Connecting Synthetic Ester Base Oil Innovation with Industry Trends

Novel Hybrid Ester Technology

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CTO - VBASE Oil Company

VBASE Oil Company

Location
Commercial & R&D Center
Pendleton, South Carolina, USA

Manufacturing
Southeast USA

Technology Competencies
Expertise in molecular design, seed oil chemistry and material science

Hybrid Ester Base Oil Development & Market Introduction

VBASE Oil Company formed
2021

Spin off from Tetramer Technologies, USA

Hybrid Ester base oils developed (ISO 32-100) (GEN 1)

Scaling
2022

Toll manufacturing begins in N.Am.

NSF HX-1 & Bio-preferred listing

Customer collaborations
2023

EU-LuSC accreditations granted

Complex Hybrid Ester base oils developed (GEN 2)

Complex Ester Product Launch
2024

New high viscosity Complex Ester launch (ISO-100 to 460)

2025

New additives. Friction modifiers & deposit control.

Industry Mega-Changes & Lubricant Innovation

Political change is driving our **Energy Transition** driven by a **Technology Revolution** in Industry 4.0. New lubrication solutions are needed to address new goals on **energy efficiency, thermal management** and **equipment reliability.**

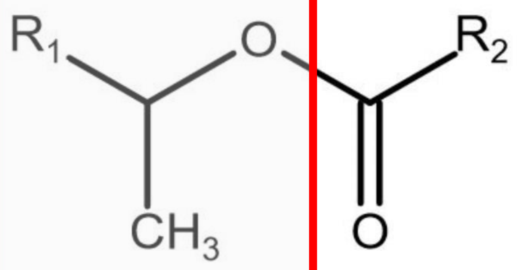
Technology Revolution	Implications for Lubricant Technology Development
❑ Robotics	✓ Advanced base stocks
❑ Advanced computing	✓ Superior heat management versus hydrocarbon oils
❑ Digitization	✓ Increased volumetric heat capacities and thermal conductivities
❑ Electrification (EVs)	✓ More thermo-oxidatively stable lubricants
❑ Higher industrial productivity	✓ Safer lubricants (fire resistant, food safety)

Energy Transition	Implications for Lubricant Technology Development
❑ UN climate change policy	✓ Energy efficient lubricants (friction control, fuel economy)
❑ EU Green Deal	✓ Lubricants from alternative feedstocks (oleochemical feedstocks)
❑ Circular economies	✓ Longer life fluids (less waste)
❑ Decarbonization	✓ Recycling/reconditioning
❑ Sustainable development	✓ LCAs/ Product carbon footprint

Hybrid Ester Technology

Oxygen-rich Hybrid Ester Base Oils

Proprietary oxygen rich polyols



Esterification of a **secondary** hydroxyl on the polyol

Hybrid structures:
Functional performance of PAGs and environmental performance of esters

Wide design space for molecular development to control performance

Design for Functional Performance

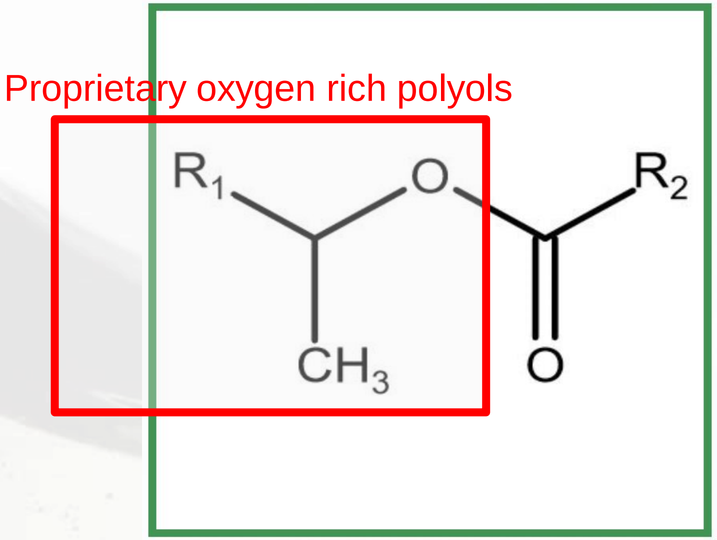
- In-built detergency
- Friction control
- Oxidation stability
- Hydrolytic stability
- Deposit control
- Gas solubility
- Oil solubility
- Fire resistance

Design for Environmental Performance

- Biodegradability
- Bio-carbon content
- Non-Toxic

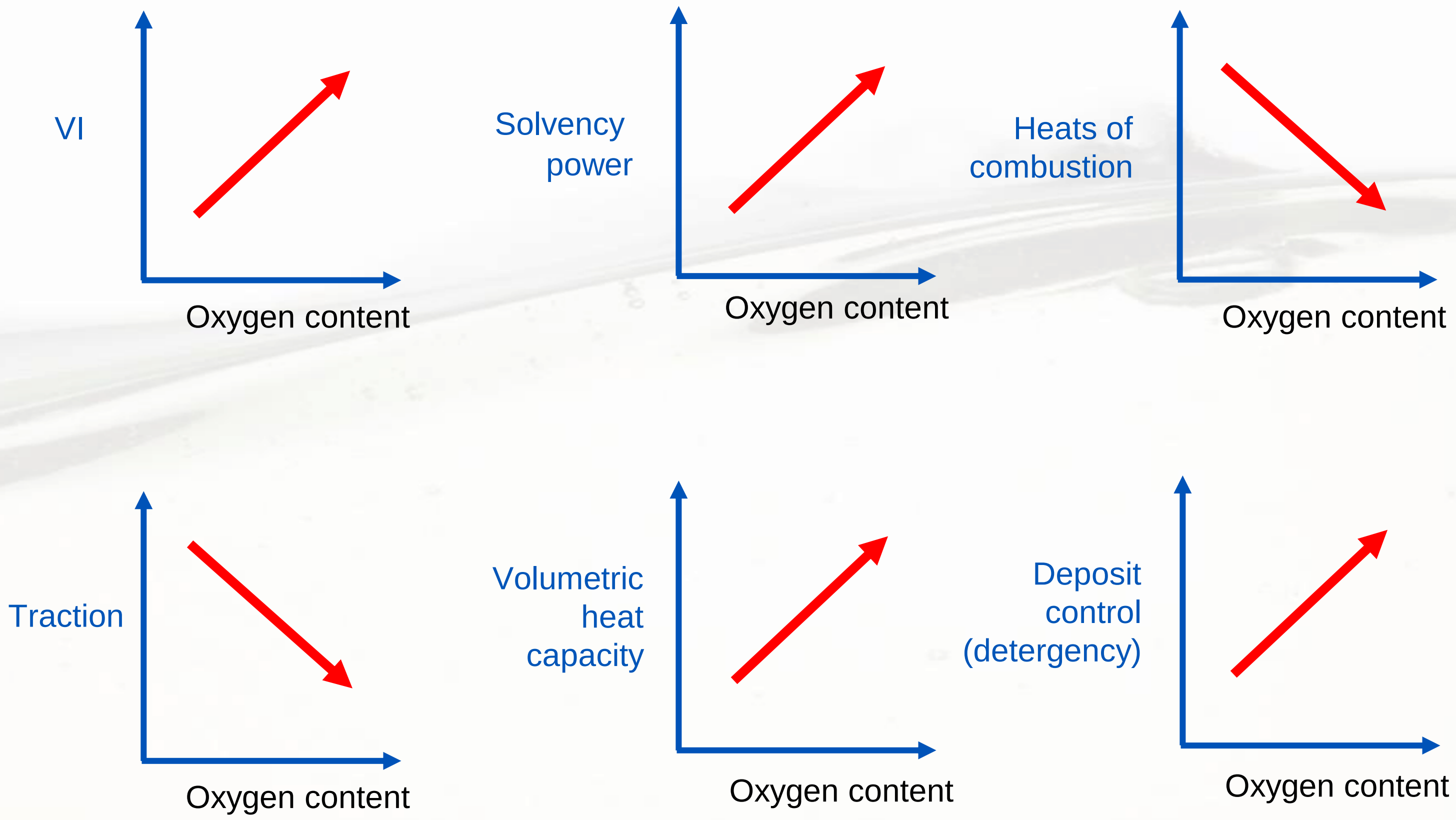
Hybrid Ester Technology

Novel
Hybrid Ester Technology



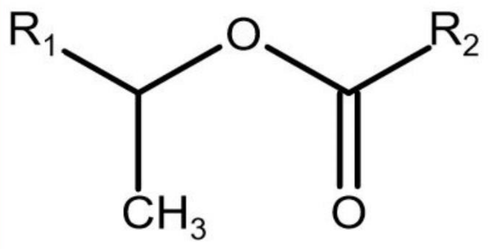
ISOVG 32 to 460

General design rules when increasing oxygen content in esters



Hybrid Ester Base Oils & Heat Capacity

Volumetric Heat Capacity is the amount of heat required to raise the temperature of a unit volume of a substance by one degree.



Oxygen-rich base oils

	ISO Viscosity Grade	Density at 40ºC (g/ml)	Specific heat capacity at 40ºC, J/g/K	Volumetric heat capacity (J/cm³/K
TMP-Trioleate**	46	0.903	2.03	1.83
PAO-6**	32	0.811	2.33	1.88
ISO-46 Hybrid ester	46	0.960	2.10	2.02*
ISO-68 Hybrid ester	68	0.950	2.17	2.06*

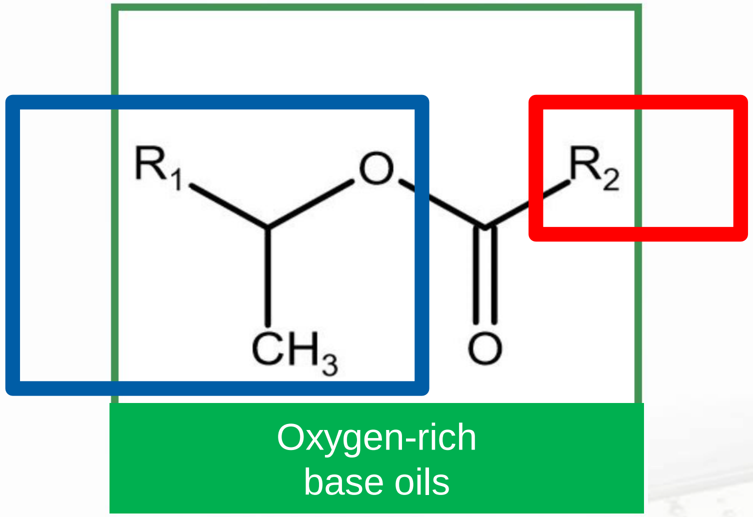
* Measured using ASTM D7896-19
** Thermochemica Acta 703, (2021) 178994

Oxygen-rich Hybrid Ester base oils offer **high volumetric heat capacities** and may be a useful building block in formulating lubricants by improving **heat management in equipment**.

Hybrid Ester Base Oils & Fire Resistance

Designing **Hybrid Ester** base oils for fire resistance

High oxygen content in polyol (R_1)



Unsaturated moiety

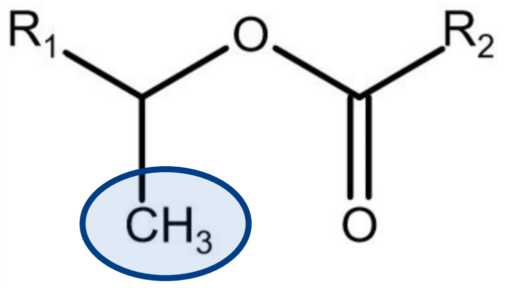
- **Hybrid Ester base oils** offer **low heats of combustion** and **high fire points.**
- The inclusion of oxygen-rich **Hybrid Esters** in formulations can create safer to use **fire resistant hydraulic fluids.**

		Petroleum base oil	TMPTO	Hybrid Ester ISO-68
ISO Viscosity Grade	ASTM D445	46	46	68
Heat of combustion (MJ/kg)	ASTM D240	43-44	38.0	34.0
Fire point, ºC	ASTM D92	<240	>320	>320

TMPTO is trimethylolpropane trioleate and dominant industry base oil for HFDU Fluids

Saturated Hybrid Ester Base Oils & their Hydrolytic Stability

Oxygen-rich Hybrid Ester base oils



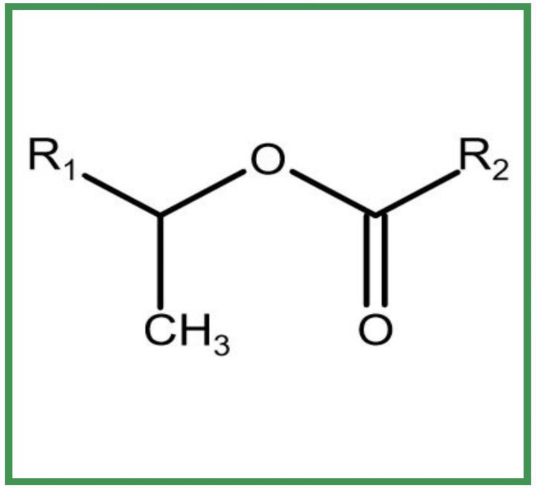
Hydrolytic stability using ASTM D2619

	ISO-32	ISO-46	ISO-68	ISO-100
Acid number change, mgKOH/g	0.28	0.13	0.2	0.46
Copper appearance	1B	1B	1B	1B
Copper loss (mg/cm^2)	-0.083	-0.008	-0.025	-0.033
Kin. viscosity change (%)	-3.3	-2.1	-0.2	-1.8
Insolubles (%)	0.02	0.02	0.03	0.02

Alkyl groups in the polyol backbone significantly slows rate of hydrolysis

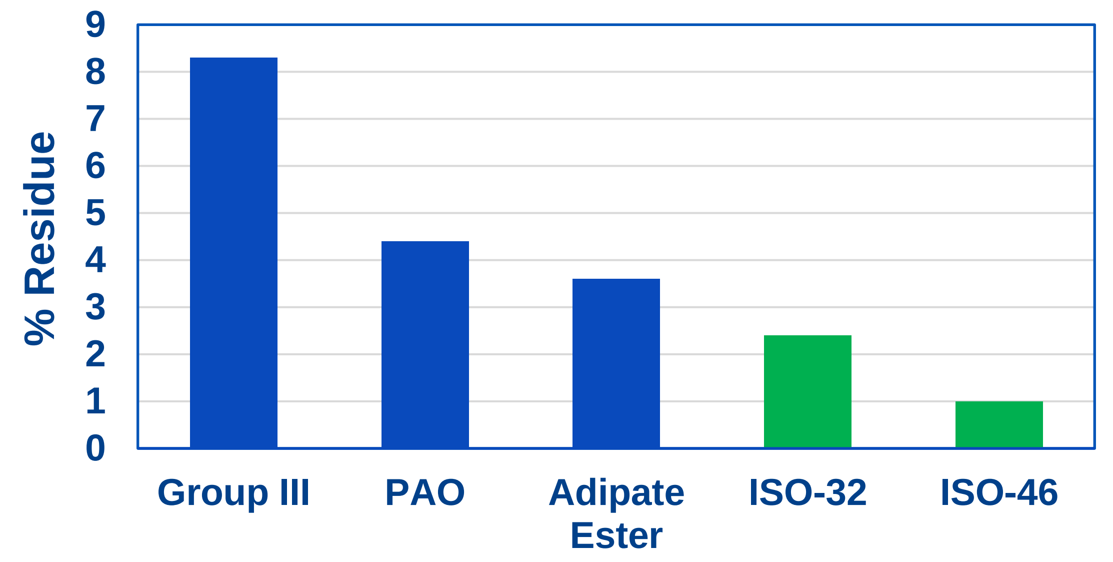
Hybrid Ester Base Oils & In-Built Detergency

In-Built Detergency



Oxygen-rich base oils

DSC Experiment – Residue at end-of test



Heating from ambient to 400°C at 10°C/min in an air atmosphere and measuring remaining residue.

- Thermo-oxidative degradation at high temperatures shows **lower deposits for Hybrid Ester base oils**
- As components of hydrocarbon oils, their high polarity can help **improve equipment and lubricant cleanliness and minimize risk of varnish formation**

Applications for Hybrid Ester Base Oils (ISO 32-100)

Hydraulic Fluids

Varnish control
Shear stability

In-built detergency and oxidation stability leads to equipment reliability.

Premium choice for mobile hydraulics and bio-hydraulic fluids.

Fire Resistant Fluids

Fire resistance
Hydrolytic stability

Low heats of combustion and **high fire points** leads to safer HFDU fluids.

Turbine Oils

Varnish control
Hydrolytic stability

In-built detergency and **hydrolytic stability** leads to equipment reliability and long life fluids.

Premium choice in environmentally sensitive areas.

Metalworking Fluids

Hydrolytic stability
Wear protection

Oxygen-rich molecules enhances film forming and **wear protection** properties.

In-built detergency enhances equipment cleanliness.

Applications for Hybrid Ester Base Oils (ISO 100-460)

Gear Oils

High temperature stability
Energy efficiency

High volumetric heat capacities and **thermal conductivities** is favourable for lower oxidation rates

Oxygen-rich structures enhance film forming and **wear protection** properties.

Greases

High temperature stability
Friction control

Oxygen-rich structures **enhance load carrying capacity.**

Environmental properties offer new solutions for marine and railroad greases.

Chain Oils

High temperature stability
Deposit control

Oxidation stability and film forming properties protect chains.

Their **in-built detergency** enhances equipment cleanliness

2-T Oils

Cleanliness & clean burn
Wear performance

Oxygen-rich structures enhance film forming and **wear protection** properties

Premium choice as a **viscosity builder or deposit control additive** in formulations

Hybrid Ester Base Oils (ISO 32-460) & their Environmental Performance

Designed for Sustainability

Biobased (> 50%)
ASTM D6866

Biodegradable (> 80%)
OECD 301B

Non-Toxic (LC_{50} > 1000 mg/L)
OECD 201, 202, 203, 236

Non-Bioaccumulating
OECD 117

EU LuSc Listed

HX-1 certified for use as components in **Food Grade Lubricant** Compositions

USDA BioPreferred Program

Conclusions

Oxygen-rich Hybrid Esters are a new Group V base oil technology

Offer the environmental performance benefits of esters and the functional performance of PAGs.

Platform Technology

Our novel platform chemistry allows a diverse range of hybrid structures to be developed to solve some of the tribology challenges of today.

Heat Management

Unique thermo-physical properties such as high volumetric heat capacities.

In-Built Detergency & Hydrolytic stability

High degree of branching on proprietary polyol leads to good hydrolytic stability. Oxygen-rich structures improve equipment cleanliness and can create longer life fluids.

Sustainable Synthetic Base Oils for EALs

Beneficial for Marine Lubricants and other EALs.