The Influence of Lubricant Formulation on Emissions from a CIDI Engine: Basestock and Additive Effects

Shawn D. Whitacre
National Renewable Energy Lab

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Catalyst compatible lubricants

- 2007 HD standards and Tier 2 LD standards will require aftertreatment
- Growing concern over lube oil sulfur and ash
  - Potential to interfere with catalyst performance
  - NO_x adsorber poisoning
  - Diesel particle filter plugging
- APBF-DEC has established a multi-year project to quantify lubricant effects on emissions and catalyst performance

- ***Objective:*** Determine which, if any, lubricant derived emission components are detrimental to ECS performance or durability.

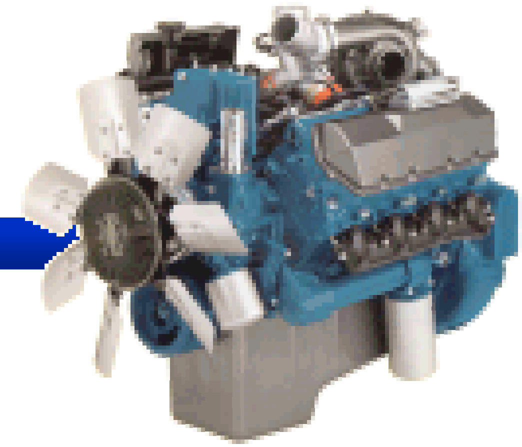
Workgroup Participants

- BP
- Caterpillar
- ChevronTexaco
- Chevron Oronite
- Ciba Specialty Chemicals
- Cummins, Inc.
- Equilon
- Ethyl Corporation
- ExxonMobil
- Infineum
- International
- John Deere
- Lubrizol
- Mack
- Marathon-Ashland Petroleum
- Motiva
- Pennzoil-Quaker State
- RohMax
- Shell Global Solutions
- Toyota
- Valvoline

Test Laboratory

- Subcontractor: Automotive Testing Laboratories (East Liberty, OH)
- Principal Investigators:
  - Chris Tennant, Lisa Lanning
- Team members:
  - Michael Traver
  - Tom McDaniel
  - Brian Mace

Test Engine

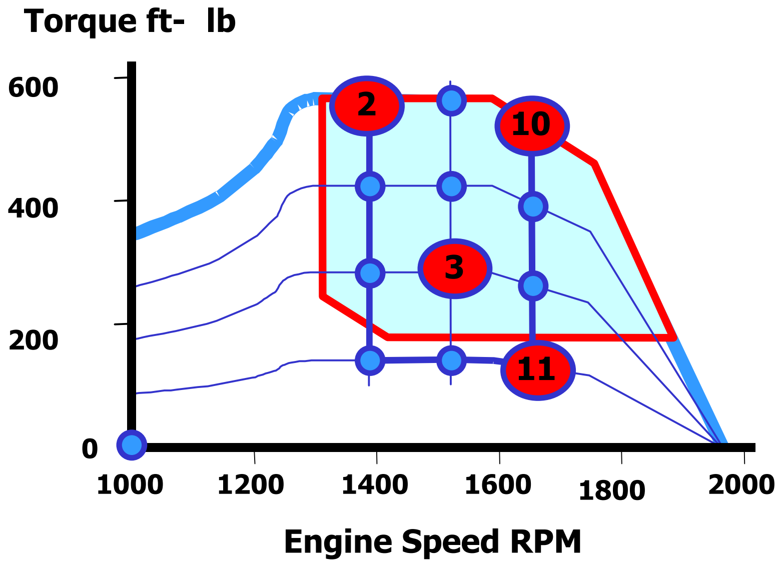


- 1999 International T444E
  - 7.3L OHV V-8
  - Direct injection, turbocharged w/ wastegate
  - 215 hp at 2400 rpm
  - 540 ft-lbs torque at 1500 rpm
  - Exhaust gas recirculation (retrofit)
  - Closed crankcase ventilation with filter
  - Lube system capacity: 18 quarts

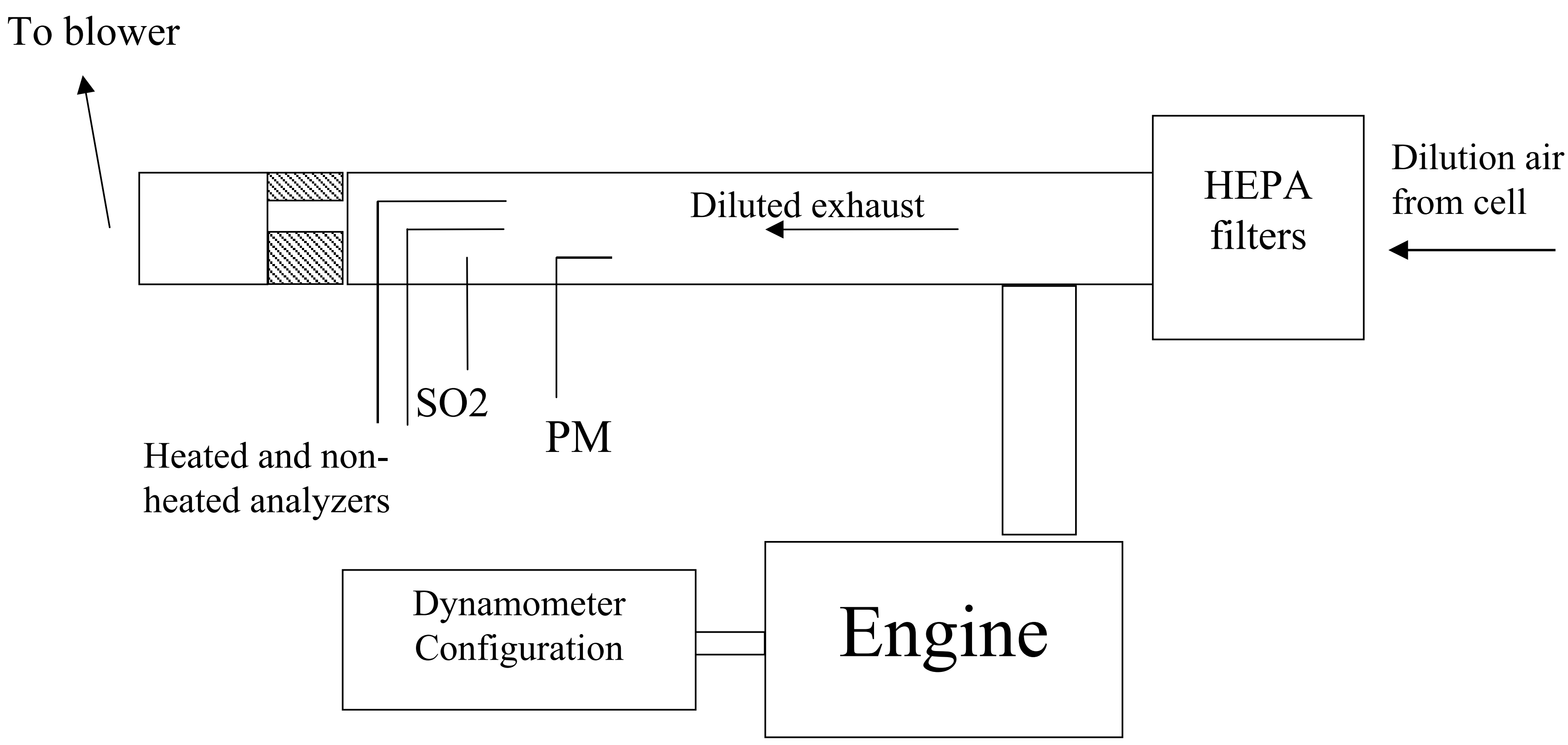
Emissions Measurements

- PM (three sample trains)
  - total weight
  - SOF and sulfate
  - metals
  - PAHs
- Four mode steady-state (OICA)

- NO_x
- SO_2
- Hydrocarbons
- CO



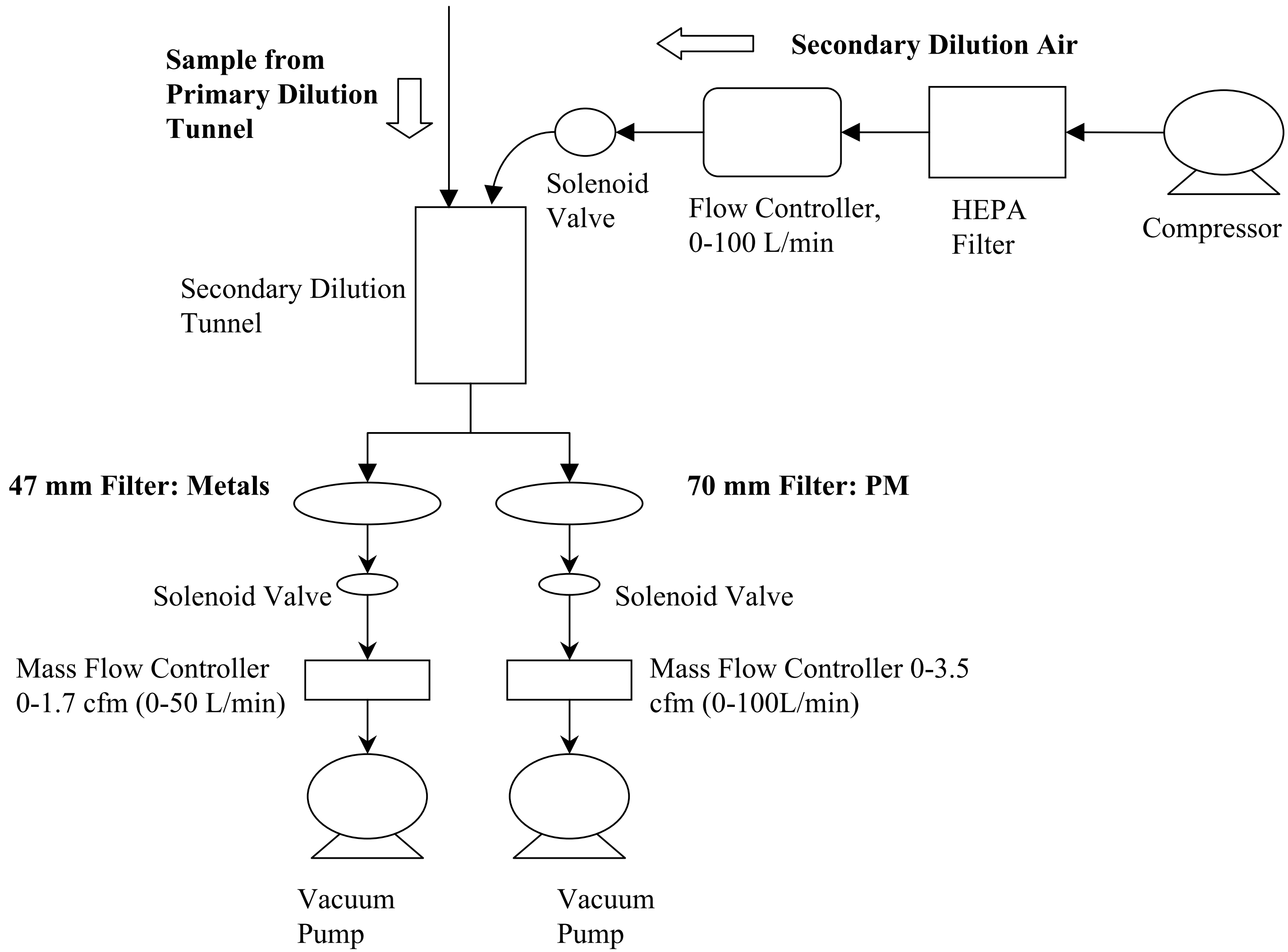
Test Cell Layout



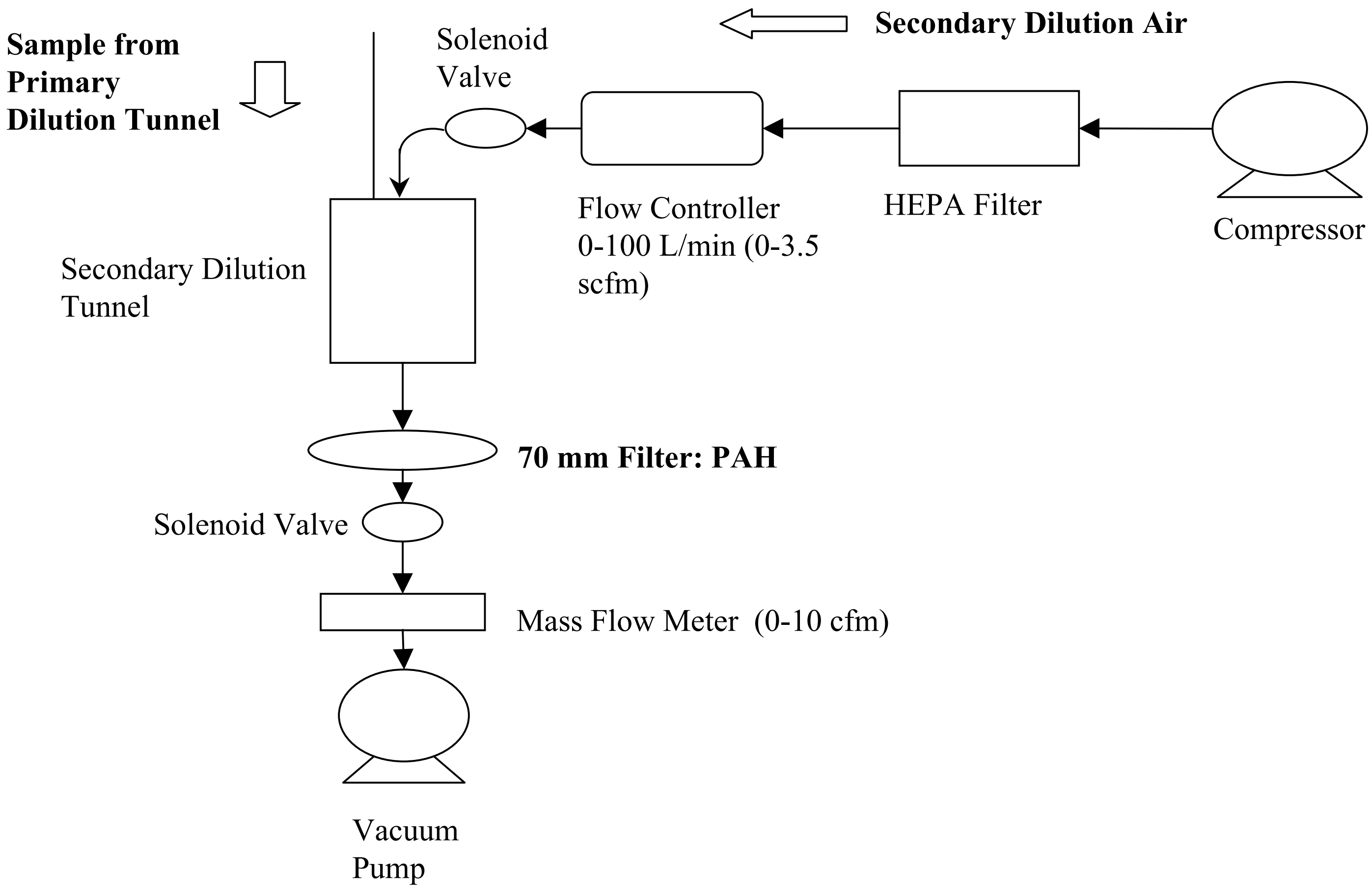
Particulate Matter Sample Collection

- Train #1: PM mass (ATL/ORNL)
  - 70 mm Pallflex ‘Emfab’ (glass fiber w/bonded PTFE)
  - analysis for sulfate and soluble organic fraction (ORNL)
- Train #2: PM Metals
  - 47 mm Gelman ‘Teflo’ (PTFE w/ PMP support)
  - determined by x-ray fluorescence (DRI)
- Train #3: Poly-cyclic Aromatic Hydrocarbons (PAH)
  - 70 mm Pallflex ‘Fiberfilm’ (glass fiber w/bonded TFE)
  - Determined by GC-MS (SwRI)

Sample Train 1&2 Configuration



PM Sample Train 3 Configuration



SO_2 Analysis - Overview

- SO_2 measured via impingement in aqueous hydrogen peroxide (wet chemistry method)
  - SO_2 converted to SO_4
- Modeled after EPA methods 6, 8, 16
- Post-test quantification of SO_4 concentration using ion chromatograph yields SO2 emission rate (exhaust flow measured)

Additive Systems Selected

Element	a	b	c	d	e	f	g	h	i	j	k	l	r
Ash Level (%)	1.2	0	1.2	1.5	1.85	0.75	1.4407	1.4016	0.6	1.4	0.3	0.23	1.35
S	0	5	4950	4500	6590	2785	3246	2921	4226	2224	20	725	4454
Ca	3484	0	3950	800	4770	1820	3130	3130	1748	4128	870	415	3412
Zn	0	0	0	1900	1560	860	1319	865	0	0	0	225	1269
N	0	950	2000	1200	970	1286	1182	1137	0	1560	2235	1457	855
P	0	670	600	1700	1420	760	1201	788	0	0	0	587	1156
B	1099	0	0	300	150	60	1235	143	0	0	985	176	0
Cl	100	0	<100	200	0	126	0	0	100	18	0	60	80
Mo	0	0	0	0	170	0	0	284	0	0	0	0	0
Mg	0	0	<50	1700	0	0	277	277	0	0	0	0	0

Reference Oil   Duplicate test

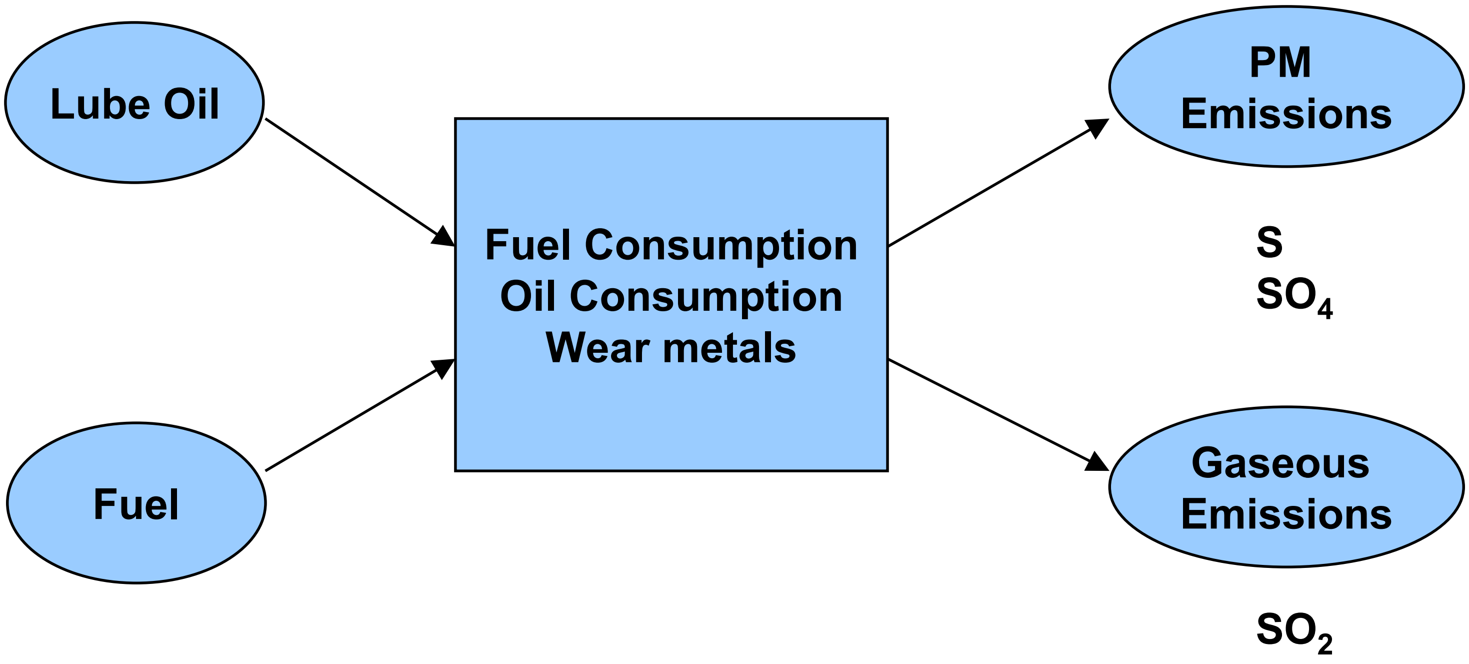
Additives supplied by:

Ciba, Chevron Oronite, Ethyl, Infineum, Lubrizol

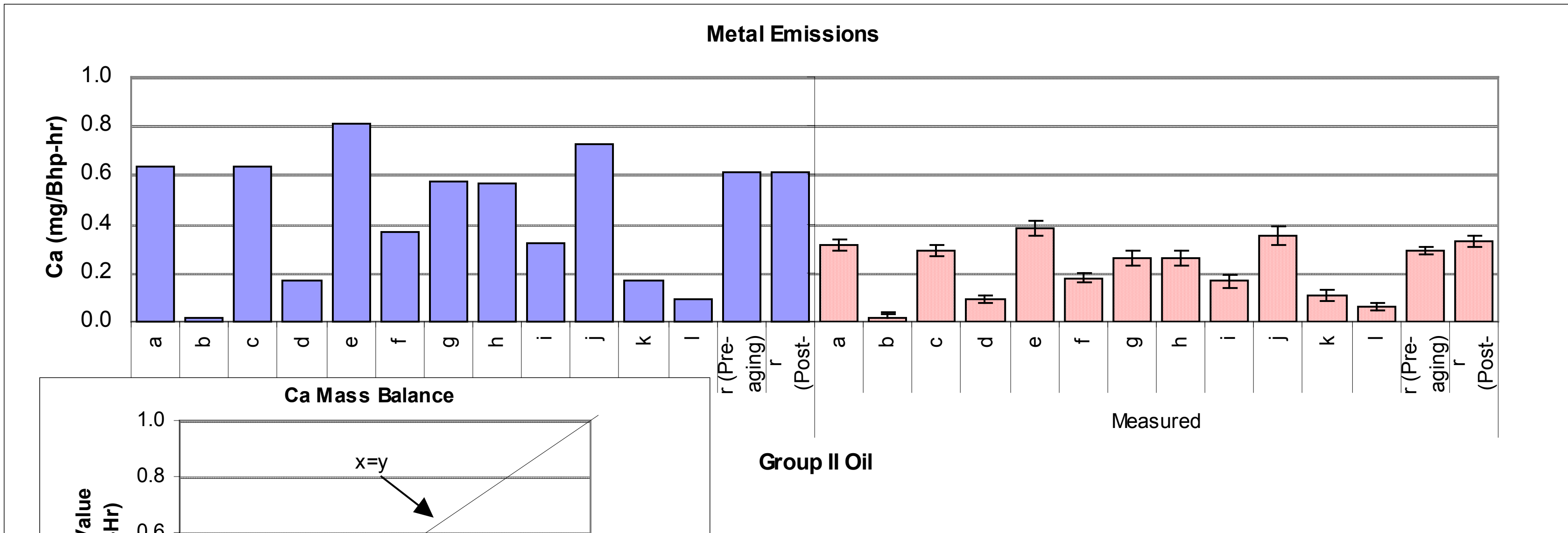
Base Oils Selected

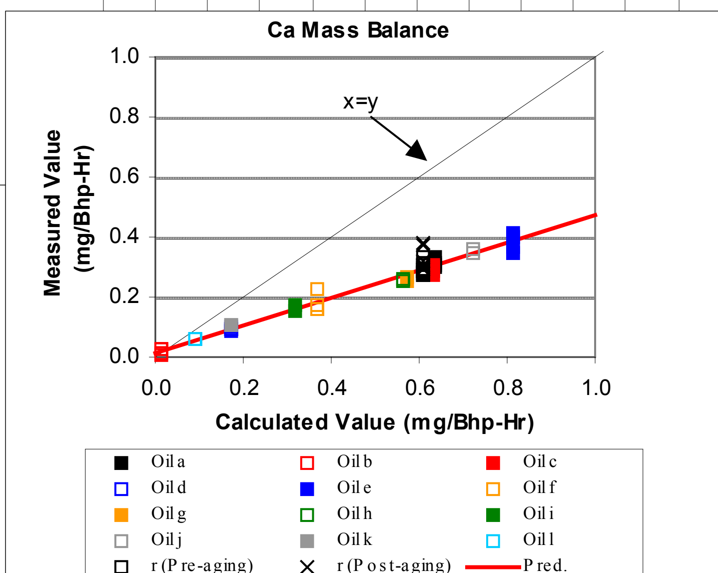
- Group I: Valero (Paulsboro)
  - 4800-5600-ppm S, 75% saturates
- Group II: Excel (Lake Charles)
  - <20-ppm S, >99% saturates
- Group III: Motiva (Houston)
  - <5-ppm S, >99% saturates
- Group IV: BP
  - PAO (poly-alpha olefin, synthetic)
  - 0 sulfur
  - 5% ester for additive solubility

Material Balance



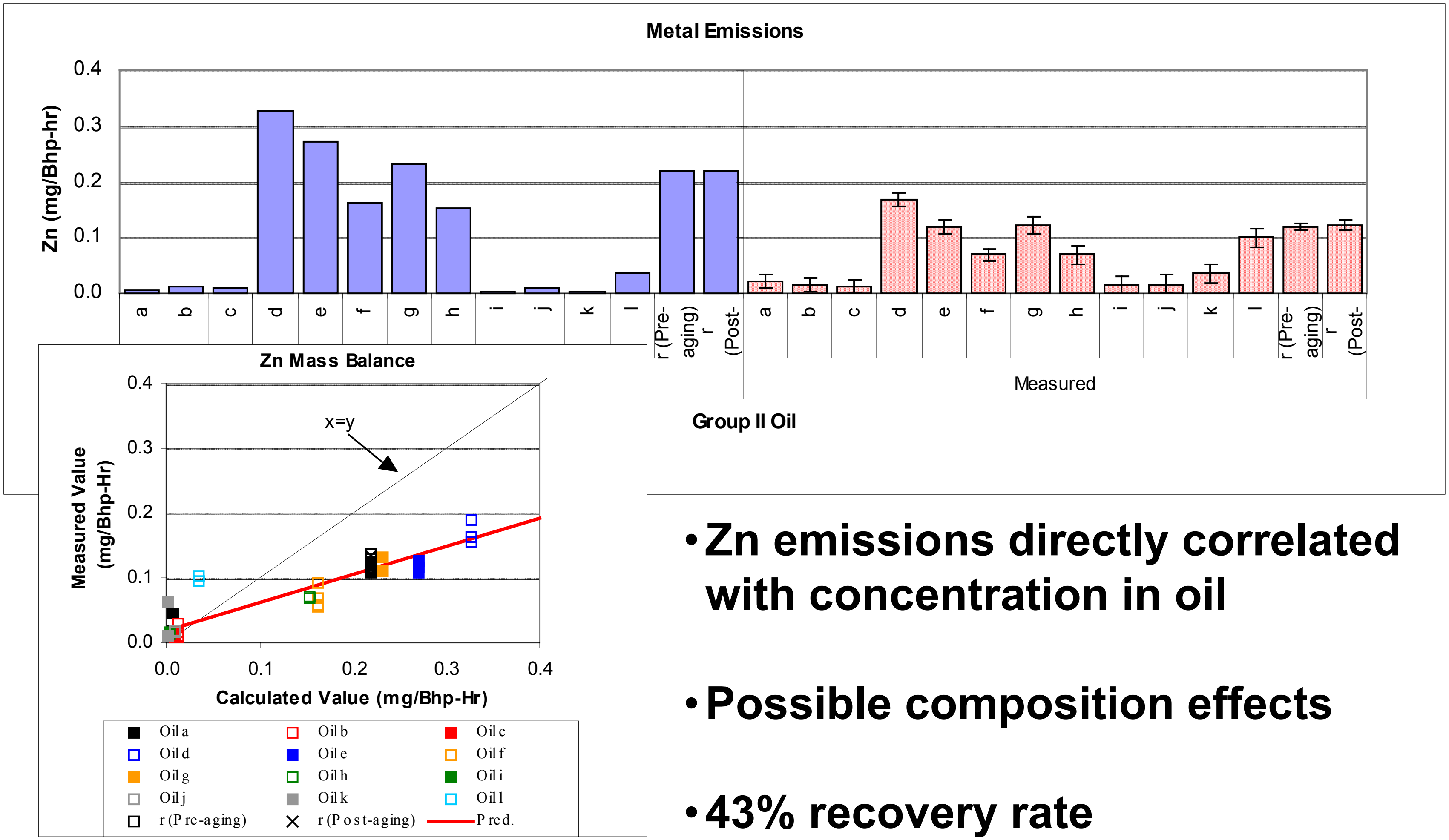
Ca in PM Emissions





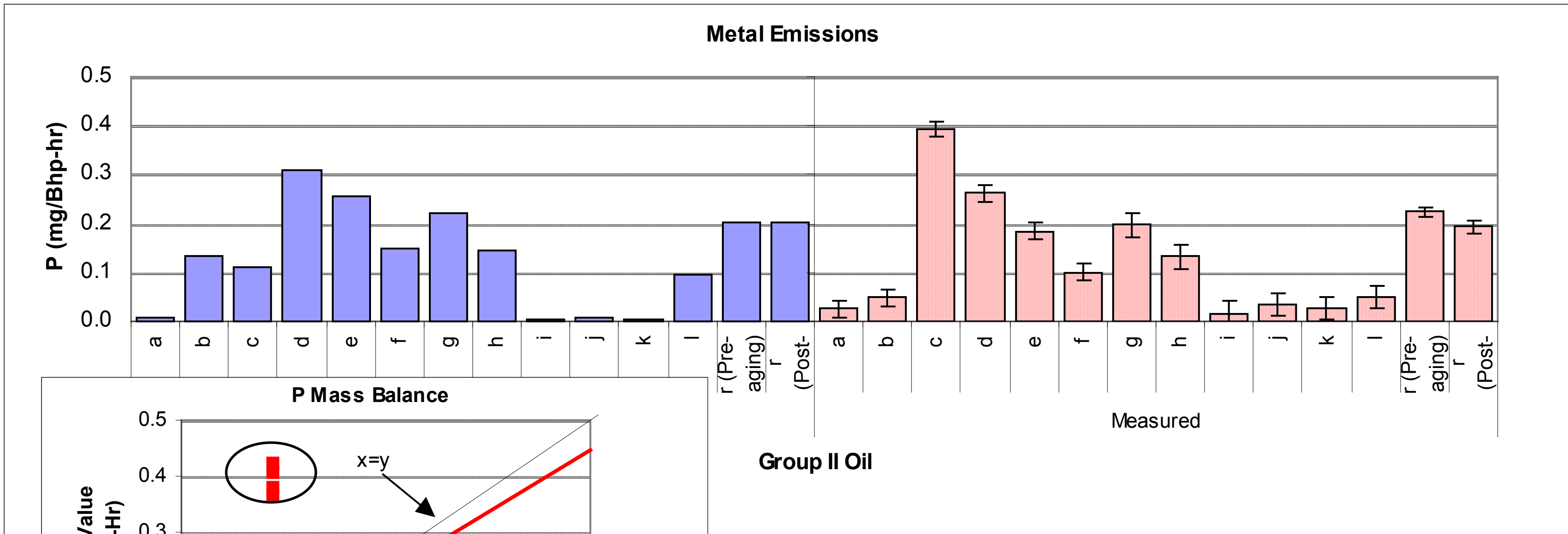
- Ca emissions directly correlated with concentration in oil
- No apparent composition effects
- 46% recovery rate

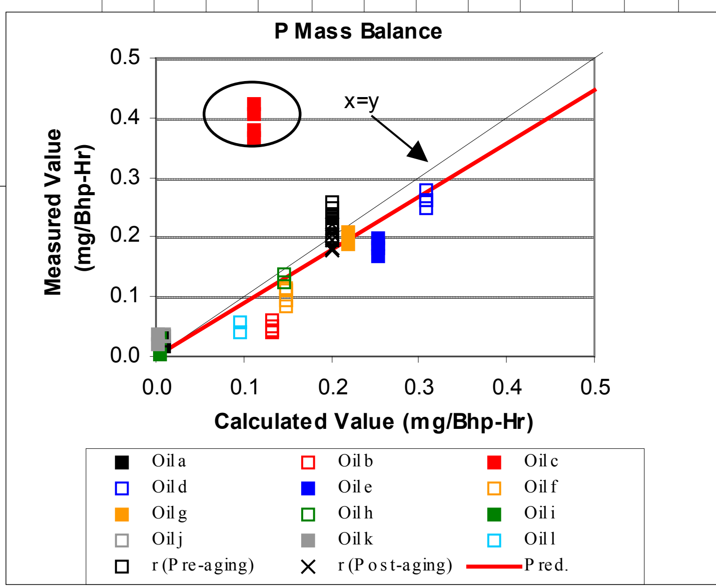
Zn in PM Emissions



- Zn emissions directly correlated with concentration in oil
- Possible composition effects
- 43% recovery rate

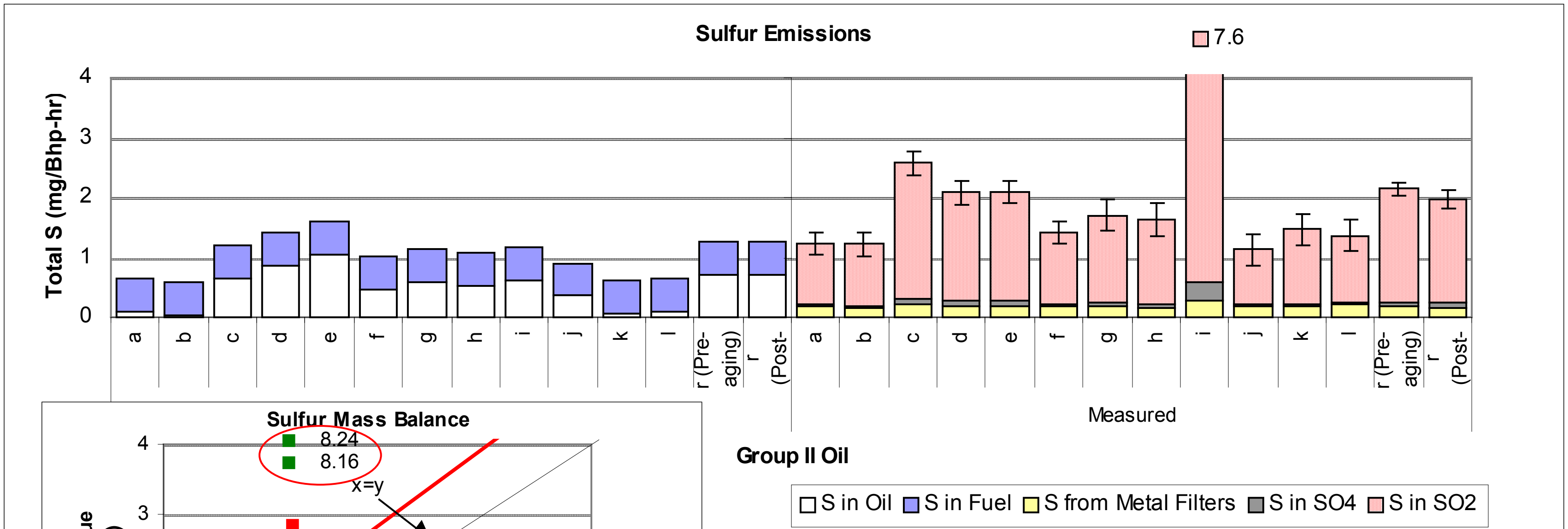
P in PM Emissions

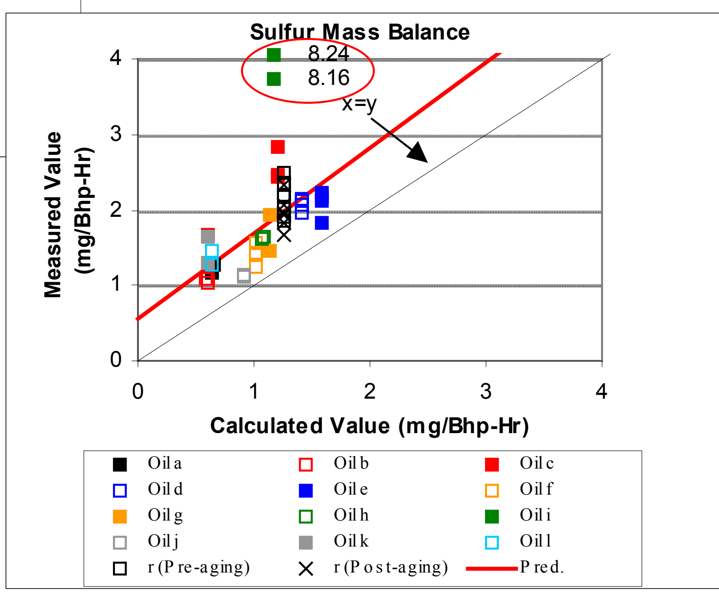




- P emissions directly correlated with concentration in oil
- Oil C significantly deviates
- 90% recovery rate (excl. Oil C)

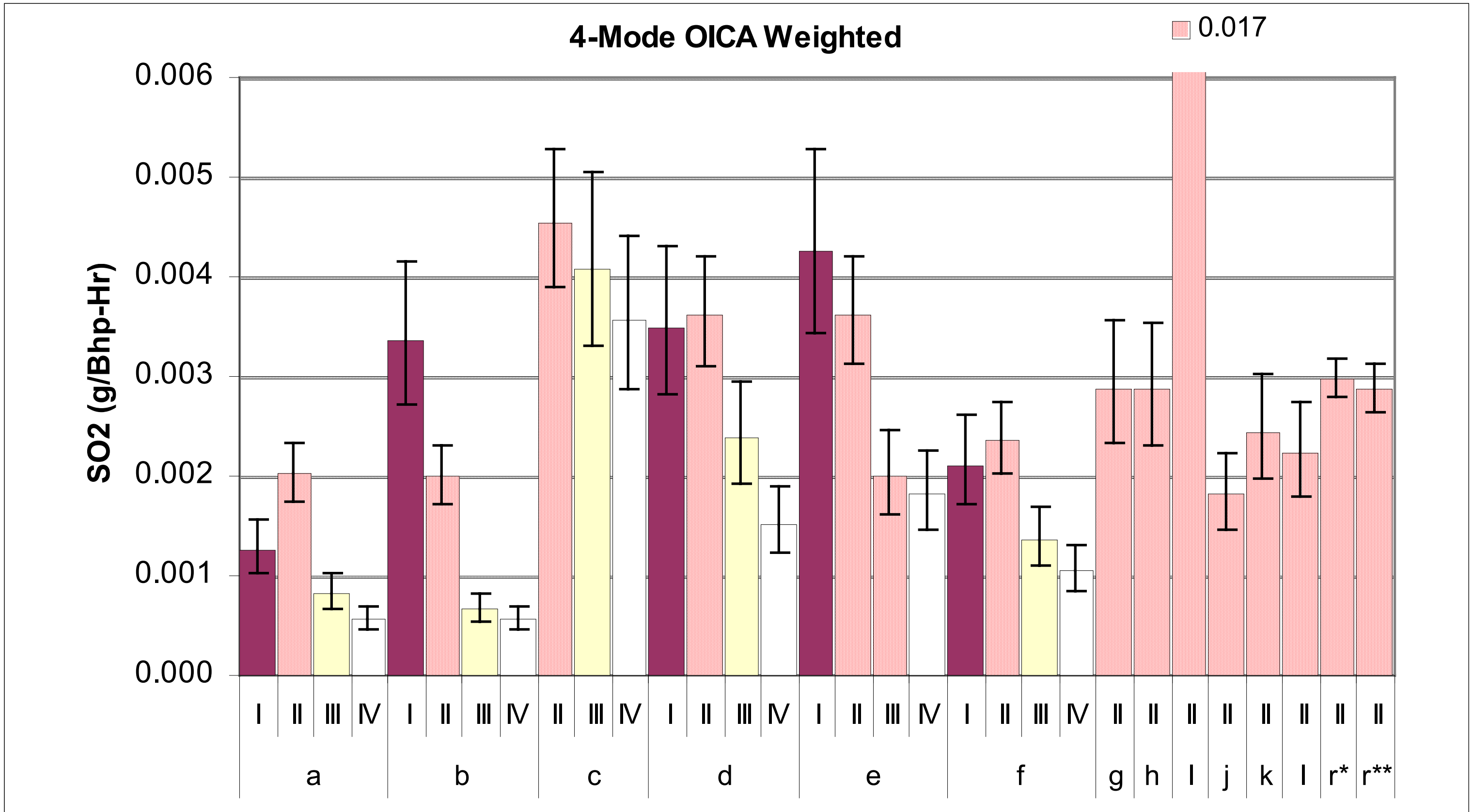
Sulfur in Emissions





- S emissions directly correlated with concentration in oil
- Oil l significantly deviates
- 113% recovery rate (excl. Oil l)
  - uncertainty in fuel S level

Base Oil and Additive Effects on SO_2 Emissions



*Pre-aging.
**Post-aging.

ATTACHMENT 6, 19 OF 21

Summary

- Preliminary results show the effects of oil composition on selected emissions, including metals and sulfur
- Results indicate that emissions from certain formulations deviate from those using more traditional chemistry
- Data from all additive/basestock combinations are currently being analyzed and will be reported in late summer.
- Phase II will focus on development of a rapid catalyst aging protocol to determine lubricant effects on durability

Acknowledgements

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