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

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ArvinMeritor™

Introduction

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

$$C_nH_m + n/2\ (O_2 + 3.76N_2) \rightarrow nCO + m/2\ H_2 + 1.88n\ N_2 + Heat$$

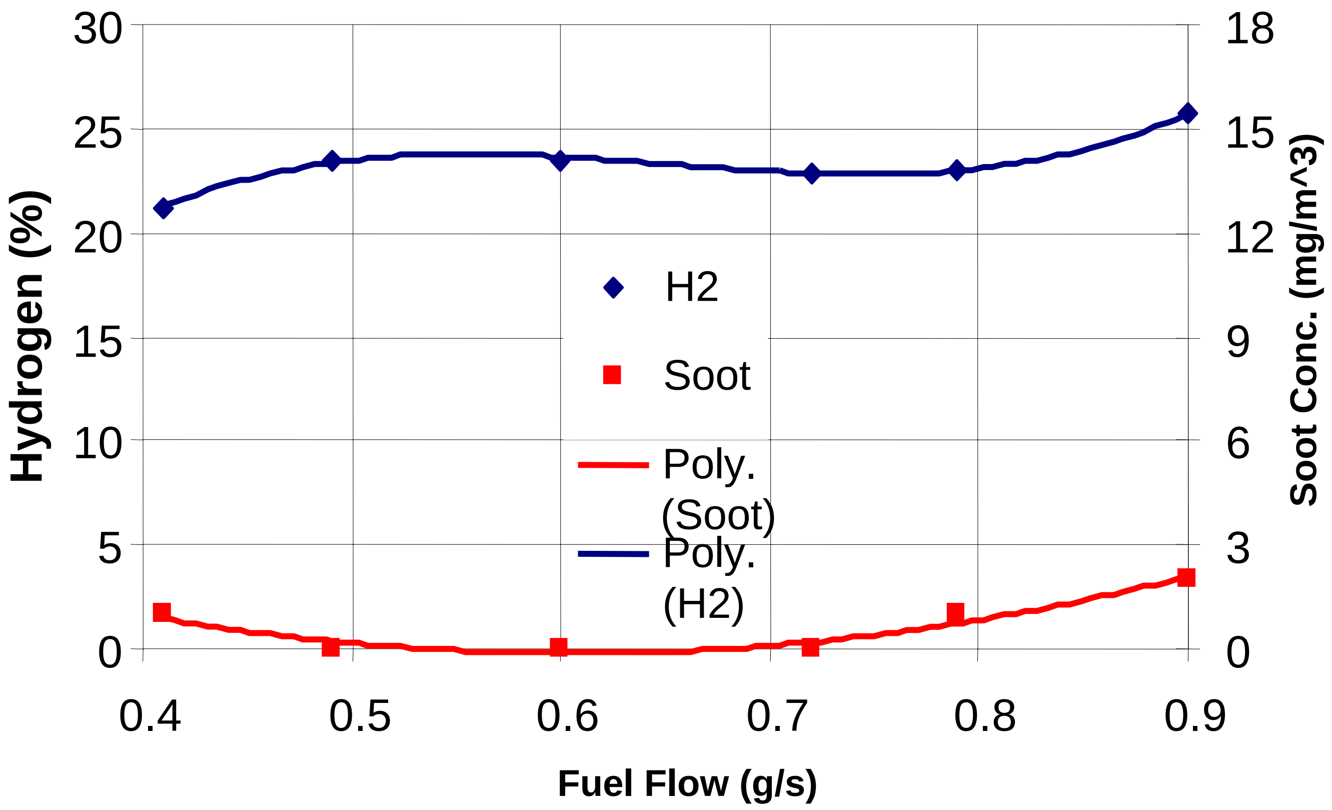
  - Ideal partial oxidation occurs at O/C = 1
  - For $n \approx 14.5$, $m \approx 26.5 \rightarrow X_{H2} \approx 24\%$, $X_{CO} \approx 26\%$

- Electrically generated plasma is the main reforming mechanism, and a catalyst is used for high H_2 yields

Key Characteristics

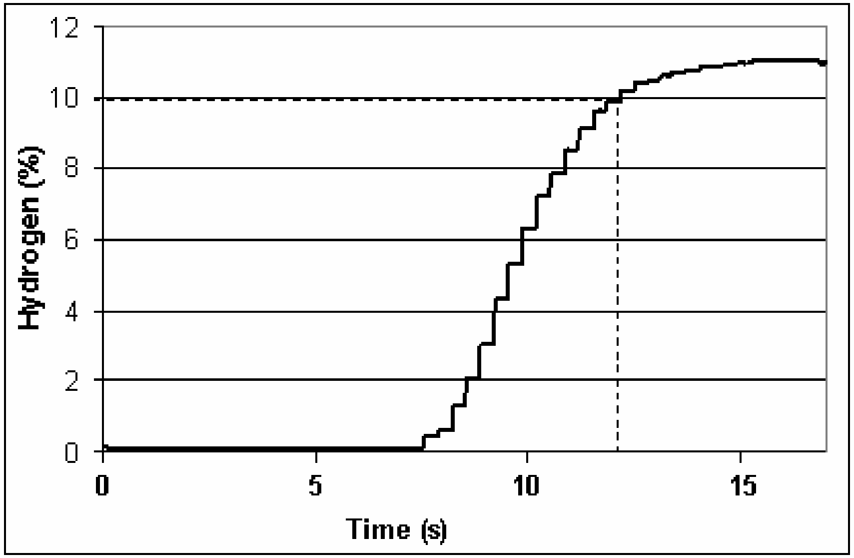
- Fuel Independent
  - Nearly same hardware can reform both gasoline and diesel!
- Wide turndown
  - Currently 0.3 – 1.0 g/s, targeted 0.3 – 1.5 g/s
- Fast Start-up
  - Currently < 10 s, targeted < 5 s for 90% of H_2
  - First 15% of H2 yield produced in < 2 s
- Sulfur Insensitive
- Low electrical plasma power
  - Currently < 200W, target < 100W

Steady-State Performance



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

Startup Characteristics (T_{90})



Measurement System:

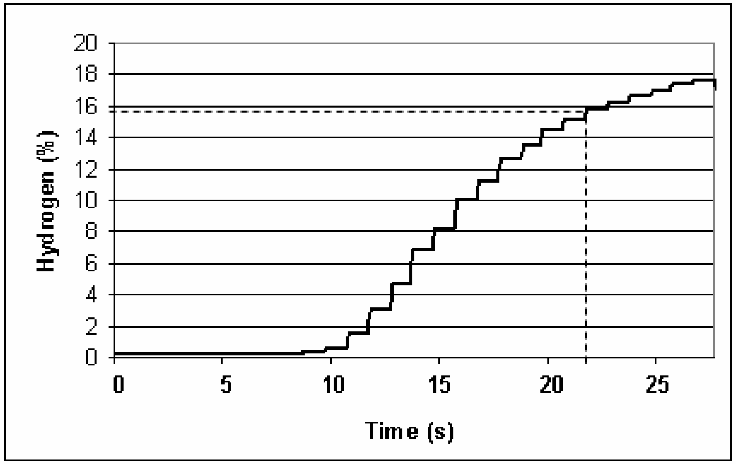
Dead time: 7.4 s

Rise time: 4.4 s

Fuel Reformer incl. Meas. System:

Dead time: 8.7 s

Rise time: 12.7 s

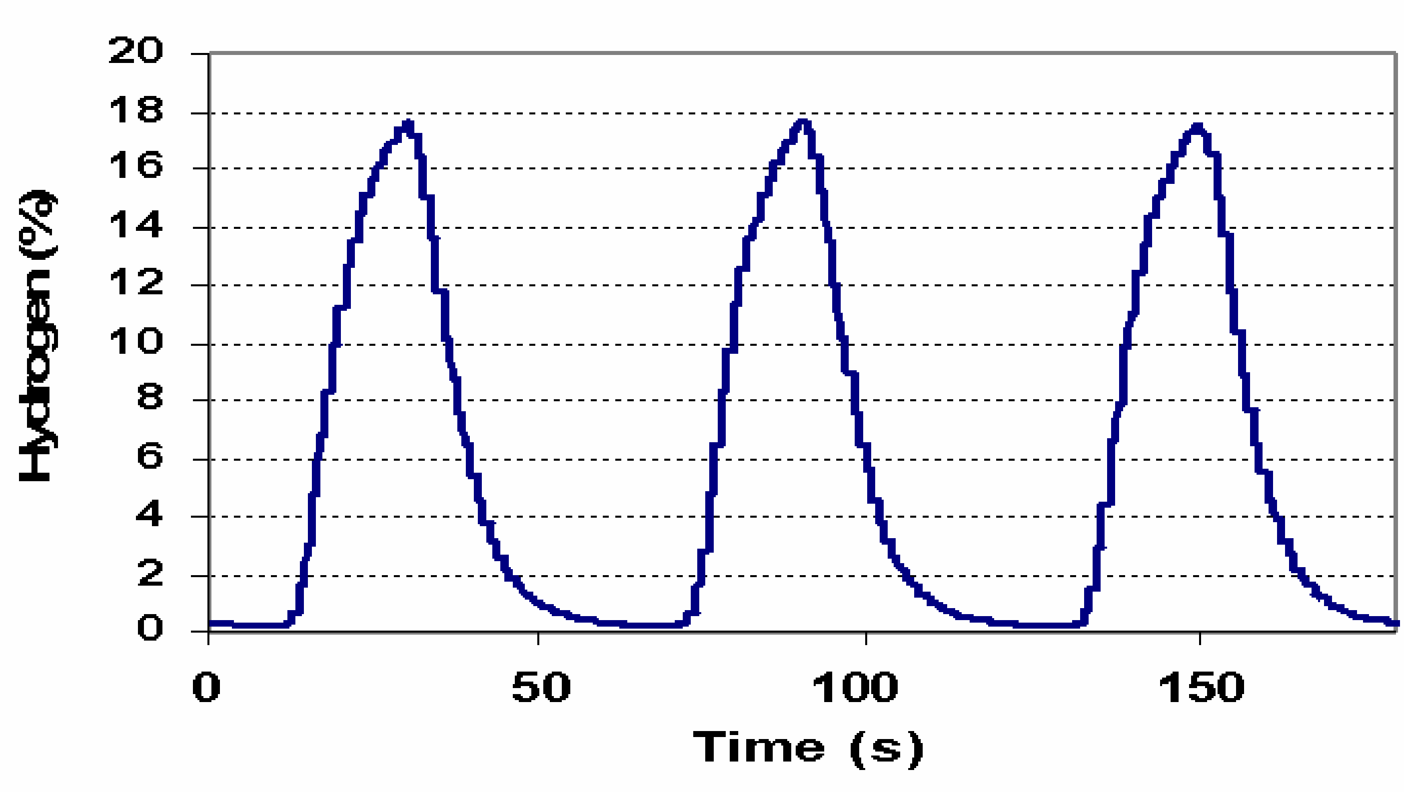


Actual Startup time of the Reformer:

Dead time: 1.3 s

Rise time: 8.3 s

Cycling Performance

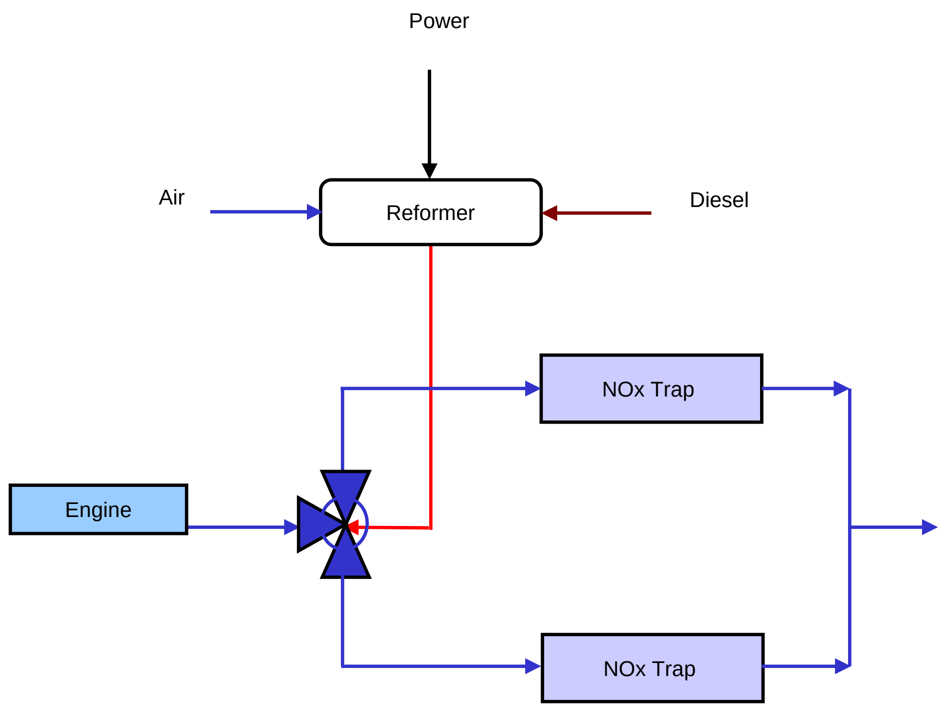


Performance after > 3000 ON/OFF cycles is nearly constant

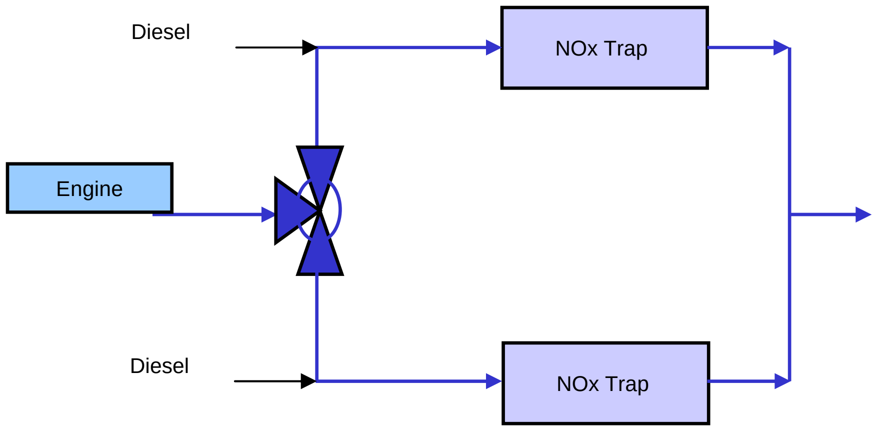
NOx Adsorber Testing

- H_2 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



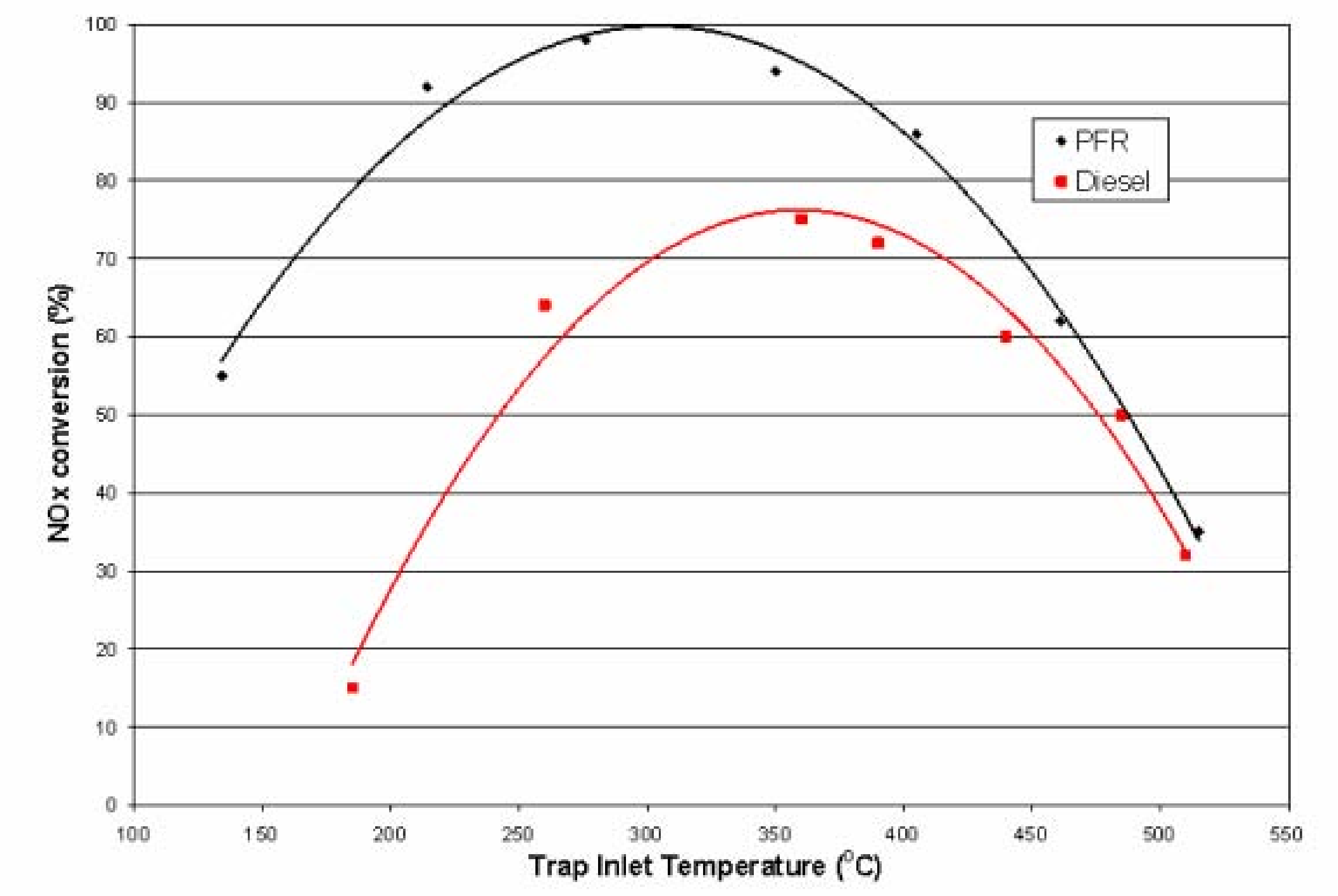
Fuel Reformer Setup



Diesel Injection Setup

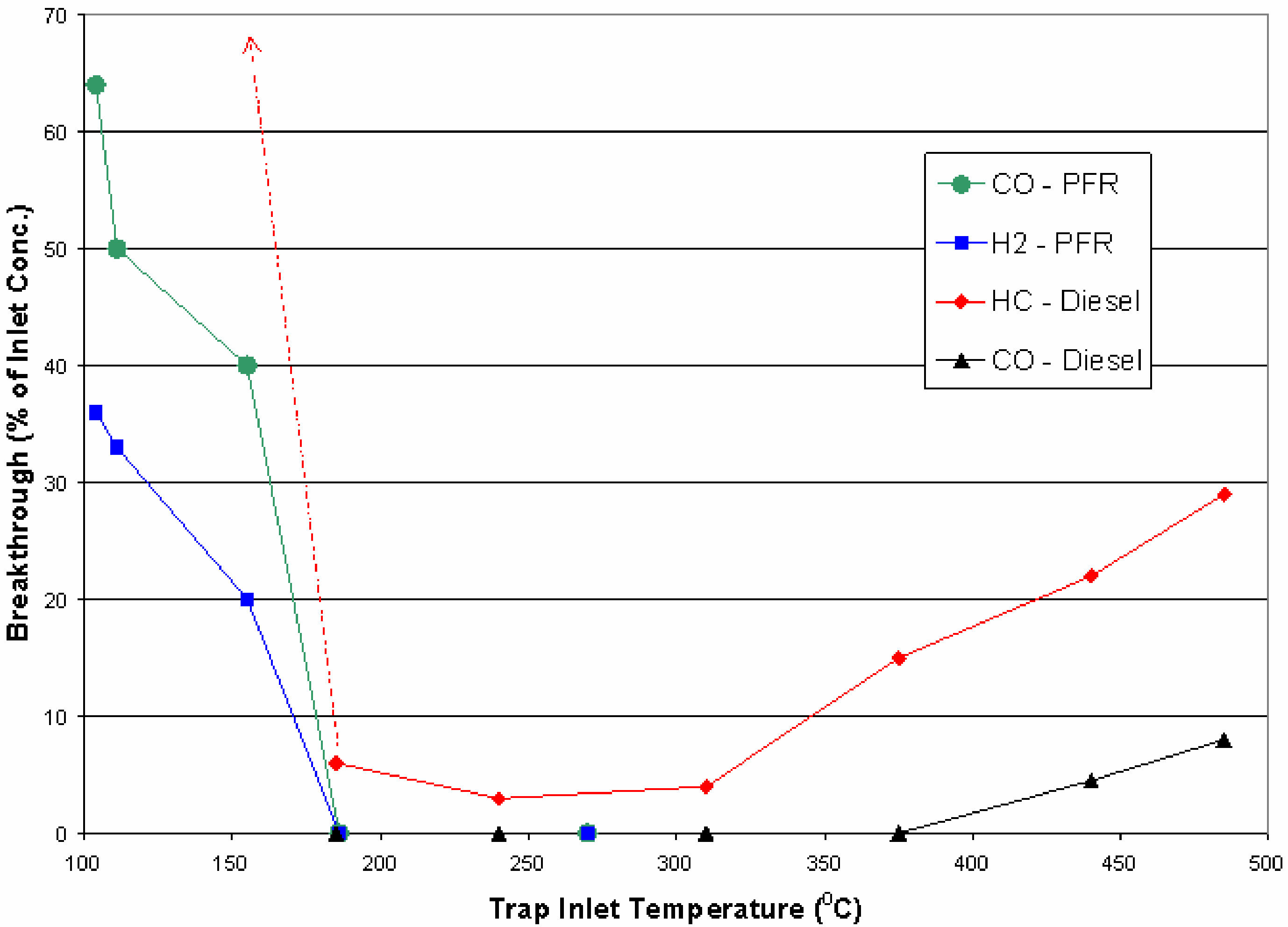
Regeneration Performance – HT

- Low & medium temperature benefits due to greater H_2/CO effectiveness in NOx reduction
- High temperature conversion limited by adsorbtion capacity
- Fuel Penalty ~ 2 – 7% except at the lowest temperature



CO, H_2, 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 H_2 > CO > Diesel



Desulfation Test Procedure

- Rapid Sulfation using ~35 ppm SO_2 gas at 260ºC 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:

$$\frac{(\text{Post Sulfation Outlet } NO_x - \text{Post Desulfation Outlet } NO_x)}{(\text{Post Sulfation Outlet } NO_x - \text{Presulfation Outlet } NO_x)} \times 100$$

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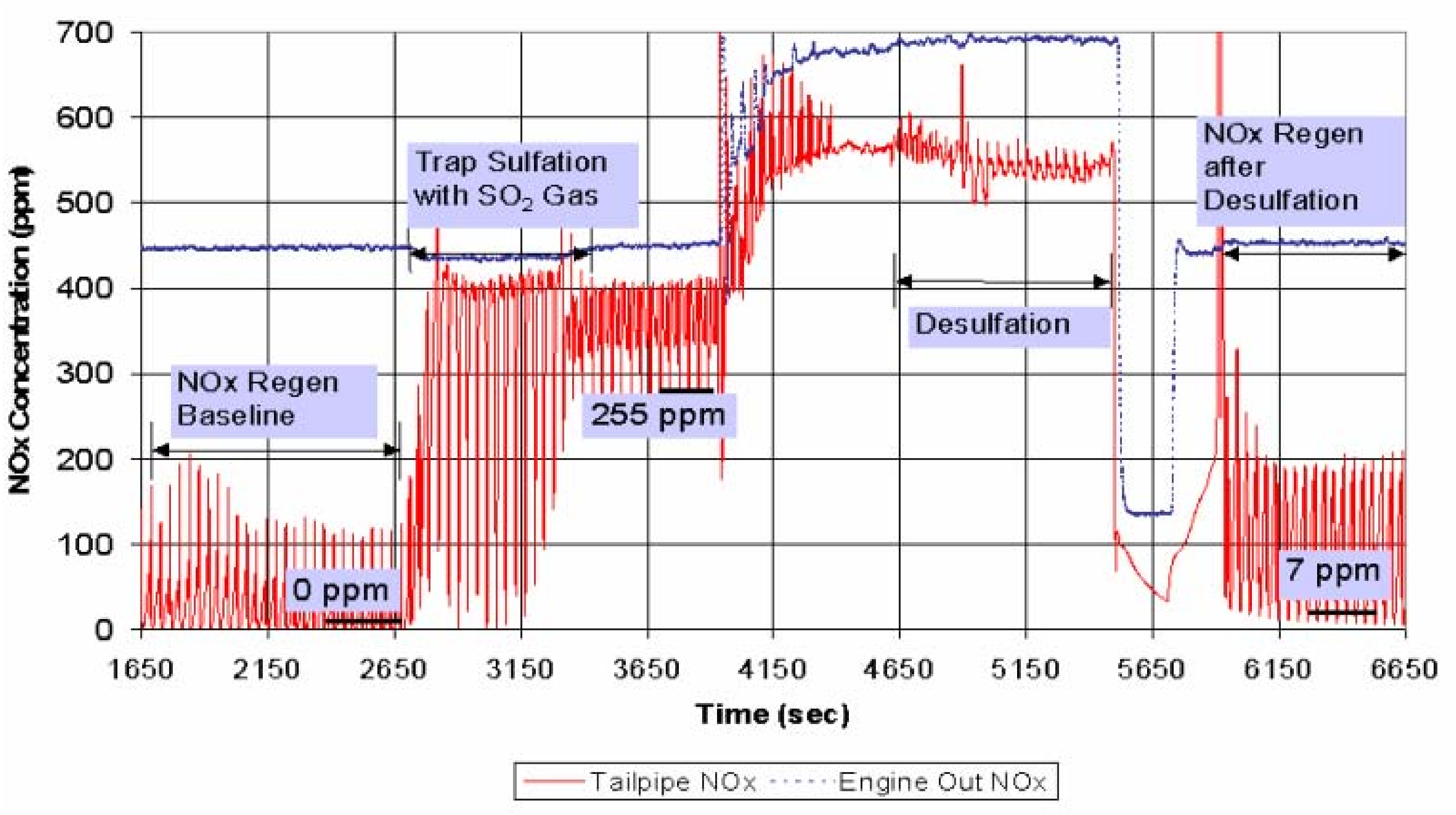
Desulfation with Diesel - LT

100% Recovery in 6.3 min at 510ºC



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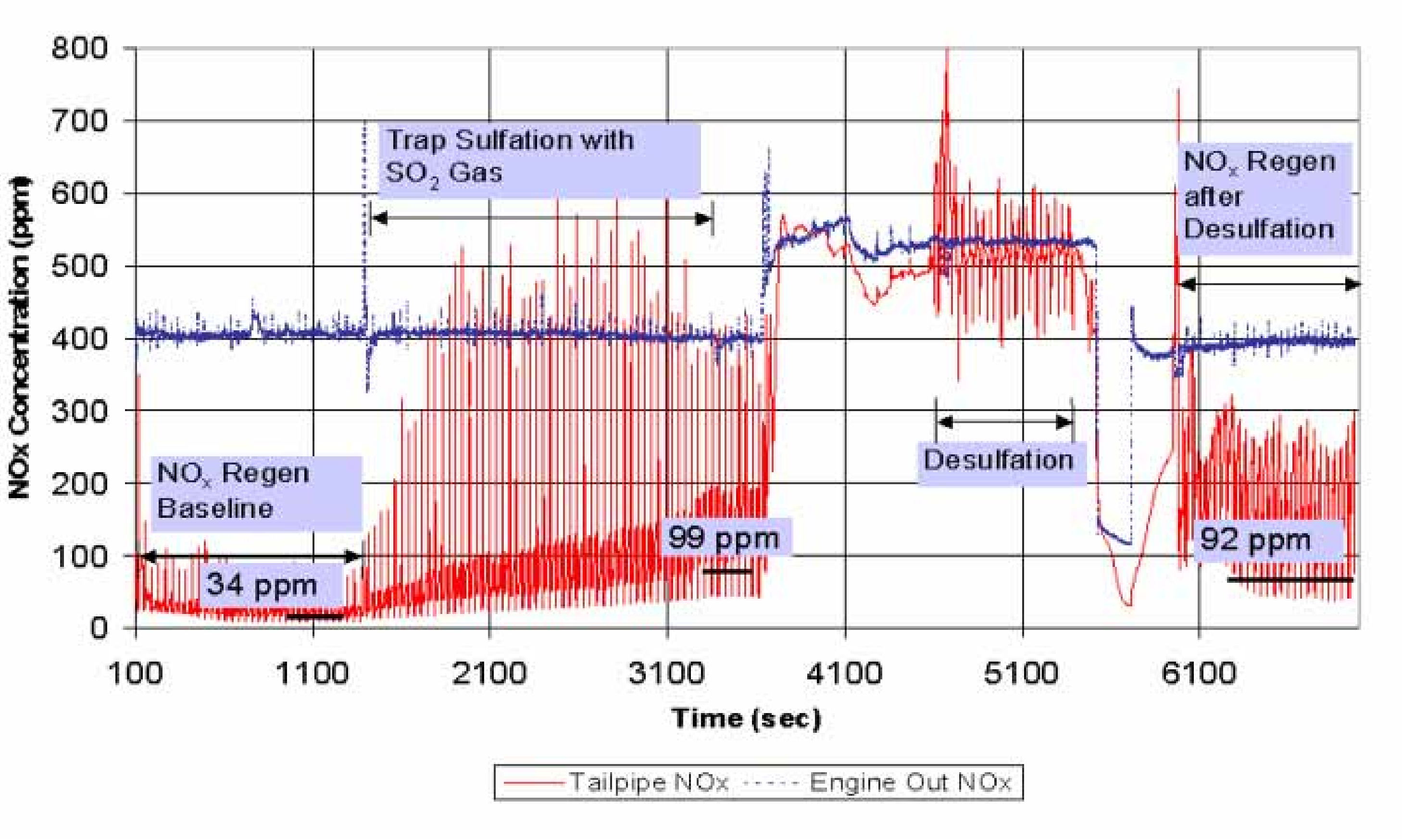
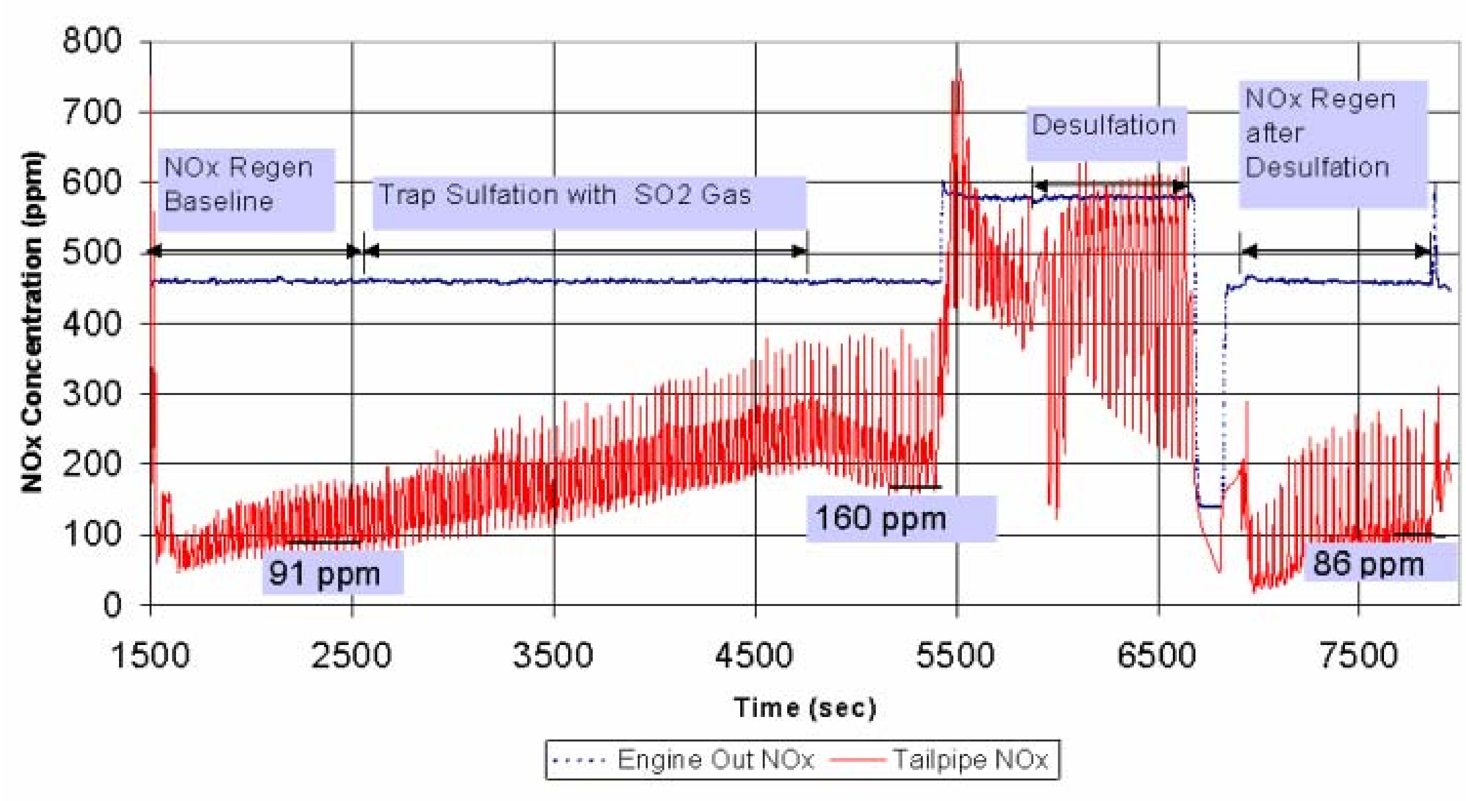
Diesel Desulfation - LT

Only 8% Recovery in 6.3 min at 450ºC



Reformate Desulfation - LT

100% Recovery in 6.3 min at 400ºC



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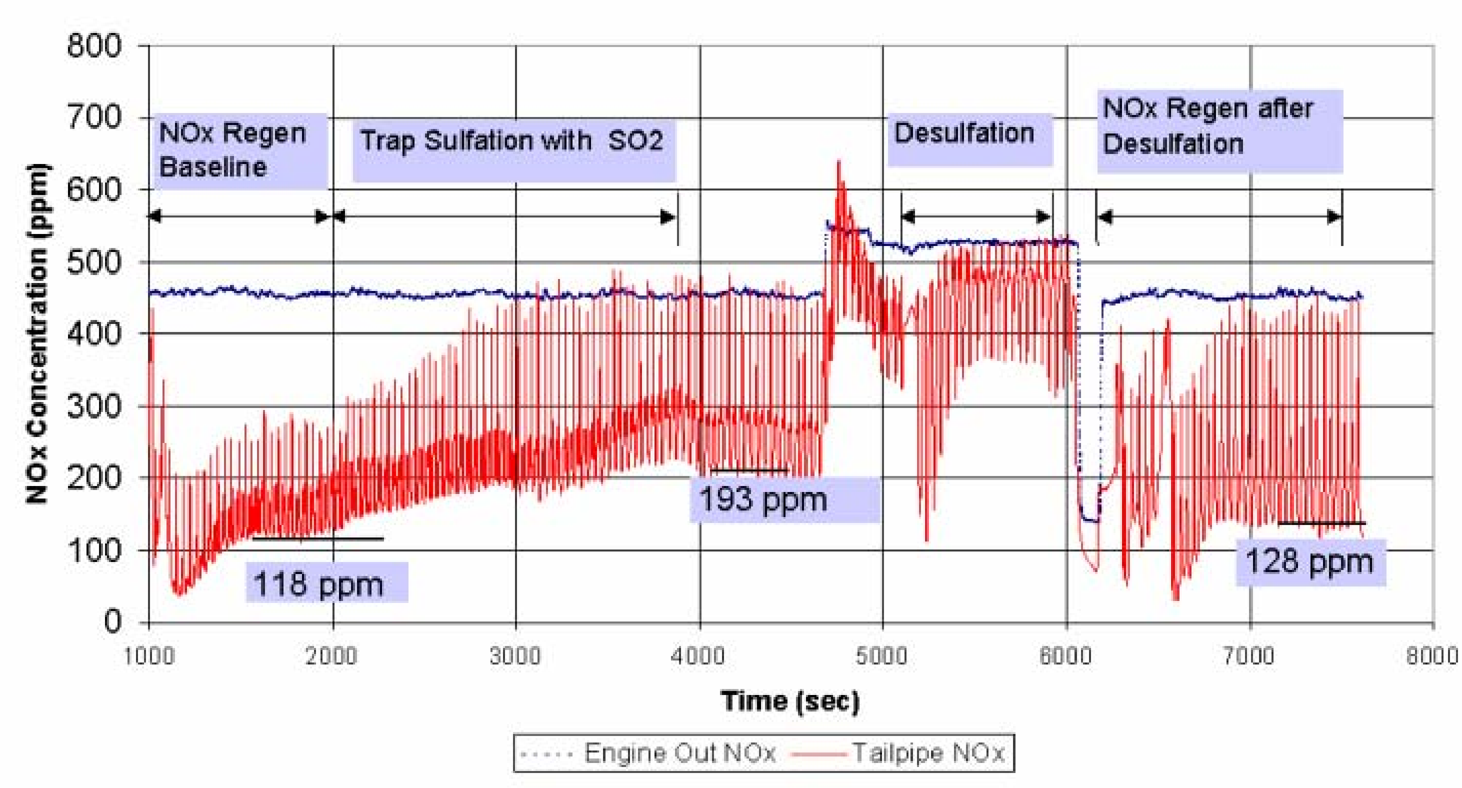
Reformate Desulfation - LT

87% Recovery in 7.3 min at 350ºC



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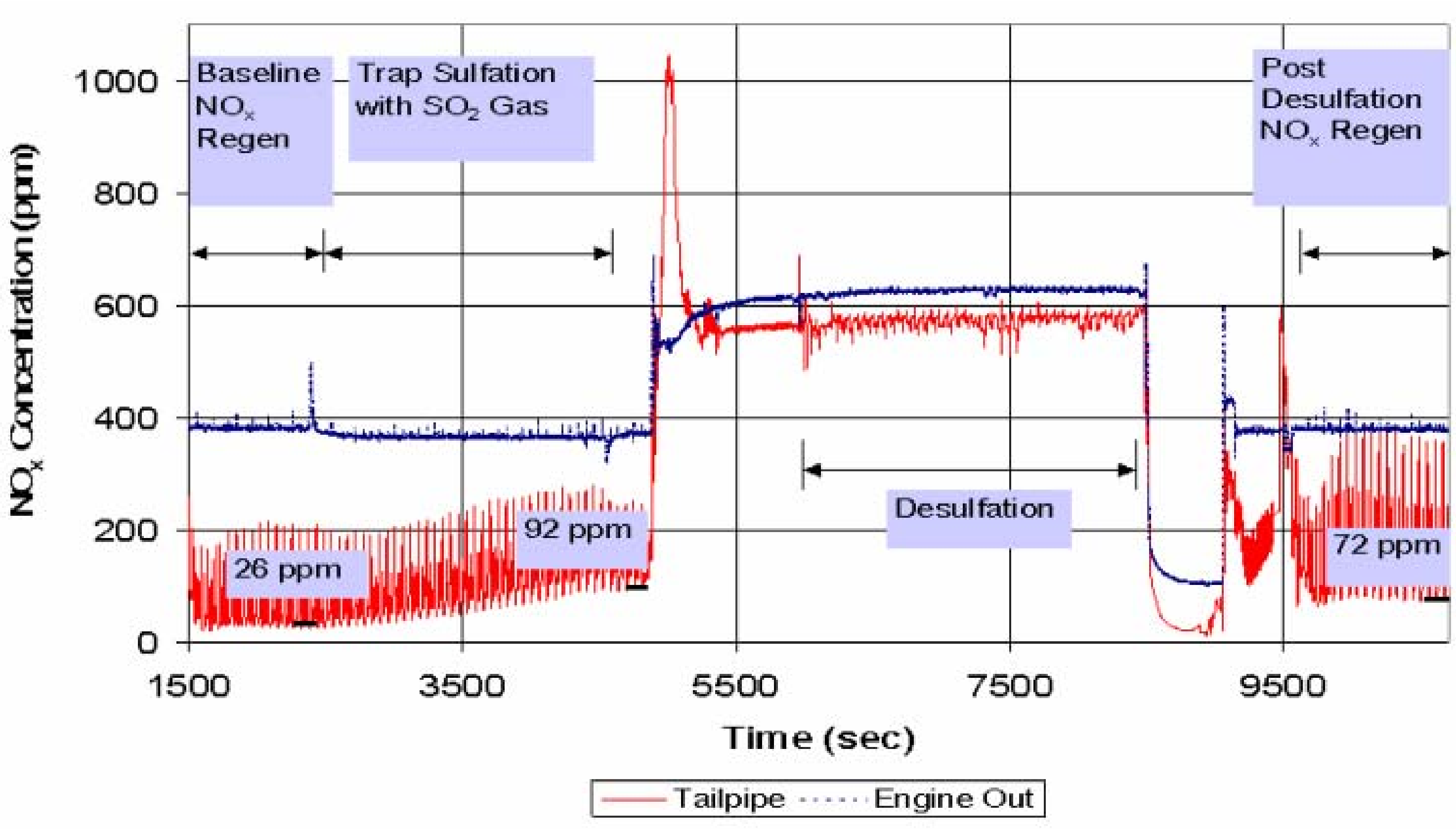
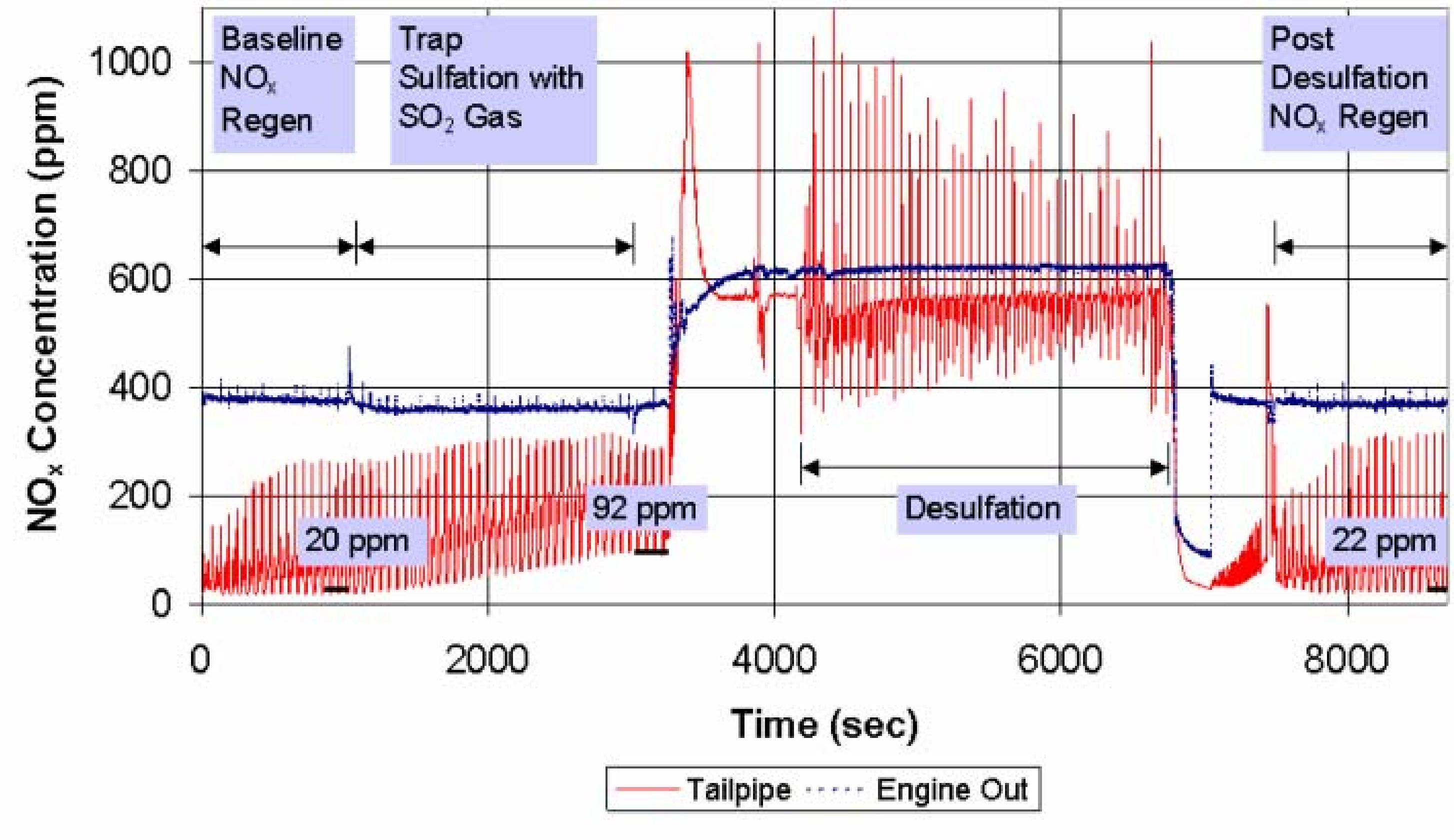
Diesel Desulfation - HT

30% Recovery in 20 min at 540ºC



Reformate Desulfation - HT

Nearly 100% Recovery in 20 min at 540ºC



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

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