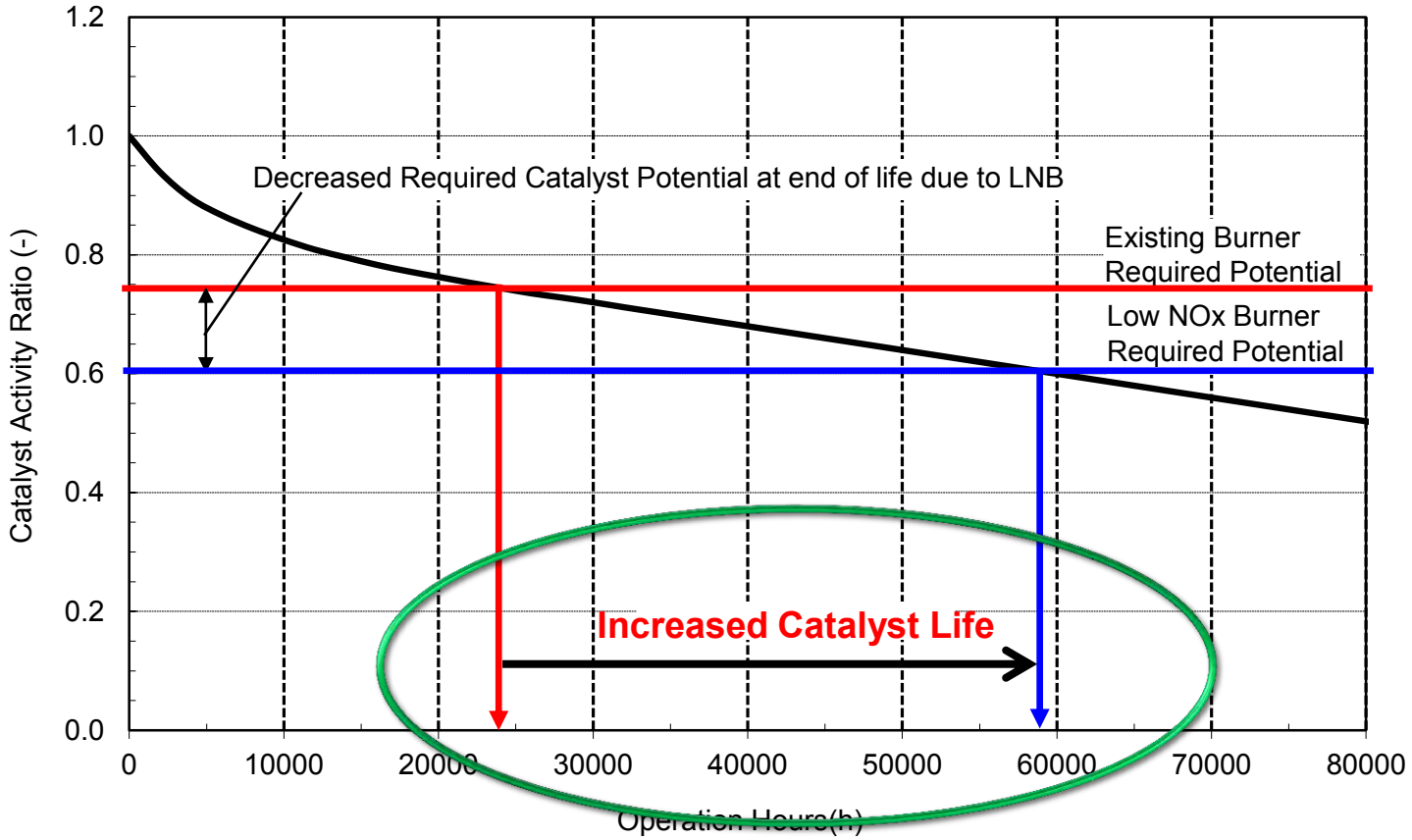


Catalyst Effect of Utilizing Advanced LNB

- Catalyst activity potential required – 2.6 ↓
- Catalyst Life - 58k hrs ↑
- Annual Catalyst cost = $0.166M + installation = $0.06M ↓

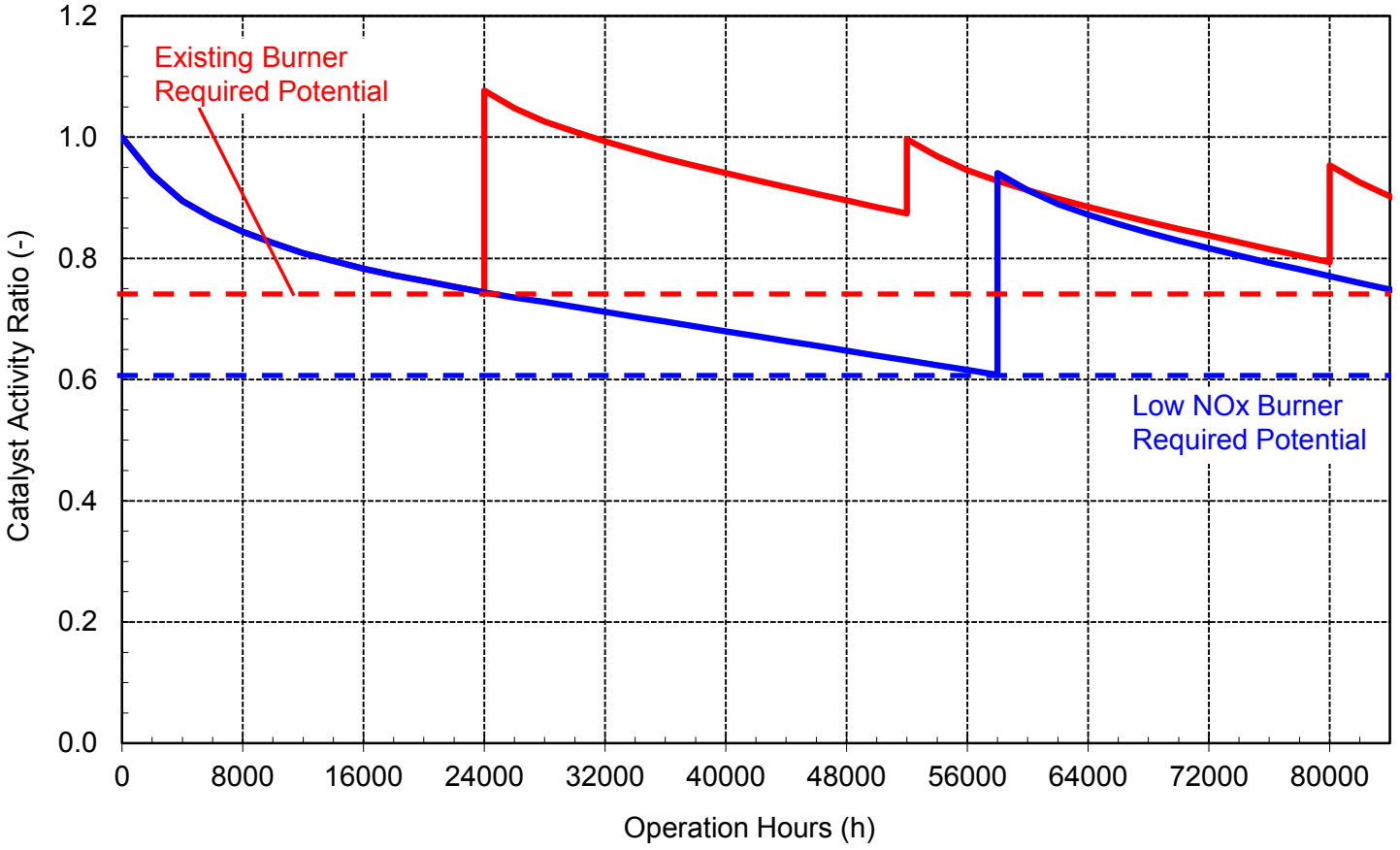
Annual Catalyst/Installation savings is $0.35M

LNB Impact to Catalyst Life



Small Changes in Catalyst Potential provides 2+ year catalyst life extension

Advanced LNB Impact to Catalyst Life



Over 10 years 2 Catalyst Replacements eliminated, resulting in $3.4M savings

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Summary: LTNSA NPV Analysis

	Existing Burners	Existing Annual Cost	MHPSA Burners	Retrofit Annual Cost
NOx Rate (lb/mmbtu)	0.28		0.17	
SCR NOx Workload to 0.05lb/mmBtu	0.23		0.12	
Ammonia Usage	100%	$1,850,000	52%	$950,000
Catalyst Life	24k hrs	$570,000	58k hrs	$225,000

Capital Cost Investment:

- $3.5M – Design, Supply and Installation of Ultra LNB

Annual O&M Savings:

- $0.9M – Ammonia Consumption
- $0.35M – Catalyst Life Extension

NPV = $2.0M with 30% ROI

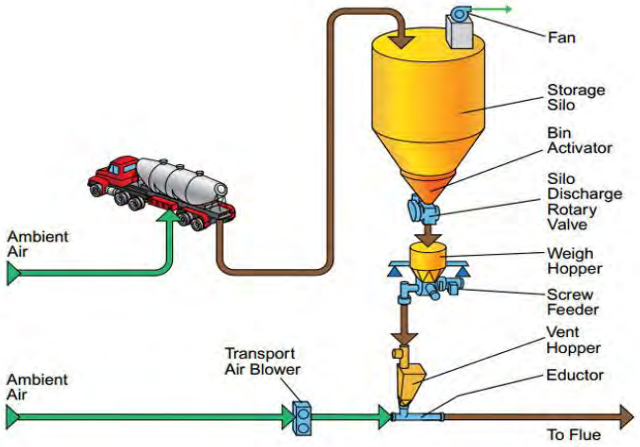
Payback Period of <3 Years

Guarantee O&M savings of $12.4M over an 10 year period

Additional Benefits

Mercury Oxidation ↑

- Ammonia acts as an inhibitor to Mercury Oxidation
- Reducing Ammonia by 50% drastically increases Mercury Oxidation
- Minimize Activated Carbon, Calcium bromide, etc.



Minimum Operating Temperature (MOT): ↓

- MOT is defined Ammonia concentration
- Reducing Ammonia allows for a lower MOT
- Lower MOT gives boiler more operating load flexibility

Additional improvements in Mercury oxidation and reduction in operating temperature are further co-benefits to Utility operating costs

DeNOx System LTNSA Parameters

Included Aspects of LNTSA:

- Design, supply and installation of latest Low NOx Burners technology
- Supply and Installation of Replacement Catalyst
- Fixed range of O_2, Pulverizer Fineness, and Over-fired Air Percentage
- Design, supply and installation of Over-fired Air Ports (as required)
- Periodic Pulverizer Fineness Tuning as required
- Periodic Combustion Tuning as required
- Periodic SCR Tuning as required

Process Requirements

Information required to run LTNSA Model:

- Burner/Windbox drawings
- Furnace dimensions
- Operating data
- SCR Gas data
- Catalyst deactivation curves
- Pulverizer fineness reports
- Fuel Analysis

MHPSA - your guaranteed sole source total solution provider

Summary

- Bringing MHI and Hitachi together provides our customers the most advance class technologies for all US Coal Plants.
- M-PM Burner technology for T-fired boilers will provide the lowest NOx emissions to meet existing and future regulations.
- MHPSA is the ONLY company that has advanced technology in ALL aspects of DeNOx Systems
- Will provide Guaranteed O&M savings as a “wrapped” total NOx solution package:
  - Ultra-Low NOx Burner
  - Catalyst Life Extension
  - Ammonia Consumption Savings

Single Source for Solid Fuel and Environmental Services

Thank you very much

MITSUBISHI HITACHI POWER SYSTEMS, LTD.