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Diesel Reformers for On-board Hydrogen Applications in Exhaust Aftertreatment Systems

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Overview

- **Presentation Outline**
  - Background
  - Results of using hydrogen to regenerate NOx Adsorbers
  - Diesel reformer development
  - Present activity and future work
- **Terminology**
  - NOx Adsorber = Lean NOx Trap = LNT
  - Diesel Reformer => Hydrogen-rich gas = Hydrogen reformate = Syngas = H_2 + CO mixture
  - Catalytic Partial Oxidation = CPOx

HydrogenSource Background

Created in 2001

UTC Fuel Cells
A United Technologies Company

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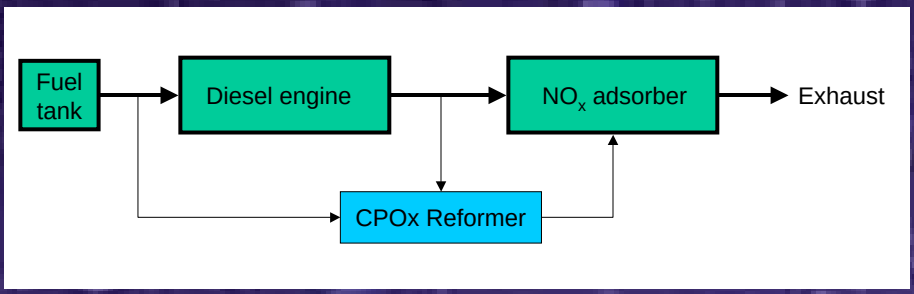
Develop, manufacture and sell
Fuel Processors

HyS On-Board CPOx Reformer System



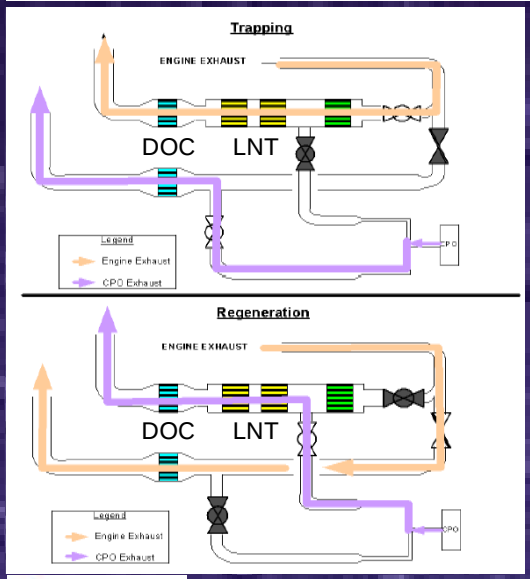
Diesel + Engine Exhaust => H_2 + CO + H_2O, CO_2, N_2, HC

- Ultra Low Sulfur Diesel (15 ppm sulfur)
- O_2 and H_2O from exhaust

Initial LNT Regeneration Test

- **Test Objective**
  - Determine feasibility of using hydrogen-rich gas from an existing CPOx reformer for LNT regeneration
- **Demonstration Test Configuration**
  - Naphtha used for reformer fuel rather than diesel
  - Air used as oxidant rather than engine exhaust
  - Steady state engine & reformer operation
  - One leg of dual leg LNT exhaust system
  - Fixed NOx trapping & regeneration cycle times

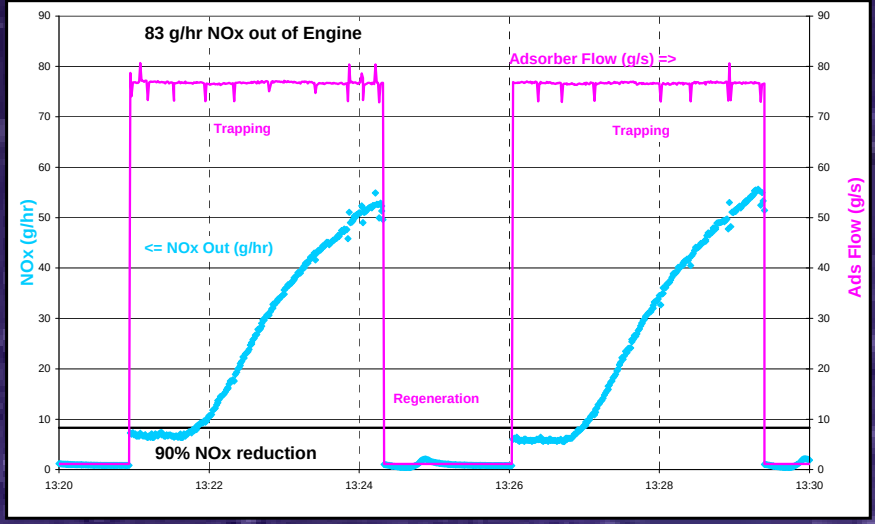
LNT Regeneration Test Configuration



- 5.9L engine
- 14L LNT
- Reformate comp.:
  - 30% H_2
  - 16% CO
  - 5% CO_2
  - 38% N_2
  - 10% H_2O
  - <1% THC

LNT Regeneration Test Results

90 % NOx Reduction at 150°C LNT Temperature



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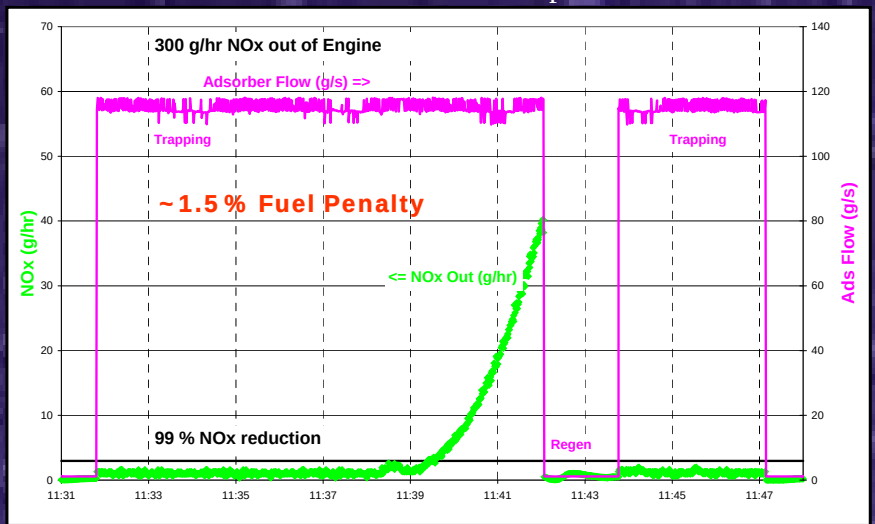
LNT Regeneration Test Results

99 % NOx Reduction at 300°C LNT Temperature



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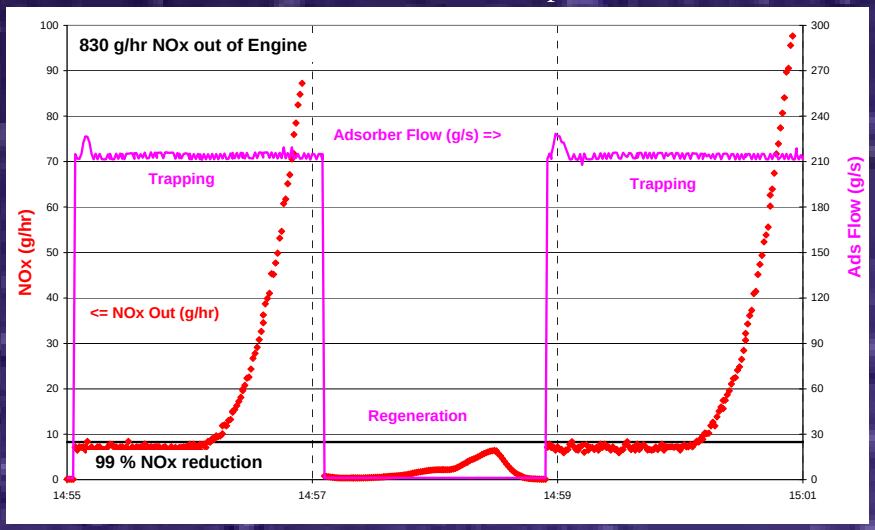
LNT Regeneration Test Results

99 % NOx Reduction at 450°C LNT Temperature

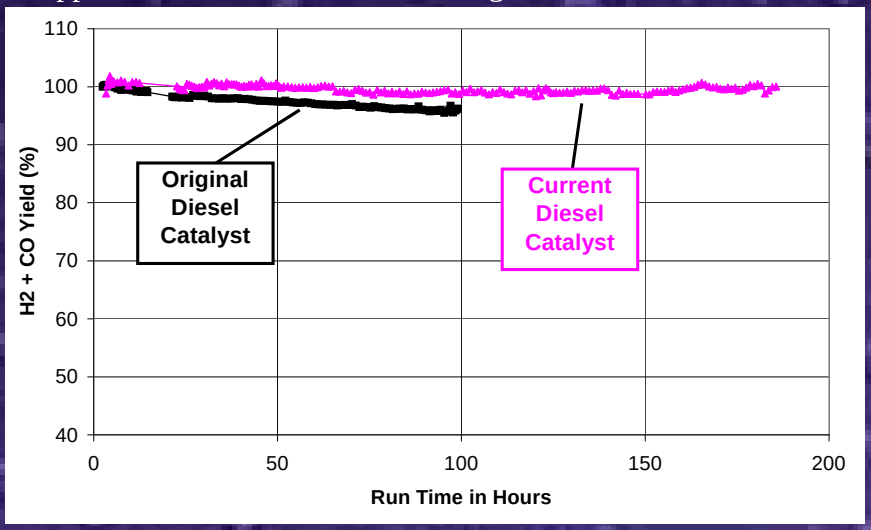


Challenges for CPOx Reformer

- **Durability**
  - Operation on engine exhaust
  - Thermal cycling for operating temperatures >800°C
  - Long-term durability
- **Total System Cost**
  - CPOx catalyst cost not expected to be an issue
  - Exhaust system configuration needs better definition to estimate CPOx cost impact (e.g. LNT size and precious metals loading, regeneration time & frequency, integration with engine operation)

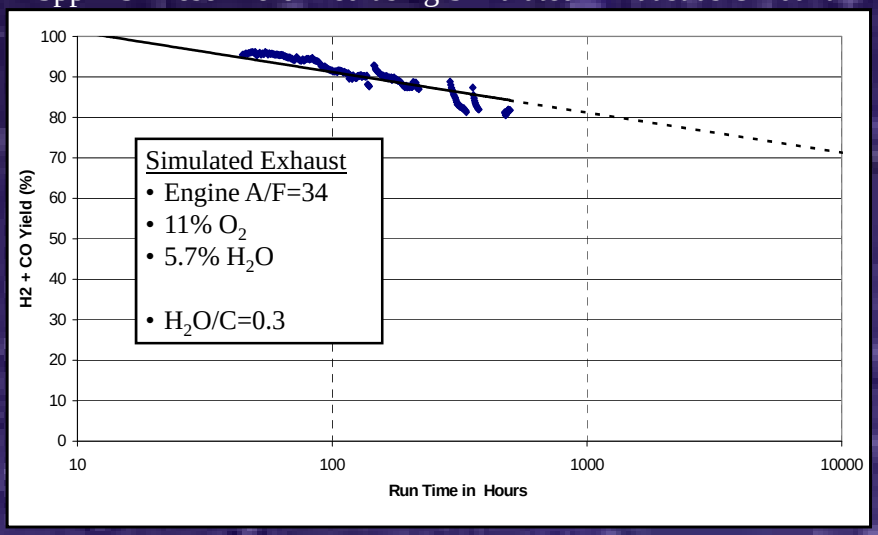
Diesel CPOx Reforming Durability

15 ppm Sulfur Diesel Reformed using Air as Oxidant



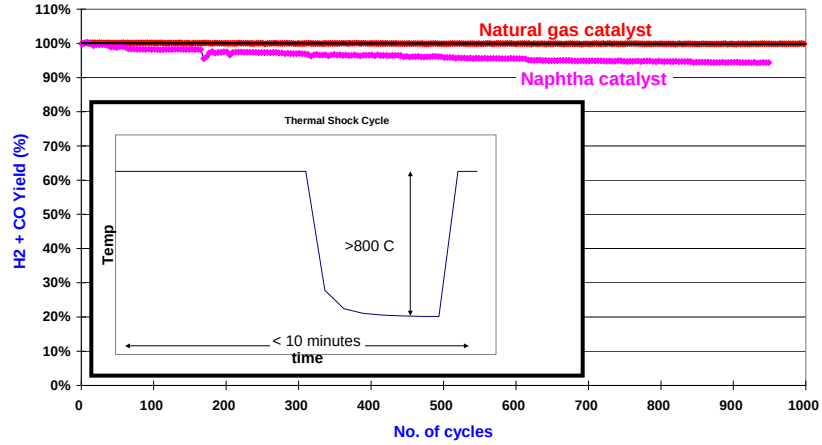
Diesel CPOx Reforming Durability

15ppm S Diesel Reformed using Simulated Exhaust as Oxidant



CPOx Thermal Cycling Data

800°C Thermal Shock Cycling



Benefits of Hydrogen for LNT Regeneration

- **Demonstrated Benefits**
  - Low Temperature Regeneration
  - >90% NOx Conversion from 150°C to 450°C
- **Expected Benefits**
  - Rapid exhaust catalyst light-off & thermal control
    - High temperature of reformer exhaust (~800°C)
    - H_2 combustion on low temp noble metal catalysts
  - Faster or lower temperature desulfation
  - Lower fuel penalty
  - Smaller, more durable LNT system

Present Activity

- **Light Duty Truck Demonstration**
  - Use diesel reformer to regenerate LNT-equipped aftertreatment system
  - Drive cycle testing planned in Q1 2004

Next Steps

- **Aftertreatment System with CPOx Reformer**
  - Demonstrate benefit for desulfation
  - Demonstrate rapid exhaust light-off
  - Cyclic & steady state durability testing
  - Optimize configuration for cost and performance
- **CPOx Reformer**
  - Longer term cyclic & steady state durability testing

Summary and Conclusions

- **Hydrogen-rich gas from a CPOx reformer is highly effective for regenerating NOx adsorbers**
  - >90% NOx conversion demonstrated at 150°C
  - >99% NOx conversion demonstrated at 300 – 450°C
- **A CPOx reformer has been developed to:**
  - Operate on ULSD fuel and engine exhaust
  - Integrate into a diesel powered vehicle equipped with a LNT aftertreatment system
- **Future development is focused on:**
  - Demonstrating durability
  - Optimizing system with respect to performance and cost

Thank you

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