Interlayer Mixing for Improved SCR Performance

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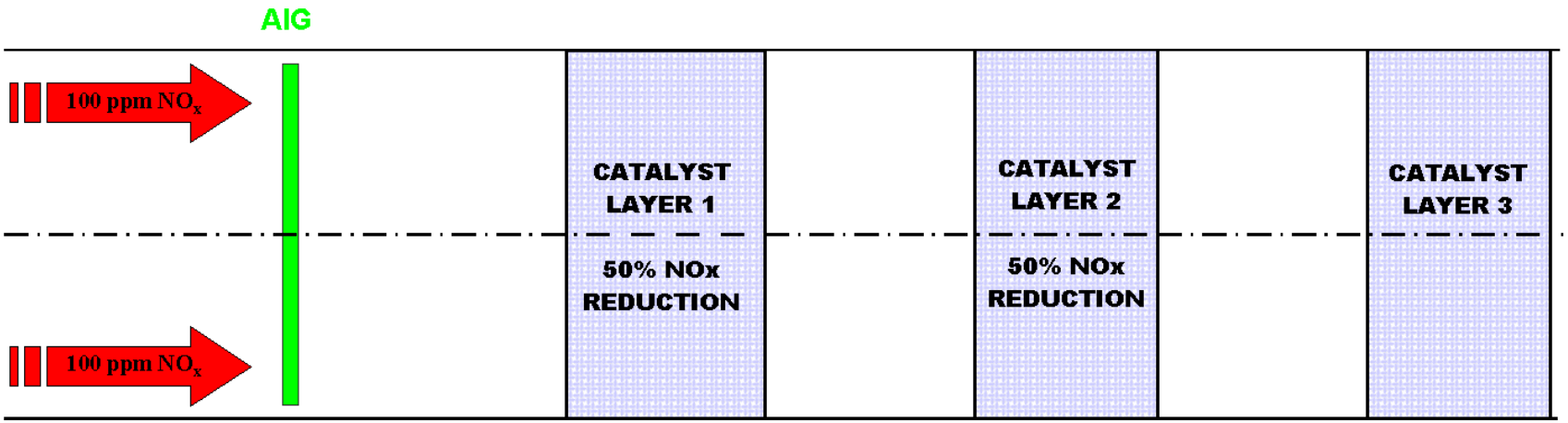
INTRODUCTION

- *WHAT IS INTER-LAYER MIXING?*
  - Introduction of devices to induce mixing between layers of catalyst
- *WHY IS INTER-LAYER MIXING NEEDED?*
  - Good NH_3/NO_x distribution uniformity of a "tuned" SCR exists only at the 1st catalyst layer
  - As the flow progresses though each layer, the NH_3/NO_x uniformity degrades
- *WHAT DOES INTER-LAYER MIXING DO?*
  - Mixing between the catalyst layers will help re-distribute NH_3
  - Improving the uniformity to the next layer
  - Allows higher dNO_x with lower NH_3 slip
- *WHAT APPROACHES CAN BE USED FOR INTER-LAYER MIXING?*
  - Static Mixers
  - Dynamic Mixers
- *HOW MUCH INTERLAYER MIXING CAN TAKE PLACE ?*

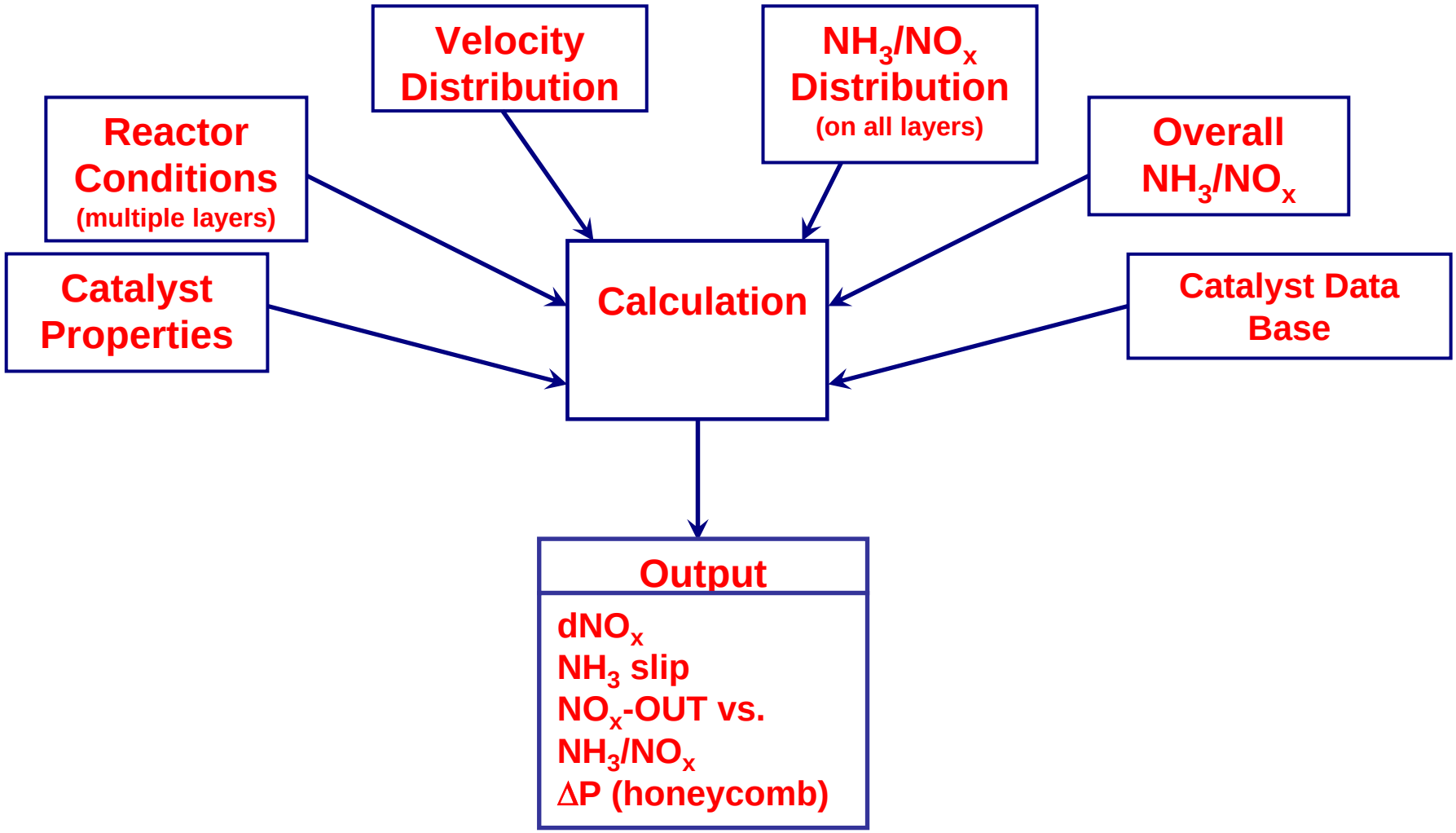
Layer to Layer Changes in NH_3/NO_x Uniformity



APPROACH TO STUDY INTERLAYER MIXING

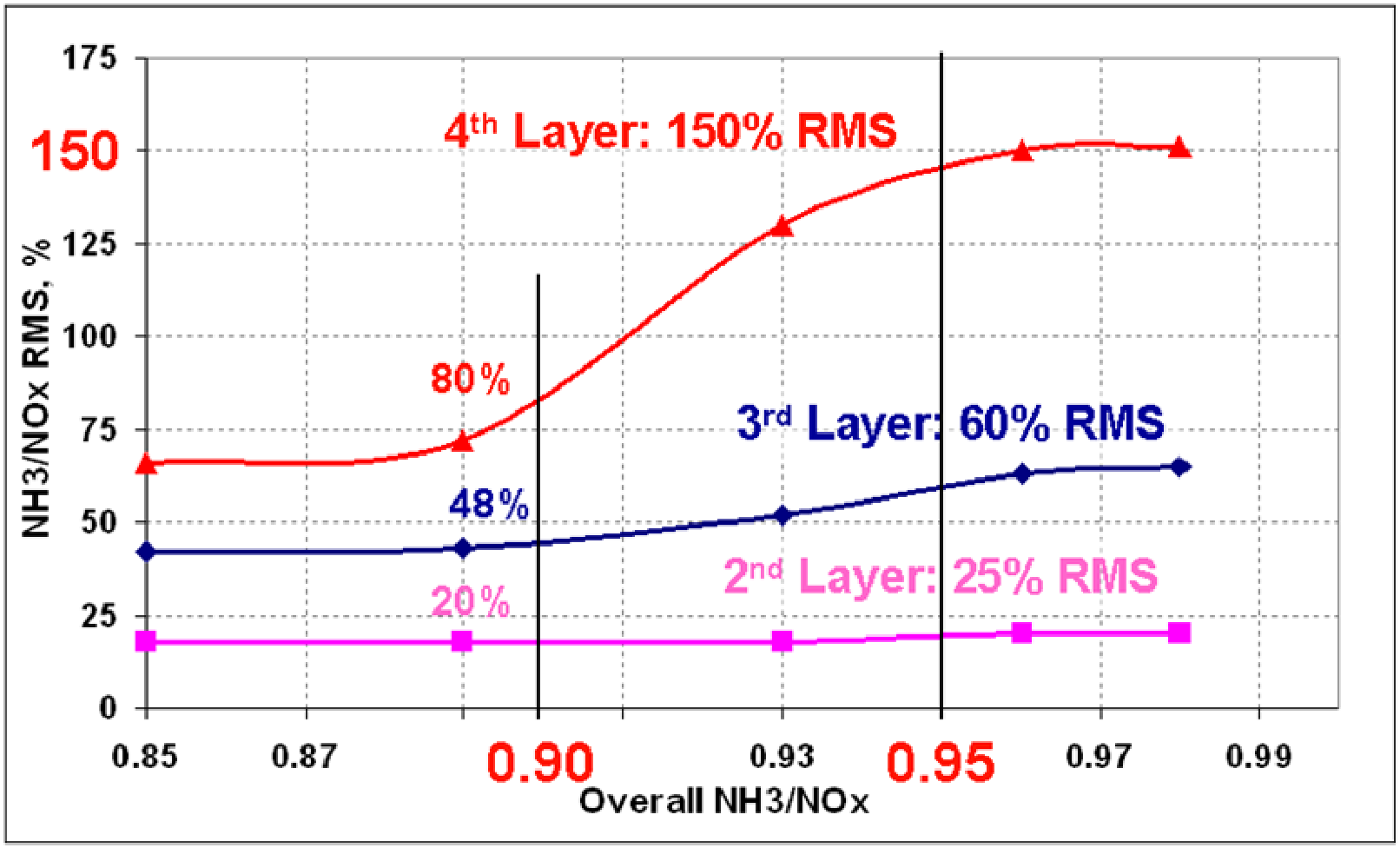
- **Computer-based SCR Multilayer Process Model**
  How much can SCR performance be improved by inter-layer mixing?
  - **What is the relationship between increased NOx reduction and the amount of inter-layer mixing?**
  - **Does the benefit depend on the number of catalyst layers?**
  - **Do all the layers need to be mixed?**
- **Physical Cold Flow Model**
  - **Are static or dynamic mixers more effective?**
  - **How much mixing can be achieved?**
- **Pilot Scale (planned for 2006)**
  - **Does interlayer mixing actually improve performance?**
  - **If so, by how much?**
- **Full Scale (planned for 2006)**
  - **What are the operational issues with the mixers in a full scale SCR reactor?**

SCR PROCESS MODEL



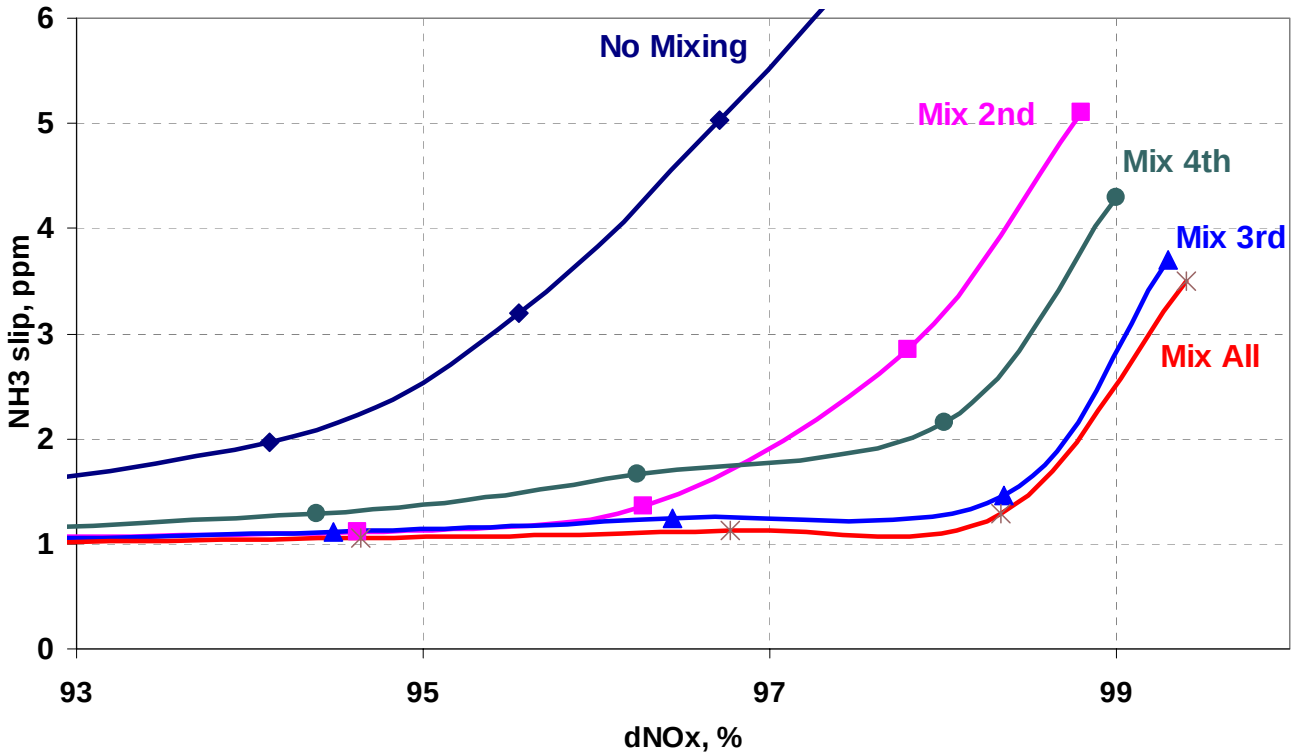
INTER-LAYER NON-UNIFORMITY

NH_3/NO_x distribution uniformity degrades through each layer



WHICH LAYERS TO MIX?

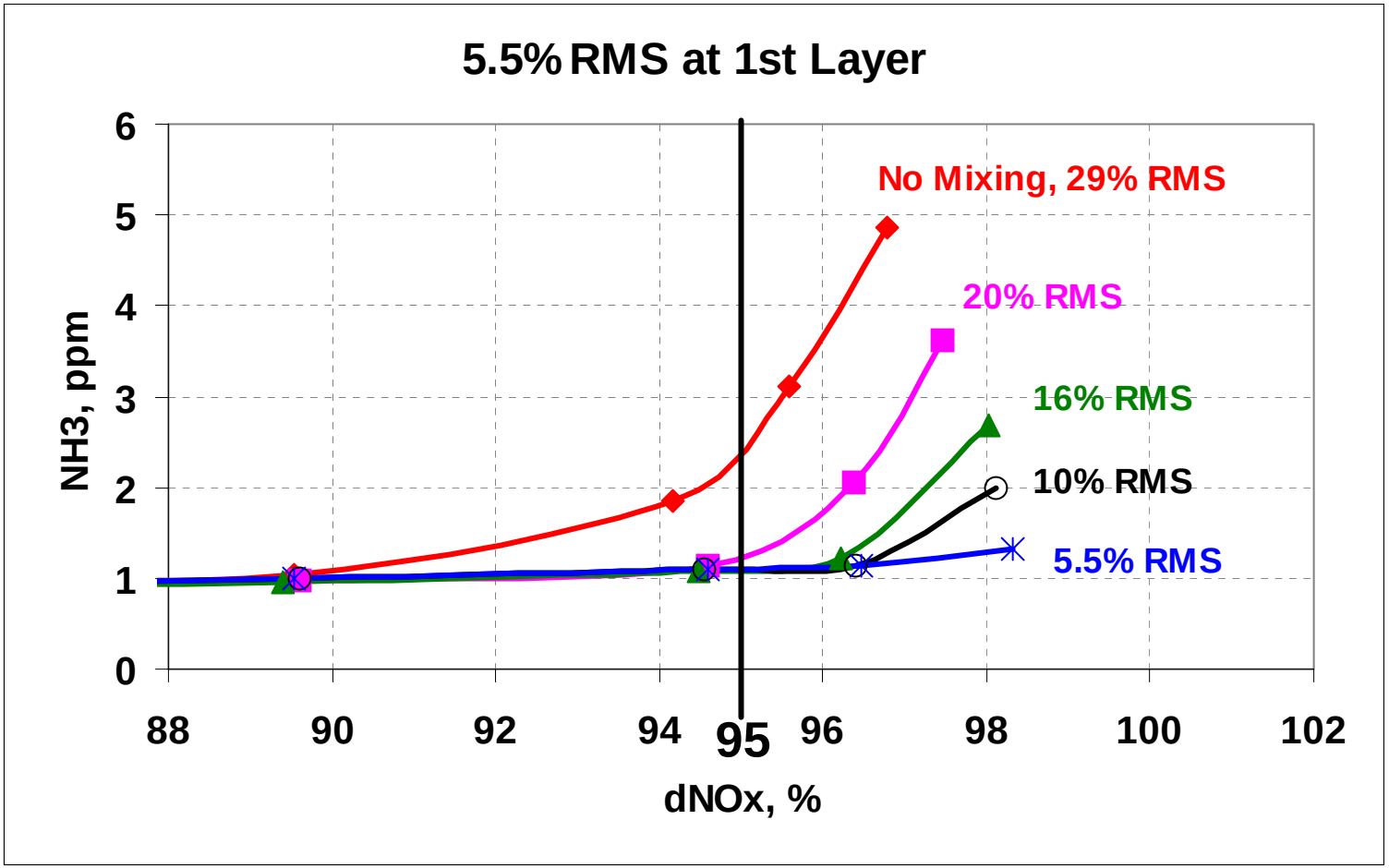
- No difference between mixing only the 2nd or only the 3rd, up to 95%
- Mixing in only the third is better than only the 2nd, for greater than 96% reduction



DETERMINING HOW MUCH TO MIX

(Mixing the 2nd Layer, 3 Layers Total)

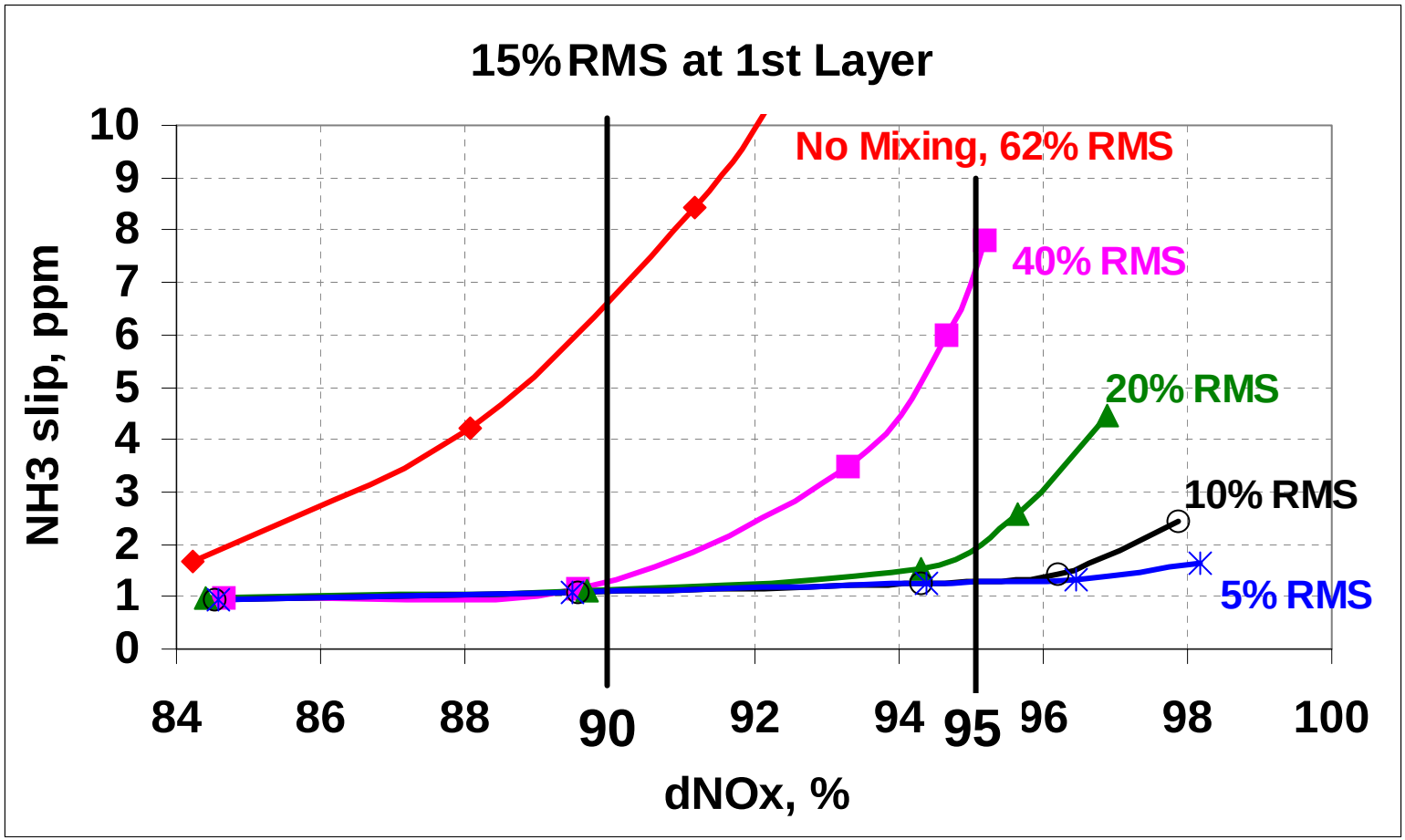
For 95% dNOx, only need to reduce NH3/NOx RMS from 29% to 20%



DETERMINING HOW MUCH TO MIX

(Mixing the 2nd Layer, 3 Layers Total)

Reducing NH_3/NO_x RMS from 62% to 40% would still be a significant improvement (increase dNO_x from 85% to 90%)



CAN THE REQUIRED MIXING BE ACHIEVED?

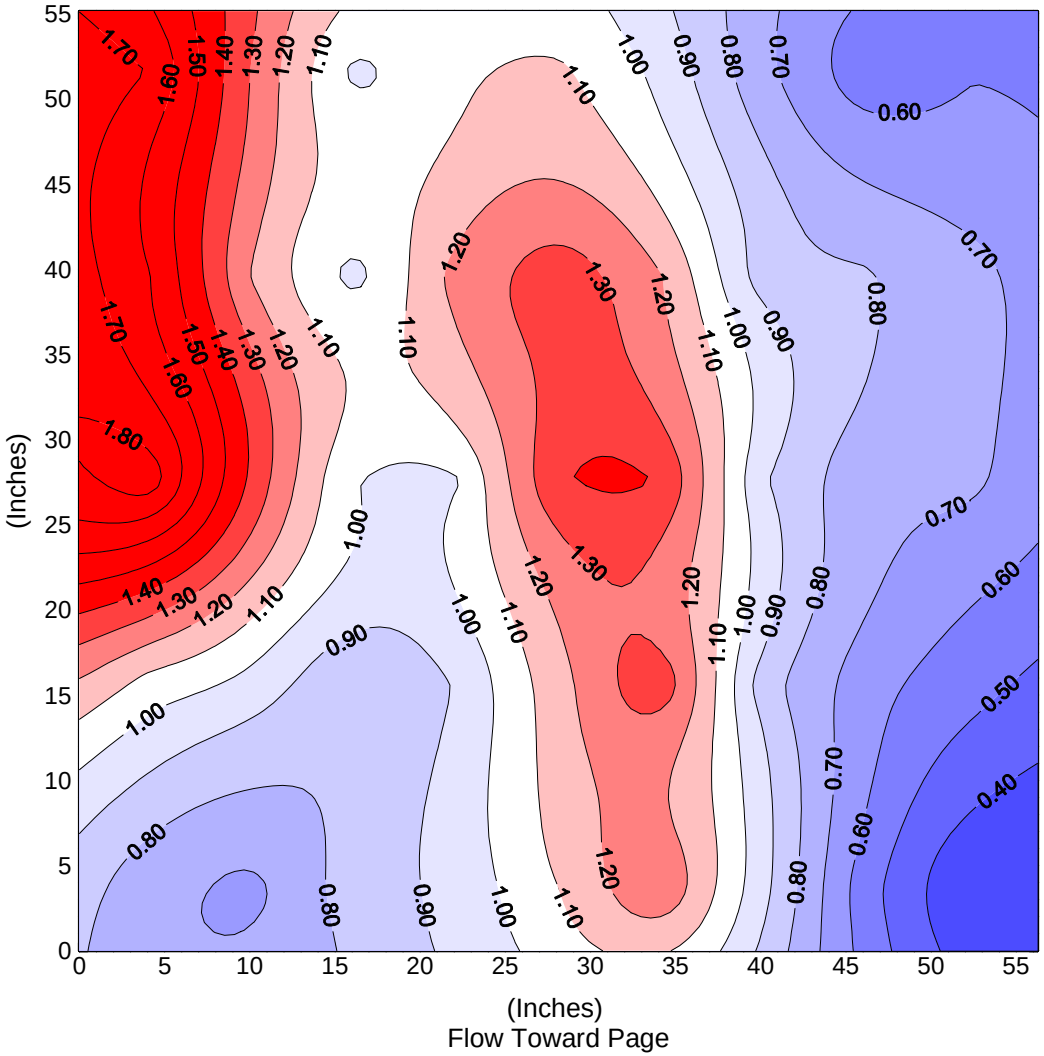
This question was investigated using physical cold flow modeling

COLD FLOW MODEL

- **PREPARATION:**
  - **Reviewed full-scale reactors to determine average catalyst spacing (6.8 feet)**
  - **Reviewed actual NH_3/NO_x distributions to determine typical profile shape and average RMS**
    - **Inlet RMS: 3% - 5%**
    - **Outlet of 1st layer RMS (based on computer model): 22%-35%**
  - **De-tuned the AIG of cold flow model to produce 30-35% RMS**

COLD FLOW MODEL:
Normalized NH_3/NO_x Profile into Second Layer

Baseline 33% NH_3/NO_x RMS



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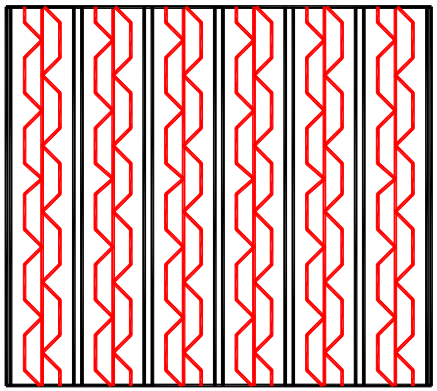
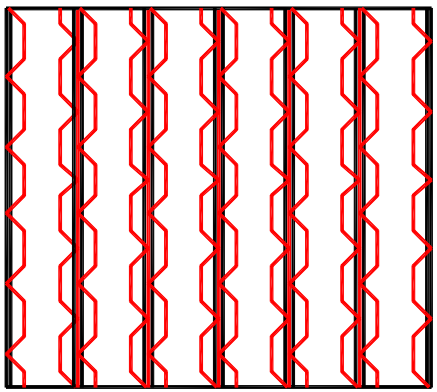
INTER-LAYER MIXING DEVICES

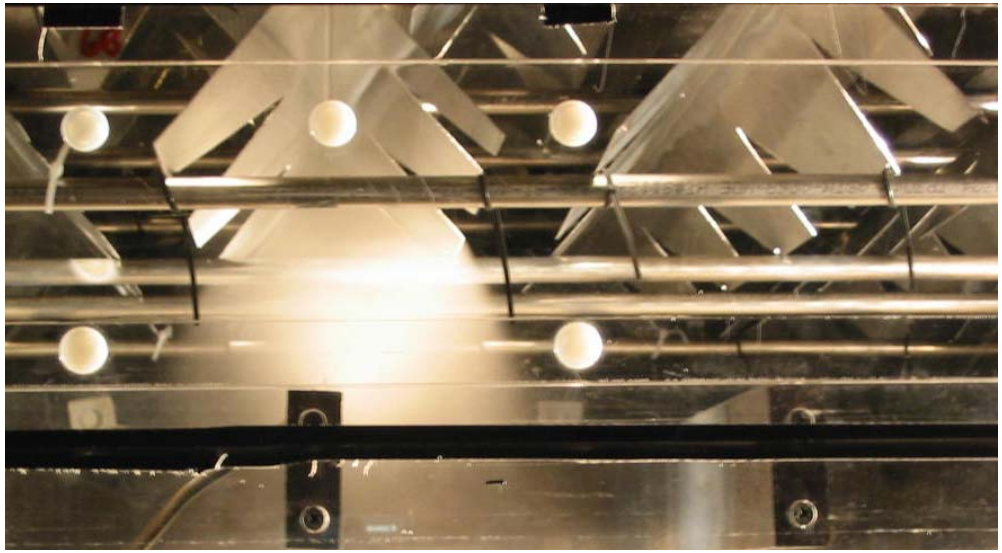
- Static Mixers
  - Bluff body discs and swirlers
  - High blockage – crossed slats
  - Inverted Sawtooth
- Dynamic Mixers
  - Wall Mounted Air Jets
  - Internal Air Amplifiers
- Combination of Static and Dynamic
- Other Parameters:
  - Mixing Distance
  - NH_3/NO_x Profile (RMS, Shape)

Plan view of 2 layer sawtooth mixer

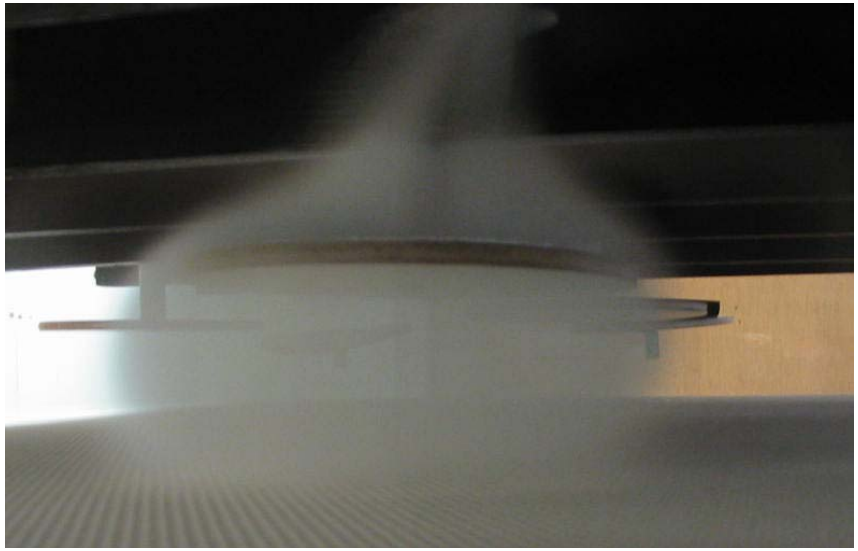




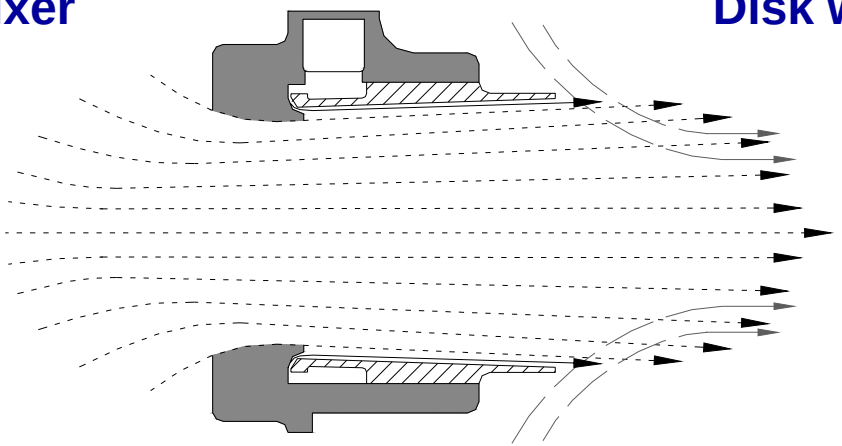
INTER-LAYER MIXING DEVICES



Sawtooth Mixer



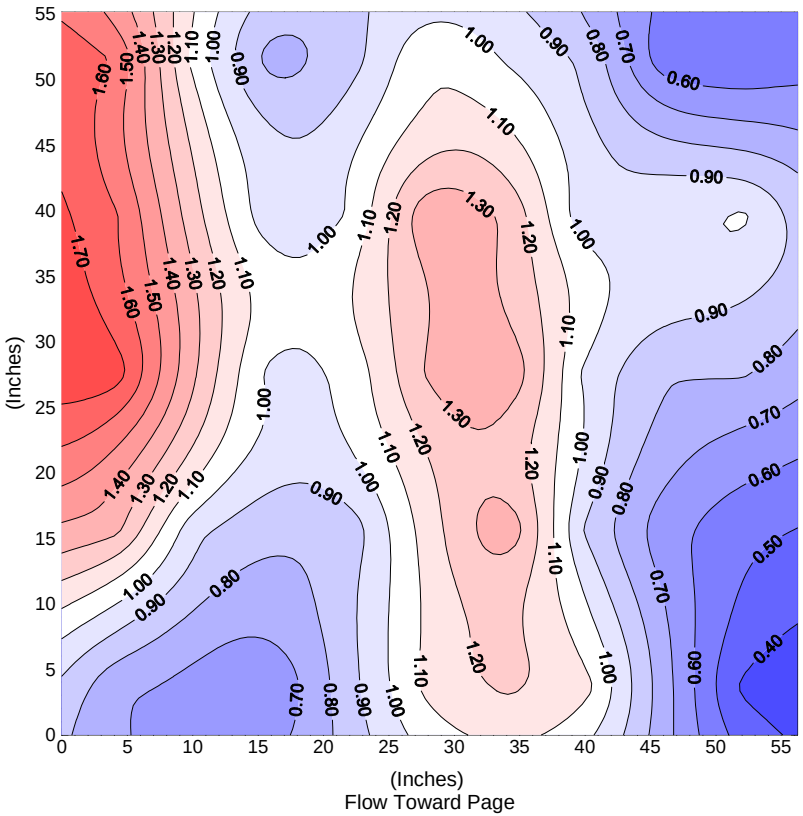
Disk with Smoke



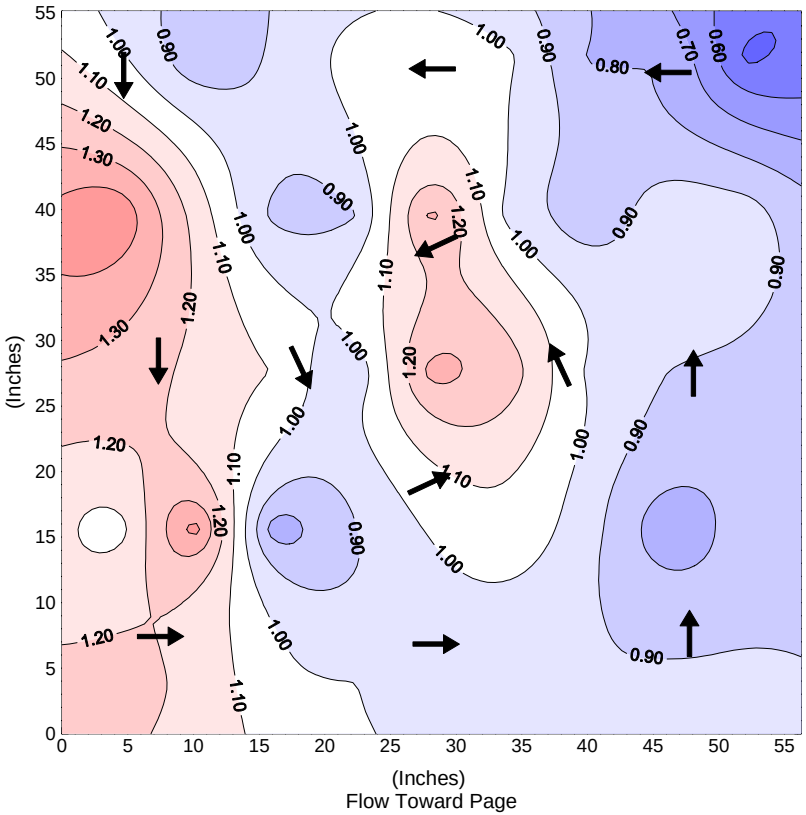
Air Amplifier

Inter-Layer Mixing

Sample Mixing Results

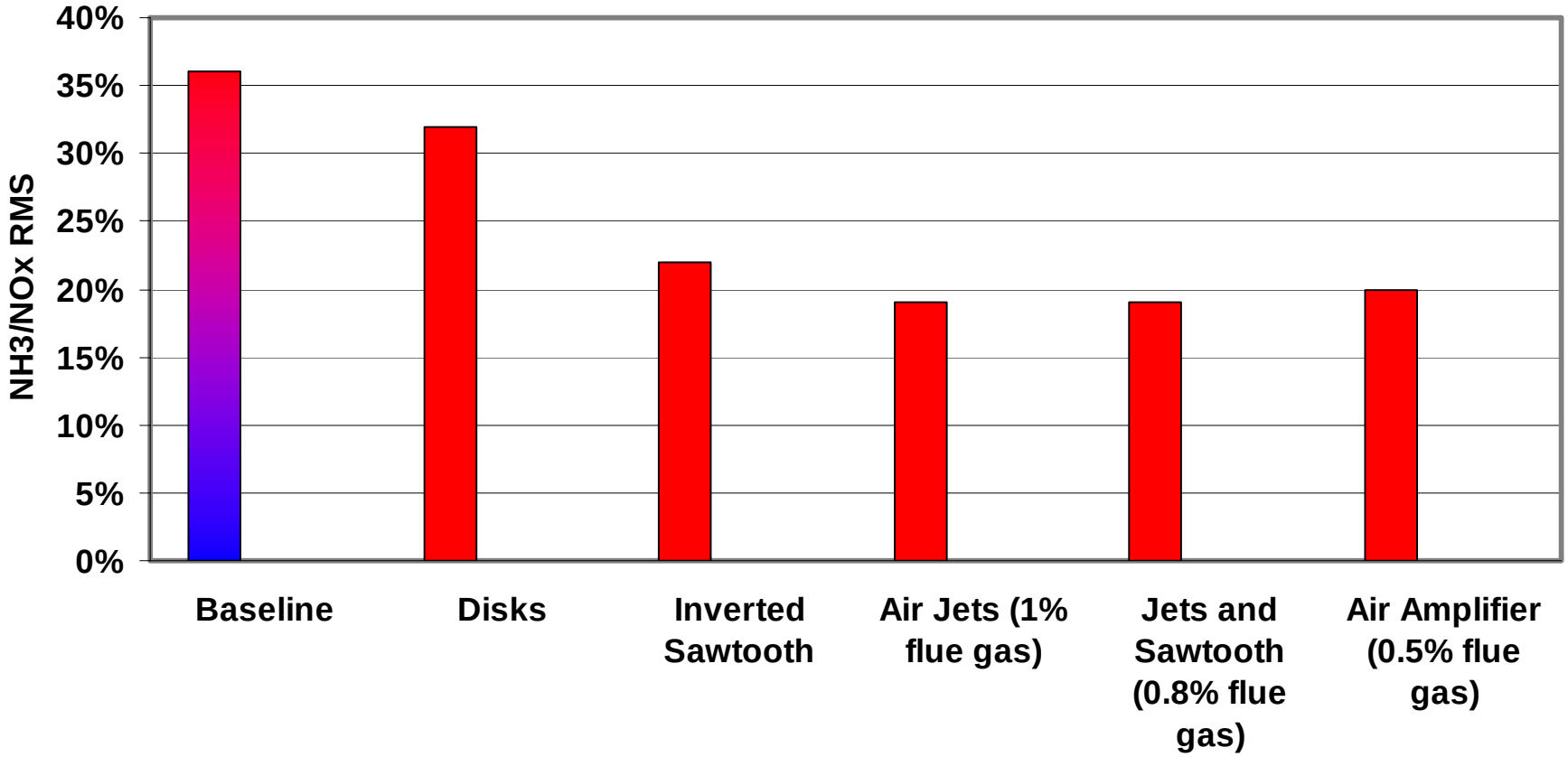


Normalized Baseline Tracer Gas Profile, Catalyst Layer #2 Inlet, RMS = 30.2%



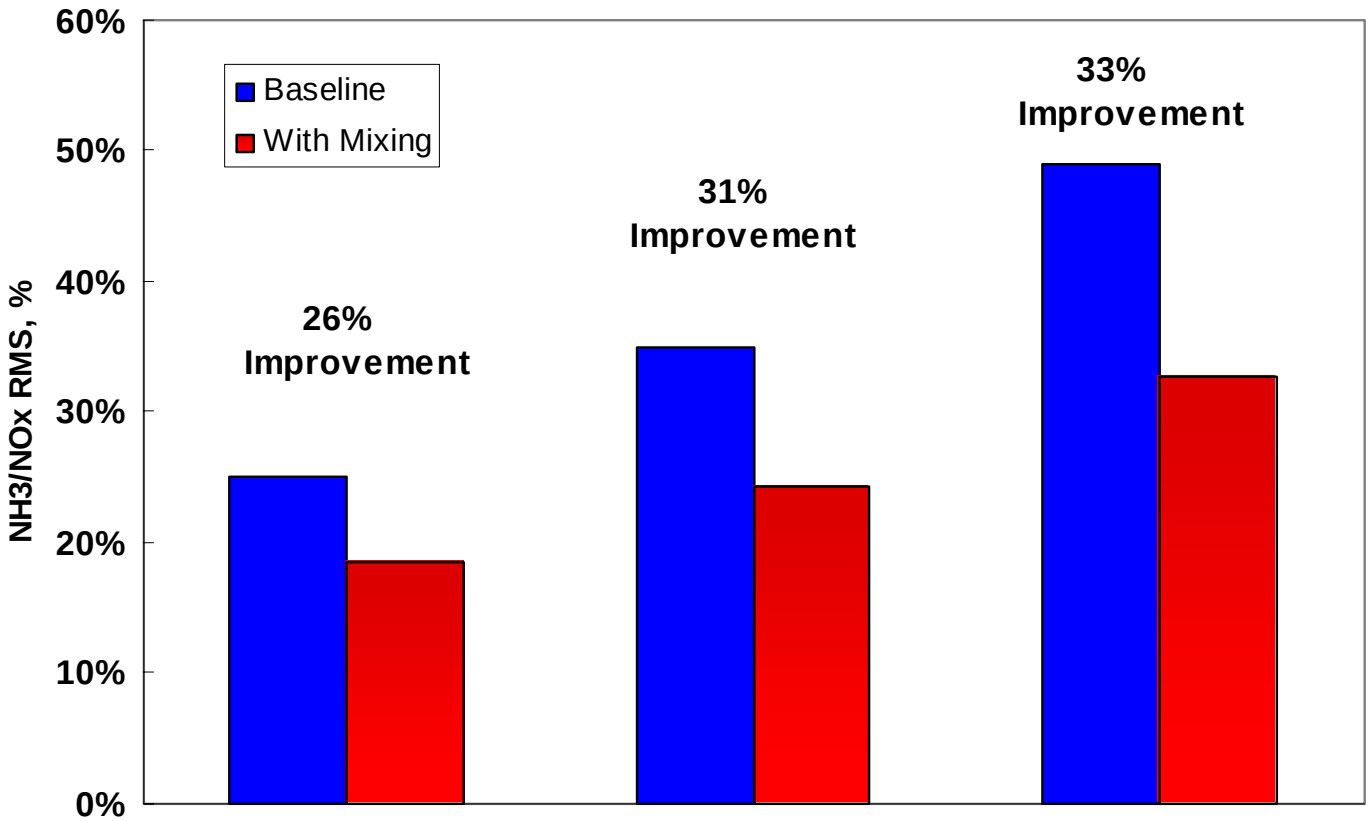
Case 11: Arrows denote location of 12 mixers, RMS = 19%

RESULTS


NH3/NOx RMS
40%
35%
30%
25%
20%
15%
10%
5%
0%
Baseline
Disks
Inverted Sawtooth
Air Jets (1% flue gas)
Jets and Sawtooth (0.8% flue gas)
Air Amplifier (0.5% flue gas)

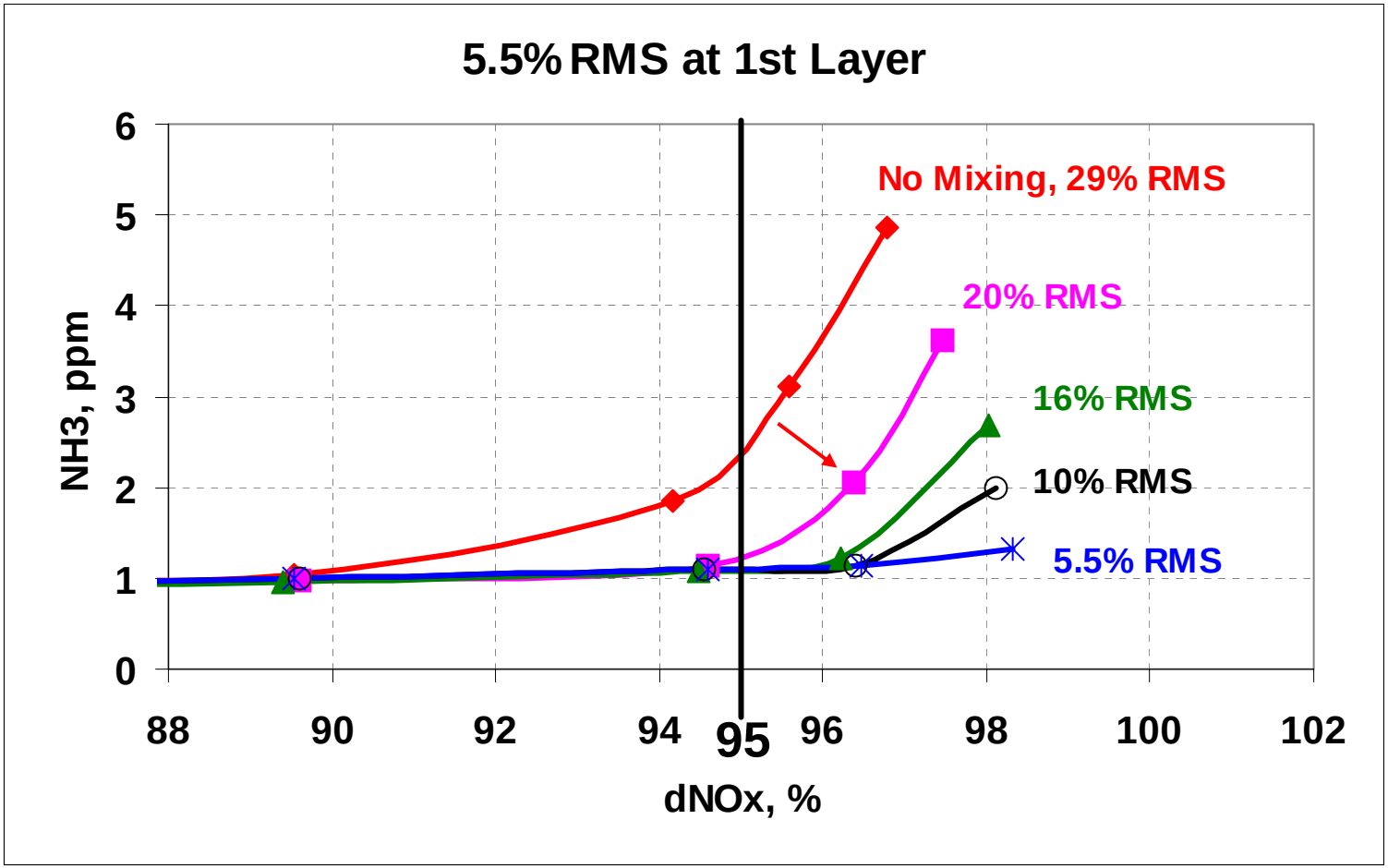
EFFECT OF INITIAL RMS

- **It is easier to mix a profile with a higher baseline RMS**



SCR PERFORMANCE IMPROVMENTS

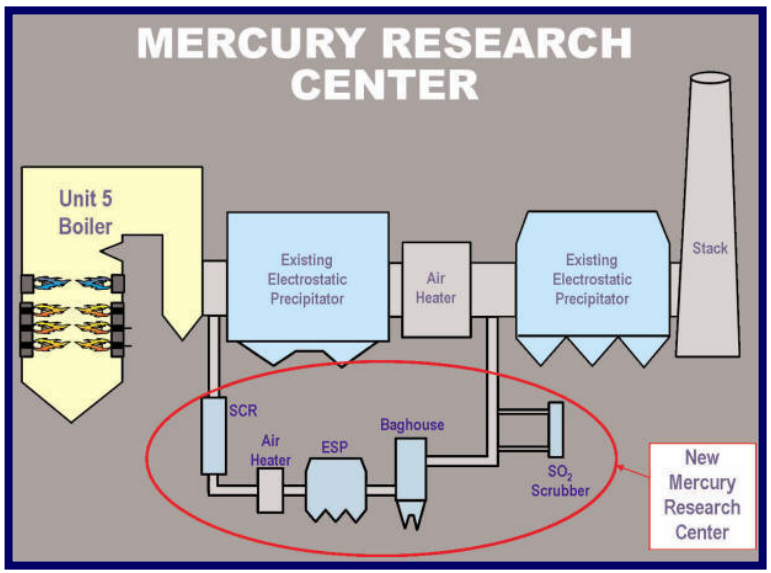
- With 30% improvement increase of dNOx from 90 to 95% at 1 ppm slip.



Inter-Layer Mixing

2006 Plans

- Pilot-Scale Demo
  - **Mercury Research Center at Gulf Power's Plant Crist (Pensacola, FL)**
  - **Pilot-scale SCR reactor**
    - **2 m x 2 m cross section**
    - **Multiple catalyst layers**
    - **Controllable gas flow rate and inlet gas temp.**
  - **Plan**
    - **Proof of concept**
    - **Document SCR improvement with interlayer mixing**
    - **Evaluate a series of mixer configurations**



Inter-Layer Mixing

2006 Plans

- Full-Scale Investigation of Mixer Erosion and Pluggage Potential
  - **Alabama Power's Plant Gorgas Unit 5 (Parrish, AL)**
  - **Install a dynamic mixer in order to monitor erosion and plugging potential**
  - **Mixer(s) location is downstream of last catalyst layer**
  - **No impact on SCR operation**
  - **Power mixer with compressed air throughout the test period**
  - **No performance data will be collected**

CONCLUSIONS

- Air Amplifiers currently provide best results:
  - Lower percentage of introduced air into flue gas
  - No associated pressure losses
  - Little/no expected ash deposition – will investigate
  - Can be turned off/down when not needed

- Potential Issues:
  - Plugging – maintain air flow, easy removal
  - Erosion – use better materials, replaceable
  - Catalyst Erosion – add a flow rectifier