

Balancing Oil Formulations
for
Fuel Economy & Robustness

July 30, 2009

Summary

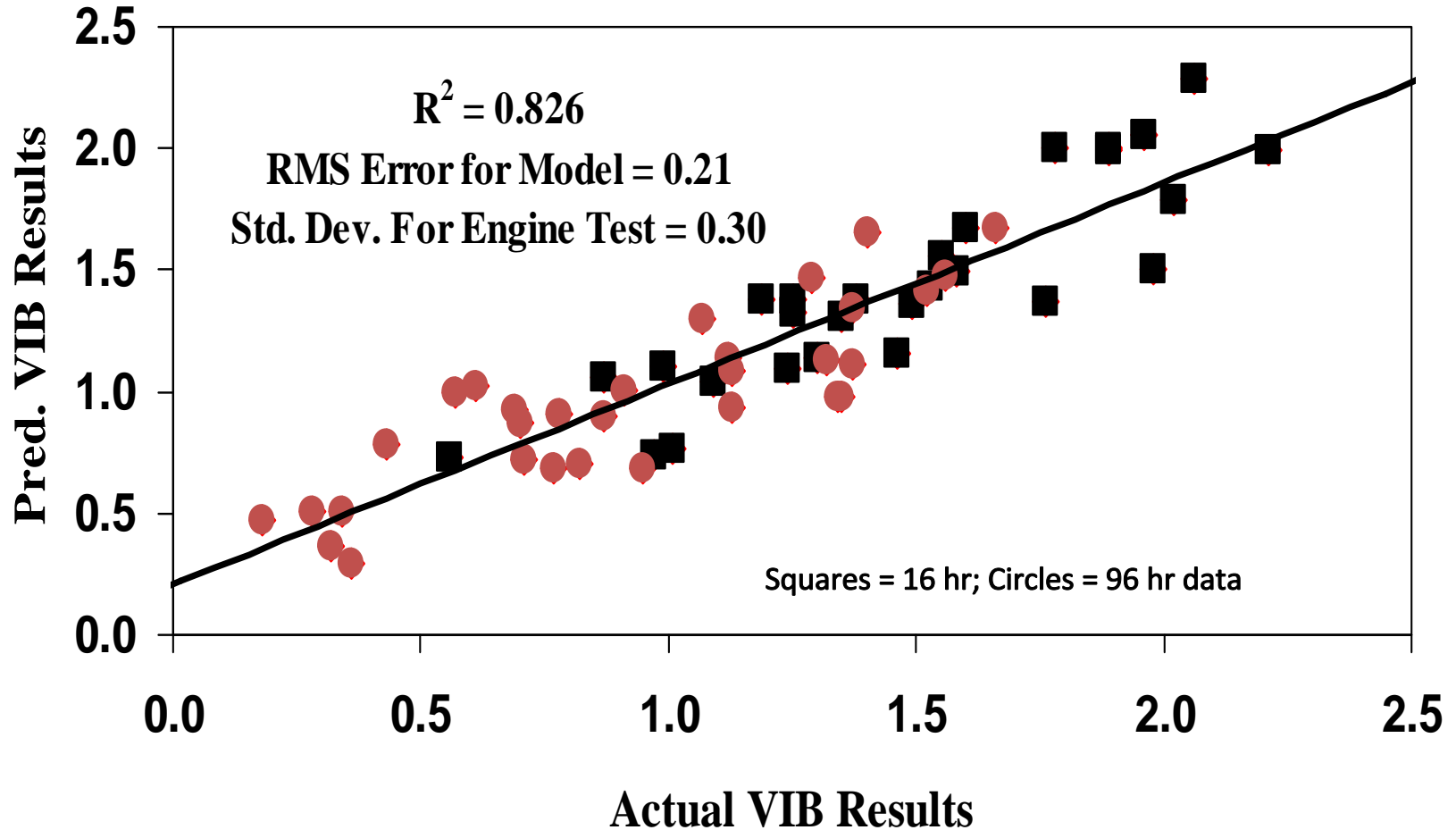
- Fundamental Formulation Studies
- Previous VIB Presentations
- ACC is working towards gathering data on IIIG WPD versus Fuel Economy in the VID. The goal is to have a presentation to ILSAC/Oil sometime in September 2009.

Fundamental Friction Studies

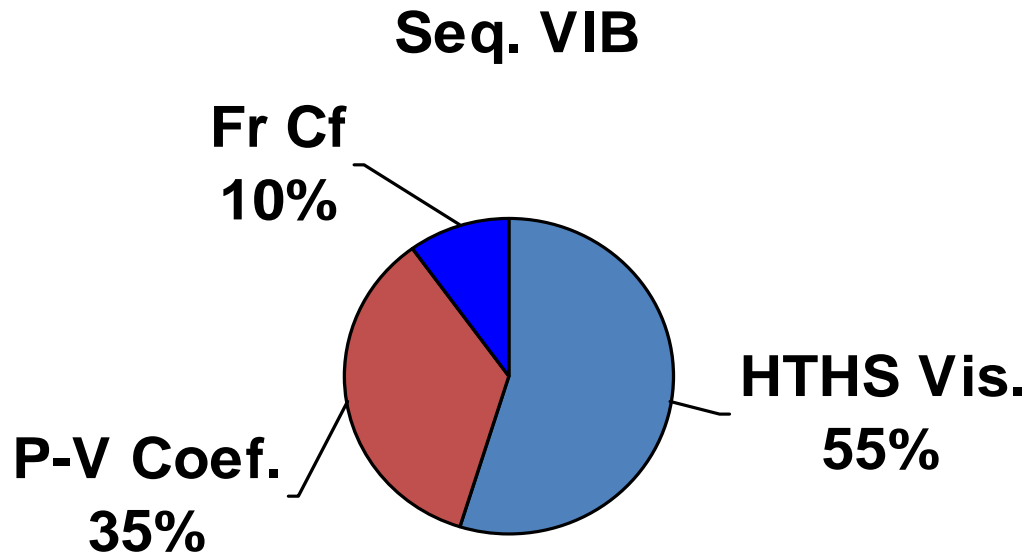
- Various Engine and Vehicle Tests Exist to Measure Fuel Economy Improvement. The improvement obtained with oil formulations depends on the which lubrication regimes are emphasized during the engine tests.
- A Reduction in Oil Viscosity, Boundary Friction, Pressure-Viscosity Coefficients and Thin Film Friction have been Related to Improvements in Fuel Economy.
- A correlation was established between basic fluid properties and fuel consumption in the Sequence VI B test*
 - HTHS viscosity
 - Boundary Friction Coefficient
 - Pressure viscosity coefficient
 - Thin film friction

* Bench Test Modeling for Current and Future PCMO FE Requirements, Devlin M.T., et al. 2007

Effect of Oil Properties on Fuel Economy Measured in the Sequence VIB Engine Test



Effect of Critical Physical Properties on Fuel Economy



ADDITIVES IMPROVE OIL PERFORMANCE

GF-4 Engine Test
that Stresses
Property

Additive

Function

Dispersants

Sludge and
varnish control

VG

Metal detergents

Rust control

BRT

Antioxidants

Oxidation control

IIIG

Antiwear agents

Valve train wear

IIIG, IVA

Friction modifiers

Fuel economy

Sequence VIB

Viscosity modifiers

High-temperature
high-shear viscosity

VIII, VIB

Detergents

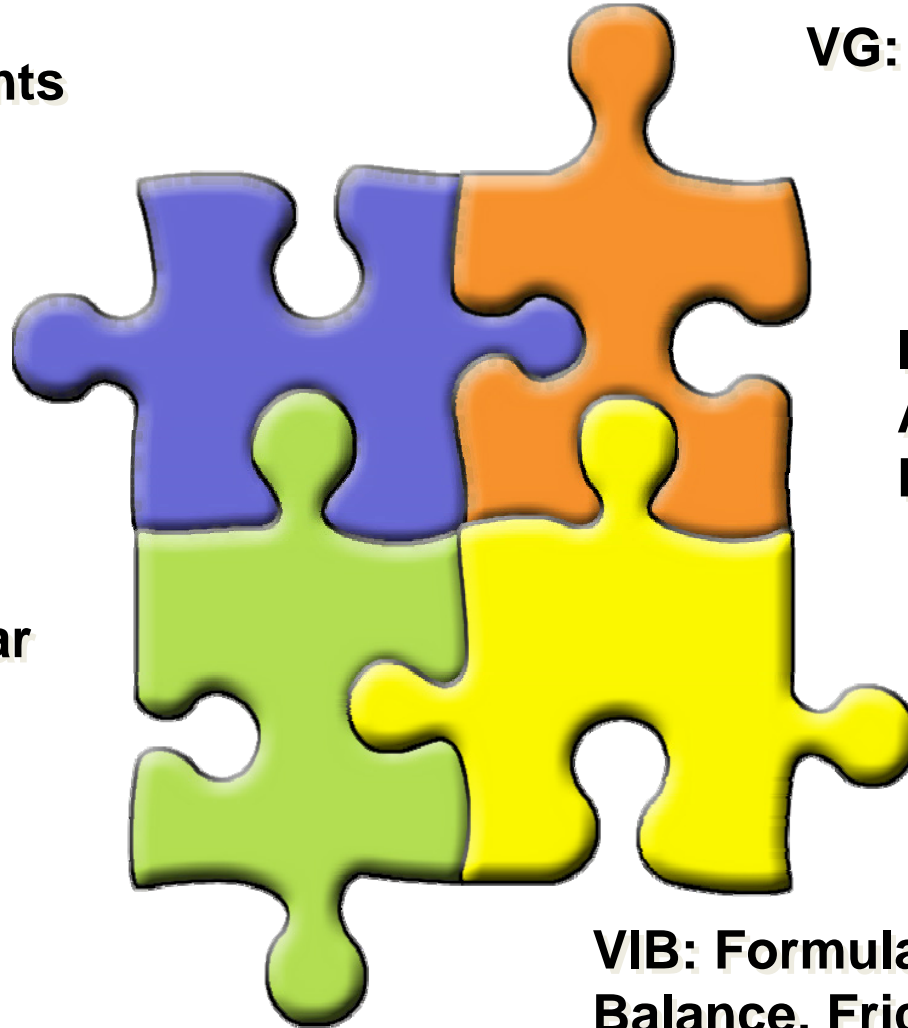
Piston deposits

IIIG

FORMULATION BALANCE

BRT: Detergents

VG: Dispersant



**IIIIG:
Antioxidants,
Deposit Control**

IIIIG/ IVA: Antiwear

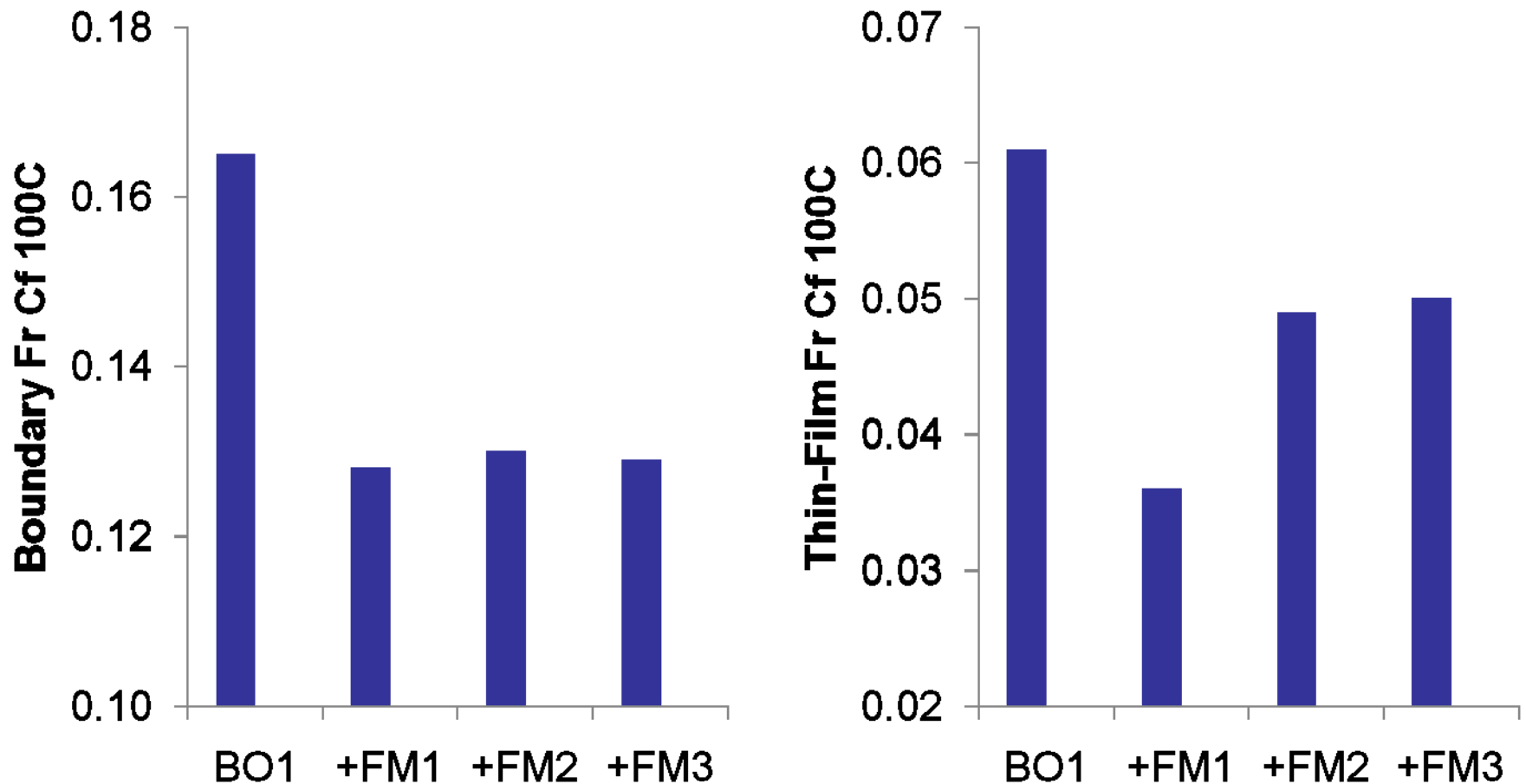
**VIB: Formulation
Balance, Friction
Modifiers**

FORMULATION BALANCE SEQUENCE VIB

- Base oil viscosity
- Base oil viscosity index
- Viscosity Modifier treat rate
- Optimized components
- Friction modifiers

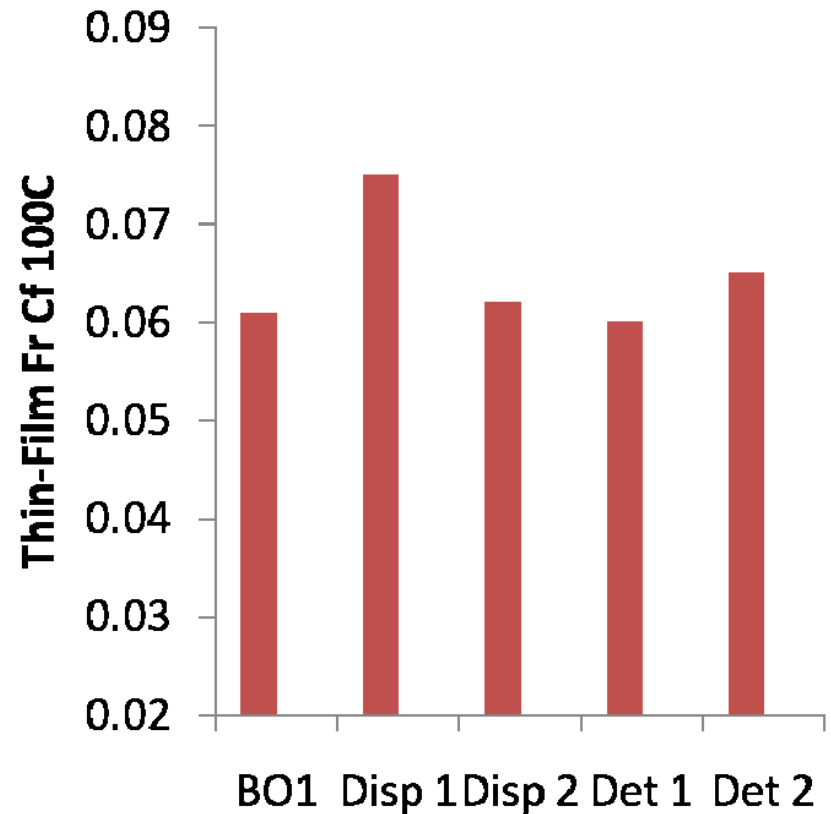
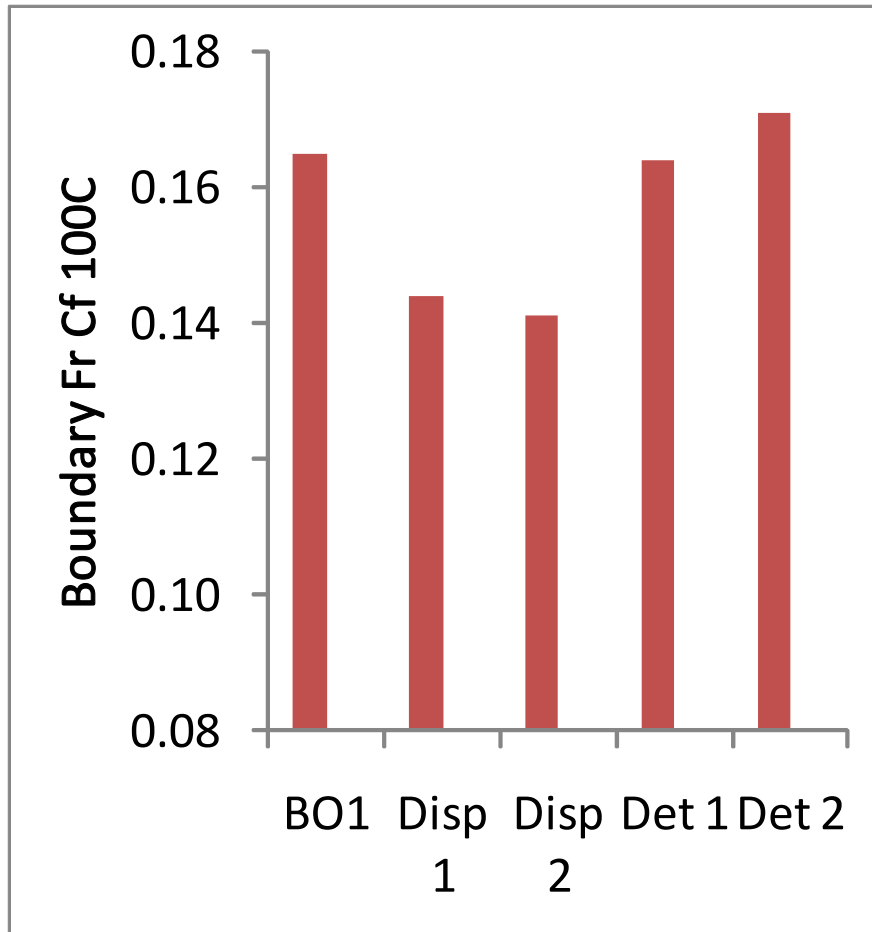


Effect of Friction Modifiers on Friction



* Bench Test Modeling for Current and Future PCMO FE Requirements, Devlin M.T., et al. 2007

Effect of Detergent and Dispersant Additives



* Bench Test Modeling for Current and Future PCMO FE Requirements, Devlin M.T., et al. 2007

FRICITION/FUEL ECONOMY BALANCE FOR CRANKCASE ENGINE OILS

	Hydrodynamic Region (<u>Bearings</u>)	Boundary Region (Piston Ring/Cylinder) (<u>Camshaft/Valve Lifter</u>)
Large temporary viscosity loss of VI or low viscosity	Credit	Debit
Boundary friction modifier	No effect	Credit
DI components	No effect	Credit or debit

Improved fuel economy based on balanced reduction
of both hydrodynamic and boundary friction

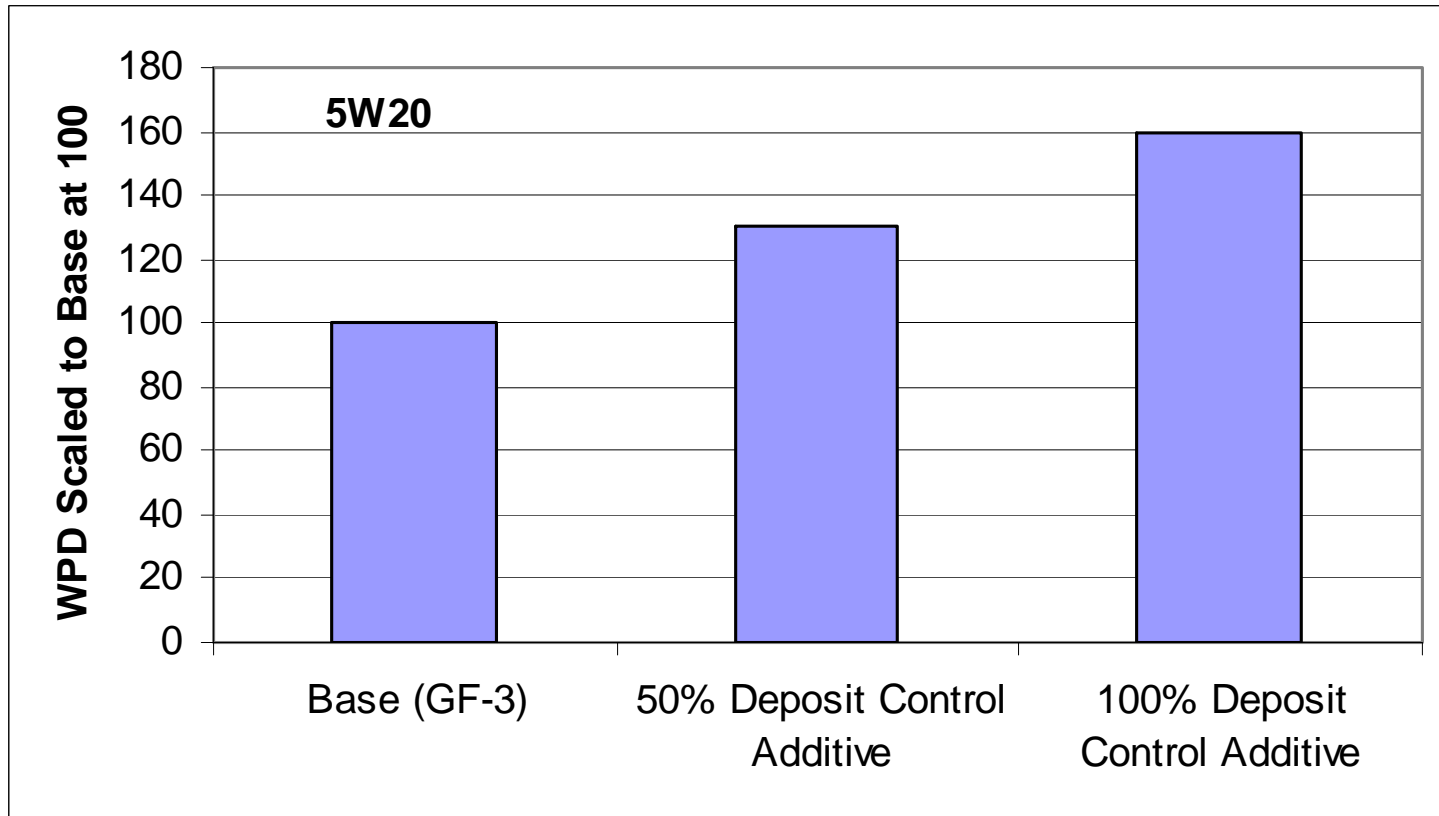
Balancing Sequence IIIG & Sequence VIB

Presentations from GF-4

Sequence IIIG

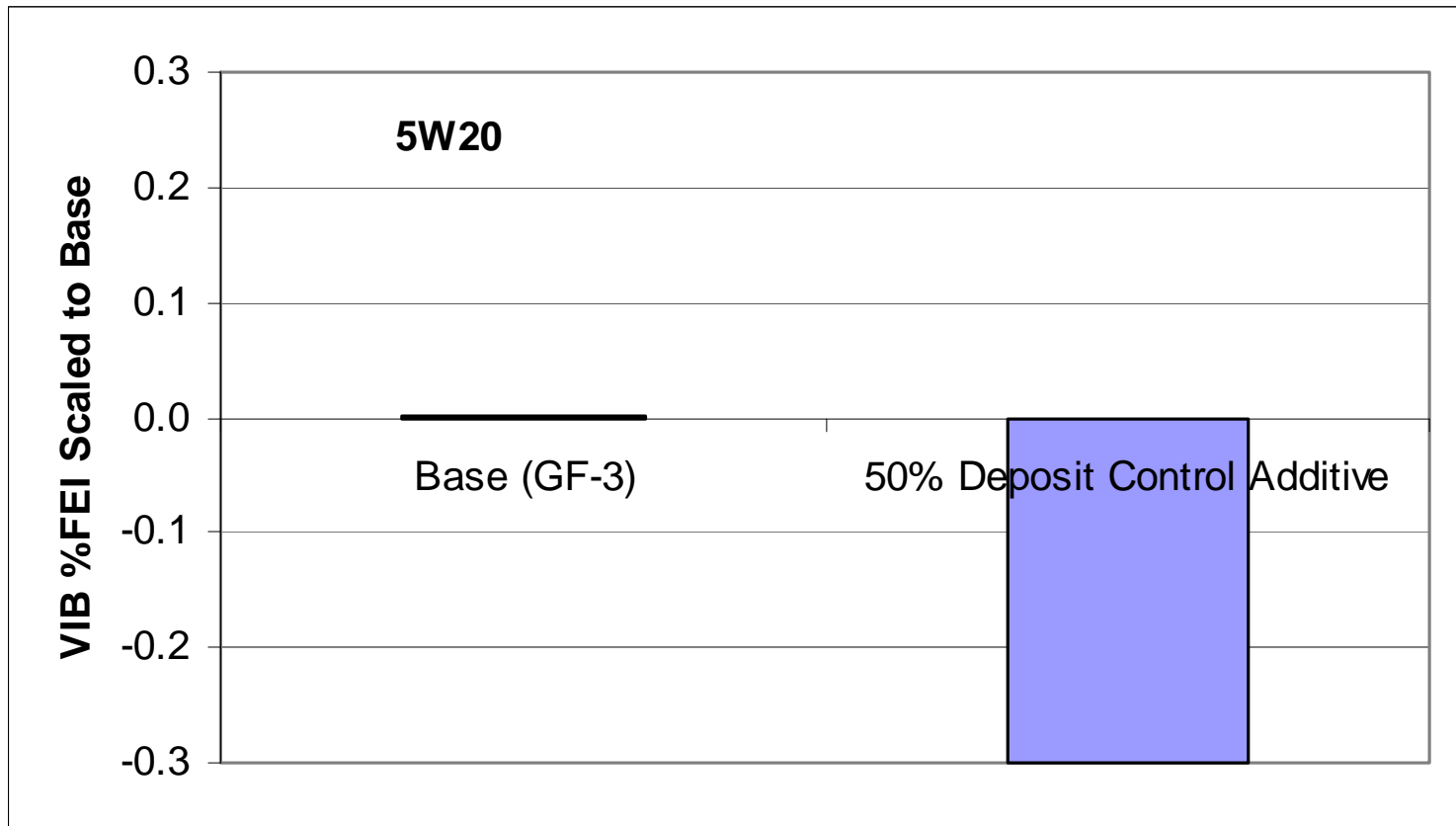
Weighted Piston Deposits Response

- ◆ An increase in deposit control additives is needed to pass Sequence IIIG WPD



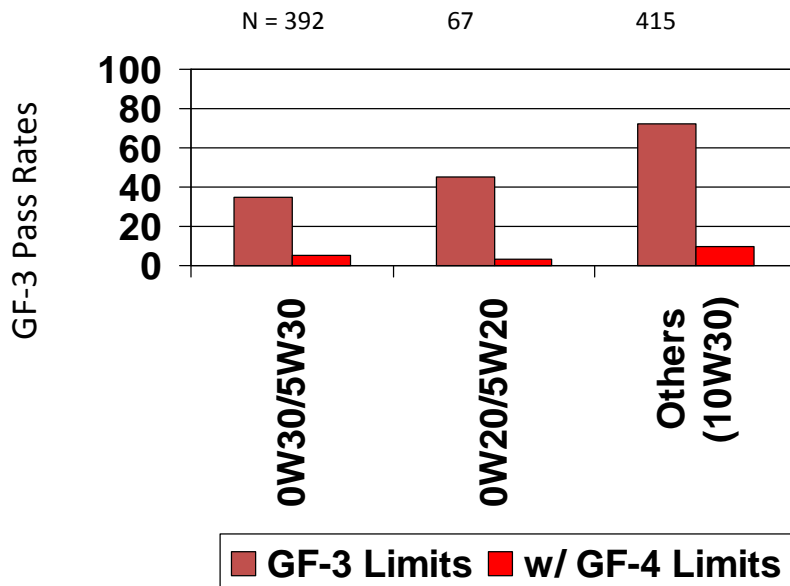
Sequence IIIG vs Sequence VIB

- ◆ There is a balance between Fuel Economy Performance and Deposit Control



Sequence VIB FEI Limits Increase

- +0.4 % increase in limits for all grades relative to GF-3 limits is extremely challenging



Pass rates against GF-3 limits from RSI database (all registered VIB tests)

Pass rates at GF-4 limits (+0.4 %) are from the independent laboratories (all registered VIB tests at independent laboratories)

- Formulation options are limited for improvement
 - ✓ Friction modifier effects are already saturated
 - ✓ Viscometric effects are limited by J300
 - ✓ Sequence IIIG limits will introduce additional constraints

Sequence IIIG Limit Impact on Attainable VIB Performance

- GF-3/**GF-4** technology performance in Seq. IIIG WPD & VI-B %FEI:

	<u>pre-matrix</u>	<u>matrix (5/28)</u>	<u>%FEI</u>
ASTM 433 (5W-30)	3.07 (n=3)	-----	
ASTM 538 (5W-20)	3.09 (n=4)	3.31 (n=7)	1.89/1.55
TMC 434 (5W-30)	4.02 (n=5)	4.30 (n=6)	1.8/1.4 (n=1)
TMC 435 (5W-20)	3.13 (n=3)	3.40 (n=7)	2.4/2.1 (n=1)

- Improvements in deposit protection will require the addition of dispersants and detergents. These additives will have a negative impact on Sequence VI-B pass rates
- ASTM 538 average FEI is actually below GF-3 limit
 - 5W-20 GF-3: FEI-1=2.0% min.; FEI-2=1.7% min.
- For a given base oil system, ACC estimates -0.3% to -0.4% FEI debit incurred in Seq. VI-B to improve Seq. IIIG WPD from 3.0 to 4.0 rating.

Conclusions

- Fuel economy improves when a crankcase oils' viscosity, boundary frictional properties, pressure-viscosity coefficient and/or thin-film or mixed frictional properties are reduced.
- Surface active agents such dispersants and detergents affect boundary and thin-film friction. Therefore, the effects of all additives and not just friction modifiers need to be considered when formulating a crankcase oil with optimized fuel economy properties