

REINHOLD ENVIRONMENTAL Ltd.



2017 NO_x-Combustion-CCR Round Table Presentation

February 27 & 28, 2017, in Cleveland, OH / Hosted by FirstEnergy

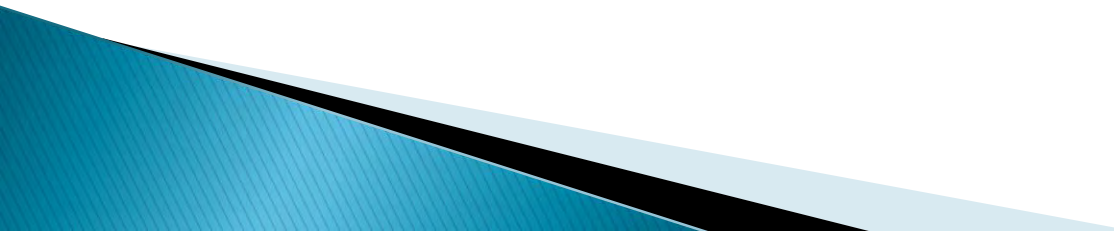
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CSAPR Update & SCRs

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2017 NOx-Combustion-CCR Round Table
Monday, February 27, 2017

CSAPR Rule Update

- ▶ Updated Rule Proposed Sept. 7, 2016 and published in Federal Register Oct. 24, 2016 with final rule effective on Dec. 27, 2016
 - ▶ Compliance ozone season 2017
 - ▶ No new SCRs required
 - ▶ Lower NO_x emissions required for some sites
 - ▶ Implementation cost = \$68,000,000 (annual)
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EPA's Compliance Cost

- ▶ For operating SCRs
 - Marginal cost to increase from partial operation to full operation reflects cost of additional reagent (does not include increased catalyst or O&M costs)
- ▶ Cost Estimates for Returning an Inactive SCR to Full Operation
 - All fixed and variable operating costs such as auxiliary fan power, catalyst, and additional administrative expenses, labor, and reagent
- ▶ Cost per unit \$241,000 per boiler??

Ballpark Cost Including Non-CAIR Units

	Plants with SCRs MW	Heat Rate used by EPA Btu/kWhr	Convert kW to MW 1,000	NOx Emissions lb/MMBtu	Convert MMBtu to Btu 1/1,000,000	Convert lb/Tons 1/2,000	Ton of NOX/hr
Current operations	143,163	10,900	1,000	0.14	0.000001	0.0005	109.23

EPA projected	143,163	10,900	1,000	0.081	0.000001	0.0005	63.20
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Nox Reduction T/hr	46.03
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Hrs in ozone season	3,672
Availability	80%
Ozone NOx tons reduced	135,230

Reagent cost based on EPA's cost of \$500/t of NOx

\$ 67,614,831

EPA TOTAL cost projection

\$68,000,000

Reagent Cost 500 MW

	Plants with SCRs MW	Heat Rate used by EPA Btu/kW hr	Convert kW to MW 1,000	NOx Emissions lb/MMBtu	Convert MMBtu to Btu 1/1,000,000	Convert lb/Tons 1/2,000	Ton of NOX/hr
Current operations	500	10,900	1,000	0.14	0.000001	0.0005	0.38
EPA Projected	500	10,900	1,000	0.081	0.000001	0.0005	0.22

NOx Reduction T/hr	0.16
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Hrs in ozone season	3,672
Availability	80%
Ozone NOx tons reduced	472

Reagent cost based on EPA's cost of \$500/t of NOx

\$ 236,146

EPA TOTAL cost projection per boiler

\$241,000

CSAPR and Allowance Prices

- ▶ Why Allowance Prices are Important
 - Some units may not be operating at design capacity
- ▶ 2013 Allowance Market Prices
 - CAIR NO_x annual allowances averaged \$40/T
 - CAIR NO_x ozone season allowances averaged \$17/T
- ▶ Reagent cost: EPA used \$500/ton of NO_x
 - EPA used the wrong reagent cost

Allowance History

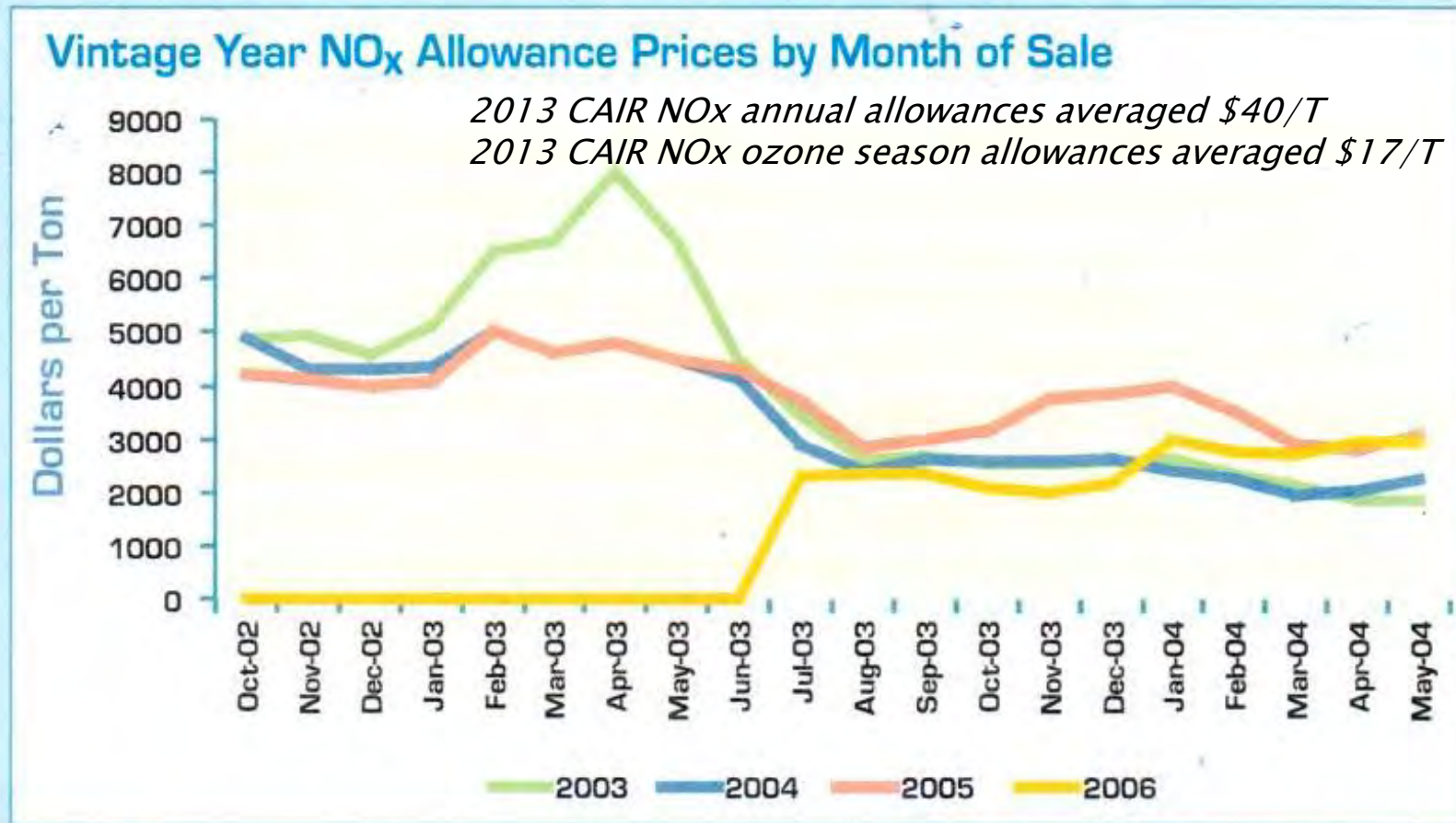



Figure 12

NBP allowance prices have fallen sharply after some early price spikes.

Source: Evolution Markets, LLC and Cantor Environmental Brokerage

EPA Control Approach: Page 1

- ▶ Fully operating existing SCRs to achieve 0.081 lb/MMBtu NO_x emission rate (costs estimated outside IPM) moving from an emission rate of 0.075 lb/MMBtu
 - ▶ Shift generation to minimize costs (costs estimated within IPM) gas, nuclear, etc.
 - ▶ Turn on idled SCRs (costs estimated within IPM)
 - ▶ Install or upgrade combustion controls (costs estimated outside IPM)
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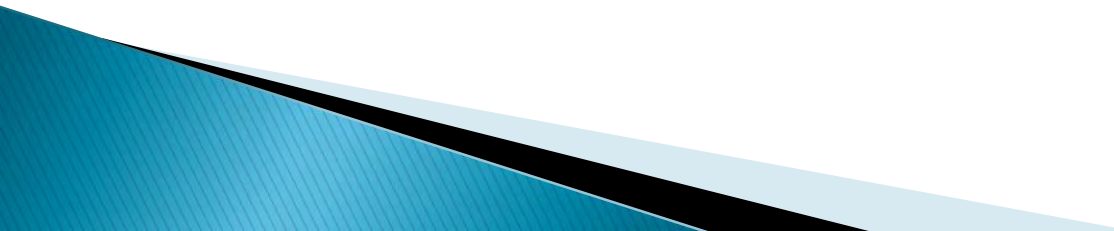
EPA Control Approach: Page 2

- ▶ Upgrade existing SCR's to meet 0.081 lb/MMBtu NO_x Annual NO_x Emission Rates. In 2013 the CAIR and ARP annual NO_x emission rate was 0.14 lbs/MMBtu, a 49 percent reduction from 2005. Despite the dramatic decrease in tons of NO_x emission, heat input has remained relatively steady, indicating an improvement in emission rate. This is due in large part to greater use of control technology on coal-fired units and increased heat input at natural gas-fired units.

EPA Economics

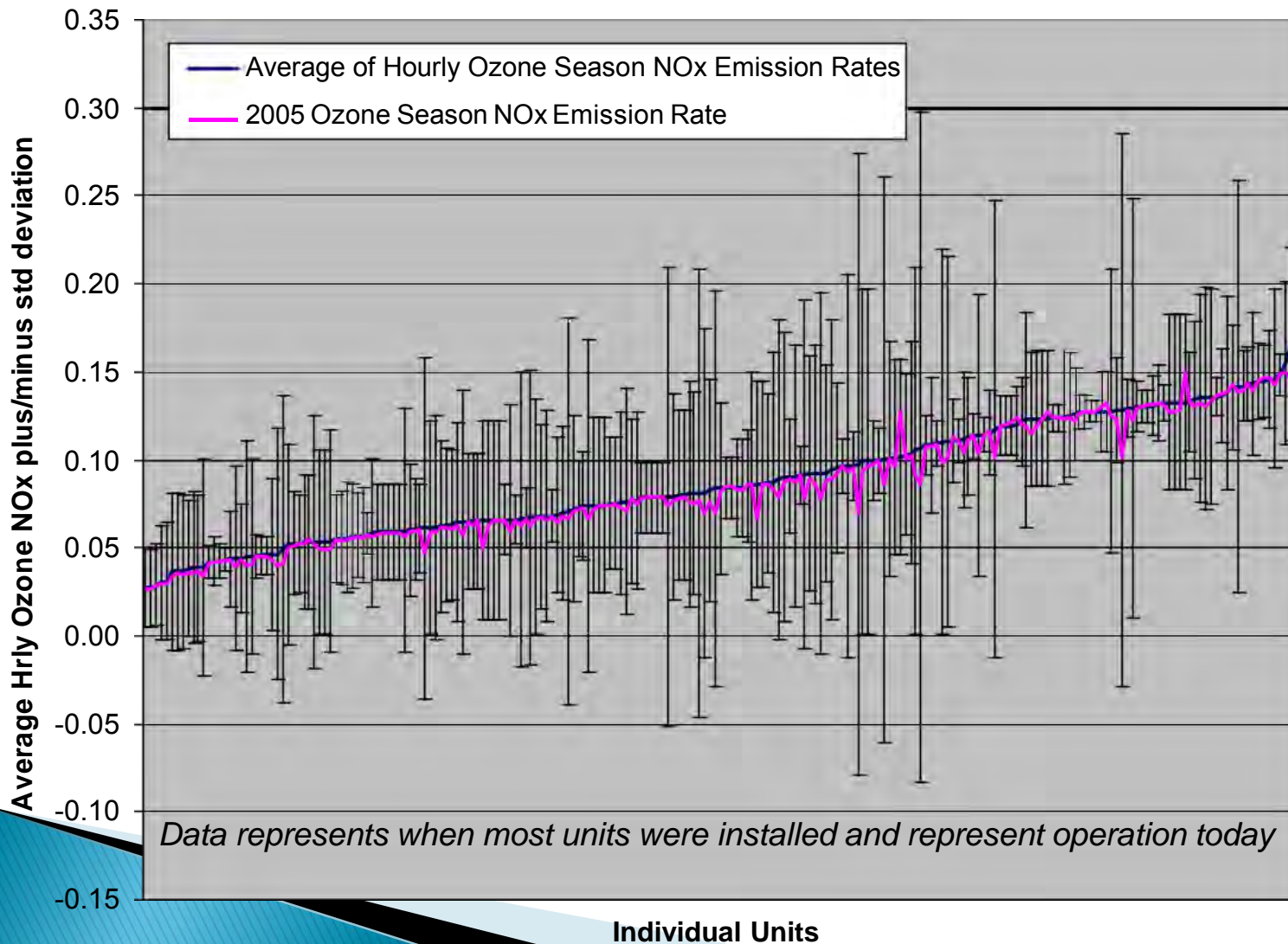
- ▶ Fully operating existing SCRs (SCRs operating in base case): 24,100 tons \$670/ton
- ▶ Fully operating existing SCRs (SCRs not operating in base case): 4,500 tons \$1,000/ton
- ▶ Installing or upgrading NOx combustion controls: 9,700 tons \$1,200/ton
- ▶ EPA's projected reagent cost \$/ton NOx
 - In 1999 cost per ton \$108
 - In 2015 cost per ton \$500

NOx Emissions – Conflicting Databases


- ▶ 226 coal-fired EGUs with SCRs in EPA Clean Markets database avg. annual NOx emissions 0.13 lb/MMBtu (2015)
 - ▶ EPA's Needs 5.15 database has 282 coal-fired EGUs currently operating representing 143,163 MW approximately 50% of coal fleet.
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Historical Data 2005 Ozone Season

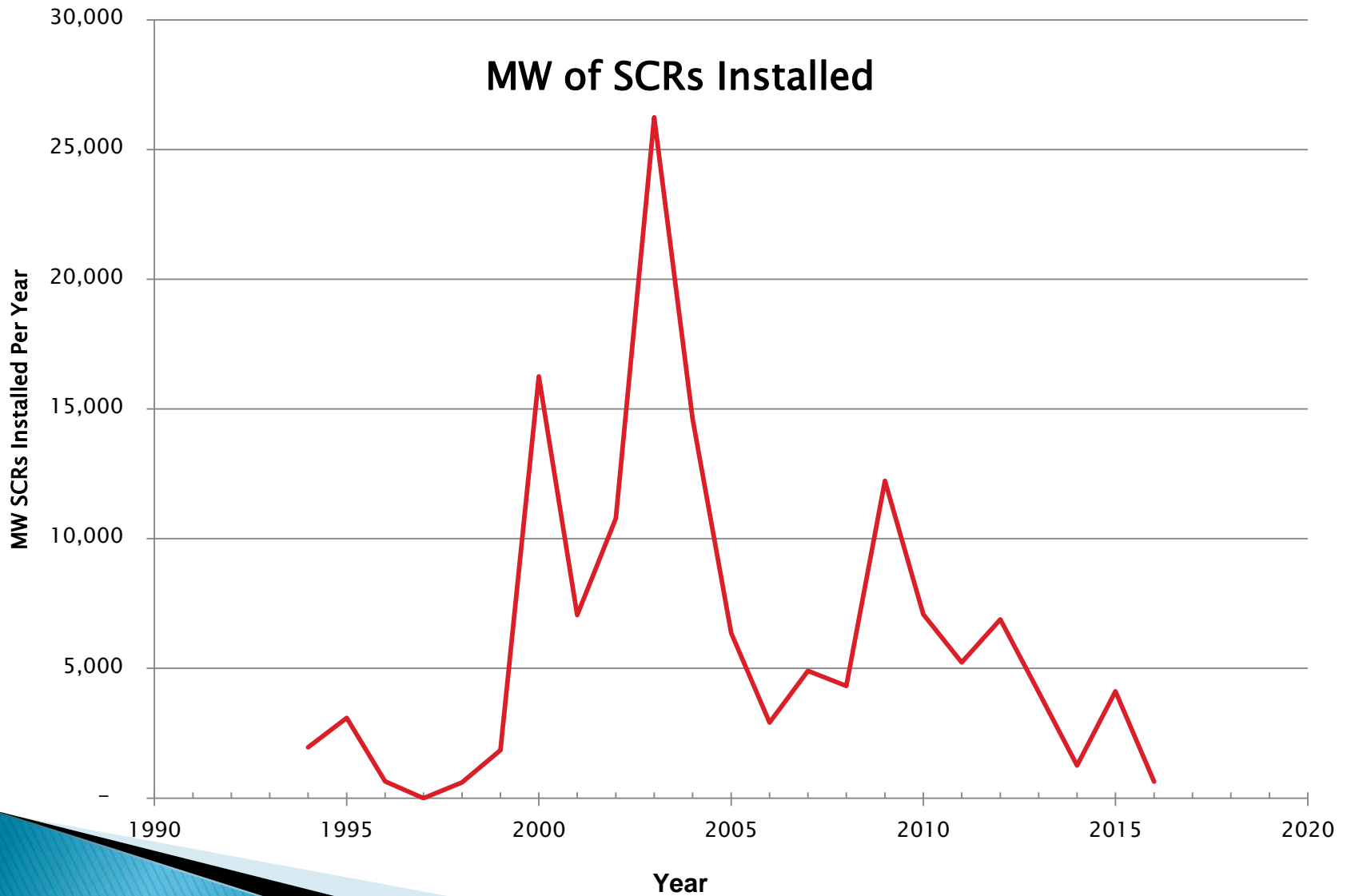
Average Hourly Ozone Season NOx Emission Rate Plus/Minus Standard Deviation



SCRs Return to Service

- ▶ Re-commissioning of idle SCRs
 - ▶ Upgrading low performing SCRS
 - ▶ Many SCRs are over 10 years old and were installed with SCR bypasses for OTAG.
 - ▶ Must consider compliance with CSAPR Update rule in conjunction with MATS and the Startup, Shutdown and Maintenance rules (SSM) also cycling loads, and extended shutdown periods and low load operations
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Aging Fleet of SCRs



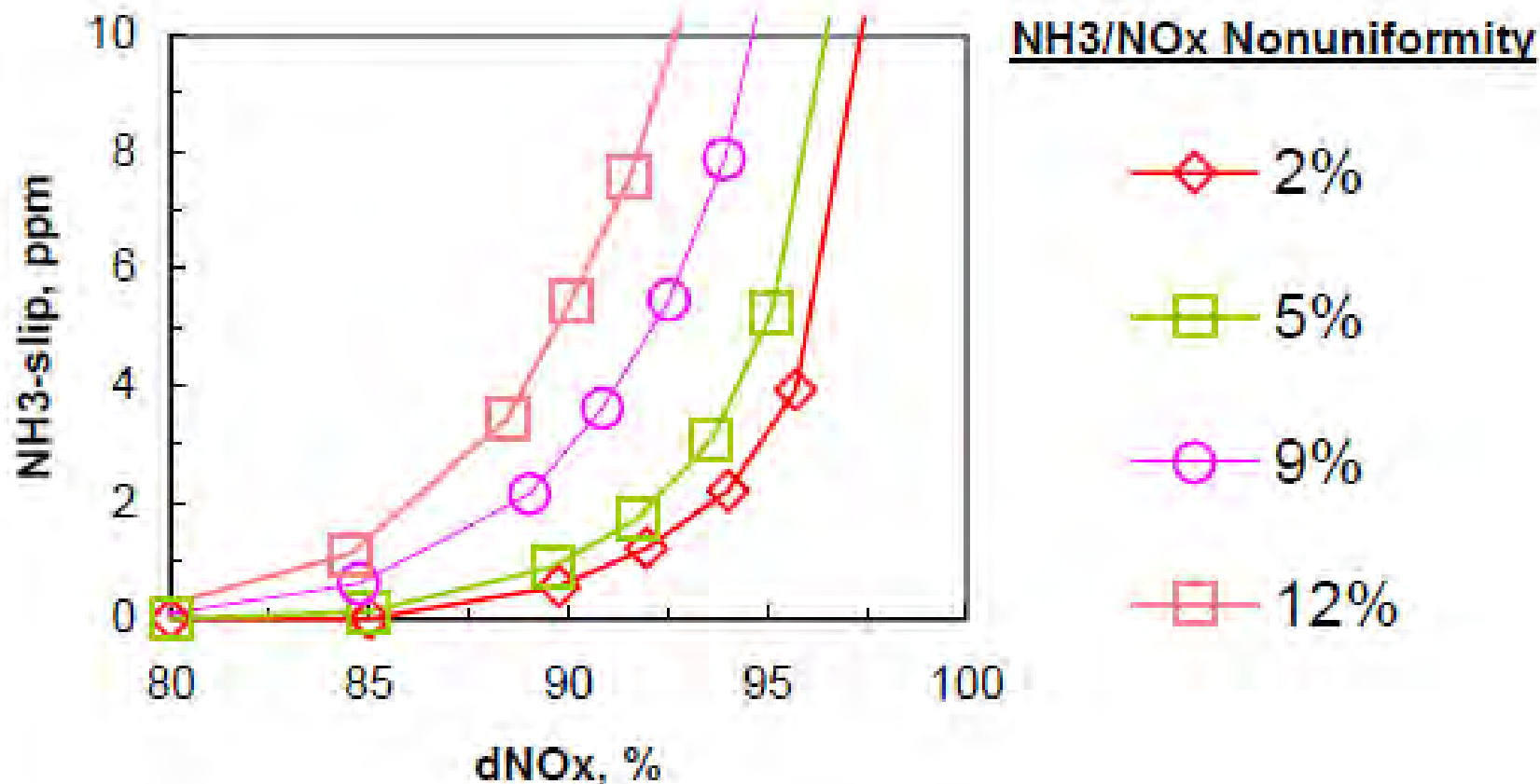
Issues Impacting SCR Performance: Page 1

- ▶ Variable load and flue gas conditions
 - Installation of economizer bypass
 - Startup/Shutdown rule
- ▶ Variable firing conditions (dual fuel configurations)
- ▶ Poor distribution
 - ABS formation in lances, catalyst and air heater
 - Ash build up in duct and on catalyst face
 - Poor temperature distribution impacts reduced load operation
 - High ammonia slip impacting marketability of fly ash

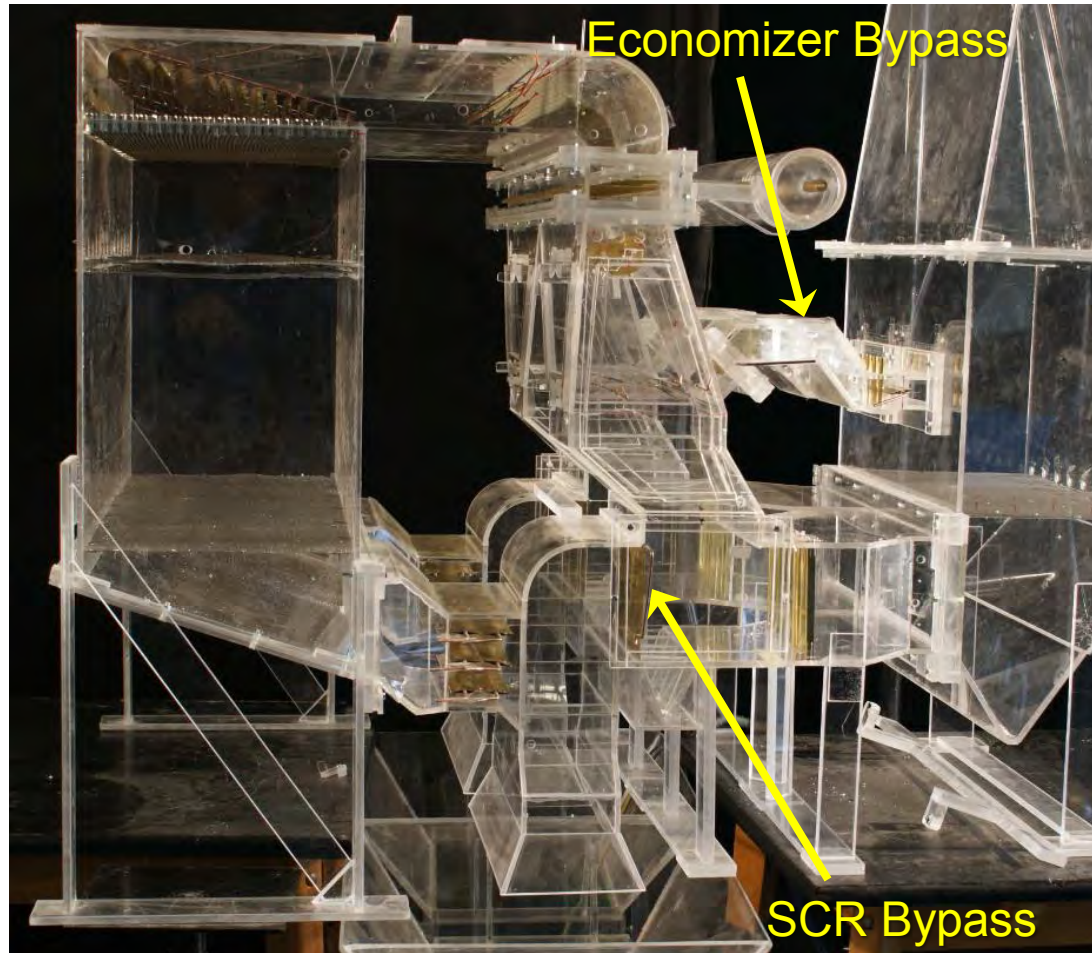
Issues Impacting SCR Performance: Page 2

- ▶ Year round SCR operation
 - More frequent catalyst change out may require quick-release large access doors (limited to number of times cut/weld panels off and on)
 - Utilize spare layer
- ▶ SCR bypass
 - Not required for startup/shutdown operation (even with oil)
 - Impacts flue gas distribution
 - Flue gas leaking through bypass causing issues with corrosion and issues with maintaining emissions limit
 - O&M associated with seal air system

Effect of Maldistribution on SCR Performance



SCR & Economizer Bypass Dampers

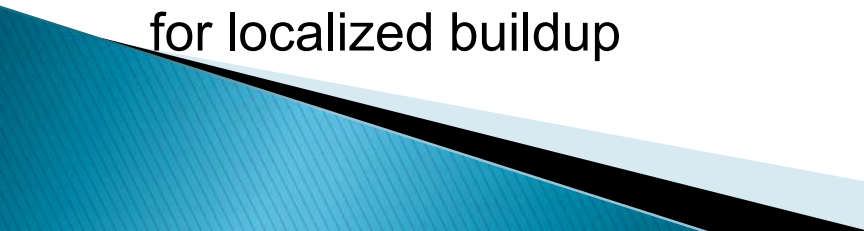


SCR Issues to Improve Performance: Page 1

- ▶ Proven Physical Modeling to improve distribution at full and reduced loads
 - Complete model to reflect actual operation
 - Improve distribution; additional mixers, turning vanes and air flow straighteners
 - Determine additional pressure drop and load on structural steel members
- ▶ Eliminate SCR bypass – Add Economizer gas or water-side bypass
 - Seal bypass & remove damper to off-balance weight added with additional mixers
 - Install screens over catalyst face; if necessary, add cleaning devices for localized buildup

SCR Issues to Improve Performance: Page 2

- ▶ Eliminate Corrosion: Structural and expansion joint leakage
 - New expansion joints and welding repairs

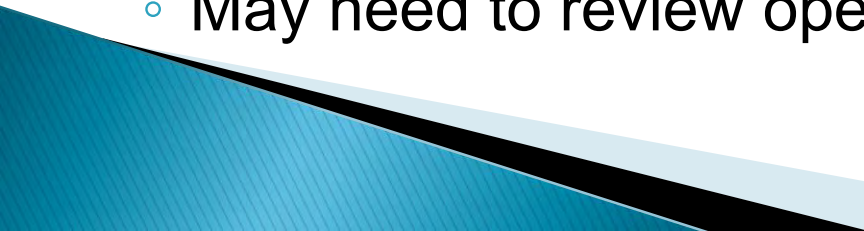
 - ▶ Improve Ash Distribution
 - CFD modeling to reduce number of high velocity zones; if necessary utilize erosion protection if high velocity areas cannot be eliminated and protect all leading edges
 - Complete dust model to maintain ash entrainment, improve distribution and minimize erosion issue on catalyst sections
 - Install screens over catalyst face and, if necessary, add cleaning devices for localized buildup
- 

SCR Issues to Improve Performance: Page 3

▶ Reagent Type/Supply

- Wide fluctuation in price related to gas prices
- Urea vs anhydrous or aqueous ammonia
- Vaporization vs direct ammonia injection

▶ LPA Screen/Issues

- Complete CFD modeling to reduce high velocity zones
 - Correct hopper issues with ash movement
 - May need to review operation and modify installation
- 

SCR Issues to Improve Performance: Page 4

▶ New Catalyst

- Replace catalyst or add spare layer to meet lower NO_x emissions
- Meet MATS Hg emission limits and/or minimize SO₃ formation
- Lower minimum operating temperature (coupled with improving temperature distribution)

▶ Startup bypass installed

- Meet the SSM rule and better annual NO_x rate

What an Upgrade Can Do: Page 1

▶ O&M Savings

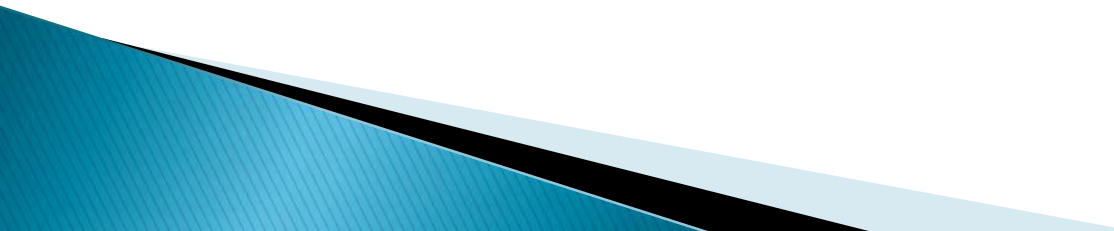
- Reduce ammonia slip across all load
- Reduce pluggage and negative effects of ABS
- Reduce ammonia consumption and costs
- Reduce vaporizer trips and leaks
- Reduce SCR tuning requirements
- Increase catalyst life

▶ Improve Safety

- Reduce ash buildup

What an Upgrade Can Do: Page 2

▶ Optimize Performance

- Lower NO_x emissions due to better mixing can reduce emissions while maintaining slip
 - Increase SCR system reliability
 - Improve load following capabilities of SCR systems
 - Improve gas distribution
 - Generate additional allowances
 - Improve air heater performance/heat rate
 - Fuel flexibility
- 

What an Upgrade Can Do: Page 3

▶ Additional Benefits

- Improve dry sorbent injection performance (by improving distribution)
- Faster startup/ramping for SSM
- Increased operating time and compliance
- Improve ash sales

Flue Gas Distribution – Flow Modeling

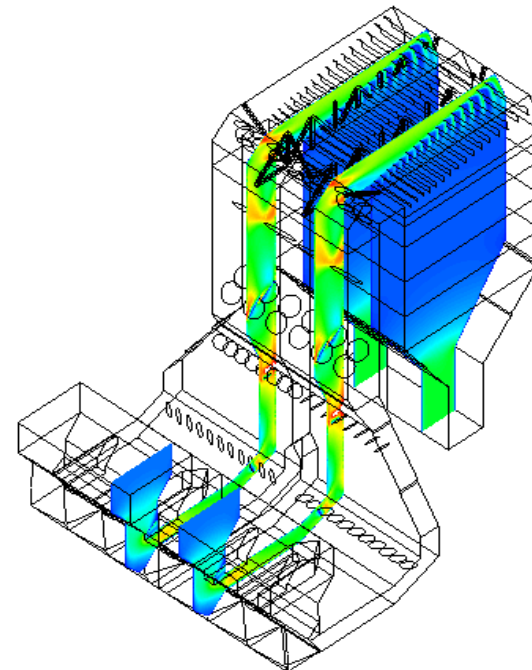
Physical Flow Models

- Multiple, iterative runs
- Model ductwork internals (i.e., trusses)
- Model dust drop out, build-up and re-entrainment
- Model pressure drop
- Proven scale-up

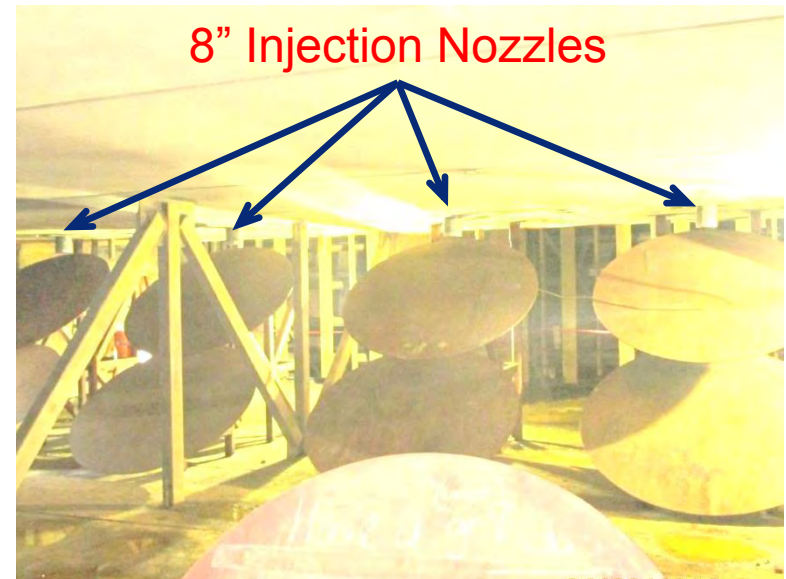


CFD

- Utilized to augment the physical flow model results
- Velocity profile can be reviewed in any section
- Design LPA screen layout
- Model interrogation capabilities



AIG Replacement with Static Mixers

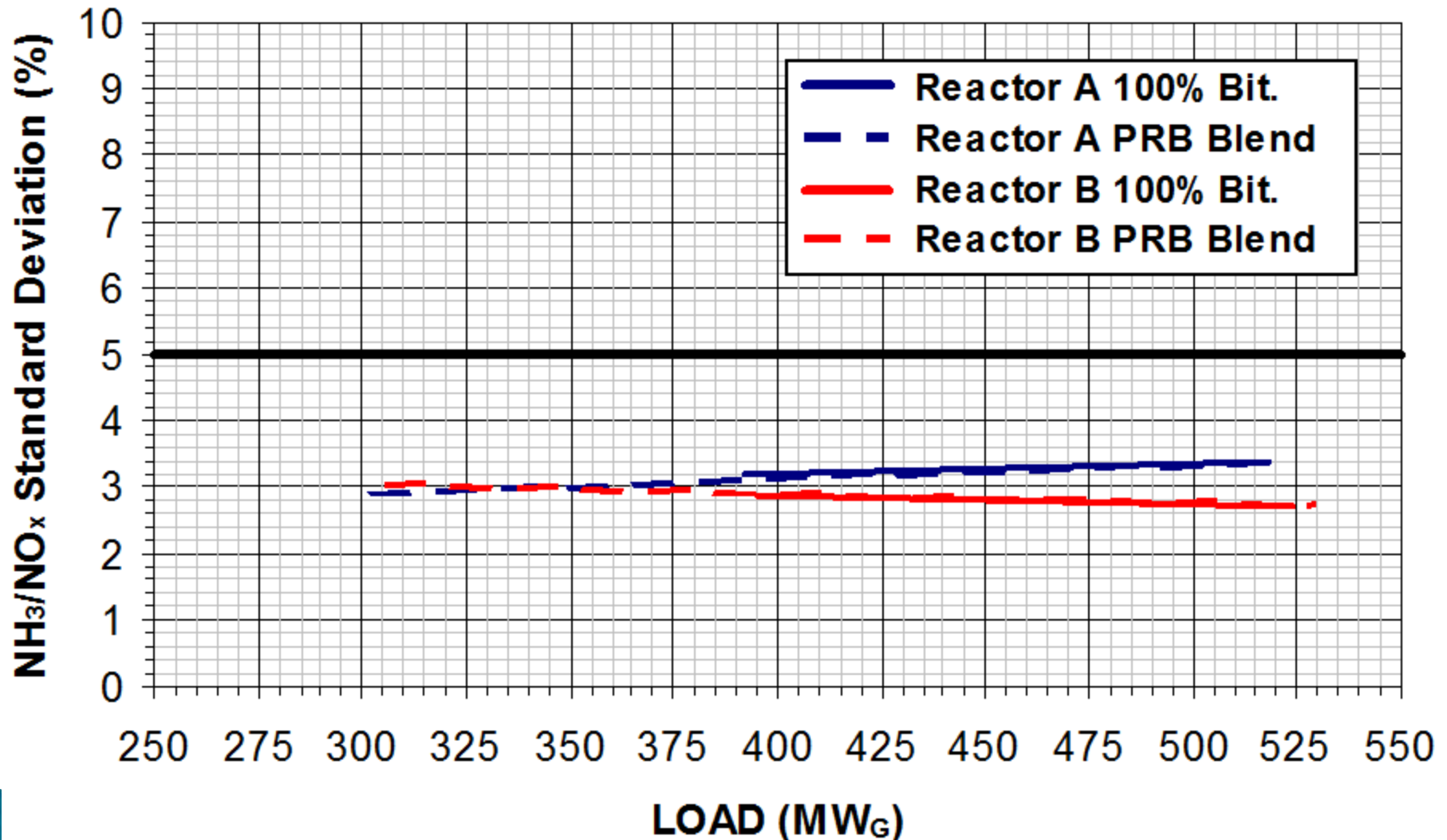


AIG Replacement with Static Mixer Results

	Unit 1	Unit 2
NOx Emissions before upgrade	0.088 lb/MMBtu	0.092 lb/MMBtu
NH ₃ /NOx, RMS%		
Before Upgrade	9.7%	7.5%
After Upgrade	3.8%	3.2%
Pressure Loss Increase	<2.0 iwc	<2.0 iwc
NOx Emissions after upgrade	0.057 lb/MMBtu	0.062 lb/MMBtu

Upgrade technology proven to address poor performance and unreliable operational issues with existing SCR systems

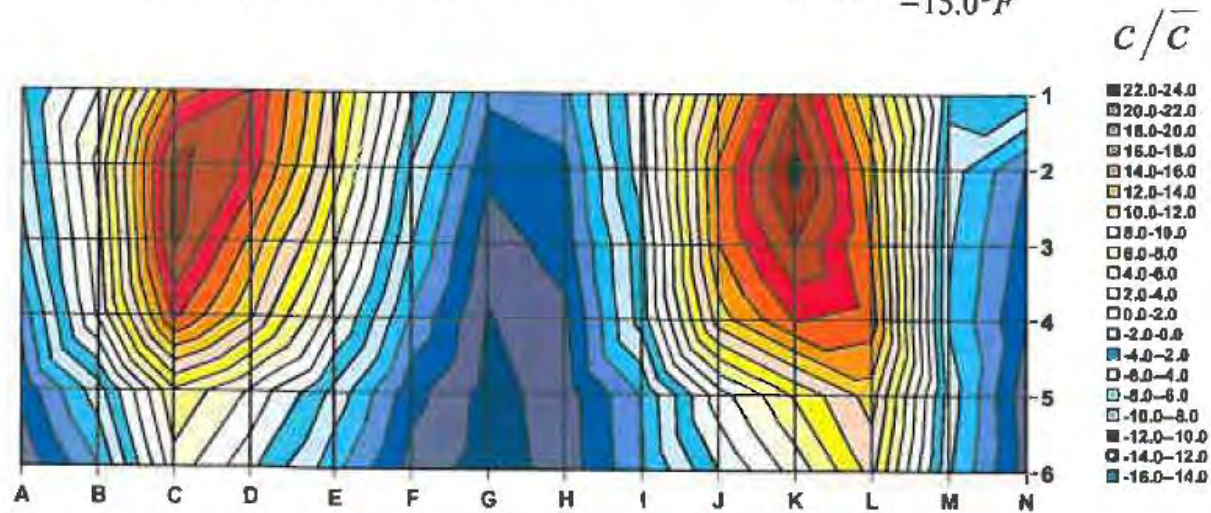
Mixing Consistency Throughout Load Range



Temperature Distribution Improvement

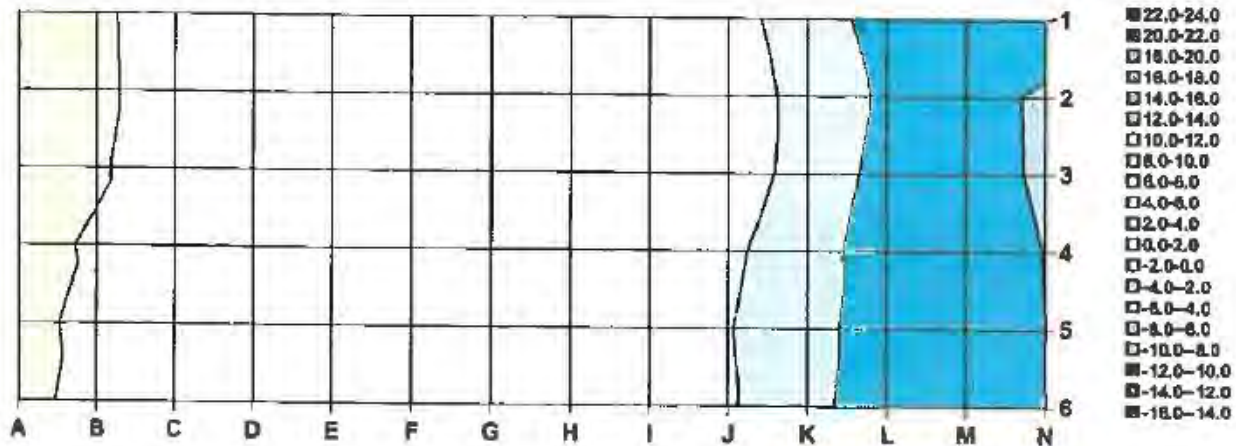
standard deviation $\sigma_{\Delta t} = 10.7^\circ\text{F}$

max $\Delta t = +22.9^\circ\text{F}$
 -15.0°F



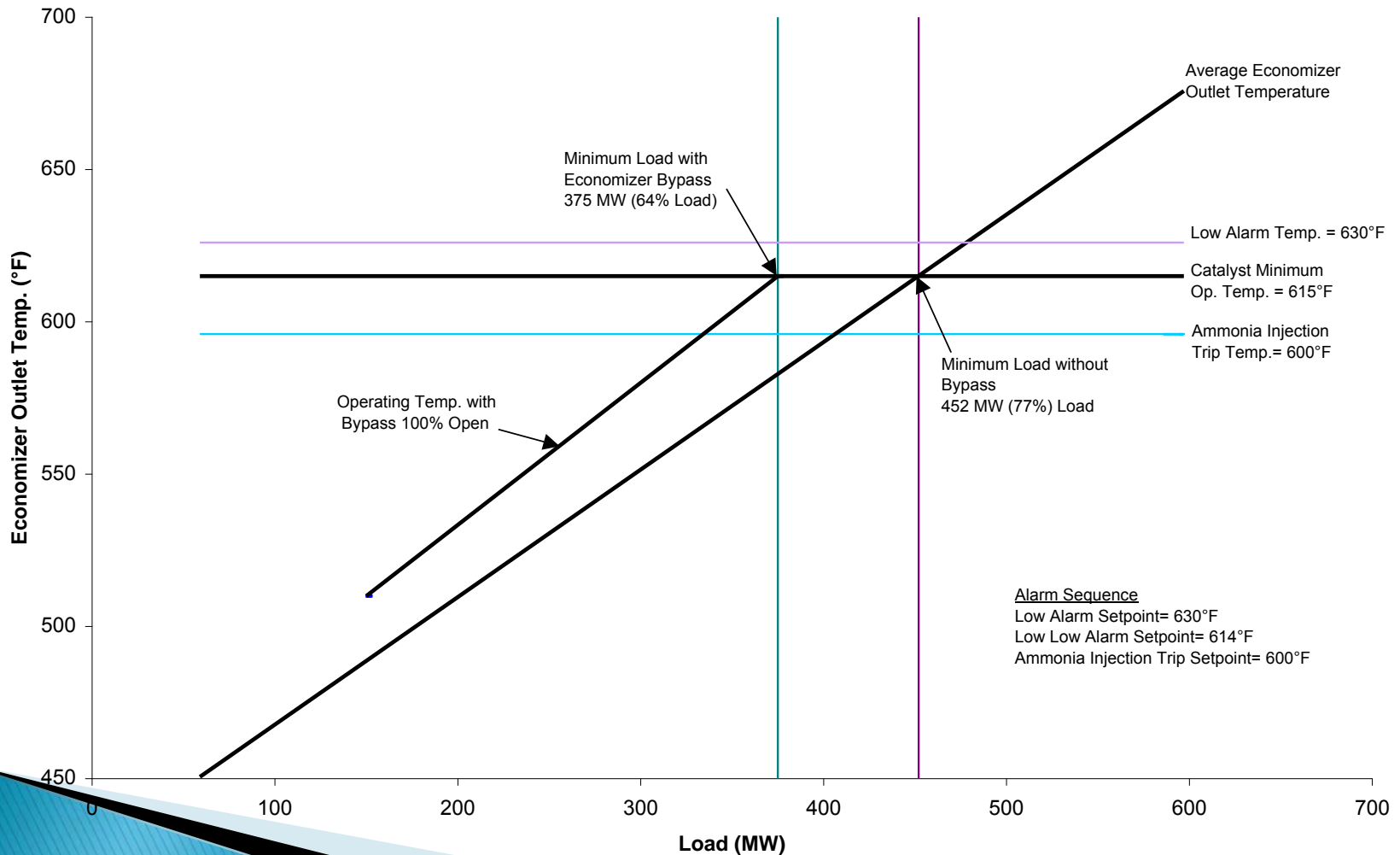
standard deviation $\sigma_{\Delta t} = 2.0^\circ\text{F}$

max $\Delta t = +3.2^\circ\text{F}$
 -4.2°F



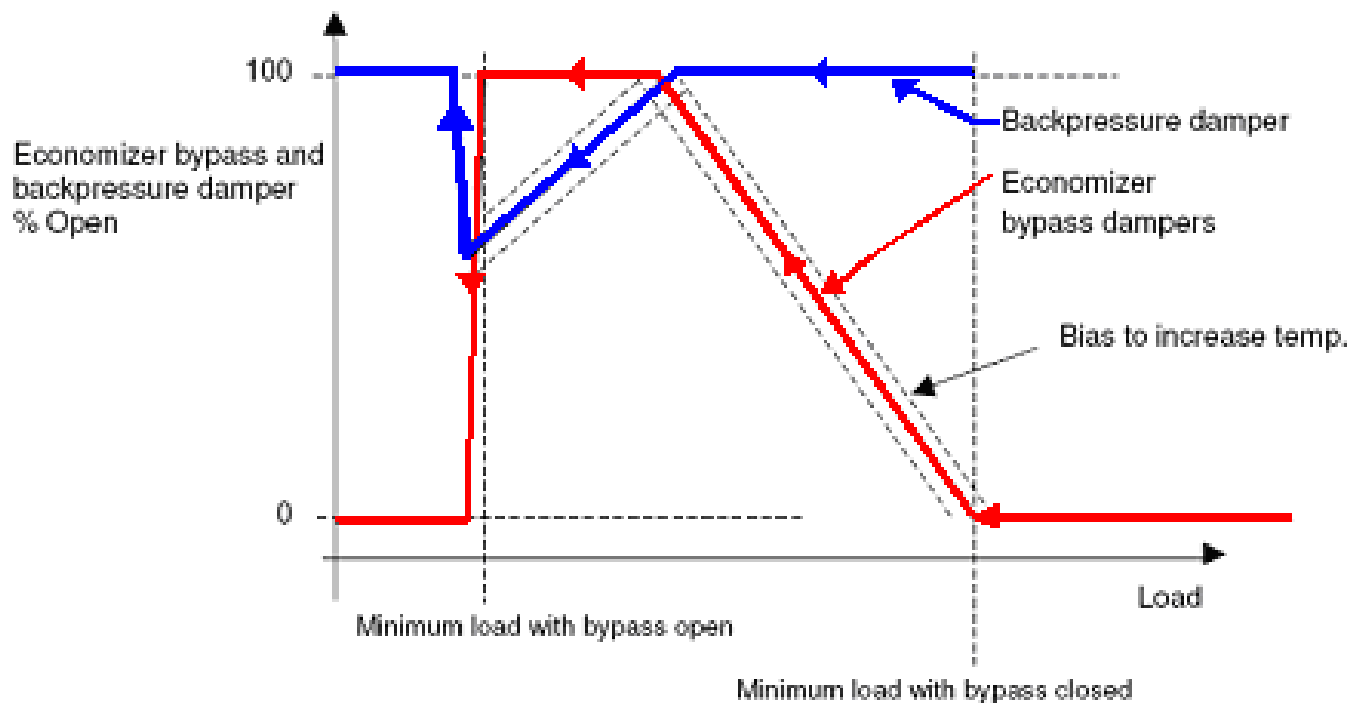
SCR Economizer Bypass Operation: Faster Startup, Load Operations, Cycling Loads

Economizer Outlet Temperature vs. Load

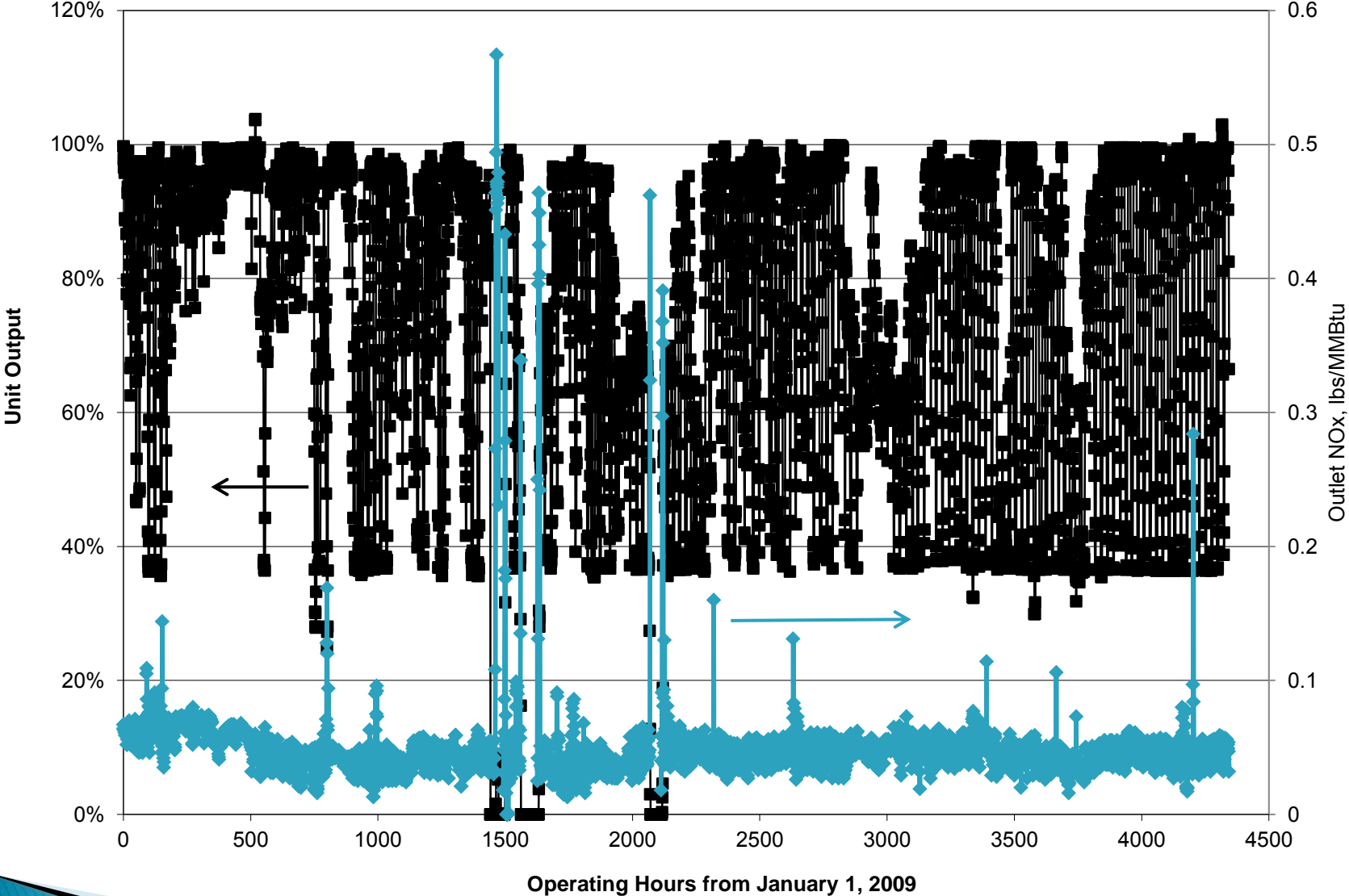


Morgantown – Min. Load 33% MCR

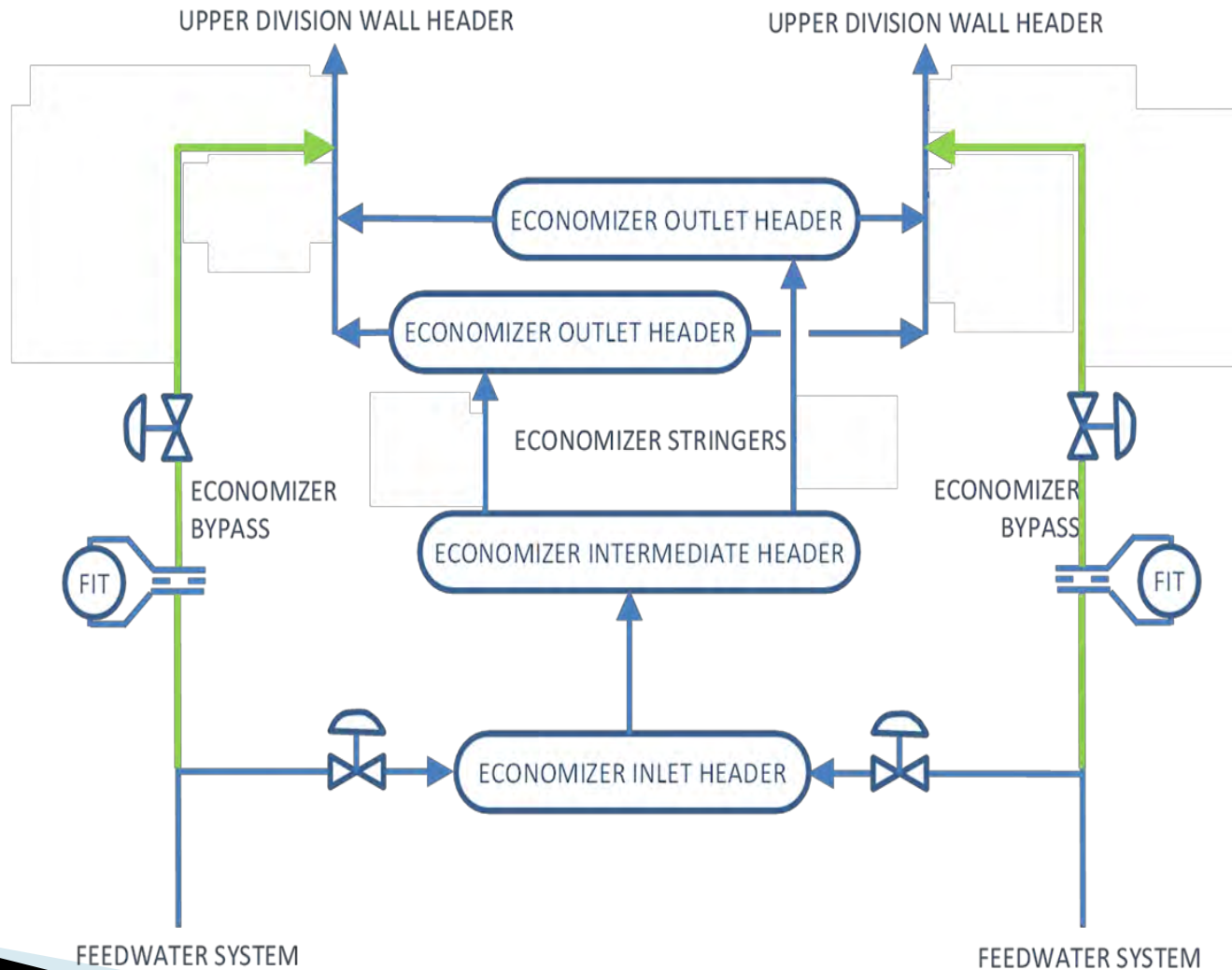
- ▶ Economizer exit gas temperature without bypass at minimum load: 495°F
- ▶ Flue gas temperature with economizer bypass at minimum load: 676°F
- ▶ NOx emissions:
 - Full load: 0.032 lb/MMBtu (93.6% – Guarantee 92.5%)
 - Min load: 0.048 lb/MMBtu (90.6% – Guarantee 90.0%)



Morgantown SCR, Unit 1

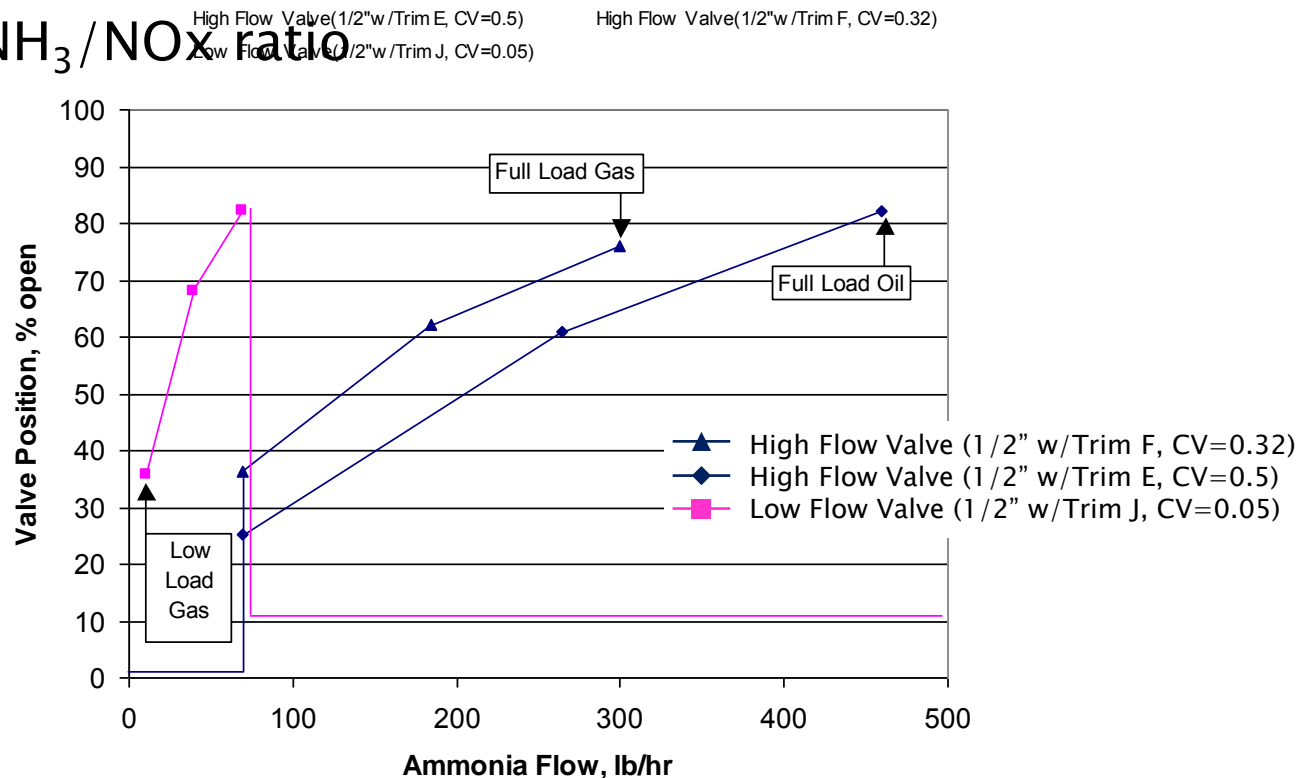


Alternative Option: Economizer Water-Side Bypass Design



Option – Enhanced Automatic Controls

- ▶ Address a wide range of ammonia demands for dual fuel systems
- ▶ Address large NOx gradient issues on systems where upstream mixing is limited
- ▶ Utilize two control valves in series installed on each injector
- ▶ Control individual regions based on NOx concentrations
- ▶ Optimize NH₃/NOx ratio



EPA Final Rule Questions

- ▶ EPA considered agricultural grade ammonia and urea in cost analysis. Should have used industrial grade at $\approx 20\%$ higher cost. See ICAC Report
- ▶ EPA may not have consider cost of outages to install combustion controls. Most plants have already installed upgraded combustion controls.
 - Some new burners will not fit in existing openings and over fire air requires new opening
- ▶ Did EPA consider the cost on intelligent controls, modeling, new AIG injection, MATS?

Summary and Conclusions

- SCR systems are a mature technology
 - Installed US fleet can benefit from upgrades based on proven technology approach of modeling and utilization of mixers
 - Reduced load operation may require modifications around the economizer section
 - Problems solvable with upgrades to current SCR technology but may exceed EPA's cost estimate
- 