Balancing Lubricant Properties with Bio-Ultimax Technology and PAO Blends

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STLE

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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, Pour Point, Hydrolytic Stability*
- Biodegradation Studies of Blends
- Physical Properties of Formulated Oils
- Energy Conservation Advantages of Bio-Ultimax /PAO
- 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

+ 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

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

Physical Properties

Base fluid	Viscosity 100℃, cSt	Viscosity 40℃, cSt	Viscosity Index	Pour point, ℃	Biodegrad. %
Soybean[1]	7.6	31	227	-9	75-100
Sunflower[1]	7.7	31.6	226		75-100
Corn[1]	7.7	31.9	223	-15	75-100
Rape seed oil[1]	9.1	40.3	217	-18	75-100
Peanut[1]	8.3	36.9	212	3	75-100
Olive[1]	8.4	38.3	203	-9	75-100
Castor[1]	19.5	255.5	87	-33	75-100
High oleic sunflower[2]		39		-21	70-100
PAO 8[1]	7.8	46	140	-63	20-22
Mineral oil[2]		ISO 32		-12	15

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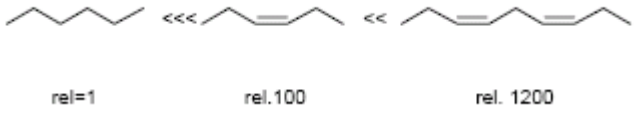
References for Table:
1 - L.R.Rudnick in Ed. S.Z.Erhan, J.M.Perez, *Biobased Industrial Fluids and Lubricants*, AOCS Press, Champaign, Ill., USA 2002, p.51.
2 - M. Schneider, P. Smith, Government-Industry Forum on Non-Food Uses of Crops (GIFNFC 7/7) Case Study: Plant Oil Based Lubricants in Total Loss & Potential Loss Applications, Final Report, May 16, 2002, p. 20.

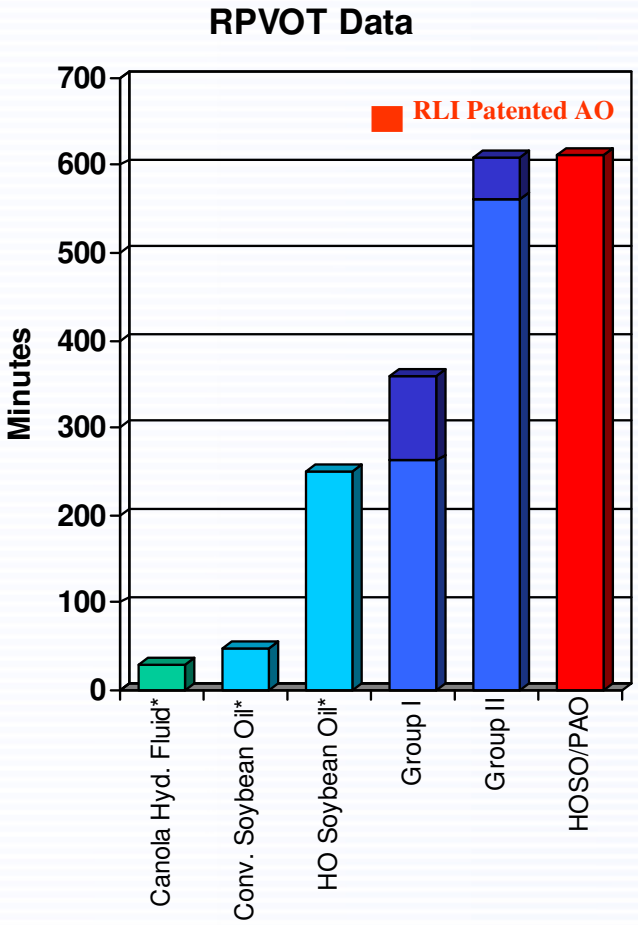
Oxidative Stability

- 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



Relative reactivities for oxidative attack**

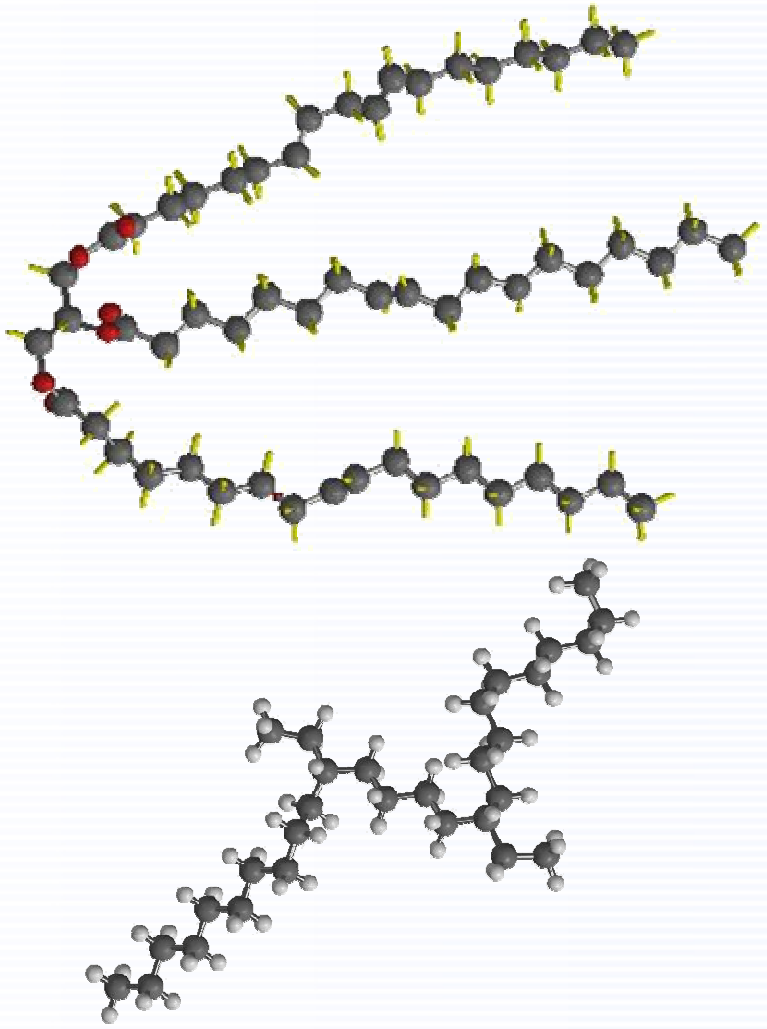


* J. L. Glancey, S. Knowlton, and E.R. Benson. Development of a high oleic soybean oil-based hydraulic fluid. *Feedstocks (United Soybean Board Publication)* 4: 1-2, 1999.

** 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.

Optimizing Pour Point

- Saturation:
  - The pour point decreases with increasing number of double bonds in the molecule
  - Fully saturated materials have exceptional oxidative stability but are solid at ambient temperature
- Branching gives rise to improved low temperature properties
- PAOs are highly branched and highly saturated



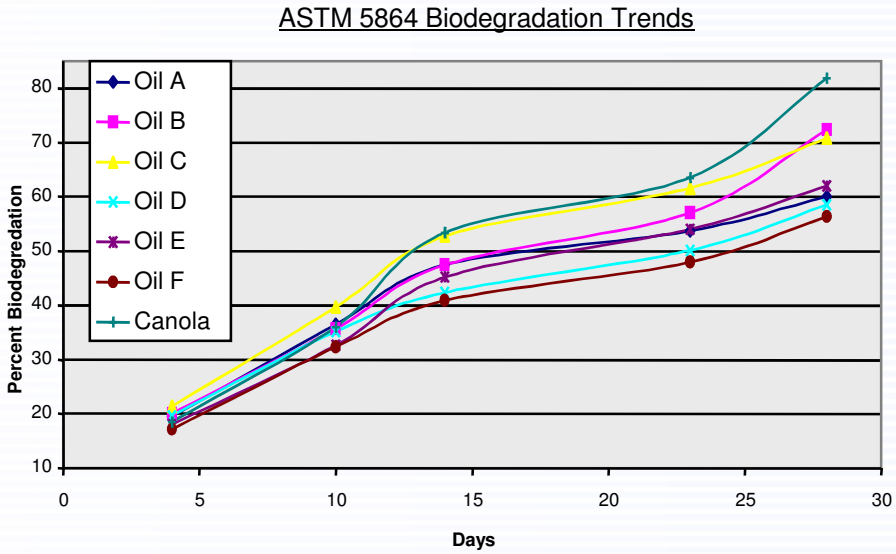
Hydrolytic Stability

Acid + Alcohol ⇌ Ester + Water

- Hydrolysis occurs due to the ester functionality in the presence of water, giving rise to an acid and an alcohol
- Hydrolysis can be reduced by several factors:
  - Low moisture levels
  - Branching increases hydrolytic stability
  - Low acid values
  - Low contaminant levels
  - Certain additives

Biodegradation

Some PAOs are biodegradable and most can be formulated into Pw1 biodegradable fluids*



	Oil A	Oil B	Oil C	Oil D	Oil E	Oil F	Canola
Viscosity	ISO 68	ISO 68	ISO 68	ISO 100	ISO 100	ISO 68	
Biodegradation	**60.0%**	**72.3%**	**70.8%**	**58.5%**	**62.0%**	**56.3%**	**81.8%**
	PAO 6	***PAO 7***	***PAO 8***	***PAO 9***	***PAO 4***	***PAO 4***	
% PAO	**27.85**	**27.85**	**18**	**25**	**25.25**	**34**	
% Bio Oil	58.05	59.05	69.15	57.15	50	47.25	
% Ester	9.2	9.2	9.2	9.2	10	9.2	

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** Ultimate Biodegradability Pw1 in ASTM D-5864 is the highest biodegradability standard and is preferred in government and and in industries over inherently biodegradable products.*

Properties of Bio-Ultimax Hydraulic Fluids

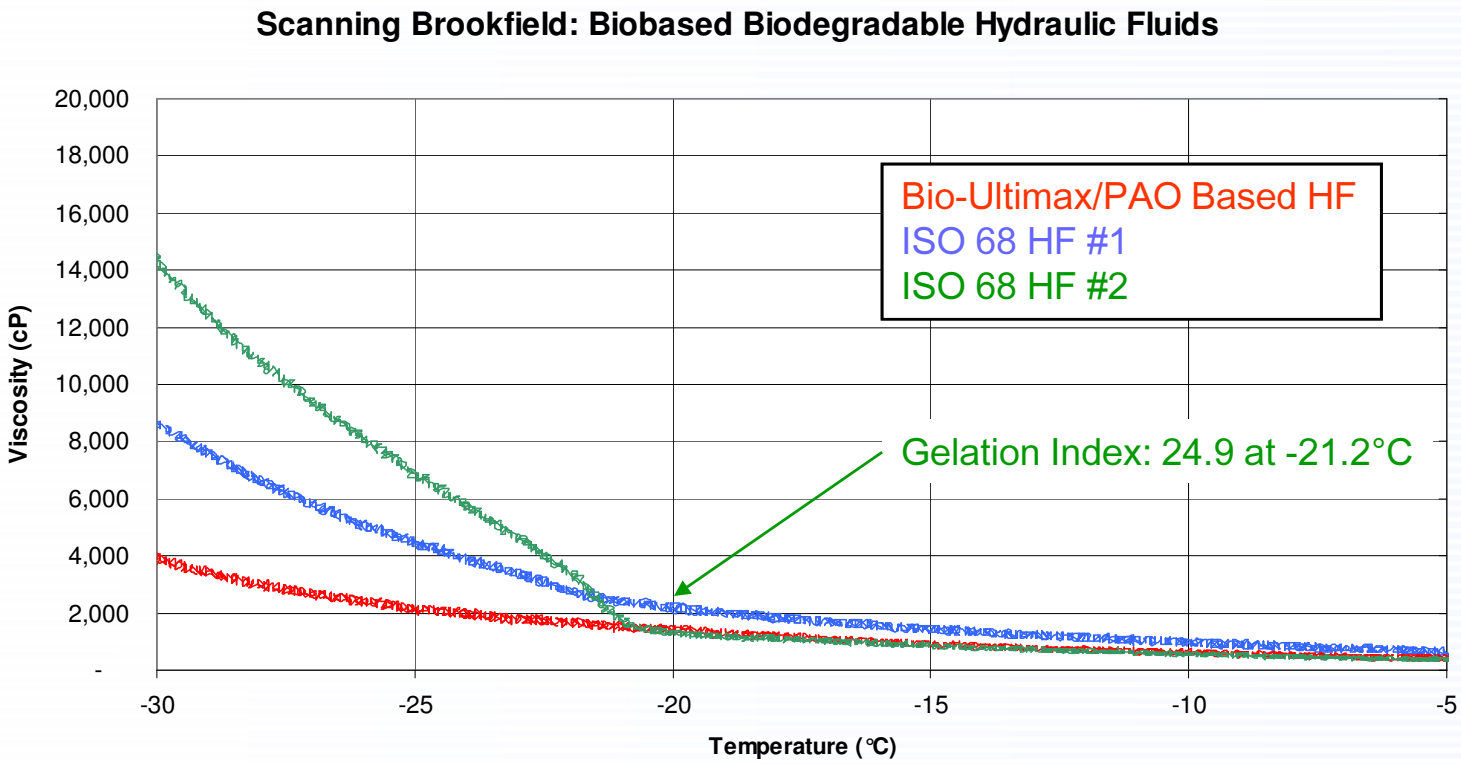
	(BIO ISO 32) HYDRAULIC FLUID	(BIO ISO 46) HYDRAULIC FLUID	(BIO ISO 68) HYDRAULIC FLUID	SPECIFICATION (MIL-H-46001)
#909 Seal Compatibility				
VOL CHANGE %	4.9	7.5	12.7	0 - 12 ISO 32/46, 0-10 ISO 68
DUROM CHANGE %	-4	-6	-7	0 to -7 ISO 32/46, 0 to -6 ISO 68
D2619 Hydrolytic Stability				
NNA CHANGE mg KOH/g	0	0.5	1.7	4.0 max
WT CU CHANGE mg/(cm)^2	-0.0139	-0.0208	-0.0208	-0.2 max
D892 Foam Seq I-III	pass	pass	pass	0 foam after 10 min
Denison TP-02100 Filteribility				
TIME (1) sec (dry)	223	267	335	600 max
TIME (2) sec (dry)	224	268	332	600 max
TIME (1) sec (wet)	172	269	446	1200 max
TIME (2) sec (wet)	171	271	449	1200 max
D4172 4 Ball Wear				
AVG. SCAR DIA. mm	0.38	0.52	0.31	0.5 max

Properties of Bio-Ultimax Hydraulic Fluid for Transportation Equipment

TYPICAL SPECIFICATIONS TEST	METHOD	Bio-Ultimax ISO-32 Hydraulic Fluid	Mil-H 46001 Reference Mineral Oil	Spec. Requirements
Specific Gravity @ 15.6°C	ASTM D287	**0.874**	0.87	Report
API Gravity @ 15.6°C	ASTM D287	**30.4**	31.1	Report
Viscosity @ 40°C	ASTM D445	**30.87**	ISO-32 31.43	28.8 to 35.2
Viscosity @ 100°C	ASTM D445	**6.9**	5.29	Report
Viscosity @ -15°C, Brookfield	ASTM D2983	**550**	1544	Note 1
Viscosity @ -35°C MRV TP1	ASTM D-4684	**2,679 cP**	Not Complete	5W= <60,000(Max)
Viscosity Index	ASTM D-2270	**184**	99	90 (min)
Pour Point	ASTM D97	**-42°C**	-39°C	-12°C (Max)
Flash Point (COC)	ASTM D-92	**236°C**	212°C	198°C (min)
Fire Point (COC)	ASTM D-92	**260°C**	234°C	218°C (min)
Foam Sequence I, II, III (10 min)	ASTM D 892	**0 Foam**	(Fail)	0 Foam
Neutralization Number mg KOH/g	ASTM D 974	**0.37**	0.58	1.5 (max)
Rust Prevention	ASTM D 665			
Distilled Water		**Pass**	Pass	Pass
Syn. Sea Water		**Pass**	Pass	Pass
Rotary Bomb Oxidation, (min. @ 150°C)	ASTM D2272	**360**	262	USS 120 (min)
Demulsibility, ML Oil/Water/Emulsion	ASTM D 1401	**40/ 40/ 0**	40/ 40/ 0	30 min. 40 (Max)
4-Ball Wear, 1h, 167°F, 1200 RPM, 40 kg	ASTM D 4172	**0.39**	0.4 – 0.5	USS 127 0.5 (Max)
FZG Test	DIN 51354	**12**	Not Complete	US. Steel 10 (min)
Biodegradability (Ultimate Pw1)	ASTM D-5864	**>60%**	(Fail)	>60%

Low Temperature Viscosity

- Reducing the low temperature viscosity provides:
  - better fluidity
  - lower viscous drag
  - wider operating range



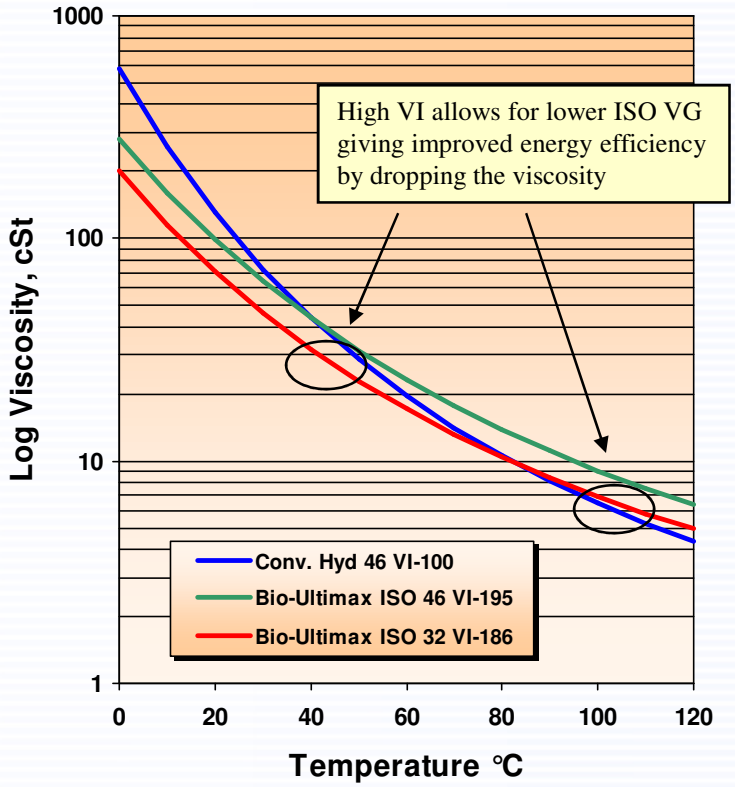
Energy Efficiency

High viscosity index of the Bio-Ultimax is key to improved energy efficiency

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

- Lower lubrication friction will lead to lower operating temperatures yielding improved heat transfer and longer life.

Grade ISO	Conv. 46	Bio-Ultimax 46	Bio-Ultimax 32
KV 40°C, mm²/s	46	46	32
Viscosity Index	100	195	186
KV 100°C,mm²/s	6.72	9.39	6.89
Temperature for 10 mm²/s	82.7	96.6	80.8
Temperature for 750 cP (°C)	-1.4	-12.8	-16.5
Temperature Operating Window*	84.2	109.6	97.4



**As defined by National Fluid Power Assn, calculated using www.mehf.com*

Summary

- High oleic vegetable oils offer excellent starting points for biobased, biodegradable lubricants
- Deficiencies in the physical properties of soybean oils can be overcome by using RLI Patented Technology and PAOs to improve low temperature characteristics, oxidative and hydrolytic stabilities
- Bio-Ultimax formulated lubricants have been demonstrated based on the combination of these base oils, which possess very good finished lubricant properties
- Improved energy efficiency are achievable with RLI Patented Technology Bio-Ultimax high VI formulations