NOx Adsorber Developments

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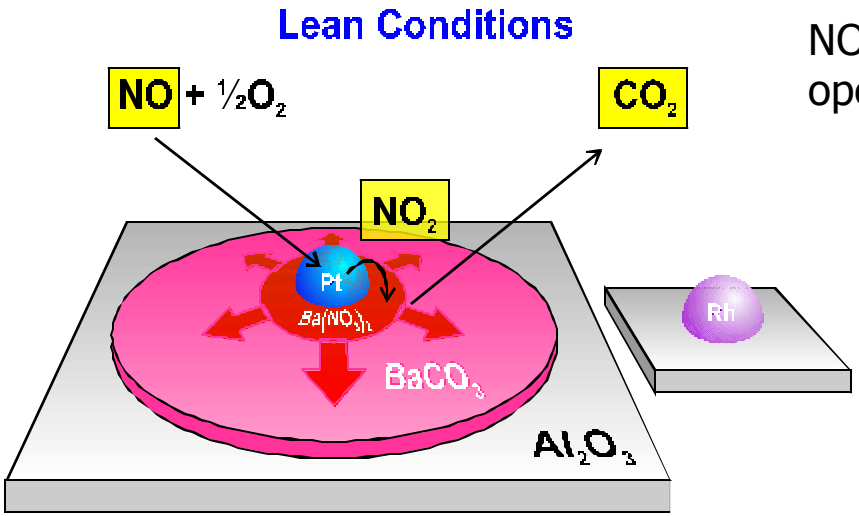
NOx Adsorber - Overview

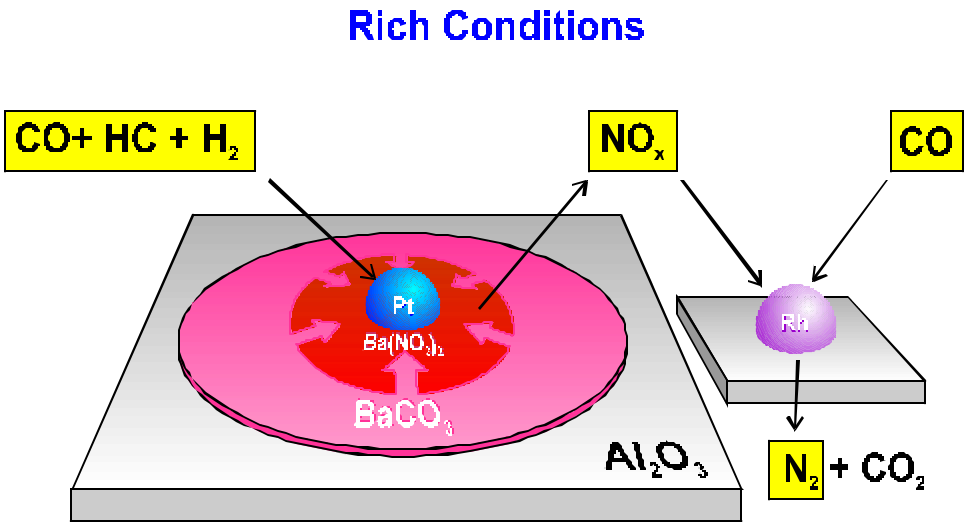
- Introduction/Objectives
- Results from single branch system
- General open issues
- Conclusions

Introduction - NOx Adsorber Operation



NOx Adsorber (Trap, Storage catalyst) operation:

- Diesel engine runs lean and NOx is captured
- Trap is soon saturated and requires regeneration
- Exhaust system runs rich (lambda<1.0) for several seconds.
- In the rich environment NOx converted (reduced) to N_2.

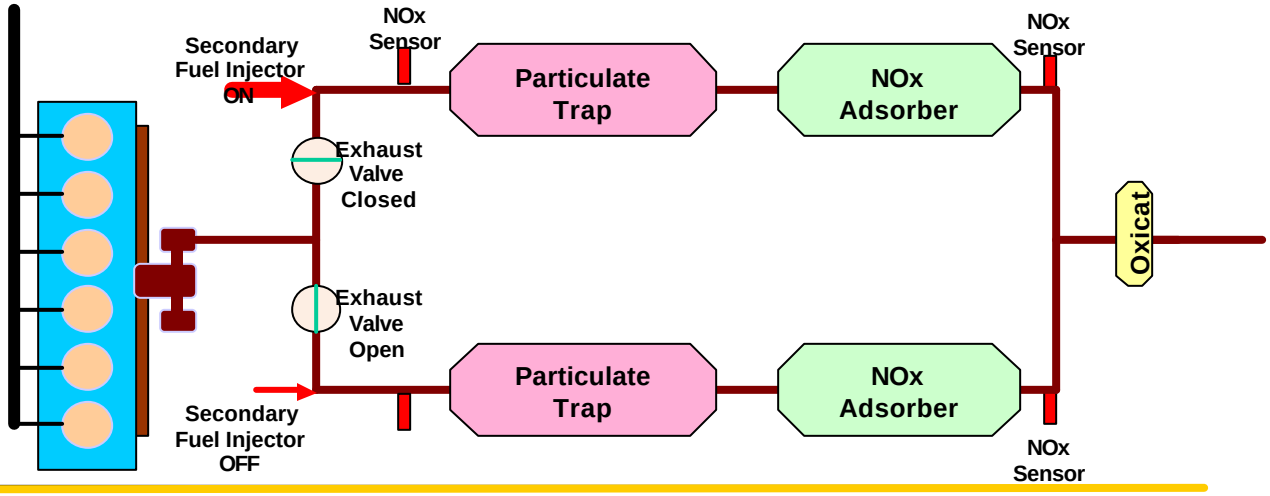


Source: JM

Introduction - NOx Adsorber

- EPA's preferred route for 2007/2010
- 95% NOx reduction shown with 1.5% fuel economy penalty
- Major Issue Exist
  - Tremendous system complexity, packaging
  - Cost of precious metals (12litre engine - $4300 NOx adsorber)
  - EPA Economic analysis $500 for NOx adsorber PGM
  - Sulfur degradation and catalyst durability

Dual path system as EPA demo

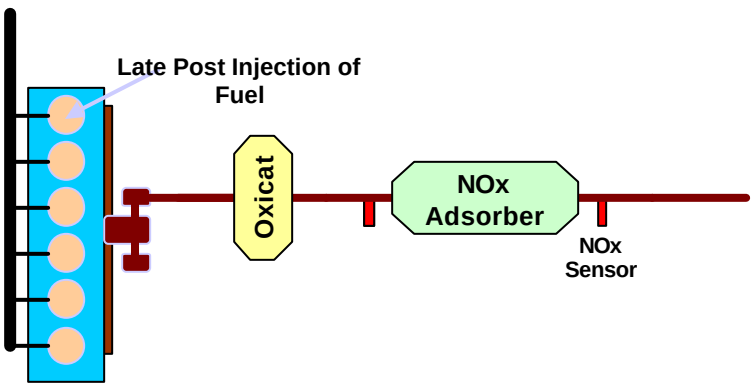


Objectives

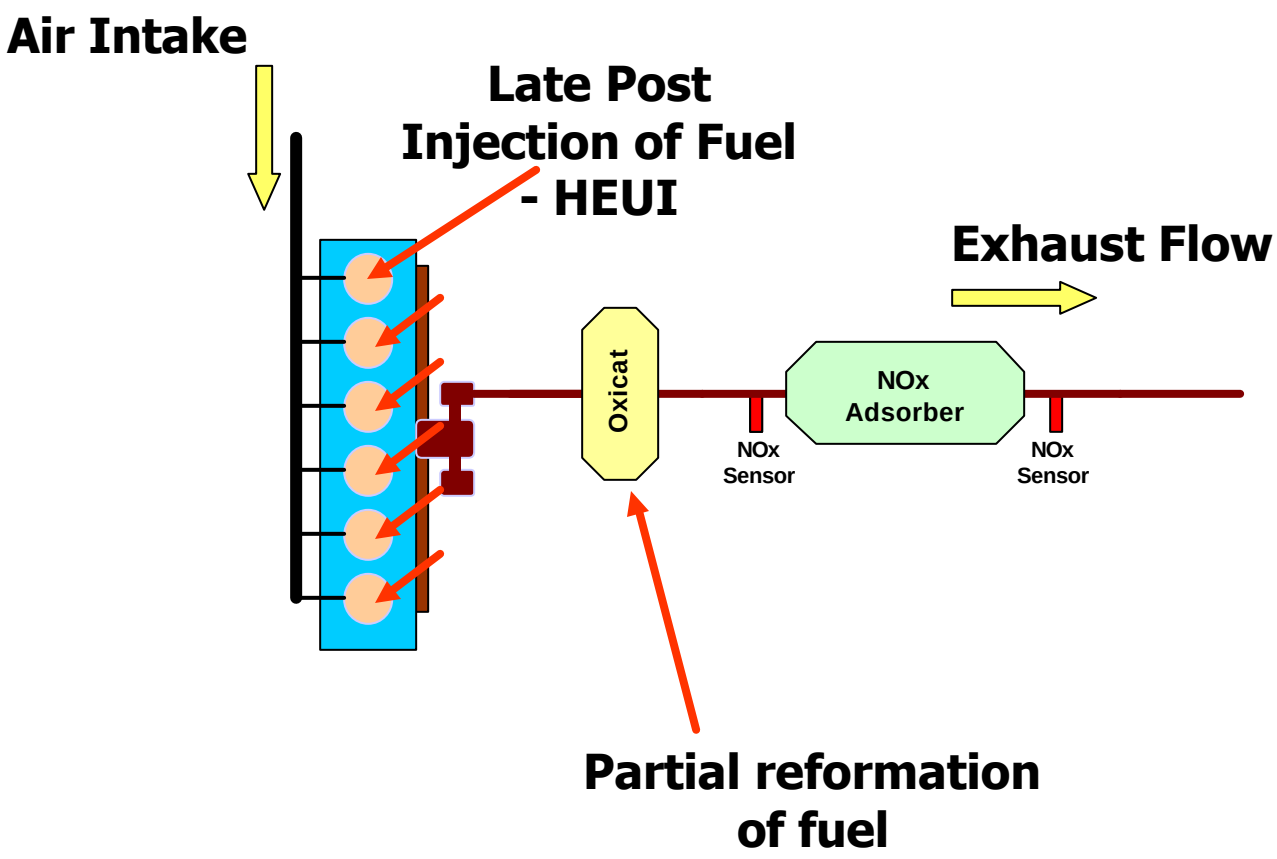
- Objectives:
  - To establish the feasibility of single branch system as a **cost effective** system for achieving long term emission standards for both LD and HD engines

NOx Adsorber – Single Branch

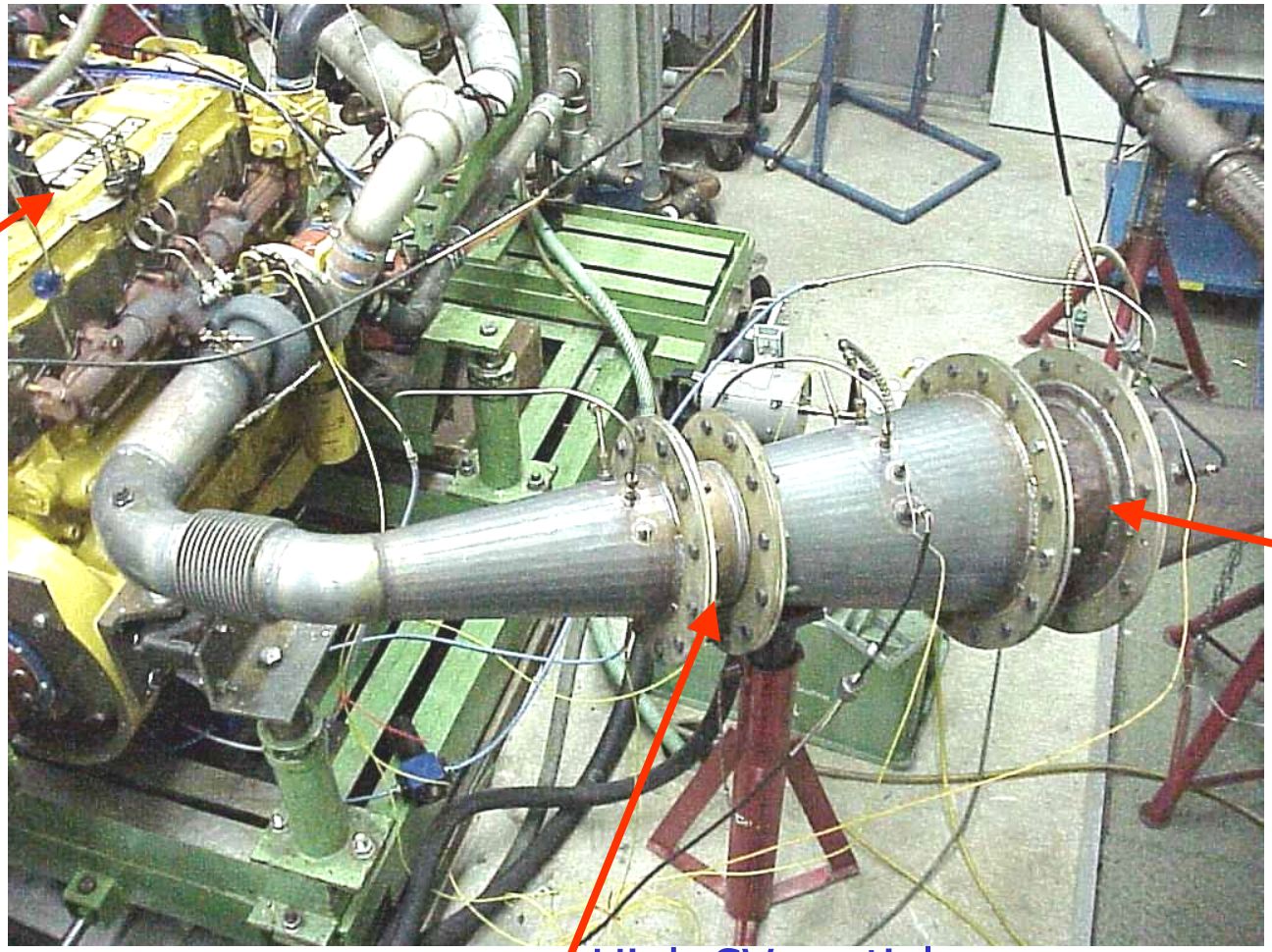
- NOx Adsorber Project
  - 3126B engine, 7.2 liter
  - Investigate potential of 'simplest' configuration
  - Expand the learning
  - 5 primary keypoints selected to establish rich operating strategies for 25, 50 and 100% load points
  - Strategies expanded to 13 mode points
  - Look at potential for light and heavy duty applications
  - NOx adsorber Catalyst size 1.8xSwept Vol (cost of precious metals ~ $850)



NOx Adsorber – Single Branch



NOx Adsorber – Single Branch



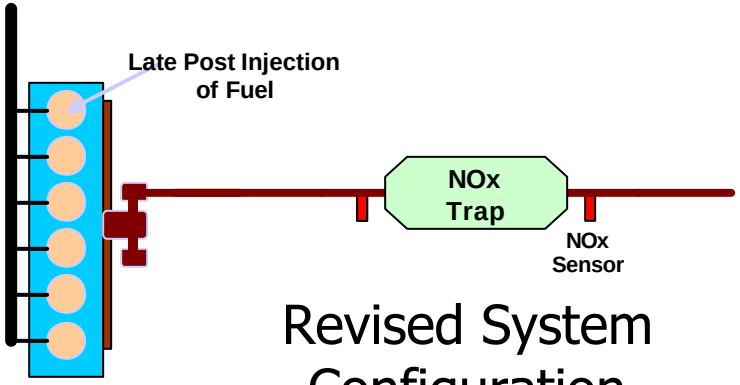
3126B Engine with HEUI

NOx Adsorber Catalyst 12.5″ x 6″ 12liter

High SV partial oxidation catalyst

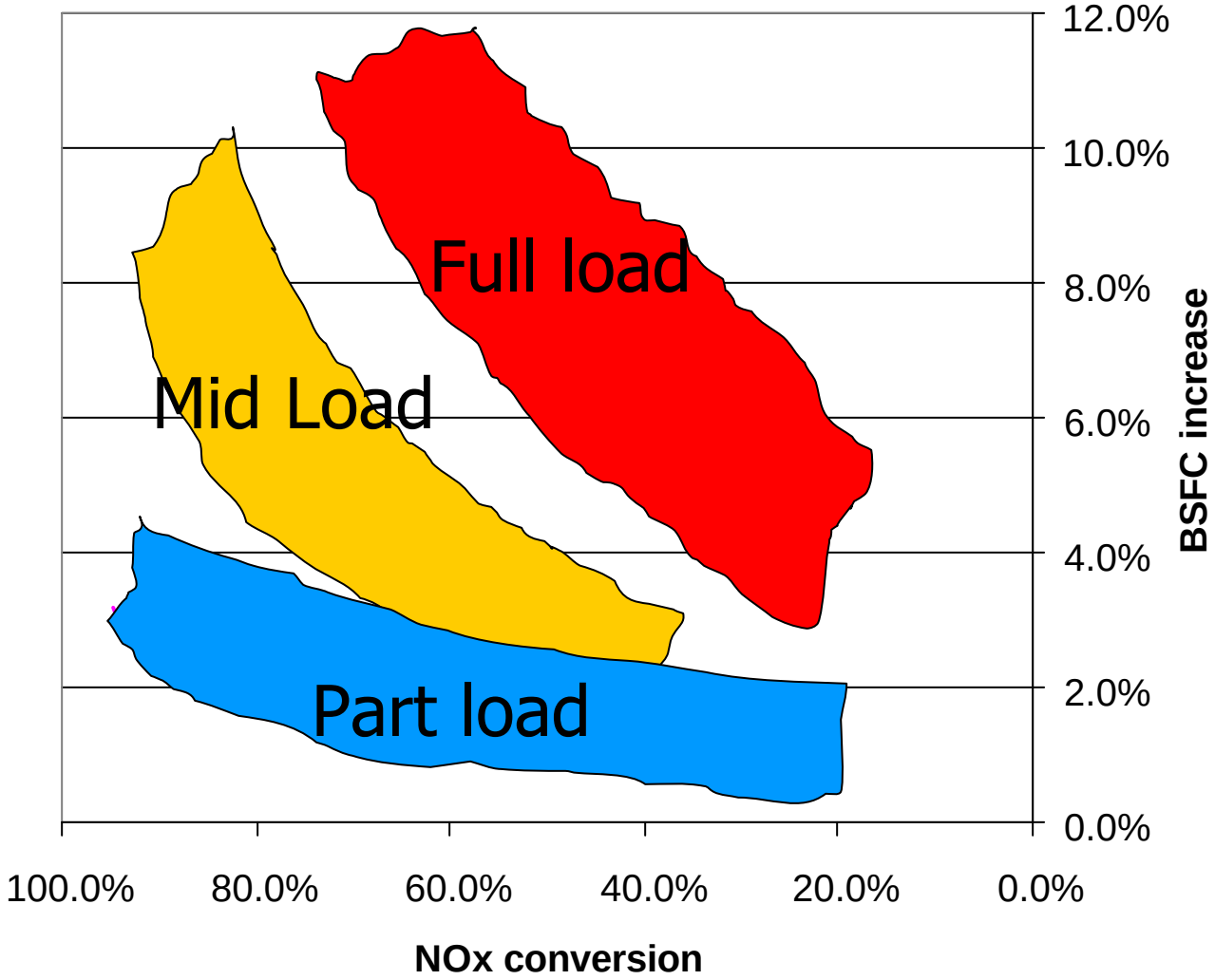
Single Branch - General Results

- Strategy for rich operation
  - Numerous strategies investigated
  - Reduce airflow to get λ as low as possible within smoke, exhaust temperature constraints
  - Then apply post injection
  - Low λ possible - to 0.85, engine stable, smoke <= 4.0 bsu
- Effect of partial oxidation catalyst
  - No net benefit on CO concentration
- Competitive Package Size



Revised System Configuration

NOx Adsorber - Single Branch - Results

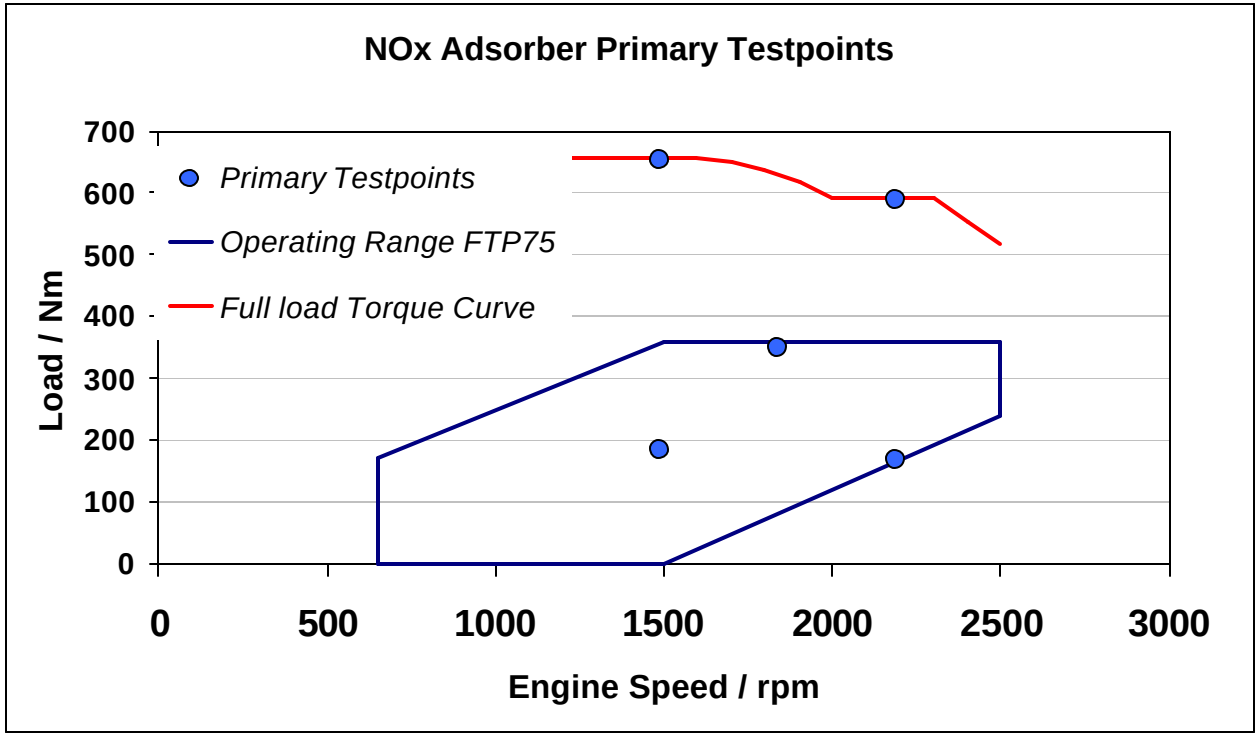


Single Branch - Additional Issues

- Project has highlighted the following:
  - Exhaust manifold temperature limits reached
    - Impact on engine durability
  - Increased combustion noise
  - Torque fluctuations
    - Transparency to the driver/operator
  - Smoke to 4.0bsu
    - Additional burden on DPF

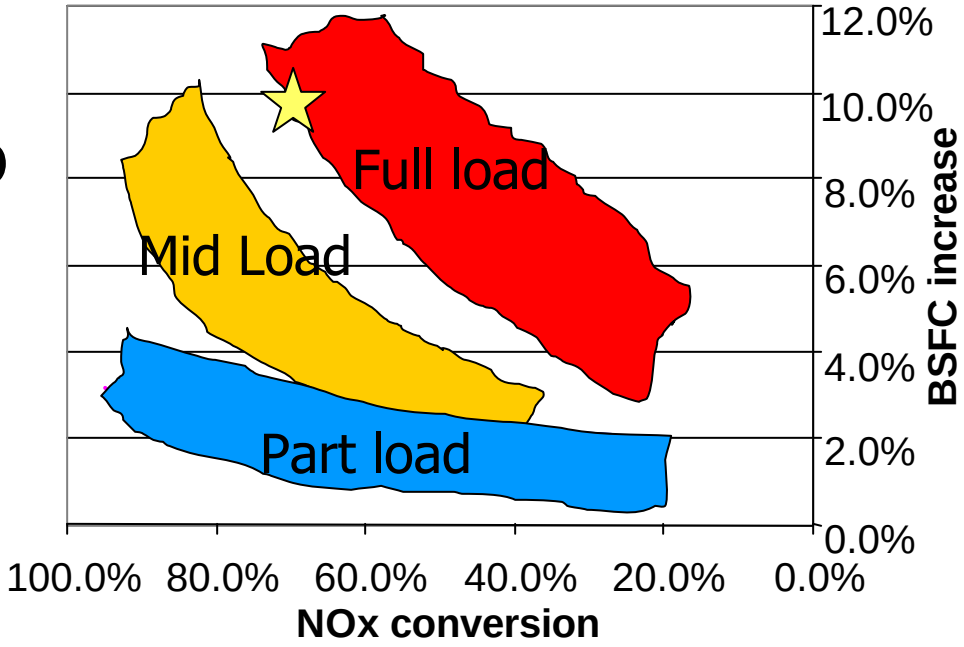
Single Branch for Light Duty Application

- Emissions prediction over FTP 75 test cycle for 6500lbs truck.
- Cycle average NOx reduction 90% for 3% bsfc penalty

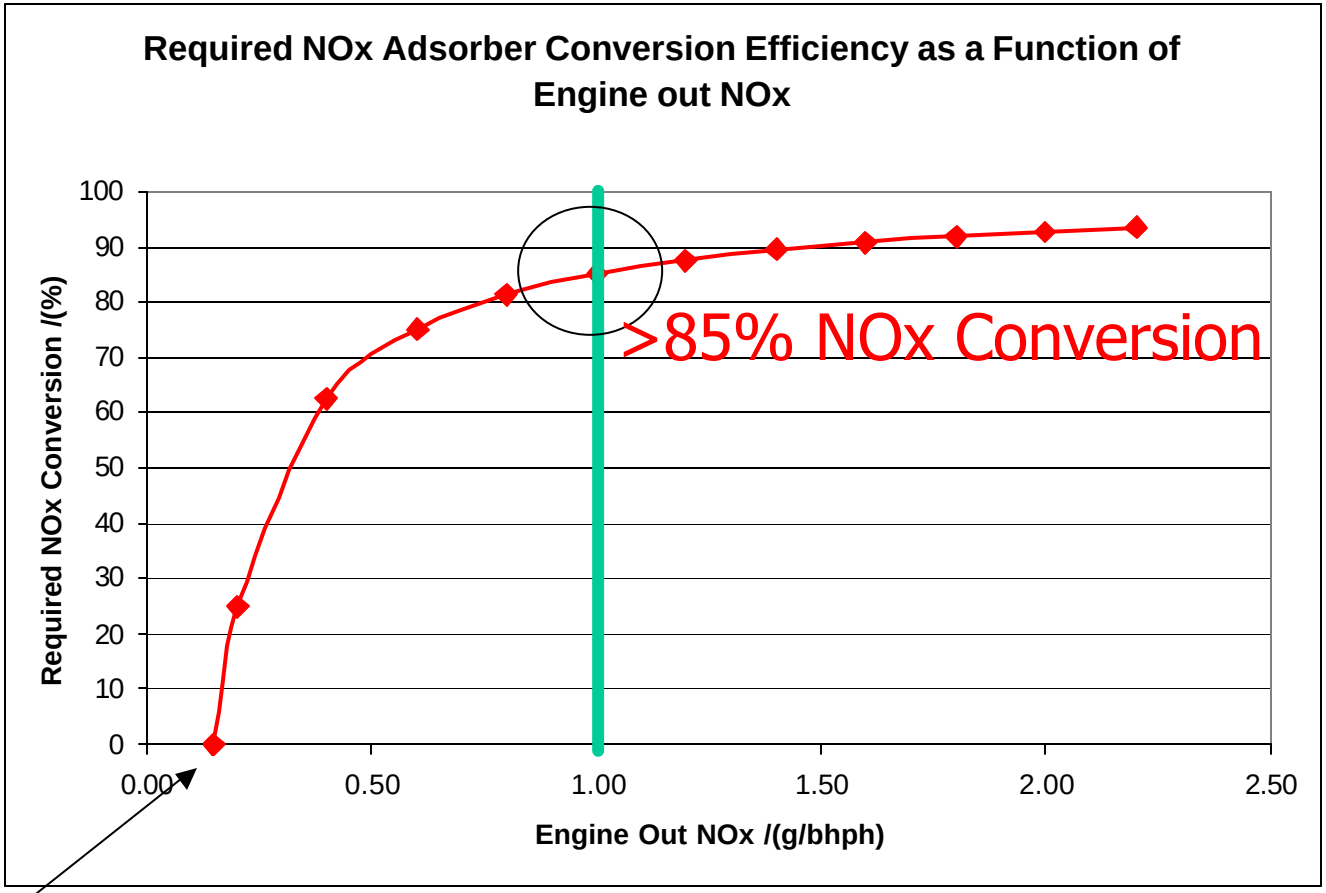


Single Branch for Heavy Duty Application

- ESC 13 mode test
- Full load has more impact
- Cycle average NOx reduction 70% for 10% bsfc penalty
- Single branch unlikely to be competitive for HD



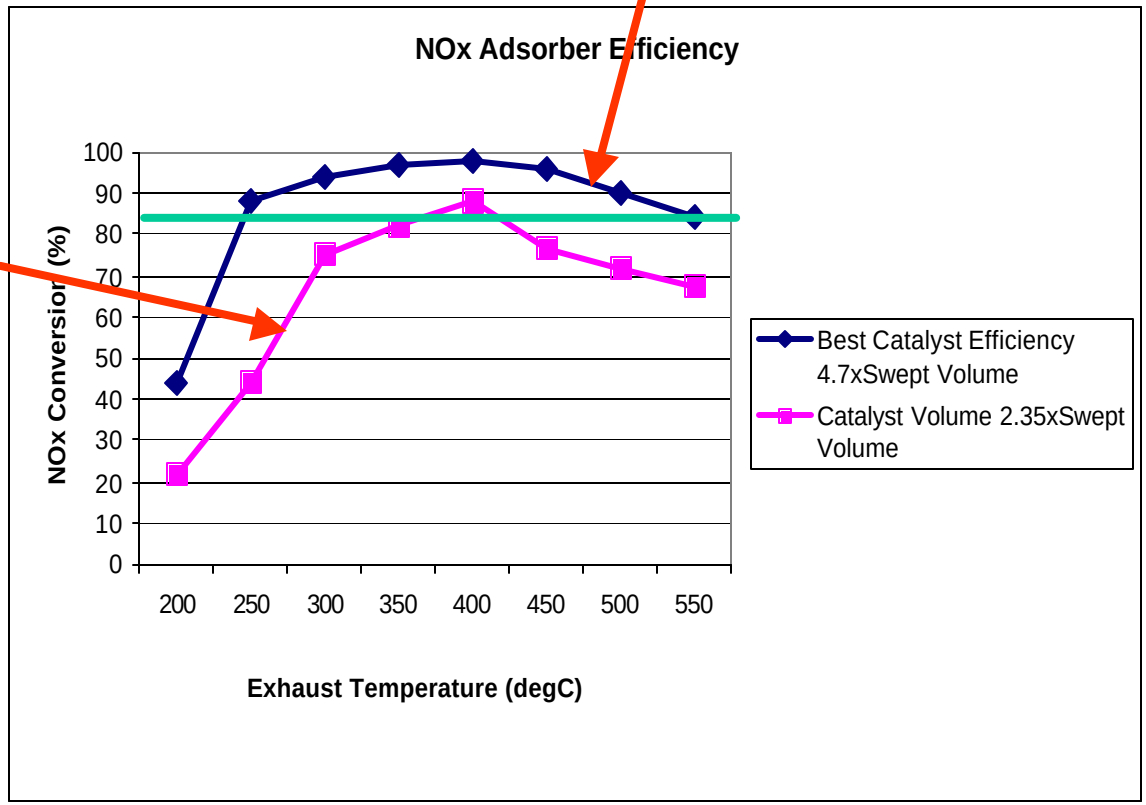
NOx Adsorber - Efficiency Requirements



Assumes 0.15g/bhph requirement

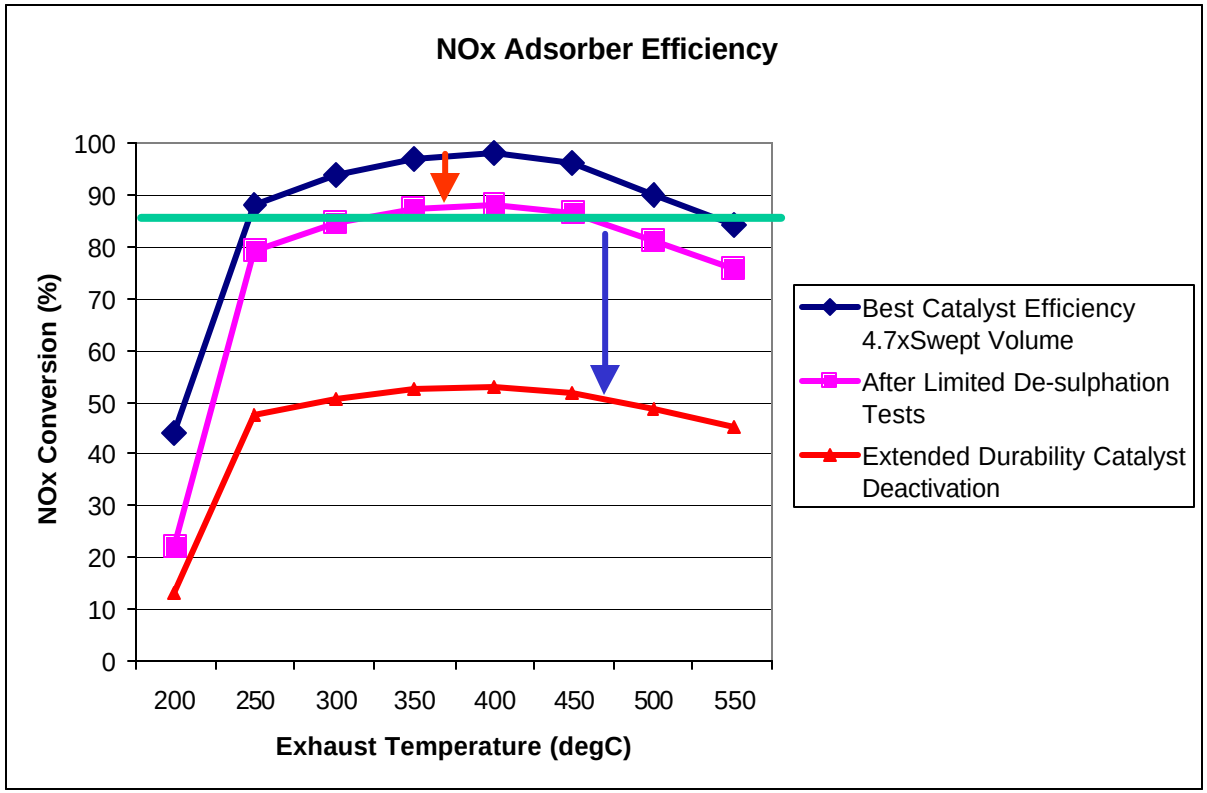
NOx Adsorber - Catalyst Size

- Catalyst Size – Fresh – For 12litre engine
  - 'Best catalyst system demo' - 4.7xSV catalyst - $4300 PGM
  - Significant performance loss in going from 4.7 to 2.35 x swept volume
  - Cost precious metals 2.35xSV catalyst $2150
  - Alternative for smaller catalyst is more frequent regenerations - fuel consumption Unacceptable
  - Reference $500 from Economic Analysis



NOx Adsorber - Catalyst Durability

- Sulfur poisoning - S traps and S insensitive catalyst formulations
- Thermal aging - Improvements in Precious metal sintering
- Ash/Phosphorous poisoning – Traps needed
- **Or** further catalyst volume increase to offset long term deterioration (x2?)



Summary

- 0.2g/bhph NOx can only be achieved with parameters as below:
  - Engine out NOx <<1.0g/bhph
  - Huge catalyst – cost unacceptable
  - Catalysts with no degradation
- We do not have a solution.
- Enormous research effort required – breakthroughs needed

Summary and Conclusions

- Single branch system is well matched to light duty applications.
- For light duty, 90% NOx reduction for 3% bsfc penalty possible.
- Single branch unlikely to be competitive in HD applications, bsfc unacceptable.
- Especially for HD engines catalyst size, cost and durability remain major outstanding issues for full life operation. Enormous amount of research required industry wide - breakthroughs required.