One Source…Many Solutions…One Purpose

What's New in SCRs

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DOE's Environmental Control Conference

SCR Technology

- System uses NH_3 or urea injected into the flue gas upstream of active reduction catalyst
- In the catalyst, NOx is reduced selectively by the NH_3 to produce N_2, & H_20
- Catalyst reduces temperature for reduction reaction to ~600F
- Catalyst requires proper temperature, homogeneous NOx/ NH_3 mixture, homogeneous temperature, and uniform flow distribution at its inlet to perform properly
  - Catalyst typically is honeycomb or plate configuration
  - Life is dependent on poisons present in flue gas; typically 8,000 to 24,000 hours of operation

Operating History of SCR Retrofits in US

- Before 1998 < 1,000 MW
- By 2005 ≈85,000 MW
- By 2009 140,000 MW

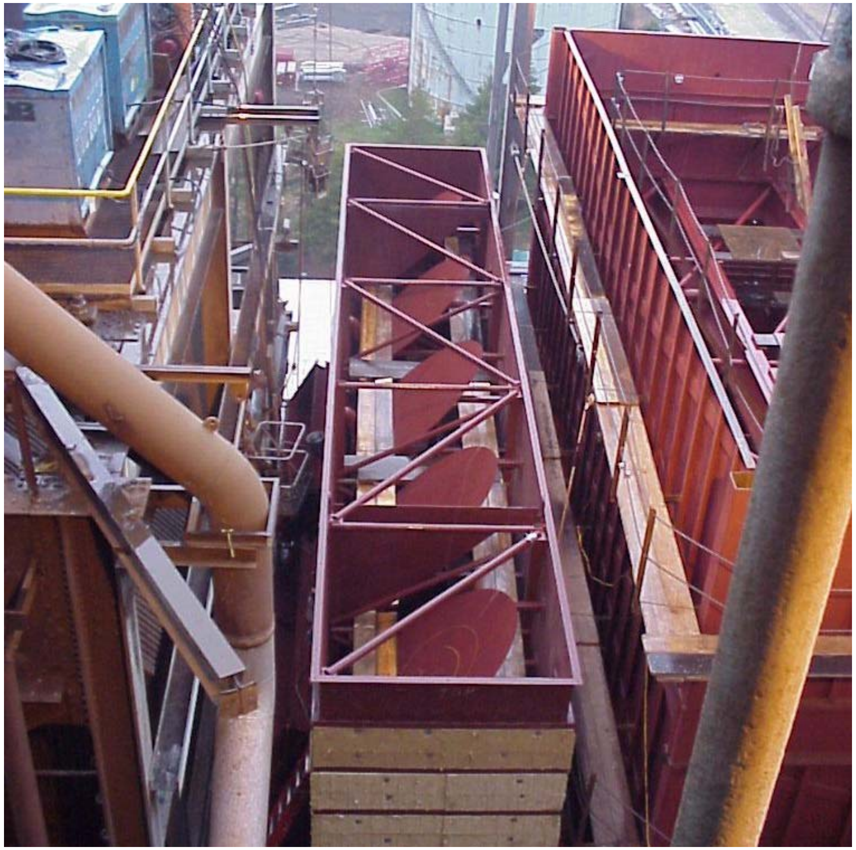
- NOx removal
  - 85 – 92%
- Availability
  - >99%

Technological Challenges

- Currently most SCRs operate during ozone season 5 months per year
- Under new CAIR rules NOx control will be required 12 months per year
  - Catalyst management
  - Outage scheduling

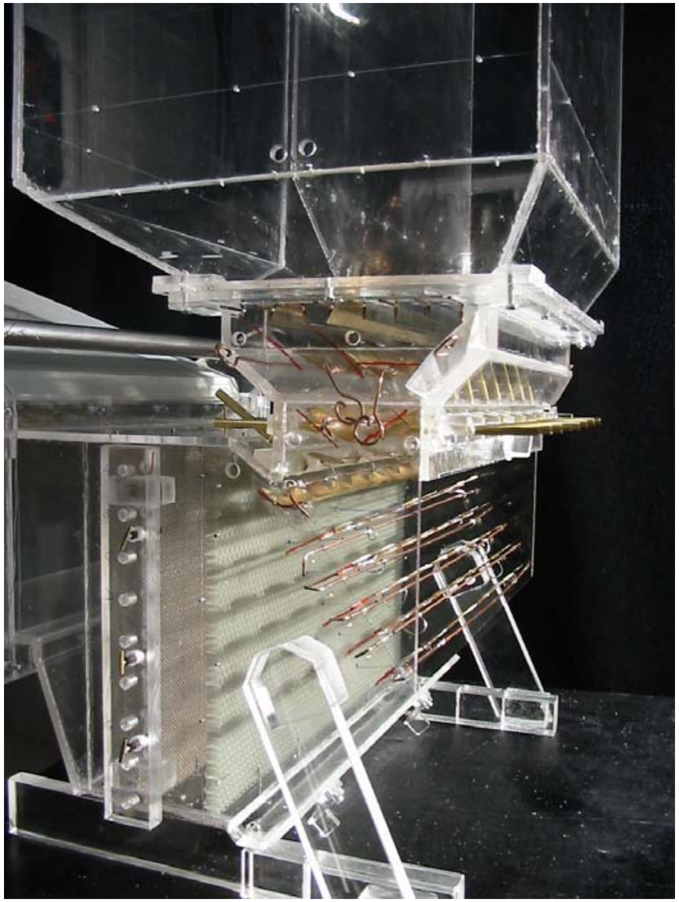
CAIR Retrofit Cost Challenges

- High Cost Low Revenue Units
  - Older Units
  - Smaller Units
  - Peaking Units
  - High Heat Rate Units
- High Retrofit Cost
  - Tail-end SCRs
  - Marginal Cost
- Boiler Modifications



CAIR Retrofit Challenges

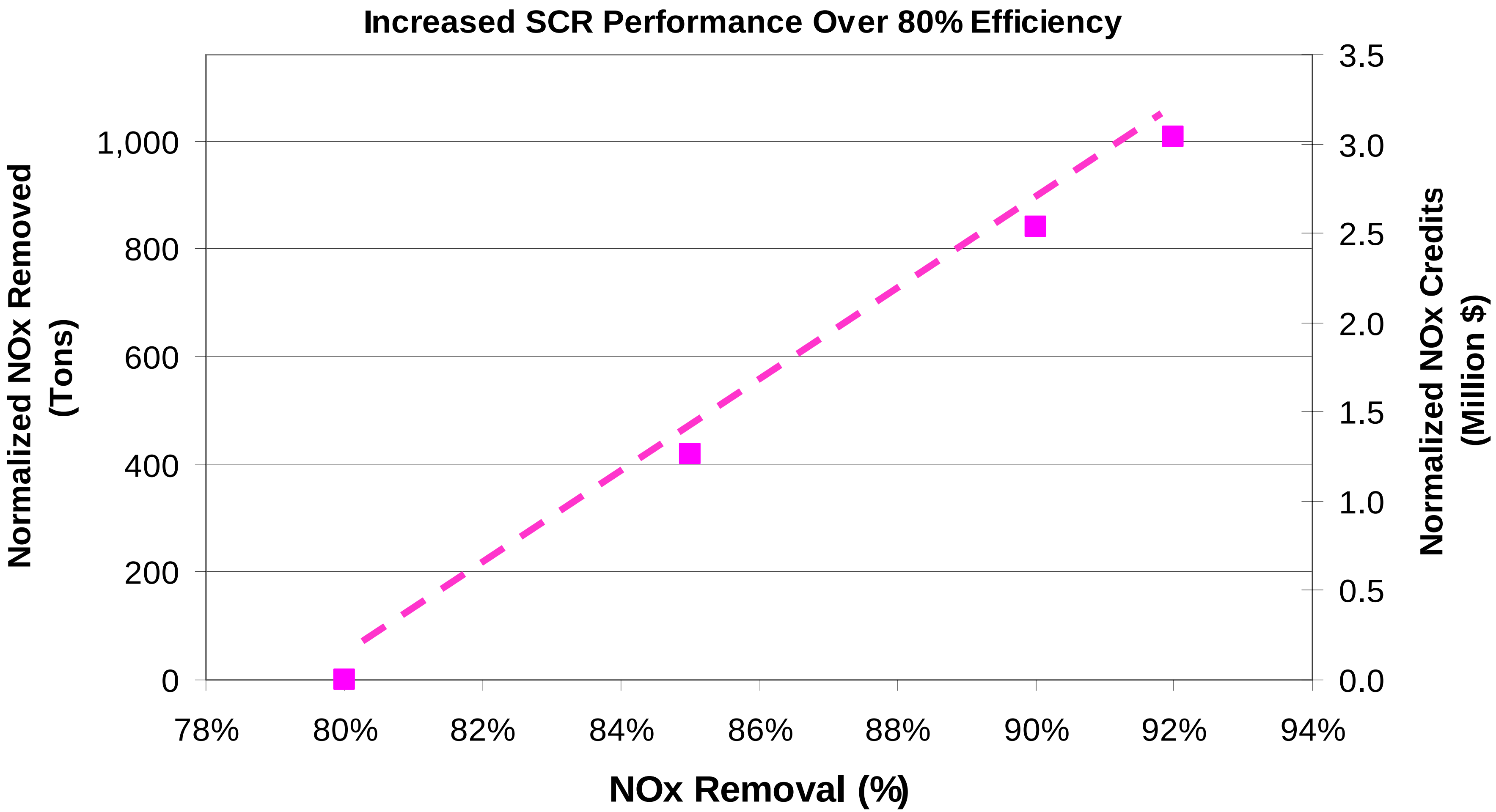
- Fuel flexibility
  - Catalysts are a component of fuel cost
  - Poisons, NOx compliance
  - PRB proliferation
- Shorter emission averaging times
- Mercury, SO_3
  - Higher S fuels
  - New catalyst



New SCR Challenges

- Most new SCR will not be built with bypass system
  - Lower capital and maintenance cost
  - May limit fuels burned
  - Need improved catalyst management/fuel use strategy
  - SO_3 conversion
- Future value of NOx and SO_2 credits
  - Banking, availability, $

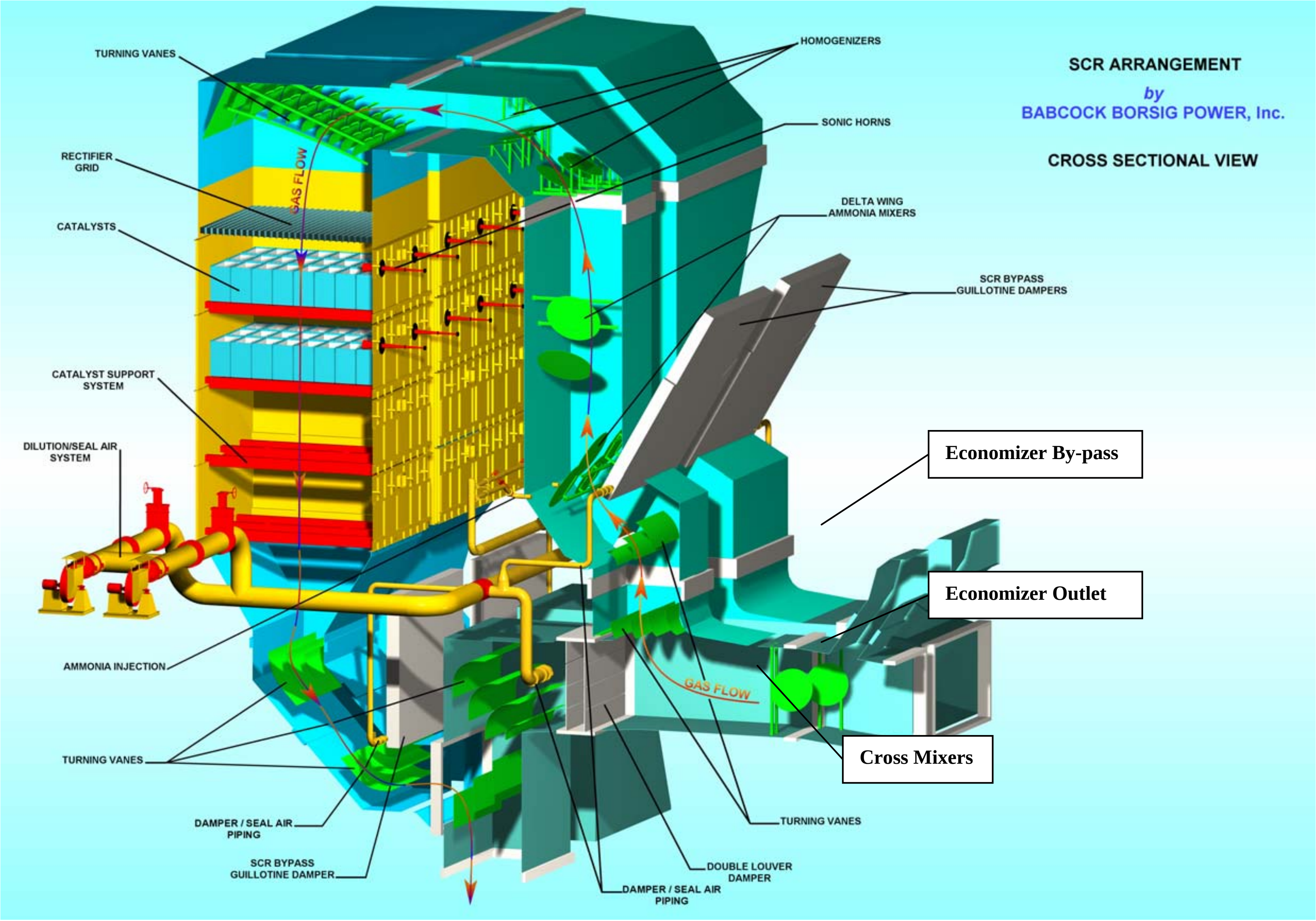
$ Impact of 600 MW SCR Operations



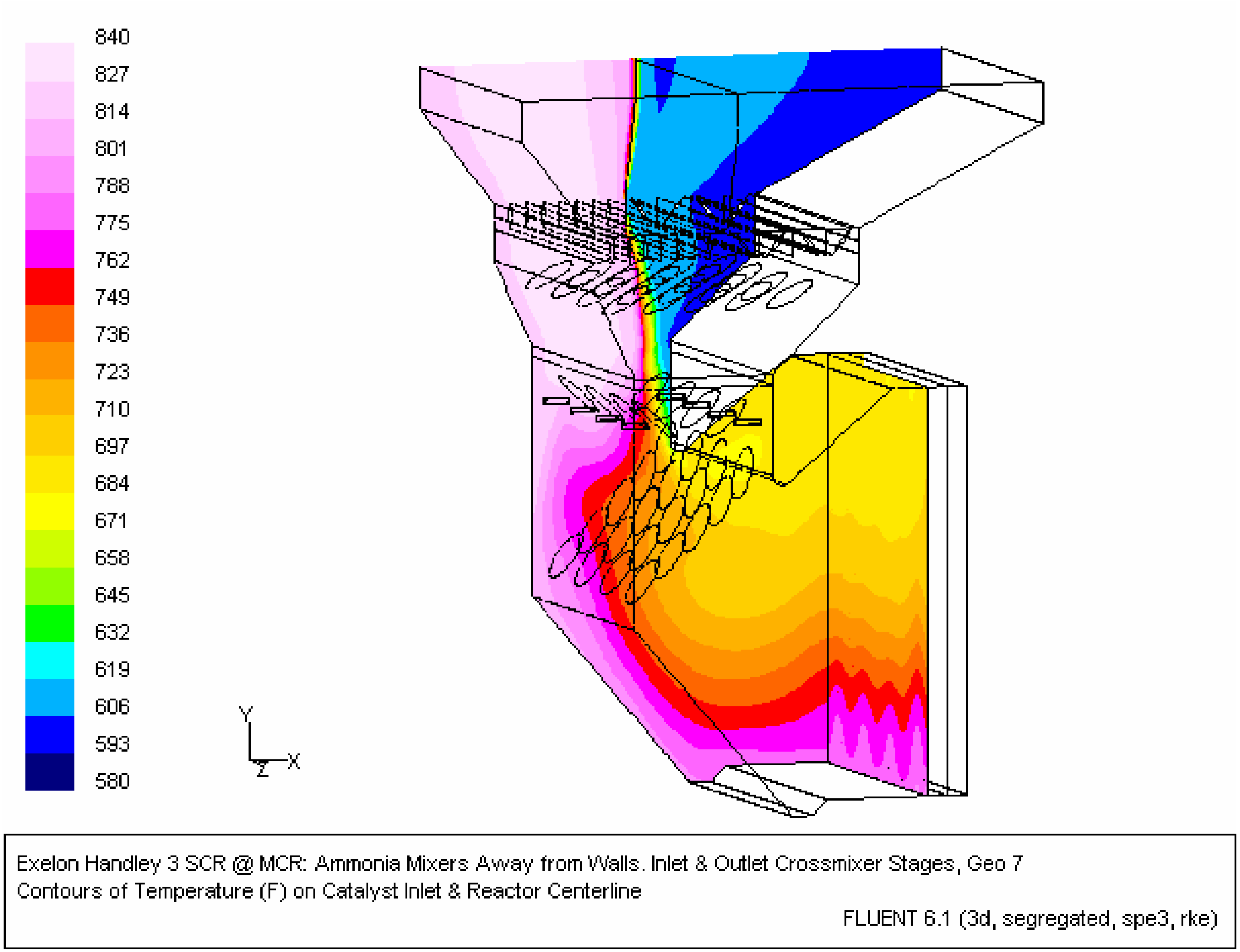
SCR Options

- "Full" SCR System
- Compact In-Duct SCR Reactor
- Hybrid SNCR/ In-Duct SCR System ("Cascade®")
- Tail-end SCR systems (RSCR)

Full SCR System



In Duct SCR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Exelon Handley 3 SCR @ MCR: Ammonia Mixers Away from Walls. Inlet & Outlet Crossmixer Stages, Geo 7
Contours of Temperature (F) on Catalyst Inlet & Reactor Centerline
FLUENT 6.1 (3d, segregated, spe3, rke)

Hybrid Project Overview

- BPE has been selected to provide a hybrid SNCR/In-Duct SCR to coal-fired plant
- Fuel Tech to supply Noxout reagent, storage, injection and controls
- BPE to provide static mixers to homogenize the flow and excess slip, SCR reactor, and controls
- Unit will be in operation 5/2006
- Overall NOx reduction of ~ 65% required

Tail-End SCR Systems

- Installed upstream of stack, downstream of particulate removal
  - Clean gas
  - Low temperature gas (~300F)
- Only practical SCR solution for WFB, WTE plants (catalyst poisoning issues) space limitations – Mercer Station
- Erected, then tied in; minimal disruption to operations
- Requires energy input/heat recovery to minimize operating costs
- Typical tail-end unit consists of:
  - Heat exchanger
  - Duct burners
  - Ammonia injection
  - SCR reactor
  - Booster fans
- NOx reductions 60- 90%; energy efficiency ~70%; high $/KW

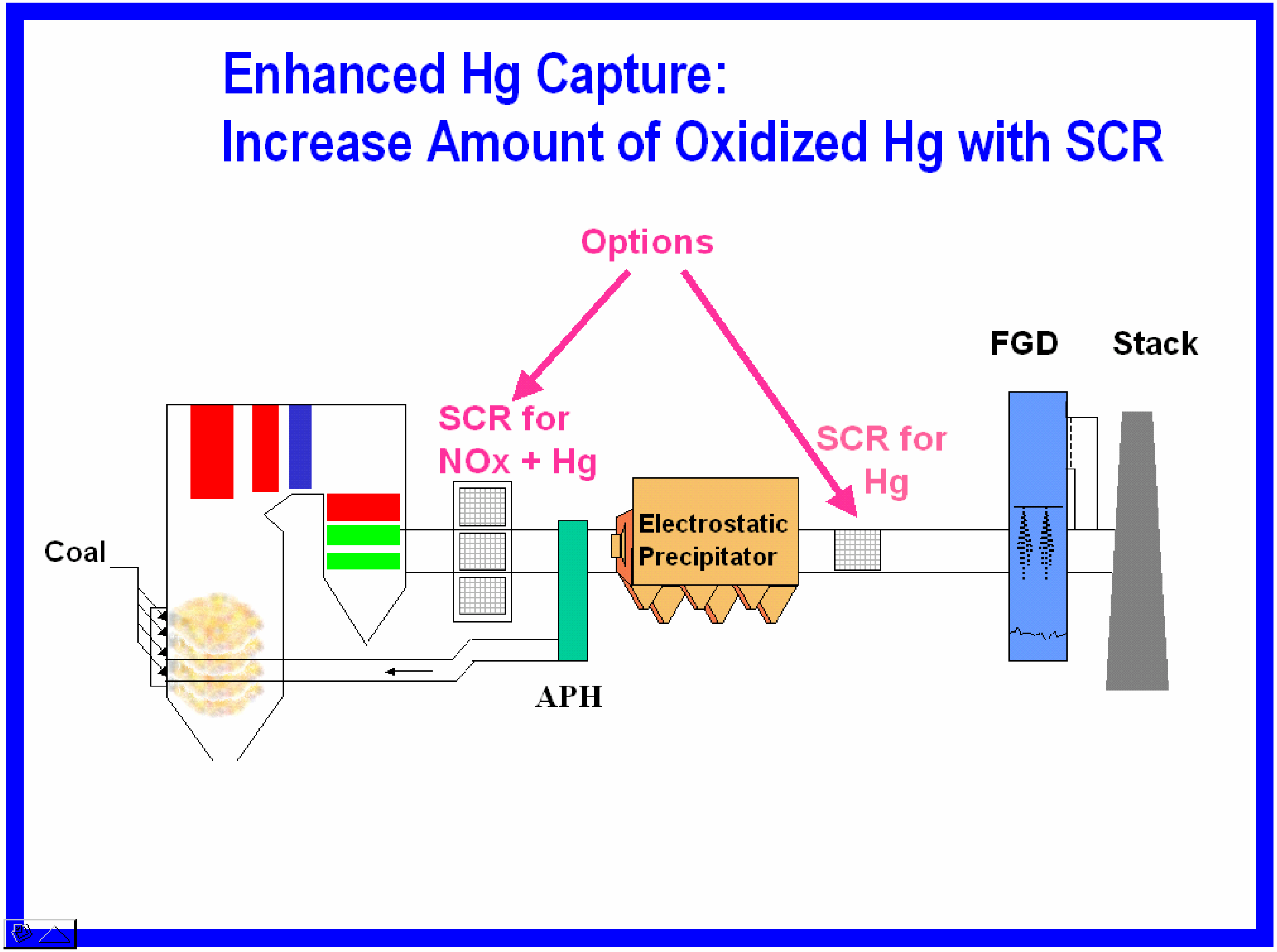
Self Tuning SCR

- 170 MW Gas Plant with Single Feed Forward/Feed Back Control
- Two Injection Points with Delta Wings
- Modified with Additional Outlet NOx Meter For Two Feed Back Loops
- Installed in Summer 2005
- Extended Time Between Injection Point 'Tune Ups'

Trends in SCR Specifications Requirements

- Lower Specified SO_2 Conversion Rates
  - Industrial Experience
  - Anticipating the Use of Higher Sulfur Fuel – Scrubbers
- Higher Removal Efficiencies (91% to 92%)
  - > 10 Units with > 90% Removal
- 'Pre-Engineered' Large Particle Ash Removal Screens
- Year Round Operation
  - Units without SCR Bypasses
- No Clear Winner on Reagent
  - Anhydrous, Aqueous, or Urea
- High Ash Loading Criteria

SCR Effect on WFGD Mercury Capture

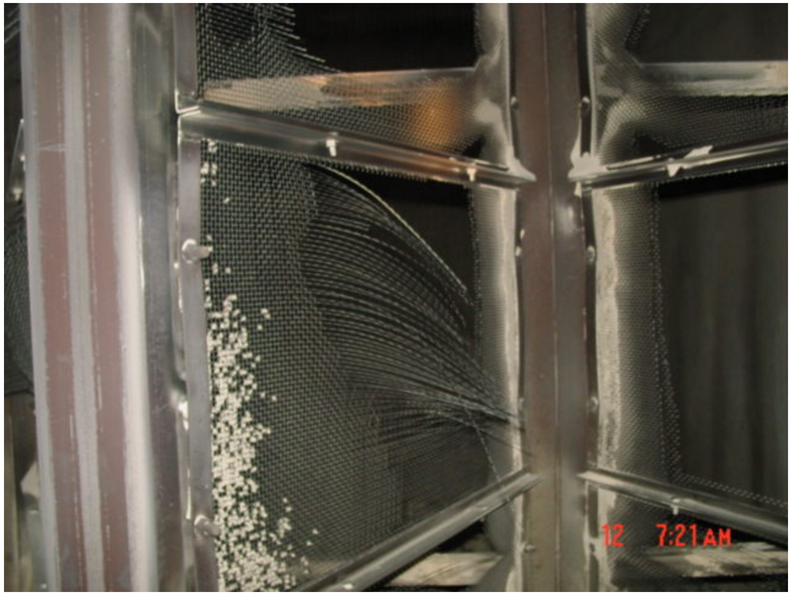


SCR – Effect on Mercury Capture

- Reaction $Hg + 2Cl \rightarrow HgCl_2$ Downstream Wet FGD Capture
- Full Scale Bituminous Test Results
  - Mg-Enhanced Lime, Lime Venturi, Limestone Forced Oxidation
  - Hg Capture Efficiency of 80% to >90%
- Some indication that catalyst Hg Oxidation deactivation similar to DeNox Deactivation
- No affect on PRB coals to assist in Hg capture
  - Lack of chlorine

Large Particle Ash Design

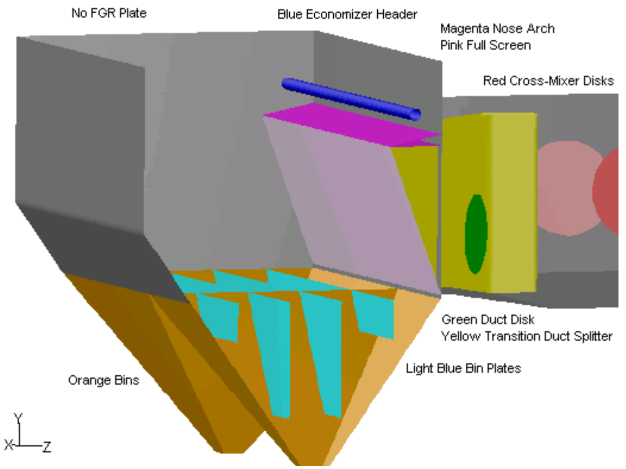
- LPA Properties
  - Size >4.0 mm
  - Density 0.7 to 1.25 g/cc
  - Sphericity 0.7 to 0.99
  - Coefficient of Restitution 0.15 to 0.2

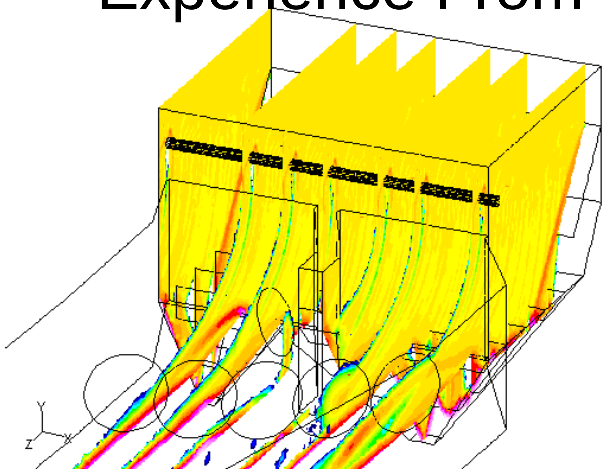


- Screen Design Important
- Pluggage
- Erosion

Large Particle Ash Design

- Design and Modeling
  - CFD Modeling
  - Industry Coated Screens
  - Experience From Past





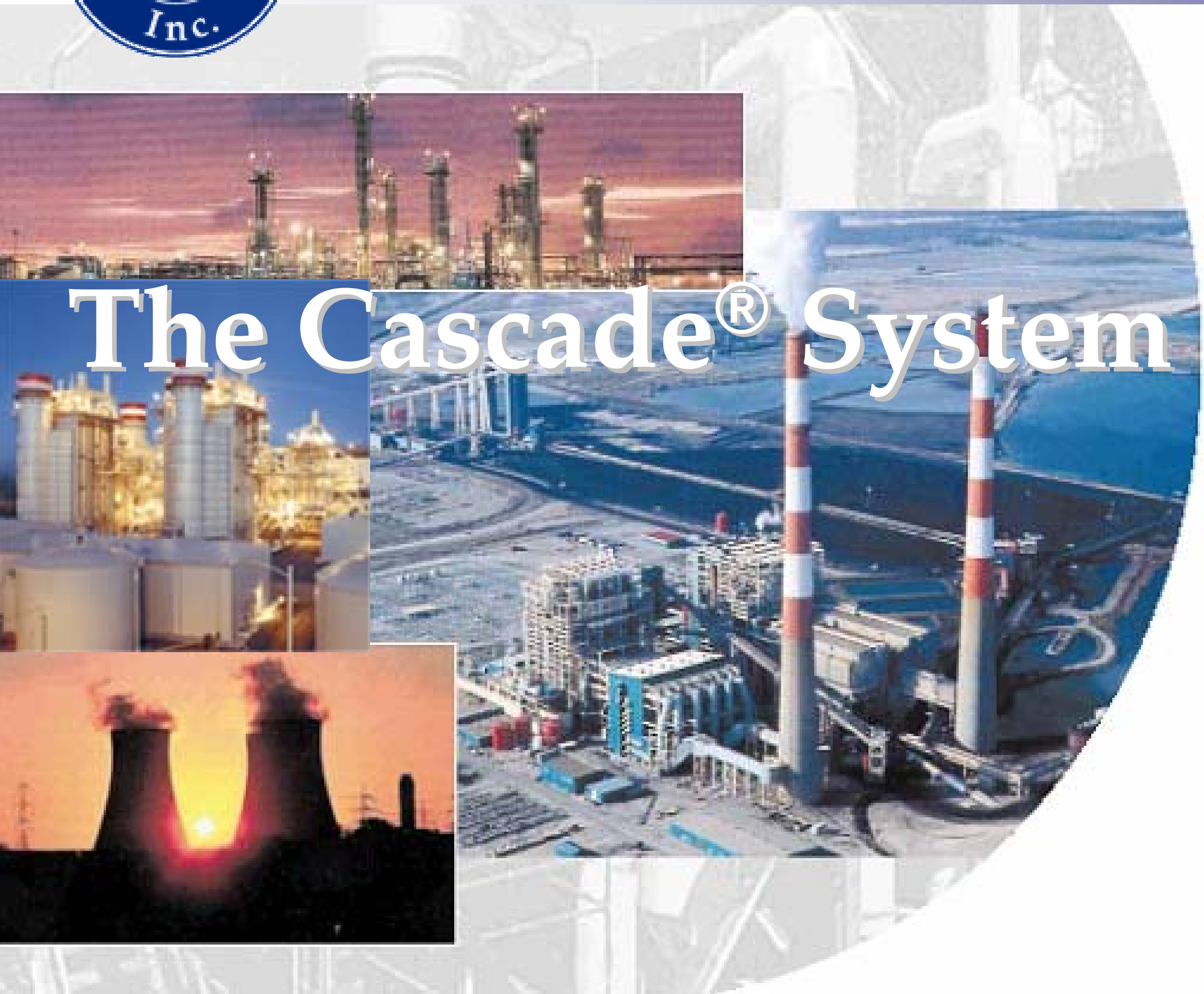
- Soot Blowers
- Low Velocity
- Low Pressure Loss

Start Up and Availability

- Clean Tuning and Start Up Over the Load Range
- No Gross Difference in Reliability of Different Ammonia Systems
  – Urea , anhydrous, or aqueous system
- Overall system Availability

One Source…Many Solutions…One Purpose

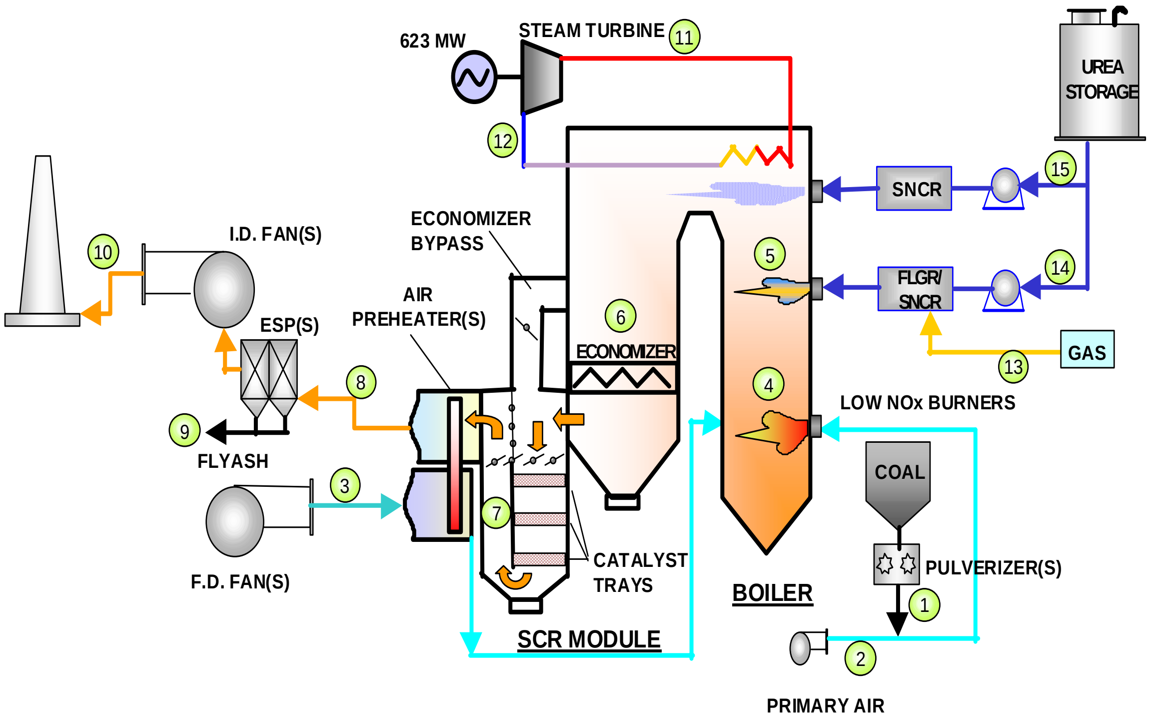
The Cascade® System



Technology for a renewed environment™

Hybrid NO_x Control System “Cascade®”

- SNCR (using urea)
- Compact In-duct SCR
- SNCR slip consumed in SCR
- Up to 80% overall NO_x reduction
- Low capital costs



Cascade® Process

- System Description
  - The Combination of In-Furnace SNCR with downstream Selective Catalytic Reduction (SCR) to Extend the NOx Reduction Capability of SNCR, Improve Overall SNCR Reagent Utilization and Mitigate Downstream Balance of Plant Impacts
- A Redesigned SNCR system with SCR
- Higher NO_x reduction and utilization than SNCR
- Lower capital costs than full-scale SCR
- Greater operational flexibility
- Seasonal NO_x emission limits

Cascade Process Application and Limitations

- Single Layer of Catalyst (SCR Requirements)
  - Space Restrictions, 16 – 20 fps face velocity
  - NH_3 Scrubber vs. Significant NOx Reduction
- No Requirements for new fans
  - Utilize existing fans or re-tip
  - Deploy in conjunction with backend APC equipment such as new scrubbers/baghouses which may require new fans
- Limited Structural Steel Modifications
- No New Foundation Requirements
- No NH_3 Injection Grid Required

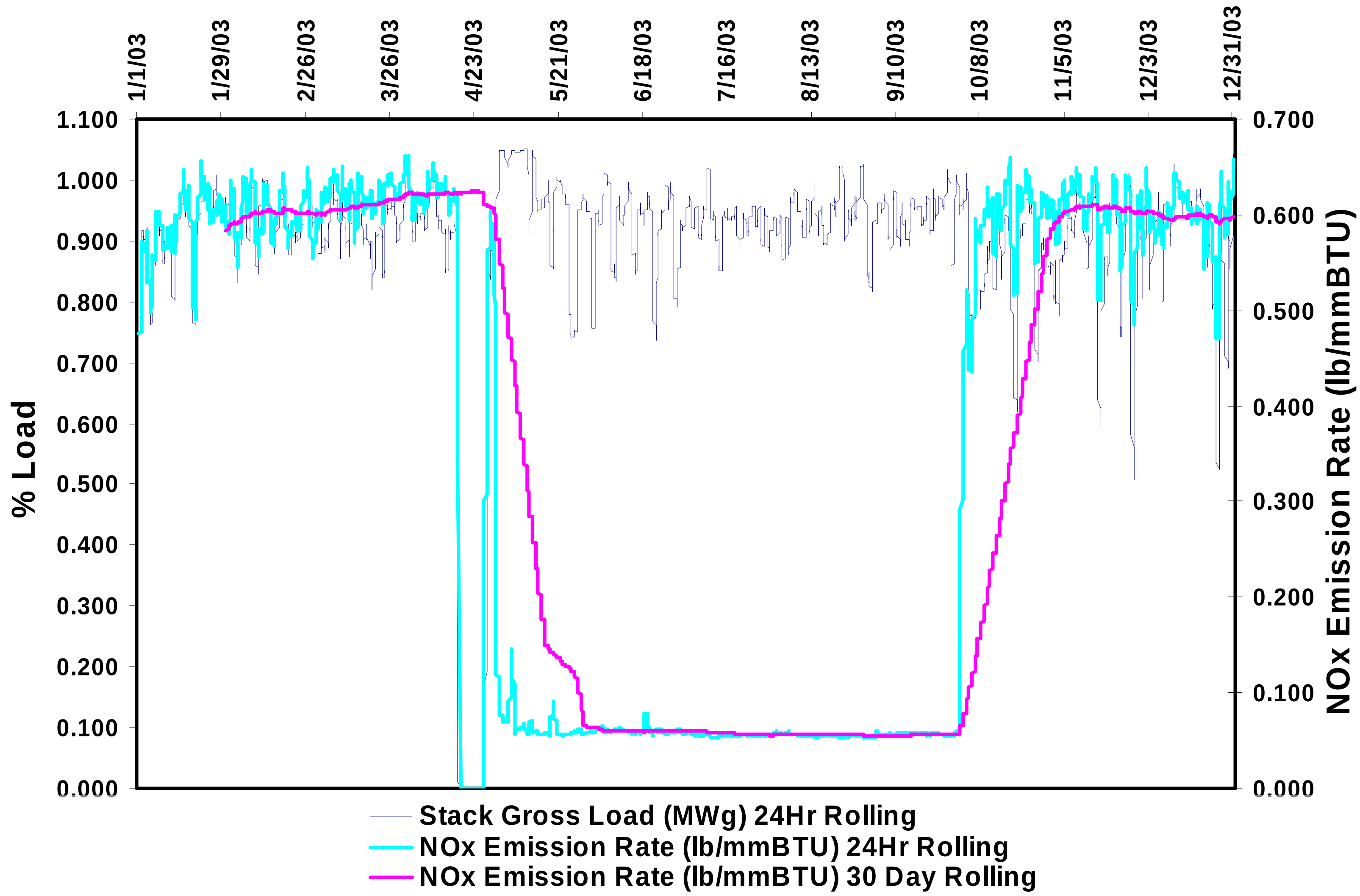
Summary of Cascade® Process

- Cascade Performance Ranges from 55 to 80% NOx Reduction
  - NH3 “Mop” vs. NOx Reduction
- 1/4 to 1/2 Capital Cost of Full SCR System
- Improved Chemical Utilization over SNCR System
- Shorter Boiler Outage Requirement
- Single Layer of Catalyst; Easy Removal and Replacement
- Staged Installation; SNCR 1st Followed by Compact SCR Later

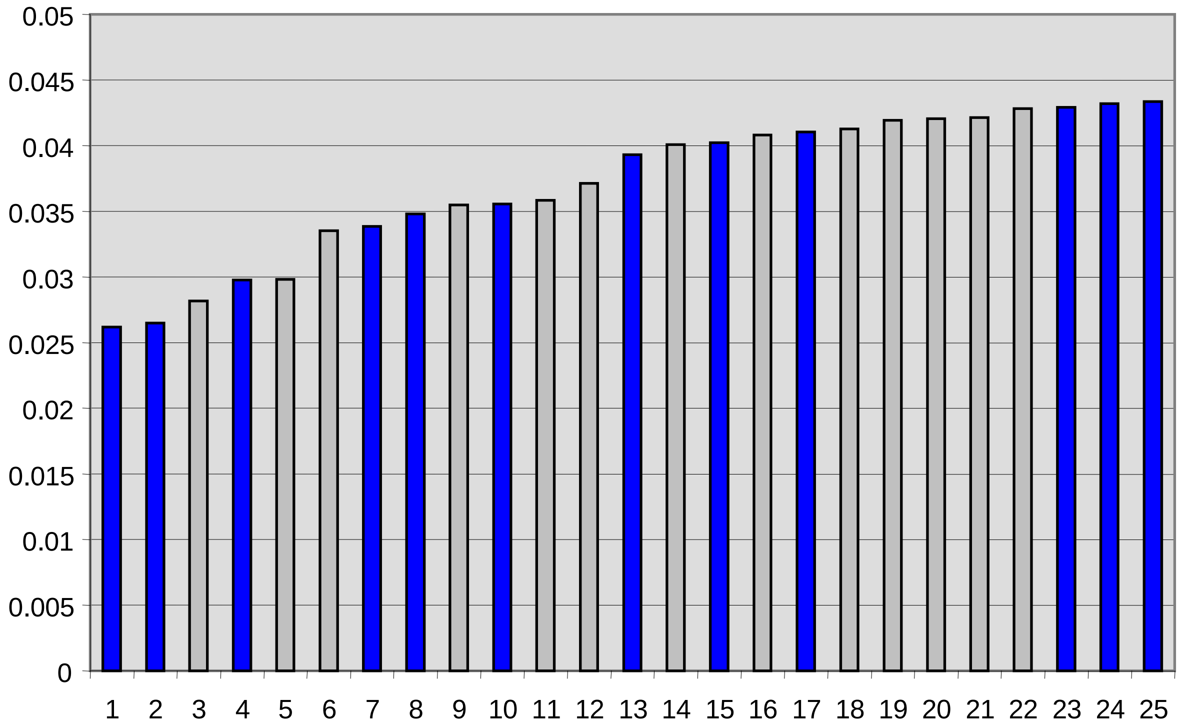
Summary

- SCR options exist to reduce NOx to meet requirements
- More expensive systems than SNCR and/or low-NOx burners
- Removal efficiencies much higher than SNCR/burners
- Higher performance than needed to meet permit can generate revenues from NOx credits
- Unique mixing technology enables in-duct, and hybrid systems
  - Lower capital costs than conventional SCR
  - Greatly reduced installation costs
  - Performance comparable to full SCR obtained

SCR System Performance



Lowest Outlet NOx Units

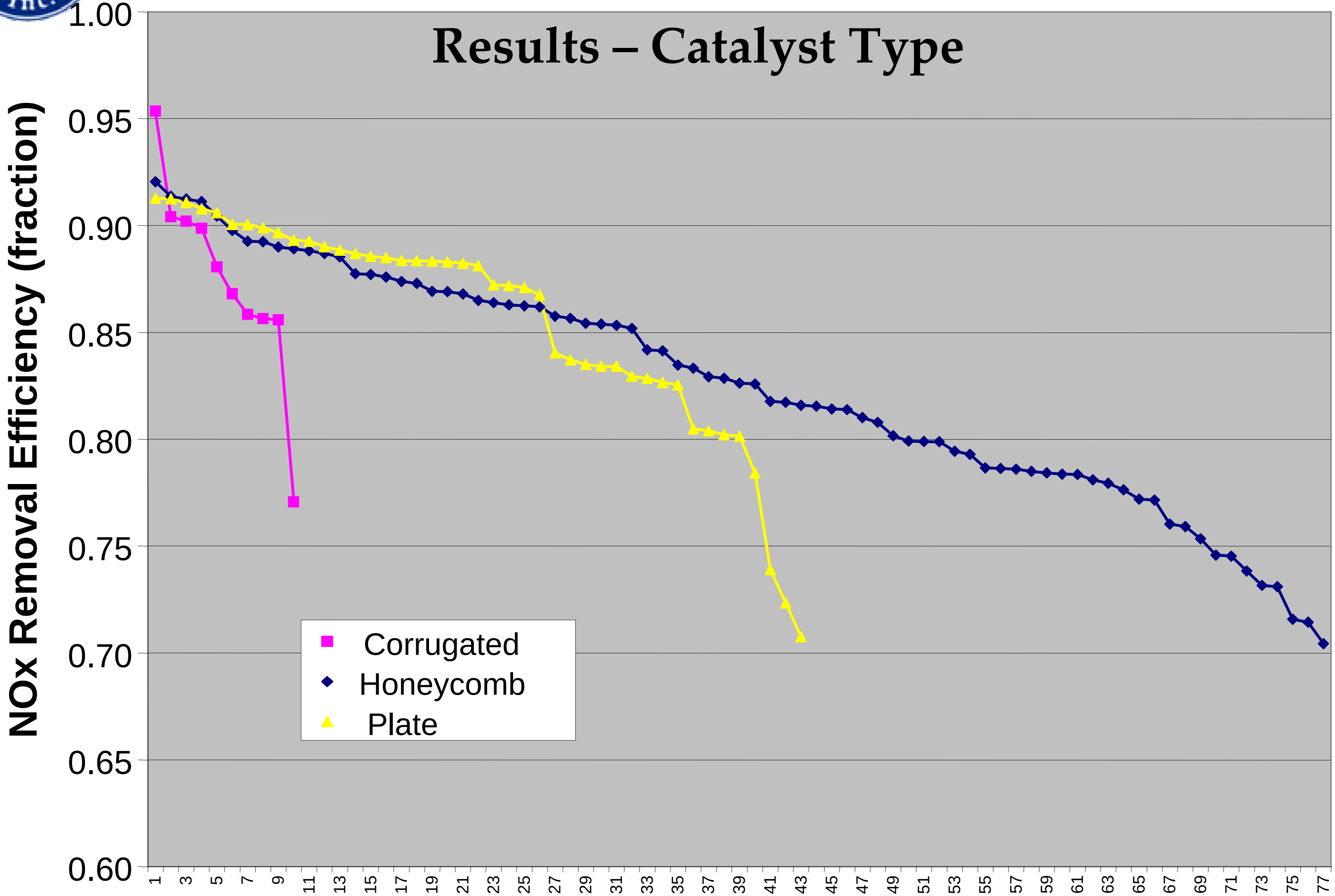


Source US EPA

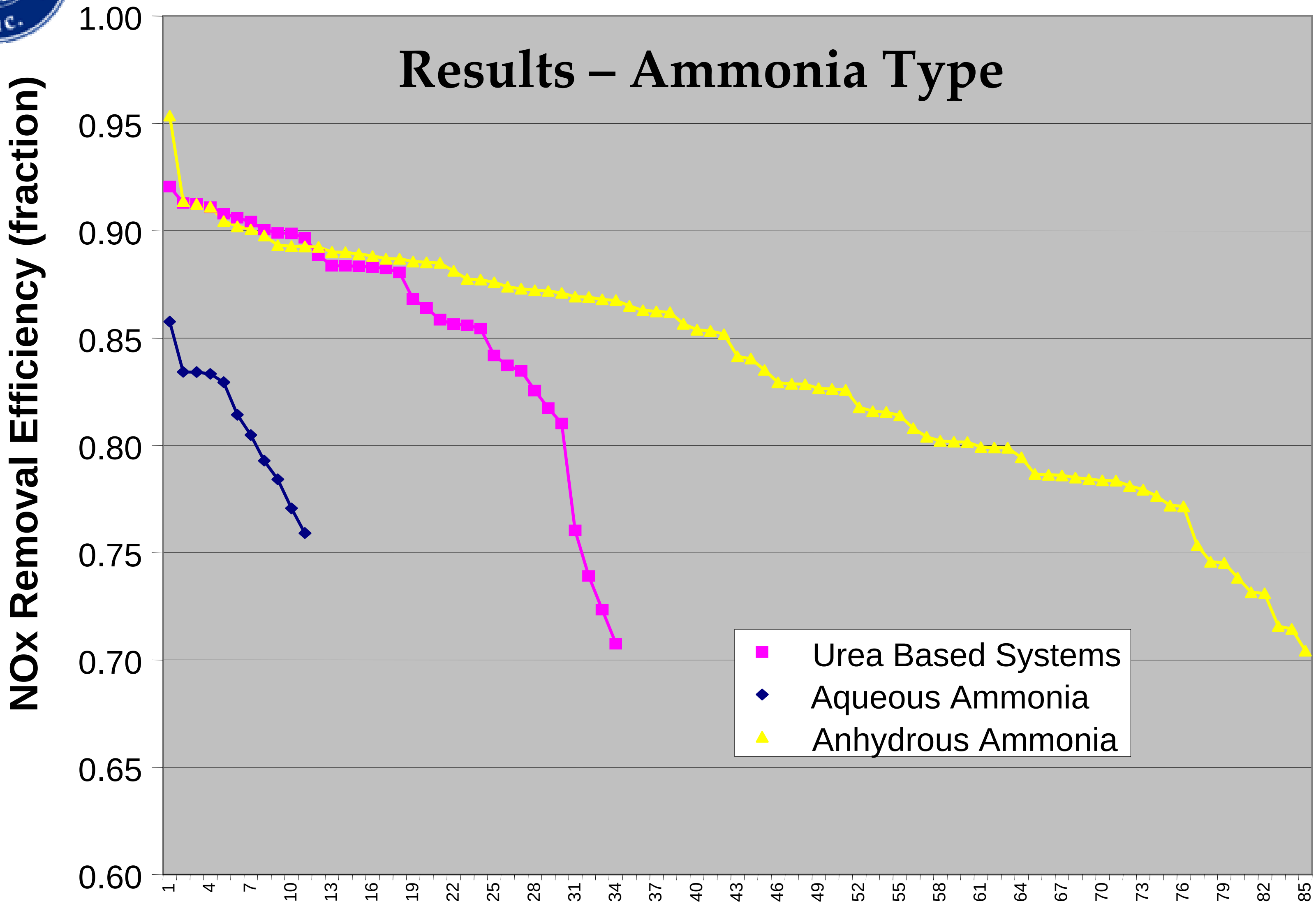
Results – Unit Size

- 19 units between 90 and 1,300 MW achieving above 90%
- 34 units between 200 and 1,300 MW achieving 87% to 90% (19,757 MW)
- 44 units between 200 and 1,300 MW achieving 80% to 86% (26,205 MW)
- 33 units between 150 and 1,300 MW achieving 70% to 80% (15,043 MW)
- Availability not sensitive to unit size

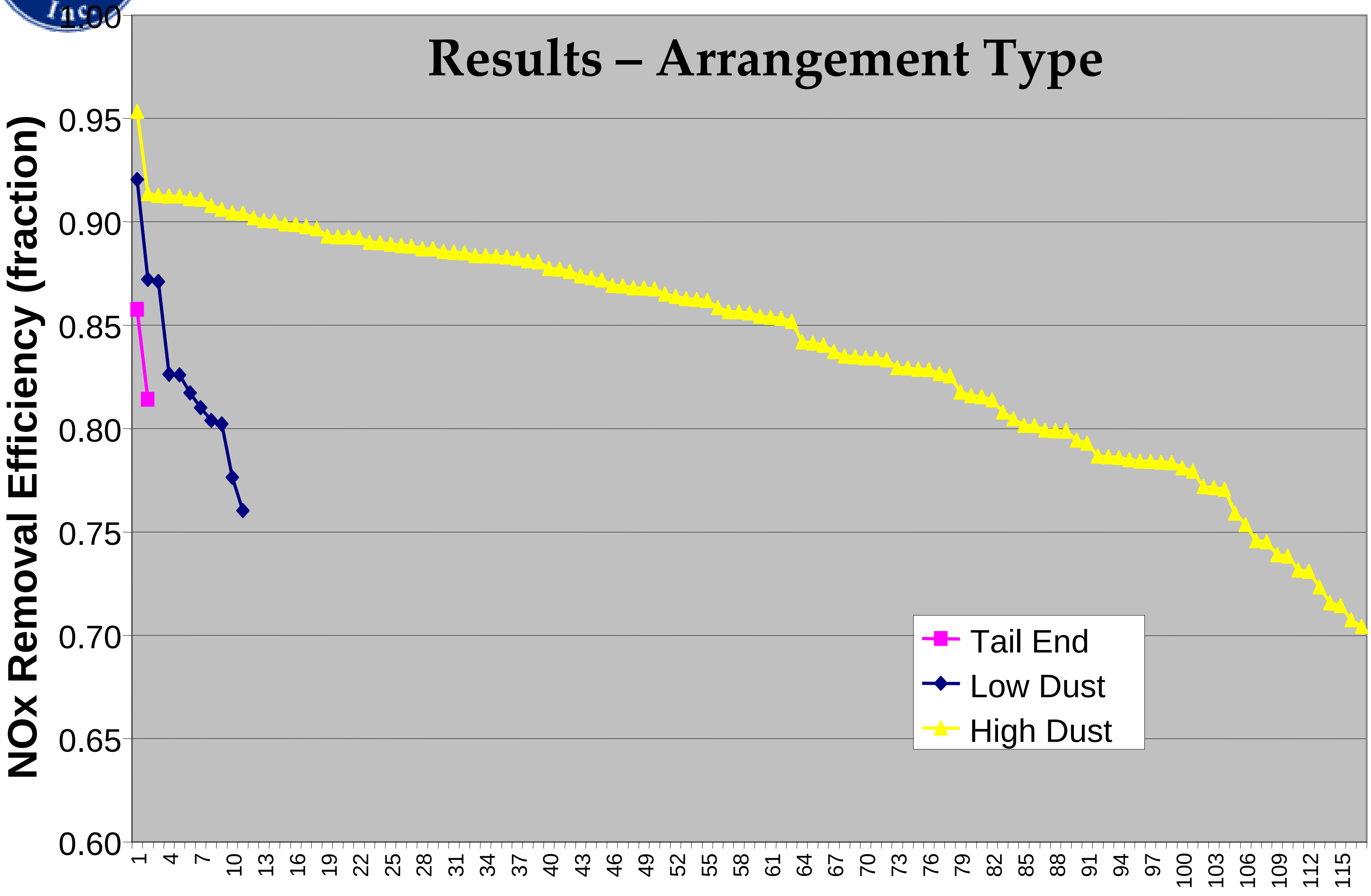
Results – Catalyst Type



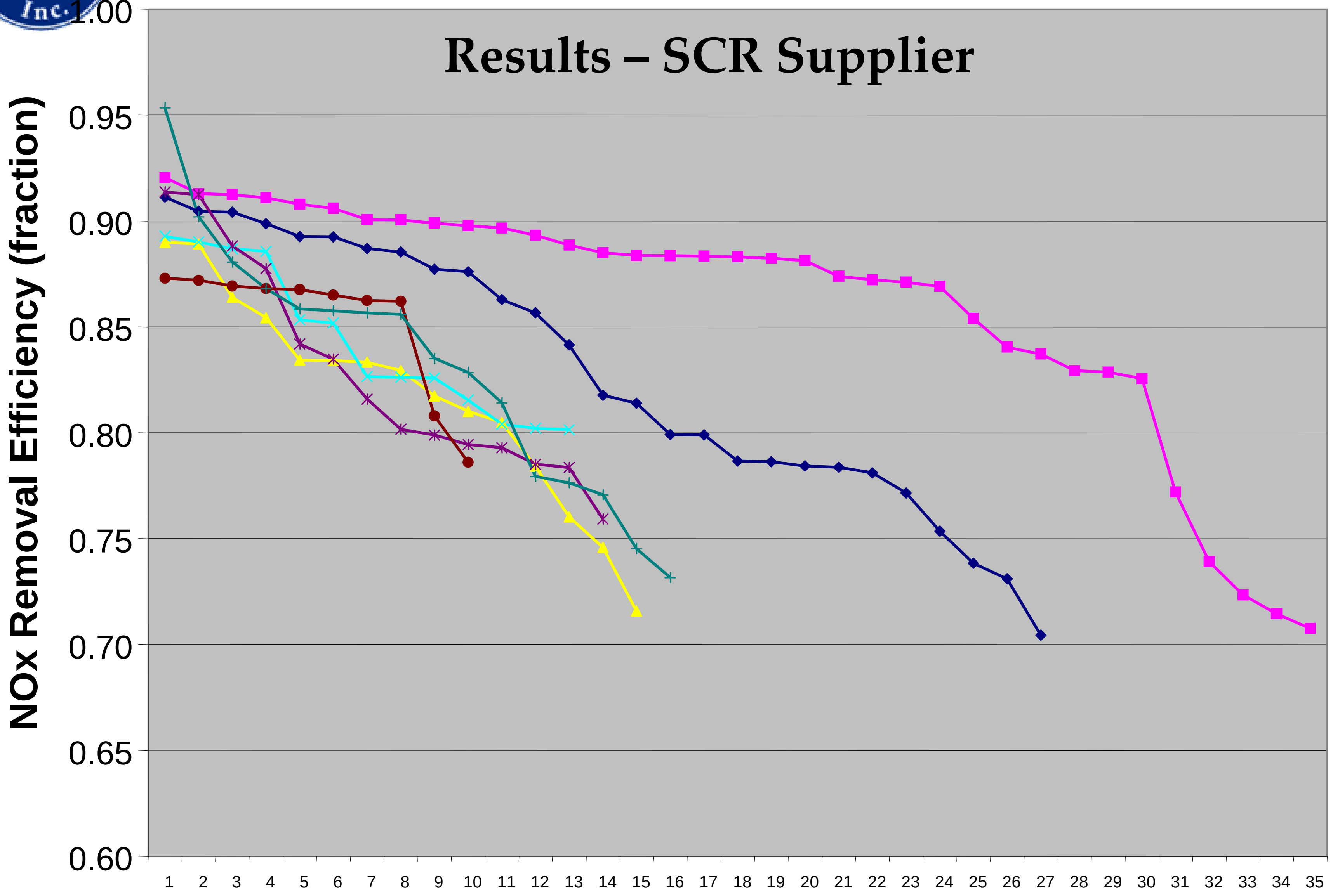
Results – Ammonia Type



Results – Arrangement Type



Results – SCR Supplier



Data Analysis

- 90% NOx removal achieved by ~10,000 MW
- Outlet emissions on less than 0.05 lbs/mmBtu achieved by multiple units
- Availability insensitive to catalyst type, all types have achieved 90%
- Availability insensitive to ammonia type, all types have achieved 90%
- Arrangement type appears to affect, mostly due to sample size

Data Source

- Data downloaded from
  - Acid Rain/OTC Program Hourly Emission Data
  - www.epa.gov/airmarkets/emissions/raw
- Analysis period year 2004
- Ozone season June 1st to September 30th
  - Some states had one month start delay
- Single stack only data, common stacks removed