University of Houston and City of Houston: Collaboration to Determine Best Solutions for Diesel Emission Reductions

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NOx Reduction Challenge for Houston

- Diesel Power
  - Large contributor to NOx
  - Increased Durability
  - Improved Fuel Efficiency
  - Lean Combustion
    - Exhaust NO_x –> N_2 difficult
- Challenge: Reduce diesel NO_x emissions* with cost-effective & reliable technology

*EPA Target: 90% reduction in NOx emissions by 2007

Houston/Galveston Area NOx Emission Sources**

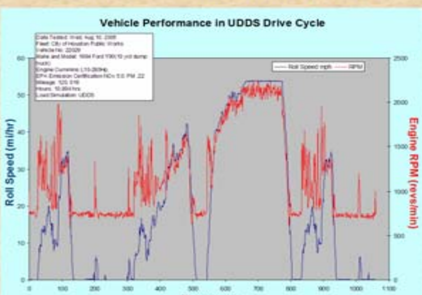
Diesel: 51% of all mobile sources

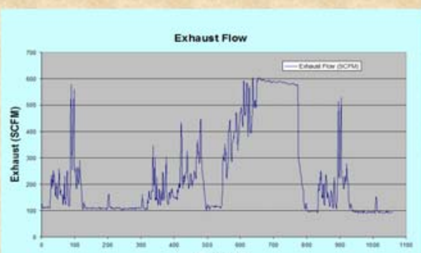
Total NOx: 417,000 tons/year*

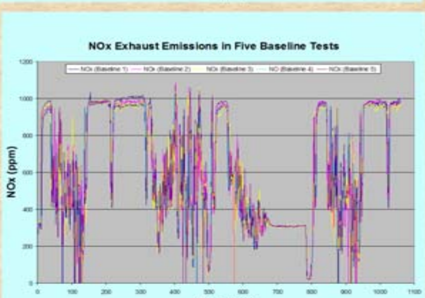
**1996 data: Source: TCEQ Website

UH Diesel Testing Facility

- Major equipment
  - 500 HP AC Chassis Dynamometer (Burke Porter)
  - MEXA 7100 Exhaust Gas Analytical System (HORIBA)
  - MDLT 1300T Micro Dilution Tunnel (HORIBA)
  - Annubar 485 Exhaust flow meter (Rosemount)
  - MKS FTIR spectrometer
- Key Measurements
  - Exhaust: (g/mi, %): NOx, CO, THC, CO_2, O_2, PM (Future: NH_3, NO_2, N_2O)
  - Fuel consumption (gal/mi)
  - Engine: RPM, Boost Pressure, Back Pressure
  - Exhaust Temperature
  - Ambient: Relative Humidity, Temp., Pressure







UH Program Overview

Objective:

- Research, develop, and test diesel emission reduction systems for NOx, particulate and VOCs

Approach:

- Apply advanced catalysis and reaction engineering tools spanning fundamental experiments, bench-scale performance studies, first-principles modeling & simulation, and state-of-the-art testing

Principal Collaborators

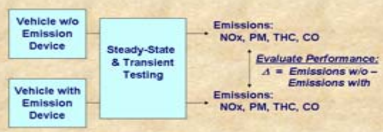
University of Houston -- Chemical Engineering
Michael P. Harold, Charles W. Rooks, Vemuri Balakotaiah, Rachel Muncrief, Miguel Cruz

Mechanical Engineering
Matthew Franchek, Karolis Grigoraidis

City of Houston
Public Works and Engineering
Carl Bowker

Mayor's Office
Vic Ayres

Diesel Emission Testing: Methodology



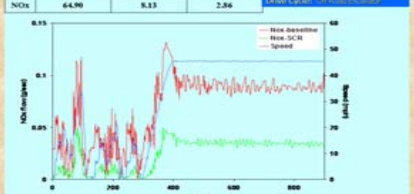
Anhydrous Ammonia SCR Retrofit: Gradall (Telescoping Boom Excavator)

Anhydrous Ammonia SCR: Extengine Inc.

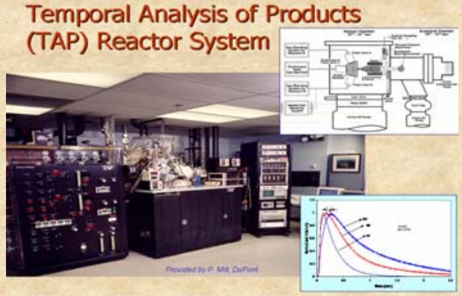
Performance Results: SCR (Anhydrous NH_3)

SCR Technology supplied by Extengine Inc.

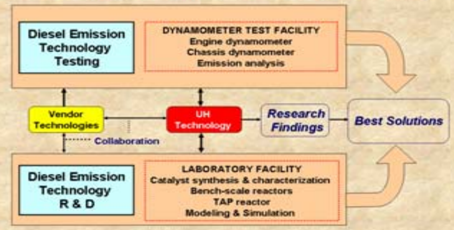
	% Reduction	g/mile (Baseline)	g/mile (SCR)
NOx	64.90	8.13	2.86



Temporal Analysis of Products (TAP) Reactor System



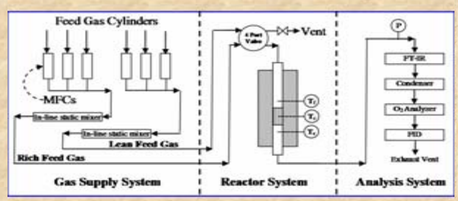
UH Program: Spans R&D and Testing



Selected UH R&D Projects

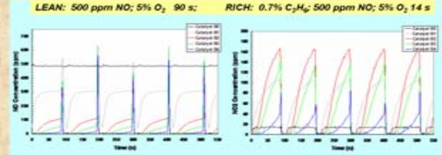
- *Reactor studies – NOx trap technology*
  - Bench-scale monolith reactor performance
  - Modeling & simulations
- *Mechanistic studies – NOx trap technology*
  - Temporal Analysis of Products (TAP)
  - Storage and regeneration – microreactor & TGA
  - Microkinetic model development
- *Integrated NOx reduction & soot oxidation*
  - Bench-scale studies
- *Monolith reactor modeling*
  - Simulations of light-off, hot spot propagation
  - Evaluation of monolith channel shape

Bench-Scale Monolith Reactor System



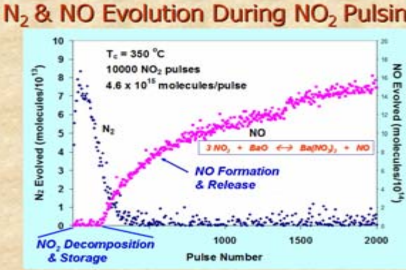
NOx Storage Reduced During NSR

LEAN: 500 ppm NO; 5% O_2 90 s; RICH: 0.7% C_3H_6; 500 ppm NO; 5% O_2 14 s



NO_2 + $BaCO_3$ <–> $BaONO_2$ + CO_2 (Storage & Reduction)
NO_2 + BaO <–> $BaONO_2$ (Storage)

N_2 & NO Evolution During NO_2 Pulsing



Acknowledgements: Program Funding

- *Diesel emission testing facility*
  - City of Houston ($3.8 m over 5 yrs.)
  - University of Houston
    - Infrastructure/Building ($450K)
    - In-kind support ($380K over 5 yrs.)
  - Third-party clients: Industry, agencies
- *Research & development projects*
  - State of Texas
    - Grants: Advanced Technology Program
  - Industry: Engelhard, Ford, Cummins
  - Federal sources: EPA, DOE (pending)

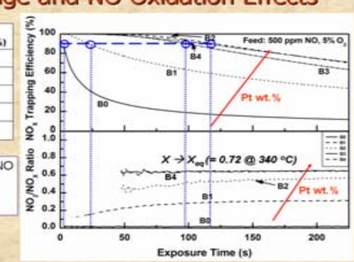
NOx Storage & Reduction (NSR)

- NOx Storage
  - Trap NO/NO_2 as surface species, nitrite, nitrate
  - Need high trapping efficiency (> 95%)
  - Catalytic adsorbent: Pt/Rh/Alkali Earth Oxide/Support
- NOx Reduction
  - Reduce NOx on Pt/Rh during rich purge
  - Need high conversion of NOx to N_2 (> 90%)
  - Ensure high conversion of reductant via oxidation

Storage and NO Oxidation Effects

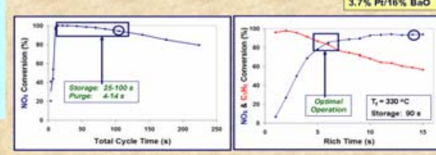
	Pt (wt. %)
B0	0.0
B1	0.32
B2	1.27
B3	2.20
B4	3.71

500 ppm NO
5% O_2
340 °C
60K hr^{-1}



Effect of Total Cycle Time & Purge Time

T_f = 330 °C
$S_{N,pulse}$ = 0.33
$S_{N,avg}$ = 10
Pulse Duty: 14%
3.7% Pt/16% BaO



NO_x Storage Pathways