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Application of a Diesel Fuel Reformer for Tier 2 Bin 5 Emissions

Joseph V. Bonadies, David A. Goulette, Dr. John E. Kirwan, Michael J. Seino, Dr. Joachim Kupe, Russell H. Bosch

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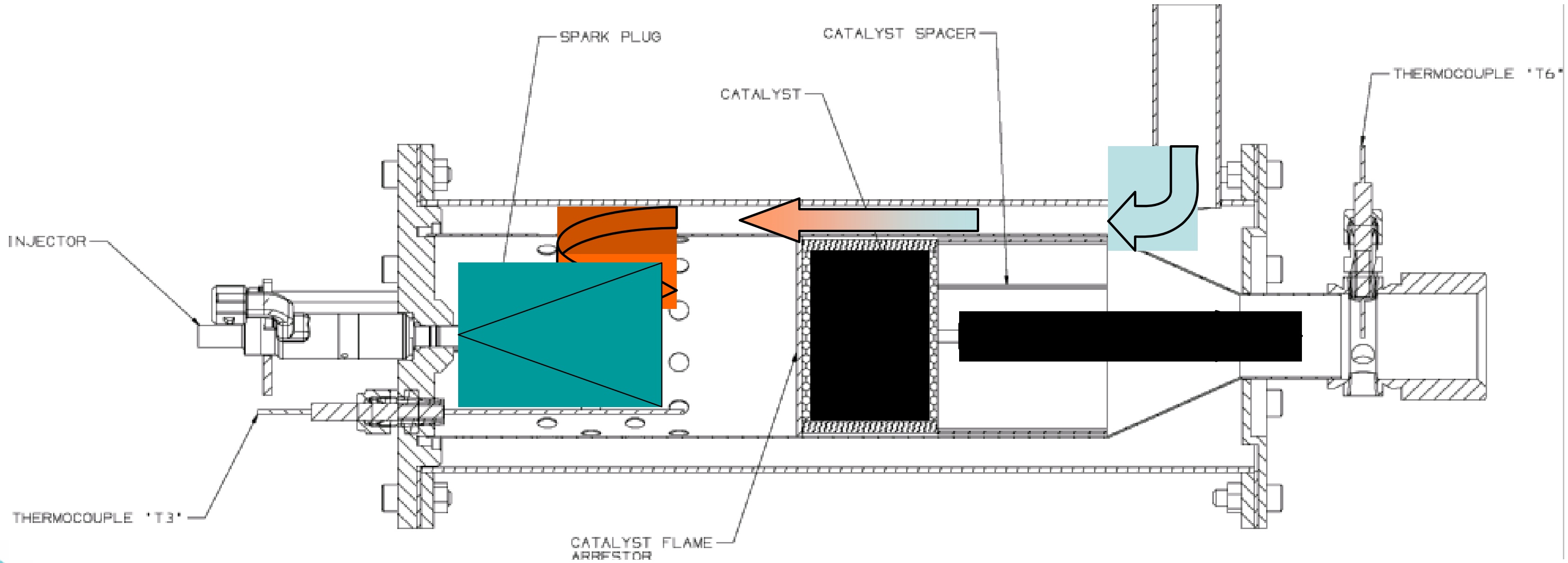
Reforming Fundamentals

Partial Oxidation (POx) Reforming Chemistry:

Diesel Fuel + Air ➔ Hydrogen Rich Reformate

$CH_{1.85} + 0.5\,(O_2) \rightarrow CO + 0.925\,H_2$ exothermic: $\Delta H = -103$ kJ / mole



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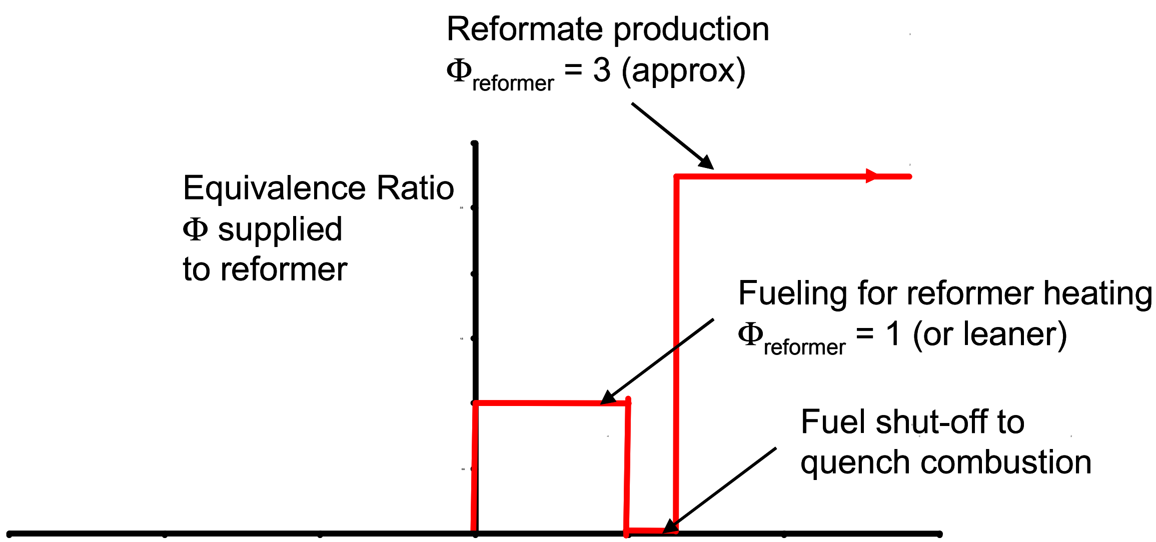
Reformer Operation

Diesel Fuel Reformer Start-up Fueling Strategy

- Preheat reformer catalyst with combustion (approx 10 – 20 secs)
- Fuel shut-off to quench combustion
- Reformate production at $\Phi_{reformer} = 3$



Test Vehicle

- 2004 HD Chevrolet Silverado
- 6.6 L Duramax Engine
- Chassis Test Weight 6875 lbs
- Simulates a worst case LD vehicle application

LD FTP Test Summary - 2004 HD Silverado	THC wt.g/mi	NMOG wt.g/mi	CO wt.g/mi	NOx wt.g/mi
Stock Vehicle Average	0.499	0.491	3.444	2.234

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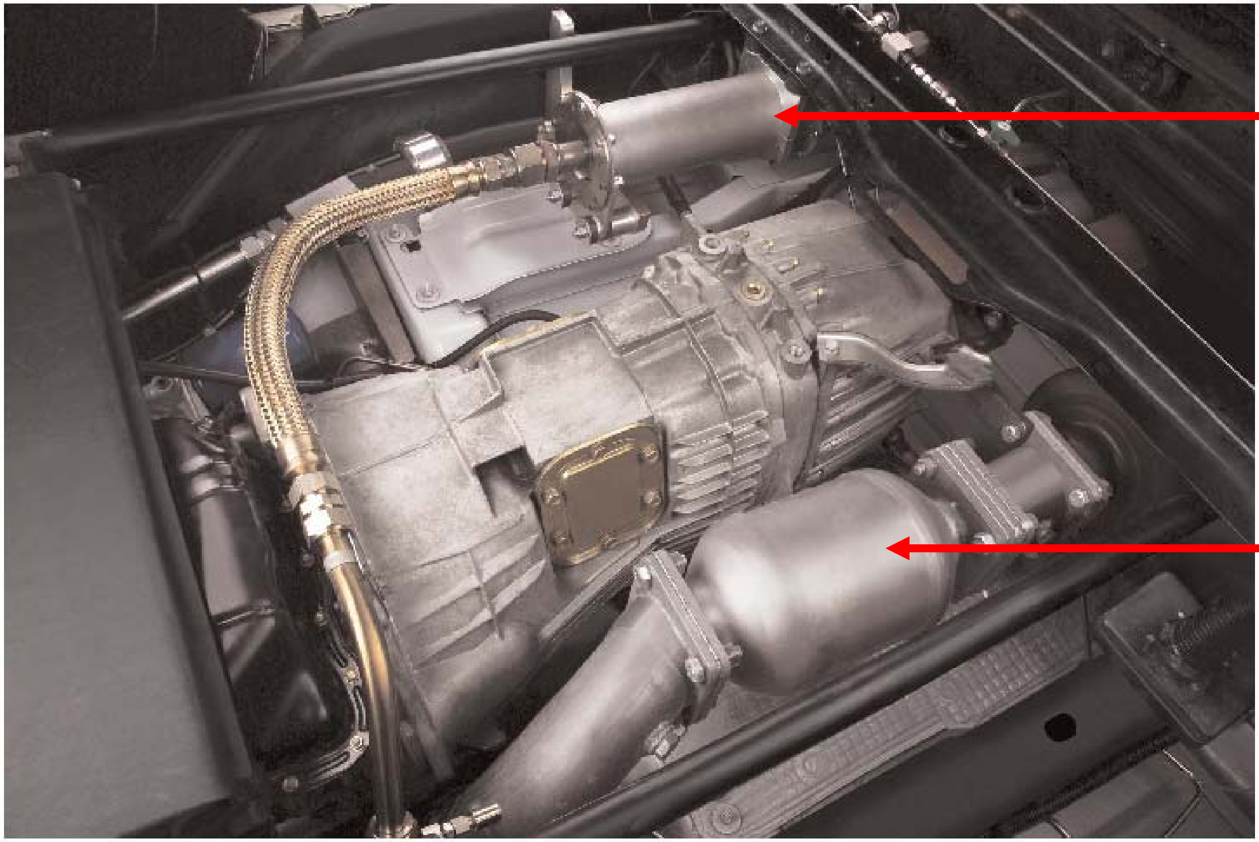
Reformer System
Vehicle Integration



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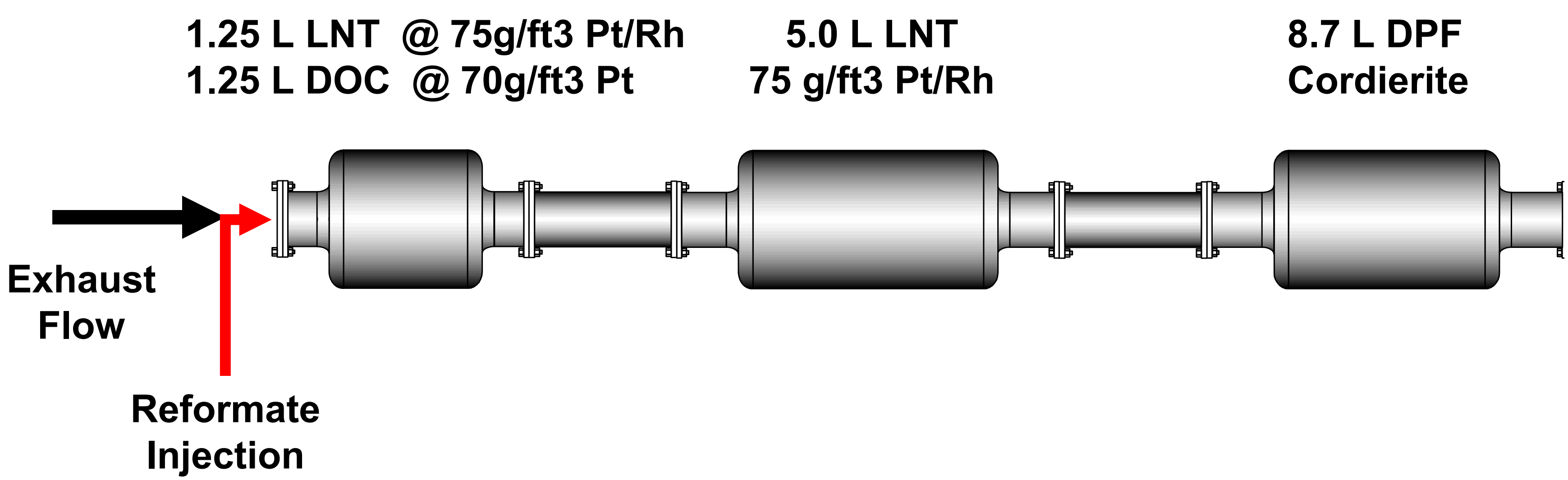
Exhaust Architecture

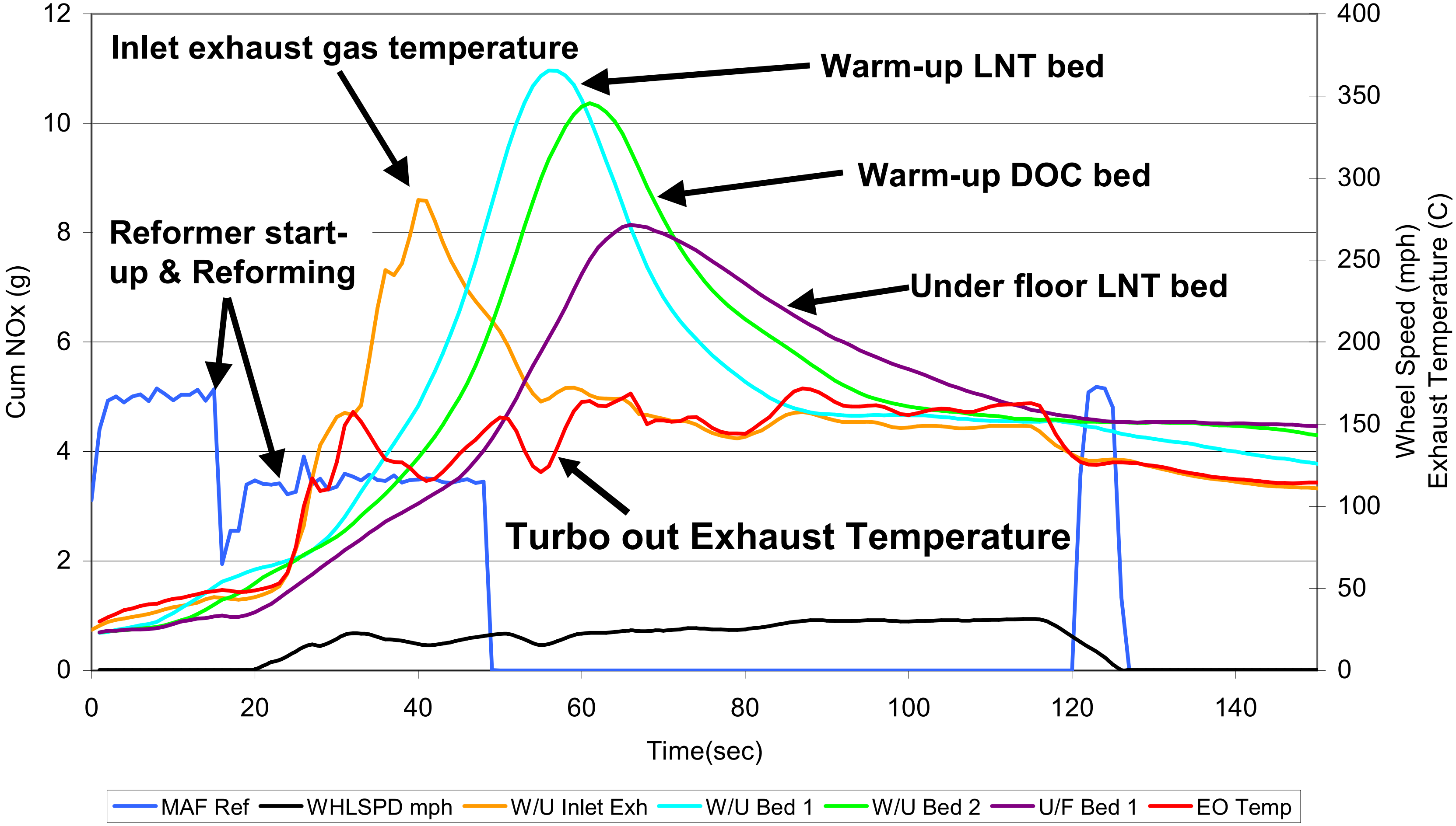


2004 Silverado
FTP Emission Summary

LD FTP Test Summary - 2004 HD Silverado	THC wt.g/mi	NMOG wt.g/mi	CO wt.g/mi	NOx wt.g/mi
Fuel Reformer System Average	0.305	0.161	1.786	0.023
Fuel Reformer System Efficiencies	86.3%		88.7%	96.4%
T2B5 50k / 120k Standards	n/a	.075 / .09	3.4 / 4.2	.05 / .07

- 7.5 L Catalyst + Non-catalyzed DPF (De-greened Catalysts)
- Average of 3 tests
- ~6% fuel economy penalty
  - Majority of reformate used to reduce exhaust oxygen concentration to stoichiometry
  - Net fuel penalty can be significantly reduced by calibration, taking advantage of the high system NOx efficiencies
- Further investigation and optimization are in process to reduce HC breakthrough

Catalyst Thermal Management Using Reformate



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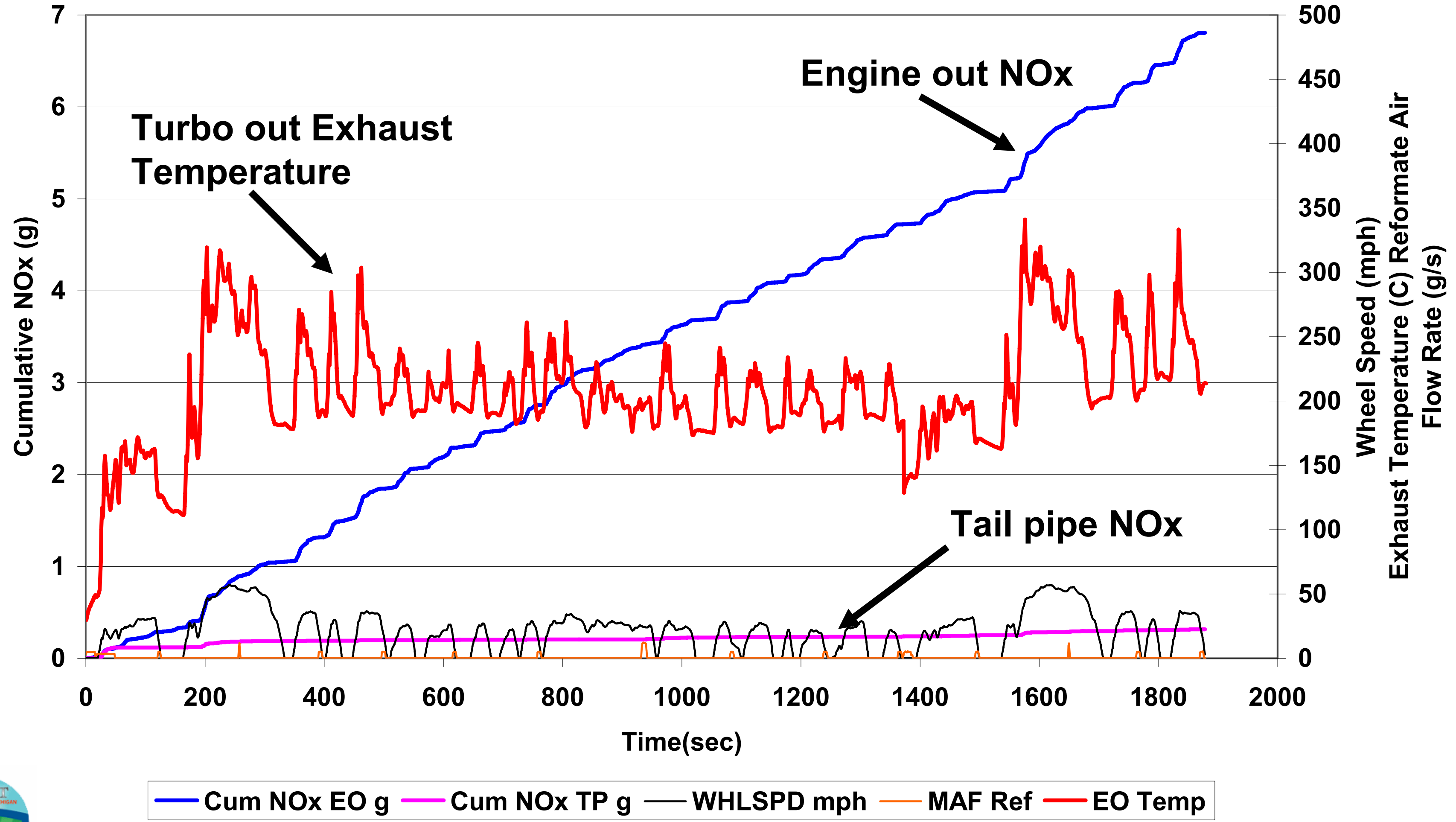
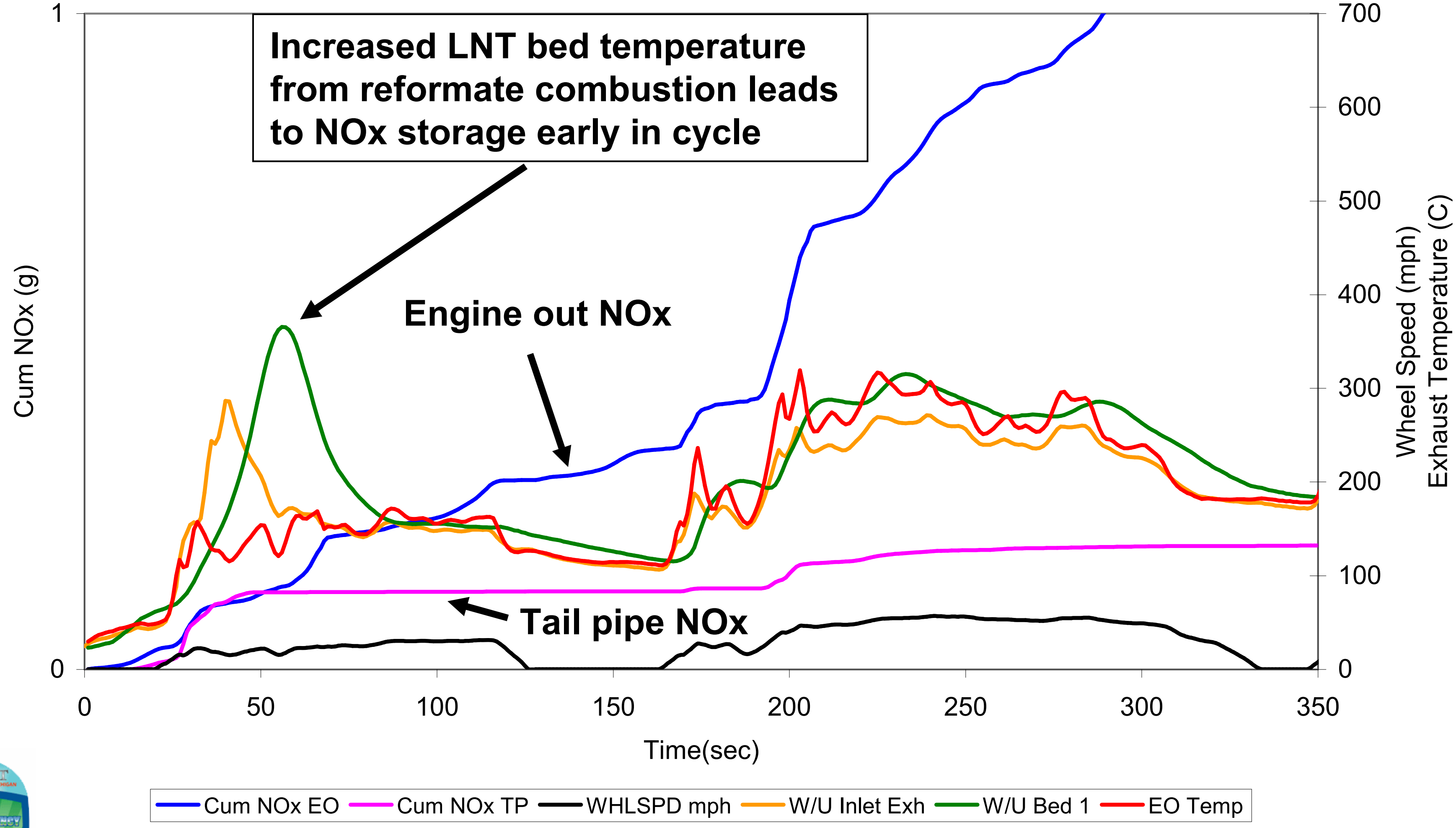
Modal NOx Emissions



2004 Silverado FTP-75
NOx & Exhaust Temperature



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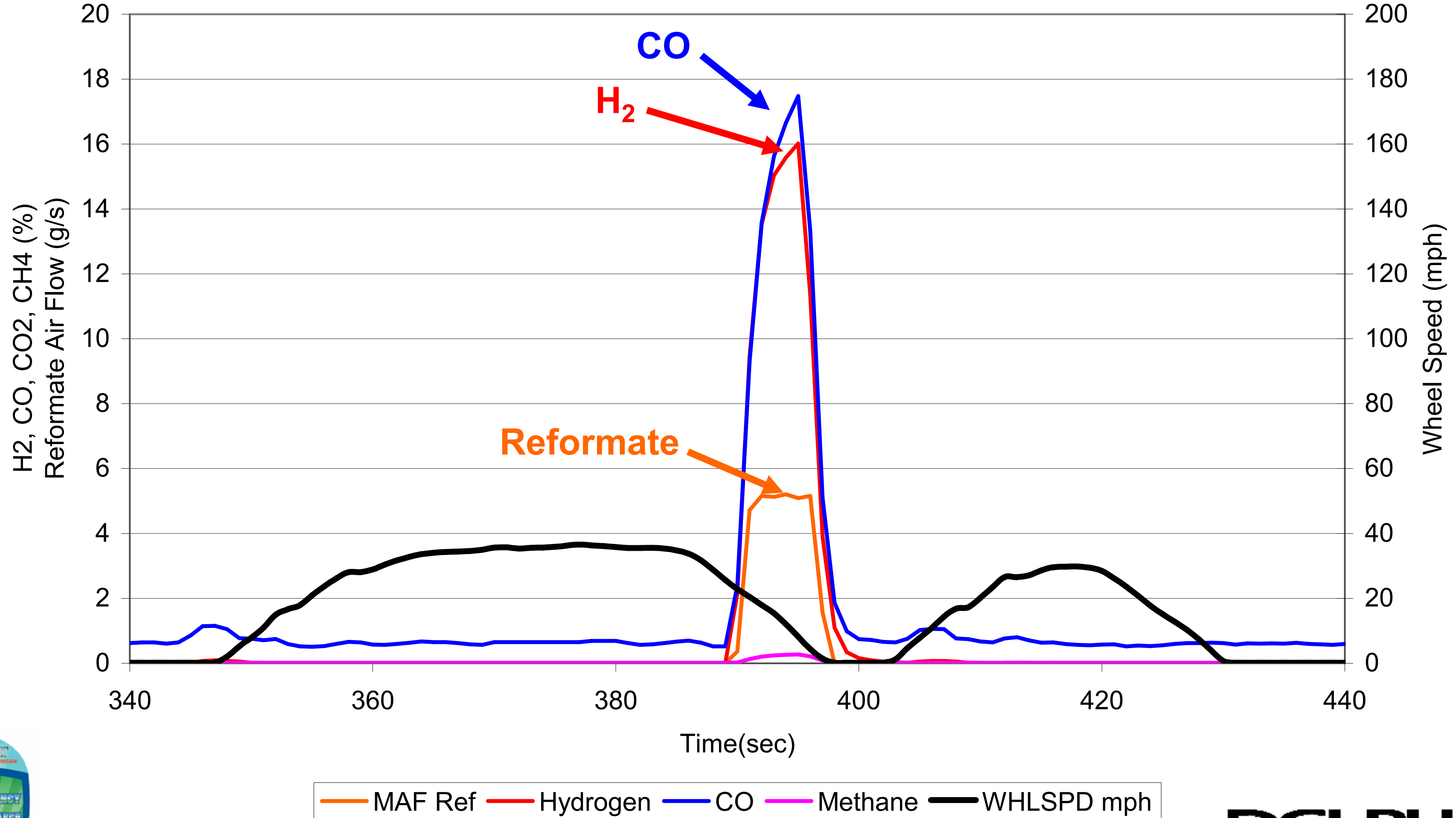
Reformate Species During LNT Regeneration



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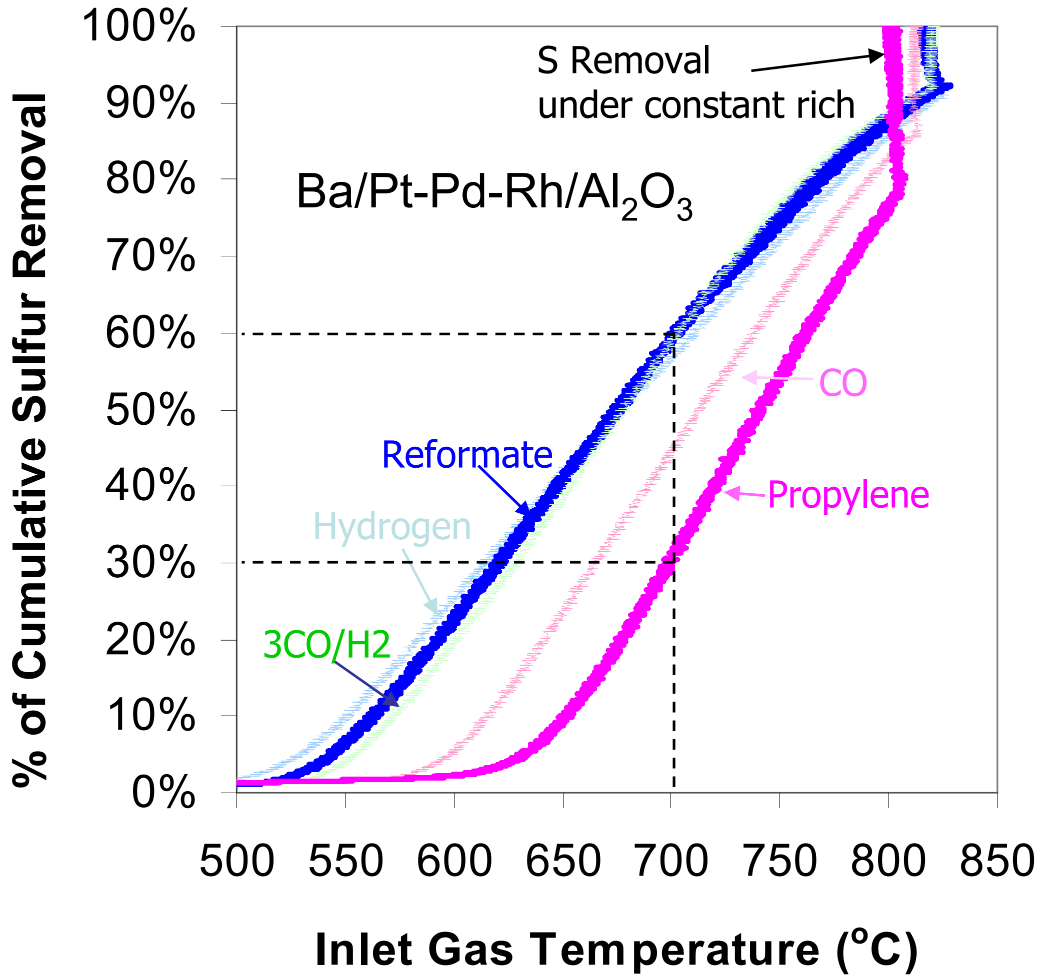
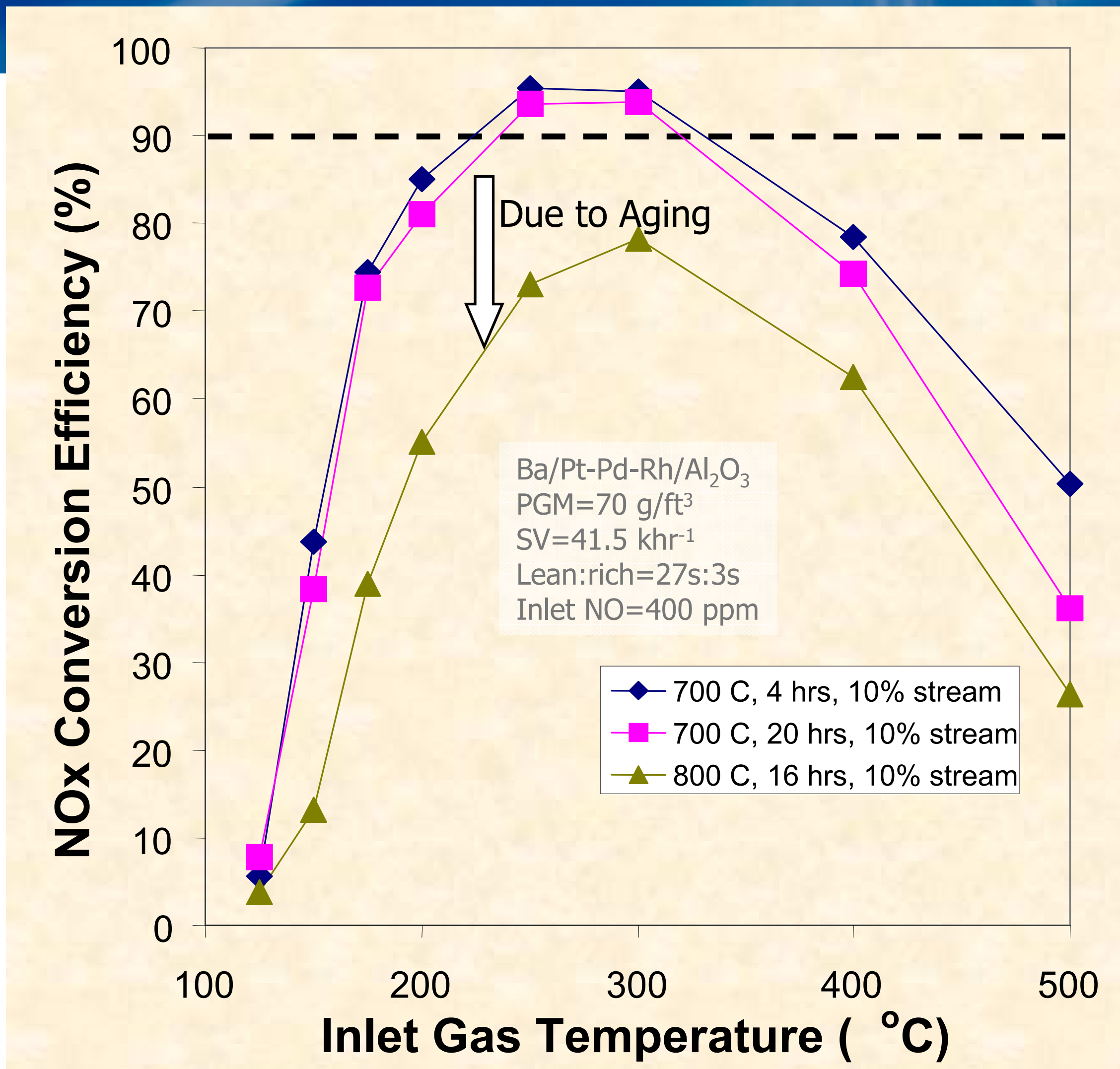
Comparison in Sulfur Release Using Various Rich Feed Gases w/ A/F Modulation



Sulfur loading = 1 g/l of cat.

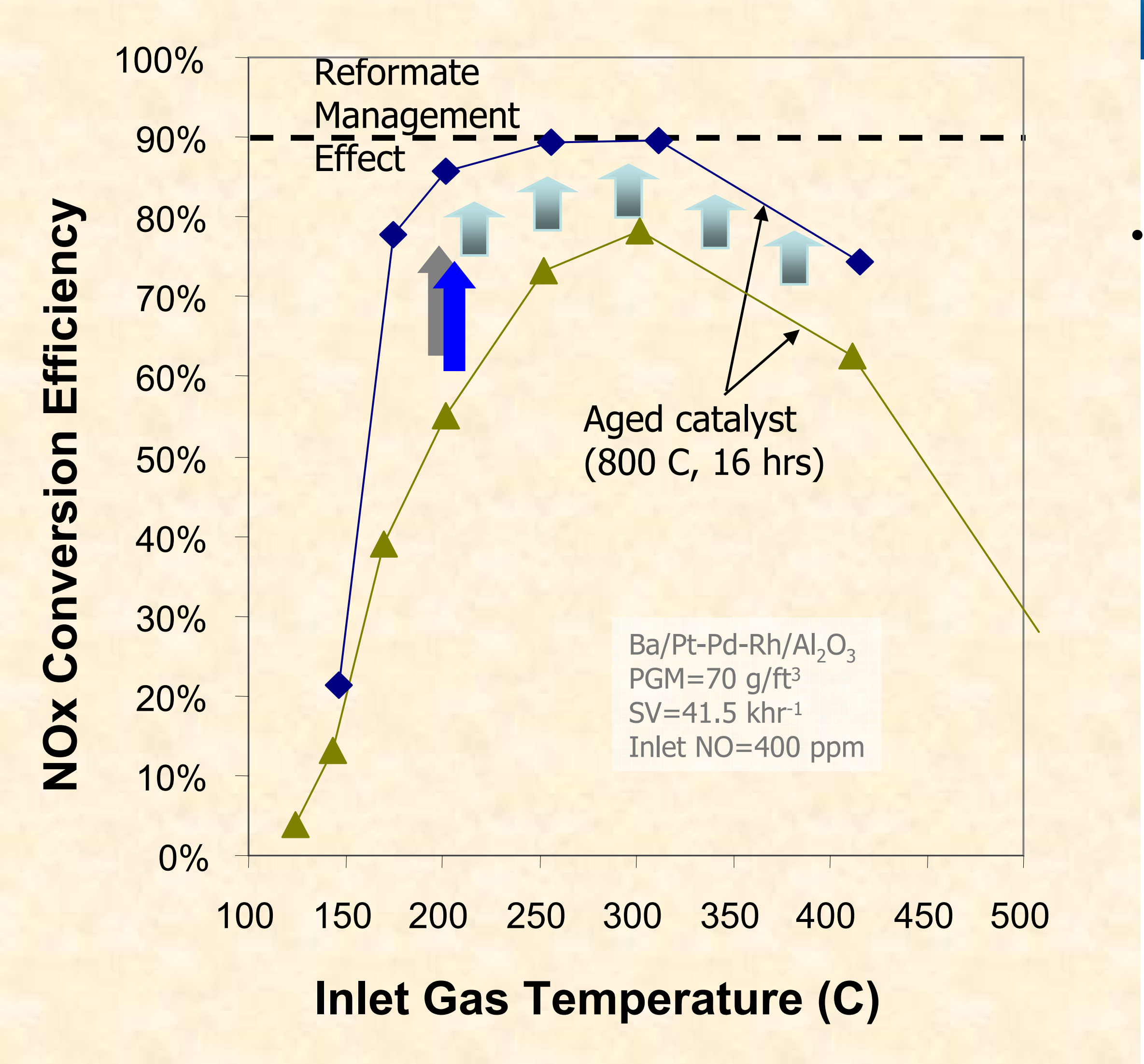
- **Hydrogen in rich feed promotes catalyst desulfation at lower temperatures**
- **Desulfation at lower temperatures reduces catalyst ageing, making the LNT system more robust**

NOx Efficiency of LNT Catalyst as a Function of Aging



- The catalyst performed well even after aging at 700 °C for 20 hrs.
- The efficiency deteriorated significantly after aging at 800 C for 16 hrs

Effect of Reformate Management on NO_x Removal Efficiency over Aged Catalysts



- **NOx efficiency of aged catalyst improved through effective reformate management**

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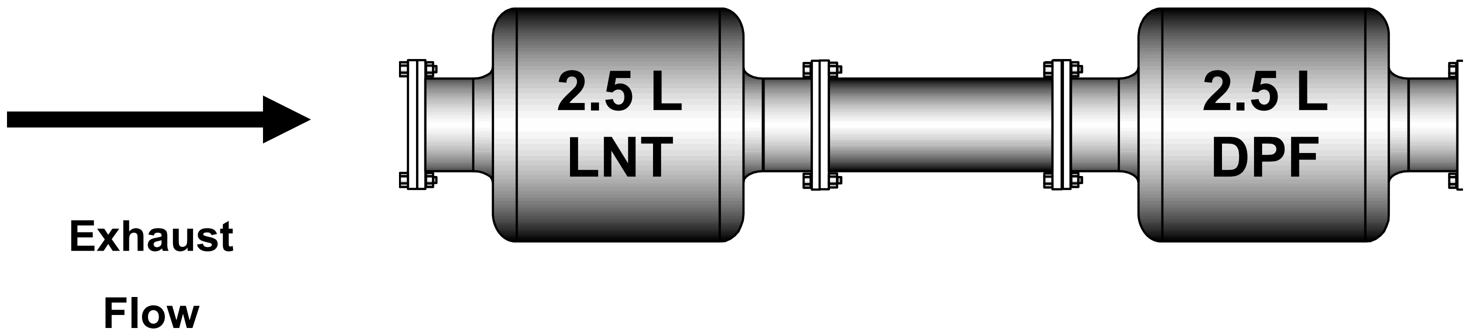
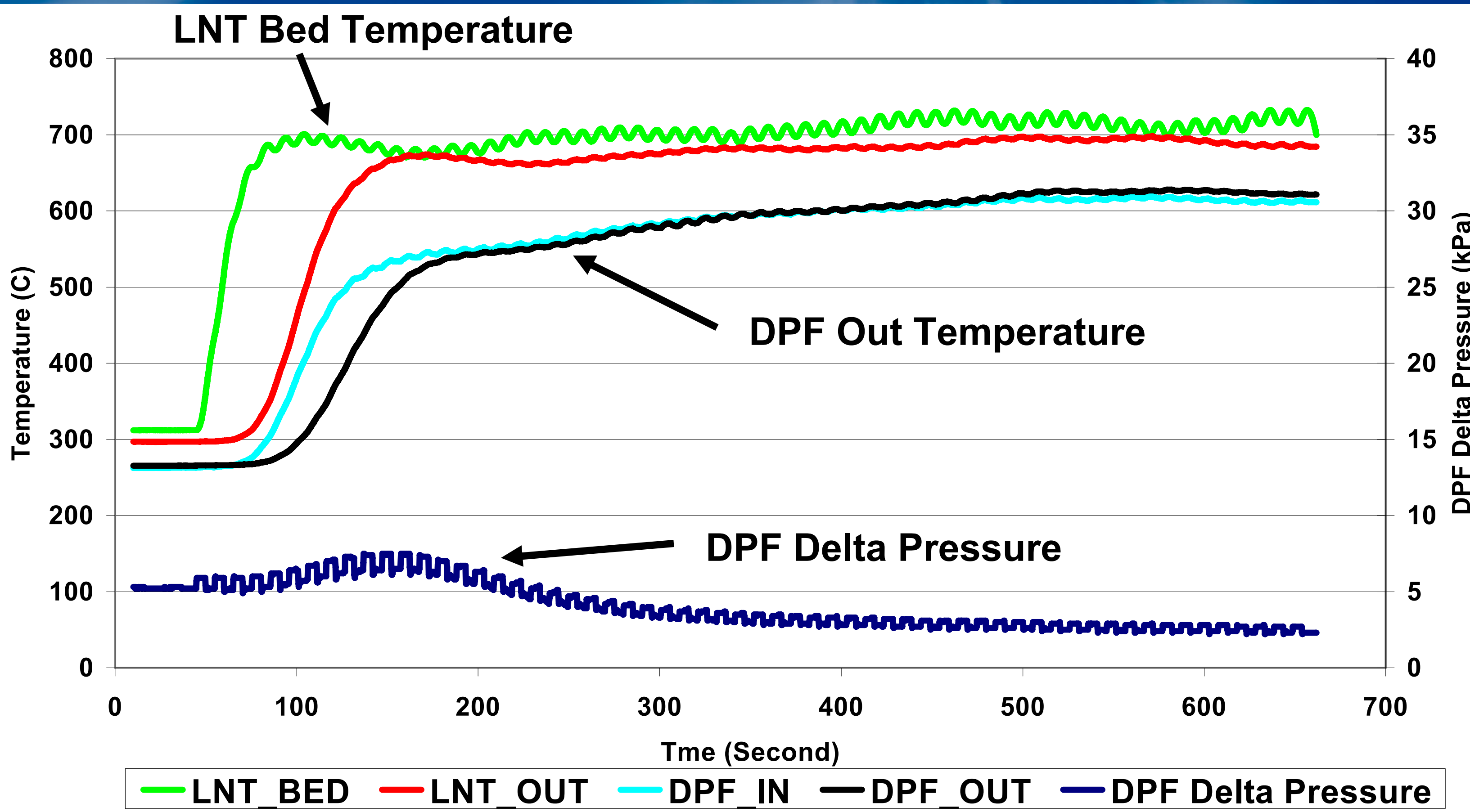
DPF Regeneration
1.9 L Engine Dynamometer Exhaust System

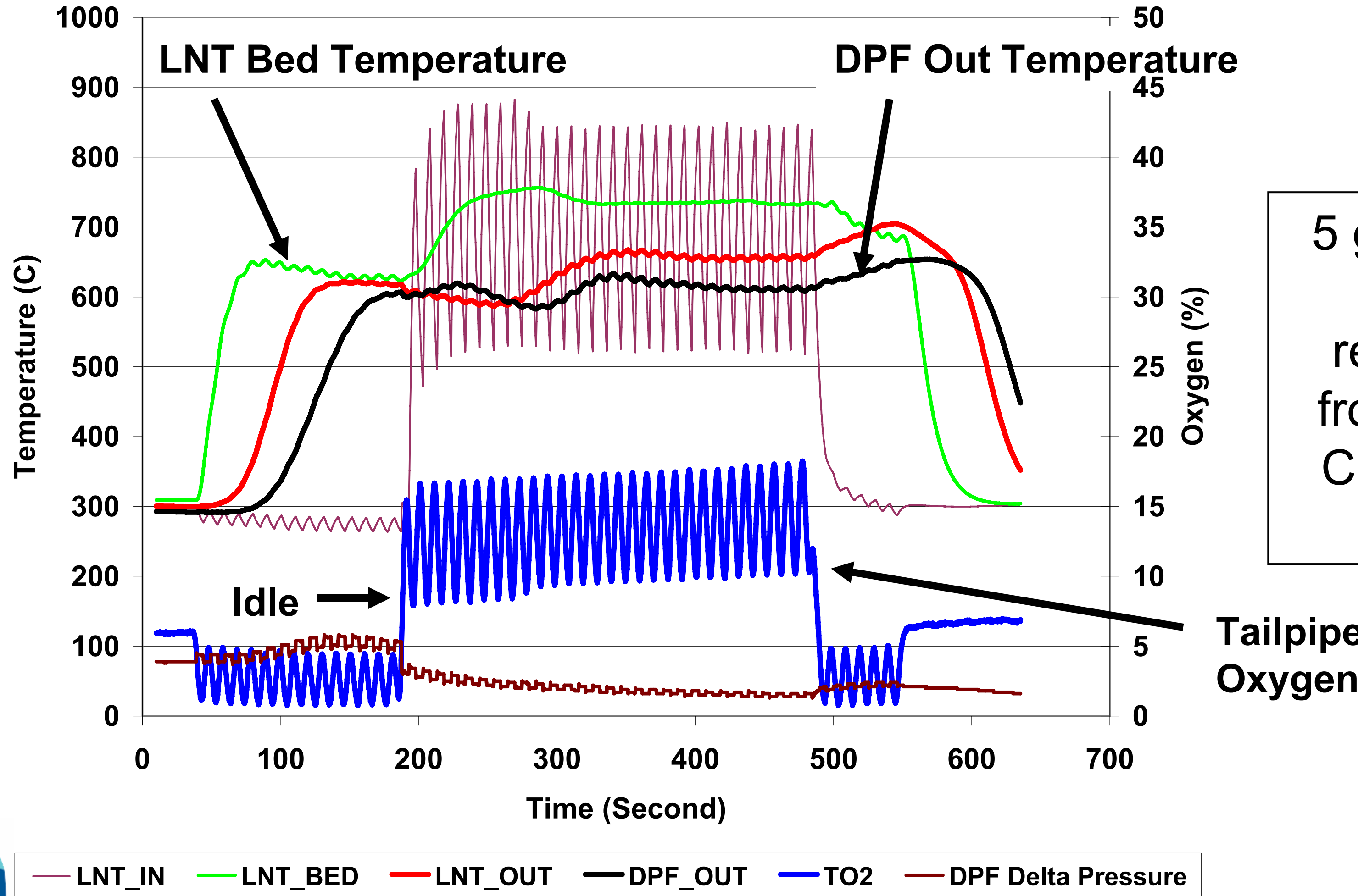


SiC DPF Regeneration with Reformate
1.9 L Engine



21 grams of soot removed from 2.5 L SiC DPF

Cordierite DPF Overtemperature Protection



5 grams of soot removed from 2.5 L Cordierite DPF

Conclusions

- The diesel fuel reformer can allow a LNT exhaust system to achieve the future stringent emission regulations such as Tier 2 Bin 5 and Euro 6 with minor interference to the engine's operation, without additional fluids, and at a **lower** system cost than urea SCR.
- The reformer system improves the robustness of the LNT catalysts by lowering the desulfation temperature and improving the aged performance
- The reformer system can also be used to regenerate a DPF under all driving conditions and protect cordierite filter substrates