

EPA Perspective on LNT Aging and Durability

May 2005

EPA Considers LNT's a Viable Option for HD Diesel NOx Control

- Non-inclusive 2010 Technology Possibilities
 - LNT
 - Durability
 - Cost/packaging
 - Urea SCR
 - Infrastructure
 - Engine Out
 - Technology readiness
 - Cost

Progress Is Being Made

Public Measures

- APBF-DEC
 - LDV Car
 - LDV SUV
 - HD
- EPA Aging Tests
 - Formulation improvements

DOE APBF-DEC Results EPA's Perspective

Encouraging LDV Results

- Car
 - Tier 2 Bin 5 FTP NOx at 1800 hours
 - NOx performance seems to be stabilized
 - US06 a challenge
- SUV
 - Over 80% NOx Reduction at 2000 hours
 - NOx performance seems to be stabilized

LDV SUV

need permission

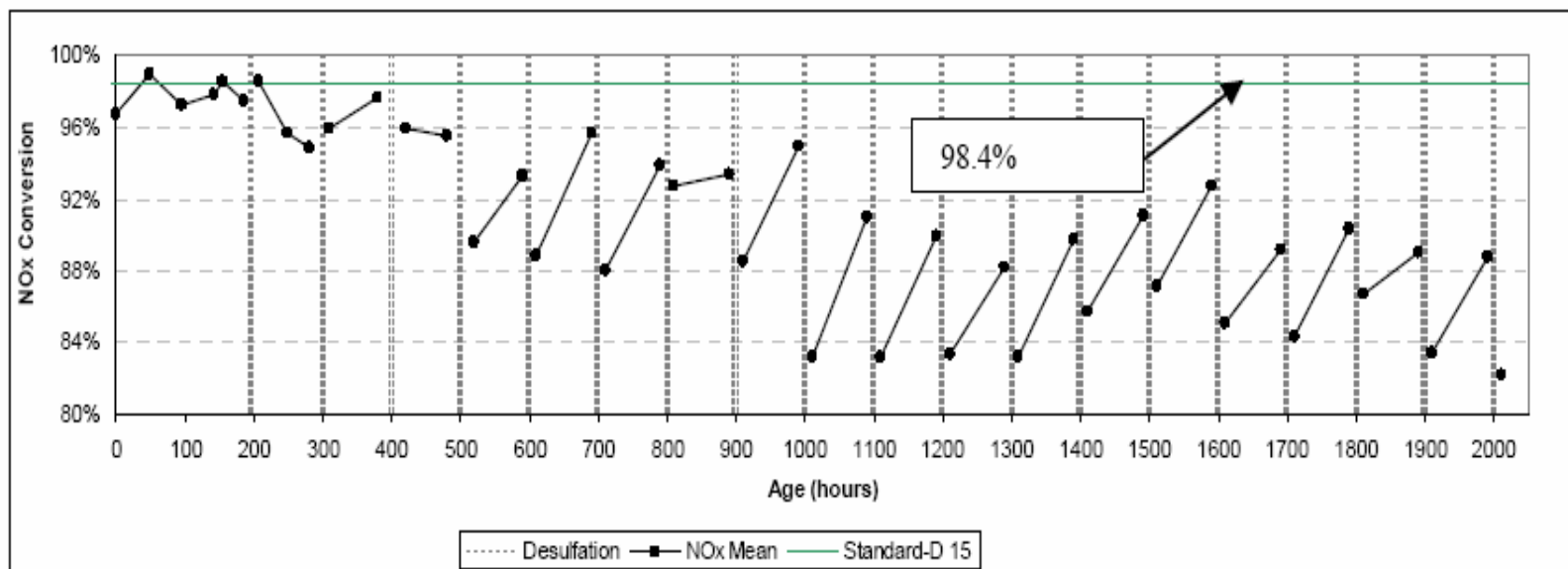



Figure 4.2-2. NO_x Conversion Efficiency (FTP Composite) versus ECS Age (Vertical Lines Identify Desulfation Events).

NOx Adsorbers for HHD

Systems Projects

| NO _x Adsorber/DPF | | SCR/DPF | Lubes | |
|--|---|---|---|---|
|  |  |  |  |  |
| FEV | SwRI | Ricardo | SwRI | AEI |
| 1.9L TDI | 6.6L Isuzu Duramax | 15L Cummins ISX | Caterpillar C12 | Cummins ISB |
| Audi A4 Avant | Chevrolet Silverado | No vehicle | | |

Test Engine

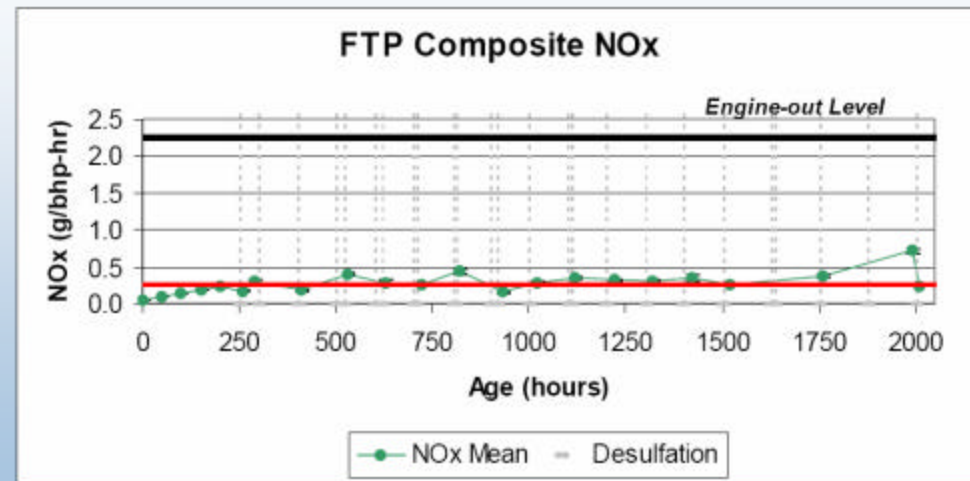
- Cummins ISX 15L
- 475 hp Rating
- DOHC 4V central EUI
- Cooled EGR, VGT
- Advanced electronic controls
- 2002/2004 Base engine out emissions (pre-production)



Extended Durability (2,000 hrs) Shows Good Performance

- Stable for last 1000 hours
- Retained 80% or better FTP NO_x reduction
- 5 year old formulation
- 2.3 g/hp-hr engine out

Aging Results - NO_x



But...

- Prototype hardware
- Prototype control systems
- Engine out NO_x not as low as it could be (SUV, HD)
- Old adsorber formulations (~5 yrs)
- 2000 hours not HHD full useful life

EPA Adsorber Experience

Adsorber Evaluation Process

1) Age on engine at AVL Mode 8 (500 C)

- 'No' Sulfur fuel
- 750 ppm S oil
- Fixed aging regens
- 25 hr optimized SET's

- Has evolved into an adsorber benchmarking test
- Recently took an adsorber to step 2)

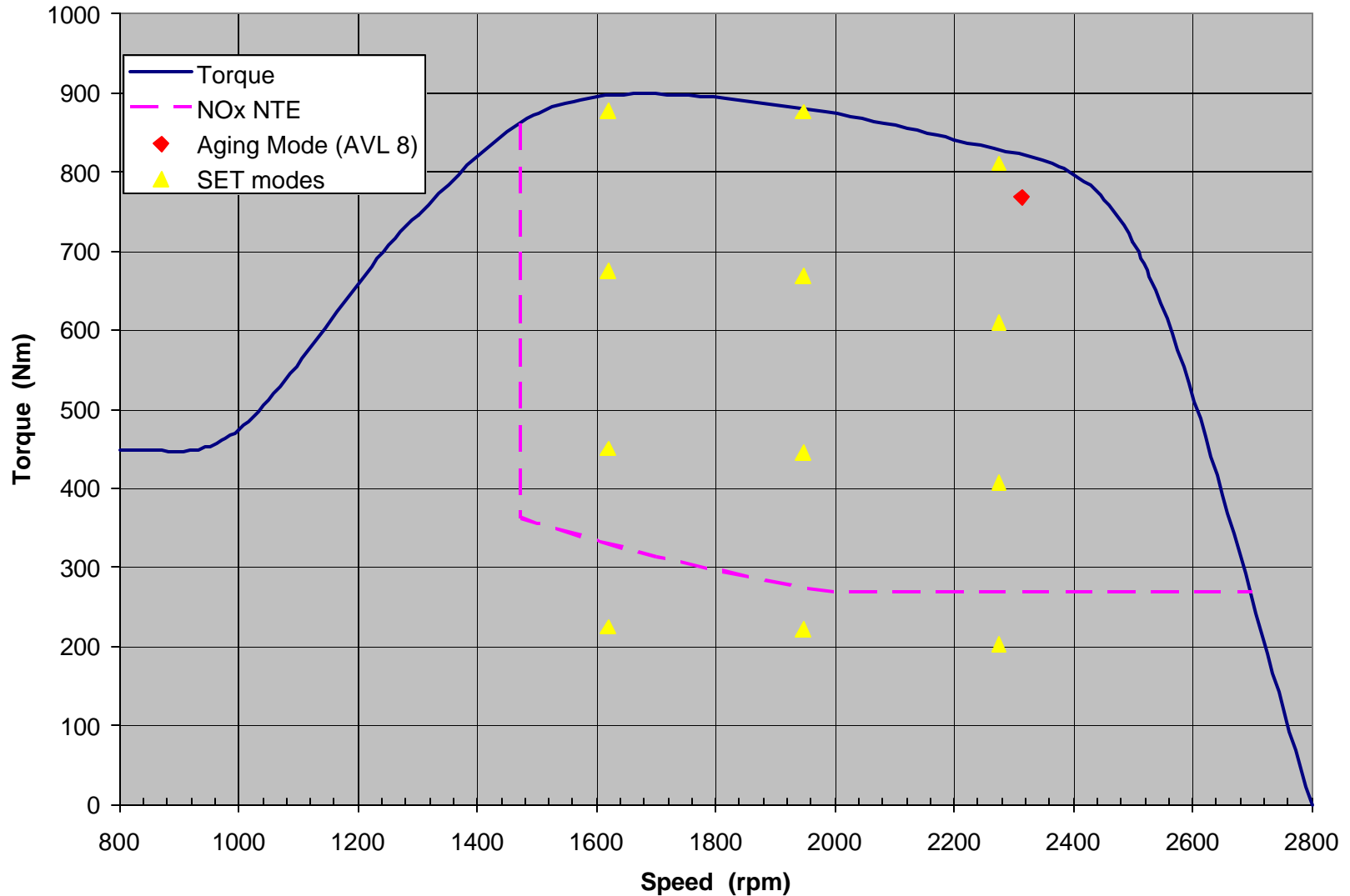
2) Add desulfurizations

- Hourly

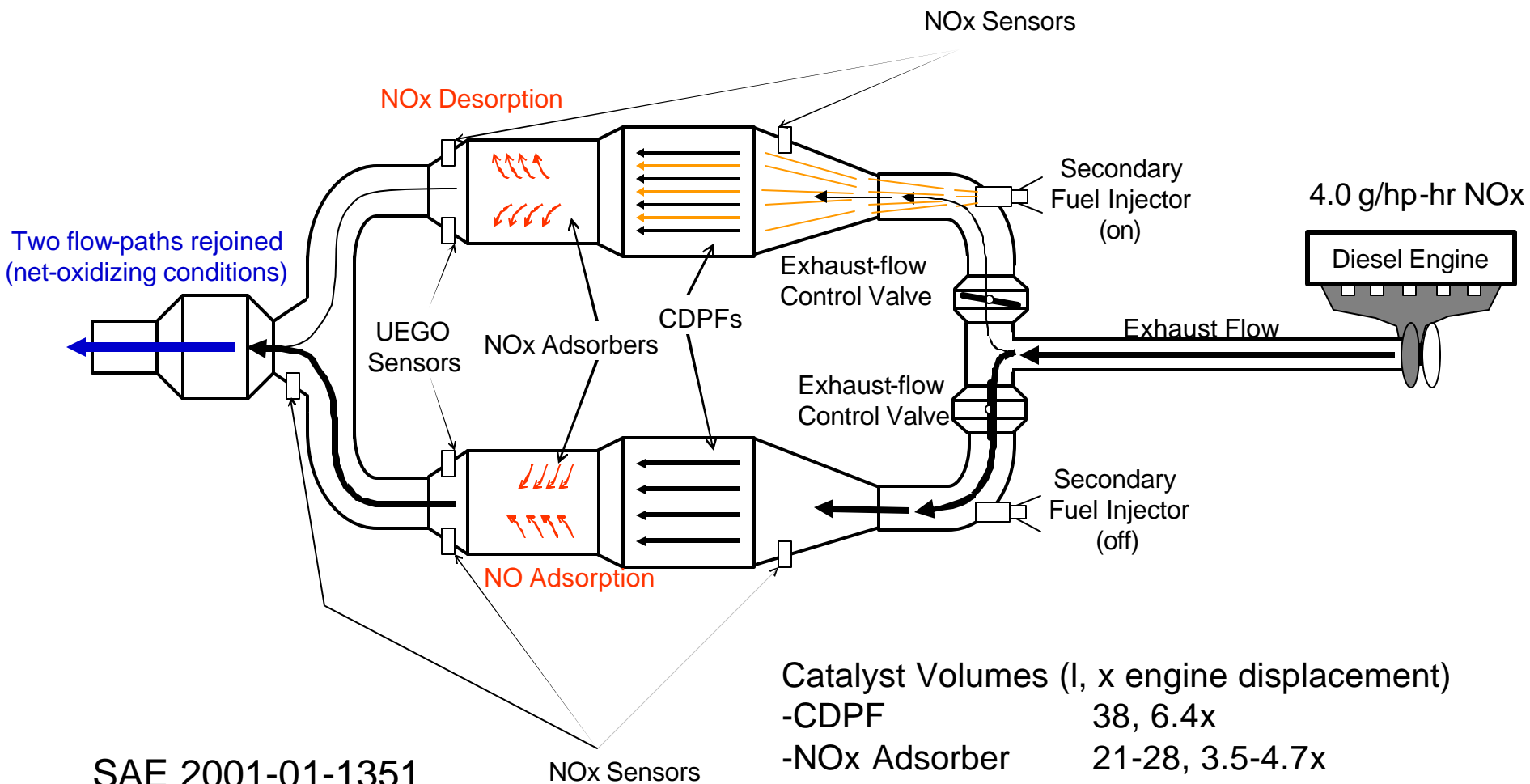
3) Add sulfur

Test Modes

260 hp Cummins ISB, 4.0 g/hp-hr NOx



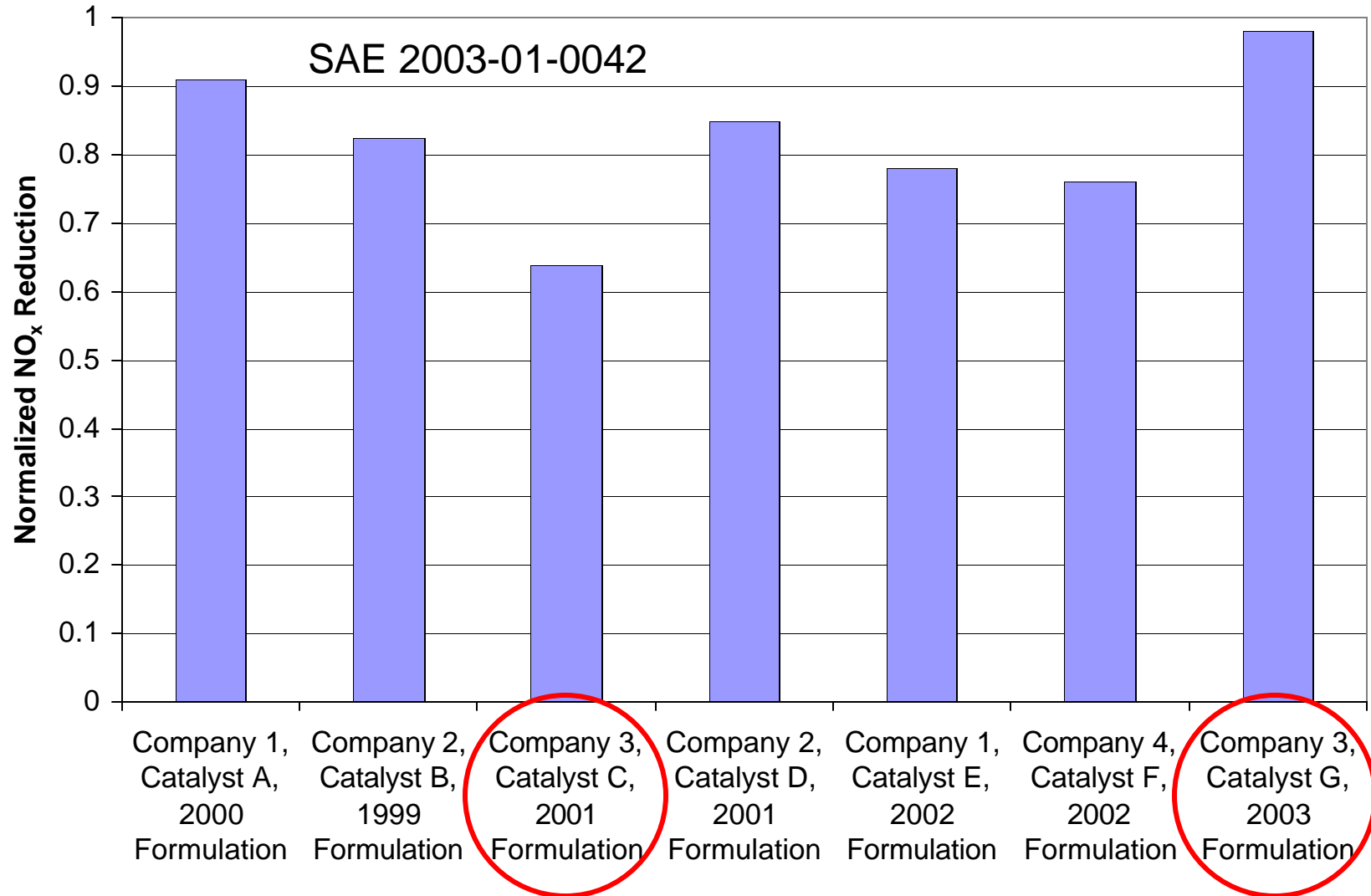
Adsorber Aging System



SAE 2001-01-1351
SAE 2001-01-3619

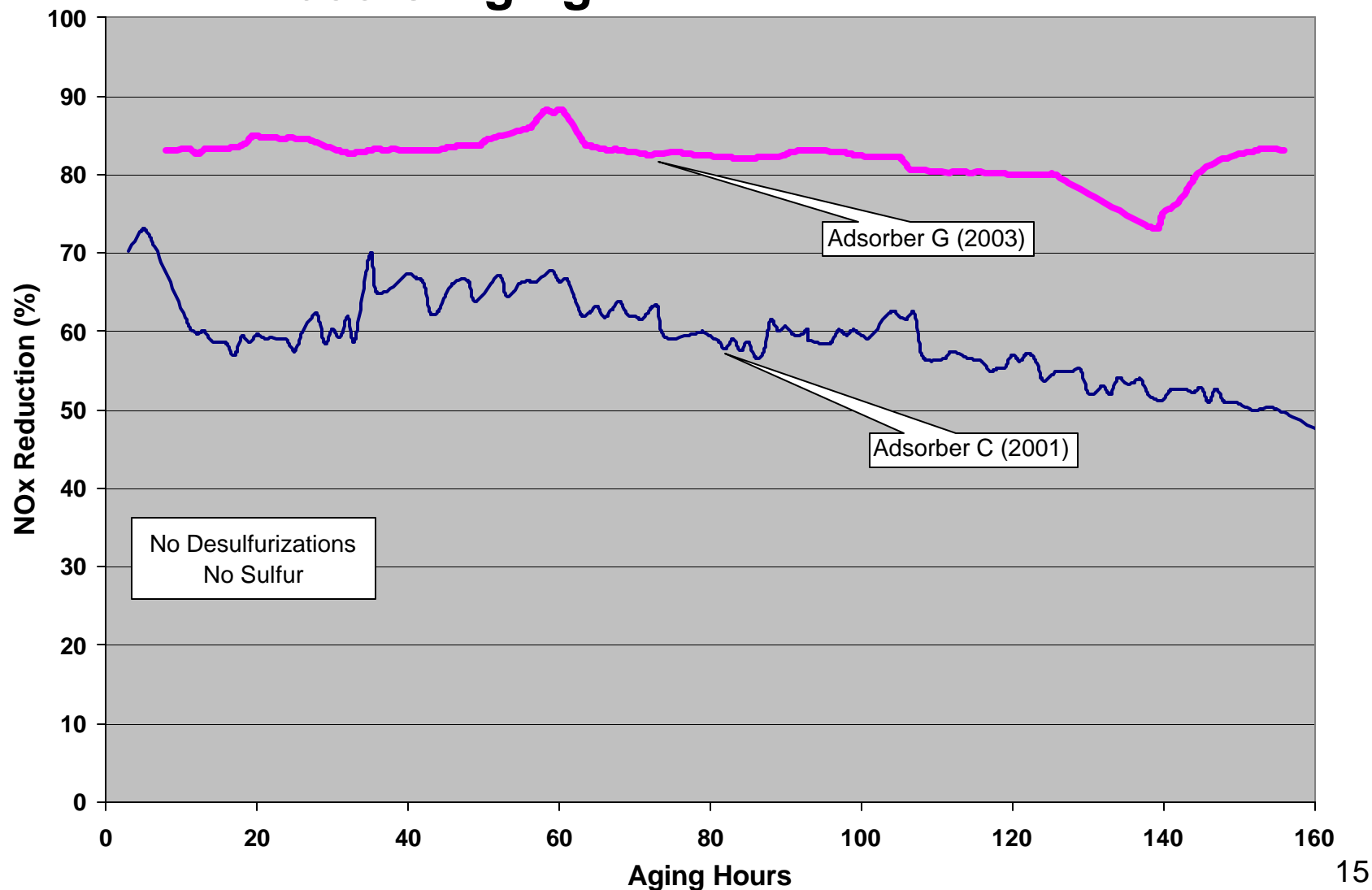
Adsorber Benchmarking

100 Hour Aging Mode Performance Compared to 0 Hour Performance

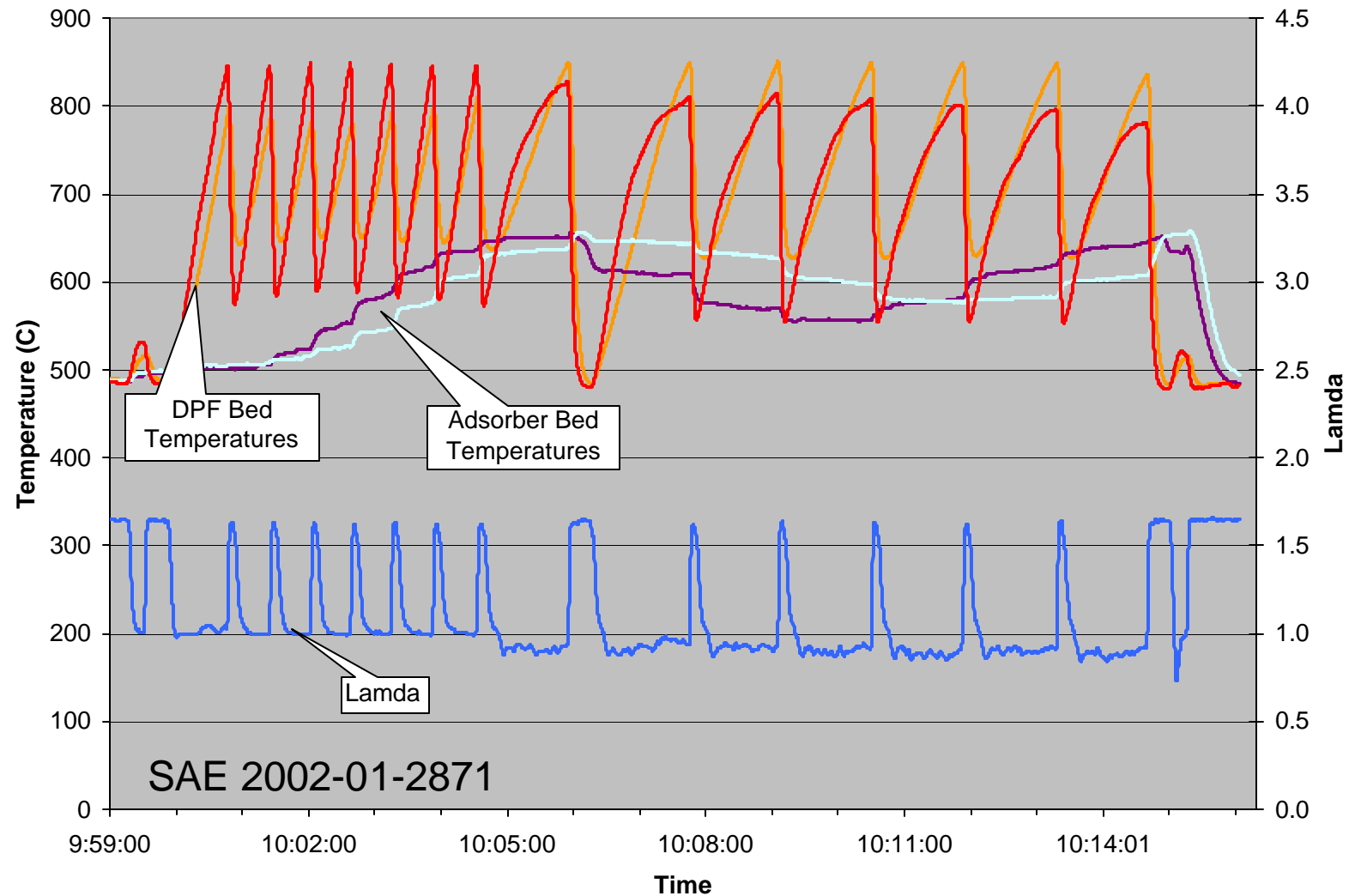


Formulation Progress

500 C Aging Mode Performance

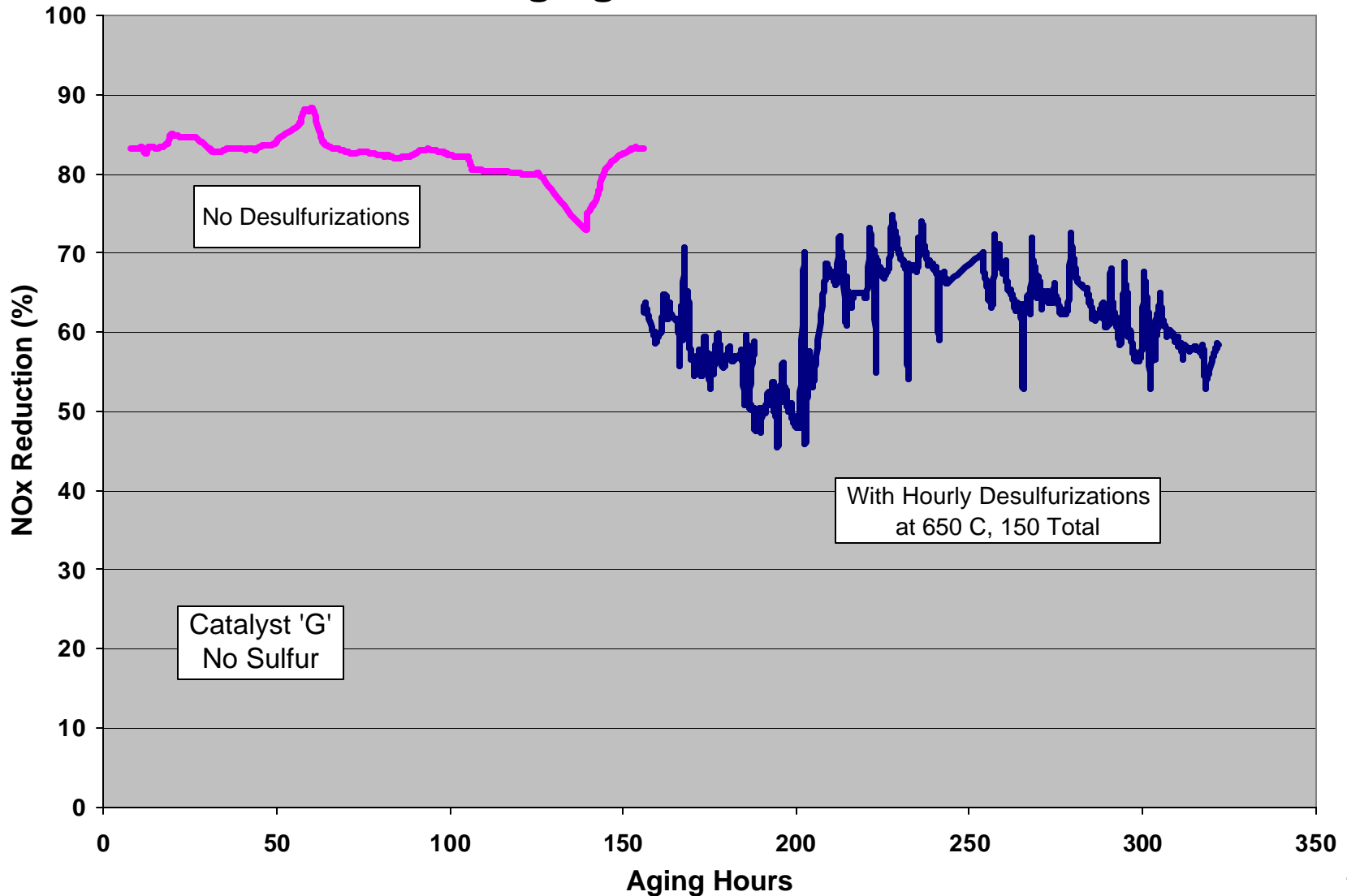


Desulfurization Procedure



Desulfurization Performance

500 C Aging Mode Performance

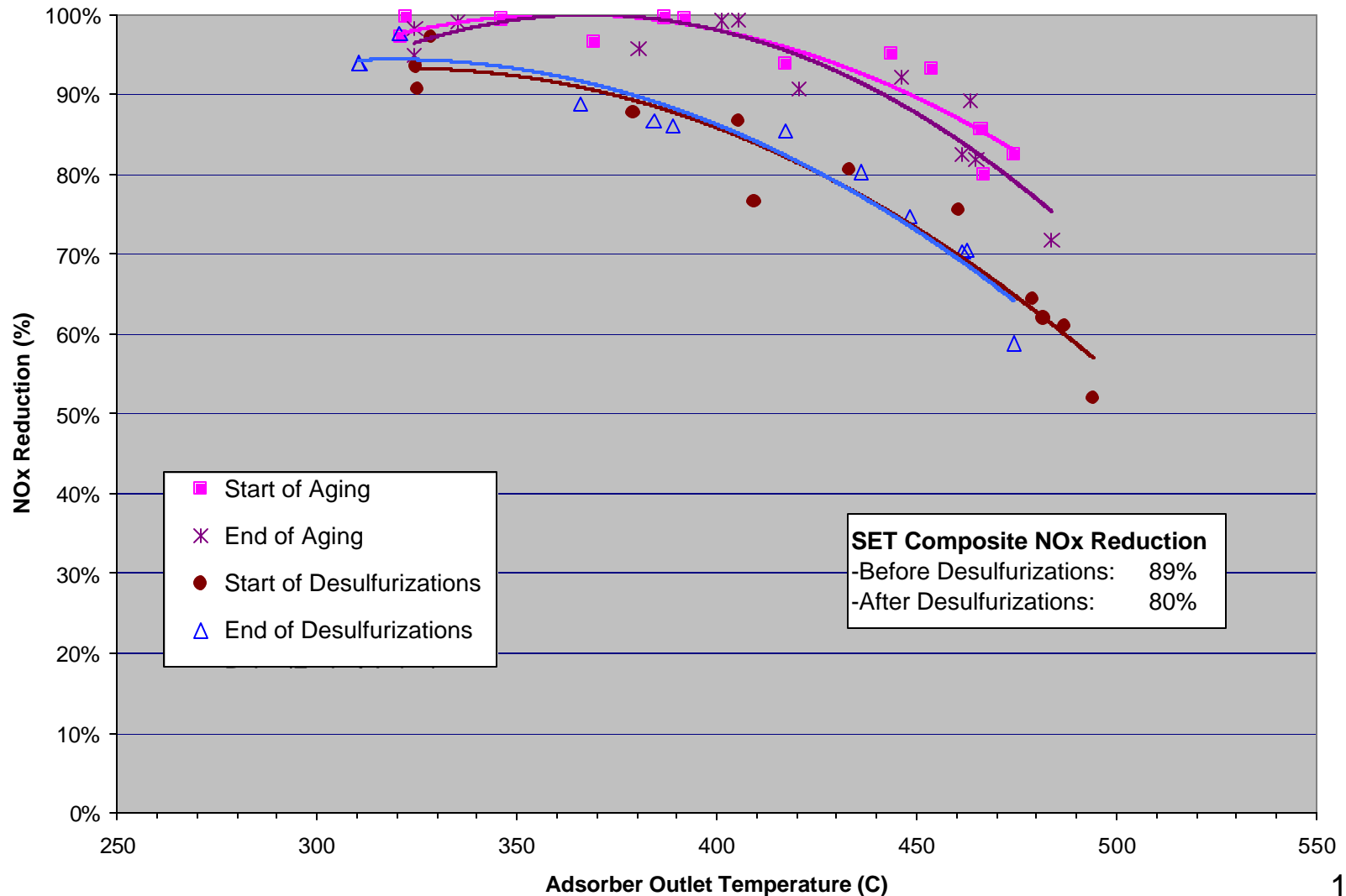


Mileage Equivalency of Desulfurizations

- Assumptions
 - 5.9 l 260 hp engine
 - A50 cruise
 - 40 mph avg. speed
 - 435,000 miles
 - 2.0 ads/eng volume
 - 1.5 g/l max S loading
 - 10 ppm S fuel
- Calculated
 - 0.1673 g/hr exh S
 - 10,875 hours
 - 1819 g S total
 - 154 g/l S
 - **103 desulfurizations**

Supplemental Emission Test

Fixed Regeneration Schedule



Durability Conclusions

- Adsorber formulations have significantly improved performance in the past 5 yrs
- Adsorbers have been thermally stabilized to withstand desulfurizations with minimal on-going performance degradation
- Tests seem to indicate adsorbers can maintain emission performance