Technical Demonstration of 2010 Emissions Regulations over Transient Operation

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Presentation Outline

- EPA 2010 Requirements
- System Layout and Vehicle Integration
- Transient Emissions Reduction – Selective Results
- Enabling Technologies – Selective Examples
- Summary

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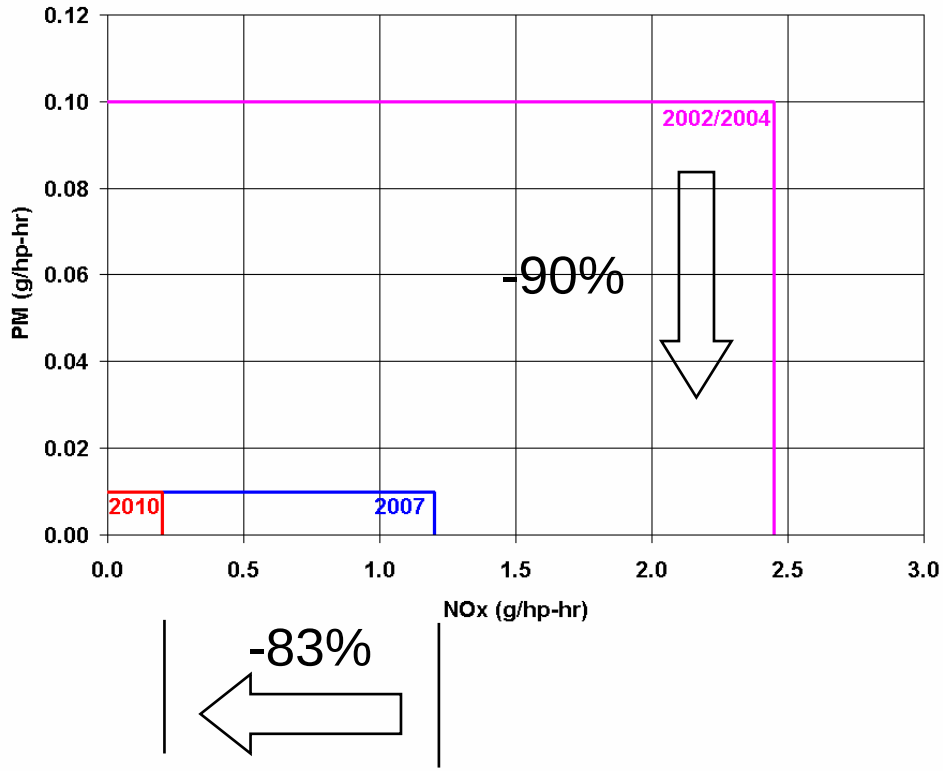
EPA 2010 requirements

- Regulatory
  - ✓ 83% reduction in NOx compared to EPA ’07
    - From ~1.20 to 0.20 g/hp-hr
    - Ramped modal cycle replaces the SET[1]
  - ✓ OBD[2] requirements
  - ✓ NTE[3] enforced through in-use emissions test run by manufacturer
  - ✓ AdBlue infrastructure and compliance issues to be addressed
- Customer
  - ✓ Fuel economy, performance, heat rejection, durability / reliability comparable or better relative to EPA ‘07
- Other
  - ✓ Minimize unregulated emissions
    - e.g. Vanadium, NH3, N2O



[1] SET – Supplemental Emissions Test a.k.a ESC / 13-mode
[2] OBD – On-board Diagnostics
[3] NTE – Not-to-Exceed

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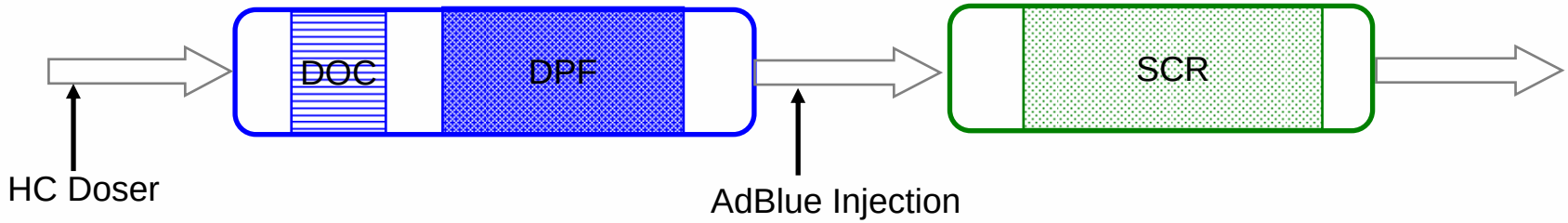
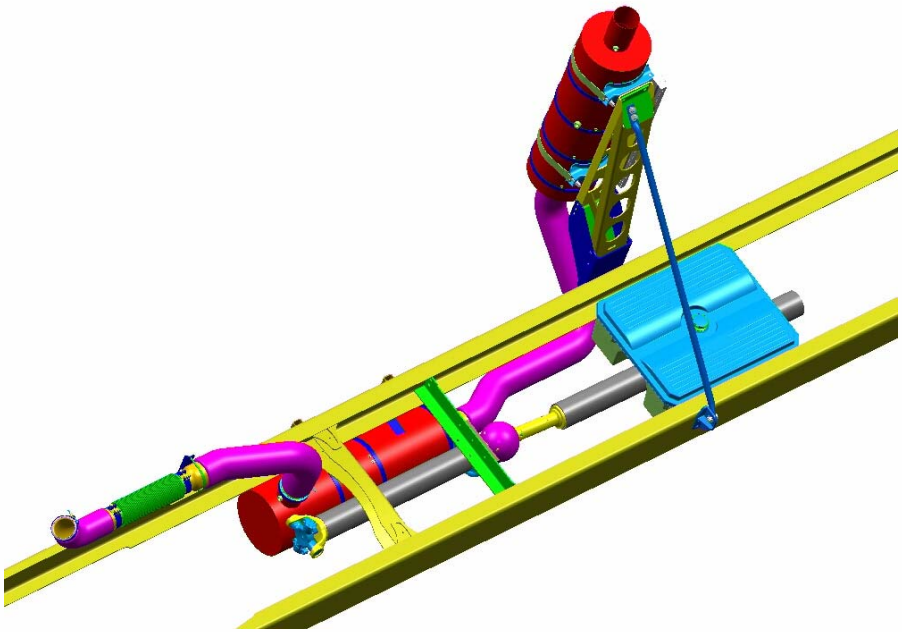
Low Emissions Combustion, DPF and AdBlue SCR Integrated on a Vehicle Test-bed



Example System Integration Installation for Long Sleeper Cabs



2010 Technology Vehicle at the DEER 2006 Vehicle Display

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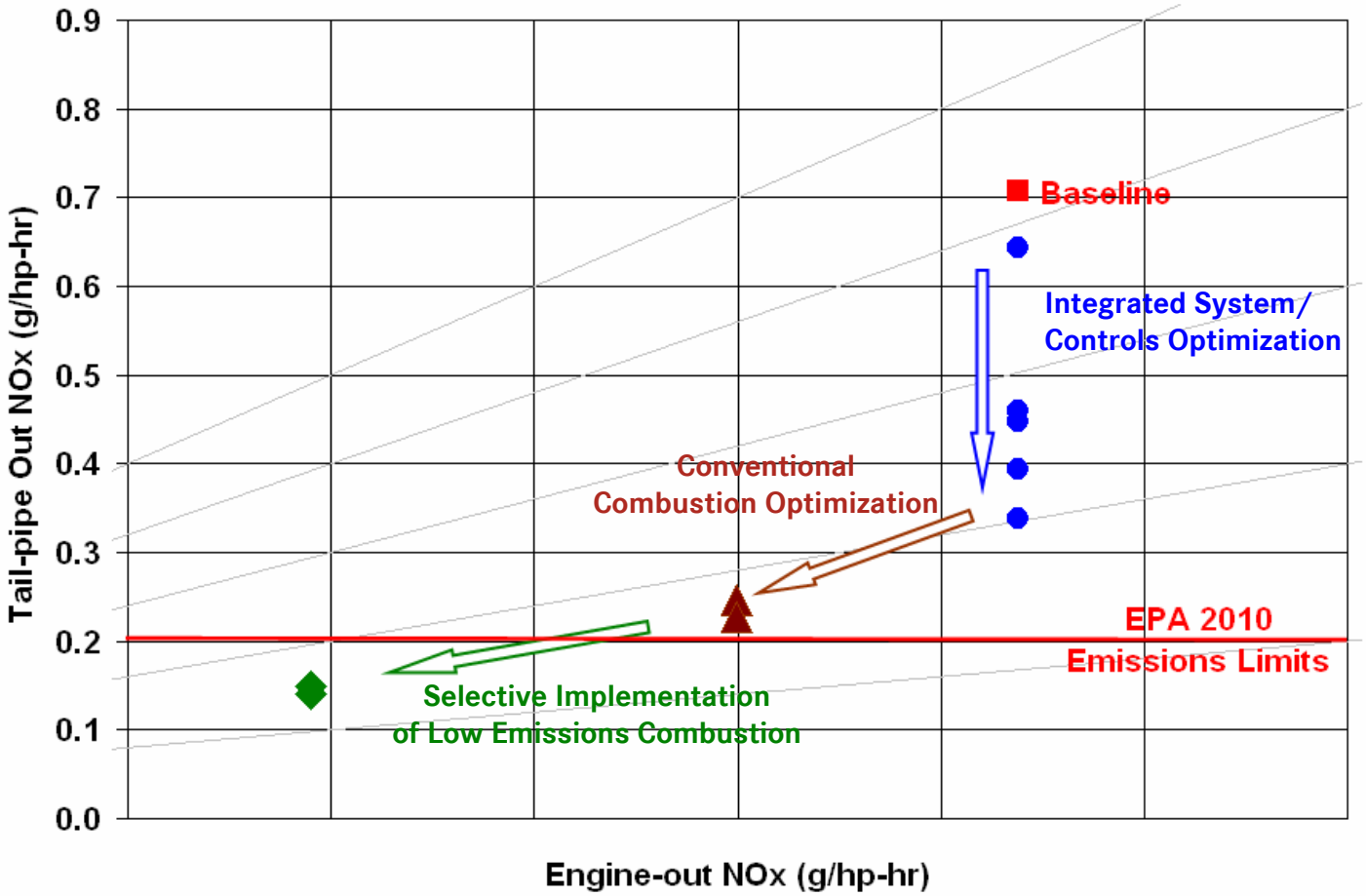
Emissions Reduction Roadmap
Experimental Multi-Cylinder Engine Results – Hot FTP Cycle



EPA 2010 System-out Emissions Levels
Demonstrated over Transient FTP

"Fresh" System

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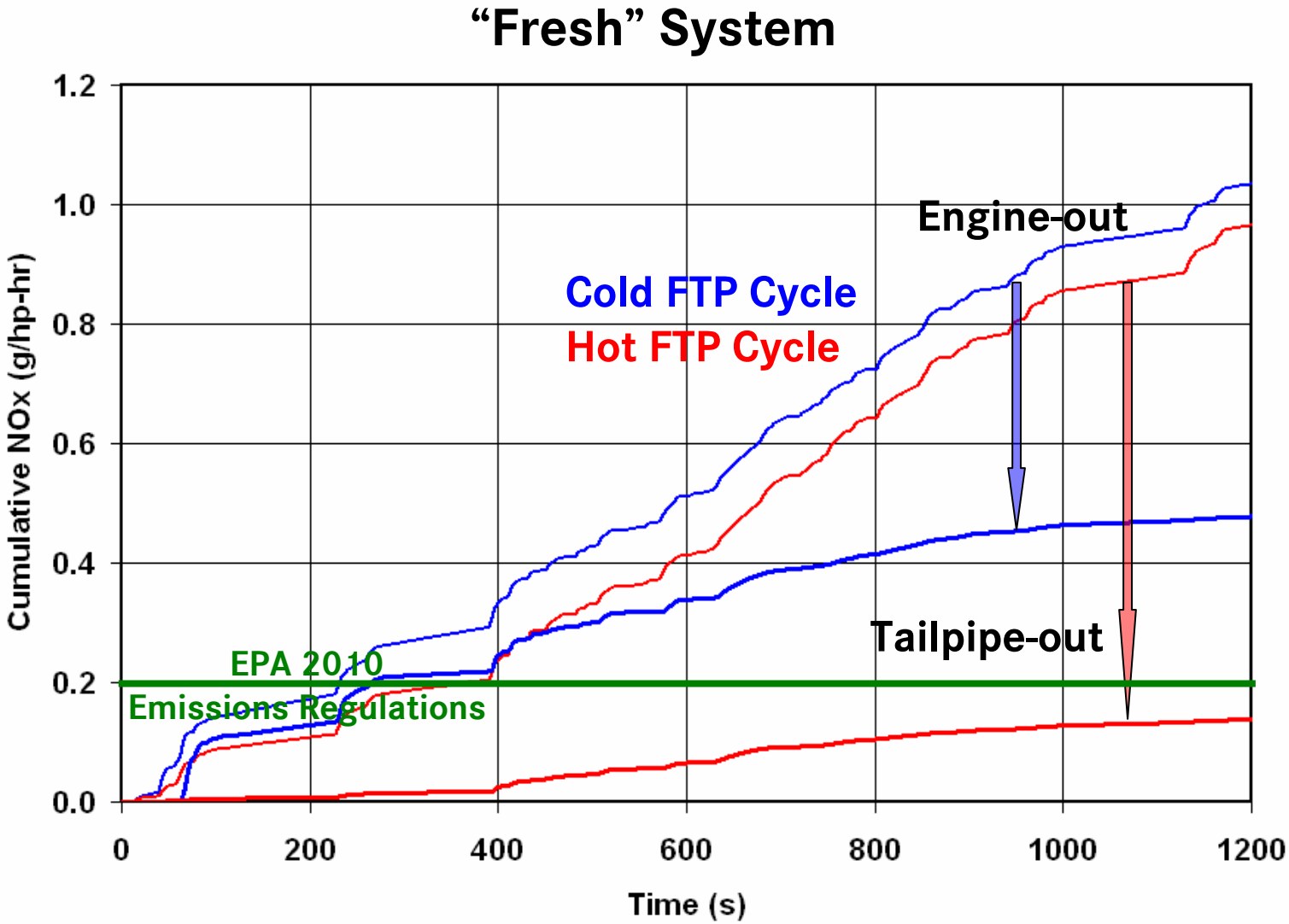
Engine-out and Tailpipe-out NOx Emissions
Example Experimental Multi-Cylinder Engine Results
Cold and Hot FTP Cycle



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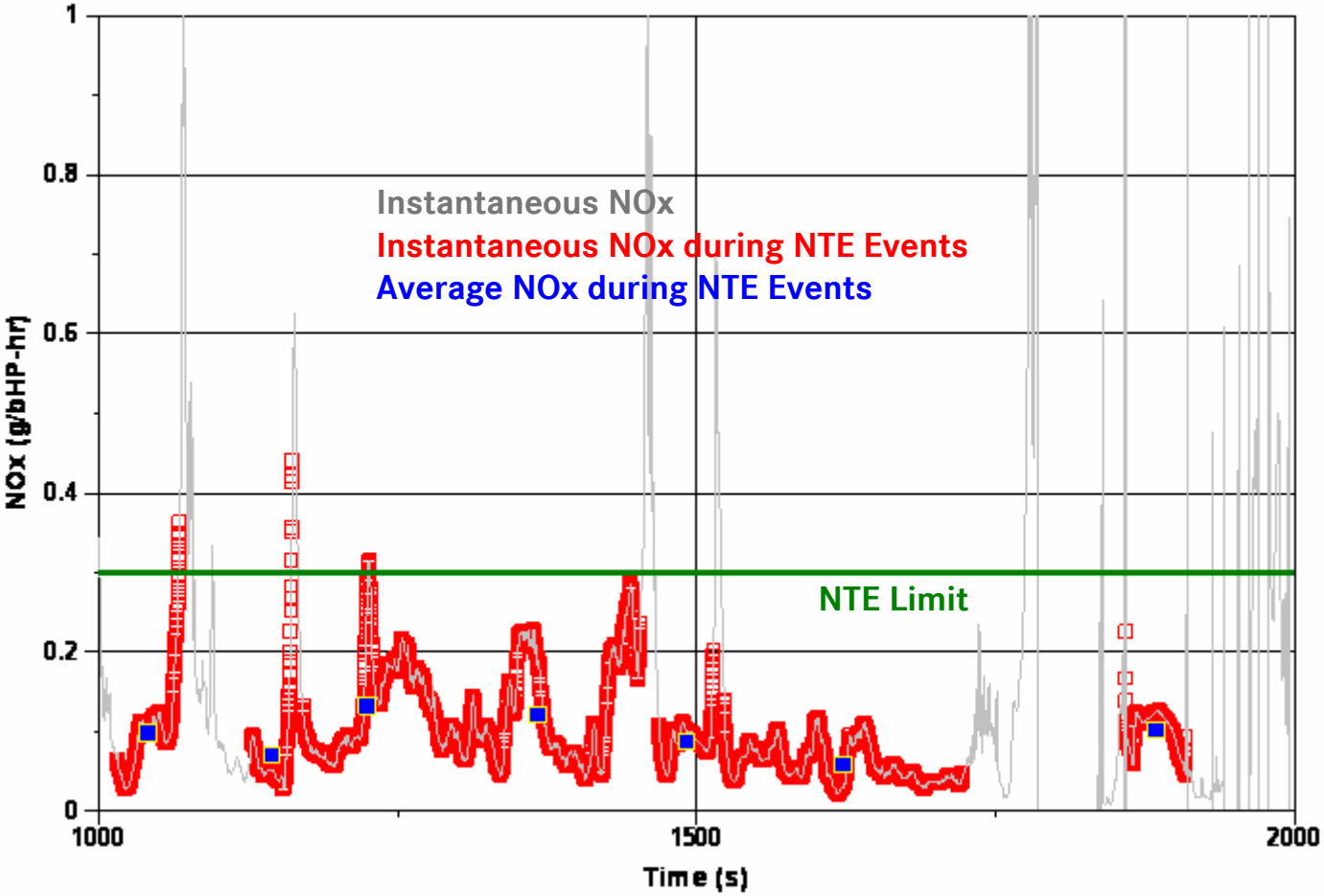
Over-the-road NTE Emissions
"Dyno Simulated" On-highway Truck Cycle
Detroit – Ann Arbor - Detroit

"Fresh" System



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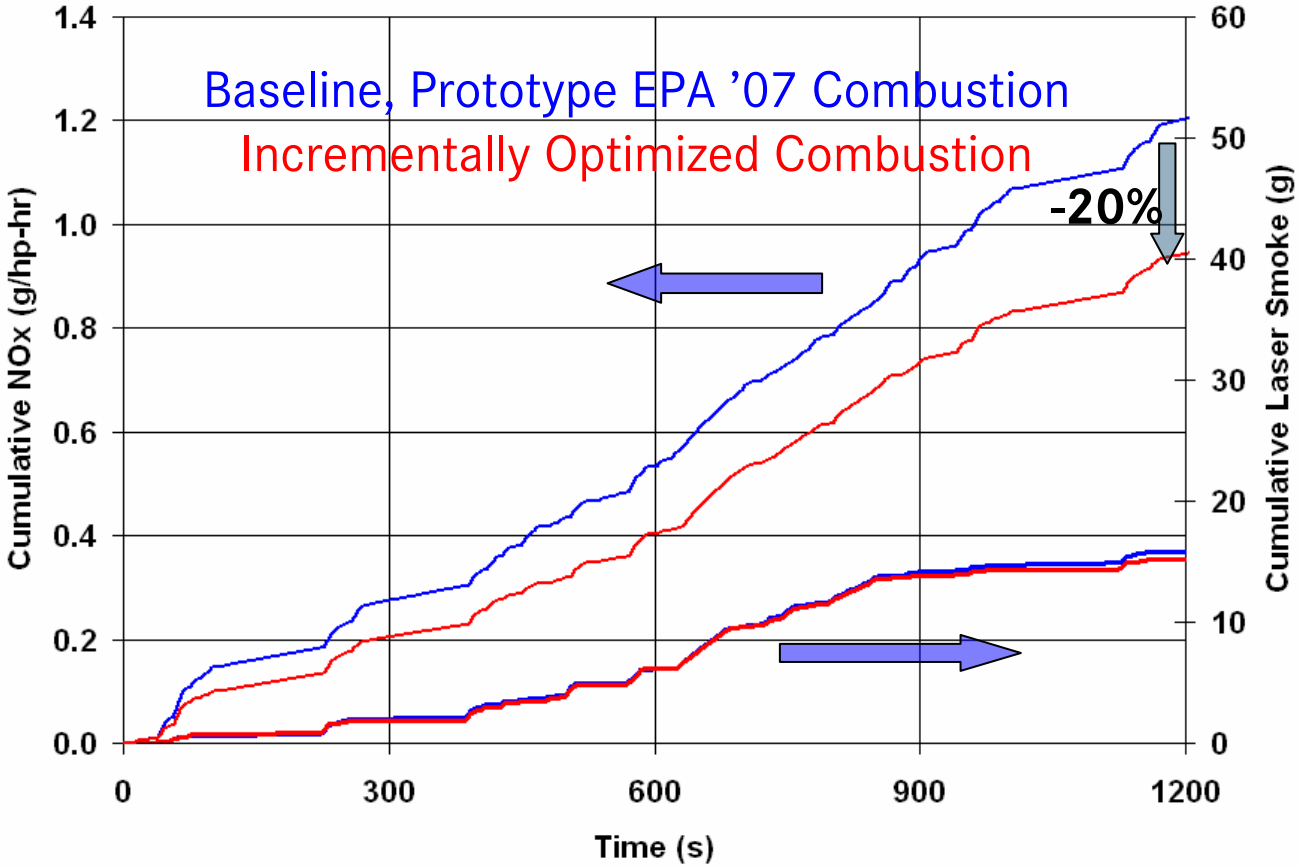
Selective Implementation of Low Emissions Combustion over Transient Hot FTP Cycle - Multi-cylinder Series 60 Test-bed

~20% Reduction in engine-out FTP NOx, relative to prototype EPA '07 reference baseline, while maintaining engine-out PM levels



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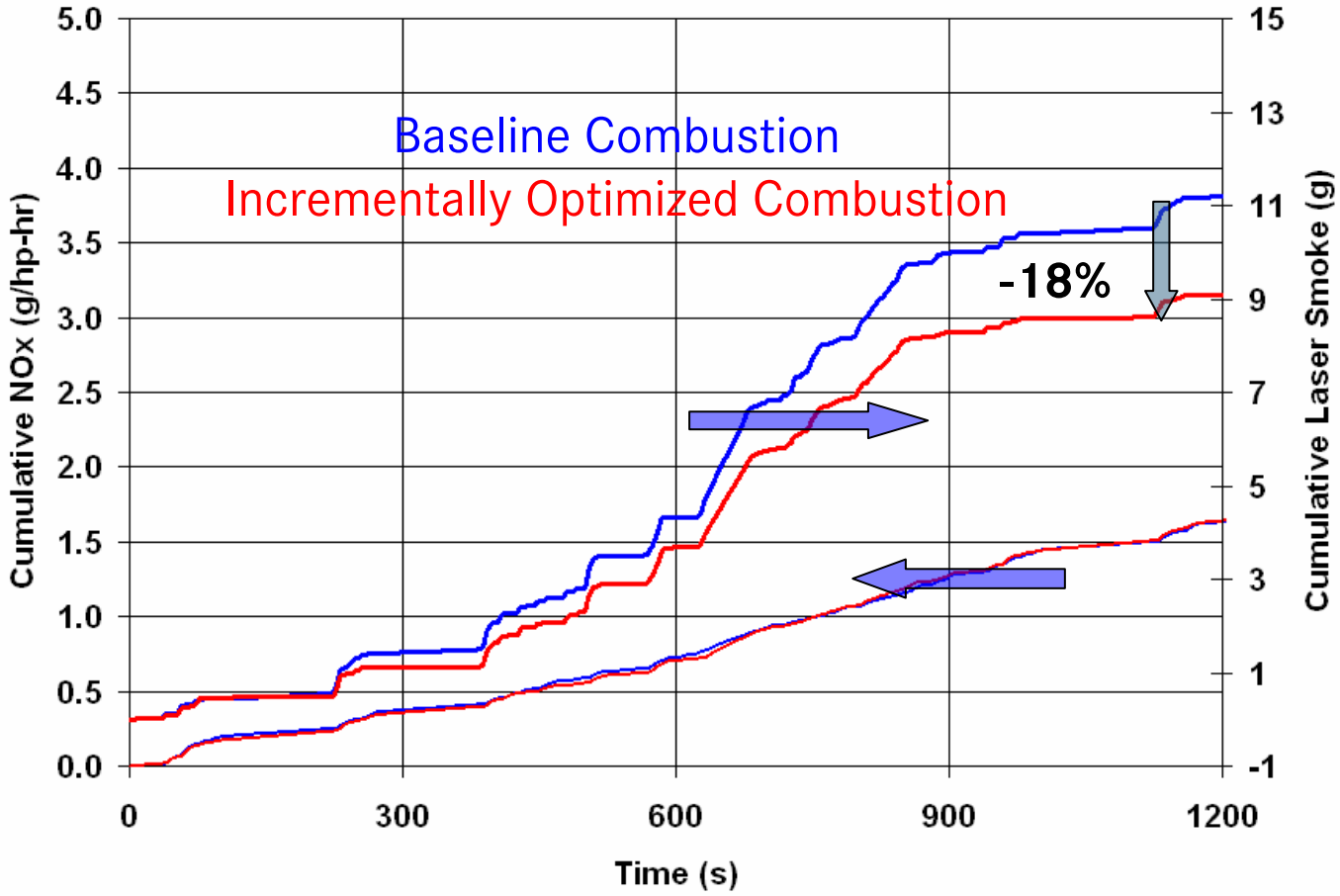
Selective Implementation of Low Emissions Combustion over Transient Hot FTP Cycle - Multi-cylinder Series 60 Test-bed

DETROIT DIESEL CORPORATION

~18% Reduction in engine-out FTP PM, relative to baseline, while maintaining engine-out NOx levels



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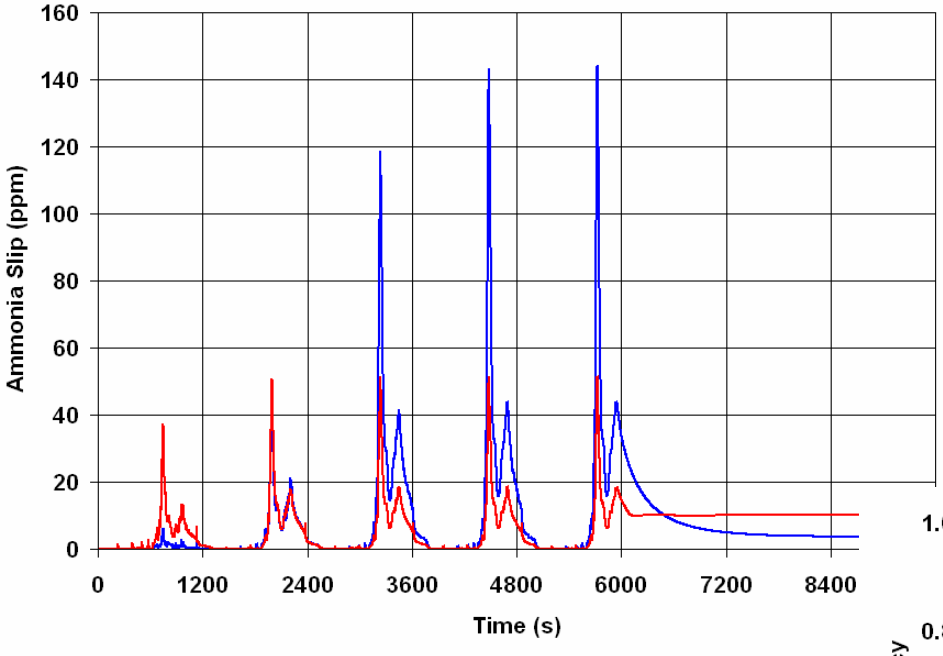
2010 AdBlue-SCR Controls

Example Results

Five FTP Cycles followed by Steady-state Operation

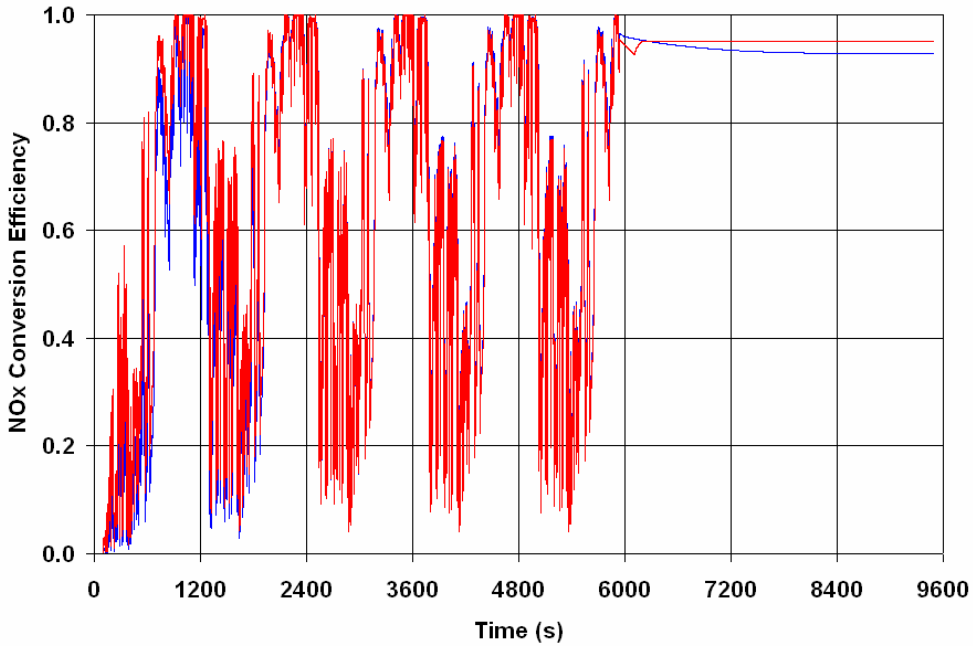


Traditional dosing control

Model-based dosing control

"Offline" analysis being utilized to develop and screen AdBlue dosing control strategies

Model-based dosing control provides opportunity to optimize NOx conversion efficiency-NH3 slip trade-off, compared to traditional dosing control



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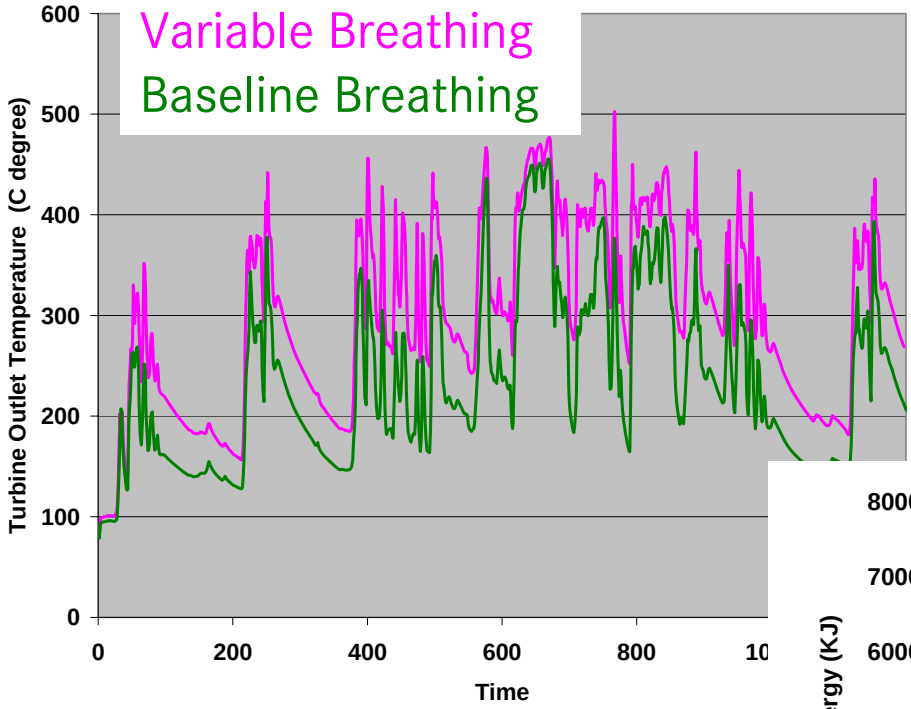
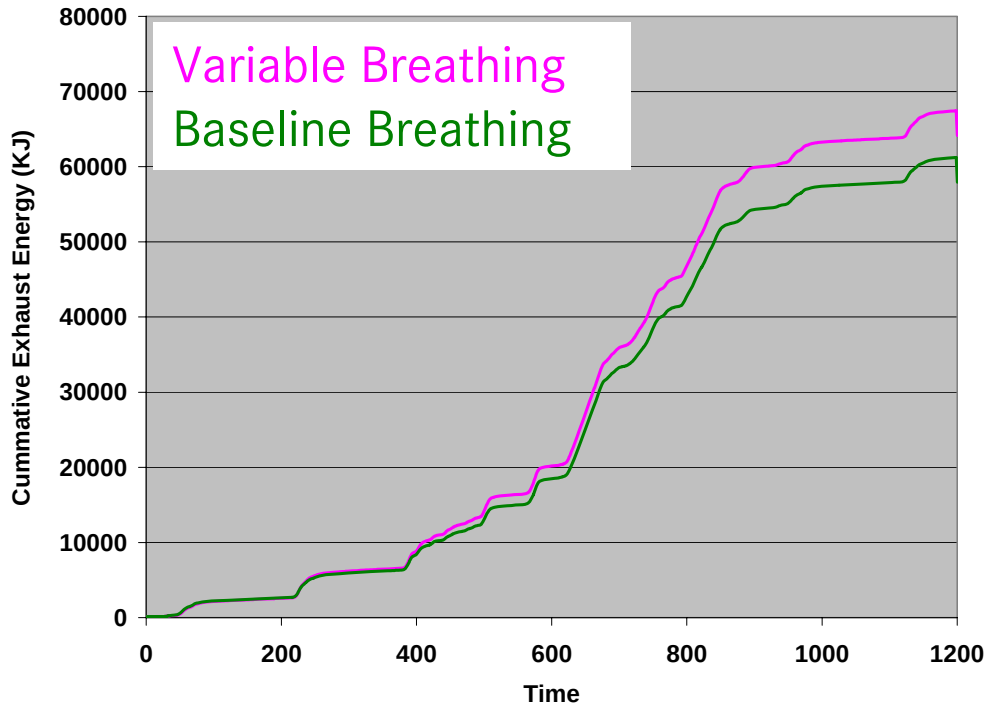
Potential of Variable Breathing Events for Aftertreatment Thermal Management

Transient FTP Cycle - Analytical Results



~10% increase in cumulative exhaust energy over transient FTP cycle, compared to baseline



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Conclusions

- AdBlue-SCR Remains a Lead Technology for On-highway, Heavy-duty Truck Systems for EPA 2010, Euro 6 and Japan ’09
- Technical Concepts to Meet EPA 2010 Transient Emissions Regulations Validated for “Fresh” Engine and Aftertreatment Systems
- However, Significant Development Still Required for These Concepts to Evolve into Viable Commercialization Strategies
  - ✓ Example Development Areas Include
    - OBD
    - Sensors, Controls and Calibration Techniques
    - NOx Margin
    - Aging / Deterioration of Engine-Aftertreatment Devices
    - Vehicle Implementation of Low Emissions Combustion

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