

A Fast Start-up On-Board Fuel Reformer for NOx Adsorber Regeneration and Desulfation

Sam Crane, and, Navin Khadiya

September 2, 2004

ArvinMeritorTM

Introduction

- ArvinMeritor's Plasma Fuel Reformer converts diesel/air mixture into a hydrogen rich gas
- Based on Partial Oxidation process, i.e.,

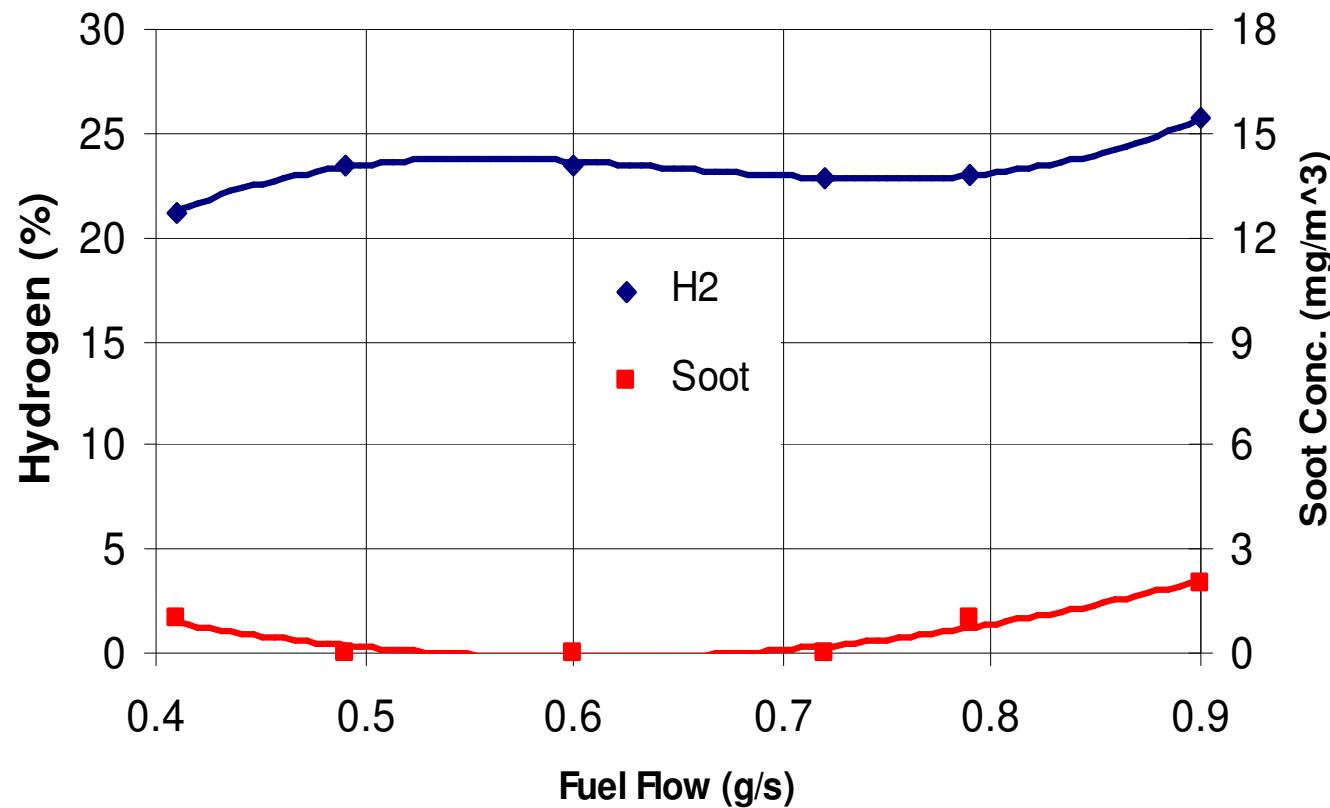


- Ideal partial oxidation occurs at O/C = 1
- For $n \approx 14.5$, $m \approx 26.5 \rightarrow X_{H_2} \approx 24\%, X_{CO} \approx 26\%$
- Electrically generated plasma is the main reforming mechanism, and a catalyst is used for high H_2 yields

Key Characteristics

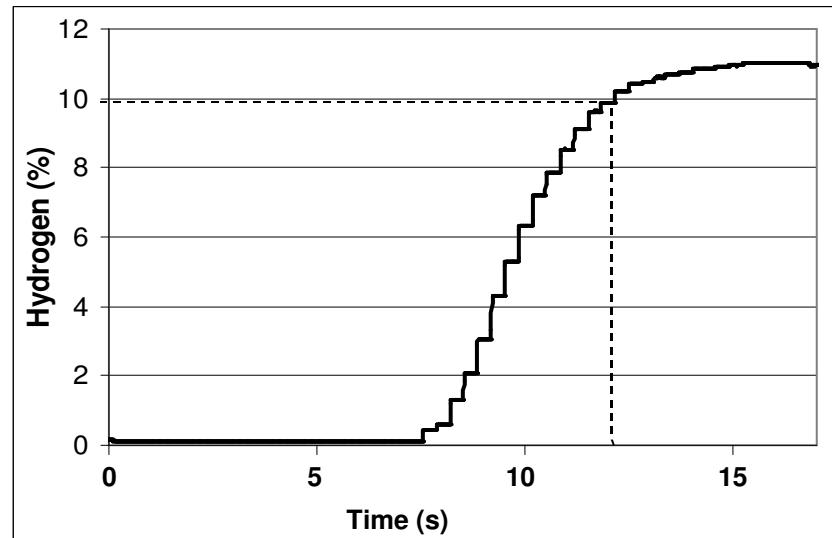
- Fuel Independent
 - Nearly same hardware can reform both gasoline and diesel!
- Wide turndown
 - Currently 0.3 – 1.0 g/s, targeted 0.3 – 1.5 g/s
- Fast Start-up
 - Currently < 10 s, targeted < 5 s for 90% of H₂
 - First 15% of H₂ yield produced in < 2 s
- Sulfur Insensitive
- Low electrical plasma power
 - Currently < 200W, target < 100W

Steady State Performance



Theoretical maximum levels of Hydrogen and negligible soot possible in a catalyst configuration

Start up Characteristics (T_{90})



Measurement System:

Dead time: 7.4 s

Rise time: 4.4 s

Fuel Reformer incl. Meas. System:

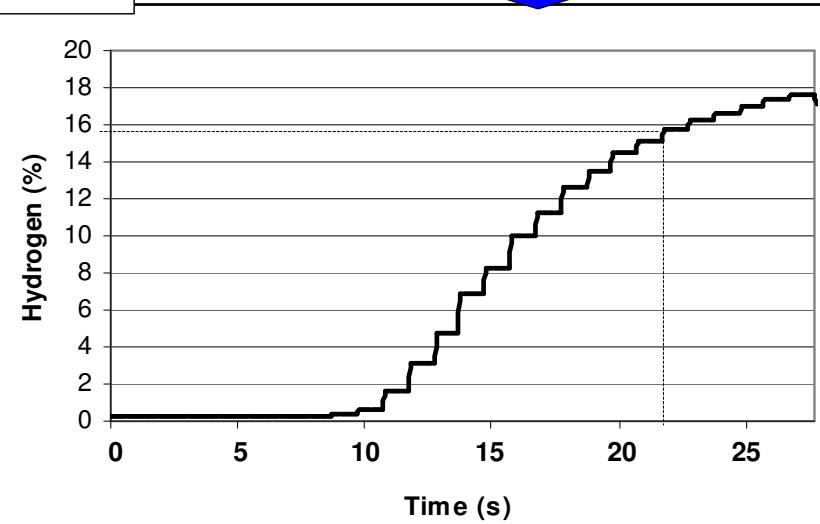
Dead time: 8.7 s

Rise time: 12.7 s

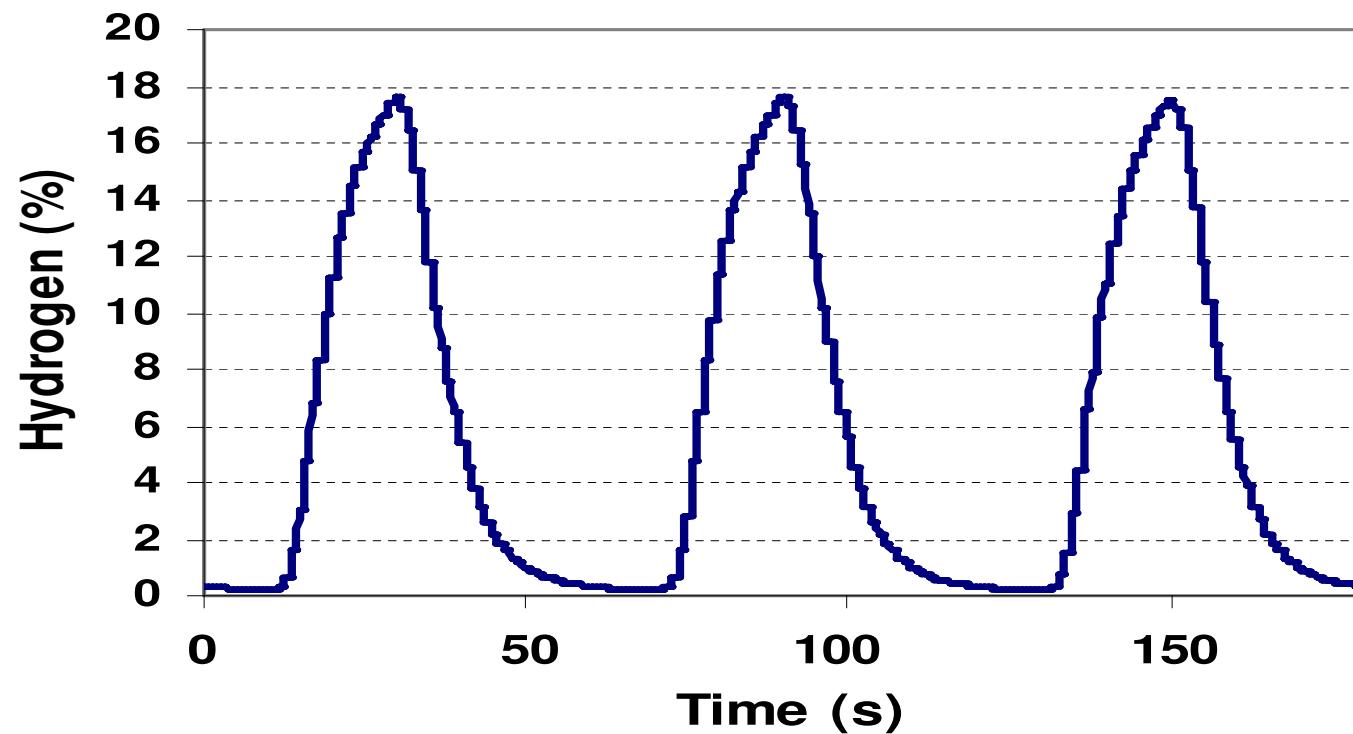
Actual Startup time of the Reformer:

Dead time: 1.3 s

Rise time: 8.3 s



Cycling Performance

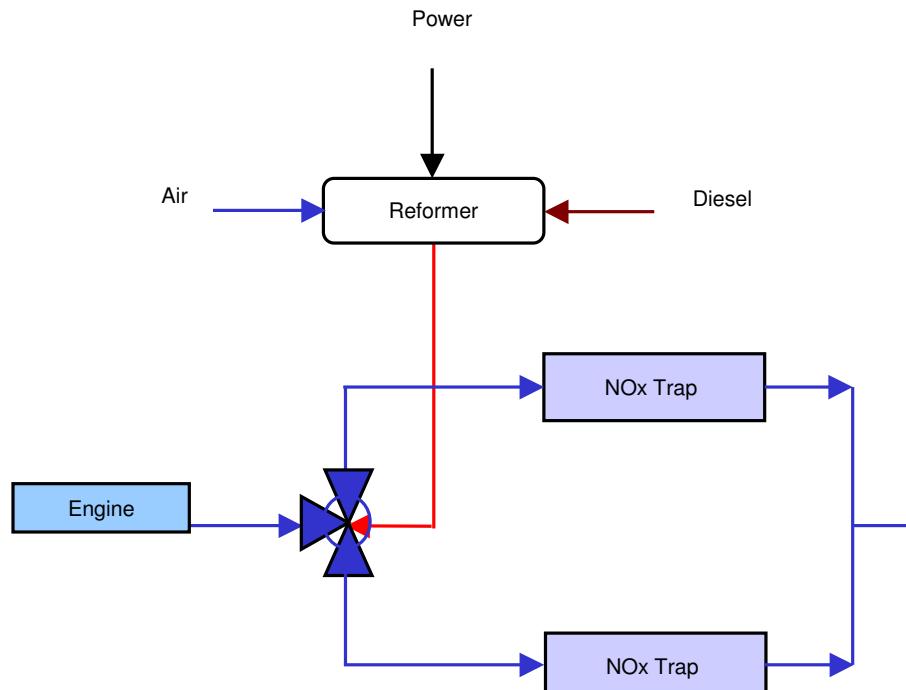


Performance after > 3000 ON/OFF cycles is nearly constant

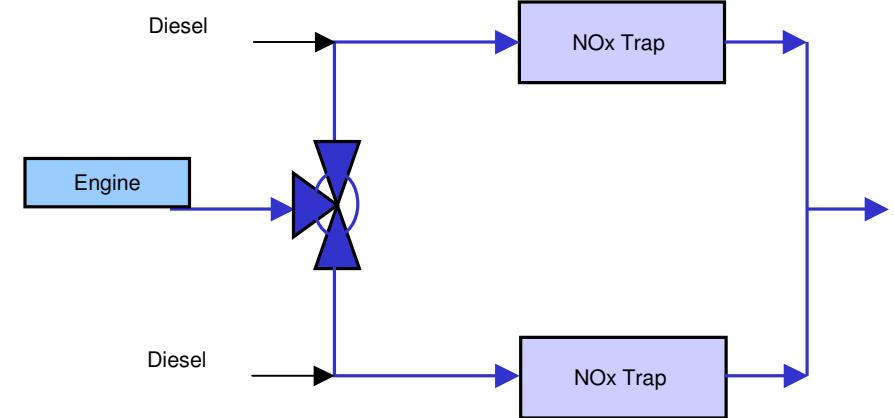
NOx Adsorber Testing

- H₂ and CO considered highly effective reductants for regeneration and desulfation of NOx traps
- Using a Fuel Reformer provides an effective “engine independent” strategy for NOx control
- Two sets of commercial LNTs tested
 - One “High temperature” formulation (HT) - Regeneration and Desulfation results
 - One “Low temperature” formulation (LT) – Desulfation results
- MY2000 Cummins 8.3L engine used in study
- Commercial Adsorbers used in dual leg configuration (14L per leg)

Experimental Setup



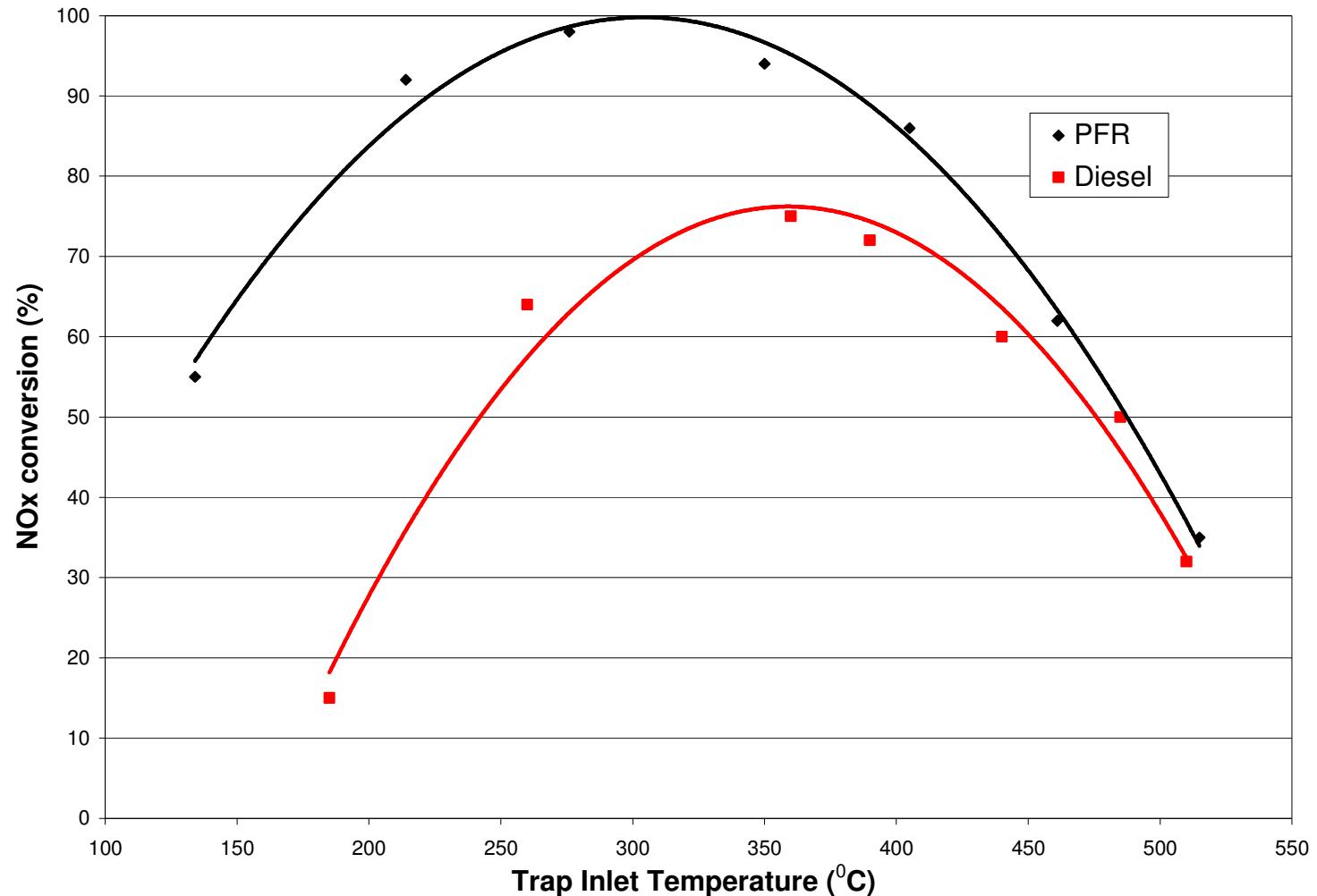
Fuel Reformer Setup



Diesel Injection Setup

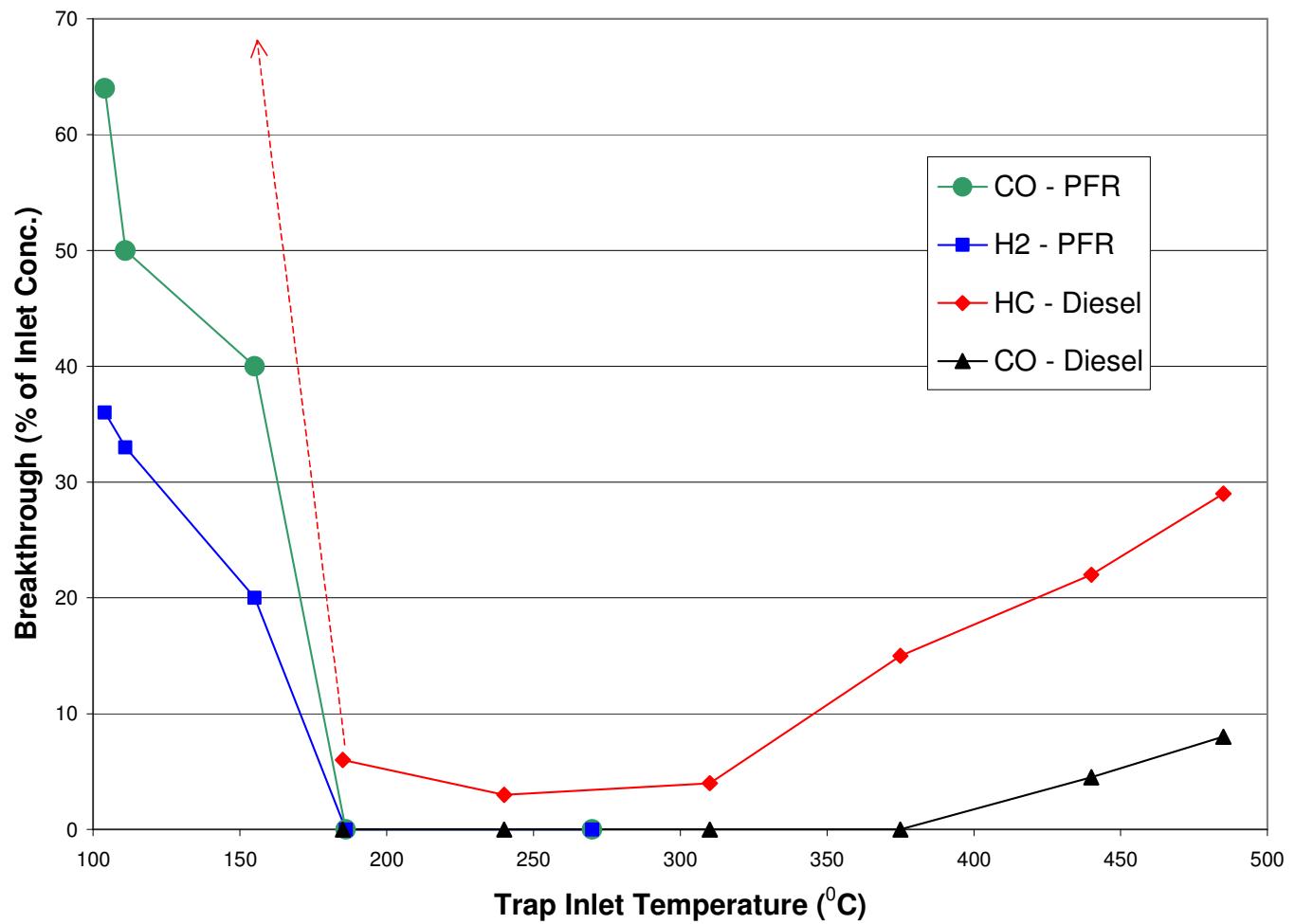
Regeneration Performance – HT

- Low & medium temperature benefits due to greater H₂/CO effectiveness in NOx reduction
- High temperature conversion limited by adsorption capacity
- Fuel Penalty ~ 2 – 7% except at the lowest temperature



CO, H₂, HC Slip Past Regenerated Leg

- Breakthrough trends show the “inverse” of the NOx conversion trends
- Data should be treated as semi-quantitative
- Shows reductant utilization in the order H₂ > CO > Diesel



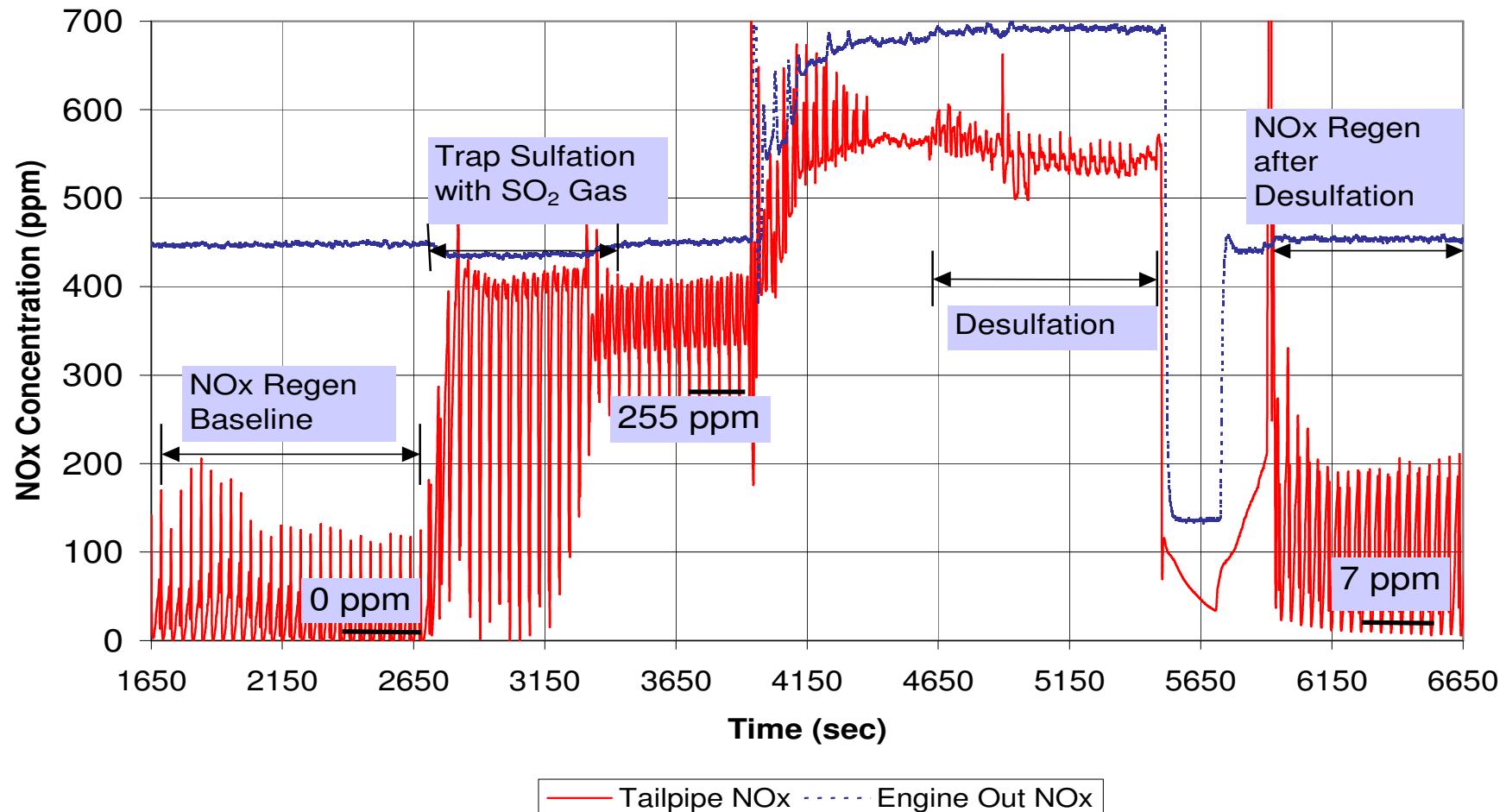
Desulfation Test Procedure

- Rapid Sulfation using ~35 ppm SO₂ gas at 260°C exhaust temperature
- Switching valve is cycled every 20 s during desulfation
- Performance compared at ESC Mode 7 before sulfation and after desulfation
- Degree of recovery (%) defined as:

$$\frac{(\text{Post Sulfation Outlet NO}_x - \text{Post Desulfation Outlet NO}_x)}{(\text{Post Sulfation Outlet NO}_x - \text{Presulfation Outlet NO}_x)} \times 100$$

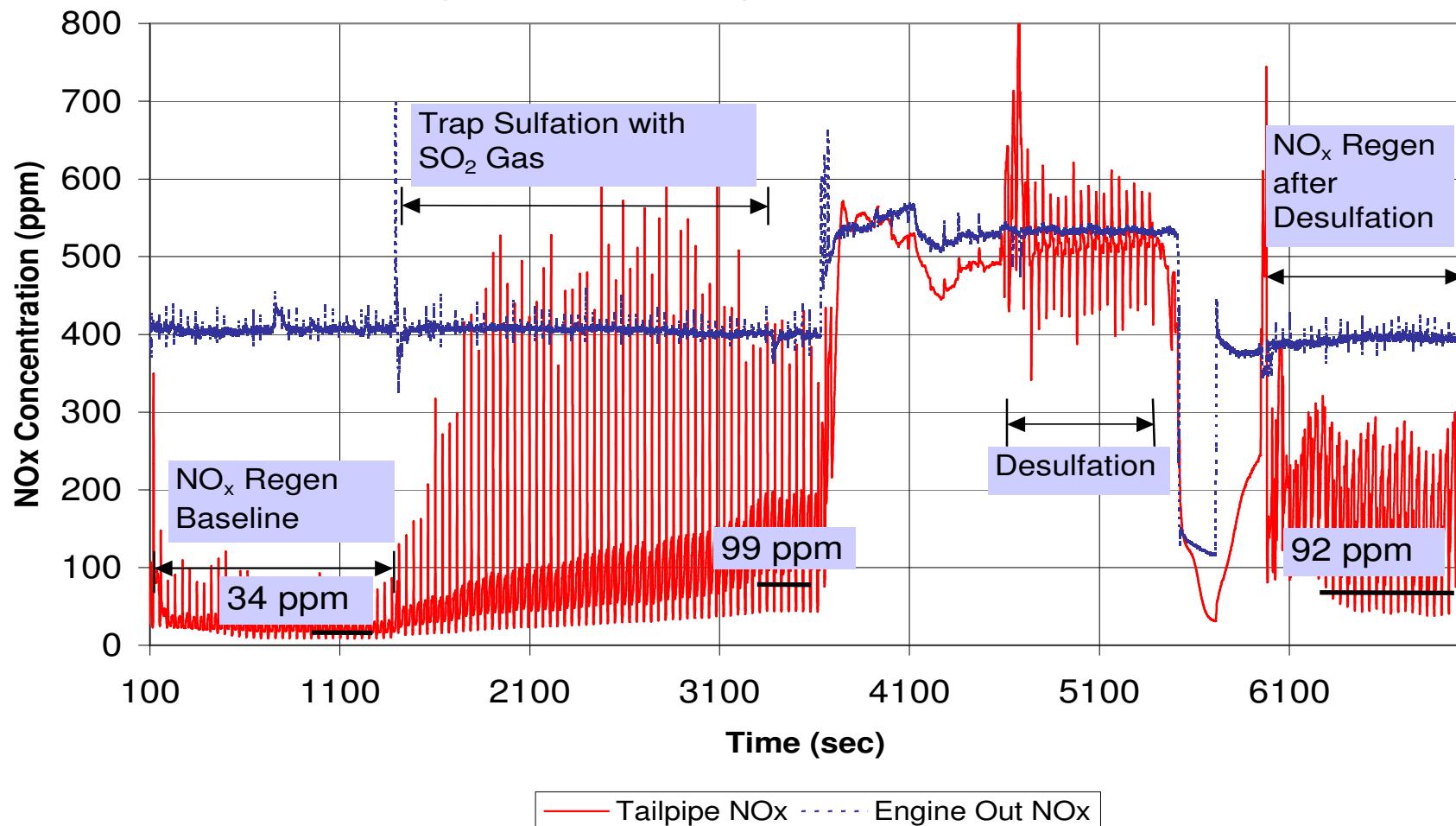
Desulfation with Diesel - LT

100% Recovery in 6.3 min at 510°C



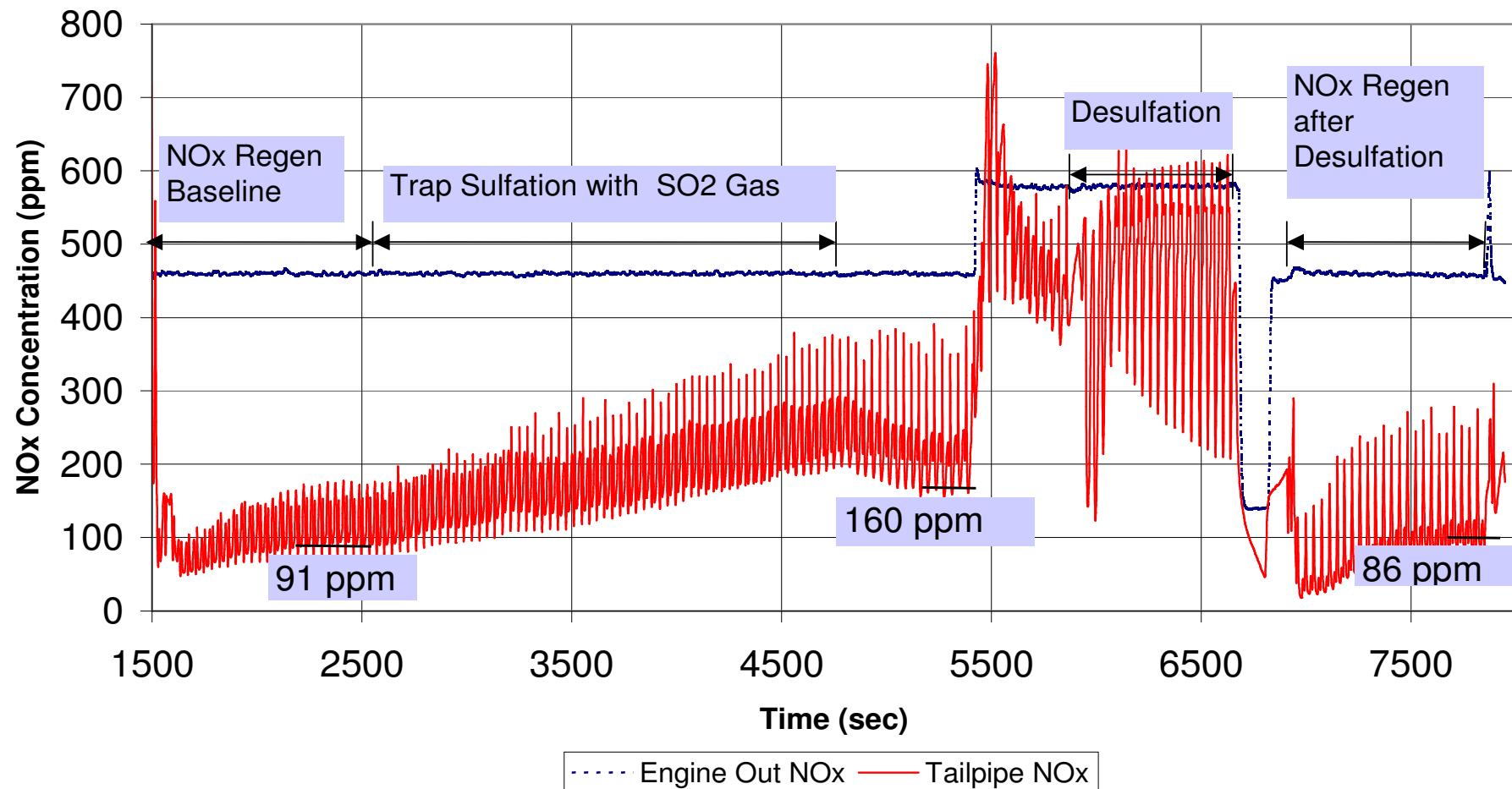
Diesel Desulfation - LT

Only 8% Recovery in 6.3 min at 450°C



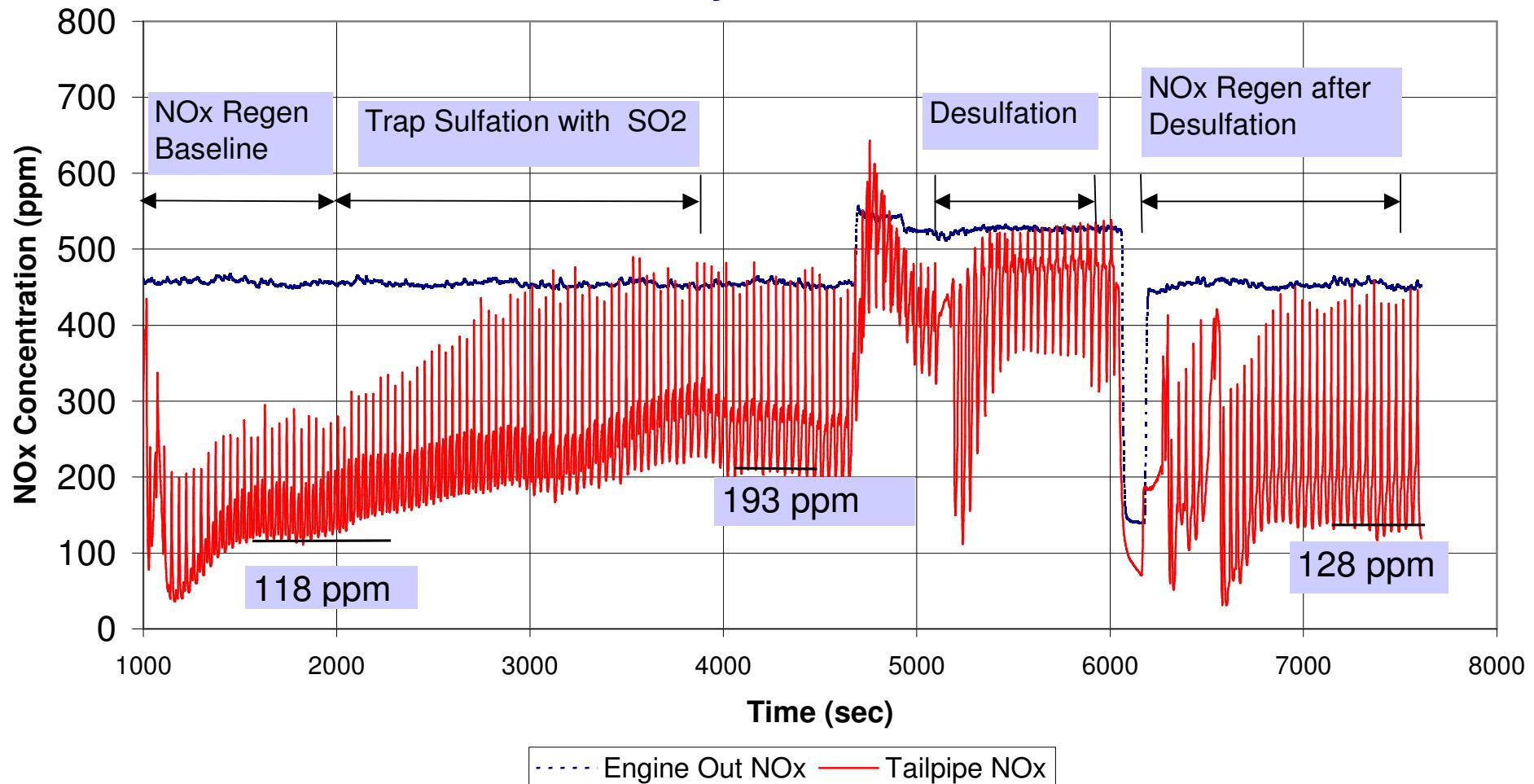
Reformate Desulfation - LT

100% Recovery in 6.3 min at 400°C



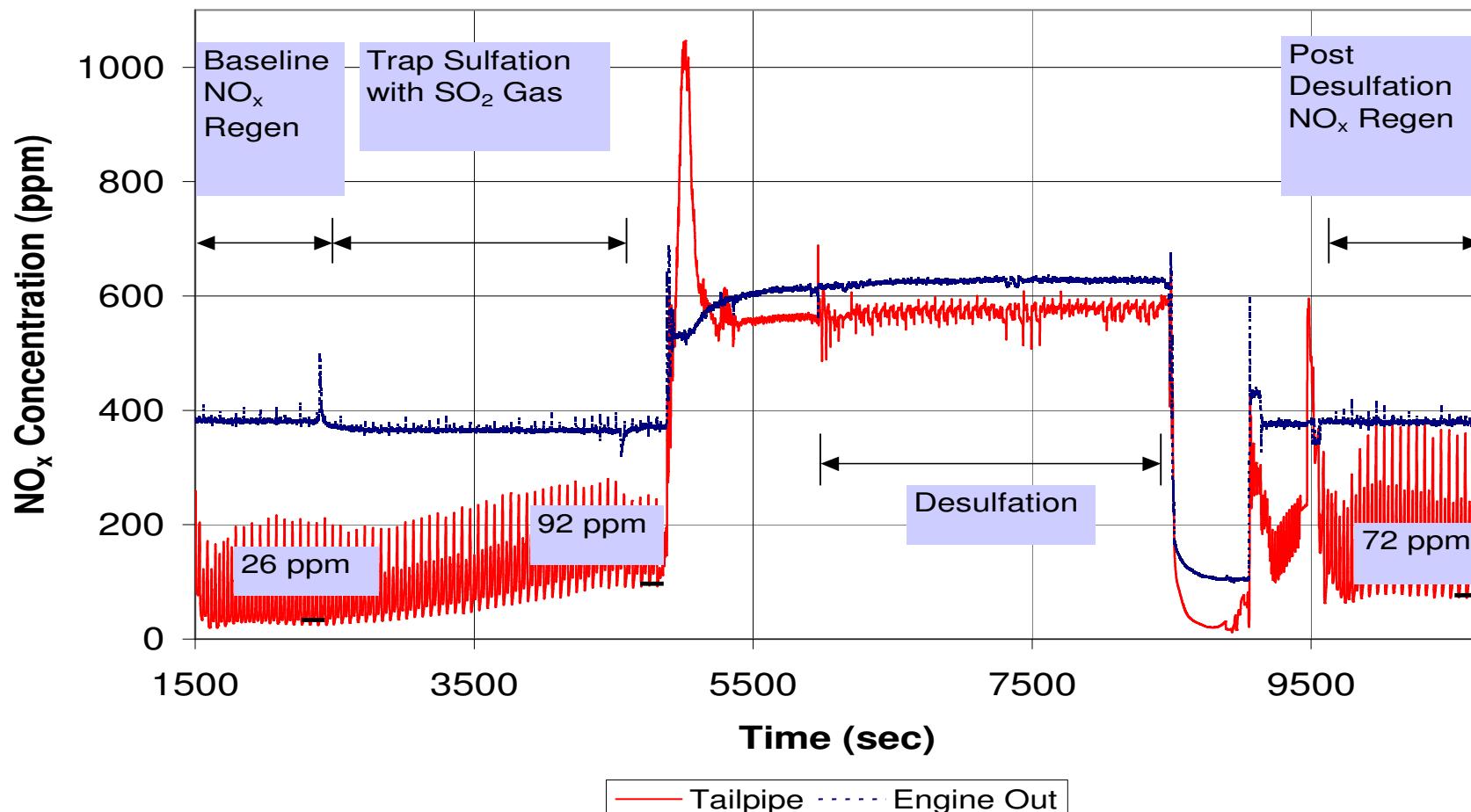
Reformate Desulfation - LT

87% Recovery in 7.3 min at 350°C



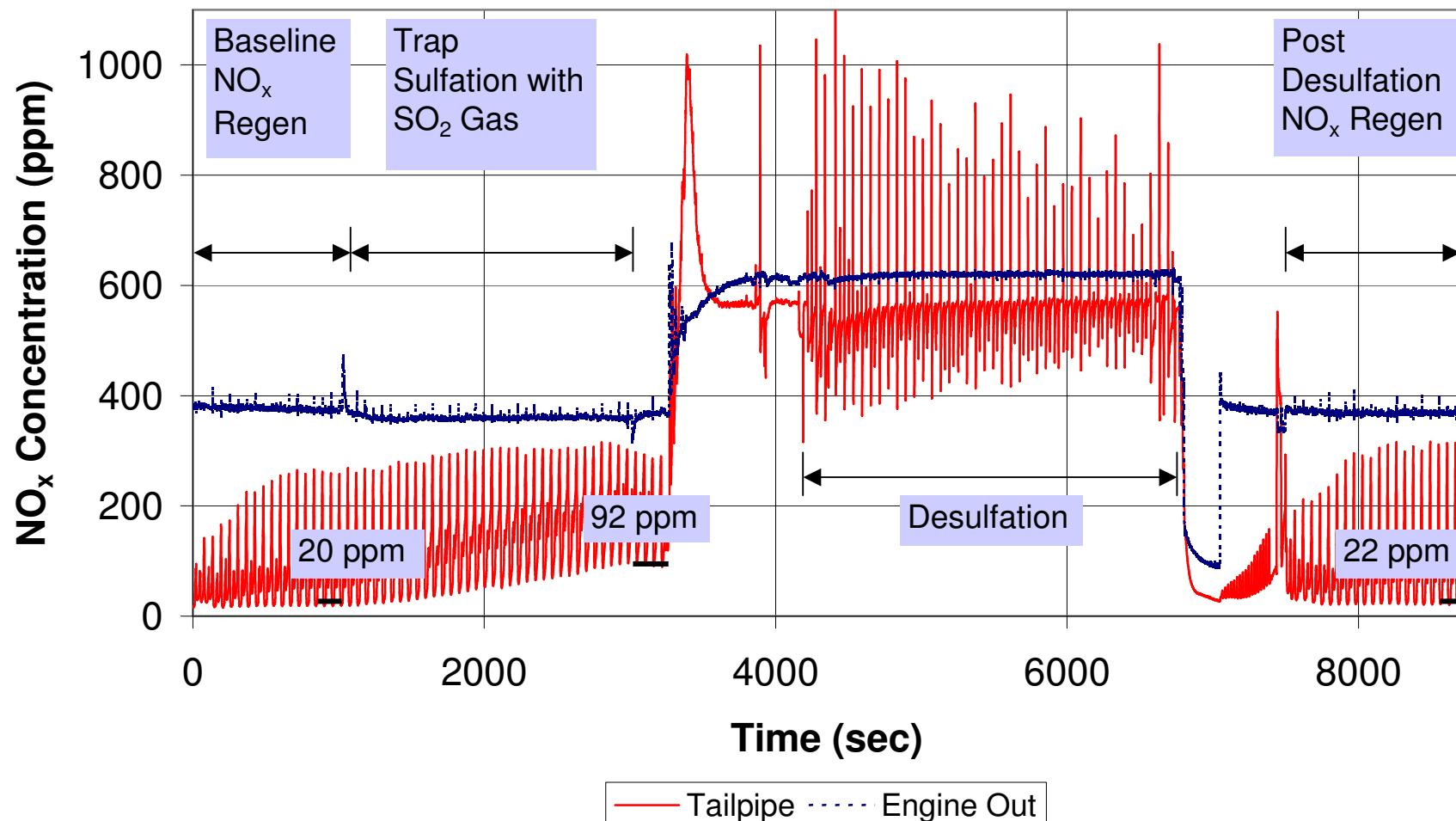
Diesel Desulfation - HT

30% Recovery in 20 min at 540°C



Reformate Desulfation - HT

Nearly 100% Recovery in 20 min at 540°C



Conclusions

- ArvinMeritor Plasma Fuel Reformer is a fast startup, aftertreatment suitable device that reforms diesel with high hydrogen yield and negligible soot
- Reformate gas provides much higher regeneration efficiency compared to Diesel, esp. at low temperatures
- Using reformate gas allows desulfation of NOx traps at more than 100 °C lower temperature compared to diesel
- Lower temperature desulfation reduces thermal degradation, a major barrier towards commercialization
- Potential for concurrent desulfation with regeneration – simple desulfation strategy

Acknowledgements

- This work was supported in part by Indiana's 21st Century Science & Technology Fund
- Other current team members who made important contributions to this project:
 - Steve Blackwood
 - Steve Goldschmidt
 - Mike Greathouse
 - Granville Hayworth
 - Bob Iverson