The Basics of Biobased Lubricants

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STLE Pittsburgh Section – April 15th 2025

Functional Products Inc.

- Based in Ohio, USA since 1985

- Focused on customer driven solutions
- ISO 9001 with Design

- *"Innovative solutions for lubricants"*
  - Polymer-based technologies

- ***Newly updated website***

Continuous capex in 2020 - Present

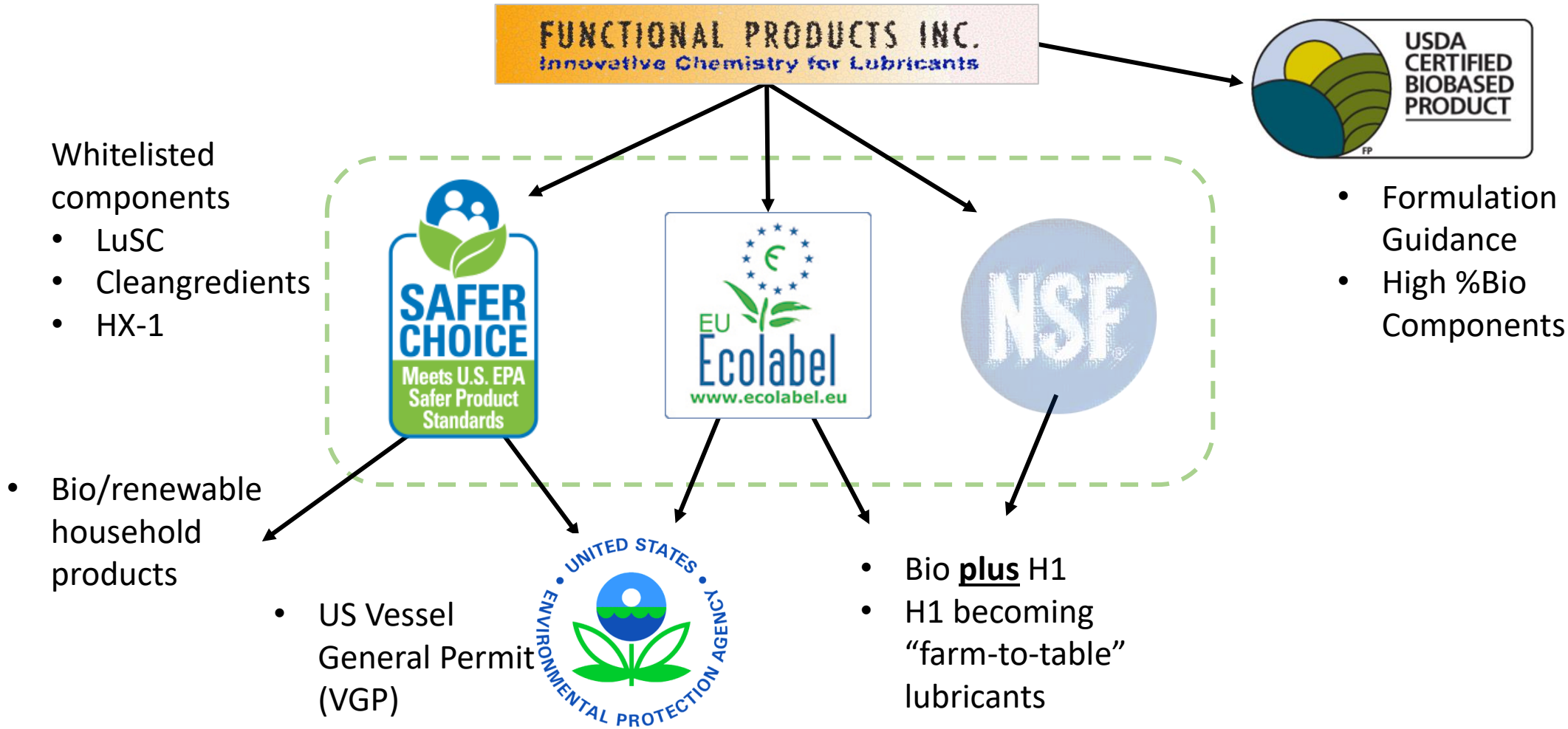
Agenda

- Programs and certifications
- Biobased & biodegradable?
- Base Stocks & Components
- Biobased Rock Drill Example

Go Green

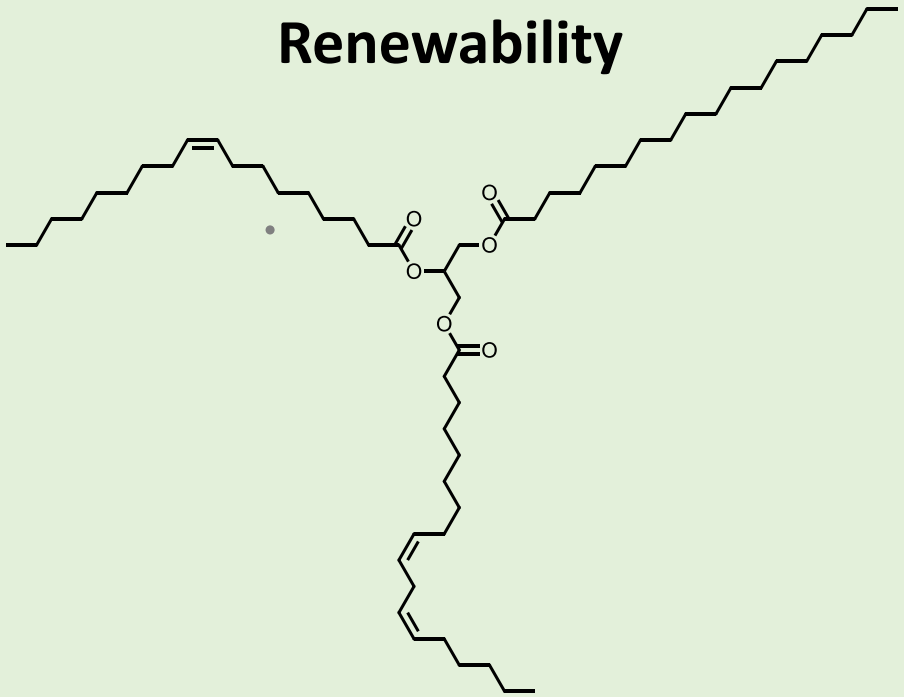
Certifications

- Luggage tag or differentiator?



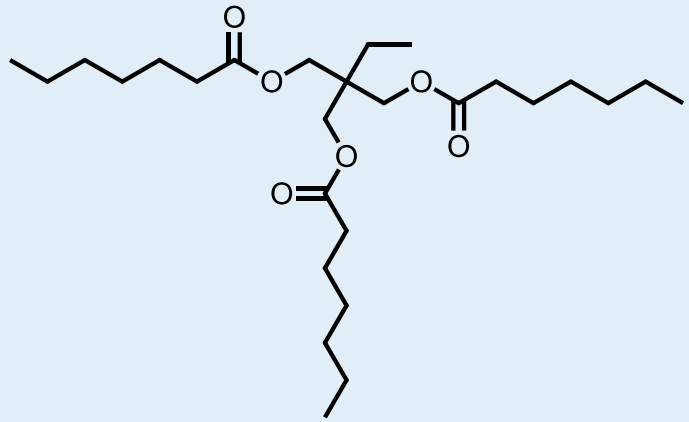
Biobased Market Is Diverse

Performance Target:
Biodegradability, Renewability



Natural Esters

Performance Target:
Stability, Long Life, Volatility, Solvency



Synthetic Ester

What is "Biobased"?

- ASTM D6866 – radiometric analysis of biobased carbon content $^{14}C/^{12}C$
- How much is enough?
  - US Vessel General Permit – not specified
  - European Ecolabel – 25%
  - USDA BioPreferred – based on product category
    - 30-90%

Rail Track Greases	30%
Mobile Equipment Hydraulic Fluids	44%
Stationary Equipment Hydraulic Fluids	44%
Water Turbine Bearing Oils	46%
Gear Lubricants	58%
Straight Oils	66%
Pneumatic Equipment Lubricants	67%
Penetrating Lubricants	68%
Multipurpose Greases	72%
Slide Way Lubricants	74%
Chain and Cable Lubricants	77%
Turbine Drip Oils	87%
Multipurpose Lubricants	88%
Heat Transfer Fluids	89%

What is “Biodegradable”?

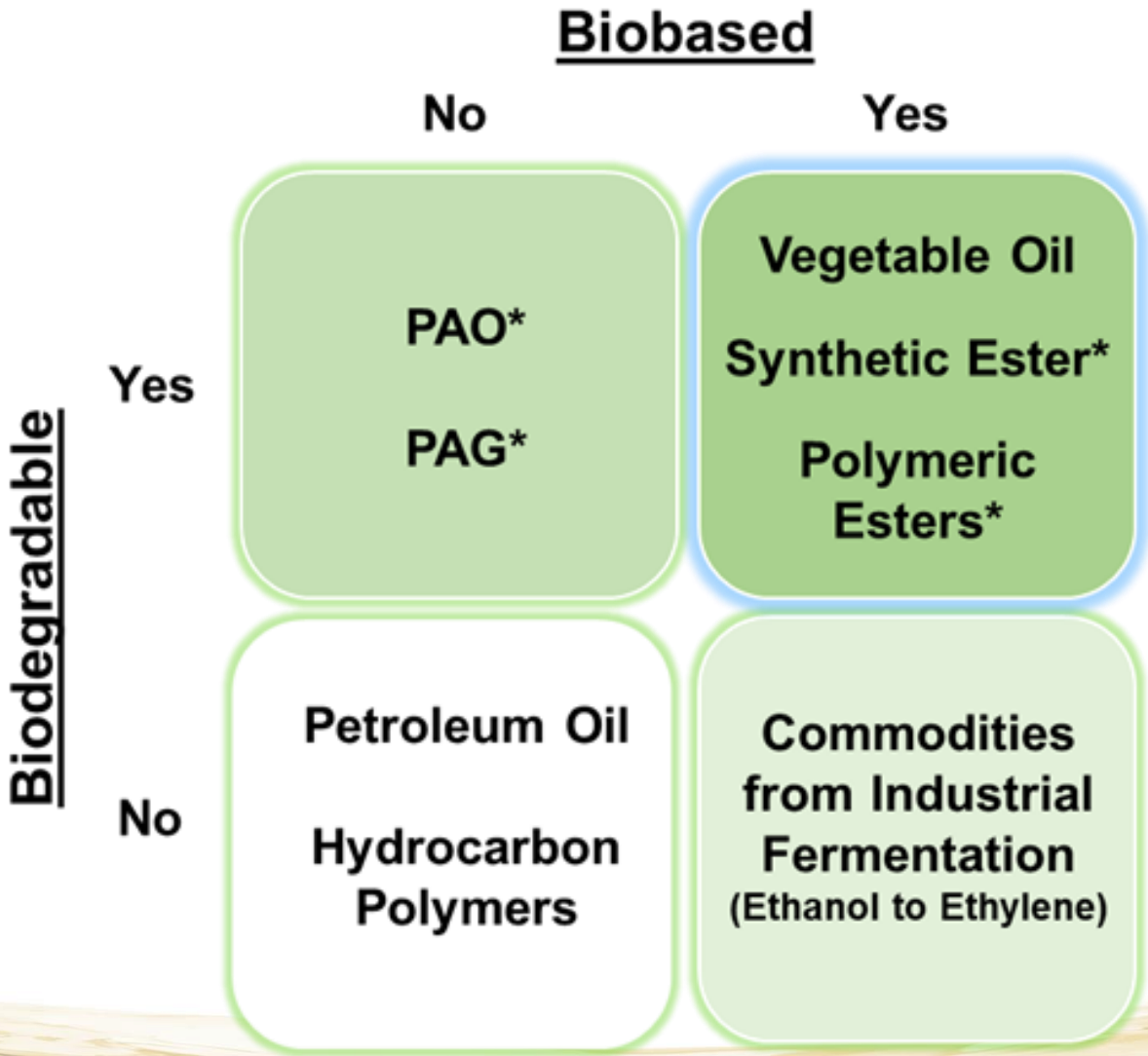
- **OECD 301B** is the main test
  - 28 day test
    - >60% = Readily Biodegradable
    - 20 – 60% = Inherently Biodegradable
    - < 20% = Non-Biodegradable

- Where to test?
  - Aropha in Oakwood, Ohio
    - Pre-screen for cheap
    - Full ISO 17025 biodegradation for certifications
  - Intertek – shops it out to India

Aropha - Fast, Cost-Effective Biodegradability Testing for Biodegradable Materials Development

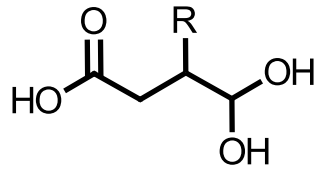
Environmentally Acceptable Lubricants

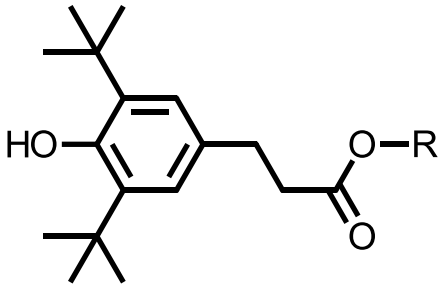
- EAL and “biobased” market
- Goals depend on which program
- Programs can change over time



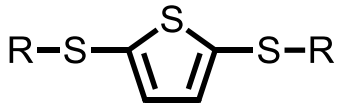
"Biobased" Lubricant Additives

- May or may not be biobased themselves
- Required for proper operation of biobased *finished* product
  - A means to an end





- i.e. antioxidants, corrosion inhibitors, antiwear, EP…
- Toxicity and wt% limited by regulatory program

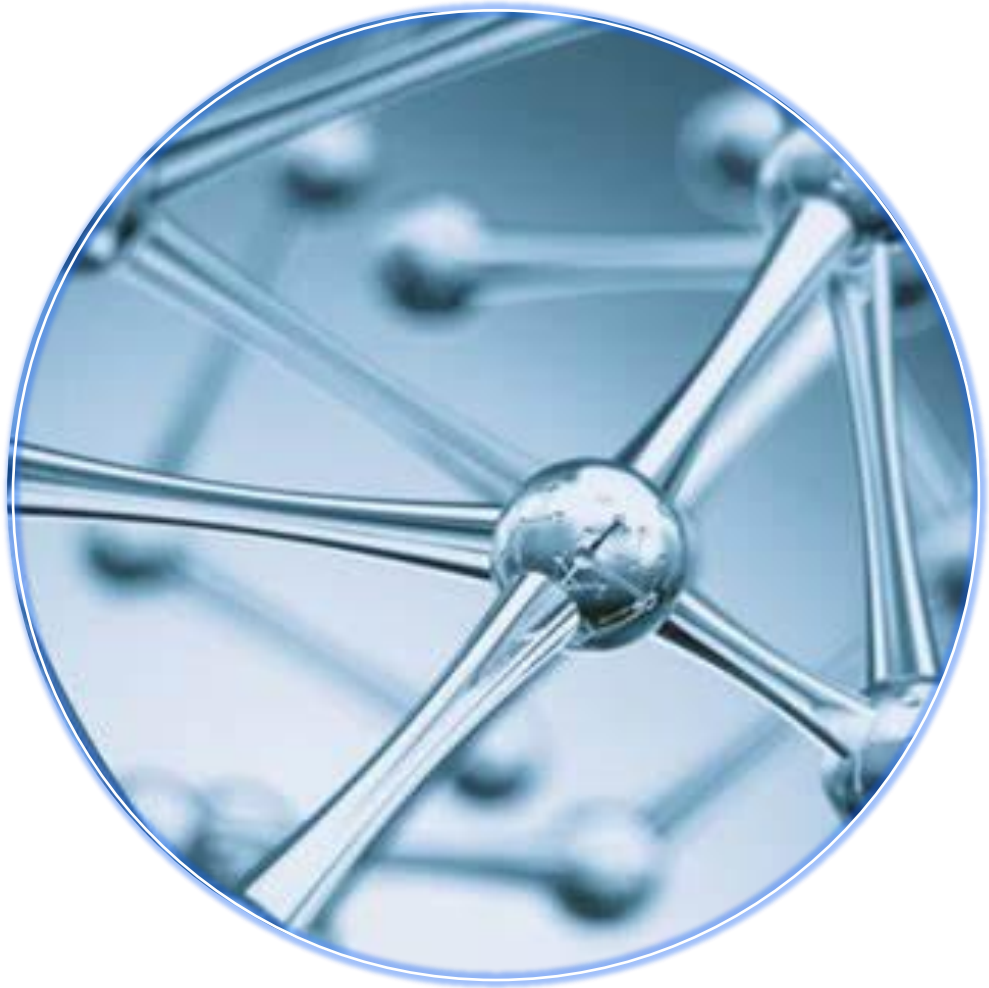


Goals for Specialty Lubes

- Provide the same range of options to specialty formulators
  - Tackifier, VM, PPD, packages, additives, etc.

- Three levels of specialty products:
  1. **Okay** products that meets the regulations
  2. **Good** products that performs same as industrial
  3. **Great** products that outperform industrial lubes
     - Truly special

A New Toolbox for Formulators



Base Stocks

- Vegetable Oils (entry level biobased, issues with oxidation stability)

- Synthetic Esters – low biobased content, typically plasticizer grades
  - Adipates
  - Short chain polyol or neopentyl glycol (NPG), < C8

- Biobased Synthetic Esters
  - TMP trioleate (entry level)
  - TMP C8-10, C9
  - Estolides

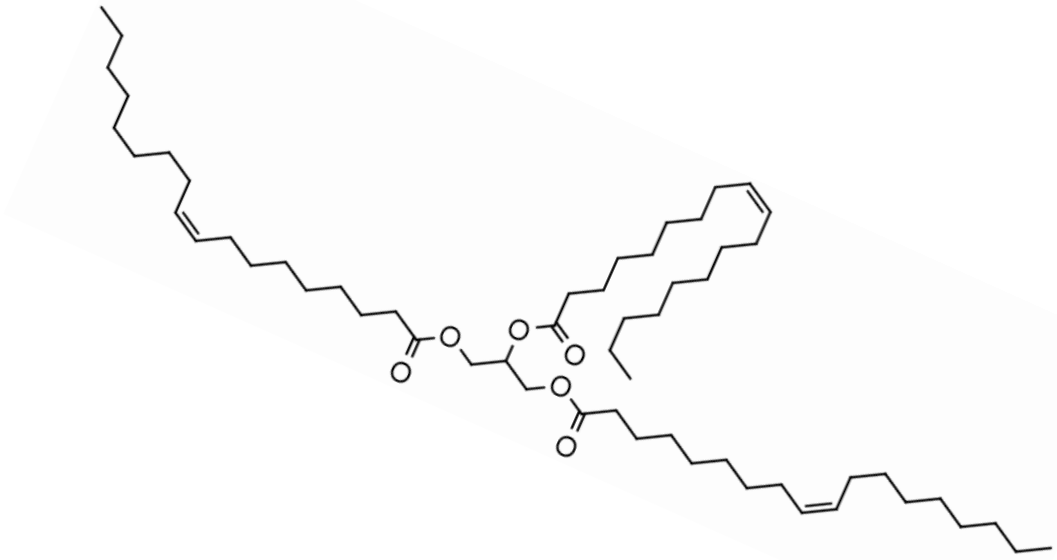
- Biobased but Not Biodegradable Ester – high viscosity complex esters

Vegetable Oils

- Canola preferred for oxidative stability
- High oleic soybean oil works well too

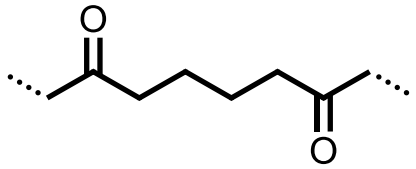
- Soybean oil and high oleic canola oil: too much polyunsaturation
  - Even if very high oleic (mono-unsaturated)

- High wax
- Needs PPD for long term cold storage

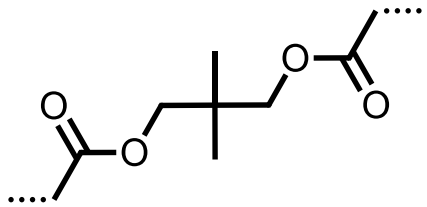


Synthetic Ester Chemical Structure

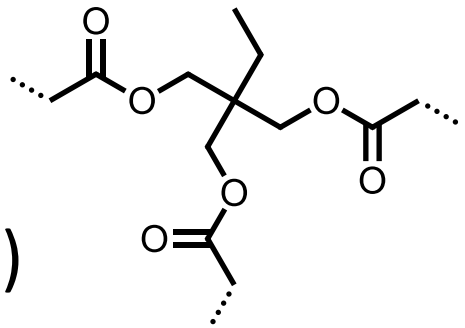
- Adipate



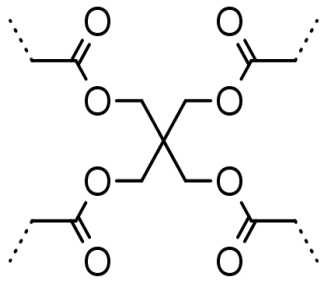
- Neopentyl glycol (NPG)



- Trimethylol propane (TMP)



- Pentaerythritol (PE)



- Complex esters

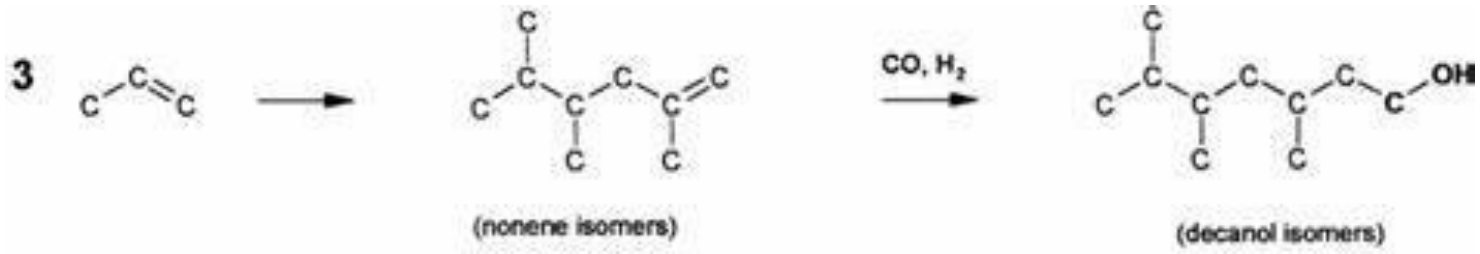
Fully Saturated +
More Branching =

More H_2O and O_2 stability
Lower solvency
Lower biodegradability

Biobased Feedstocks

- Even numbered carbons from nature
  - Short chain = palm or coconut
  - Longer chain = soy, canola, animal fats

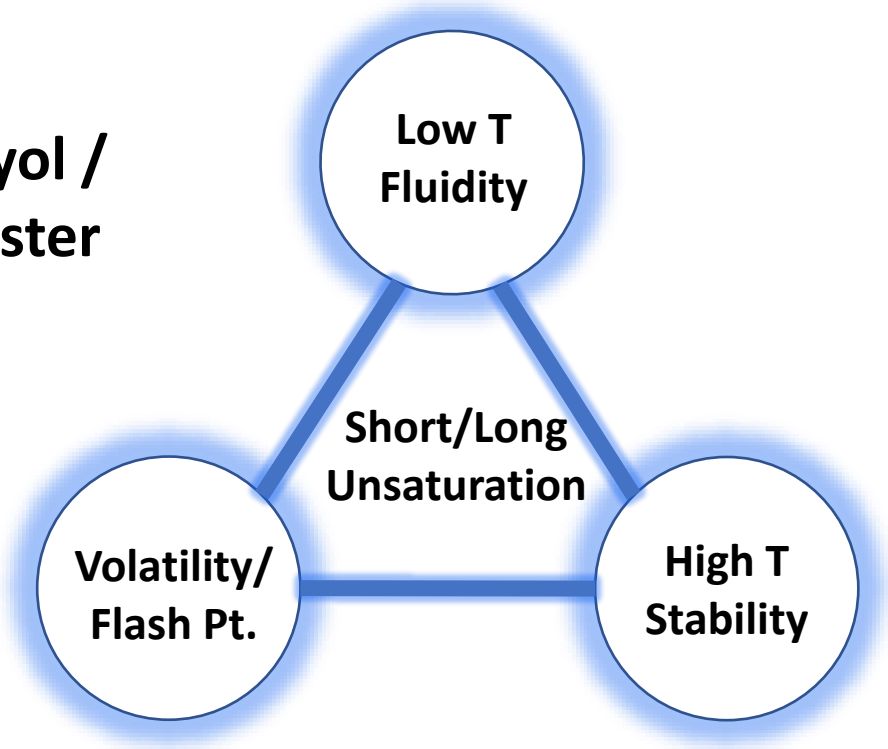
- Odd numbered carbons (C7, C9, etc.)
  - From hydroformylation via oxo-process (Oxea) or syn-gas (Sasol), etc.
  - Now using biobased feeds or cracking heavy fats

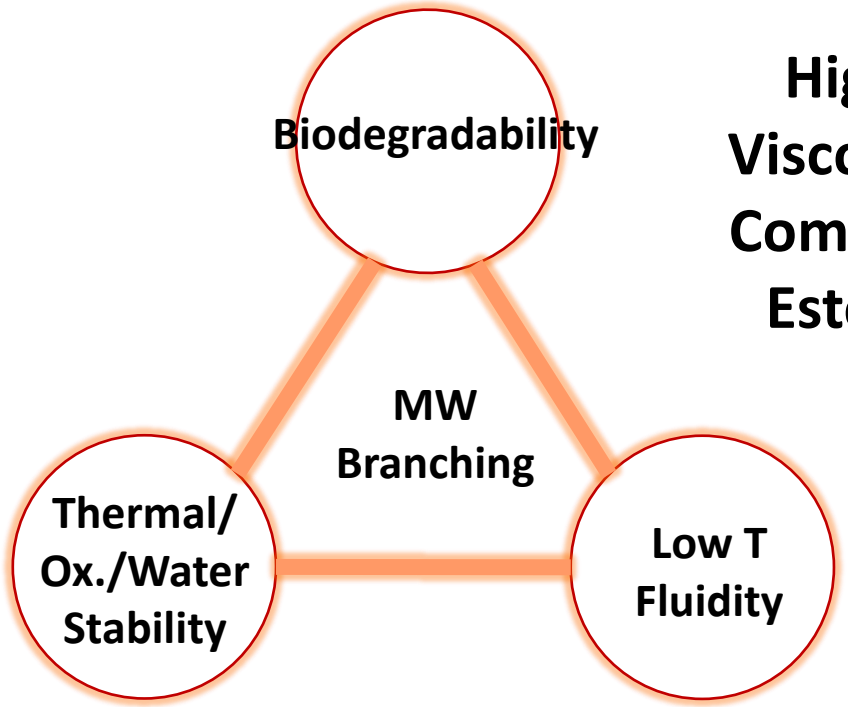


'Iron Triangle' in Picking an Ester

- To optimize one property, we lose performance in other properties
- "You can't have it all"

Polyol / Diester





High Viscosity Complex Esters

Other Biobased Basestocks

- Very unique and exciting, but: cost vs. performance vs. supply chain

- Novvi biodegradable PAO
  - Hydrogenated vegetable oil + olefin??
  - Some light conventional PAO are biodegradable

- Biosynthetic Technologies BT estolides
  - Estolides – polymer of 12-HSA, end capped with alcohol

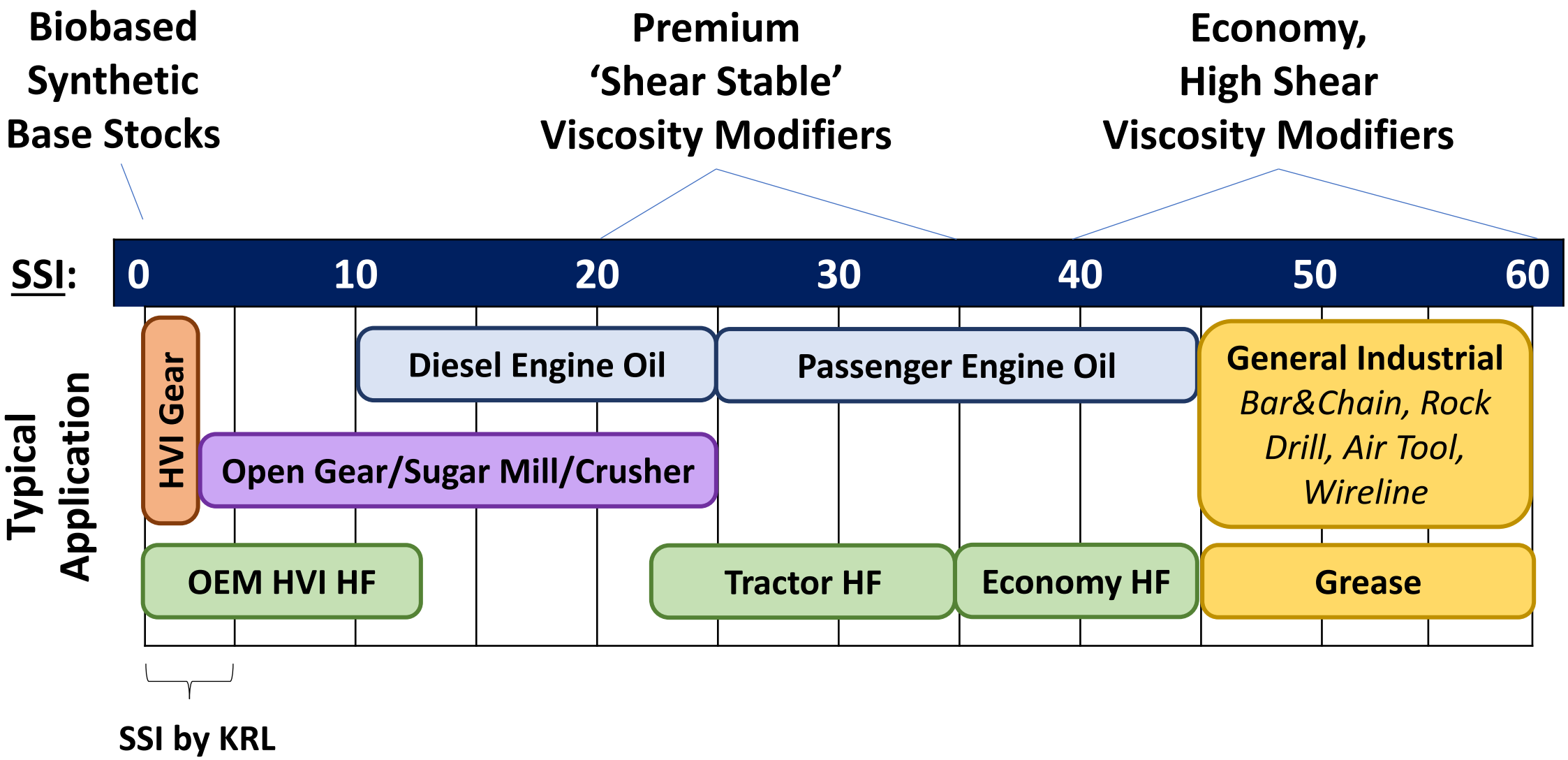
- VBASE ester-PAG hybrid
  - Triglyceride with polypropylene glycol (PAG) between the polyol and fatty acid

Component Strategy

- Polymer in *vegetable* oil or ester
  - Tackifier
  - Viscosity Modifier
  - PPDs
  - Defoamer/Demulsifier
  - Etc.
- Active components and packages
  - European Ecolabel as blueprint

Our goal is to provide anything you could get for petroleum / conventional in a biobased format

Viscosity Modifiers



Bio VMs Have Trade-Offs Too

	50 SSI "Biobased Bright Stock"	30 SSI "Low Temp VM"	29 SSI "High Temp VM"
			
Programs:	Ecolabel	Ecolabel	Ecolabel, HX-1
Thickening:	★★★	★★	★★★
Shear:	★	★★	★★
Tackiness:	★★	--	★
High Temp:	★	★★	★★★
Low Temp:	★★	★★★	★
Grease:	★	★★	★★★
Compatibility:	Ester, PAO, AN	Ester, AN	Ester, PAG, AN

Components & Packages via Ecolabel LuSC

- Looks at **biodegradability** and **ecotoxicity** of base oils + components
- Assigns ratings for all components on the whitelist

EEL Biodegradation Rating

A - Readily biodeg.; not bioaccumulative
B - Inherently biodeg.; not bioaccumulative
C - Not biodegradable; not bioaccumulative
X - Not biodegradable; bioaccumulative

EEL Toxicity Rating

D - 'Non-Toxic'
E - 'Harmful'
F - 'Toxic'
G - 'Very Toxic'

- Allows a budget of non-biodegradable or weakly toxic components <u>based on product use</u>

Ecolabel In Practice

Product Application

Open gear oils, stern tube oils, two-stroke oils, oils for temporary corrosion protection
Hydraulic fluids, metalworking fluids, gear oils for closed gears
Chainsaw oils, wire rope lubricants, concrete release agents

Likelihood of Loss (LL)

PLL = Partial Loss Lubricant
ALL = Accidental Loss Lubricant
TLL = Total Loss Lubricant

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Allowances for Non-Biodegradable / Toxins

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EEL Toxicity Rating
D - 'Non-Toxic'
E - 'Harmful'
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G - 'Very Toxic'

PLL Fluids	ALL Fluids	TLL Fluids
>75%	>90%	>95%
≤ 25%	≤ 10%	≤ 5%
≤ 20%	≤ 5%	≤ 5%
≤ 0.1%	≤ 0.1%	≤ 0.1%

PLL Fluids	ALL Fluids	TLL Fluids
No limit	No limit	No limit
≤ 10%	≤ 10%	≤ 2%
≤ 0.6%	≤ 2.5%	≤ 4%
≤ 0.1%	≤ 0.1%	≤ 0.1%

LuSC Snapshot

- 24 pages of base fluids, components, packages

	Maximum allowed treat rate[a,c]						If less than 100% see [d] or [e]				
Brand name[b,k,l] Additives and Thickeners	ALL (No Grease)	ALL (Only Grease)	PLL (No Grease)	PLL (Only Grease)	TLL (No Grease)	TLL (Only Grease)	EEL Biodegradation[d] A/B/C/X/-[f]	EEL Aquatic Toxocity[e] D/E/F/G(M[g])/-[f]	Remark	CB Assessed	Valid till
Thickeners											
Lubrizol® 75GR	5.0%	12%	12%	12%	5.0%	12%	100%C	100%D		Dutch	31 December 2028
DaeLim Synol 2000	5.0%	15%	20%	15%	5.0%	15%	100%C	100%D		Dutch	31 December 2028
FUNCTIONAL V-4051	-	45%	-	45%	-	45%	67%A; 33%C	100%D		Dutch	31 December 2028
FUNCTIONAL V-4051F	-	38%	-	38%	-	38%	60%A; 40%C	100%D		Dutch	31 December 2028
Glissopal® 2300	5.3%	10%	10%	10%	5.3%	10%	95%C	95%D		Dutch	31 December 2028
Glissopal® V 1500	5.3%	10%	10%	10%	5.3%	10%	95%C	95%D		Dutch	31 December 2028
Viscosity modifier/Pour Point depressant/Viscosity Improvers											
Functional PD-564	10%	10%	10%	10%	10%	10%	9%A; 50%B; 41%C	100%D	Bio-based fraction: *n.d.* Fraction cert. ren. ingredients: 37%NC(Palm)	Dutch	31 December 2028
FUNCTIONAL PD-585	6.1%	18%	24%	18%	6.1%	18%	18%A; 82%C	100%D	Biobased fraction: *n.d.*[i] Fraction cert. ren. ingredients: 74%NC(Palm)[h,j]	Dutch	31 December 2028
FUNCTIONAL PD-590	8%	25%	33%	25%	8%	25%	40%A; 60%C	100%D	Fraction cert. ren. ingredients: 46%NC(Palm)[h,j]	Dutch	31 December 2028
FUNCTIONAL V-188P2	5.2%	5.3%	5.3%	5.3%	5.2%	5.3%	97%C; 3%A	100%D		Dutch	31 December 2028
FUNCTIONAL V-508	30%	30%	30%	30%	30%	30%	85%A; 15%C	100%D		Dutch	31 December 2028
FUNCTIONAL V-508F	25%	25%	25%	25%	25%	25%	70%A; 30%C	100%D		Dutch	31 December 2028
FUNCTIONAL V-508M	16%	25%	25%	25%	16%	25%	80%A; 20%C	100%D		Dutch	31 December 2028
FUNCTIONAL V-508S	5.0%	10%	10%	10%	5.0%	10%	100%C	100%D		Dutch	31 December 2028
FUNCTIONAL V-508A5	20%	40%	40%	40%	20%	40%	75%A; 25%C	100%D		Dutch	31 December 2028
FUNCTIONAL V-515	50%	100%	100%	100%	50%	100%	90%A; 10%C	100%D		Dutch	31 December 2028
FUNCTIONAL V-516	45%	100%	100%	100%	45%	100%	89%A; 11%C	100%D		Dutch	31 December 2028
FUNCTIONAL V-521	28%	83%	100%	83%	28%	83%	82%A; 18%C	100%D		Dutch	31 December 2028
FUNCTIONAL V-521L	62%	100%	100%	100%	62%	100%	92%A; 8%C	100%D		Dutch	31 December 2028
FUNCTIONAL V-584	20%	20%	20%	20%	20%	20%	95%A; 5%C	100%D		Dutch	31 December 2028
FUNCTIONAL V-731	3.3%	3.3%	3.3%	3.3%	3.3%	3.3%	97%C	97%D		Dutch	31 December 2028

Considerations for EAL Chemistry

- Biodegradation
- Bioaccumulation
- Aquatic toxicity

- Ecolabel will block components at wt% treat that triggers GHS:
  - Aspiration Toxicity – **5wt% max**
  - Skin Sensitizer
  - Skin Irr / Corrosion
  - Eye Irr / Corrosion
  - Acute Toxicity
  - Etc.

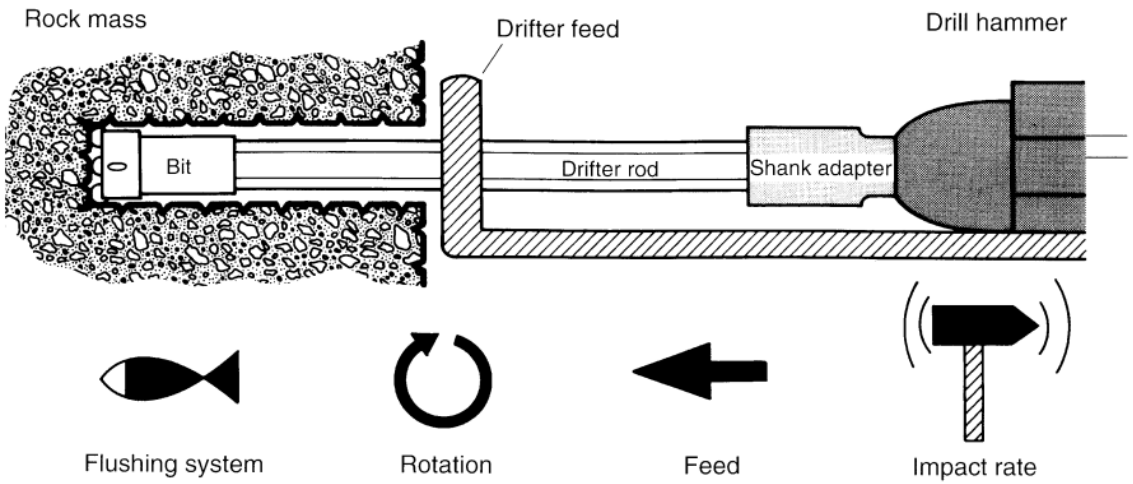
Fully Formulated Case Study - RD

Biobased Rock Drill

- Pneumatic tool / air tool oils
  - Ingersoll Rand “spec” and ISO 6743 PAC/PBC specification

Operating Conditions

- Combination of rotary and hammering
  - Crush, fragment, and strip away rock / concrete / asphalt
- Shock loading



YouTube, 4mile engines

Opportunities for Inherent Bio Advantages

- High flashpoints and less opportunity for “dieseling” or combustion of mist
  - Heavy Gr. II paraffinic f.p. is 260-300°C
  - Veg oil f.p. is 320-350°C

- Good inherent lubricity and emulsibility
  - May increase EP by one level (200 → 250 → 315 → 400) vs. petroleum

- Readily biodegradable, low toxicity, no oil sheen

- High VI (200+) for wider operating temp. range
  - Low starting PP: -27°C for canola w/o PPD
  - Customer can consolidate several grades into one

Biobased Rock Drill Performance Specs

	ISO 100 Bio Emulsifying	ISO 150 Bio Emulsifying	ISO 220 Bio Emulsifying
Canola Oil	86.9%	82.4%	78.1%
Biobased VM (50 SSI)	10.9%	15.4%	19.7%
EP Packaging (Eco-Friendly)	2.2%	2.2%	2.2%
Viscosity Index	248	251	261
Pour Point (D97)	-24°C	-24°C	-24°C
Water Separability (D1401)	5/25/50	6/25/49	3/26/51
Flash Point (D92, COC)	240°C	245°C	248°C
Load Wear Index (D2783)	53	54	51
4-Ball EP Weld Load (D2783)	315	315	315
Falex EP Load (D3223)	4502	4534	4549
Timken OK Load (D2782)	70	70	70
FZG Load Stage	>12	>12	>12

Back Around to Ecolabel Certified

Original "Eco-Friendly" EP Package and Tech (2.2wt%)

4-Ball Wear Scar (D4172, 20 kg)	0.30 mm
4-Ball Weld Load (D2783)	315 kg
• Load wear Index (LWI)	65
Timken OK Load	> 60 lbs
Demulsification, D1401, 30 min	1/6/73
FZG A/8.3/90 (D5182), Load stage	> 12

Ecolabel LuSC-listed EP Package (4wt%, ISO 100)

EP Weld Load, D2783	315
Last Non-Seizure Load, D2783	126
Load Wear Index, D2783	57
Falex EP Load, D3233A	3263
Turbine Oil Rust, D665A & D665B	Pass & Pass
Foam Sequence I, D892	0
Copper Corrosion, D130, 3hrs, 100C	1a
Demulsibility @ 82C, D1401	40/40/0 (30)

	wt%	4-Ball Weld	LWI
"Eco-Friendly"	2.2%	315 kg	65
LuSC-listed	4.0%	315 kg	57

Closing Remarks

Summary

- Biobased / biodegradable lubricants add a new spin to existing lubricant market
  - End users seeking guidance
  - Different programs with different priorities
- Use EAL programs as a blueprint rather than a hurdle
- Opportunity to build an ecosystem of EAL base fluids + components

Thank you to STLE Pittsburgh Section!

Questions or follow-up:

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