Balancing Lubricant Properties with Vegetable Oil and PAO Blends

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STLE

Canton, Ohio

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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 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

+ 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°C, cSt	Viscosity 40°C, cSt	Viscosity Index	Pour point, °C	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

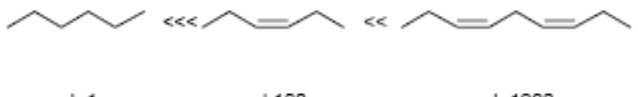
RENEWABLE LUBRICANTS

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.

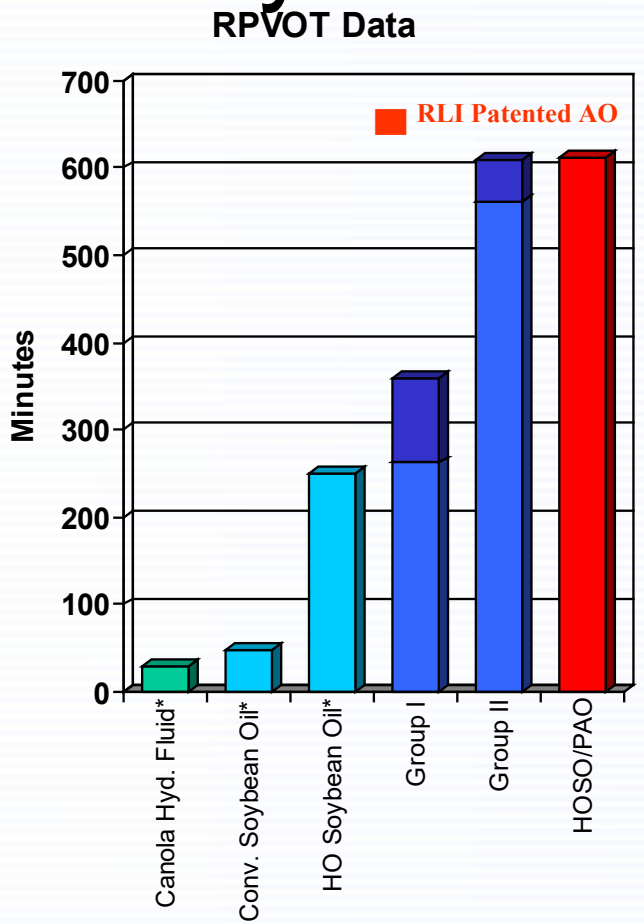
Oxidative Stability

- 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 o



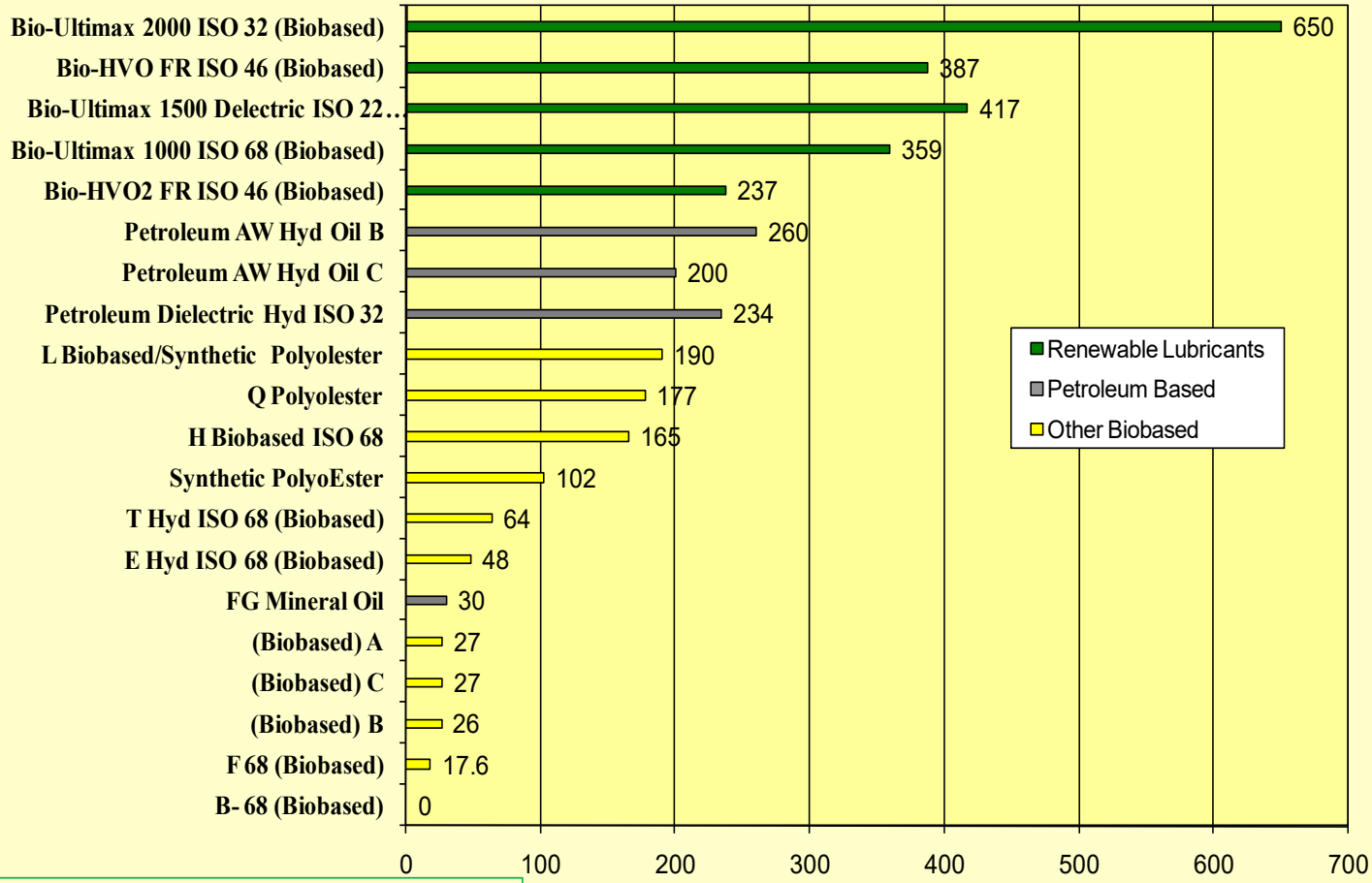
Relative reactivities for oxidative attack**



* 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.

Rotary Bomb Oxidation Test (*RBOT) @ 150°C (ASTM D-2272): A Comparative Study of Hydraulic Fluids Over Time



*RBOT, now called the RPVOT test, is a measure of the fluid's resistance to oxidation.

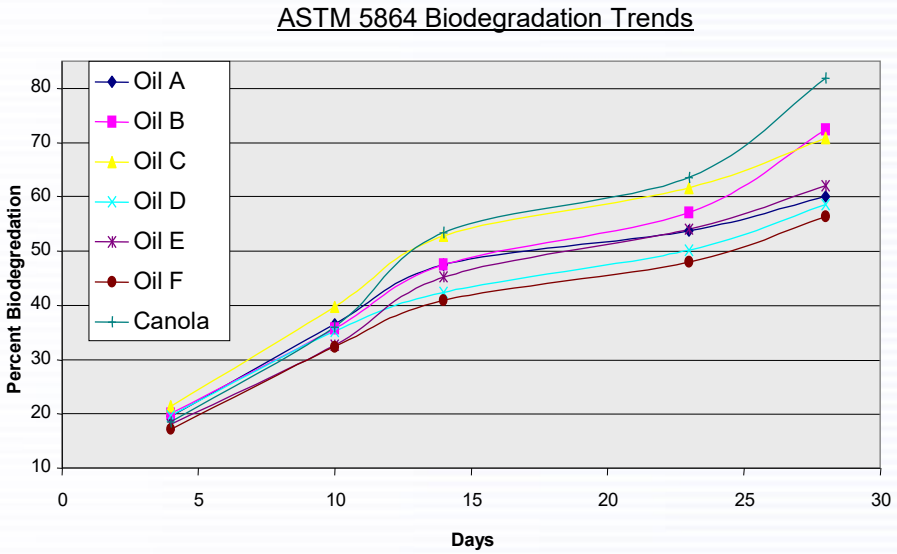
Hydrolytic Stability

Acid + Alcohol $\rightleftharpoons$ 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	

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

Properties of Bio-Ultimax/PAO Based Hydraulic Fluids

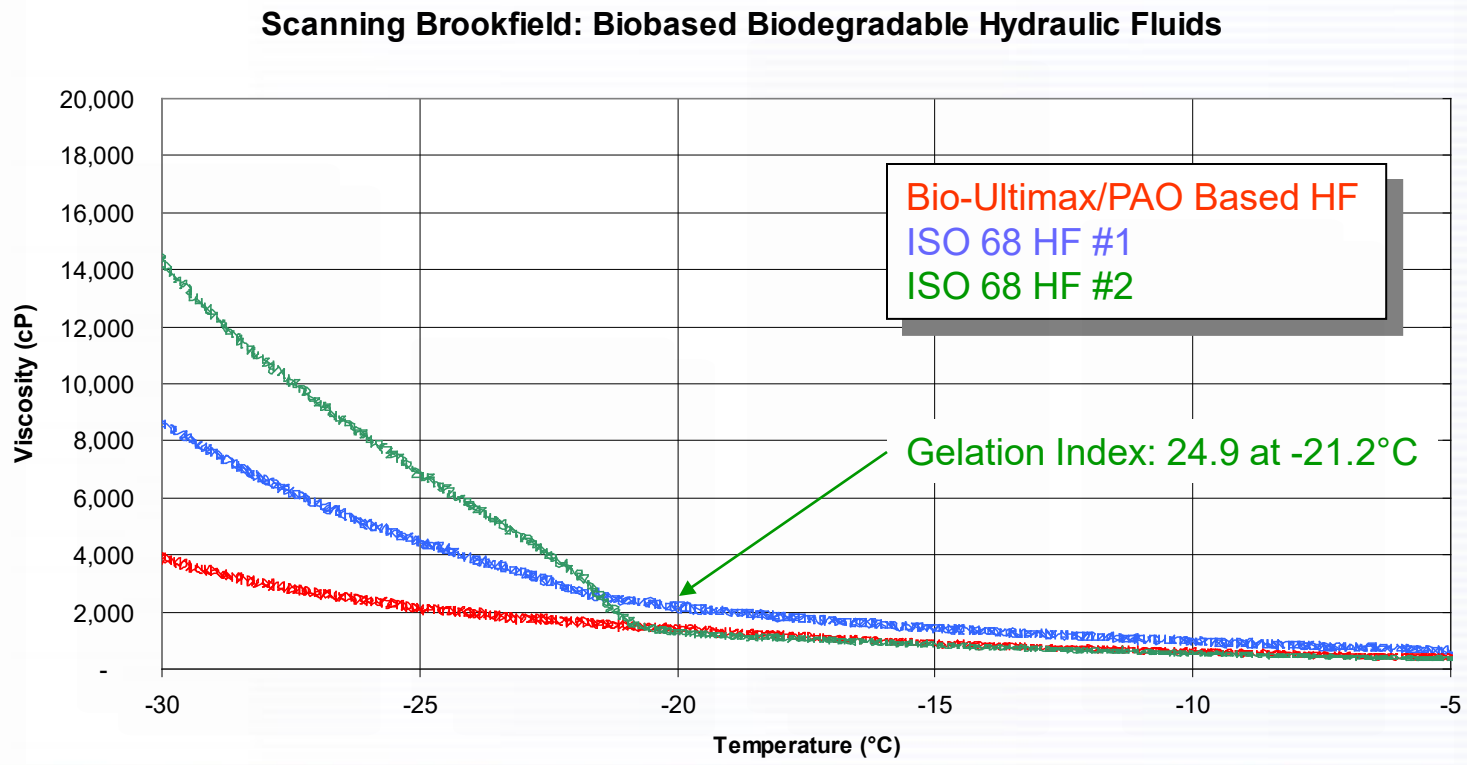
	(BIO ISO 32) HYDRAULIC FLUID	(BIO ISO 46) HYDRAULIC FLUID	(BIO ISO 68) HYDRAULIC FLUID	SPECIFICATION (MIL-H-46001)
#909 Seal Compatibility				
VOL CHANGE %	4.9	7.5	12.7	0 - 12 ISO 32/46, 0-10 ISO 68
DUROM CHANGE %	-4	-6	-7	0 to -7 ISO 32/46, 0 to -6 ISO 68
D2619 Hydrolytic Stability				
NNA CHANGE mg 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/PAO Based Hydraulic Fluid for Transportation Equipment

TYPICAL SPECIFICATIONS TEST	METHOD	Bio-Ultimax/PAO Based 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 Pwl)	ASTM D-5864	**>60%**	(Fail)	>60%

Low Temperature Viscosity

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



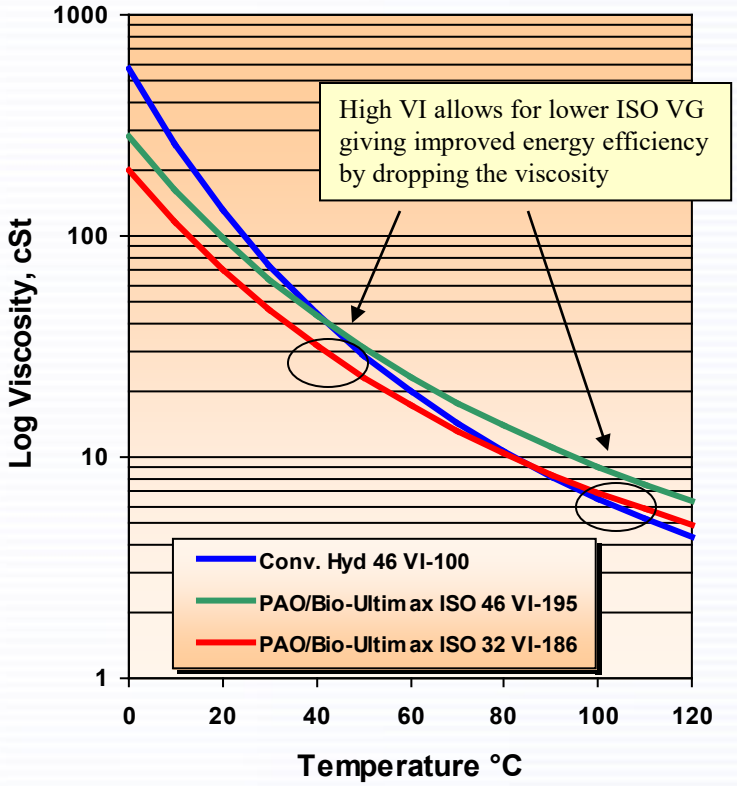
Energy Efficiency

High viscosity index is key to improved energy efficiency

- The high VI 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	PAO/Bio-Ultimax 46	PAO/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

NAVY Advanced SEAL Delivery System

- **APPROVED! Design Change Bio-Ultimax 1000 Hydraulic Fluid ISO 32 for Navy Submarine Advanced Seal Delivery System Replacing MIL-PRF-17672D**

RLI Passes Grueling, Demanding Navy Military Specifications

- Pass - Off Gas Test for Diver Safety
- Approved by Navy Medical – Non Toxic
- Pass - Biodegradable
- Improved High & Low Temperature Fluidity

America's Cup 2007

Special Bio-Ultimax 1000 Hydraulic Fluid in Steering
AmericaOne the Americas Cup Race, a NO Fail 8000 PSI Ultra High Performance hydraulic system that operates very successfully under no compromised conditions.

BMW Oracle Racing Team “Report”

“Nothing separates the men from the boys during extreme competition such as the regattas leading up to the 07 America's Cup”. And, I wanted to share with RLI an interesting report I received from the field using the specially formulated, low foaming, high performance Bio-Ultimax fluid that you formulated exclusively for BMWOracle Racing.

BMWOracle has constructed one of two of their 07 Cup boats. Their chief hydraulic fabricator technician and boat builder Rolf Engleberts, had called me about converting from their MIL SPEC 83272 fluid to the special Bio-Ultimax. And, I reviewed the flushing procedure with him. Two days later Rolf called me and said they changed out the old fluid to the Bio Ultimax overnight without telling the sailing team.

After the day of racing, the sailing team returned to port asking Rolf "what did you do to the hydraulic system?" Rolf replied, "what do you mean”? The grinders and pumpers all noticed less frictional operation. When Rolf told them that all he had done was to change out the fluid to the Bio-Ultimax special formula - they could not believe it. As a foot note, I was also told that any time they spilled the Bio-Ultimax such as in changing out a fitting. it was very easy on the hands too. Reported to be almost like a hand lotion.....but very easy to clean up. I share with you this comment because the MIL SPEC oils have a notorious reputation of eating up the sails stored under deck and are difficult to clean up do to their wicking characteristics.

The BMWOracle Team thanks RLI for your good work. We hope that BMWOracle Racing will bring back the Cup to where it rightfully deserves.....the USA! *Signed: Phil Emmons, PWS Direct Inc.*

America's Cup 2010

The America's Cup arrives in its new home.

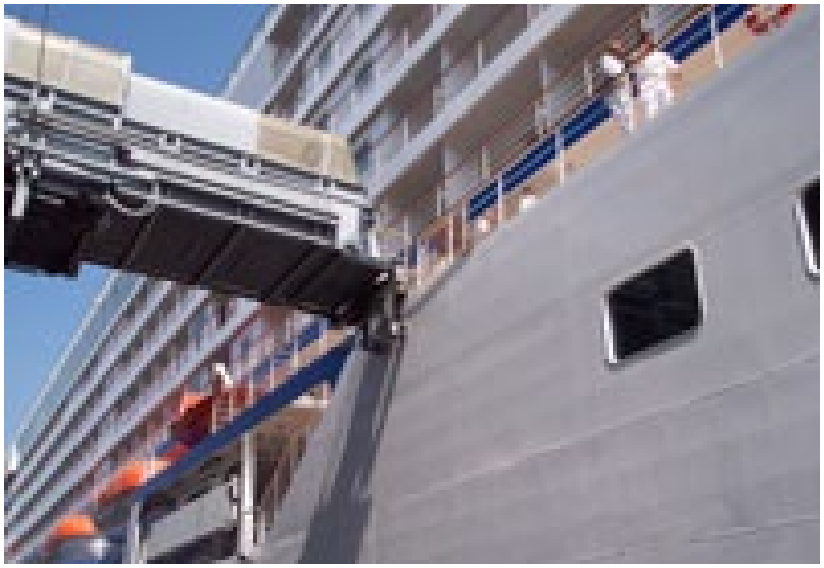
The America's Cup is back in the United States. The oldest trophy in international sport arrived in San Francisco on Friday afternoon, following BMW ORACLE Racing's win over Alinghi at the beginning of the week.

On 02/16/2010 Sunday afternoon, on the waters off Valencia, Spain, BMW ORACLE Racing became the first

Protecting Our Ports

Proven High Performance:

California. Bio-Ultimax 1000 ISO 46 High Performance Hydraulic Fluid is used to lubricate the gangways at Berth 93 Port of Los Angeles the home of the Love Boat.



Berth 93 is capable of berthing three of the most modern cruise ships in the world simultaneously and can accommodate the largest mega ships currently sailing.

Port of Los Angeles Gangway is Lubricated with RLI Bio Ultimax 1000 Hydraulic Fluid

Proven High Performance

The Tehachapi Reservoir in California. Bio-Ultimax 1000 ISO 46 High Performance Hydraulic Fluid is used to open the reservoir gates when performance is critical. Parker OEM www.pwsdirect.com

Proven High Performance

- Eleven years of Superior Performance at Pictured Rocks National Lakeshore wins the White House Closing the Circle Award using RLI Products
- Bio-Ultimax 1000 Hydraulic Fluid have been in the Snow Plows and 10 assorted Equipment for 11 years with Excellent Service
- Temperatures reaching sub zero conditions
- Over 100 State DNR and many National DOI facilities using Bio-Ultimax 1000 Hydraulic Fluid

Fluid Lift Trucks Approval

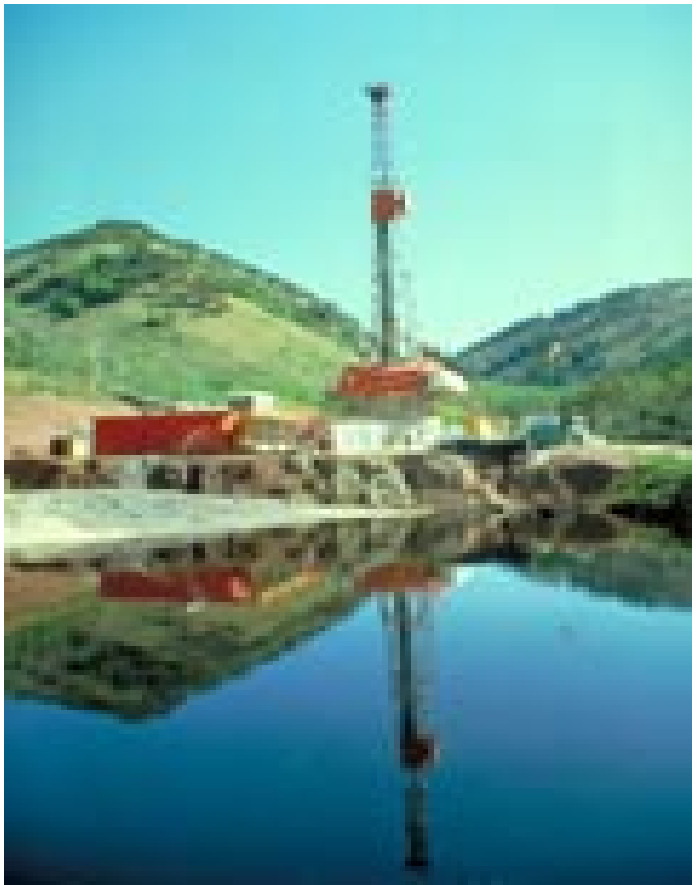
End Users: **Asplundh Tree Expert Company, *Davey Tree***

Altec Approval of Bio-Ultimax 1500 ISO 22 & ISO 32 High Performance Hydraulic Fluid is used to lubricate Lift Trucks

Proven High Performance

Proven High Performance:

Subsea Drilling - Using Bio Ultimax 1000 Hydraulic Fluids



Proven High Performance

US Army Corp of Engineers, John Day & Dalles Dam OR- WA

Using Bio-Ultimax 1000 Hydraulic Fluid & Bio-Gear Oil 220

US Army Corp of Engineers Columbia River and Snake River OR – John Day Dam Bio-Ultimax 1000 Hydraulic Fluid

Proven High Performance

- **NOAA won the DOE Leadership Award for the First Petroleum Free Federal Vehicle using RLI Biobased Products throughout.**

Proven High Performance

- **NOAA Ship Nancy Foster Oceanic Research (Atlantic)**

  All Hydraulic Systems on board using Bio-Ultimax 1000 Hydraulic Fluids. Over 2000 gallons.

Humpback with NANCY FOSTER - Look closely and you can see the tag.

Proven High Performance

- NOAA Ship Nancy Foster Deck Equipment
  - A-Frame Type: Appleton Marine, Inc.
    - Vertical Clearance: 23ft
    - Max Load: 25,000 lbs
    - Type: Electrohydraulic

Proven High Performance

- NOAA Ship Nancy Foster Deck Equipment

J-Frame:
Type: Electrohydraulic
Lifting Capacity: 5,000 lbs

EM Winch: 01 Deck

CleanScapes, Seattle, WA

- King County, **Seattle, WA**
- **Portage County Solid Waste District,**
- Bio-Ultimax 1000 Hydraulic Fluid in all Systems

Solid Waste Recycling Center in Portage County, Kent Ohio

CleanScapes WA "Beyond Waste Collection Services"

Proven High Performance

- RLI's Engine, Transmission, and Differential Fluids have lubricated Mark Thomas' 3500 HP racer to 7 IHRA World Championships.

Accomplishing the Unbelievable with Corn Oil

Summary

- High oleic vegetable oils offer excellent starting points for biobased, biodegradable lubricants
- Deficiencies in the physical properties of vegetable oils can be overcome by using RLI Patented Technology and PAOs to improve low temperature characteristics, oxidative and hydrolytic stabilities
- Fully 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

Legislation

- **Two Executive Orders in 1998 and 1999**
  Promoted the use of Renewable and Biobased Products by all Government Agencies
- **Farm Security and Rural Investment Act (2002)**
  - Procurement Program (designated Items)
  - Agency Promotion Program
  - Annual Review and Monitoring of Plan

  "BioPreferred" USDA
- **As a Result**, Federal Agencies are Required to Buy Biobased Products to the Maximum Extent Practicable, Provided:
  - Products are Available
  - Meet Performance Standards
  - Reasonable Priced / Best Value