

# The Impact of Lubricant Formulation on the Performance of NO<sub>x</sub> Adsorber Catalysts

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# Presentation Outline

- Background/Motivation
- Summary of Phase I
- Experimental Design
- Results
- Conclusions

# Advanced Petroleum Based Fuels – Diesel Emission Control Study

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## Government/Industry Sponsorship

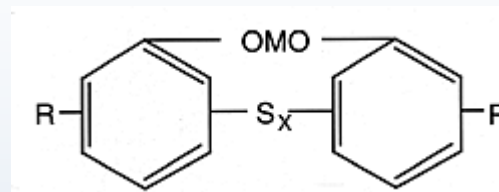
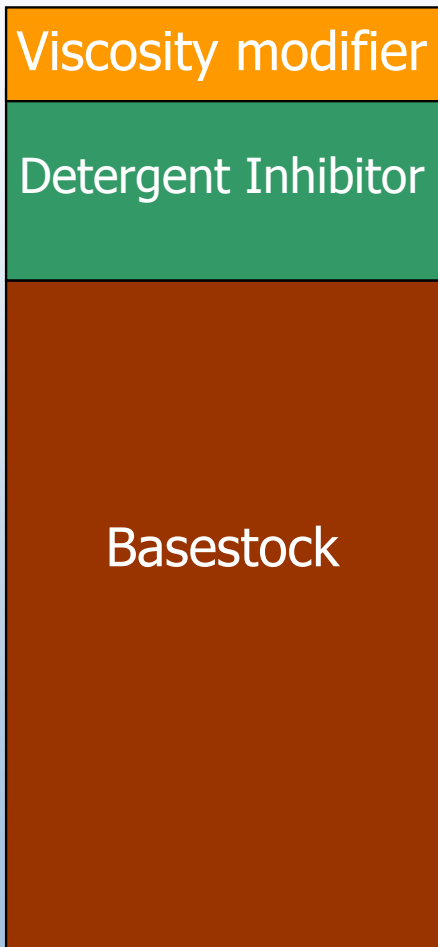


*DOE sponsors: Steve Goguen and Kevin Stork*

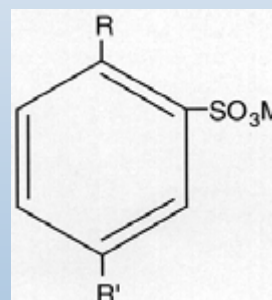
# Motivation for Research

- Lubricant effects on automotive three-way catalysts are well documented
  - Phosphorus
- Similar impacts anticipated in diesel systems
  - May involve other “poisons”, including sulfur
- ASTM already working on lubricant specs for trap equipped engines (PC-10)
- Interactions may be subtle, but still significant when useful life requirements are considered

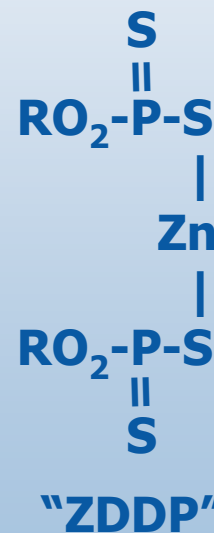
# Engine Oil Formulation



**Sulfur Coupled Phenate**



**Sulfonate**



# APBF-DEC Lubricants Project



Determine the impact of lubricant properties and composition on engine-out/catalyst-in emissions

- Part 1: Characterize effects of lubricant properties on engine out emissions
- Part 2: Develop methods to accelerate exposures of emission control systems (ECS) to lubricant-derived emissions



Determine if lubricant formulation impacts the performance and durability of diesel engine ECS

# Phase I Summary

- Results Presented at DEER 2002
- Oil formulation has significant effects on engine-out emissions
- Not all lubricant additive systems impact emissions similarly
- Lubricant sulfur content not a good predictor of sulfur emissions



# Phase II Test Protocol

- 400-hour test
- Evaluations at 100-hour intervals
  - Focus on NO<sub>x</sub> reduction efficiency
- Oil consumption measurement
- New LNT for each test
- Oil change at 200-hours
- DEC base fuel (0.6-ppm S/15-ppm S)
- Post-analysis of catalyst by XRF

## Test Hardware – Phase 2

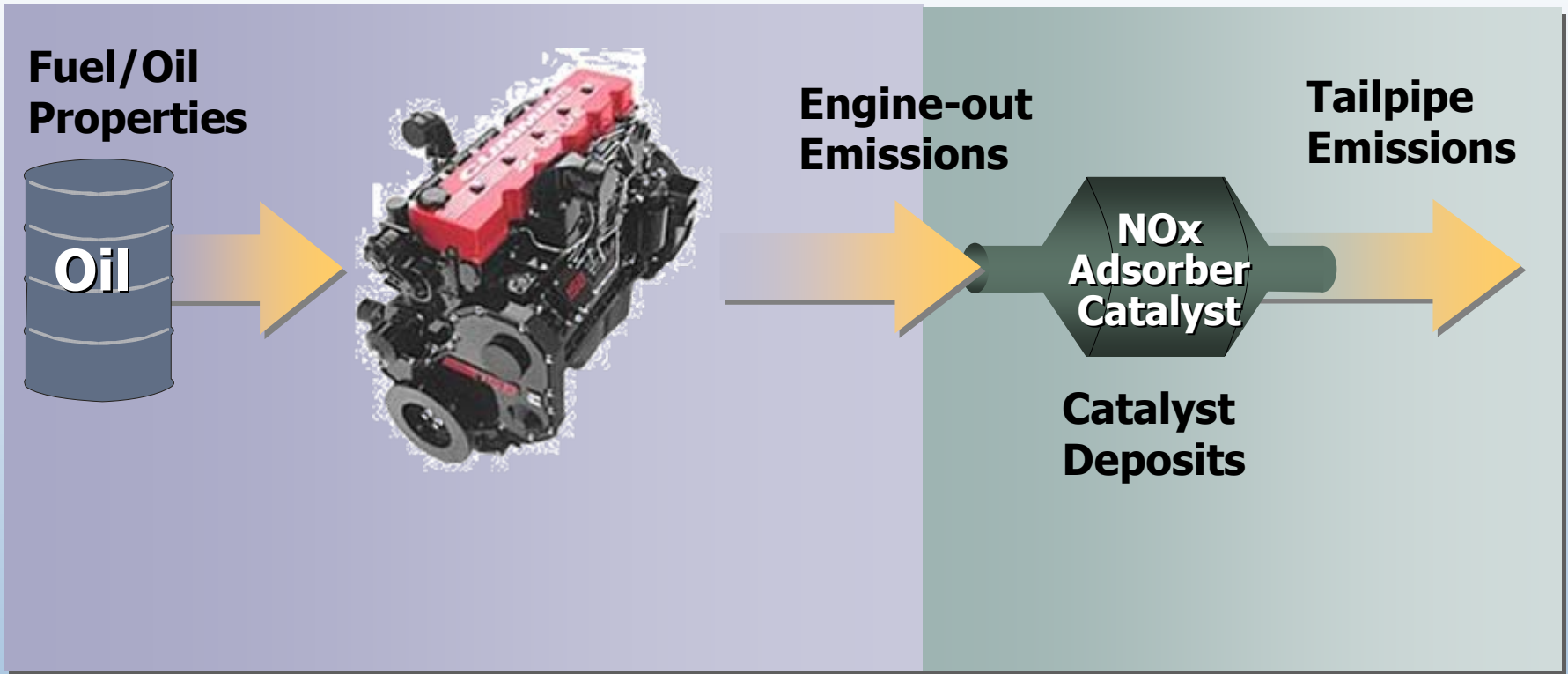
- 2002 Cummins ISB – 300 hp @ 2500 rpm
- 5.9L, inline 6 cylinder
- Cooled-EGR
- Single NO<sub>x</sub> adsorber (7L)
- In-pipe regeneration fueling



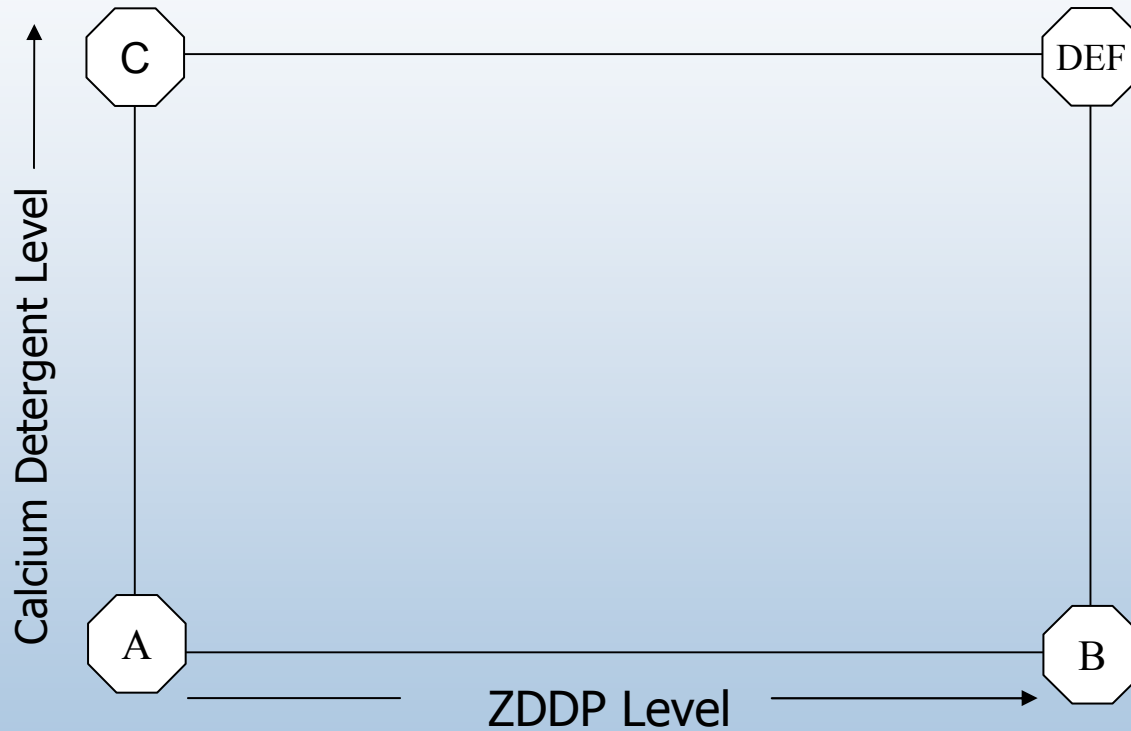
# Operating Modes

Mode	Engine Speed (RPM)	Load (FT*Lbs)	Average Catalyst Mid Temp. °F (°C)	Space Velocity (1/hr)
1	1650	140	650 (343)	30,000
2	2100	175	650 (343)	70,000
3	1400	160	750 (399)	32,000
4	1900	225	750 (399)	63,000
5	1200	275	850 (454)	33,000
6	1700	350	850 (454)	62,000

# Phase 2 Analysis Approach



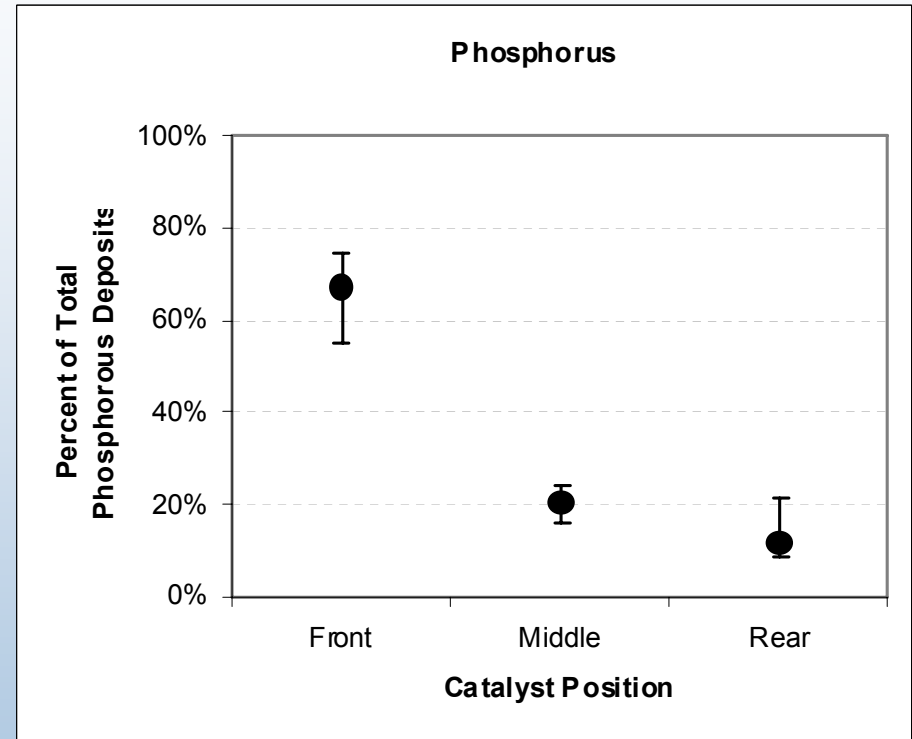
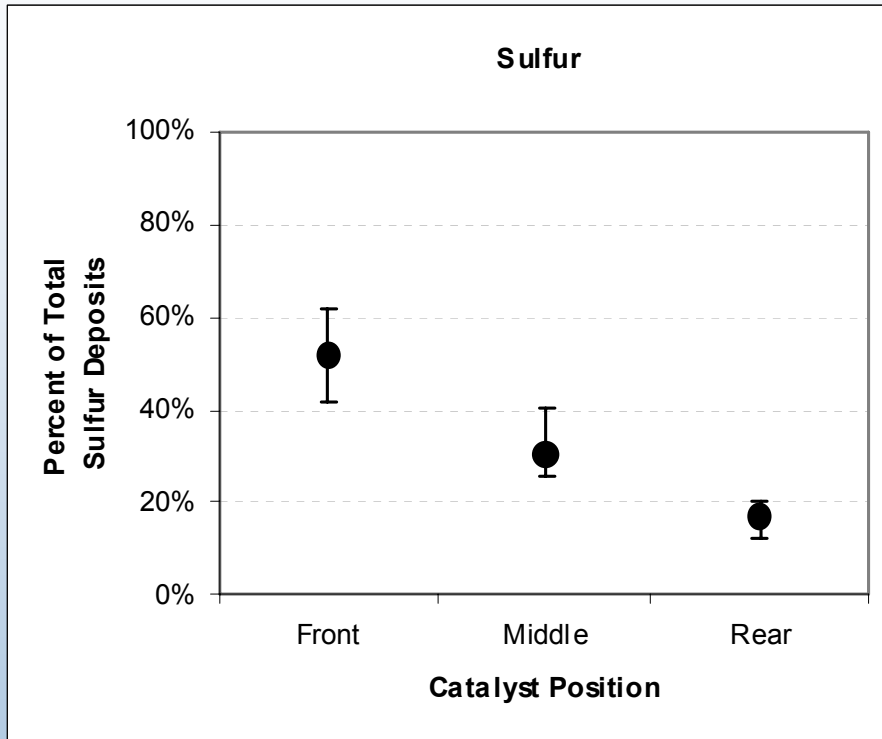
# Test Matrix



# Properties of Test Oils

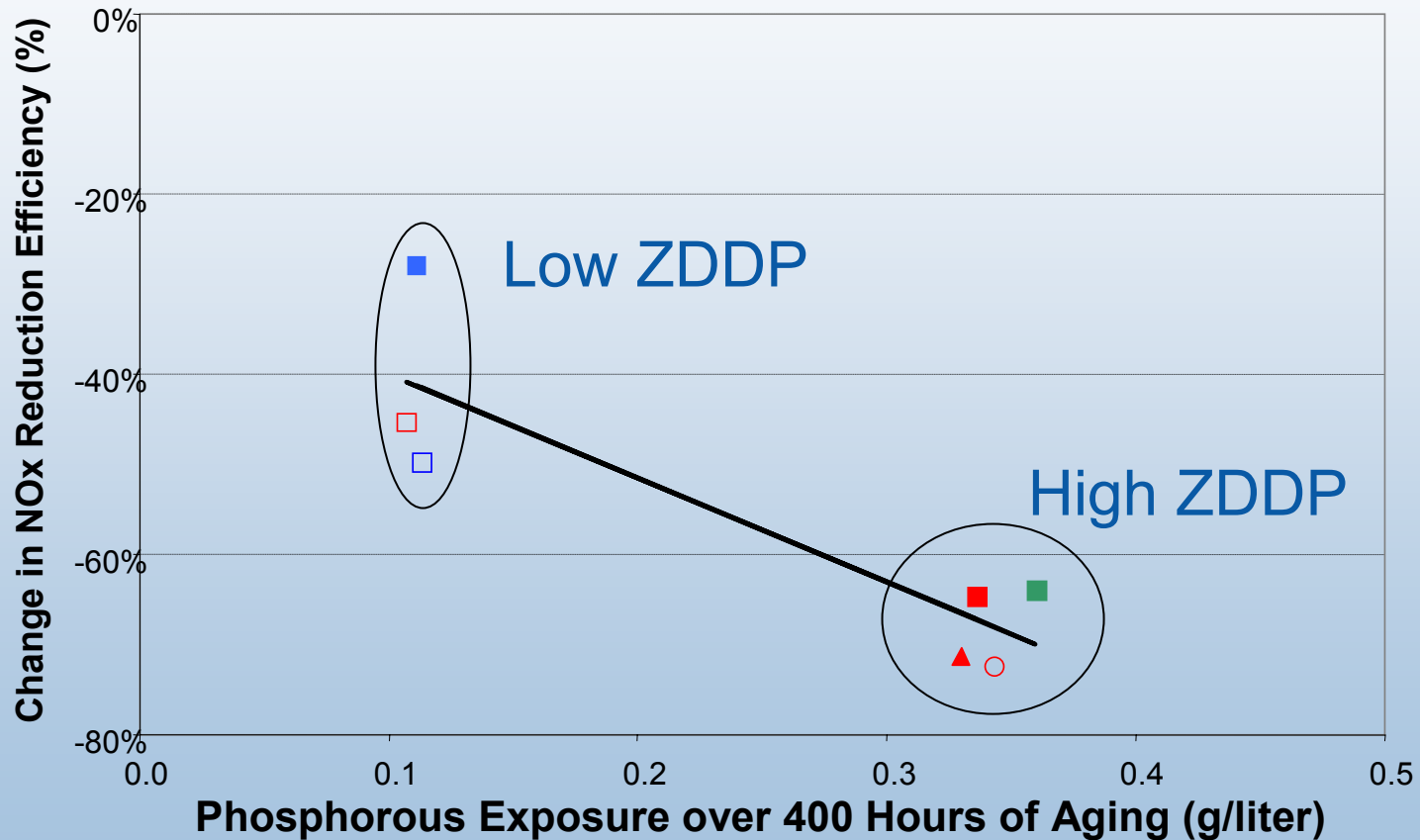
Test Number	Ash* (%)	S* (ppm)	Ca (ppm)	P (ppm)	Zn (ppm)	N* (ppm)	TBN (mg KOH/g)	Viscosity		Soot (%)
								@100°C (cSt)	@40° C (cSt)	
1	0.775	1695	1853	427	471	1128	6.99	14.9	111.3	0.07
2	1.522	2928	3258	1210	1320	1329	12.34	15.0	111.9	0.06
3	1.131	3980	2050	1430	1590	1477	7.3	15.0	111.9	0.06
4	1.316	4195	3160	1340	1520	1314	10.6	15.0	112.5	0.12
5	1.310	2228	3241	419	475	1368	9.6	14.6	107.7	0.12
6	1.497	4197	3518	1280	1480	1315	10.2	14.7	109.1	0.11
7	0.775	1695	2065	451	505	1128	6.7	14.9	110.9	0.08
8	0.775	1695	2329	483	546	1128	8.7	14.9	110.9	0.11

# Catalyst Deposit Profile



- Samples extracted from three positions and analyzed via Uniquant x-ray fluorescence
- Phosphorus deposits concentrated in front third of catalyst

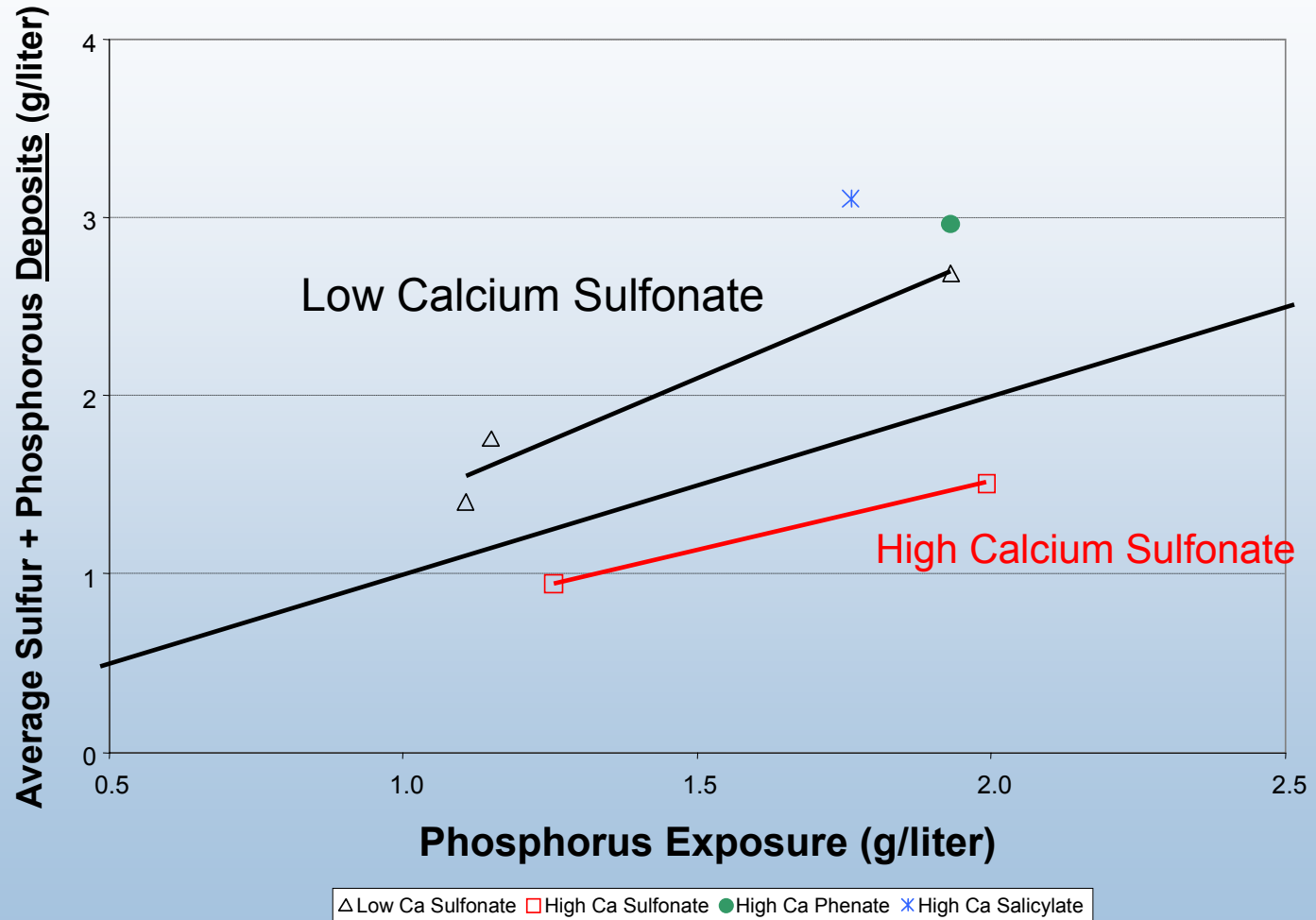
# Phosphorus Impact on Performance



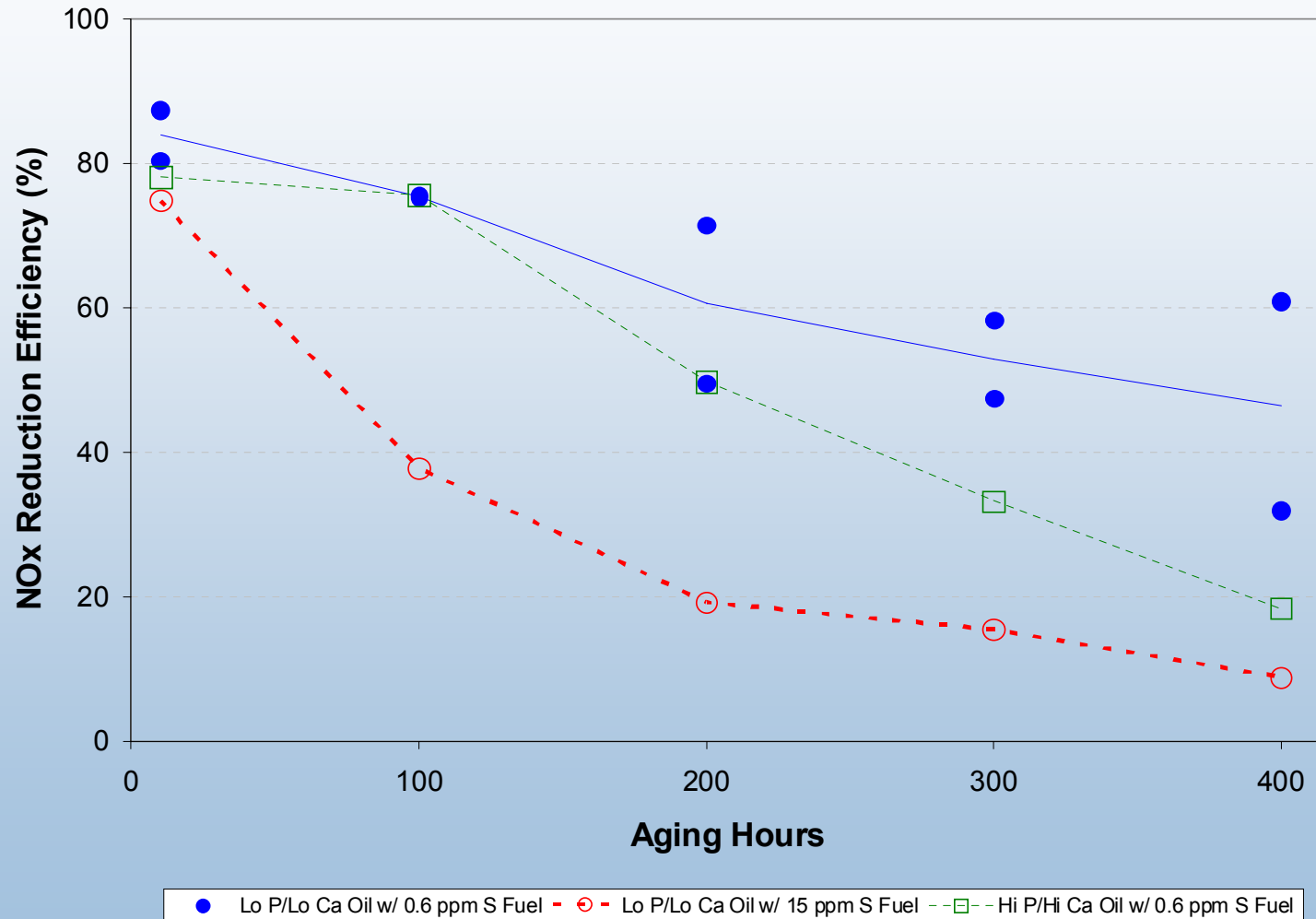
Lubricant-Test Number: ■ A-1 □ A-7 ■ B-3 ○ E-2 ▲ F-4 □ C-5 ■ D-6



# Impact of Detergent



# Relative Impact of Fuel and Lube S



# Preliminary Conclusions – Phase 2

- Sulfur and phosphorus in lube oil appear to impact LNT performance
- Deposits of lube oil derived species concentrated on front of catalyst
- Detergent level/type may impact rate of phosphorus deposition
- Fuel sulfur still appears to be dominant in terms of degradation
- Final reporting still in progress
  - Will be available late 2005