Lean NOx Catalysis Research and Development

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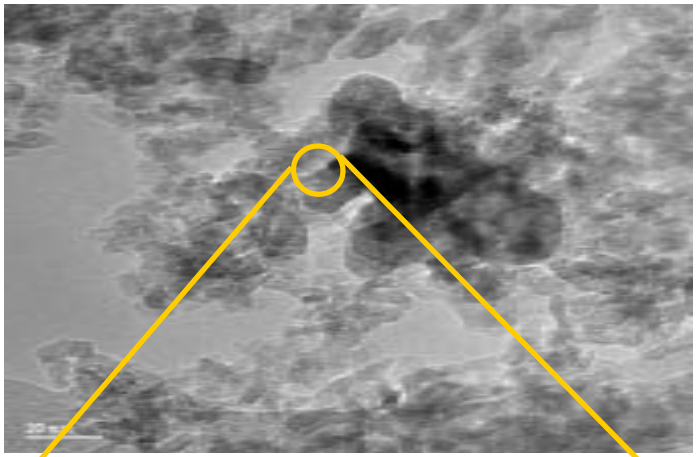
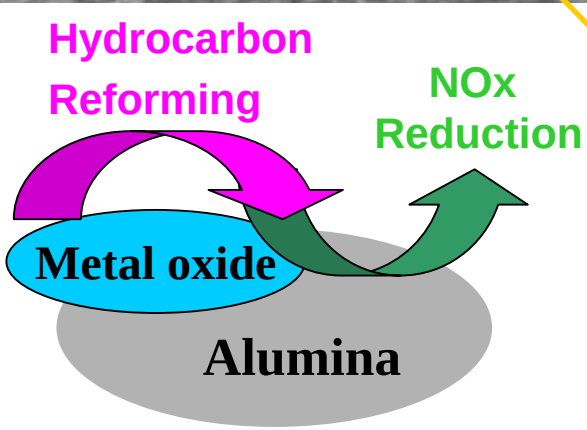
Engine Research

Catalyst Research & Development

Fundamental Understanding ⟷ **Application Engineering**





Catalyst Chemistry

Caterpillar Catalyst Research Facilities

Catalyst synthesis lab

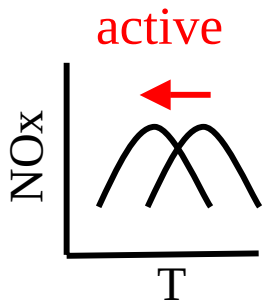
- Catalyst test lab: two powder benches, Horiba system, multi reactor system (10 reactors)
- Catalyst characterization instruments: BET, XRD, SEM, TPD/TPR, C&S analyzer

National Lab User Facilities

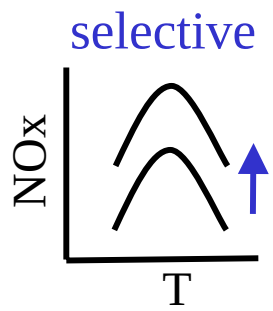
- XPS (PNNL)
- TEM, SAXS (ORNL)

Lean-NOx Catalyst Materials

- Noble metals (ex. Pt/Al_2O_3)
  - highly active, stable
  - narrow temperature range,
  - poorly selective (N_2O)



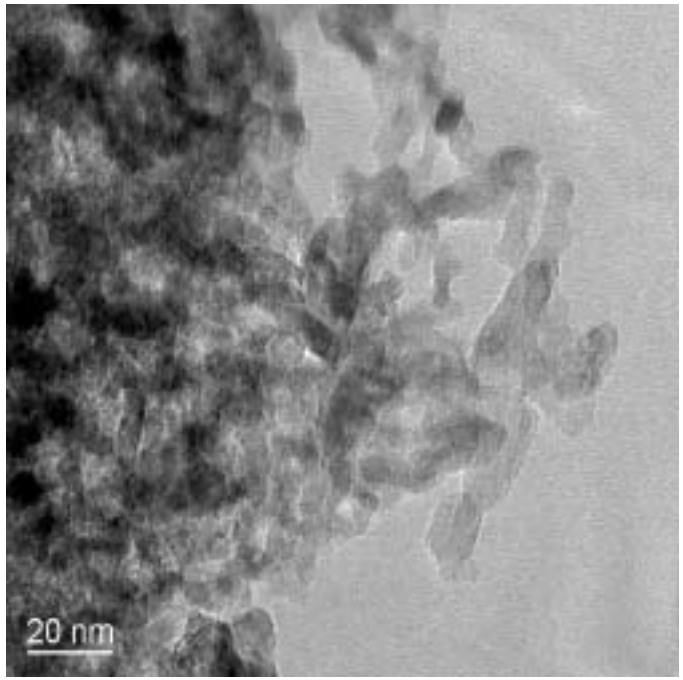
- Zeolites (ex. Cu-ZSM-5)
  - active, selective
  - hydro-thermally unstable



- Metal oxides (ex. Ag/Al_2O_3)
  - highly selective, stable, flexible formulation
  - moderately active, reductant sensitive

Alumina Support Materials

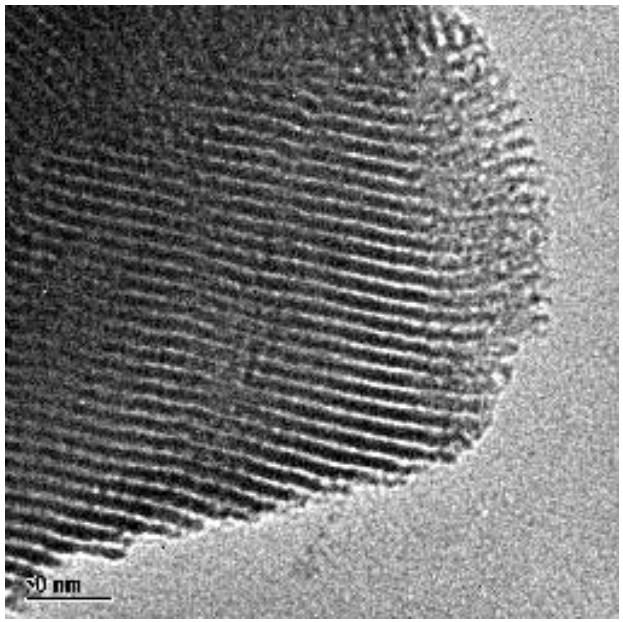
TEM image of alumina

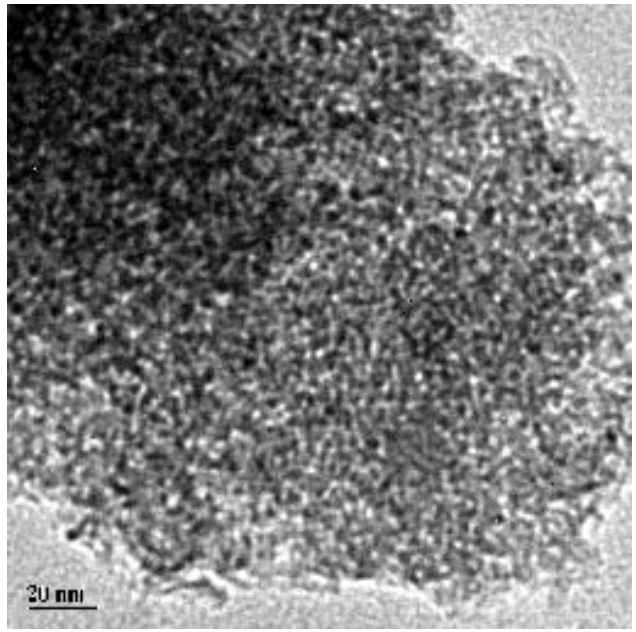


- Physical property (SS, PV, PS)
- Chemical property (acidity/basicity)
- Processing (complex agent, pH)
- Inorganic synthesis

  - mesoporous alumina material

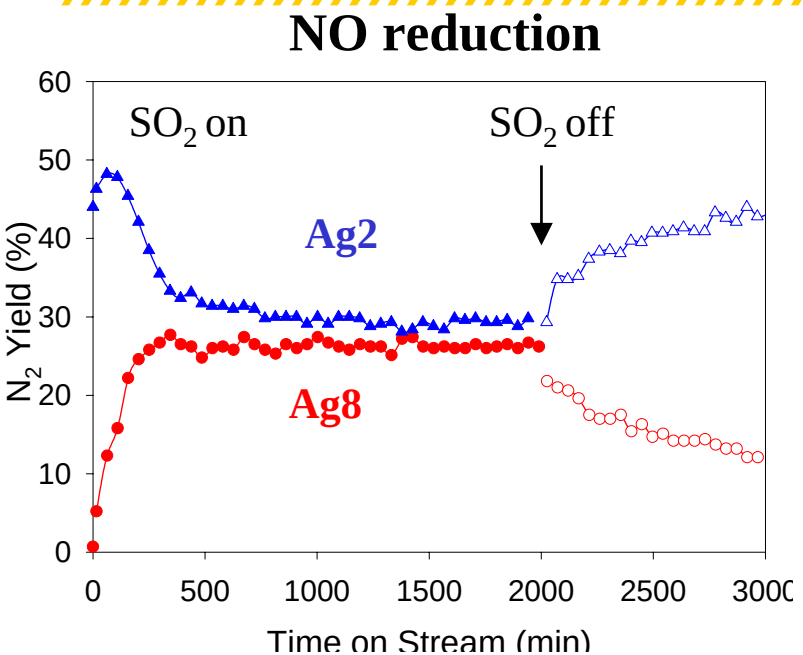
Mesoporous Alumina Synthesis

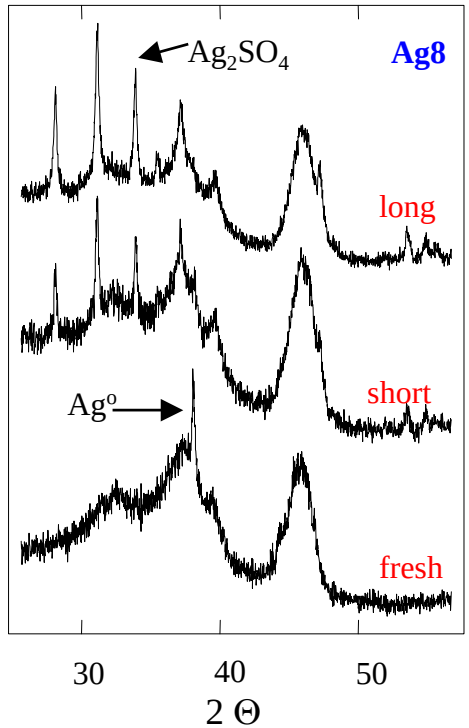




	Surface area (m^2/g)	Pore Volume (cc/g)	Pore Size (nm)
Caterpillar	566	1.4	9.9
Pinnavaia	420-535	0.21-0.68	2.4-4.6
Stucky	300	0.61	14

Performance and Characterization of Ag/Al_2O_3 Catalysts

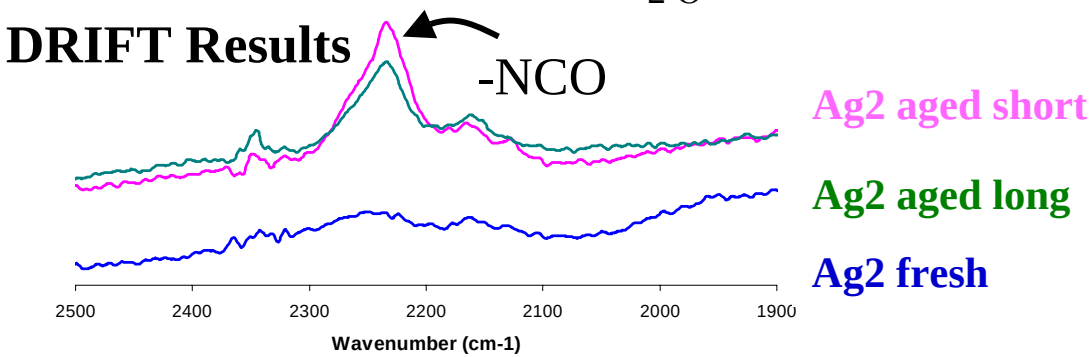




S (wt%)

1.5

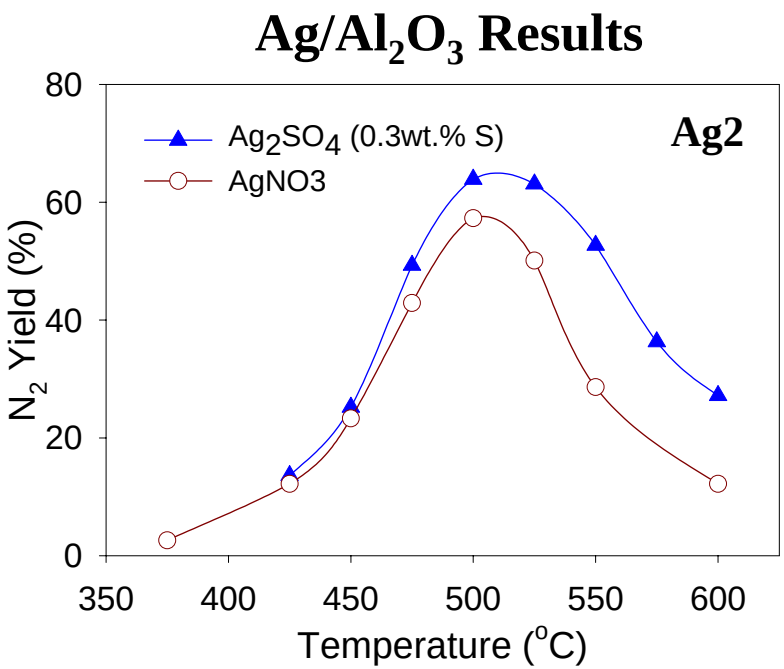
0.8

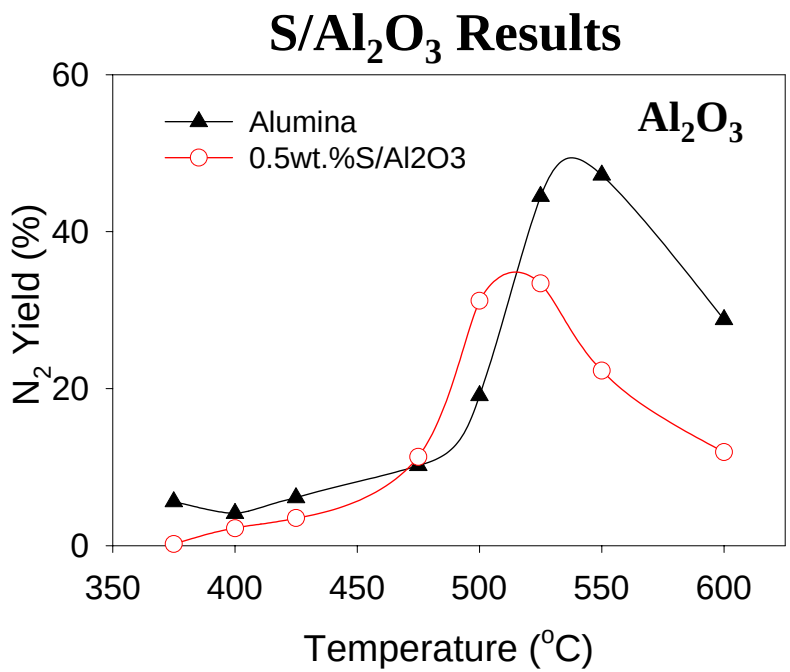


- Response to SO_2:

  Depends on silver loading

Active Site Identification of Ag/Al_2O_3 Catalyst





Catalytic activity: $Ag_2SO_4 > Ag_2O$

Al_2O_3 needs to be improved to have more durable catalyst

Engine Testing

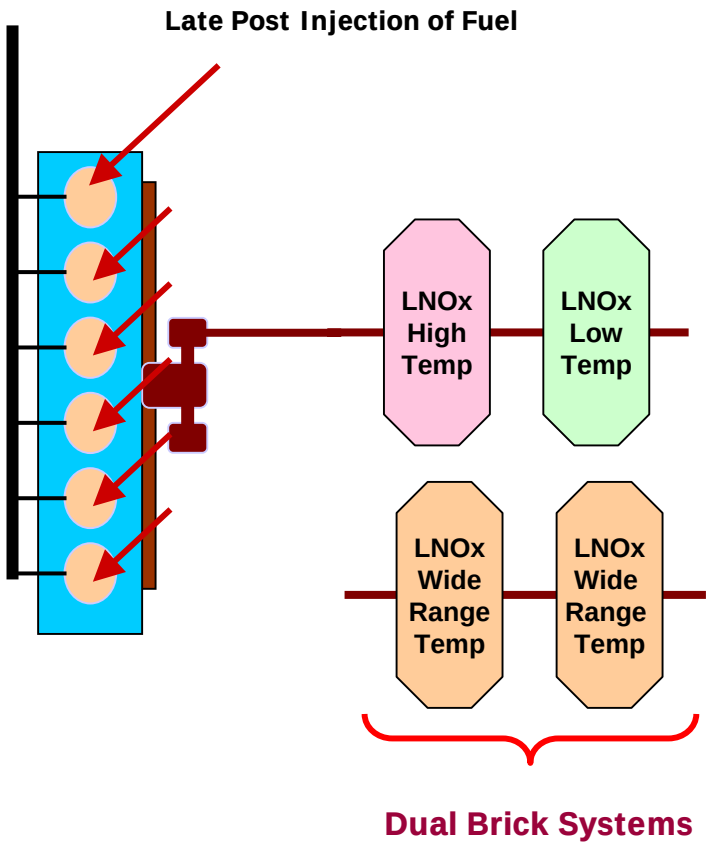
- Potential building block for 2007 or 2010 emissions regulations
  - Low engine out NOx
  - Low Fuel Penalty

- Aggressive Lean-NOx catalyst formulation for NOx Reduction
  - Low sulfur content fuel (< 15 ppm S)
  - Sulfate suppressant additives not required

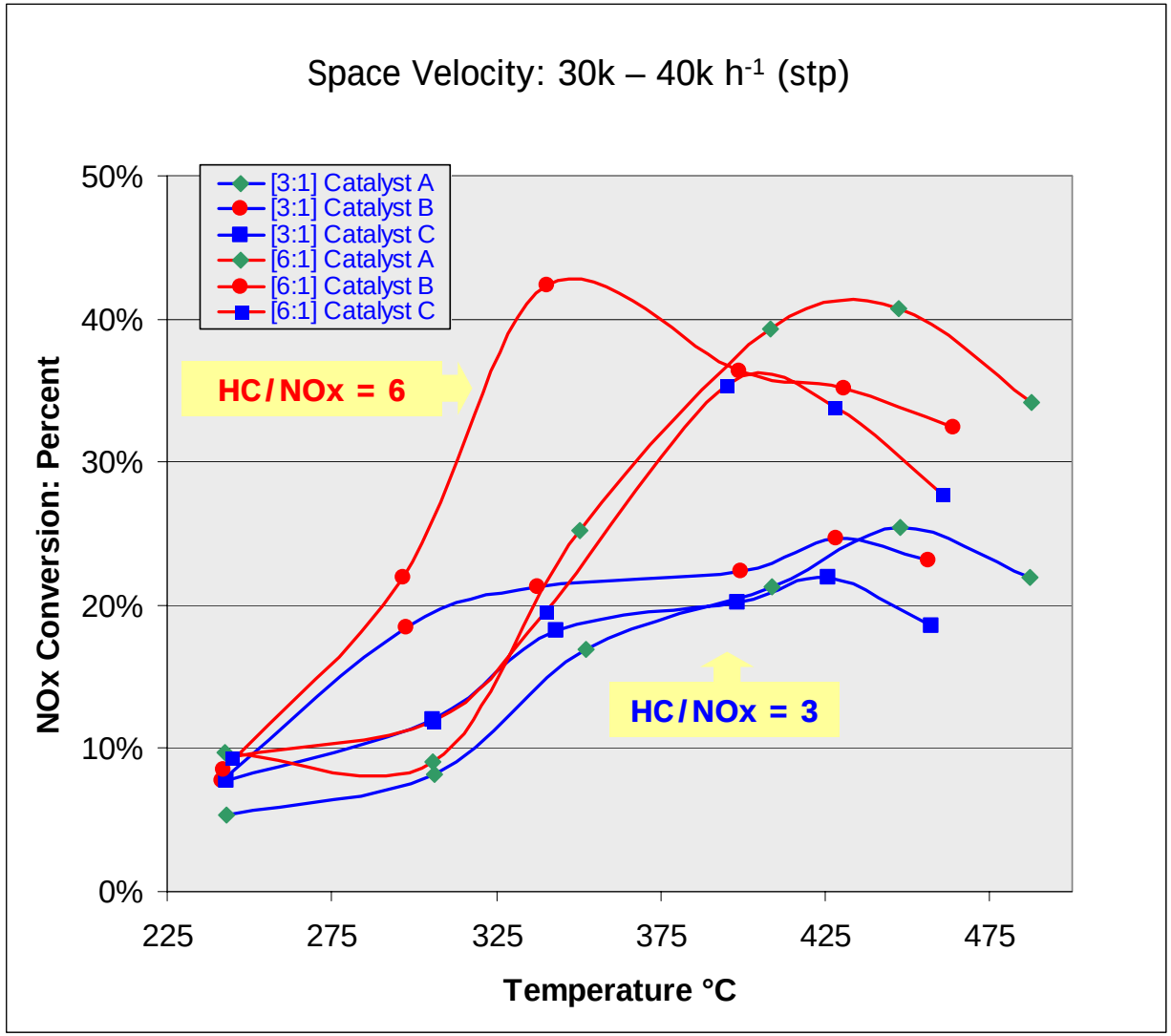
Advanced Lean NOx Catalysts

Advanced Lean NOx Catalyst Technology Development

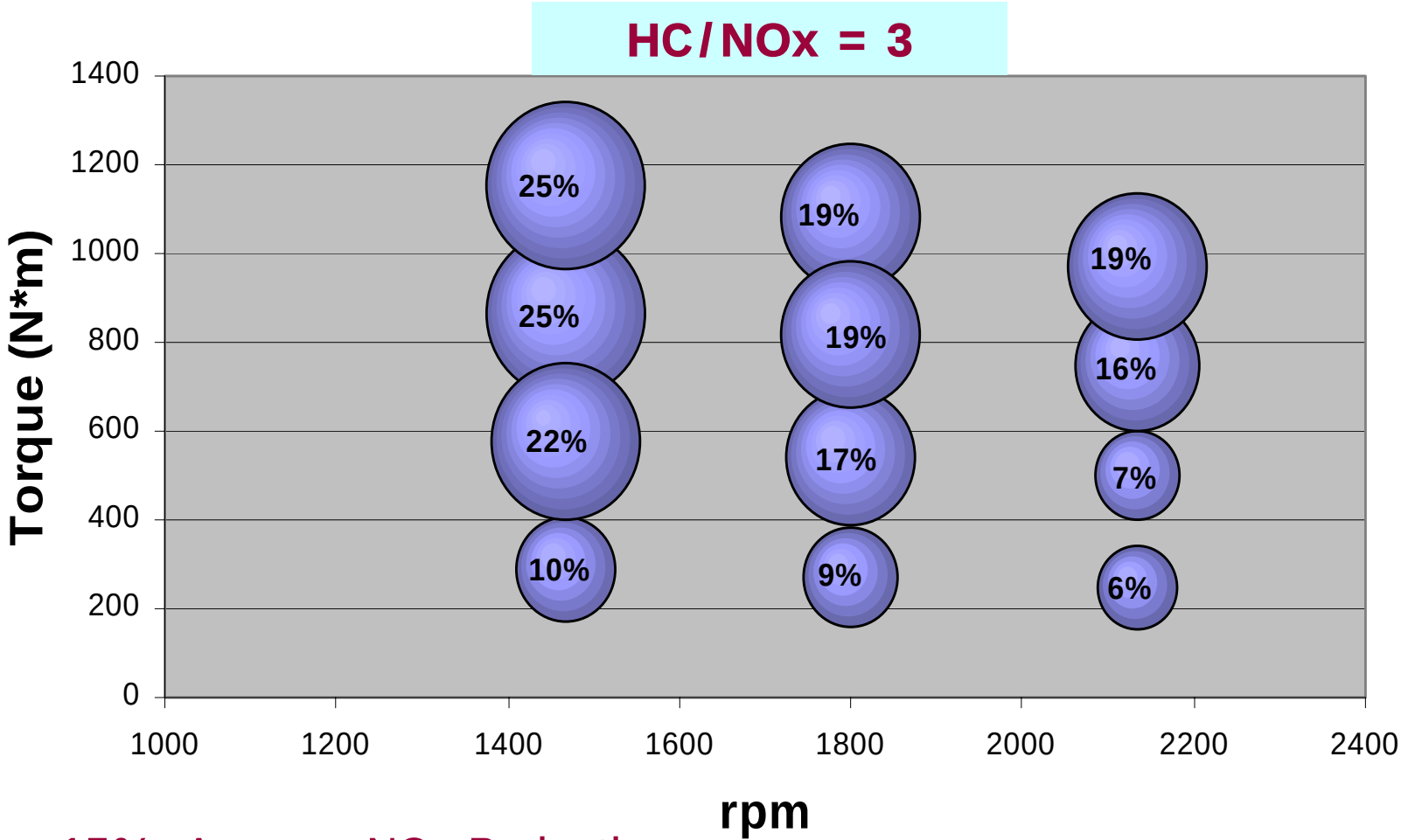
- Screened numerous formulations on Cat engine
  - Catalysts provided by supplier(s)
- Tested on Cat 3126E 300HT (2000MY)
  - Two brick catalyst systems
  - 7.2L, 300 HP, High Torque
  - 4 gram NOx setup
  - Tested for highest conversions
    - ✓ HC/NOx = 3
    - ✓ HC/NOx = 6



Advanced Lean NOx Catalysis Engine Test Results



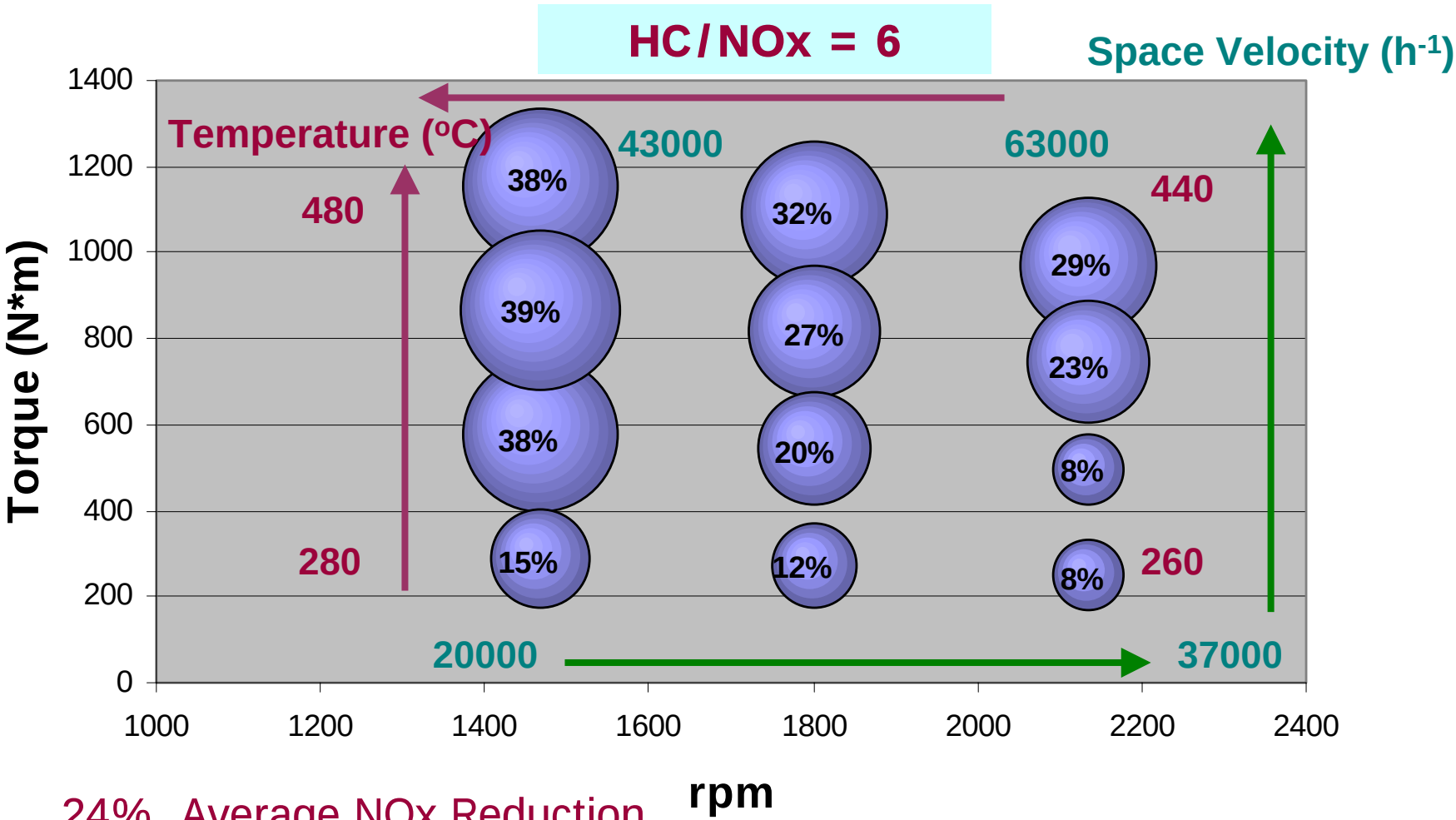
NOx Reduction: ESC Steady-state Modes



15% Average NOx Reduction

12-Mode non-idle ESC weighted average

NOx Reduction: ESC Steady-state Modes

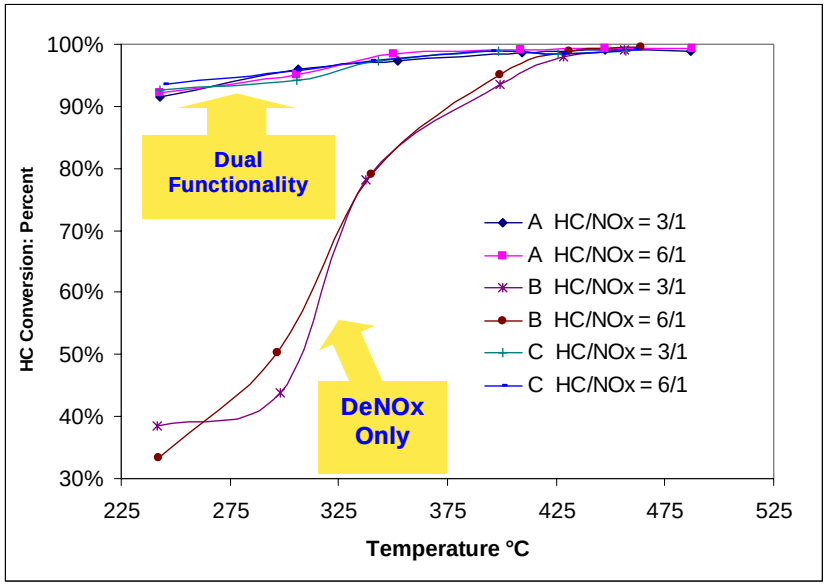


24% Average NOx Reduction

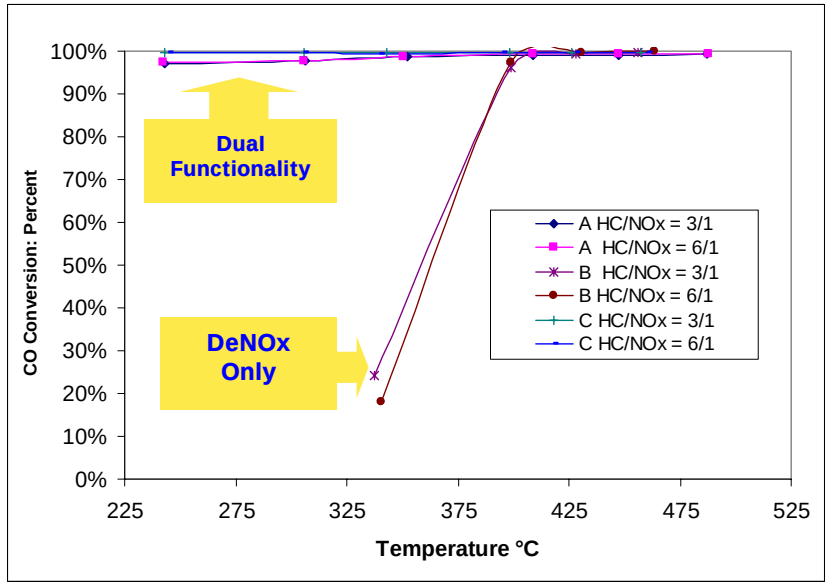
12-Mode non-idle ESC weighted average

Hydrocarbon & CO Slip

Hydrocarbon Conversion



CO Conversion

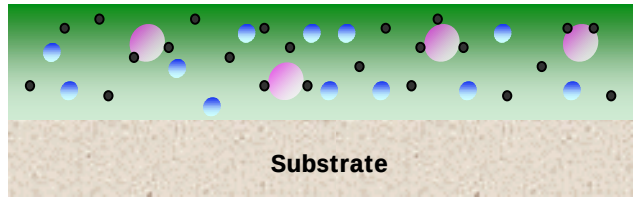


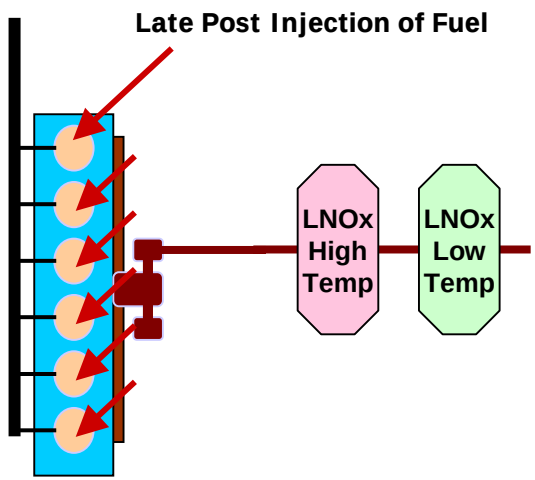
- Some DeNOx formulations showed dual functionality (Oxicat + Lean-NOx)
- The dual functionality needs to be further optimized.

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



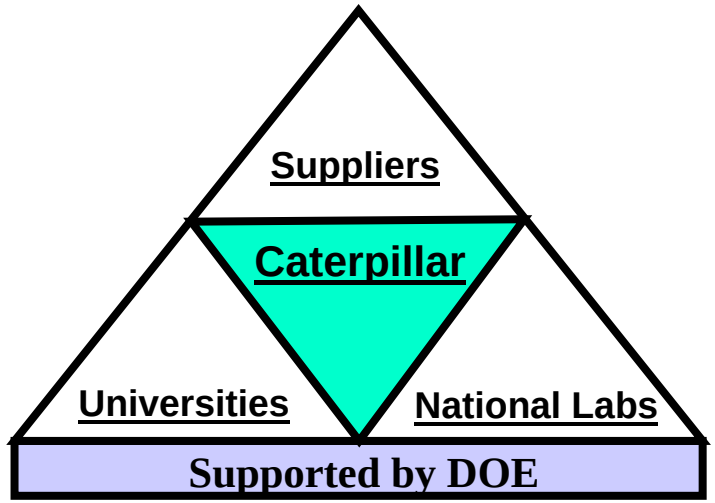


Potential for Lean-NOx Catalysis Technology - Continue

Issues/Challenges

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

Strategic Partnerships



Pathway

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

Acknowledgements

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