



High Performance Heavy Duty Diesel Engine Oils with RLI Patented Technology and PAO Blends

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Orlando, FL

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Photo Courtesy of USB/soybean check off

Overview

- Base Oil Evaluation
(Vegetable Oils and PAOs)
- Physical Property Focus Areas: *Oxidative Stability, Viscosity Index*
- Physical Properties of Formulated Oils
- Field Trials (PARTA & Ford F-250)
- Historical use of Bio-Synthetic Oils in Transportation
- Summary

Base Oil Evaluation

- Physical Properties
 - Viscosity, VI, Volatility, Pour Point
- Chemical Properties
 - Compatibility, Oxidative and Thermal stability
- Lubrication Properties
 - Lubricity, additive solubility
- Environmental Friendliness
 - Renewability, Biodegradability, Biobased
- Cost



There is no one perfect basestock but the focus is in providing a balance of the desired and deleterious properties



Obtaining A Balance

Characteristics of Vos

(Not Stabilized with RLI Patents)

- + Biobased
- Poor oxidative stability
- Poor hydrolytic stability
- Poor cold temperature pumpability
- + Additive Solubility
- Limited ability to formulate to many viscosities
- + Environmentally Friendly, Biodegradable
- + Very high VI (>200)

Characteristics of PAOs

- ± Some are Biodegradable
- + Excellent oxidative stability
- + Hydrolytically stable
- + Excellent low temperature viscometrics and pour points
- + Wide range of viscosities
- Cost
- Limited availability



Physical Properties

Base fluid	Viscosity 100 °C, cSt	Viscosity 40 °C, cSt	Viscosity Index	Noack Volatility	Biodegradable %
Soybean ¹	7.6	31	227	<1%	75-100
Sunflower ¹	7.7	31.6	226	<1%	75-100
Corn ¹	7.7	31.9	223	<1%	75-100
Rape seed oil ¹	9.1	40.3	217	<1%	75-100
High oleic sunflower ²	8.8	39	210	<1%	70-100
PAO 4	3.9	16.9	123	12.5%	50-60
PAO 6	5.9	30.5	138	6.5%	20-28
Mineral oil ²	4.37	22.7	98	23%	15

Biobased oils and PAOs provide High VI and reduced volatility

References for Table:

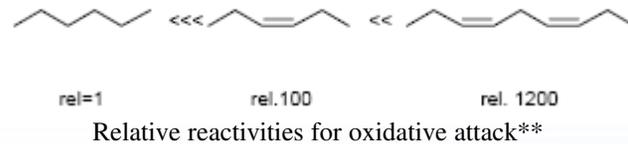
1 - L.R.Rudnick in Ed. S.Z.Erhan, J.M.Perez, *Biobased Industrial Fluids and Lubricants*, AOCS Press, Champaign, Ill., USA 2002, p.51.

2 - M. Schneider, P. Smith, Government-Industry Forum on Non-Food Uses of Crops (GIFNFC 7/7) Case Study: Plant Oil Based Lubricants in Total Loss & Potential Loss Applications, Final Report, May 16, 2002, p. 20.



Oxidative Stability

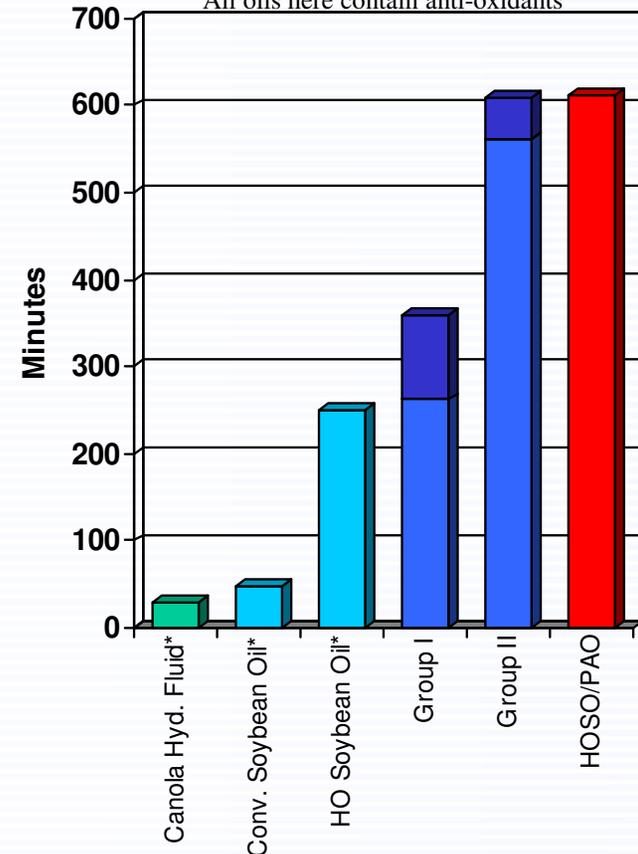
- Although some unsaturation is required for low temperature fluidity, increased oleic content in VOs provides a site for oxidative attack



- PAOs are highly saturated highly branched hydrocarbons that can substantially increase the oxidative stability in blends

RPVOT Data

All oils here contain anti-oxidants



* J. L. Glancey, S. Knowlton, and E.R. Benson. Development of a high oleic soybean oil-based hydraulic fluid. *Feedstocks (United Soybean Board Publication)* 4: 1-2, 1999.

** M. Schneider, P. Smith, Government-Industry Forum on Non-Food Uses of Crops (GIFNFC 7/7) Case Study: Plant Oil Based Lubricants in Total Loss & Potential Loss Applications, Final Report, May 16, 2002, p. 29.



Bio-Based Engine Oils

- **What is a Bio-Based Engine Oil?**
 - Currently, no definition for engine oils, but 2-cycle engine oils must have a minimum biobased content of 34% according to the final rule of 7 CFR Part 2902 (May 14, 2008)
- **Bench Tests:**
 - Noack, MRV, TEOST, Pour Point, CCS
- **Field Tests, (Portage Area Regional Transit Authority (PARTA) and Ford F-250):**
 - Wear Metals
 - Viscosity monitoring
- **Historical Experience**
 - Racing, Marine, Agricultural, Public Transportation and Industrial Engines



Blending Bio-Synthetic SAE 15W-40 Motor Oils

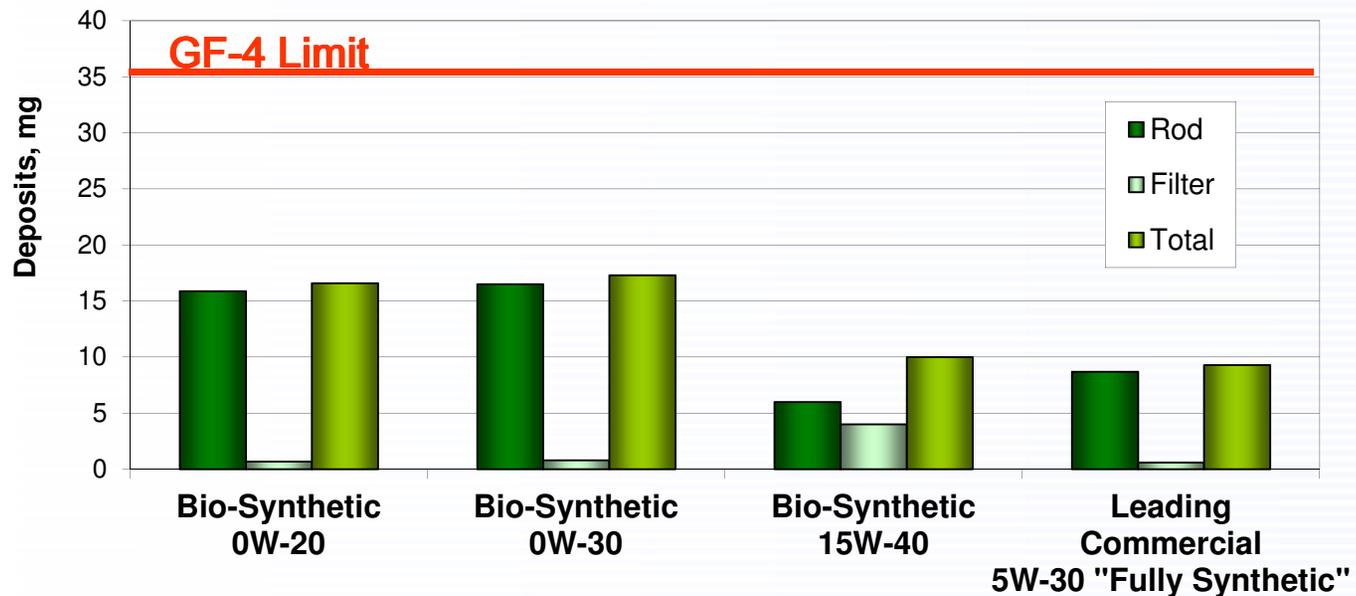
	40% Biobased Content		CJ- 4
Test Description	Commercial	Bio-Synthetic	Limit
Viscosity, cSt @ 100°C	15.2	15.8	12.5-16.3
Viscosity, cSt @ 40°C	118	103	
Viscosity Index	134	155	
Flash Point (COC), °C	199	225	
Specific Gravity	0.879	0.89	
Pour Point, °C	-30	-35	
MRV, cP @ -35°C		13000	25000
yield stress, Pa		<35	<35
CCS @ -20°C, cP	6500	Max 7,000	Max 7,000



Thermo-Oxidation Engine Oil Simulation Test (TEOST MHT)

ASTM D7097-05

- The deposits are somewhat higher for the 0W oils, but the levels are well below the GF-4 Limit and the 15W-40 oil is on par with a leading commercial synthetic 5W-30.
- 40% of the base oil content is Biobased



Field Trials

PARTA Buses

PARTA (Portage Area Regional Transit Authority – Kent, OH) 72
Buses using 15W-40 for over 1 year
Cummins Engine (# Oil Analyses): ISM (10), ISB (7), ISL (15)
Detroit Diesel Engine (# Oil Analyses): 6V92 (20) & Series 50 (7)
Bus length (#): 30ft (2), 35ft (5), 40ft (1)



Ford F-250 Turbo Diesel

7.3 liter
235 hp @ 2,700 rpm
500 lb-ft. @ 2,700 rpm
Over 110 K miles on soy based engine oil

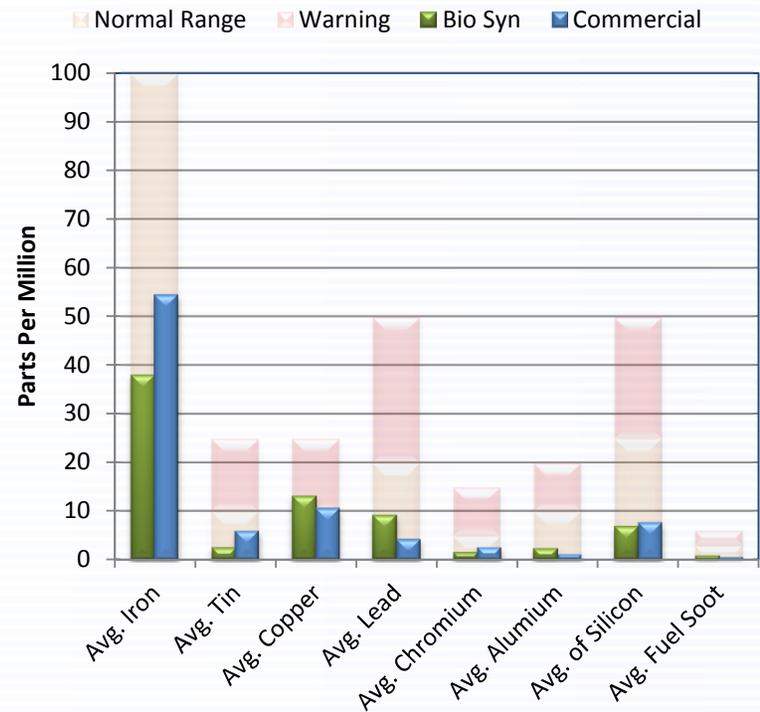




PARTA Field Trials

- Ohio area year round service over 1 year with eight buses and 26 and 22 oil analyses for Bio-Synthetic and Commercial oil analyses, respectively.
- The engine oil analysis shows comparable levels of wear metals. The normal range and warning levels are superimposed.
- The soot level is also low for both oils.

Wear Metal Analysis for 15W40 Oils



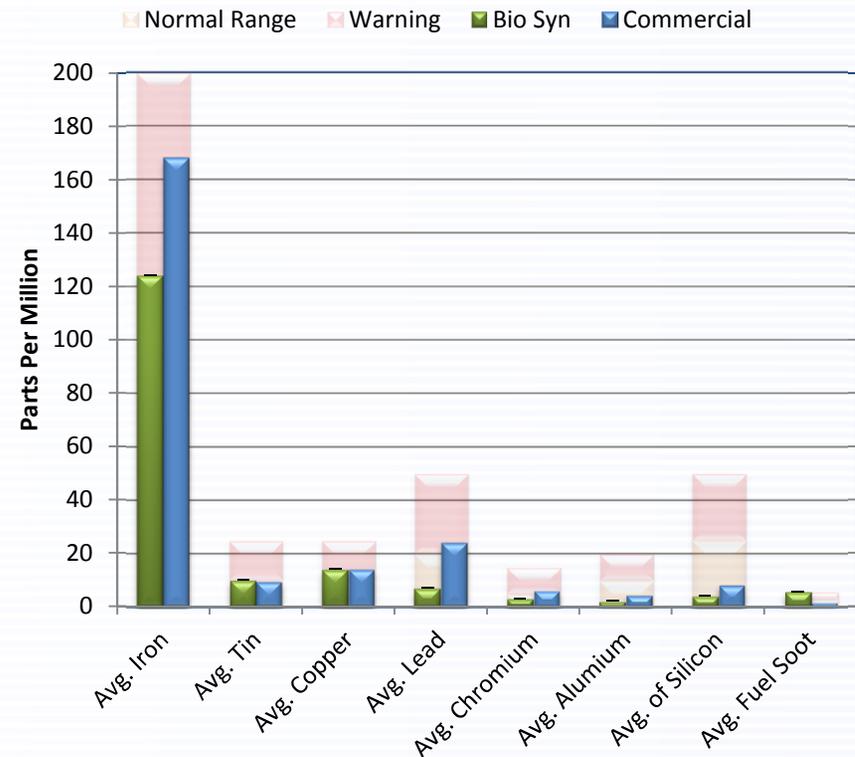
The wear element aluminum reflects piston wear, iron reflects cylinder wear, copper and lead reflect bearing wear, and chromium reflects ring or cylinder liner wear. Silicon was also examined as this reflects the wear material that moves through the air filter and into the engine.

PARTA Field Trials (cont'd)



- Ohio area year round service over 1 year with eight buses and 9 oil analyses for Bio-Synthetic and Commercial oil analyses.
- The engine oil analysis shows lower Fe and Pb levels for the Bio-Synthetic oil while all other wear metals show similar levels.
- The soot level is again low for both oils.

Wear Metal Analysis for 15W50 Oils

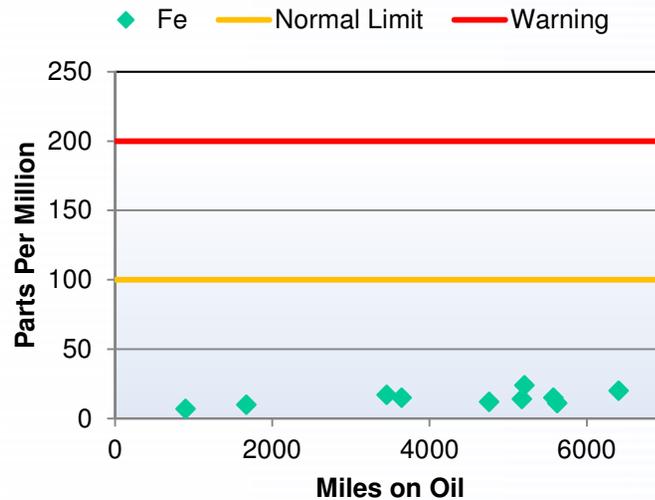




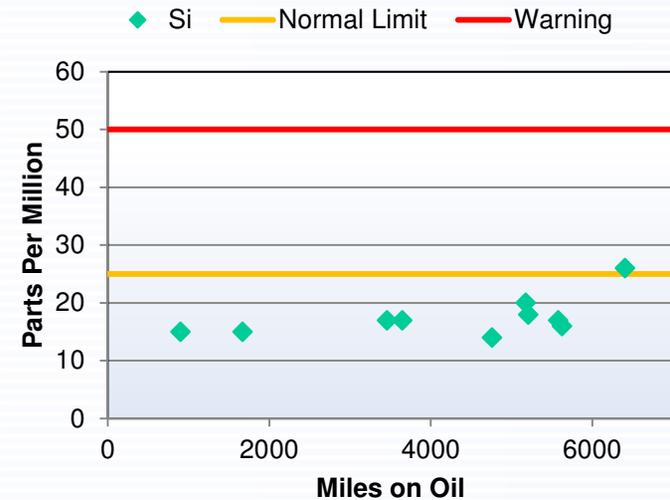
Ford F-250 Field Trials

Wear Data

Wear Metals: Iron



Wear Metals: Silicon



- F-250 field test had year round service with frequent start/stop cycles and both highway and city driving.
- The engine oil analysis shows low average Fe content with some marginal silicon levels at higher oil mileage.
- Iron wear metals would indicate cylinder wear if present

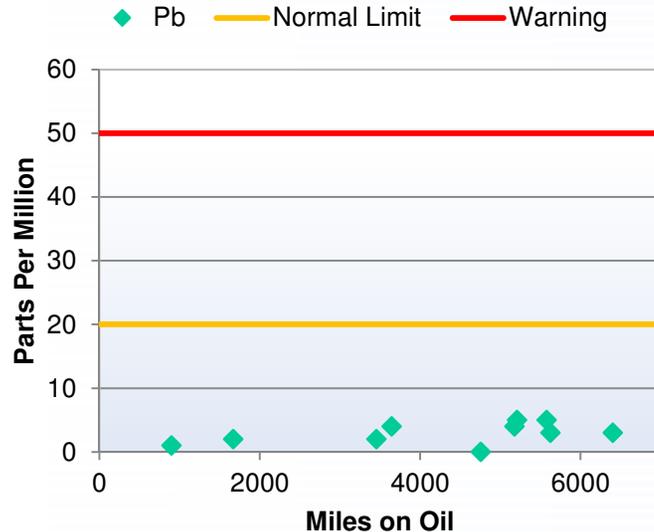
Oil Analysis provided by Predictive Maintenance Services, Inc.

F-250 Field Trials

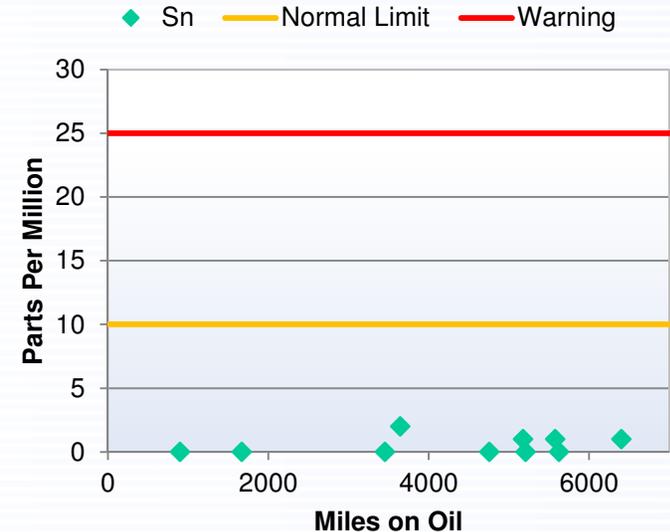
Lead & Tin Wear Data



Wear Metals: Lead



Wear Metals: Tin



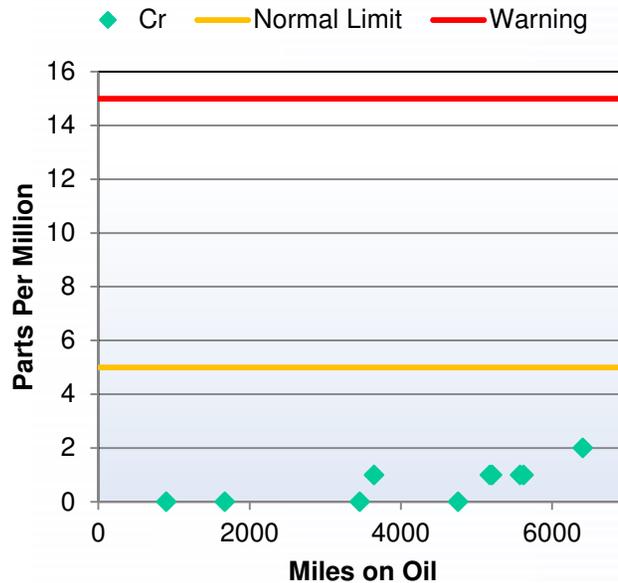
Tin and Lead would indicate bearing wear. Both show levels well within the normal limit



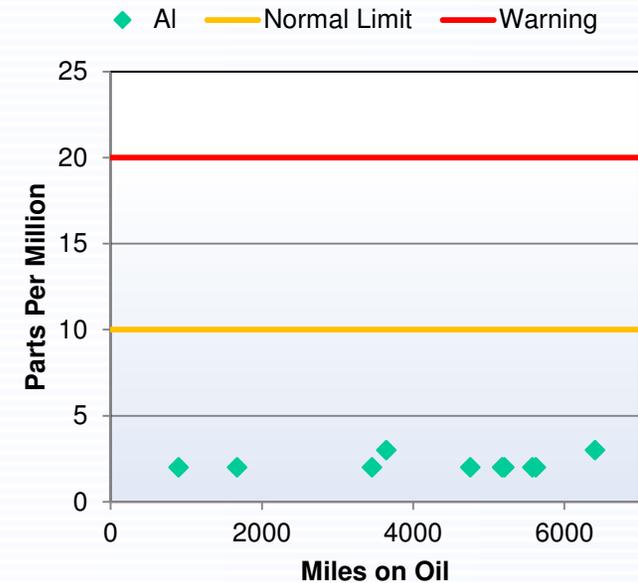
F-250 Field Trials

Chromium & Aluminum Wear Data

Wear Metals: Chromium



Wear Metals: Aluminum



Cr wear would indicate liner wear and Al would represent piston wear. Both show levels well within the normal limit.

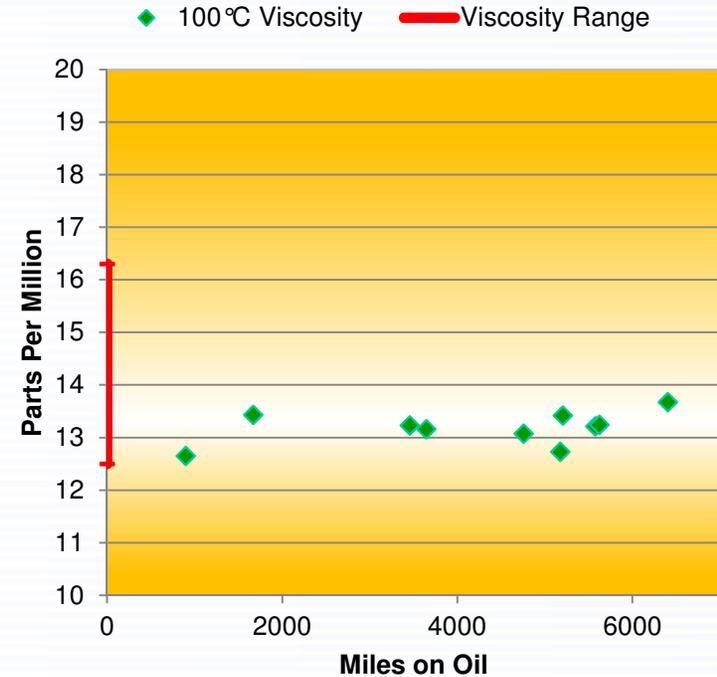
F-250 Field Trials

Viscosity Data



- *The 100 °C kinematic viscosity shows a steady level well within the normal limit.*
- *Increases or decreases in oil viscosity could be due to oxidation or shearing if present.*

100 °C Viscosity





PARTA is now using Bio-SHP High Performance Engine Oils and Bio-Power Diesel Fuel Conditioners. We are a complete Green Fleet.

“Bio-based solutions have replaced many of the additives lost with recent emission reductions in diesel fuel. Portage Area Regional Transit Authority is taking advantage of Renewable Lubricants, Inc.’s Outstanding Lubricant Performance.”

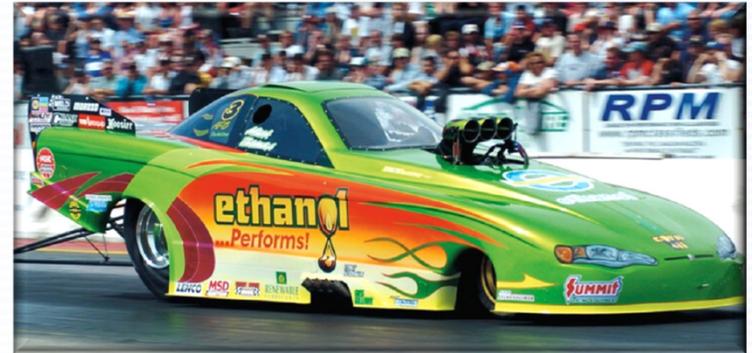
Why Bio-Based at PARTA?

- Renewable, recyclable
- Biodegradable
- Fire Resistant
- Energy Efficiency =Super High Viscosity Index
- Excellent Lubricity

Biobased Engine Oils Experience

Used by Mark Thomas in 7 IHRA World Championships

- Same technology, 70% biobased content
- SAE 20W70 Engine Oil, SAE 75W140 Gear Oil & SAE 10 Transmission Fluid
- 3500 HP!



Marine Usage of 15W-40

- NOAA won a DOE Leadership award for use of Biobased oils (Great Lakes & Monterrey Bay)



Agricultural Usage of Bio-Syn Engine Oils

- 380 Equipment & Vehicles at USDA Research facility at Beltsville, MD
- Used in all equipment since 2000

Audi RS4 Field Trials

- STLE Presentation 2008 on wear metal and fuel dilution advantages with Bio-Synthetic engine oils



Public Transportation

- Five Rivers Metro Park Dayton, OH
- USDA APHIS (Agricultural and Plant Health Inspection Service - Idaho Falls, ID) in transportation equipment

Summary

- High oleic biobased oils offer excellent starting points for biobased, biodegradable lubricants
- Deficiencies in the physical properties of biobased oils can be overcome by using RLI Patented Technology and PAOs to improve low temperature characteristics and oxidative stability
- Fully formulated RLI Bio-Synthetic lubricants have been demonstrated based on the combination of these base oils, which possess very good finished lubricant properties
- Wear metals from used oil analysis show improvements when using Bio-Synthetic Oils compared to commercial oils
- Fuel dilution is reduced for Bio-Synthetic oils in comparison to commercial oils