

Urea SCR and DPF System for Diesel Sport Utility Vehicle Meeting Tier II Bin 5

DOE and Ford Motor Company Advanced CIDI
Emission Control System Development Program
(DE-FC26-01NT41103)

**Diesel Engine Emission Reduction
Conference
August 2003**



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Presentation Overview

- DOE Program Overview
- Vehicle Results
- SCR Functional Improvements
- Exhaust Gas Sensor Development
- CDPF Strategy Development
- Urea Program
- Future Work

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Program Overview



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DOE Ultra-Clean Fuels Program

Outline of Ford's program to achieve Tier II emission standards for 2007 using low sulfur diesel fuel as an enabler for a high efficiency aftertreatment system.

Primary Contractor



Subcontractors



Catalyst Suppliers



Johnson Matthey



Phase I - Initial build/test phase (12 mos.)

Establish baseline emission control system

Deliver engine dynamometer NOx and PM test results

Demonstrate and deliver prototype vehicle NOx and PM test results

Deliver urea delivery (infrastructure) prototype

Phase II - System/component optimization phase (18 mos.)

Define final system hardware components

Deliver NOx and PM performance data

Demonstrate emission control system (includes NOx and PM data)

Phase III - Durability/Demonstration phase (18 mos.)

Definition of durability test procedure

Final NOx and PM emission levels

Define fuel sulfur limits for emission control system

Final report for the completed program



FEV Program

Concept Design

- CFD Modeling including urea injection

Engine Dynamometer

- Baseline and rapid warm-up testing
- Urea SCR/CDPF optimization
- Transient FTP/US06 testing

Emission Control System Durability

- 5000 hours (~120k miles)



ExxonMobil Program

Intellectual property discussion delayed program for 9 months; program was then accelerated to contain original objectives.

SCR urea catalyst development

- Durable, high NO_x conversion from 150° to 600°C with low N₂O make.

Urea program

- Co-fueling concept
- Low temperature urea solution
- Infrastructure studies

Fuel development

- Make and use fuel, which will be typical of 2007 production with 15 ppm sulfur cap.

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Vehicle Results

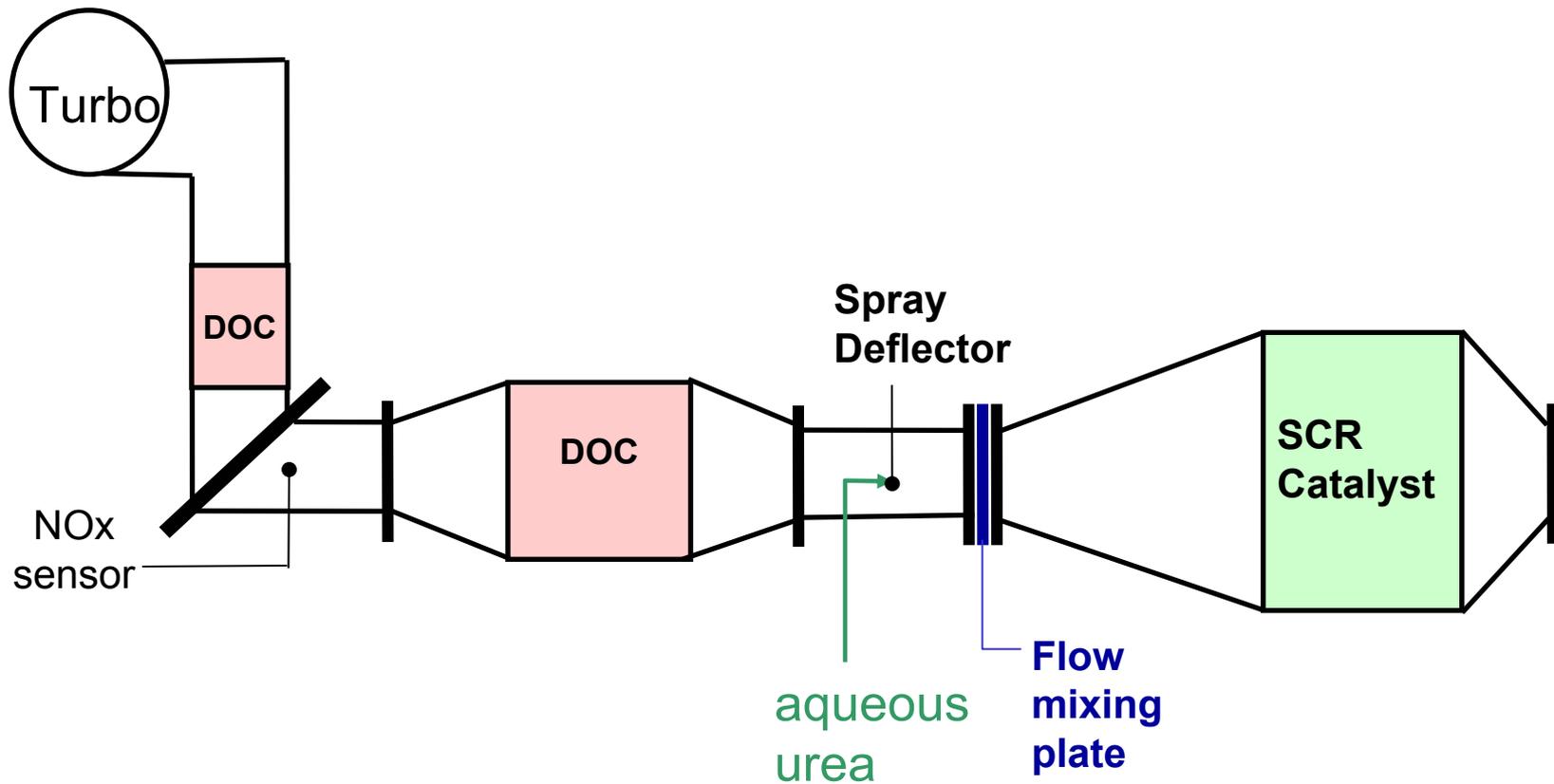


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LDT Exhaust System



Diesel Fuel Properties

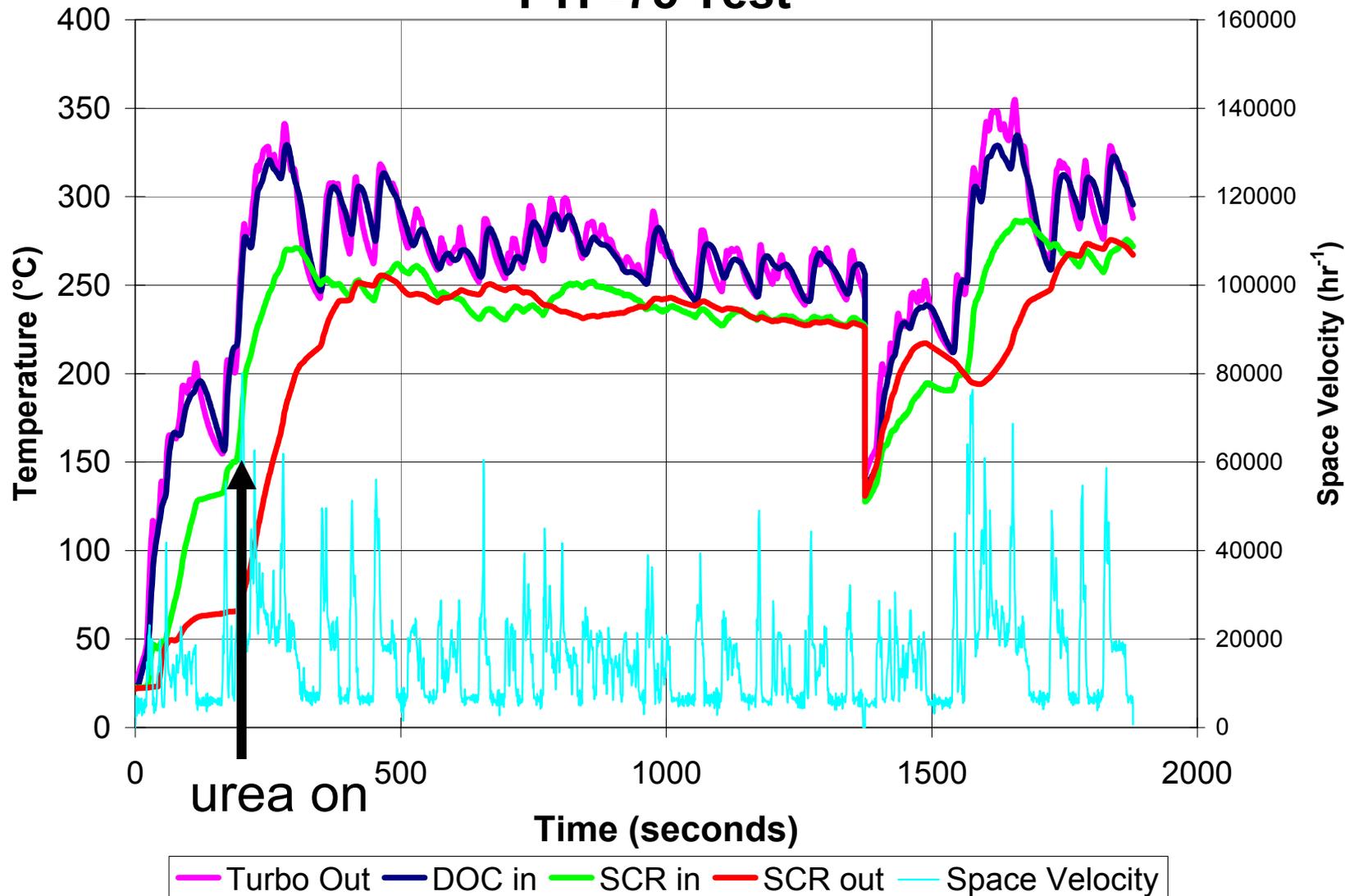
- ExxonMobil blended 14,000 gallon batch to represent typical 2007 ULSD.
 - Uniform fuel over program duration.
 - Stored and dispatched in drums.

Fuel Property	Estimated '06 Diesel Properties	Proposed DOE Program Min/Max	Program Fuel Delivered	Proposed 2007 Cert. Fuel
Sulfur, ppm	15*	10 / 15	12.5	7 / 15
Density, kg/m ³	850	820 / 850	841.1	839 / 865
Aromatics, vol. %	32	25 / 32	29.5	27 min
Polyaromatics, wt. %	10	6 / 11	11.0	no spec
Cetane number	46	44 / 48	44.9	40 / 50
T50, C	267	250 / 280	249	243 / 282
T90, C	306	300 / 320	307	293 / 332

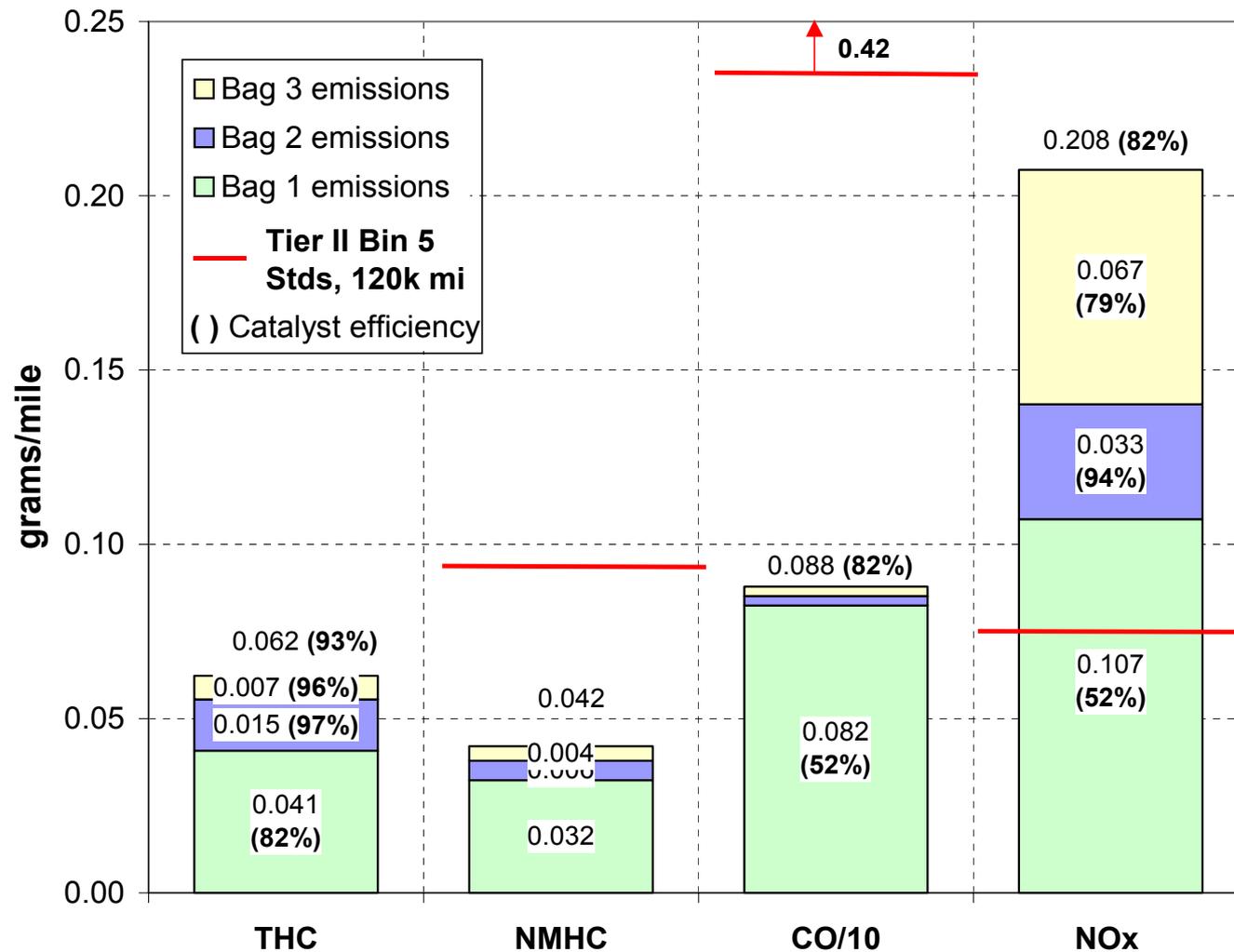
* As delivered to the vehicle

LDT Temperatures and Space Velocity

FTP-75 Test



Weighted FTP-75 Emissions



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SCR Functional Improvements

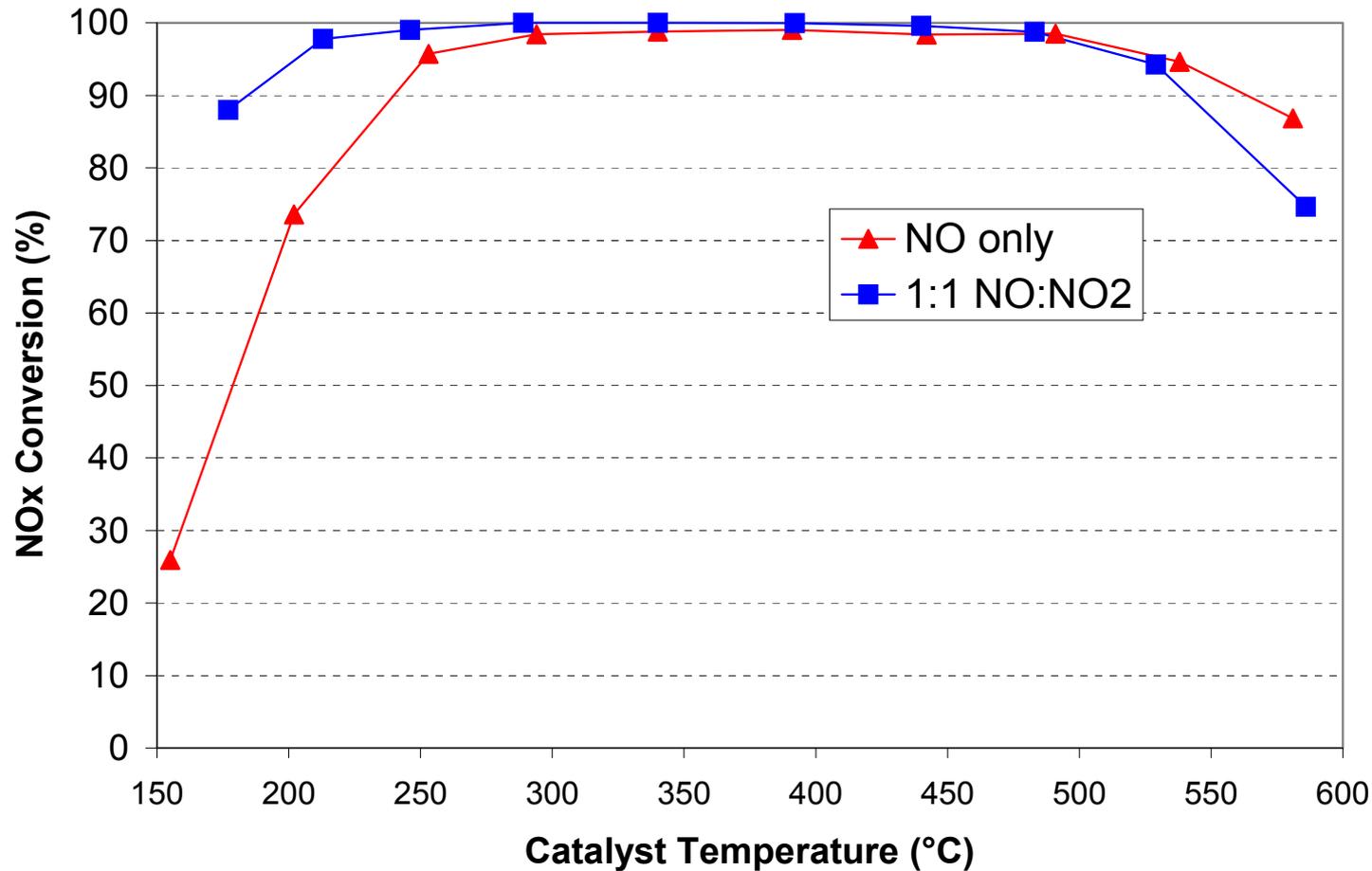


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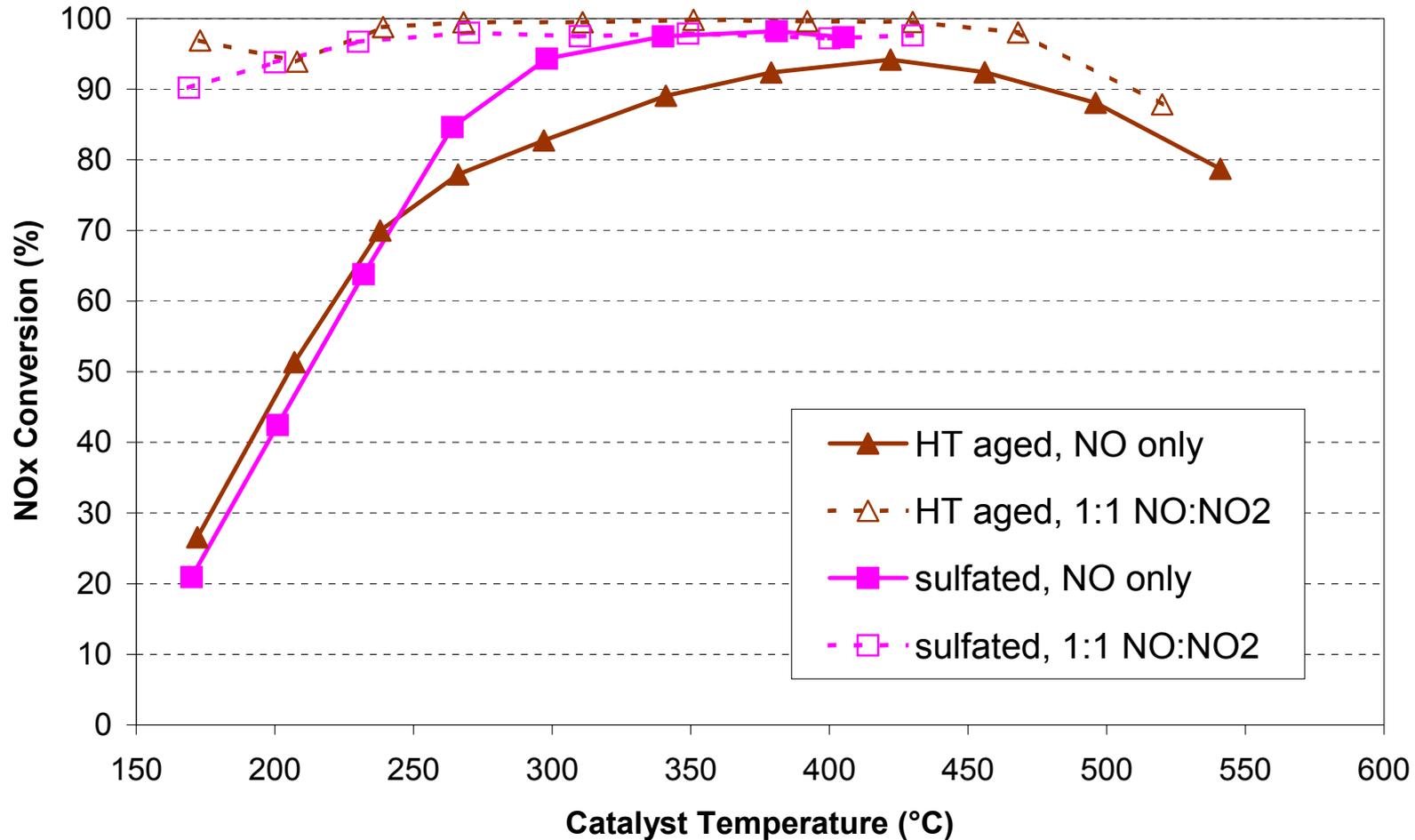
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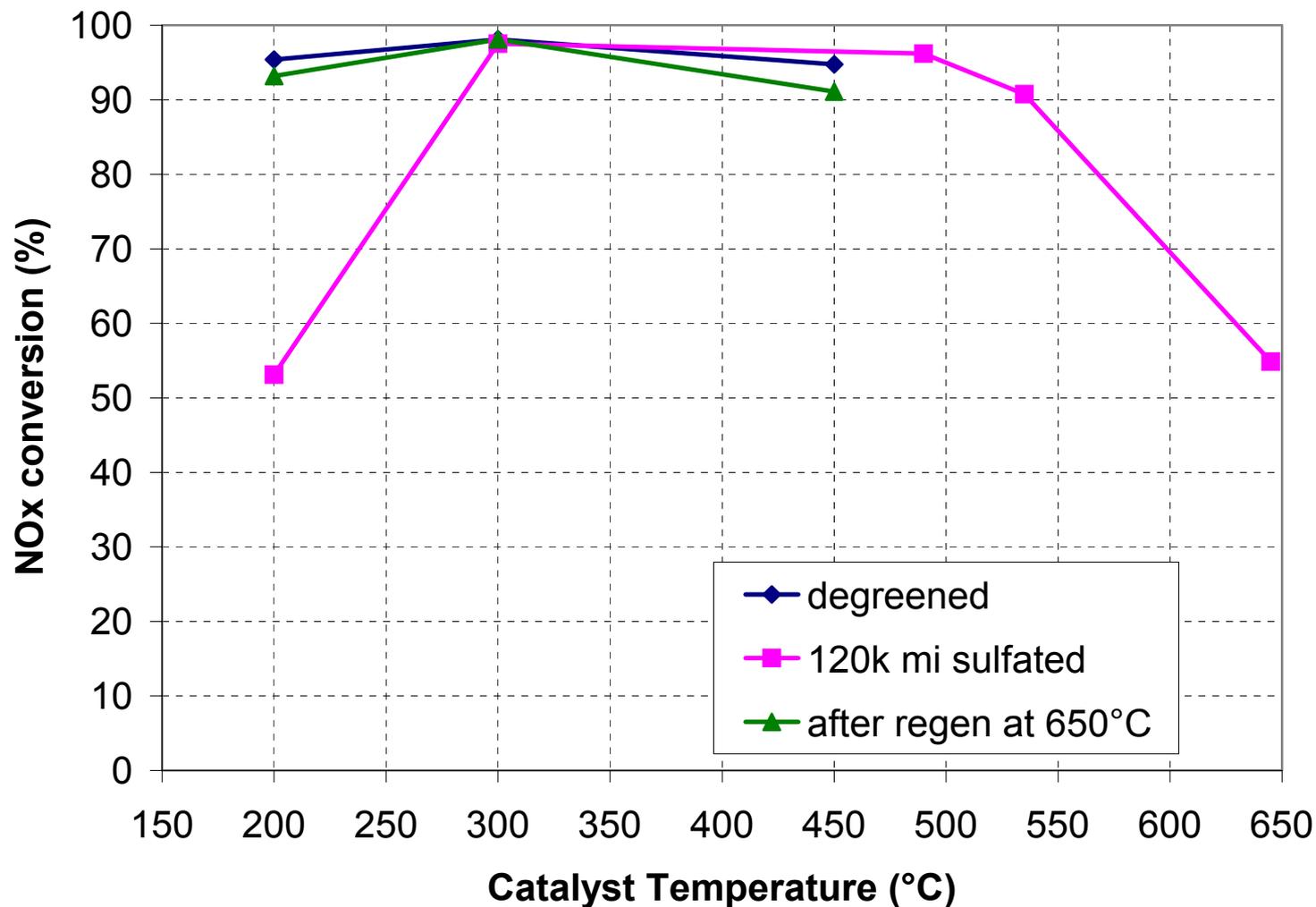
Importance of NO₂/NO_x Ratio on Degreened Catalyst Performance



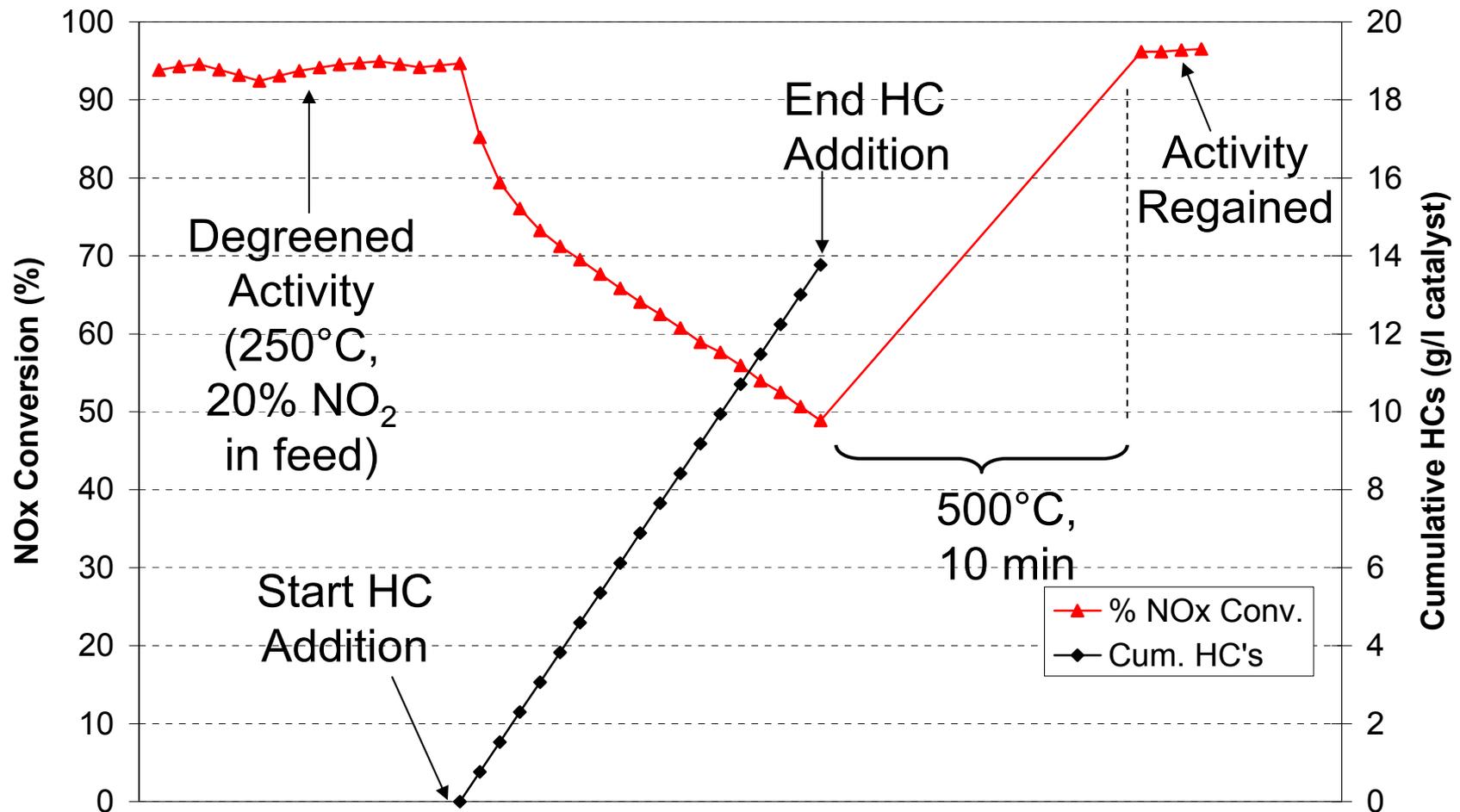
Importance of NO₂/NO_x Ratio on Aged Catalyst Performance



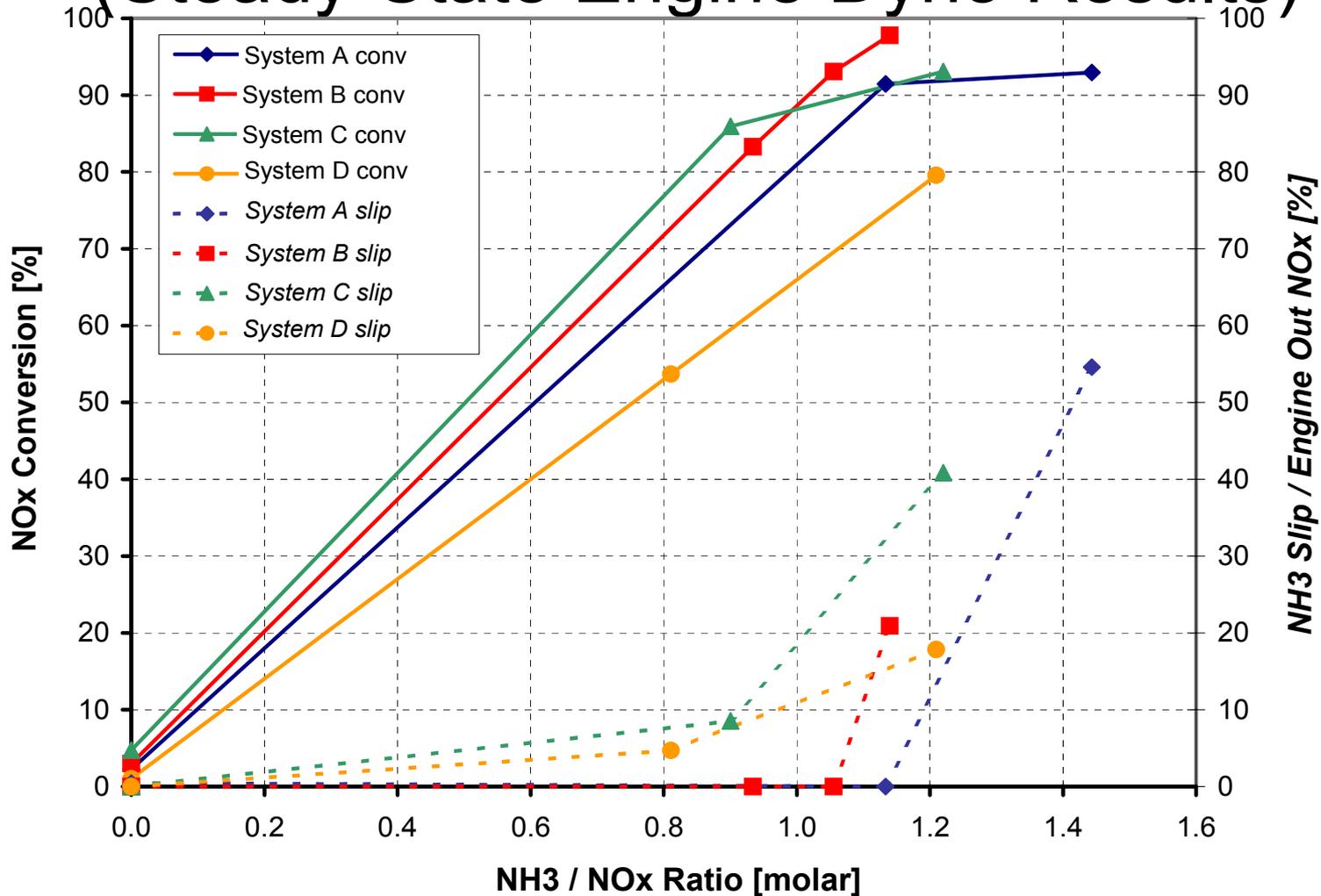
Impact of Sulfur and Regeneration on SCR Performance



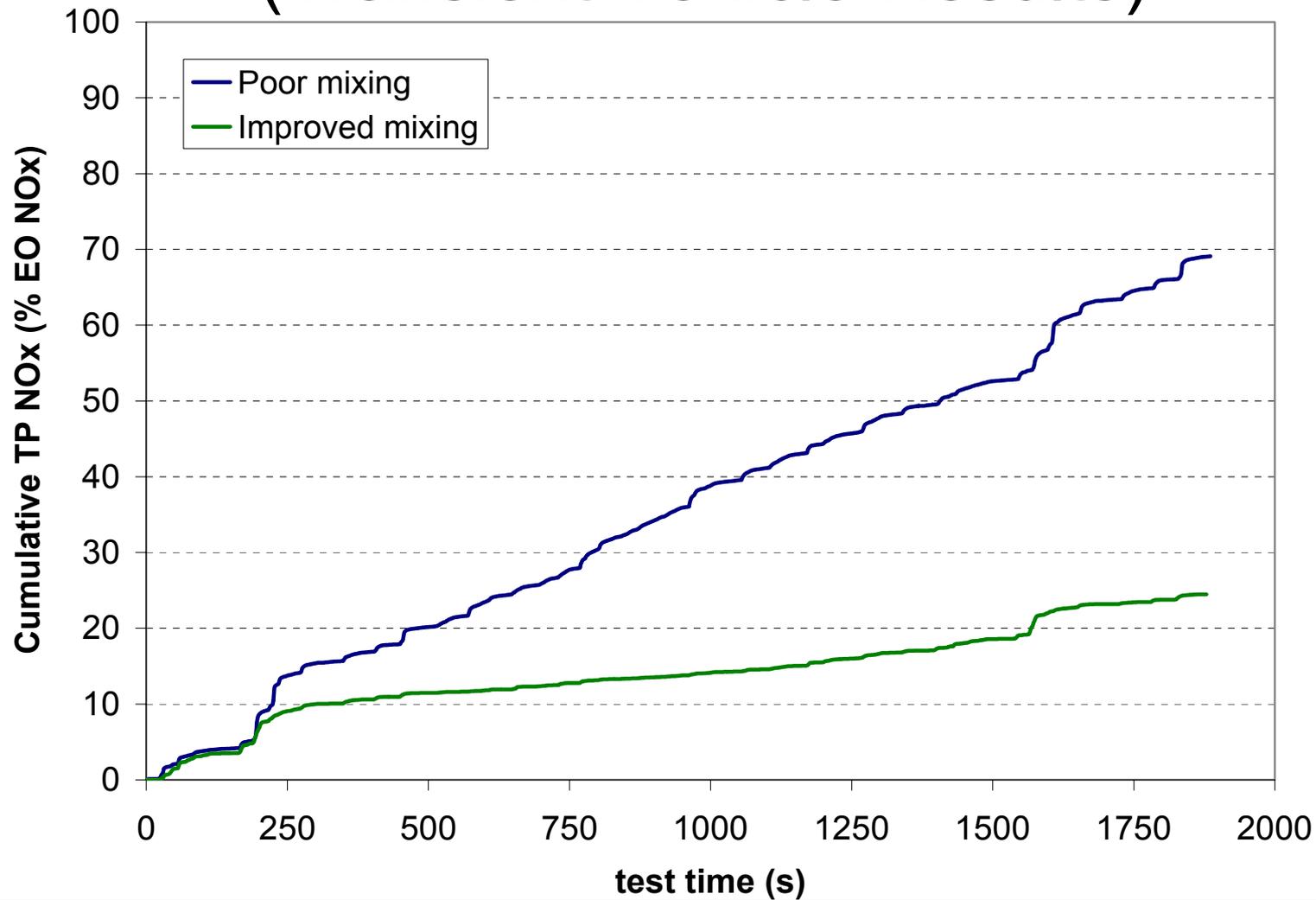
Impact of HC on SCR performance



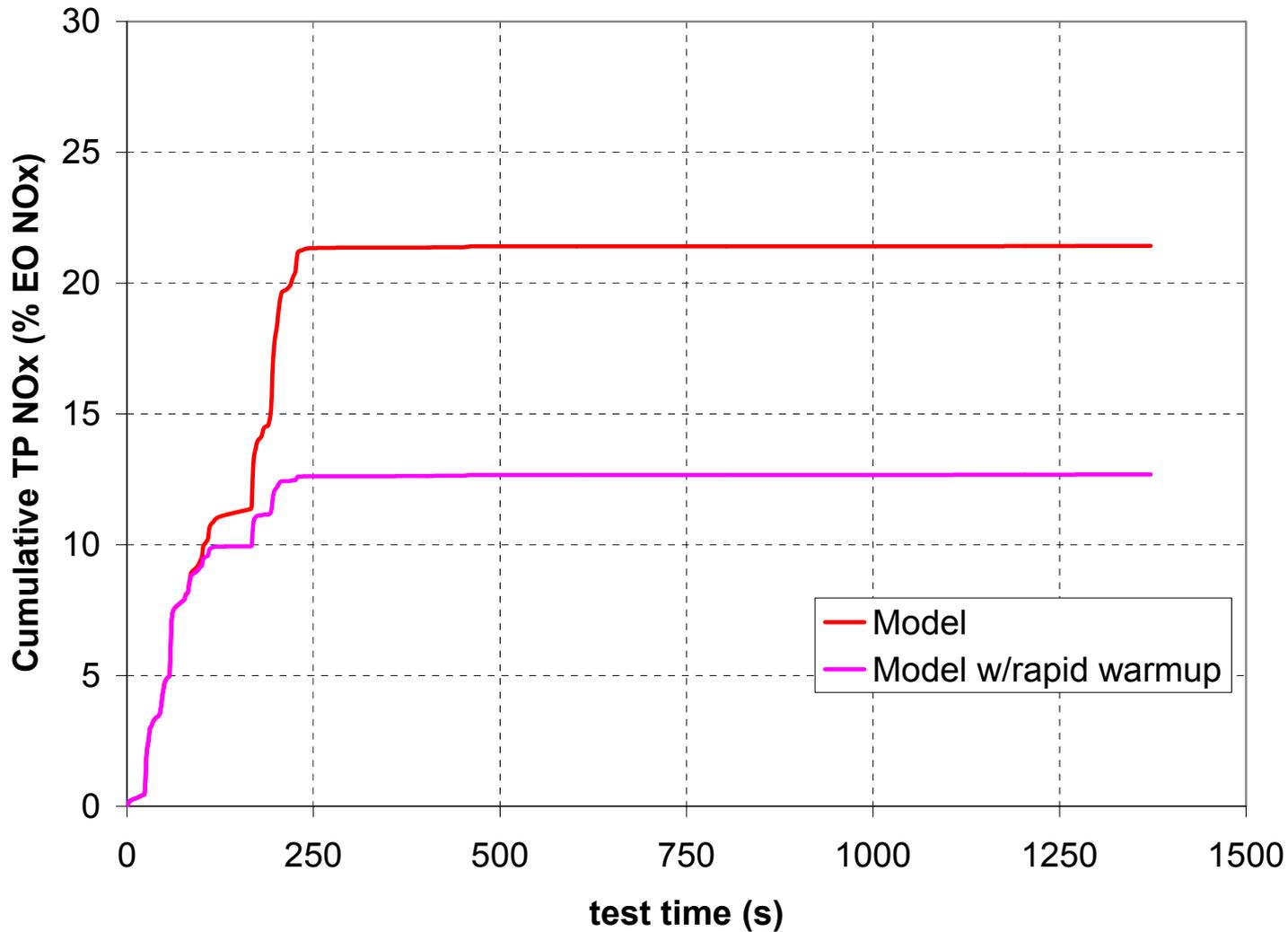
Importance of Urea Mixing (Steady-State Engine Dyno Results)



Importance of Urea Mixing (Transient Vehicle Results)



Importance of Rapid Warmup



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Exhaust Gas Sensor Development



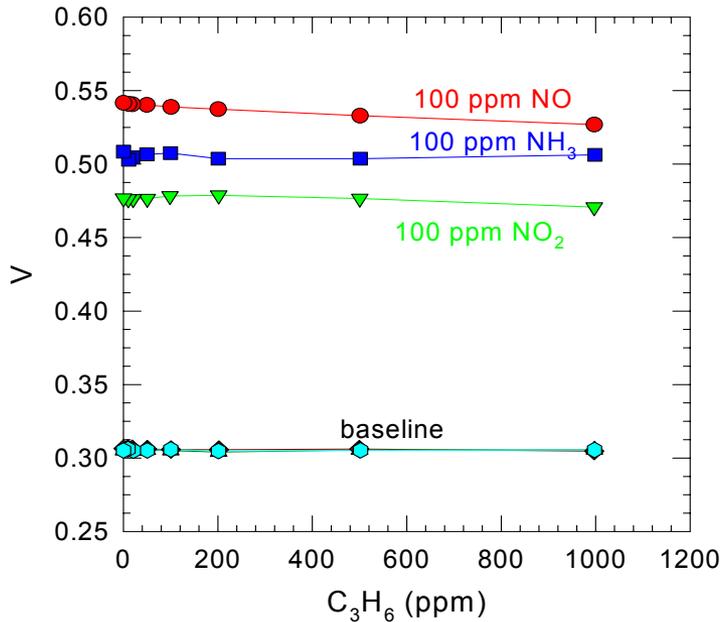
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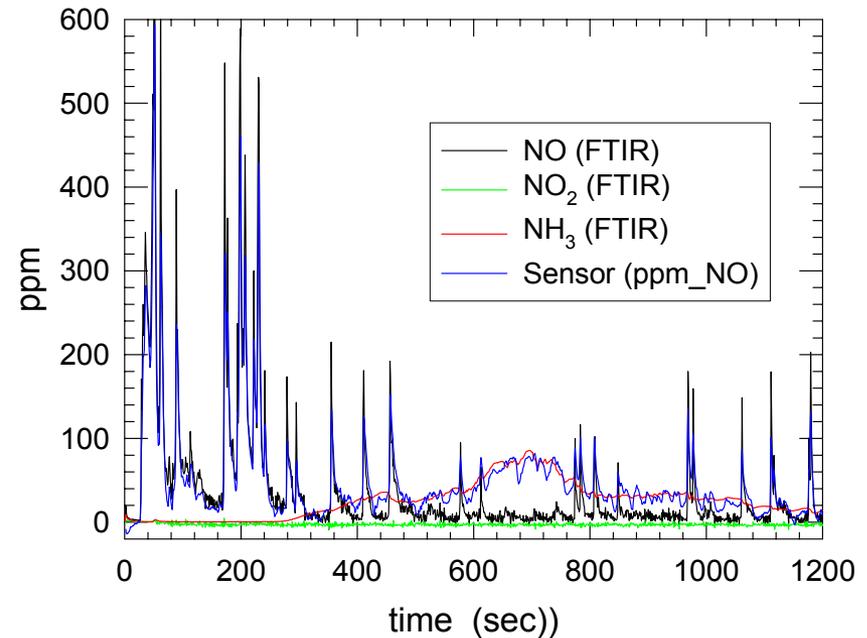


NOx sensor (NGK):

• Laboratory data:



• Vehicle data:



$$S(\text{NO}) > S(\text{NH}_3) > S(\text{NO}_2)$$

sensitivity

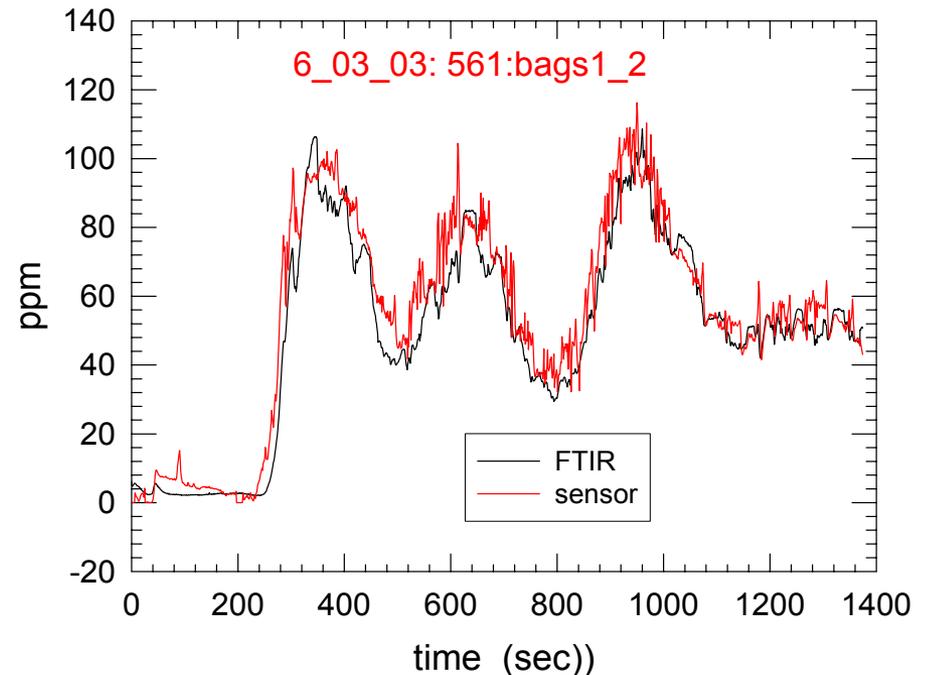
- For this test, the sensor was located downstream of SCR catalyst. As expected, the sensor responded to both NO and NH₃. Also, the tailpipe NOx was all NO.

NH₃ Sensor:

- Prototype sensors are under development by automotive suppliers.
- Vehicle data from one such sensor shown below (composition proprietary) :
 - Selective NH₃ response. Some sensitivity to H₂O.

Vehicle test:

Comparison of NH₃ measured at the tailpipe using FTIR with that predicted by the sensor (after compensating for water)



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CDPF Strategy Development

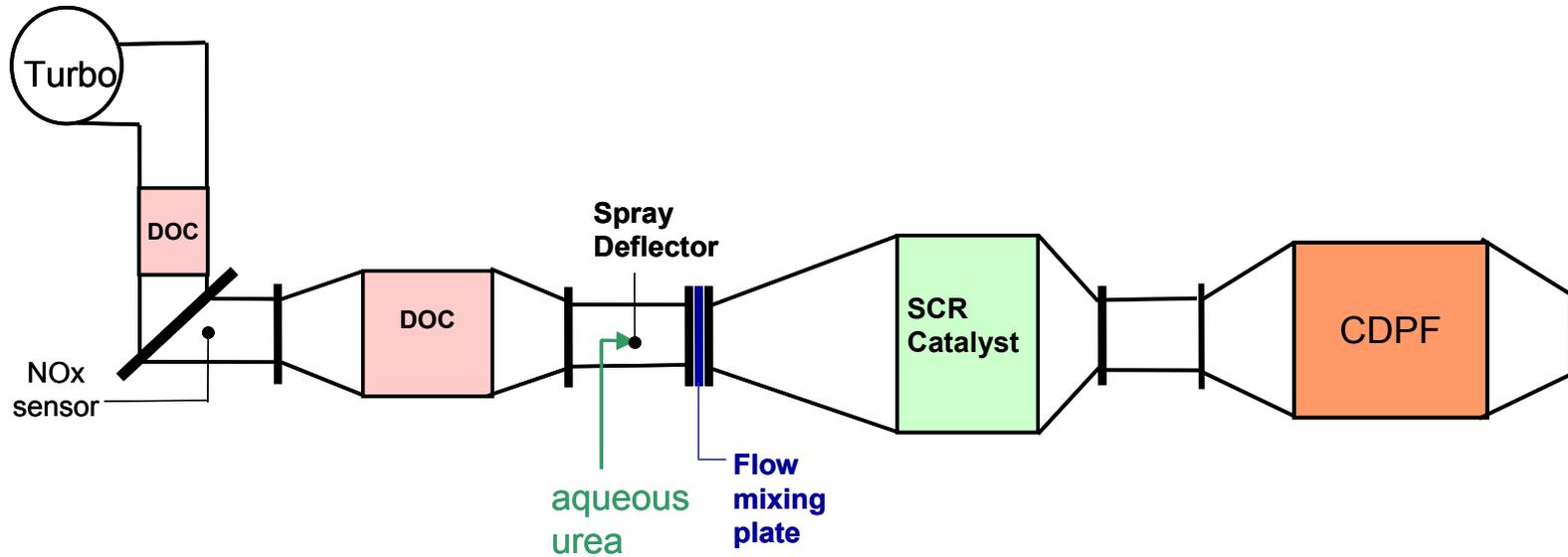


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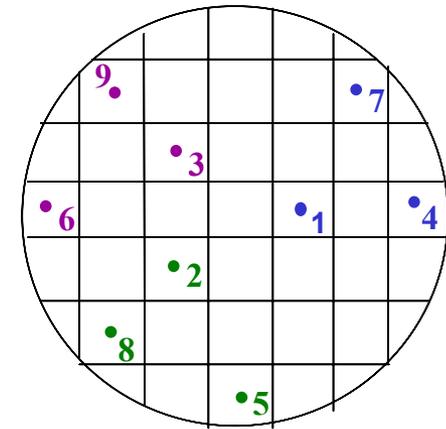
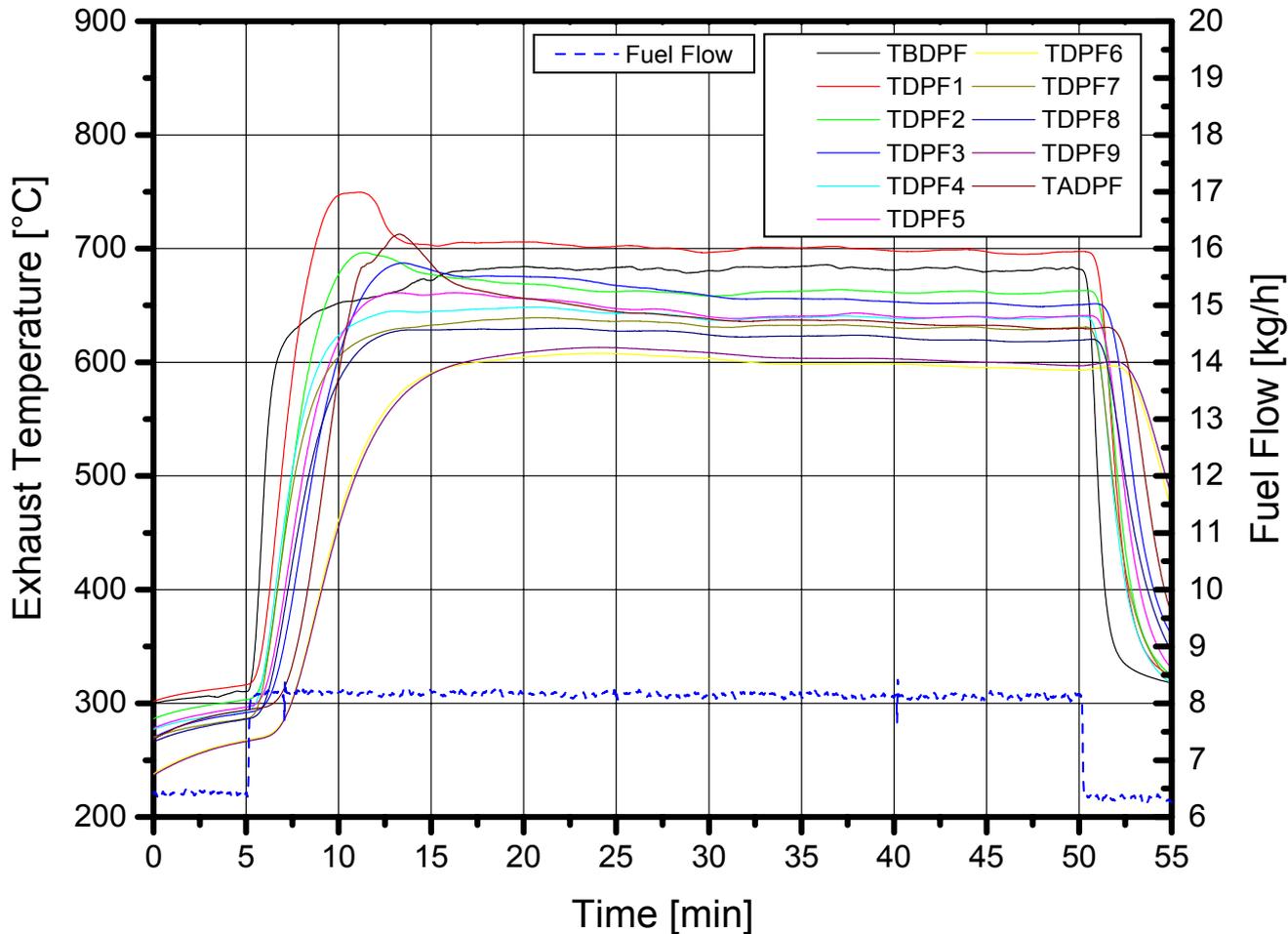
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Future LDT Exhaust System



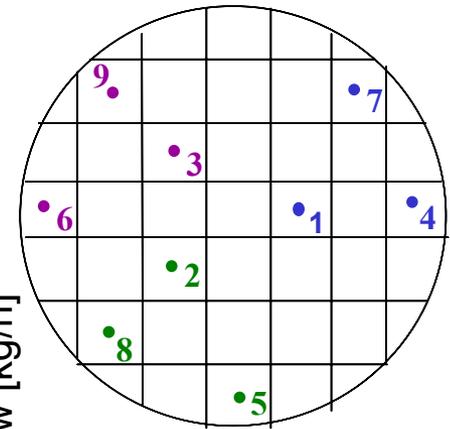
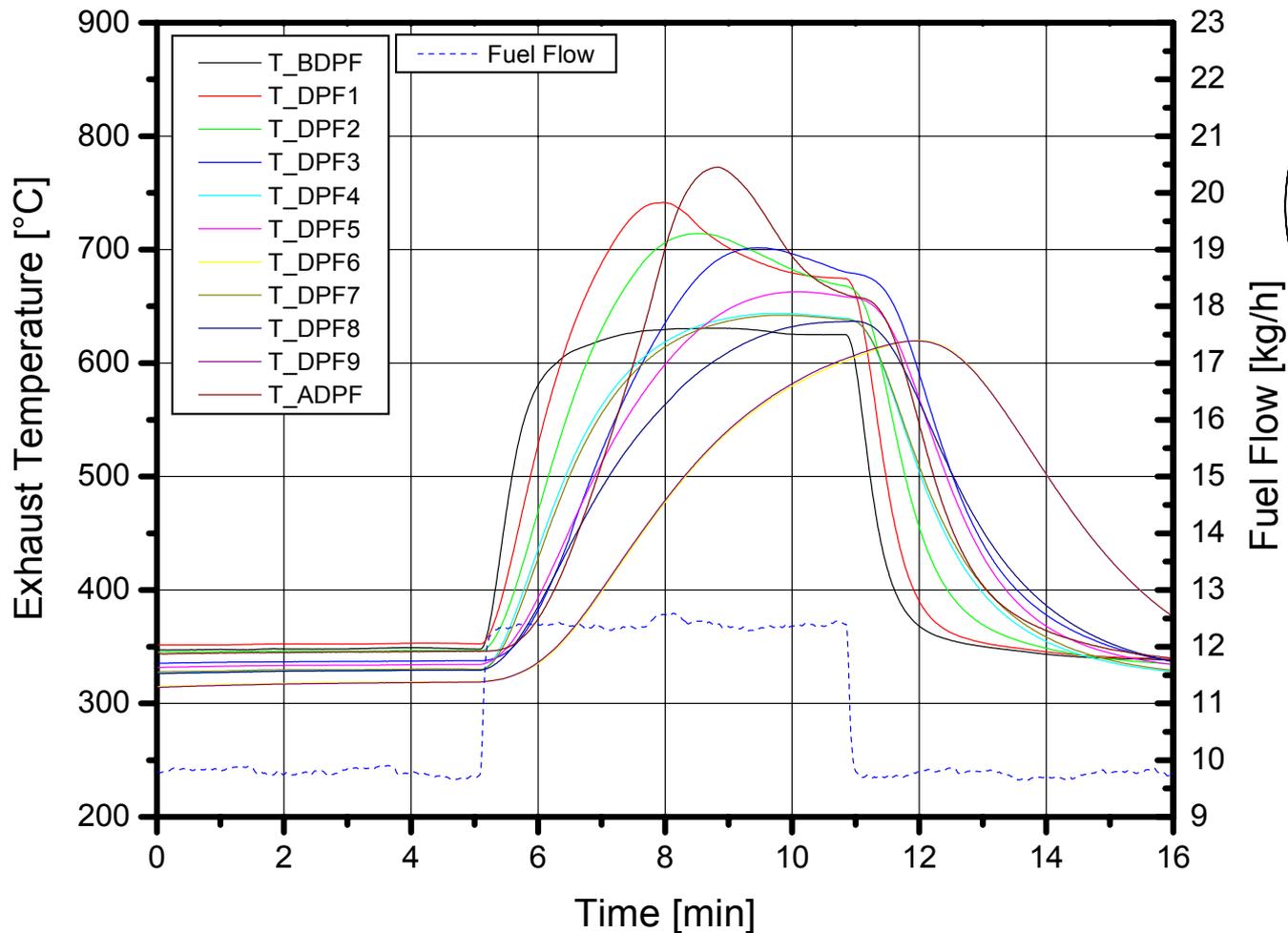
Temperatures during DPF Regeneration



9" dia x 10" L
(229 x 254 mm)

T#	L from rear of filter (mm)	grid type
1	175	complete
2	125	complete
3	50	complete
4	175	cent. side
5	125	cent. side
6	50	cent. side
7	175	corner
8	125	corner
9	50	corner

Temperatures during DPF Regeneration



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(229 x 254 mm)

T#	L from rear of filter (mm)	grid type
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Urea Program



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Urea Program

Prototype Urea Co-fueling System Status

- Co-axial nozzle design chosen and improved for durability and reliability.
- Urea pumping unit designed and feasible for modern dispenser.
- Prototype system being built to evaluate co-fueling, including low temp.
- Vehicle modified with compatible fill-neck and urea storage for demo.



Urea Program

Low Temperature Urea Solution

- Use of aqueous urea can cause difficulty in cold climates.
- Urea at 32.5 wt% has the lowest freeze point at 12°F(-11°C) of any blend in water.
- Potential freeze point depressants investigated, but found to cause negative catalyst impact at Ford.

Conclusion:

Heated systems will be needed for colder climates.

Urea Program

Study of Urea Supply Scenario

- Meeting with key urea suppliers to understand supply chain from production to service station.
- Using A. D. Little Study as baseline.
- Determining optimum supply case.
 - forecast urea volumes
 - estimate urea cost per gallon

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Future Work

Future Work

- Rapid warm-up strategy
- Choose final catalyst formulations/configuration
- Aging cycle development – 5000 hrs
- Sensor development
- Continue urea infrastructure investigation

Acknowledgements

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