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The Impact of Lubricant Formulation on the Performance of NO_x 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

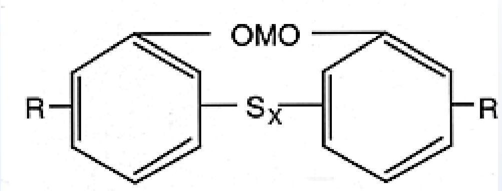
Government/Industry Sponsorship

DOE sponsors: Steve Goguen and Kevin Stork

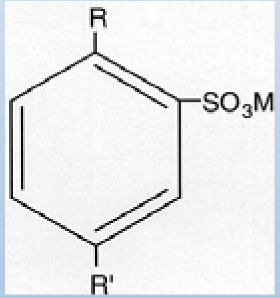
Motivation for Research

- 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

S
||
RO_2-P-S
|
Zn
|
RO_2-P-S
||
S

"ZDDP"

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_x 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

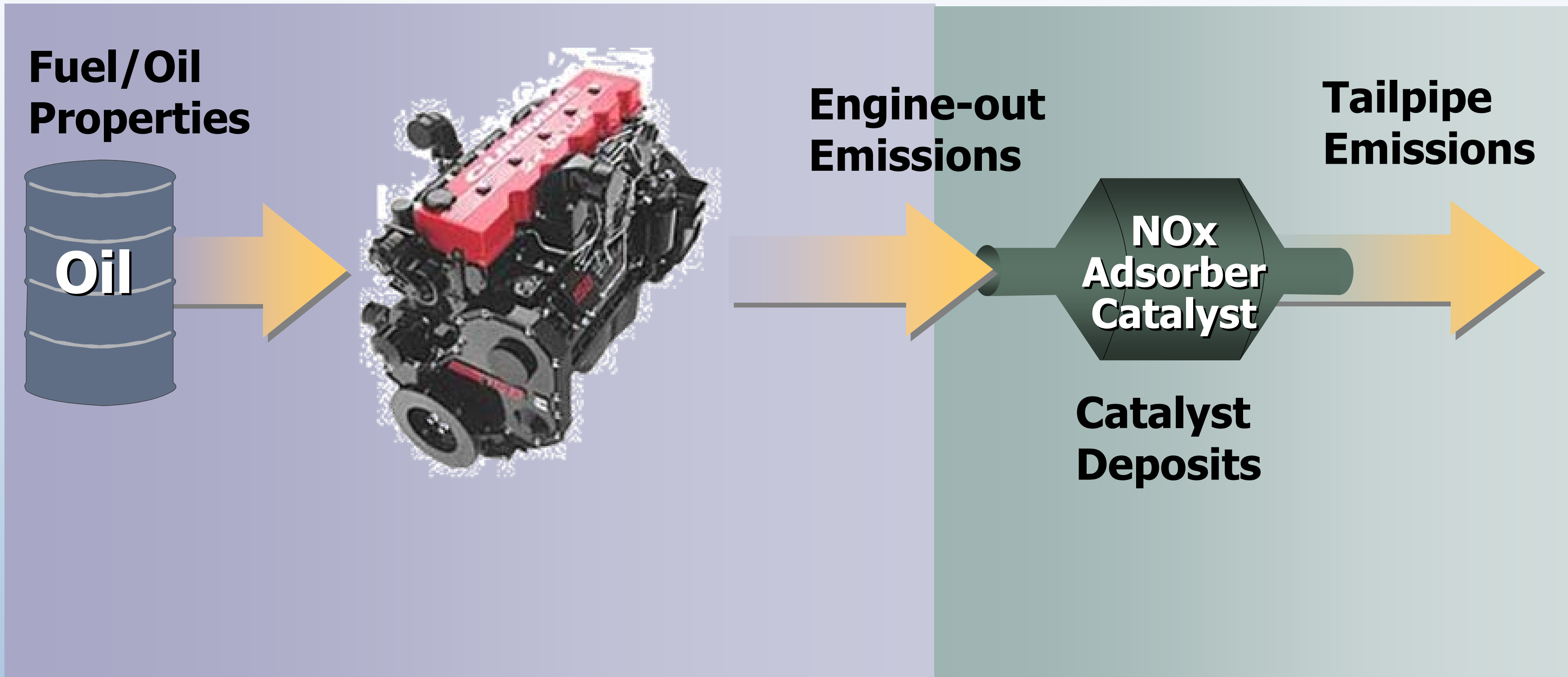
Test Hardware – Phase 2

- 2002 Cummins ISB – 300 hp @ 2500 rpm
- 5.9L, inline 6 cylinder
- Cooled-EGR
- Single NO_x adsorber (7L)
- In-pipe regeneration fueling

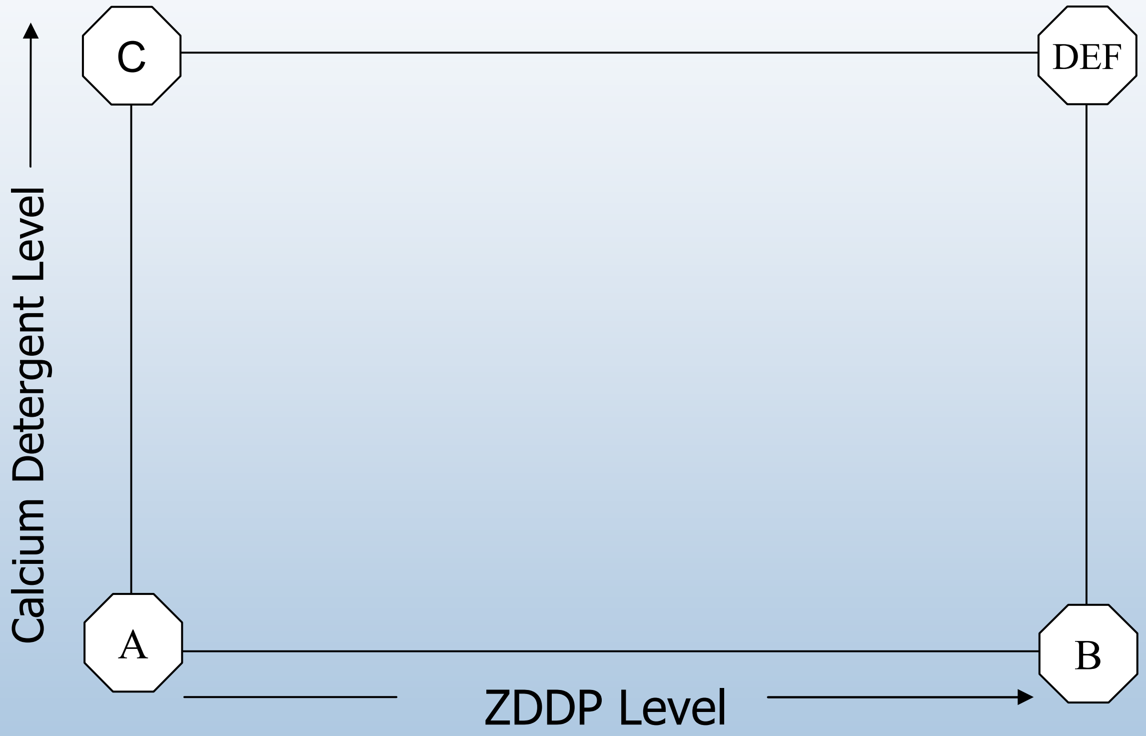
Operating Modes

Mode	Engine Speed (RPM)	Load (FT*Lbs)	Average Catalyst Mid Temp. ºF (ºC)	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



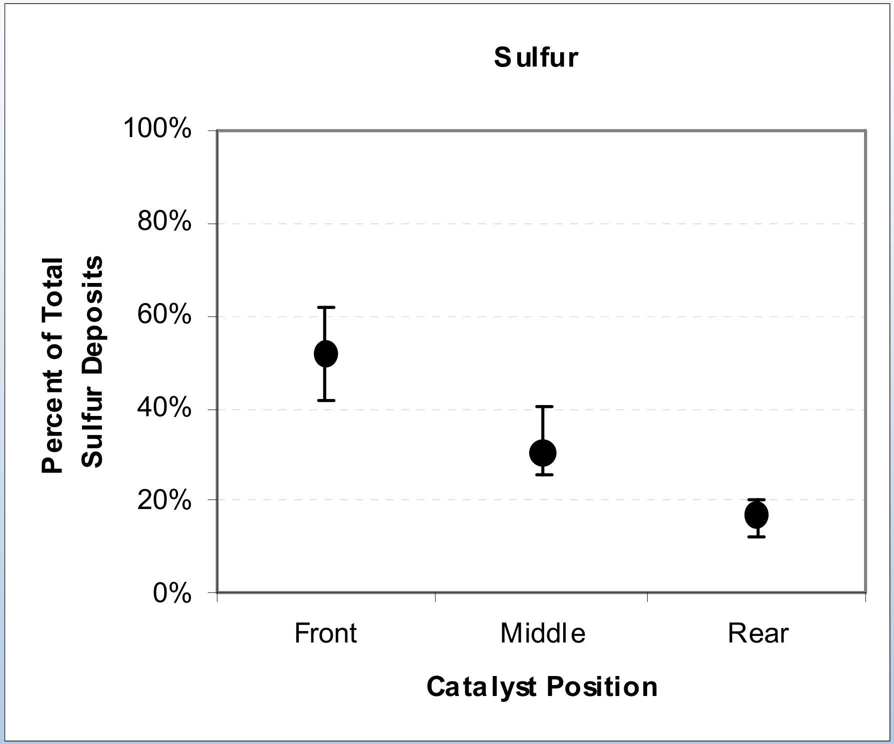
Test Matrix

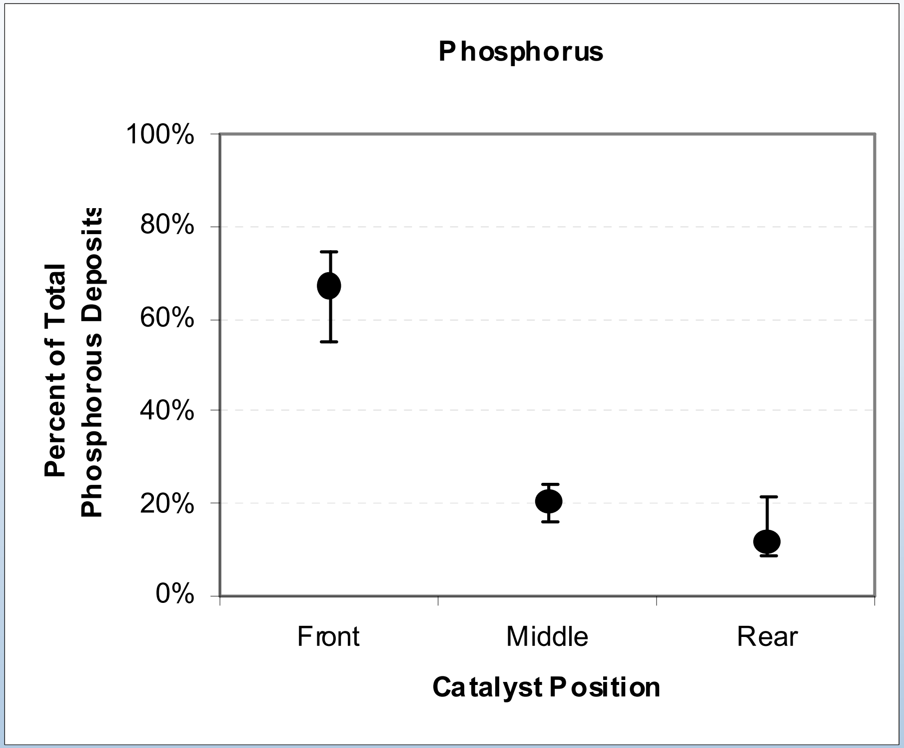


Properties of Test Oils

Test Number	Ash* (%)	S* (ppm)	Ca (ppm)	P (ppm)	Zn (ppm)	N* (ppm)	TBN (mg KOH/g)	Viscosity @100ºC (cSt)	Viscosity @40º C (cSt)	Soot (%)
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

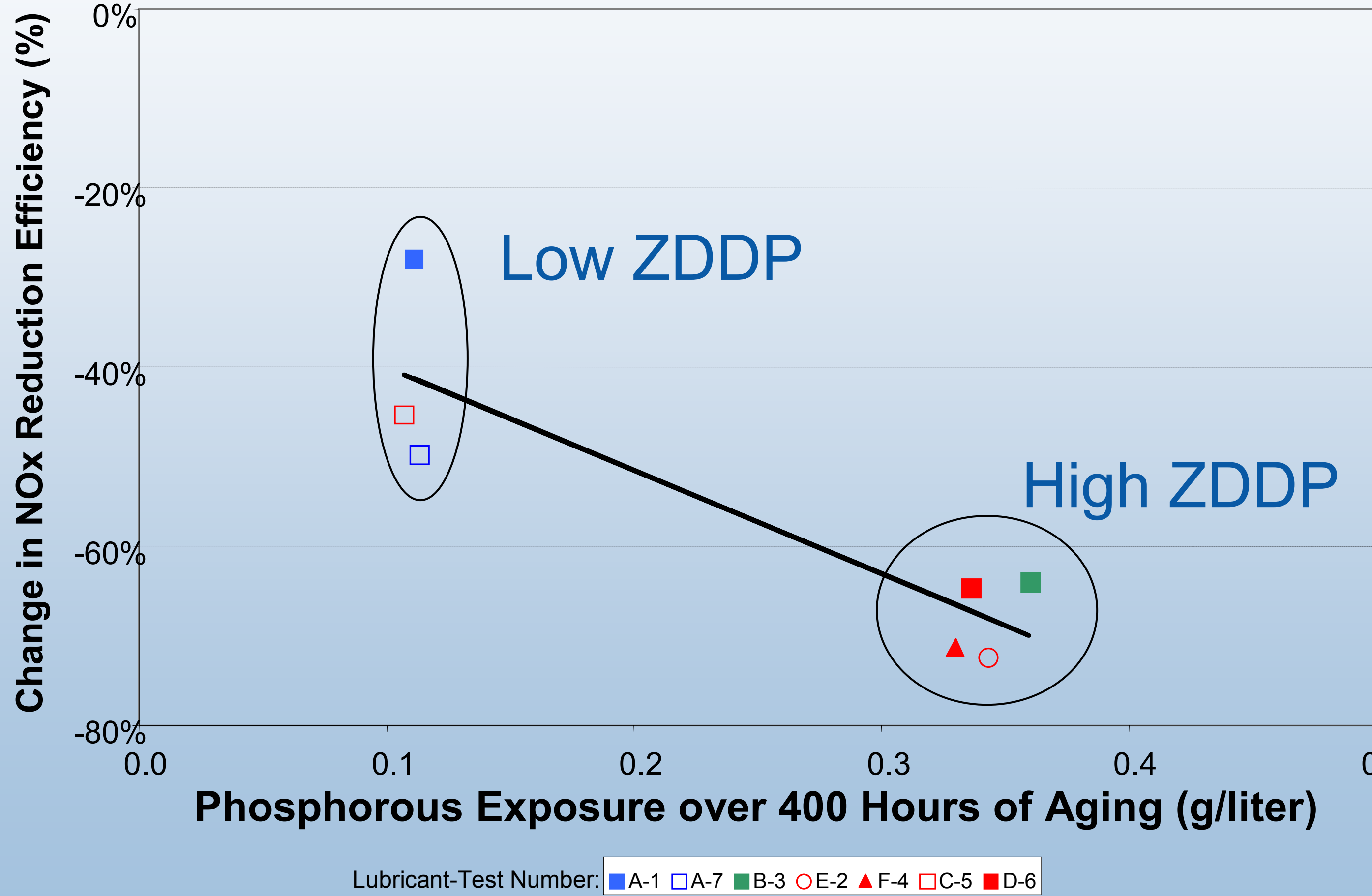
Catalyst Deposit Profile



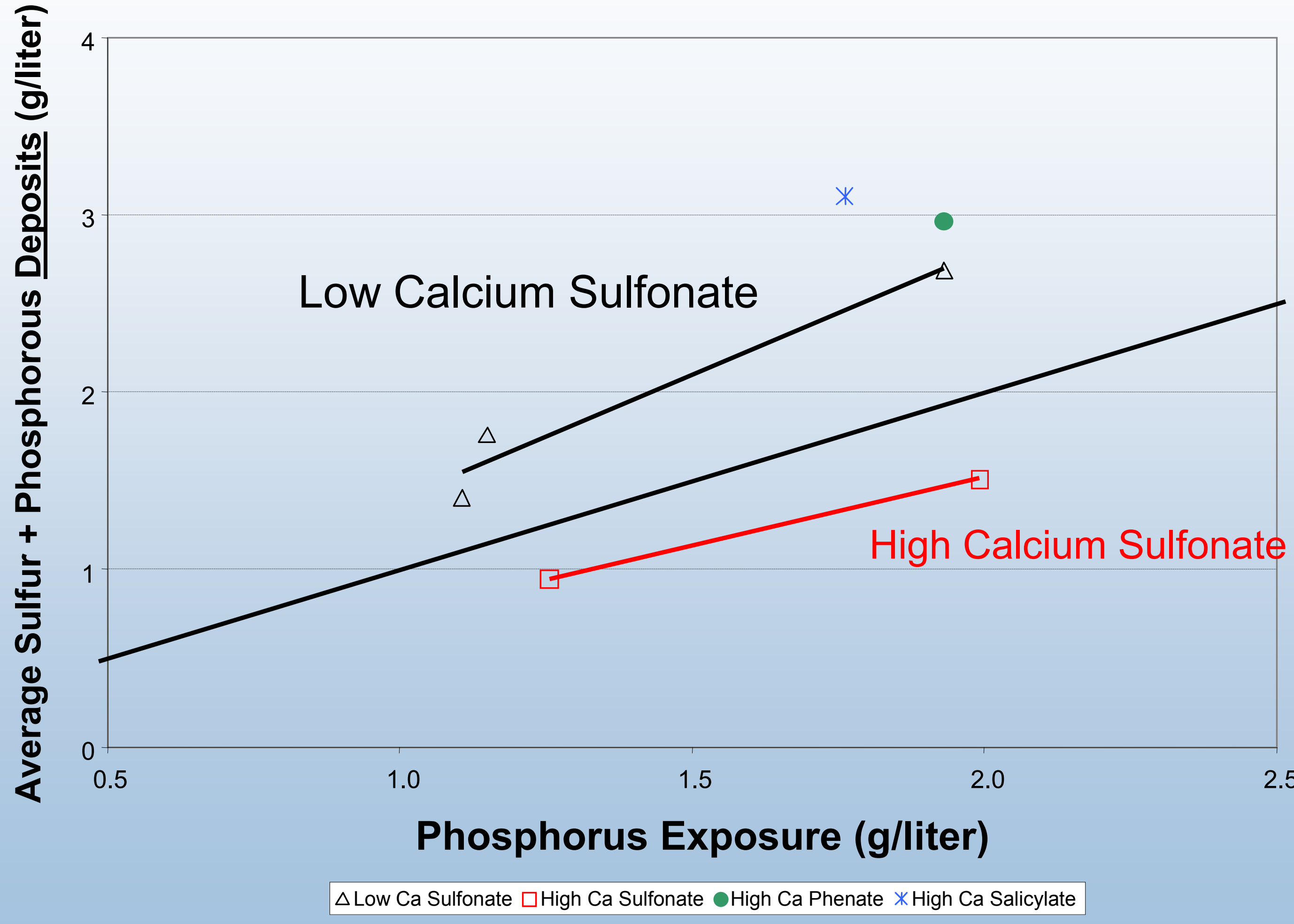


- Samples extracted from three positions and analyzed via Uniquant x-ray fluorescence
- Phosphorus deposits concentrated in front third of catalyst

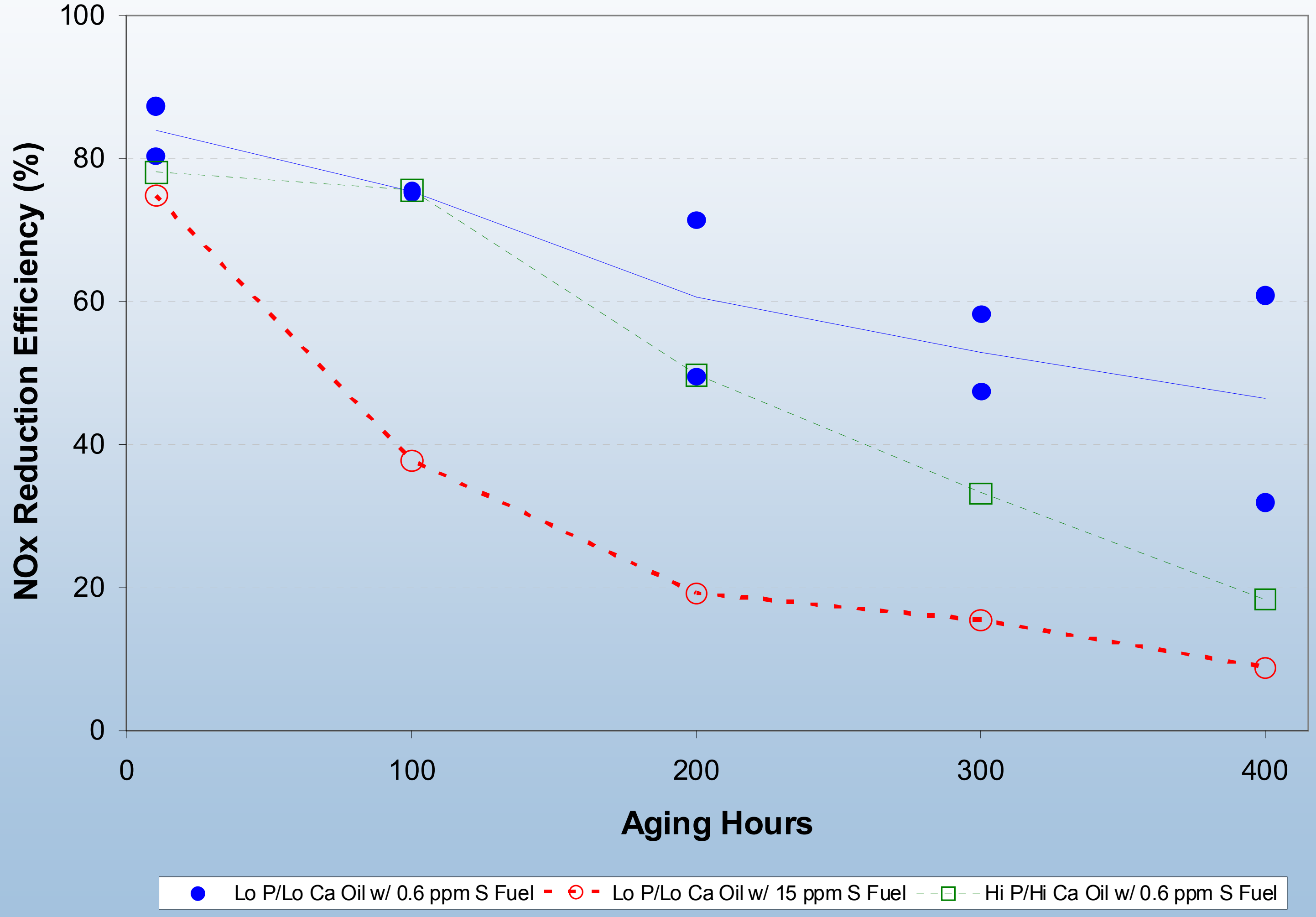
Phosphorus Impact on Performance



Impact of Detergent



Relative Impact of Fuel and Lube S



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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