Cleaner Vehicles, Cleaner Fuel, & Cleaner Air

Overview of the 2007 Heavy-Duty Engine & Low Sulfur Diesel Fuel Program

U.S. EPA

Office of Transportation and Air Quality

Presentation Overview

- EPA Progress review for 2007
  - Ongoing review of technology development
- Progress on HD engine technologies
  - NOx Adsorber Technology Progress
  - PM Filter Technology Progress
  - Conclusions for 2007 and beyond

Engine Progress - Company Visits

- EPA visited with more than 20 companies
  - In North America, Europe and Japan
  - Engine and vehicle manufacturers
  - Emission control technology developers
  - Every major HD Diesel OEM
- High level reviews of technology and business plans

Progress Review Process - Engines

- EPA In-house testing at NVFEL
  - Learn by doing
  - Novel developments that increase body of knowledge
  - Work with manufacturers to learn faster
- Work with other public programs (DOE)
  - DOE DECSE/APBF-DEC
  - Diesel Engine Oil Advisory Panel (DEOAP)
  - Opportunities for consensus building, common learning

Progress Review Scope

- Reviews "technology path" from HD 2007 RIA
- Is progress being made?
- Are resources being allocated?
- Are there new issues unanticipated in the RIA?

Diesel Particulate Filter Progress

- Diesel particulate filters are highly effective
- Challenge has always been regeneration
- Light-duty diesels are showing the way
  - Tough duty cycle (low load = low temperature)
  - Tight constraints on packaging/cost
- PSA/Peugeot system introduced in 2000
  - By end of 2002, over a 250,000 units sold
  - Other manufacturers following because of customer demand

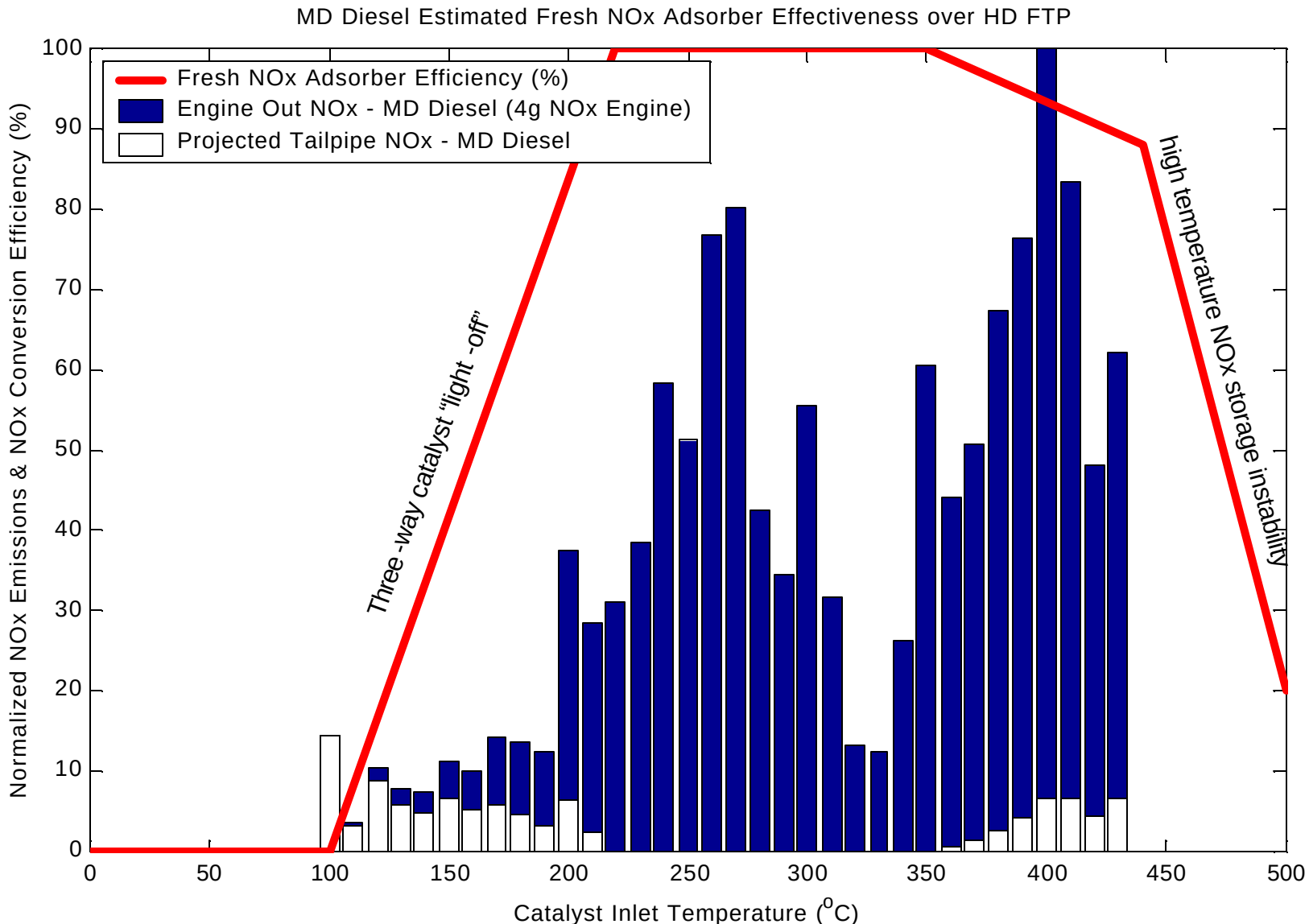
Progress Review—Engines
Conclusions - Diesel Particulate Filters

- Consensus that catalyzed diesel particulate filters will work in 2007
  - Rapid market acceptance for LD diesel vehicles in Europe
  - EPA has certified International's Green Diesel Bus a PM filter equipped diesel bus for areas where 15 ppm fuel is available
  - Widespread retrofits and field evaluations ongoing
- most expect some form of backup active regeneration system will be used to ensure soot regeneration
- substantial progress by industry to
  - improve regeneration characteristics
  - Improve ash handling
  - reduce pressure drop (improve fuel economy)

NOx Adsorber Technical Challenges

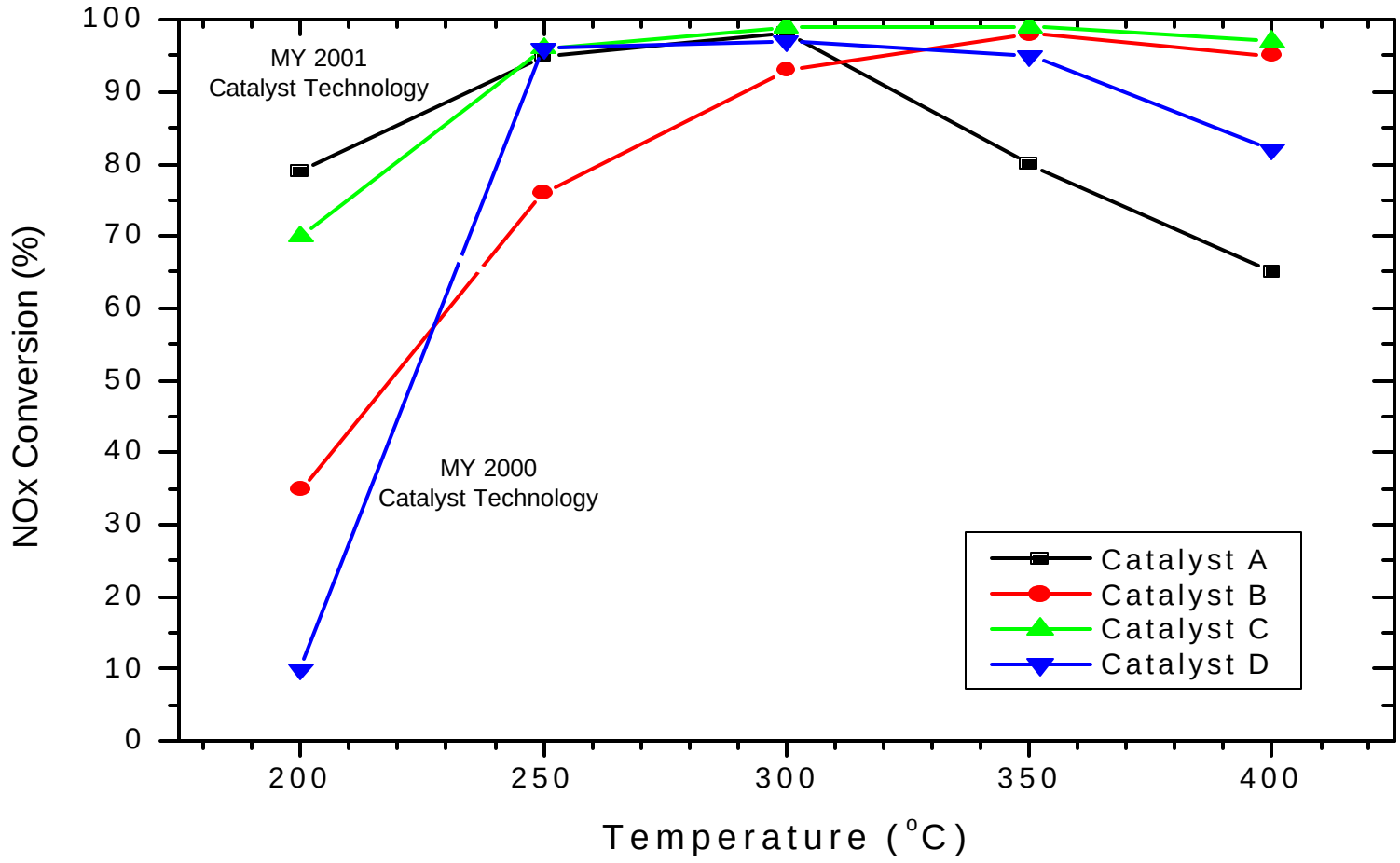
- Temperature window
  - Improved catalyst performance
  - Engine/vehicle systems that manage temperature
- Thermal durability
- Desulfation performance
- System integration

NOx Adsorber Technical Challenges



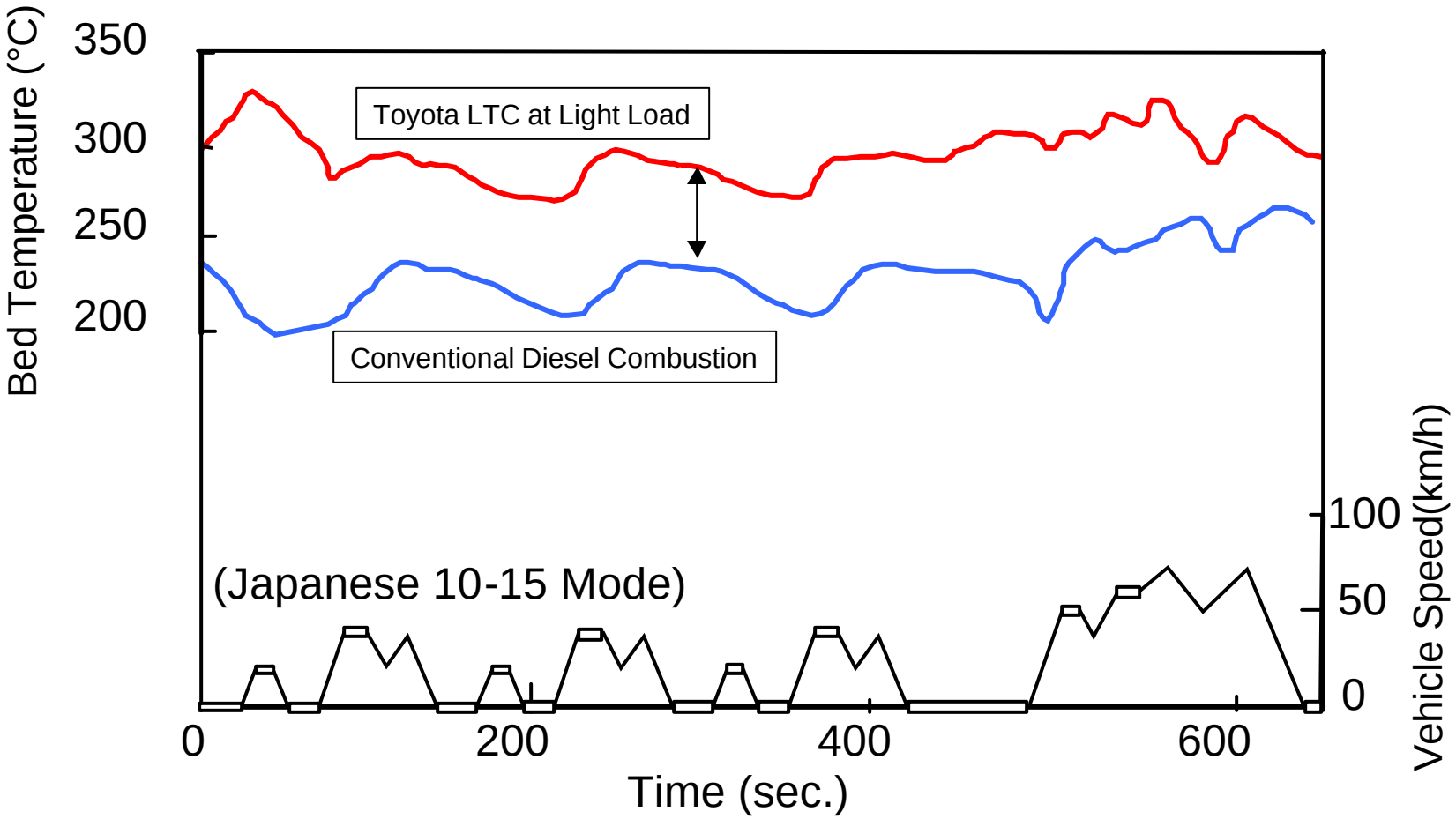
Major Catalyst Manufacturer

Continuous Improvements in Performance of NOx Traps [Temperature Window]



Major LD Diesel Manufacturer

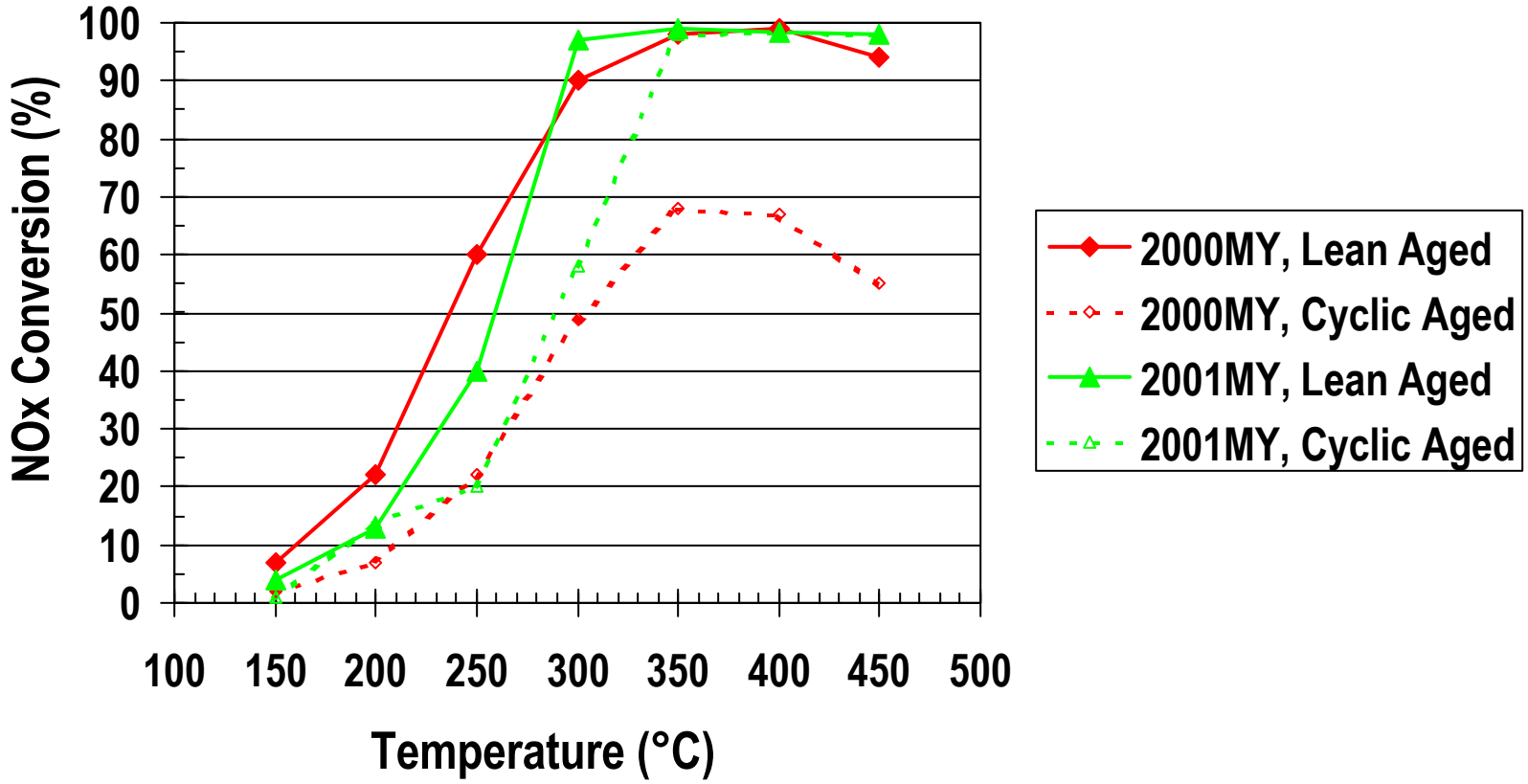
Changes in diesel combustion to improve catalyst function [Temperature Window]



S. Sasaki, T. Ito, S. Iguschi, "Smoke-less Rich Combustion by Low Temperature Oxidation in Diesel Engines," 9th Aachen Colloquium Automobile and Engine Technology 2000.

Major Catalyst Manufacturer

Improved NOx-Trap Durability Under L/R Test Cycle [Thermal Durability]



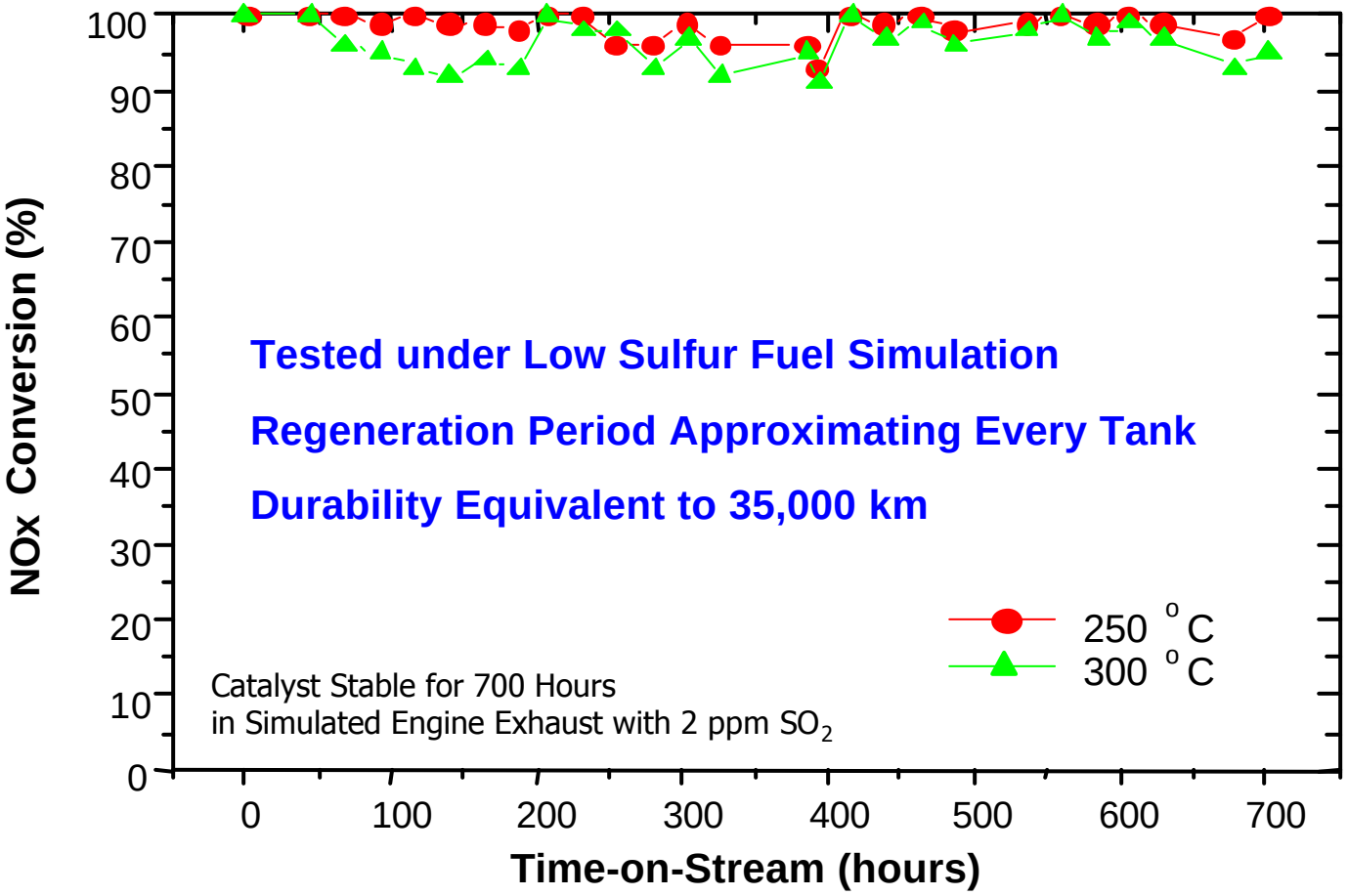
Major Substrate Manufacturer

Improved Catalyst Substrate for NOx Adsorbers [Thermal Durability]

- Potassium storage compounds can offer improved NOx storage at higher temperatures
- While effective new, potassium based NOx adsorbers can lose performance due to potassium migration into the catalyst substrate over time
- Significant fraction of historically observed deterioration can be attributed to this problem
- Corning has developed a new catalyst substrate material Celcor NX™ that addresses this problem improving durability significantly
- This material exhibits no reactivity with potassium at 1000°C (current cordierite technology has high reactivity)
- Initial testing with catalyst manufacturers shows a marked improvement in performance

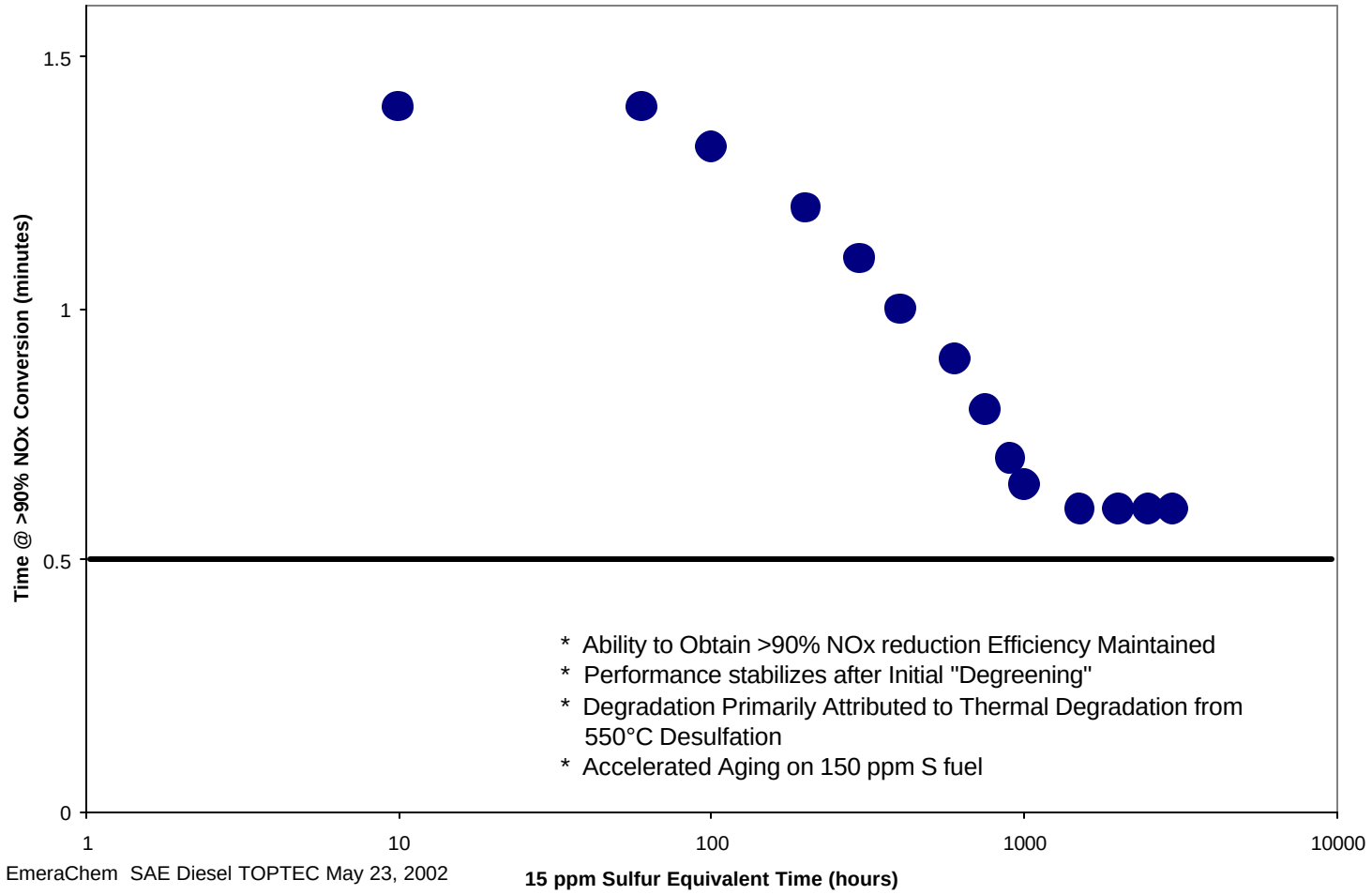
Major Catalyst Manufacturer

Frequent Desulfation to Maintain NOx Performance [Desulfation Performance]



Catalyst Manufacturer

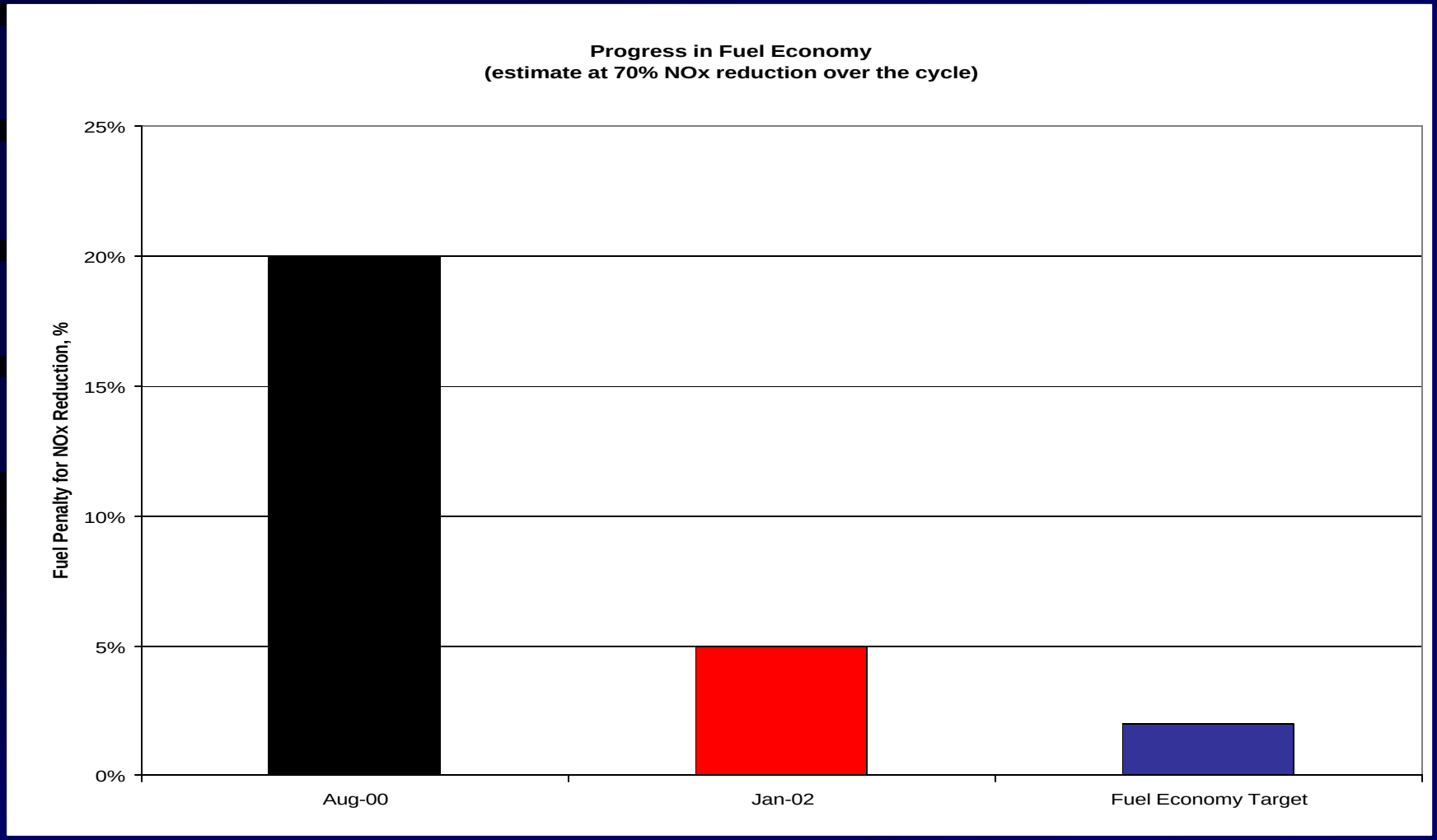
>90% Performance Maintained with Accelerated Sulfur Aging [Desulfation Performance]



Major HD Engine Manufacturer

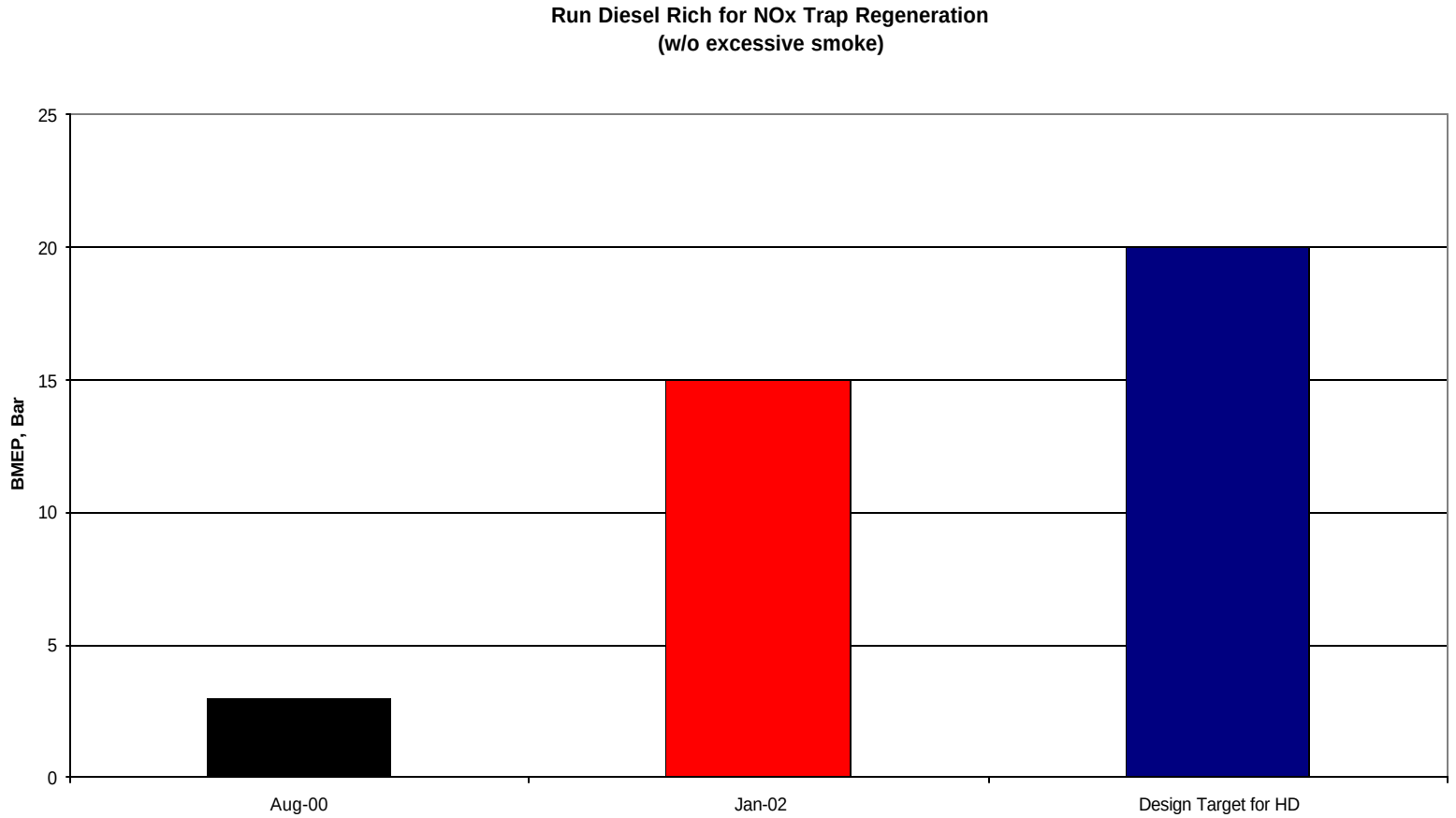
Better Engine Management for NOx Regeneration

[System Integration]



Major HD Engine Manufacturer

NOx Regeneration Accomplished Across Wide Load Range [System Integration]



Improvements in Diesel Combustion
[System Integration]

- New air-handling systems (turbomachinery, EGR) along with improvement fuel systems being implemented for 2004 will provide a good starting point for 2007
  - Allow for better A/F control for regeneration
  - Potential to lower engine out emissions
- New combustion approaches (Toyota LTC, Nissan MK)
  - Allow for very low engine out emissions under certain circumstances (e.g., at light load)
  - Create conditions conducive to NOx regeneration and desulfation

Toyota Diesel Particulate NOx Reduction (DPNR) Diesel Tested at NVFEL
[System Integration]

	NOx (g/mile)		PM (g/mile)		NMHC (g/mile)		Fuel†
Test Cycle	Test Results	Tier 2 Bin 5	Test Results	Tier 2 Bin 5 Std	Test Results	Tier 2 Bin 5 Std	Economy (mpg)
FTP75*	**0.05**	0.05	**0.006**	0.01	**0.07**	0.075	37
US06**	**0.14**		**0.005**	0.07	**0.19**		35
HWFET***	**0.001**	0.075	**0.002**	-	**0.12**	-	53
NYCC****	**0.003**	-	**0.007**	-	**0.04**	-	22

* Final Tier 2 FTP Bin 5 Intermediate Life (50k) standards, NMHC reported for NMOG

** Final Tier 2 SFTP 4k standards, USO6 std is NOx + NMHC = 0.14, PM is a weighted Std

*** Highway Fuel Economy Test NOx limit is 1.5 times the FTP standard

**** New York City Cycle

† Fuel economy numbers are not adjusted and so are not directly comparable to manufacturer reported City/Hwy fuel economy numbers for other vehicles

Progress Review—Engines Summary - NOx Adsorbers

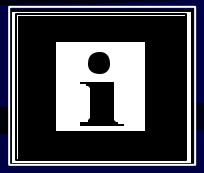
- Temperature range for high NOx conversion
  - Broader range for effective NOx control
  - New combustion approaches can match exhaust conditions to catalyst technology
- Resistance to thermal damage from desulfation
  - Improved catalyst formulations
  - Better catalyst substrates
- Improvements in sulfur management
  - Strategies to minimize effective of sulfur/desulfation
  - Demonstrated improvements in system performance at extended life
- System integration
  - Better system control, lower fuel consumption
  - Increased engine operating range for regeneration

Progress Review—Engines Conclusions - NOx Adsorbers

- Substantial progress has been made to address the important challenges
- Progress has been broadly realized and companies are making significant investments for R&D and manufacturing
- No new "show stopper" issues identified

Progress Review—Engines Conclusions - NOx Adsorbers

"We see the progress in system developments as substantial with at least one manufacturer able to produce production like prototypes for testing. Although a number of challenges remain, we are convinced that industry is well on its way to develop NOx adsorber catalyst technologies for 2007."



For More Information...

- Clean Diesel Independent Review Panel
  - http://www.epa.gov/air/caaac/clean_diesel.html
- 2007 Heavy-duty Engine and Vehicle home page:
  - http://www.epa.gov/otaq/diesel.htm