

Lean NOx Catalysis Research and Development



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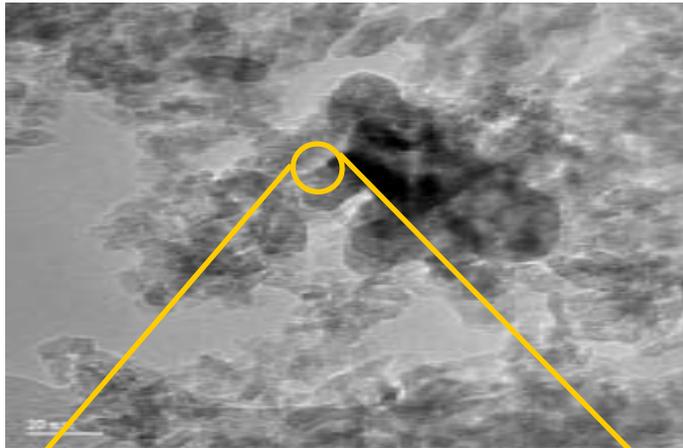


Catalyst Research & Development

Fundamental Understanding

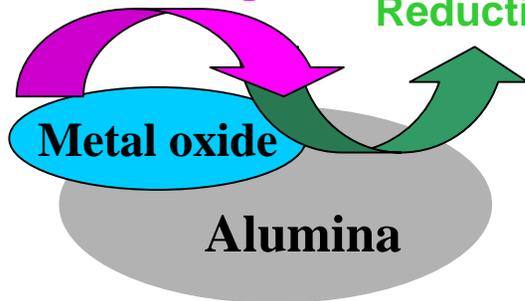


Application Engineering



Hydrocarbon
Reforming

NOx
Reduction



Catalyst Chemistry

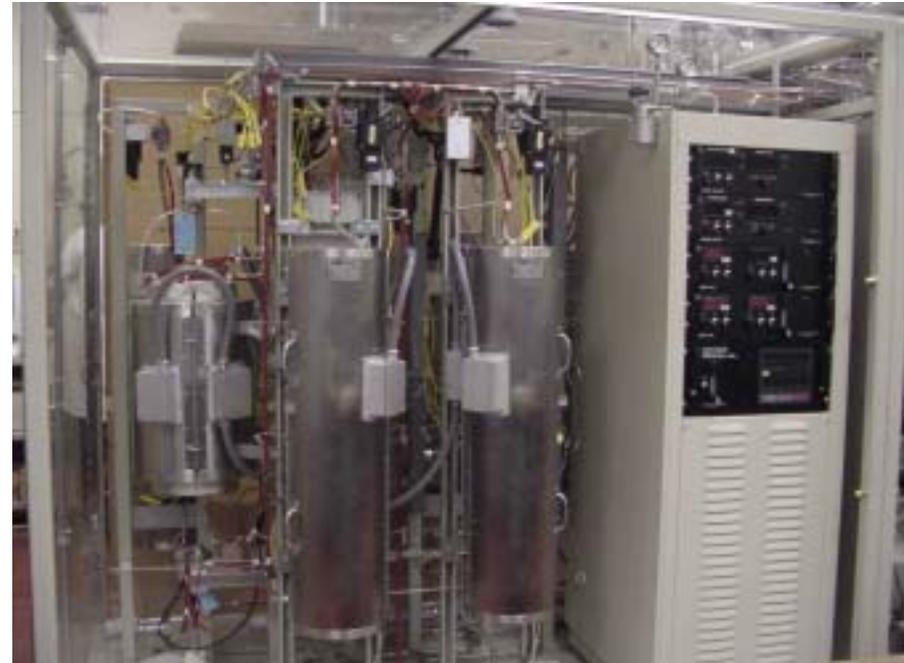


Caterpillar Catalyst Research Facilities



Catalyst synthesis lab

- Catalyst test lab: two powder benches, Horiba system, multi reactor system (10 reactors)
- Catalyst characterization instruments: BET, XRD, SEM, TPD/TPR, C&S analyzer



National Lab User Facilities

- XPS (PNNL)
- TEM, SAXS (ORNL)

Lean-NOx Catalyst Materials

- Noble metals (ex. Pt/Al₂O₃)

highly active, stable

narrow temperature range,

poorly selective (N₂O)

- Zeolites (ex. Cu-ZSM-5)

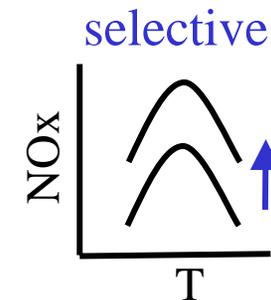
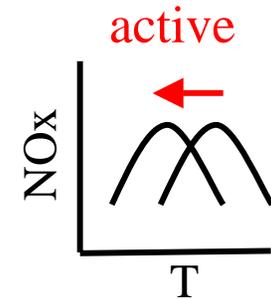
active, selective

hydro-thermally unstable

- Metal oxides (ex. Ag/Al₂O₃)

highly selective, stable, flexible formulation

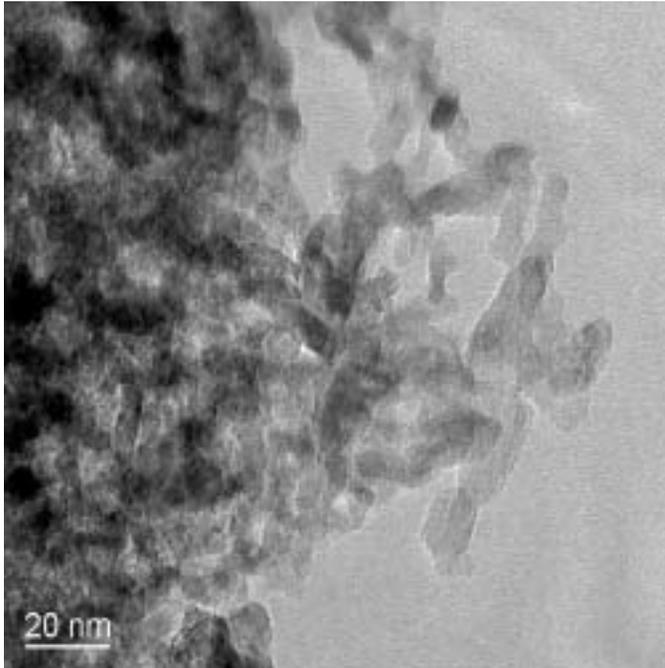
moderately active, reductant sensitive



Alumina Support Materials

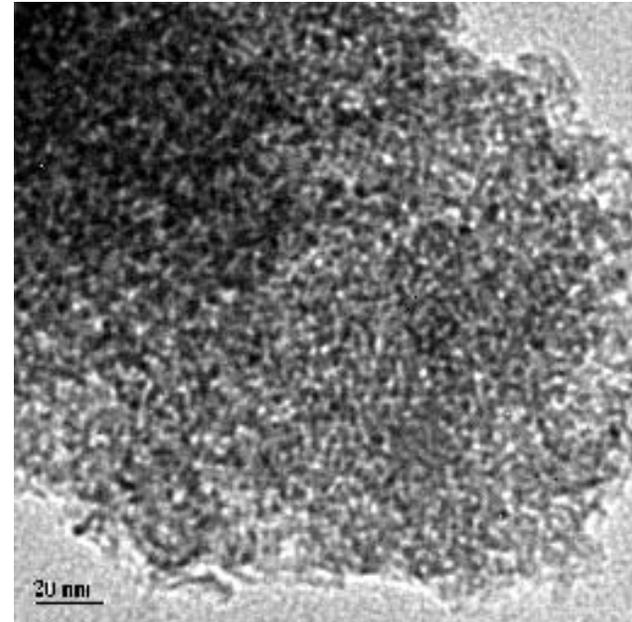
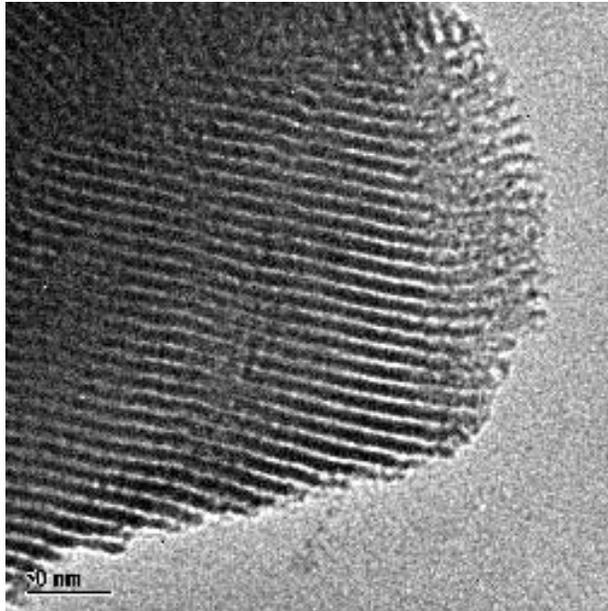


TEM image of alumina



- ◆ Physical property (SS, PV, PS)
- ◆ Chemical property (acidity/basicity)
- ◆ Processing (complex agent, pH)
- ◆ Inorganic synthesis
 - mesoporous alumina material

Mesoporous Alumina Synthesis



	Surface area (m ² /g)	Pore Volume (cc/g)	Pore Size (nm)
Caterpillar	566	1.4	9.9
Pinnavaia	420-535	0.21-0.68	2.4-4.6
Stucky	300	0.61	14

erf

of A

yield (%)

60
50
40

1500 2000 2500
m (min)

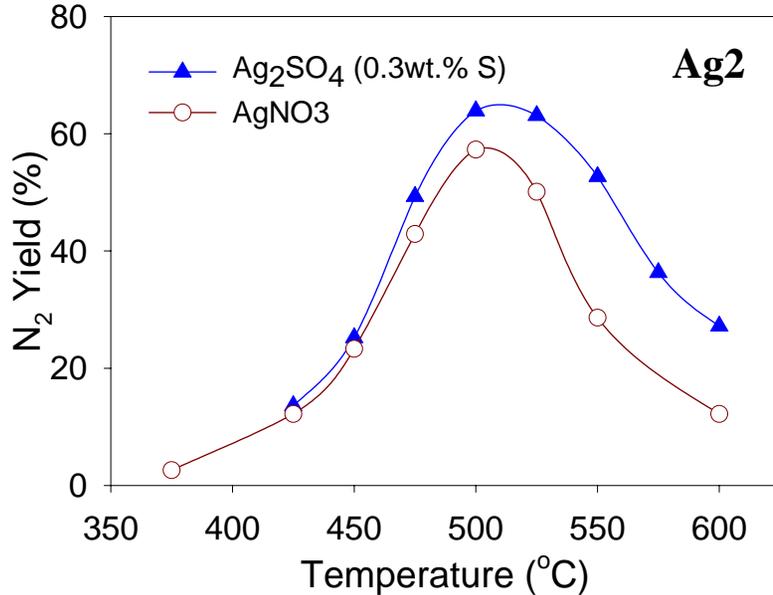
Respo
Depends

CATER **AR**

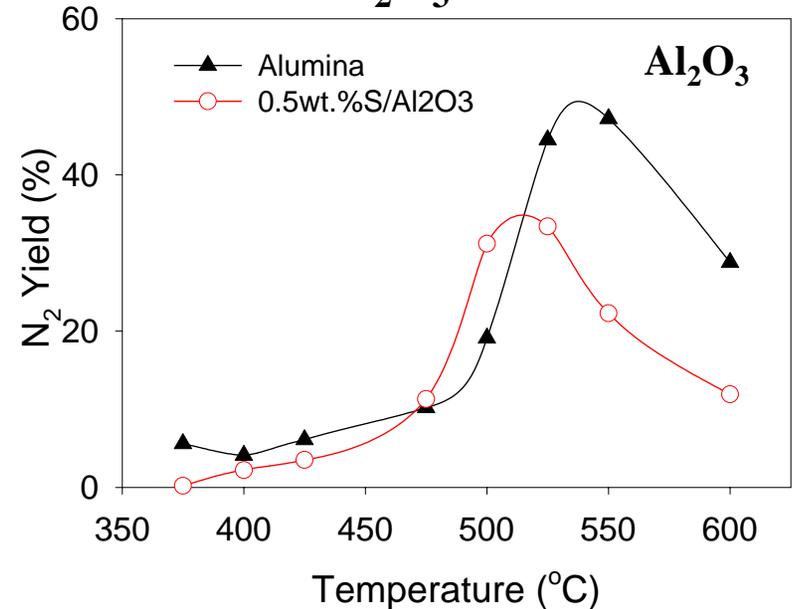
Active Site Identification of Ag/Al₂O₃ Catalyst



Ag/Al₂O₃ Results



S/Al₂O₃ Results



Catalytic activity: Ag₂SO₄ > Ag₂O

Al₂O₃ needs to be improved to have more durable catalyst

Engine Testing

- Potential building block for 2007 or 2010 emissions regulations
 - Low engine out NOx
 - Low Fuel Penalty
- Aggressive Lean-NOx catalyst formulation for NOx Reduction
 - Low sulfur content fuel (< 15 ppm S)
 - Sulfate suppressant additives not required

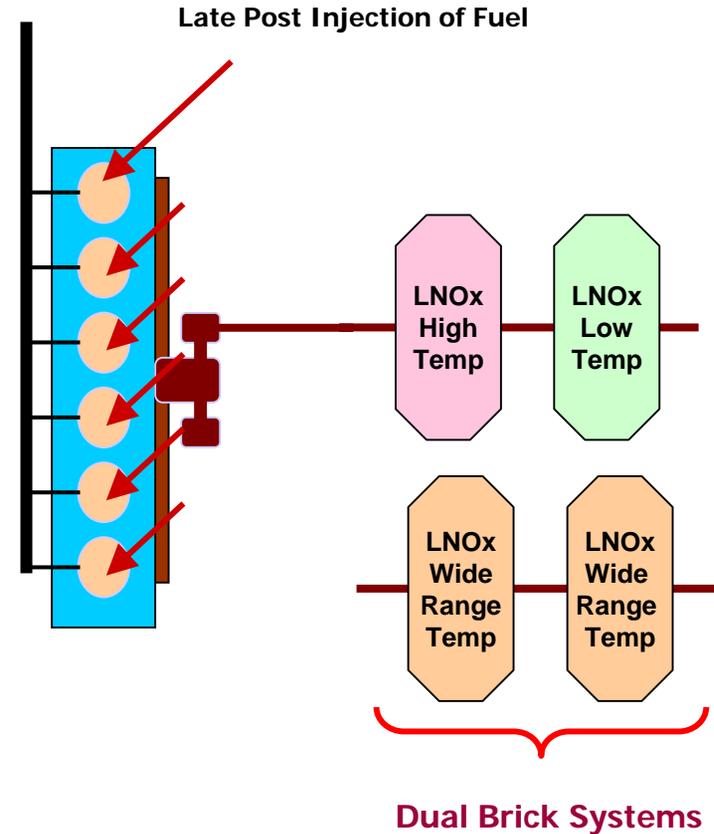
Advanced Lean NOx Catalysts



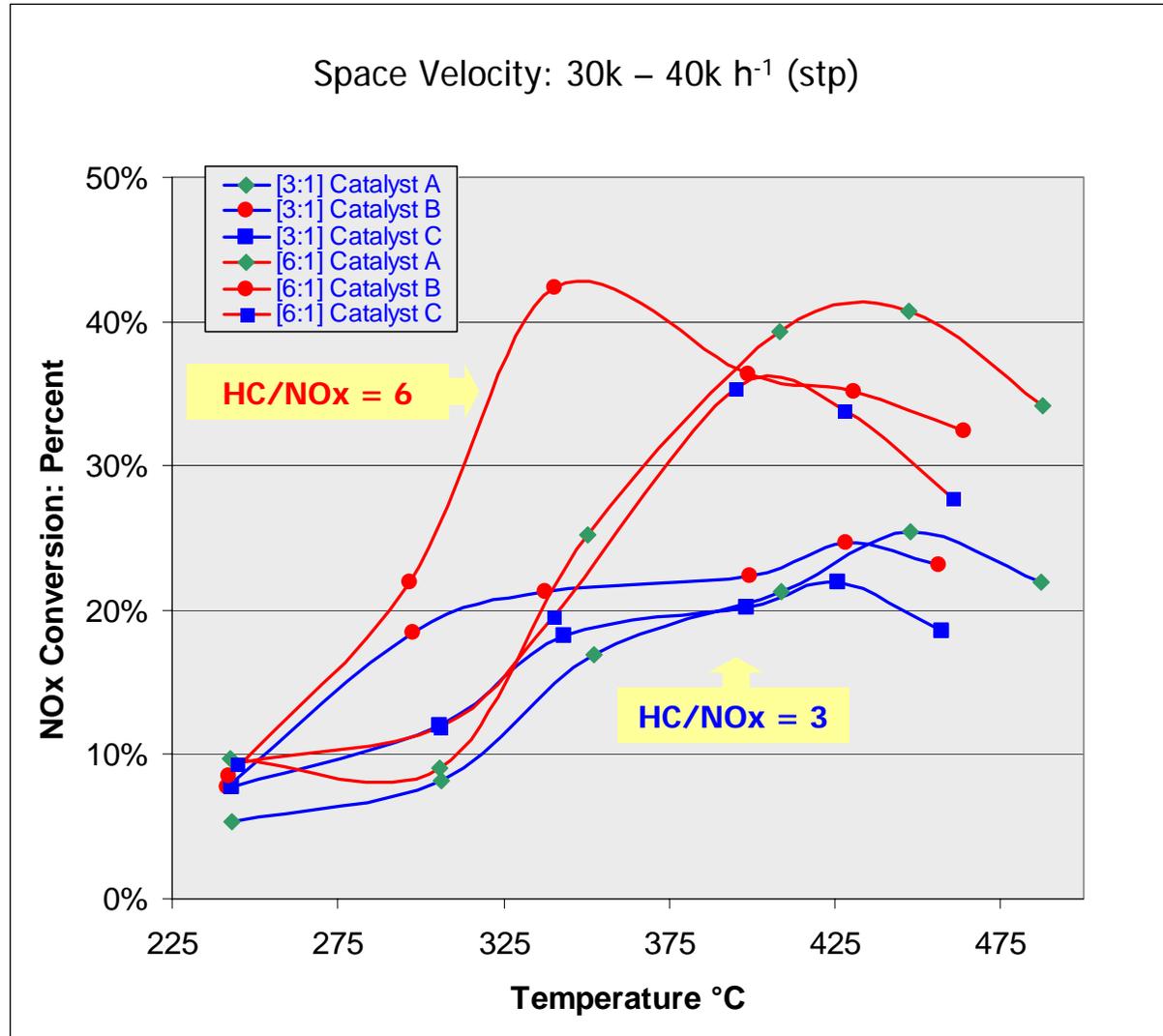
Advanced Lean NOx Catalyst Technology Development



- Screened numerous formulations on Cat engine
 - Catalysts provided by supplier(s)
- Tested on Cat 3126E 300HT (2000MY)
 - Two brick catalyst systems
 - 7.2L, 300 HP, High Torque
 - 4 gram NOx setup
 - Tested for highest conversions
 - ✓ HC/NOx = 3
 - ✓ HC/NOx = 6



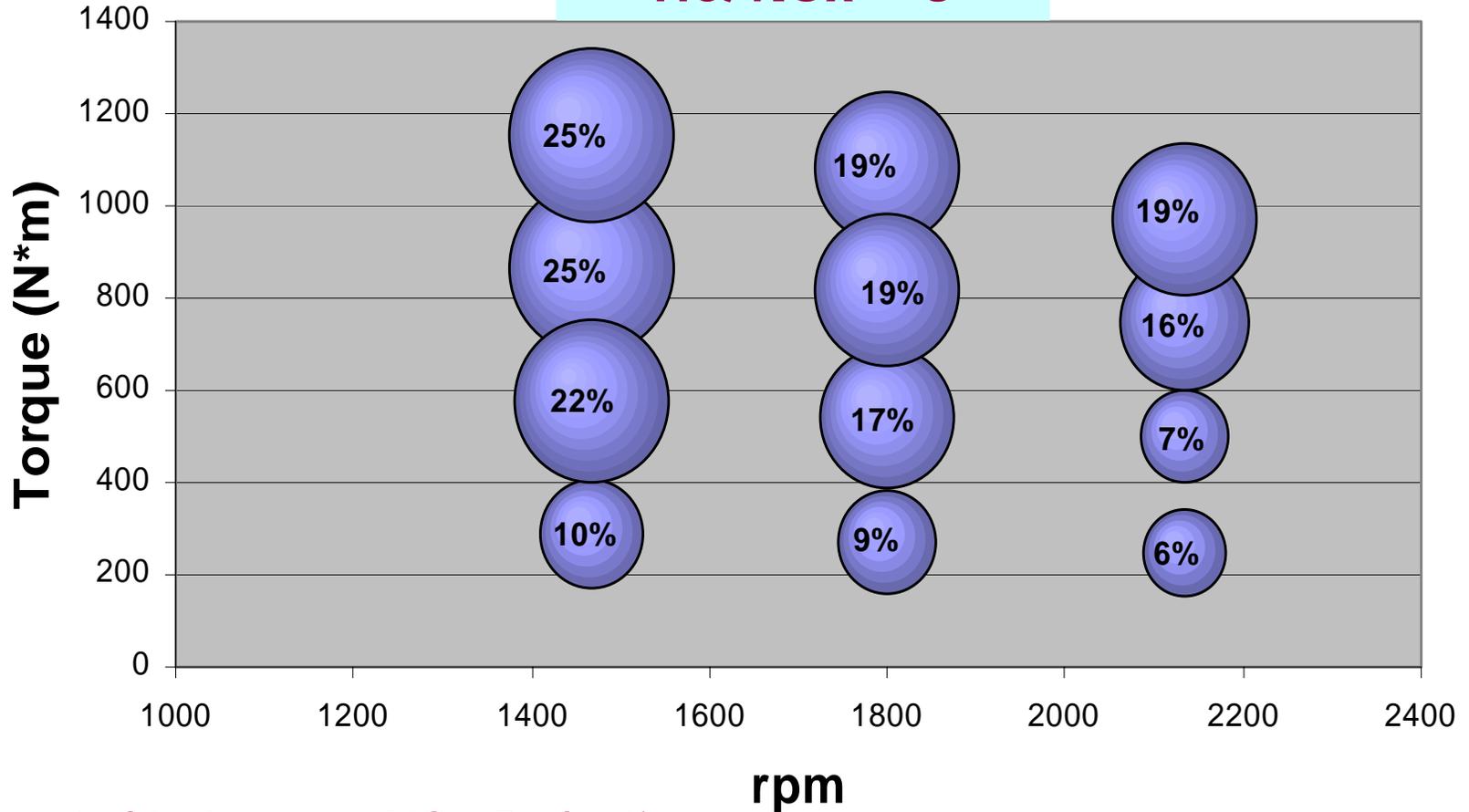
Advanced Lean NOx Catalysis Engine Test Results



NOx Reduction: ESC Steady-state Modes



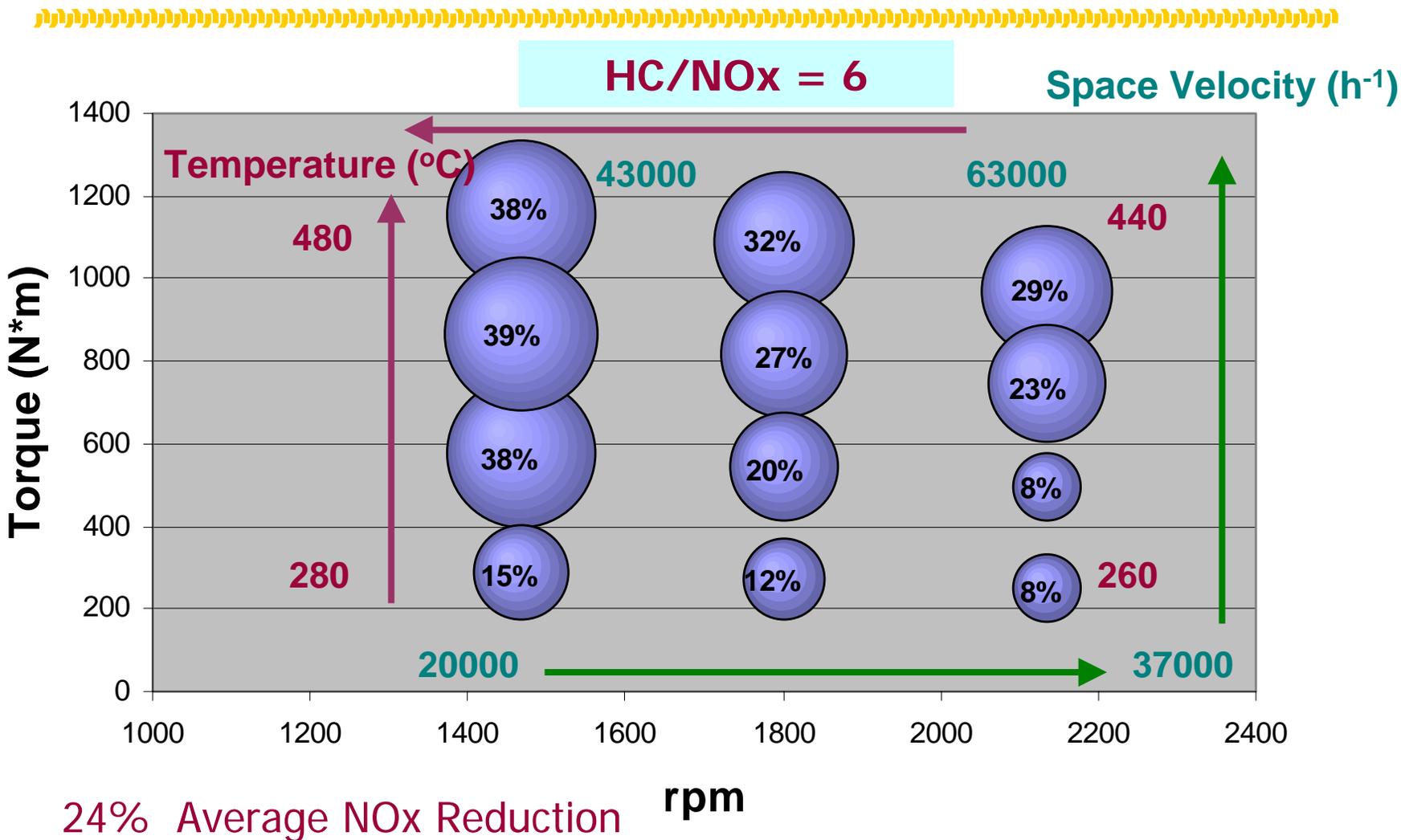
HC/NOx = 3



15% Average NOx Reduction

12-Mode non-idle ESC weighted average

NOx Reduction: ESC Steady-state Modes

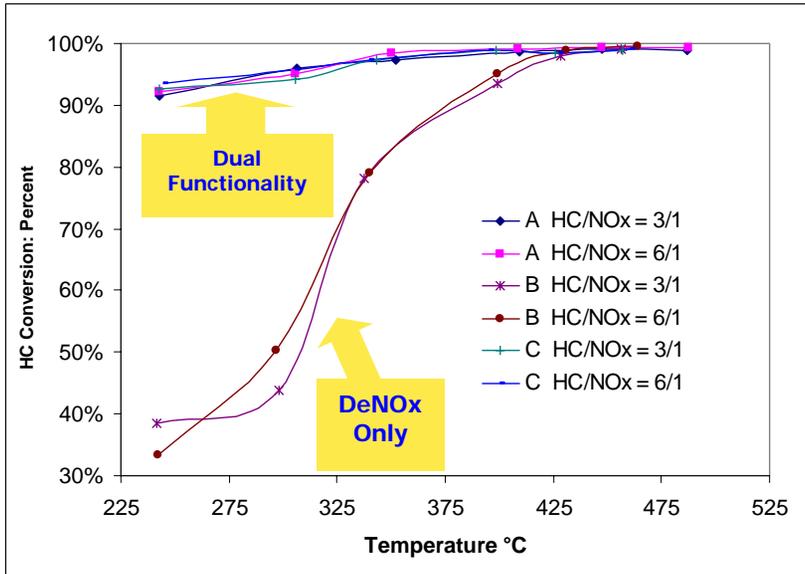


12-Mode non-idle ESC weighted average

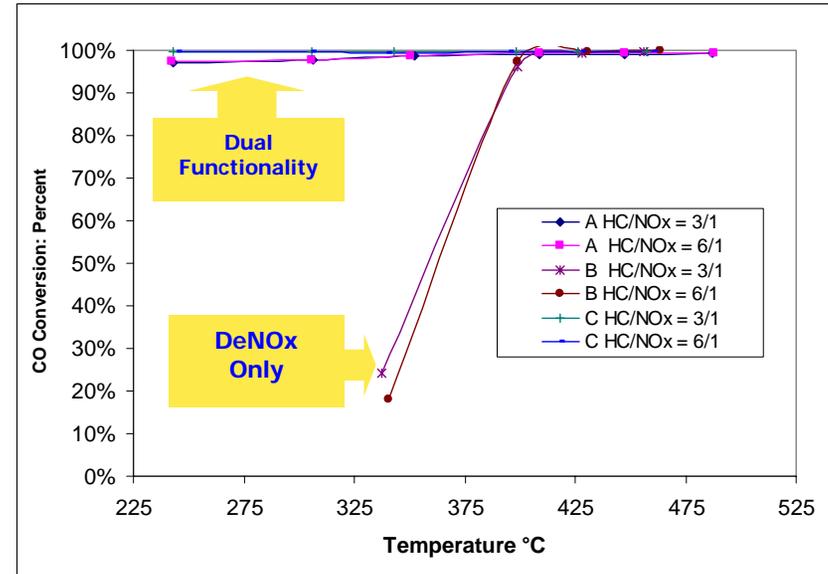
Hydrocarbon & CO Slip



Hydrocarbon Conversion



CO Conversion

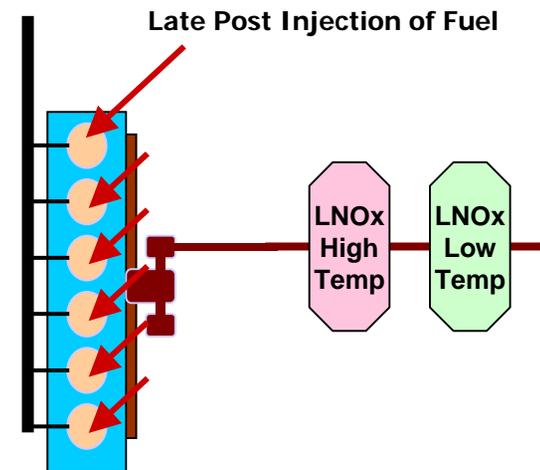
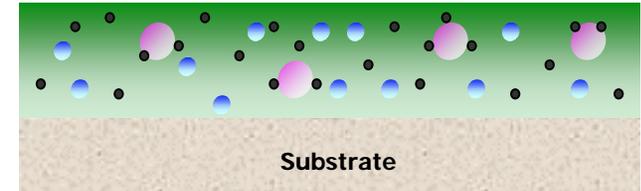


- Some DeNOx formulations showed dual functionality (Oxicat + Lean-NOx)
- The dual functionality needs to be further optimized.

Potential for Lean-NOx Catalysis Technology

Benefits

- **Simplicity**
 - No core engine modifications are needed
 - No infrastructure is required
 - Leverages flexible fuel system
 - Retrofit opportunities
- **Candidate for 20-40% NOx reduction**
 - Building block for added NOx reduction for 2007
- **Potential combined Oxicat and Lean-NOx functionality**
 - Marginal passive NOx reduction benefit while providing oxicat benefits



Potential for Lean-NOx Catalysis Technology - Continue



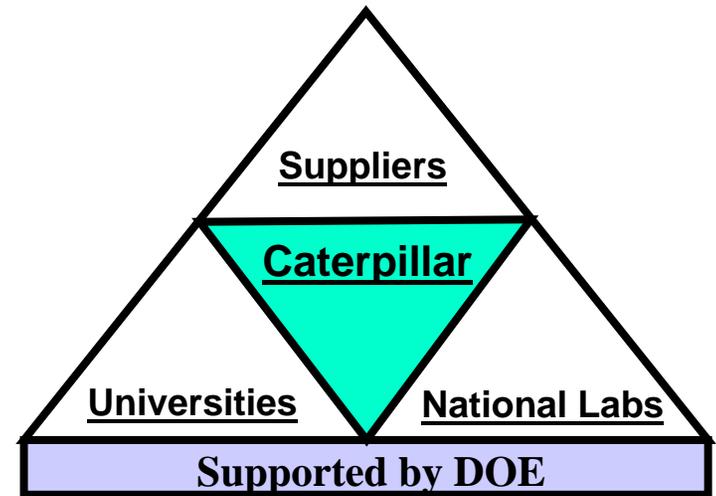
Issues/Challenges

- Higher performance catalyst
- Broader temperature window
- Higher durability
- Higher selectivity → Lower fuel penalty

Pathway

- Leverage expertise from strategic partnerships.
- System engineering of applications.
 - Integrate with developing engine combustion concepts.

Strategic Partnerships



Acknowledgements



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