High Performance Engine Oils with RLI Patented Technology and PAO Blends

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STLE

Cleveland, OH

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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 and Track Trials
- Energy Conservation Advantages of PAO/Vegetable Oils
- 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)
+ Unlimited availability worldwide

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 ℃, cSt	Viscosity 40 ℃, cSt	Viscosity Index	Noack Volatility	Biodegrad. %
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]		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.

Bio-Based Engine Oils

- What is a Bio-Based Engine Oil?
  - Currently, no definition, but 2-cycle engine oils have a bio content of at least 34% (natural ester vegetable oil)
- Bench Tests:
  - TEOST MHT, Noack, MRV, RPVOT, Micro Oxidation, Scanning Brookfield
- Field Trials, Track testing (Audi RS4 and Toyota Prius):
  - Wear Metals
  - Fuel Dilution
- Historical Experience in Racing, Marine, Agricultural, Public Transportation and Industrial Engines

Blending Biobased Bio-Syn SAE 5W-30 Motor Oils

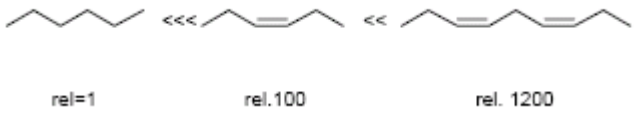
	40% Biobase in Base Oil Blends*			"GF- 4"
	Rerefined Group I	Group III	PAO 4	Limit
Viscosity, cSt @ 40°C	63.4	47.5	56.7	
Viscosity, cSt @ 100°C	11.32	9.8	11.5	9.3-12.5
Vscosity Index	174	198	203	
MRV, cP @ -35°C	38147	17158	6485	60000 Max
Noack Volatility, %	20.4	11.8	11.3	15 Max

*U.S Patents: 5,736,493,- 5,863,872, -5,990,055, -6,383,992, -6,534,454, pending and other foreign patents
Renewable Lubricants, Inc.

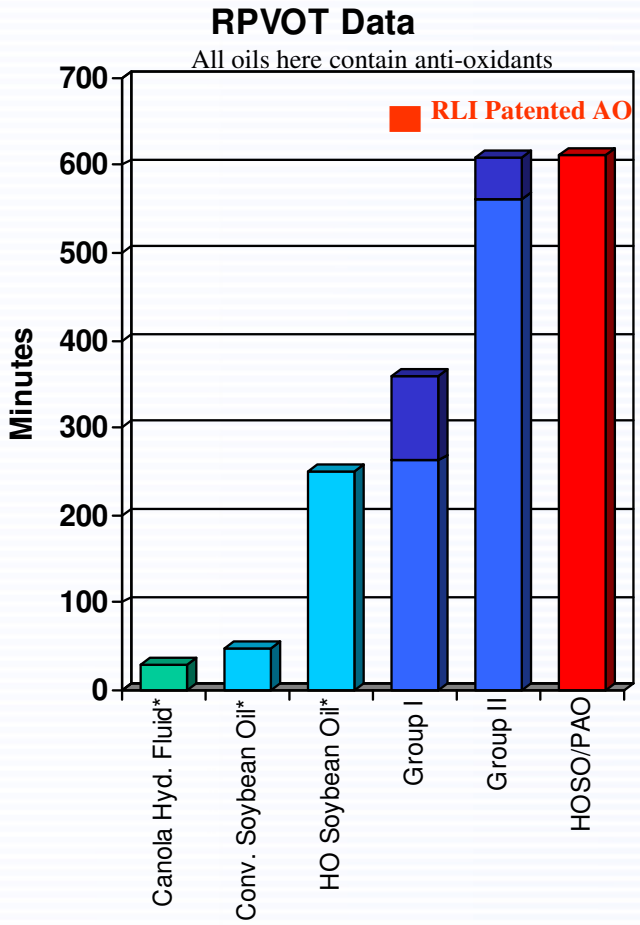
Oxidative Stability

- 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



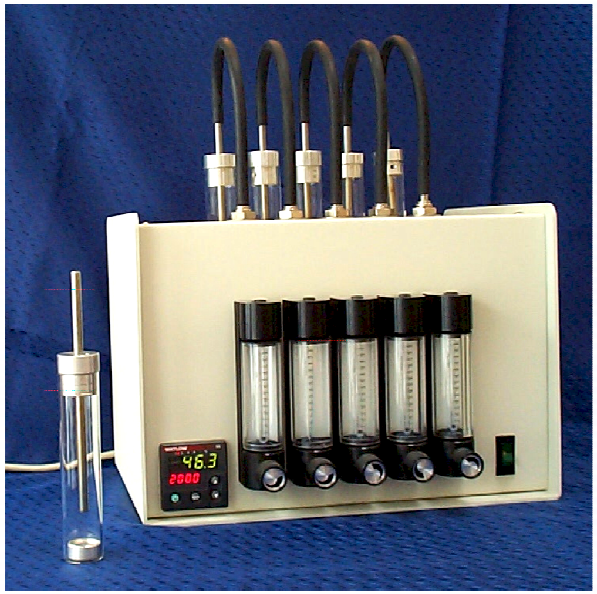
Relative reactivities for oxidative attack**



* 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.

Micro-Oxidation Test



The **Micro-Oxidation test** was developed at Penn State University to allow study of:

►Oxidative behavior of engine oils while simulating **thin-film** conditions in the **piston cylinder region** and has been adapted for use with mineral oil base stocks and fully formulated automotive crank-case oils.

►Correlation with both automotive and diesel engine tests are published. The Microoxidation test Tests under nitrogen and air atmospheres coupled with analyses using gel permeation chromatography and clay column adsorption provide for a semiquantitative analysis of the products by elution time (apparent molecular size).

►Test procedure allows for primary and secondary oxidation reaction rate studies after substantial quantities of the lubricant have been oxidized. Time-temperature studies can show the effectiveness of base oil quality as well as effects contributed by additives. A general time-temperature equivalence in the range of 200 to 225 degree C has been demonstrated for a series of formulated engine oils.

► **Microoxidation tests have been compared with III-C hot engine tests for a series of ASTM reference oils.**

Photo taken from Sales Cut Sheet from WALCOR Technology, 490 Orlando Ave., State College, PA 16803

Micro-Oxidation Test

(30 Minutes @ 225°C)

Formulated Engine Oils

Color Code

RLI Patented Stabilizers @ 190 ppm "X" + 180 ppm "XX"

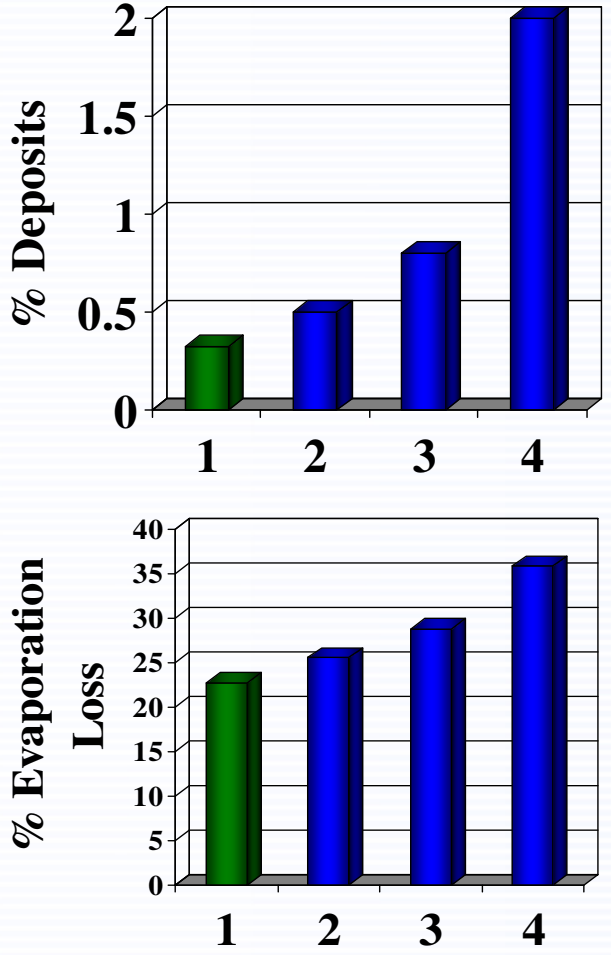
1 - 20% Biobased 5W-30

Reference Oils

2 – Commercial Synthetic 5W-30

3 – Commercial Semi-Synthetic 10W-30

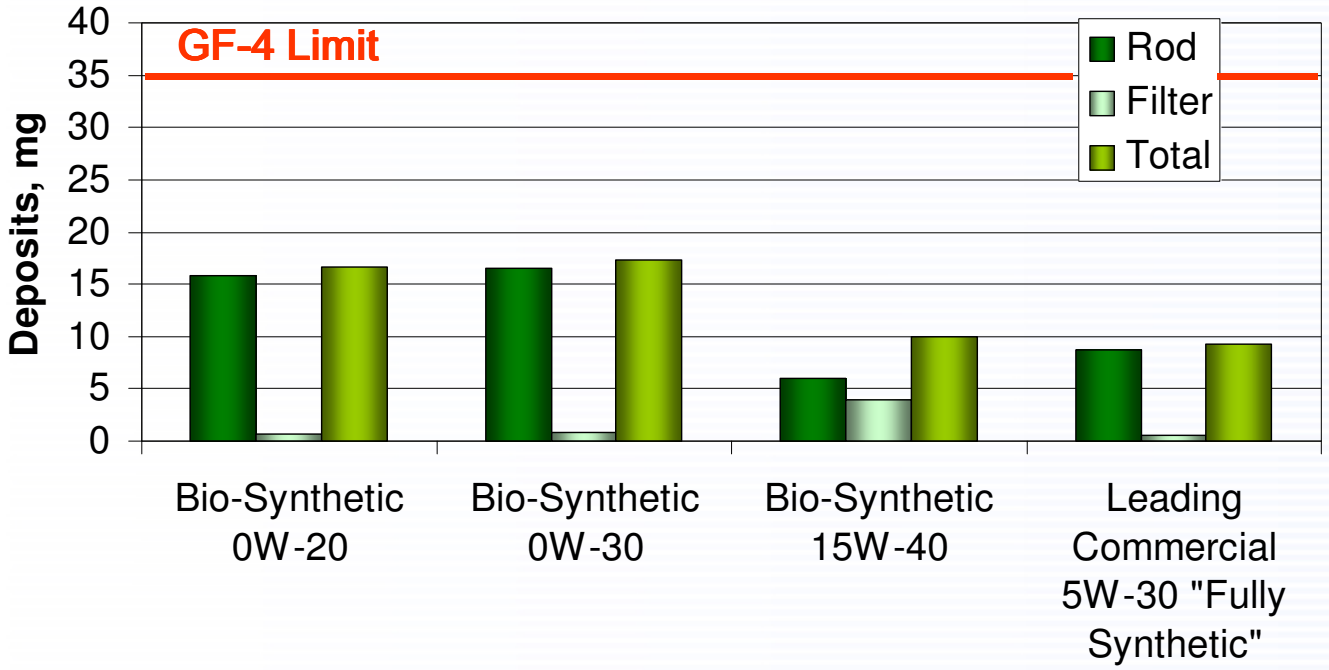
4 - Commercial 10W-30



Thermo-Oxidation Engine Oil Simulation Test (TEOST MHT)

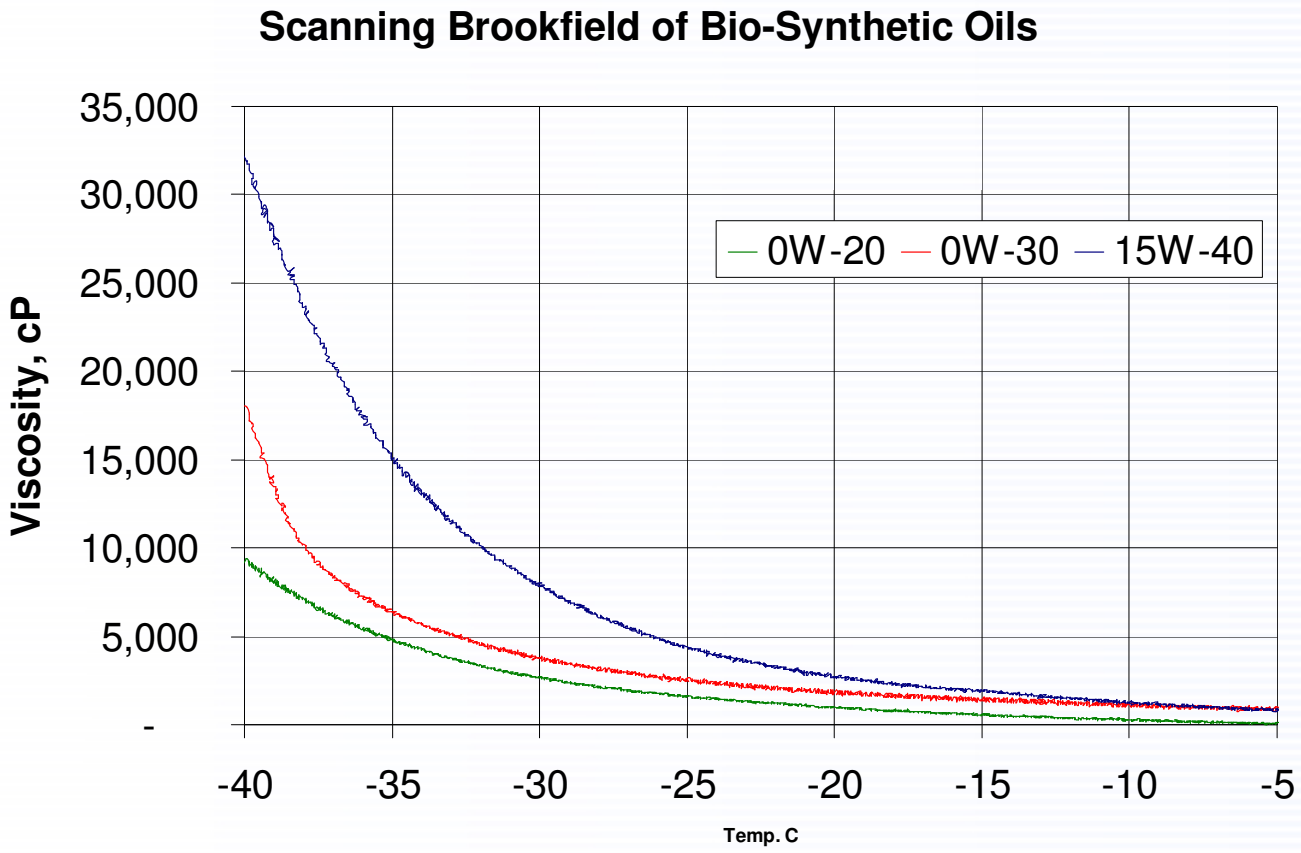
ASTM D7097-05

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



Low Temperature Viscosity

- The Scanning Brookfield shows no gelation



Field Trials and Test Track Data

Audi RS 4 V8 4.2 FSI Direct Injection Engine Features
420 hp @ 7,800 rpm
317 lb-ft. @ 5500 rpm
0-60 mph in 4.2 seconds

Audi RS4. (2008, April 22). In *Wikipedia, The Free Encyclopedia*. Retrieved 15:53, May 1, 2008, from http://en.wikipedia.org/w/index.php?title=Audi_RS4&oldid=207369389 http://en.wikipedia.org/wiki/Audi_RS4

Toyota Prius 1.5-liter DOHC four/50kW Electric Motor
76 hp @ 5,000 rpm
85 lb-ft. @ 4,000 rpm
50kW (67hp)/295 lb-ft. electric motor
0-60 mph in 9.8 seconds*

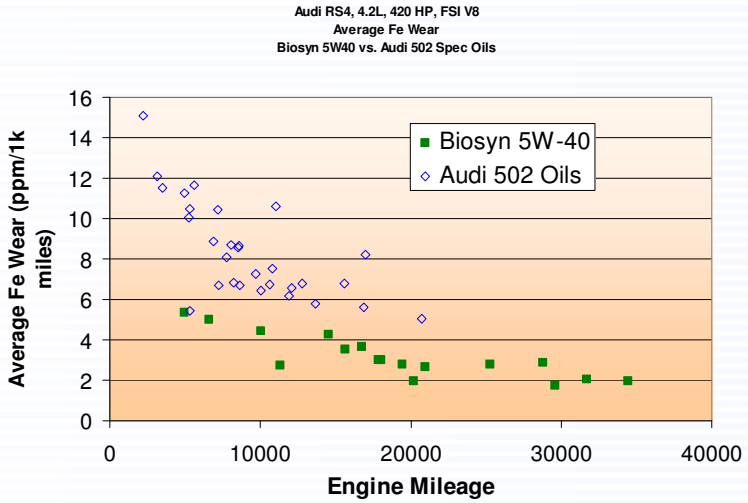
Toyota Prius. (2008, May 1). In *Wikipedia, The Free Encyclopedia*. Retrieved 15:55, May 1, 2008, from http://en.wikipedia.org/w/index.php?title=Toyota_Prius&oldid=209441145

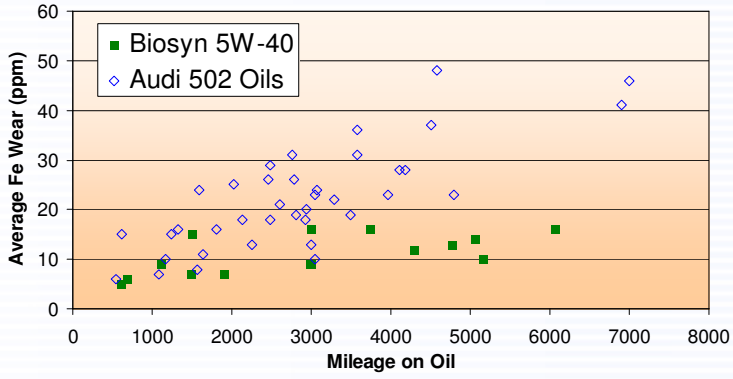
* Comparison of Toyota hybrids. (2008, April 30). In *Wikipedia, The Free Encyclopedia*. Retrieved 15:57, May 1, 2008, from http://en.wikipedia.org/w/index.php?title=Comparison_of_Toyota_hybrids&oldid=209304261

Audi Field Trials

Fe Wear Data

- Year round service and track mileage. Stock and high performance tuning.
- The engine oil analysis shows low average Fe content for the Audi RS4 automobiles
- The Fe content in the oil is also low with regard to mileage on the oil

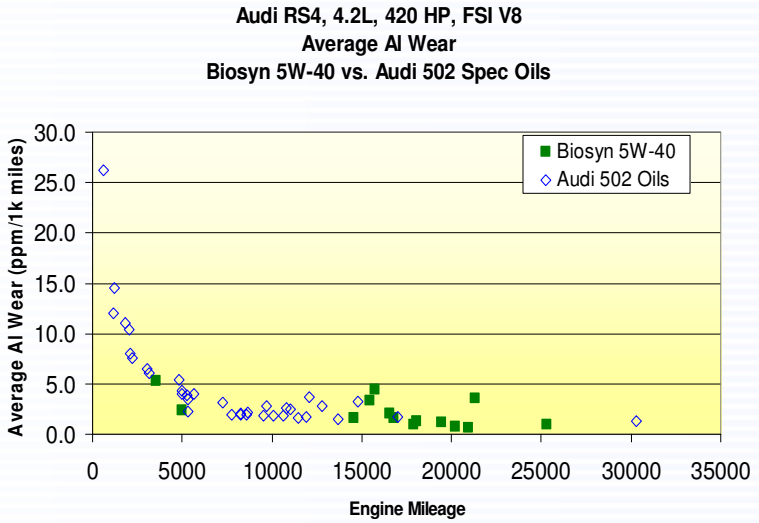


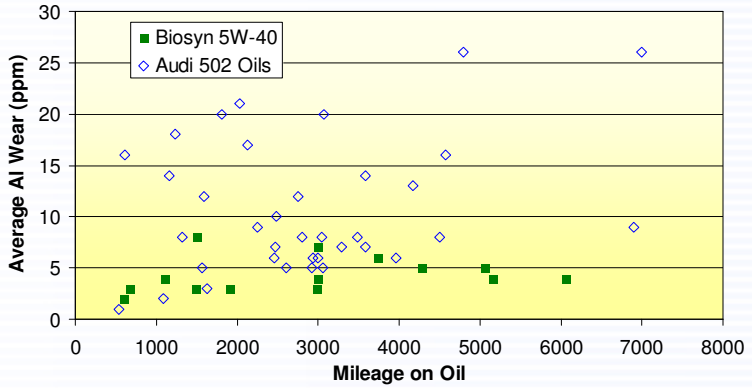


Audi Field Trials

Al Wear Data

- Year round service and track mileage. Stock and high performance tuning.
- The engine oil analysis shows low average Al content for the Audi RS4 automobiles
- The Al content in the oil is also low with regard to mileage on the oil

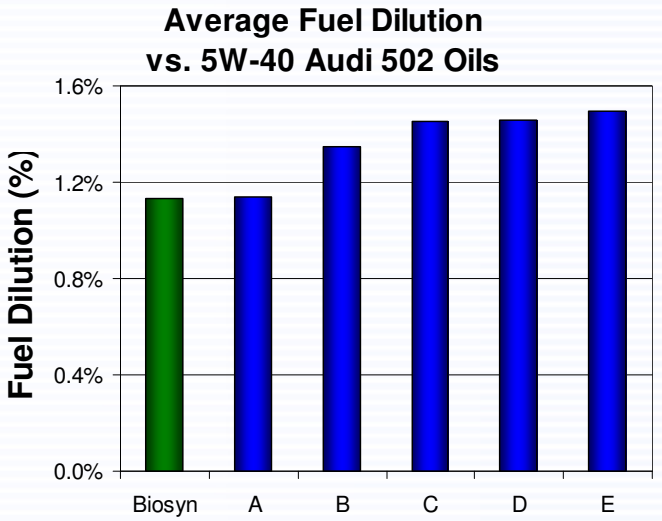


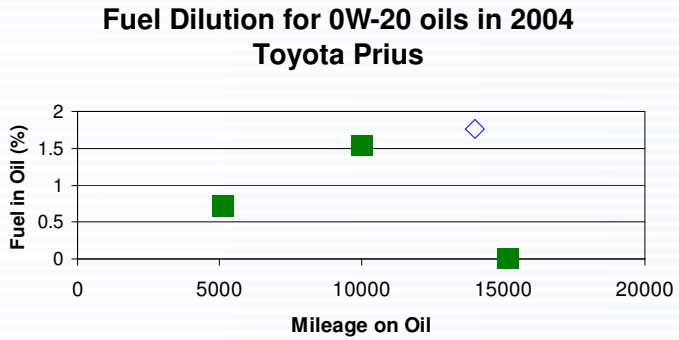


Fuel Dilution

Bio-Synthetic vs. Audi 502 Oils

- Low fuel dilution was desired by Teraspeed. DysonAnalysis recommended the Biosyn to reduce fuel dilution.
- The lower fuel dilution may be explained in part due to the high VI of the Biosyn oils giving thicker oil films at the high temperature regions in the cylinder, leading to less blow-by.
- The Prius study shows low fuel dilution for the Bio-Synthetic 0W-20 oil in comparison to a commercial synthetic 0W-20



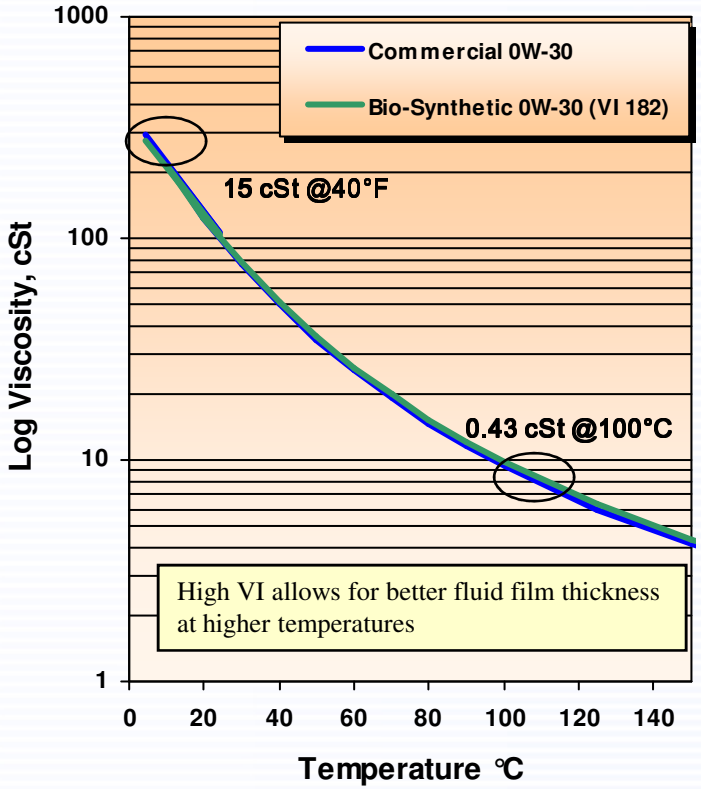


Energy Efficiency

High viscosity index is key to improved wear, reduced fuel dilution and should provide improved energy efficiency

- The high VI formulations provide less lubrication friction in the start up and provide reserved fluid film at higher temperatures.

Grade ISO	Commercial 0W-30	Bio-Synthetic 0W-30
KV 40°C, mm²/s	50.5	51.4
KV 100°C,mm²/s	9.41	9.84
Viscosity Index	171	182

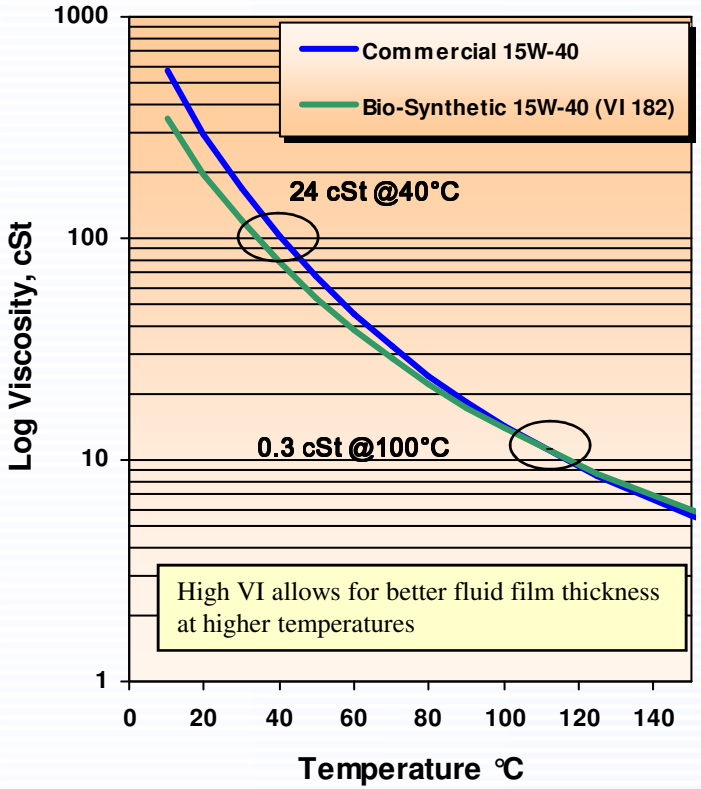


Energy Efficiency

High viscosity index is key to improved wear, reduced fuel dilution and should provide improved energy efficiency

- The high VI formulations provide less lubrication friction in the start up and provide reserved fluid film at higher temperatures.

Grade ISO	Commercial 15W-40	Bio-Synthetic 15W-40
KV 40°C, mm²/s	101.8	78.0
KV 100°C,mm²/s	14.17	13.86
Viscosity Index	142	184



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 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

Public Transportation

- PARTA (Portage Area Regional Transit Authority – Kent, OH) 72 Buses using 15W-40 for over 1 year
- 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

Acknowledgements

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