

Advancing Lubricant Performance using VBASE Secondary Polyol Ester® Base Oils

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BASE OIL INNOVATION

Rapid advancements in technology are transforming the lubricant industry, spurring the development of innovative solutions to meet the evolving demands of equipment design. Original Equipment Manufacturers (OEMs) are producing engines and industrial machinery that operate at higher temperatures, within tighter tolerances, and require longer service intervals. Concurrently, new specifications are emerging that set higher standards for fuel efficiency, emissions control, and environmental sustainability. Conventional petroleum-based oils are increasingly challenged to meet these requirements, as they are limited by their inherent constraints in thermal and oxidative stability, heat management and fluid longevity.

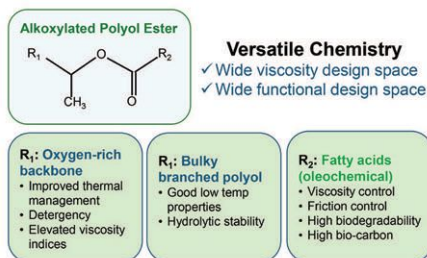
VBASE® Oil Company has responded to the demand with advanced base oils that provide superior thermal management, offering formulators the opportunity to design energy-efficient formulations with excellent environmental profiles. This paper highlights the key features of VBASE Secondary Polyol Ester® (SPE®) products whose chemistry is described as 'alkoxylated polyol ester' chemistry. It presents performance data on a formulated bio-hydraulic fluid as well as field performance data on a formulated hydro-turbine oil.

VBASE® SPE® base oils:

Alkoxylated polyol ester chemistry

Previous articles have explained the chemistry (Figure 1) and functional performance of VBASE SPE® technology^{1,2}. This chemistry is highly versatile, enabling the design of a wide array of alkoxylated polyol esters with varying molecular architectures and functionalities through the esterification of

Figure 1: Chemistry of VBASE® Base Oils



secondary alcohol groups on a proprietary polyol with fatty acids from either oleochemical or petrochemical sources. A key distinction between conventional synthetic esters and alkoxylated polyol esters is the incorporation of high levels of oxygen in the form of ether bonds within their structure. VBASE SPE® products can be generically described as 'PAG-Ester hybrids' since they offer many of the functional and environmental performance of PAGs and esters. The incorporation of oxygen provides superior thermal management, enhanced detergency, and higher viscosity indices compared to petroleum oils and many alternative

synthetic esters. Their highly branched molecular structure enhances their hydrolytic stability and low-temperature properties. High biodegradability can be achieved by using linear fatty acids. Figure 2 presents the physical properties of a range of saturated alkoxylated polyol esters, spanning from ISOVG 32 to 460.

Thermophysical Properties

Recently a growing body of knowledge has been developed regarding the thermophysical properties of lubricants. One important property is specific heat capacity (the amount of heat required to raise the temperature of a unit mass of a substance by one degree). While this value is useful, volumetric heat capacity is more relevant, as equipment is typically operated with a specific volume of lubricant rather than a specific mass. Volumetric heat capacity can be calculated by multiplying the fluid's density by its specific heat capacity.

Figure 3 illustrates the volumetric heat capacities at 25, 50 and 80°C for a range of ISO-VG46 base oils, including

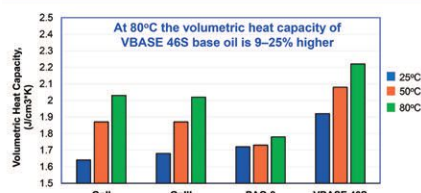
Figure 2: Typical Properties of VBASE® Base Oils

Saturated Secondary Polyol Ester® Base Oils

	VBASE 32S	VBASE 46S	VBASE 68S	VBASE 100CS	VBASE 220CS	VBASE 460CS
Kin.viscosity at 40°C, mm ² /sec	29.5	44.2	67.3	99.5	231	445
Kin.viscosity at 100°C, mm ² /sec	6.1	8.6	12.3	16.9	35.0	62.0
Viscosity Index	162	177	183	185	200	213
Pour point, °C	-60	-42	-24	-18	-18	-21
Aniline point, °C	<-10	<-10	<-10	<-10	<-10	<-10
Biodegradation* (OECD301B), %	>80	>80	>80	>80	>80	>80
Bio-based carbon (%)	62	50	59	57	54	50

VBASE also offers unsaturated Secondary Polyol Ester® base oils

Figure 3: Volumetric Heat Capacities of ISOVG-46 Base Oils



Secondary Polyol Ester® base oils offer high volumetric heat capacity and are a useful building block in formulating lubricants by improving thermal management in equipment.

API Group II and III petroleum oils, a polyalphaolefin and VBASE 46S. Measurements were made using a TA Instruments Q2000 Differential Scanning Calorimeter. At 80°C, VBASE 46S demonstrates a 9-25% increase compared to the other oils.

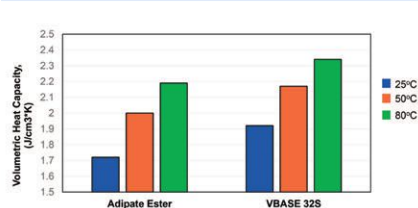
Figure 4 compares an adipate ester (ISOVG-32) with VBASE 32S, showing that VBASE 32S consistently exhibits higher values across all temperatures. The high levels of oxygen within the molecular structure significantly improves their volumetric heat capacity compared to hydrocarbon base oils and traditional esters. Lubricants with higher volumetric heat capacity enhance heat management, help maintain lower temperatures, promote safer operations, reduce oxidation rates and lead to longer drain intervals.

Field Trial on VBASE® Hydro T-EL™ – Formulated Hydro-Turbine Oil

Most hydro-turbines currently in operation use petroleum oils, which are known for their proven reliability, long service life, and compatibility with materials. However, petroleum oils pose an environmental risk in the event of spills, as they are non-biodegradable. Biodegradable oils offer several advantages, including enhanced environmental safety, regulatory compliance, reduced spill liability, and, in some cases, improved performance. They are particularly beneficial when used near ecologically sensitive waterways.

VBASE Hydro T-EL™ was developed to serve the hydropower market, and its performance data presented in Figure 5. It demonstrates a high viscosity index, excellent oxidation resistance as measured by the dry-TOST and RPVOT methods, superior corrosion protection

Figure 4: Volumetric Heat Capacities of ISOVG-32 Base Oils



Higher values are obtained for the oxygen-rich VBASE 32S base oil

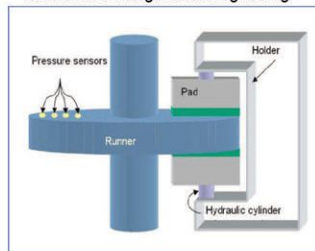
for both ferrous and non-ferrous metals, and good demulsibility. In FZG testing, it successfully passed stage 12. Hydro T-EL was initially evaluated on a combined thrust guide test rig at GE Hydro Solutions' Global Center of Excellence, ensuring its performance would meet the requirements for a large turbine equipment trial. Figure 5 illustrates the testing conditions. At speeds ranging from 400 to 800 rpm and applied loads up to 13 MPa, the fluid maintained a stable hydrodynamic film, effectively protecting the bearing and runner surfaces from damage.

Figure 5: Field Trial Evaluation at Porjus, Hydroelectric Power Station in Sweden

Hydro Turbine oil	Method	Result
Kin. Visc. at 40°C, mm²/sec	ASTM D445	57.7
Viscosity index	ASTM D2270	182
Flash point, °C	ASTM D93	254
Pour point, °C	ASTM D97	-18
RPVOT, min.	ASTM D2270	1240
Dry TOST, hours	ASTM D943	8000
Rust prevention	ASTM D665A/B	pass/pass
Copper corrosion	ASTM D130	1a
Demulsibility, ml	ASTM D1401	40-40-0
Foaming, ml, 5 mins	ASTM D892	0-0-0
FZG failure stage	ASTM D5182	12+
Biodegradation, 28 days, %	OECD 301B	81
Biobased Carbon (¹⁴C %)	ASTM D6866	57

Initial Equipment Testing at GE Hydro Solutions' Global Center of Excellence in Switzerland

Combined thrust guide bearing test rig.



At speeds of 400-800 rpm and applied loads up to 13 MPa, the fluid maintained a uniform hydrodynamic film, protecting the bearing and runner surfaces from damage.

Figure 6: Field Trial Evaluation at Porjus, Hydroelectric Power Station in Sweden

	Initial	2 months	6 months	12 months
Kin. Viscosity at 40°C, mm²/sec	58.5	58.7	58.6	58.8
Kin. Viscosity at 100°C, mm²/sec	10.7	10.7	10.7	10.7
Viscosity Index	176	176	176	175
Acid number change, mgKOH/g	-	0.03	0.38	0.39
Water content, ppm	1140	520	780	560
Demulsibility, O/W/E ml/(min) (40)	40-40-0 (40)	40-40-0 (40)	40-40-0 (40)	40-40-0 (40)
Air release, mins	<2	<2	<2	<2
Particle class	n/d	17/14/9	17/15/11	15/12/9

Fluid is operating at about 10°C lower temperature compared to the previous hydrocarbon turbine oil (ISOVG 68) in the installation.

ICP data	Initial	2 months	6 months	12 months
Al, ppm	<1	<1	<1	<1
Ca, ppm	<1	<1	<1	<1
Cr, ppm	<1	<1	<1	<1
Cu, ppm	<1	<1	<1	<1
Fe, ppm	<1	<1	<1	<1
Mo, ppm	<1	<1	<1	<1
Ni, ppm	<1	<1	<1	<1
P, ppm	16	13	11	24
Sb, ppm	<1	<1	<1	<1
Si, ppm	3	3	2	3
Sn, ppm	<1	<1	<1	<1
Zn, ppm	<1	1	2	1

was observed. Water levels fluctuated during the trial, likely due to seasonal variations. Elemental analysis revealed no signs of contamination or wear metals.

A particularly notable observation was the average reduction of fluid temperature by 10°C compared to the previous petroleum oil (ISOVG 68) used in the turbine. This improvement is attributed to the superior volumetric heat capacity of VBASE Hydro T-EL. Effective heat management remains a challenge for petroleum oils. VBASE SPE® oils offer a promising solution for OEMs seeking fluids with enhanced thermal management properties. Initial conclusions suggest that VBASE Hydro T-EL is a high performance environmentally acceptable alternative to petroleum oils for hydro-turbine equipment.

Formulating Bio-hydraulic Fluids using SPE® Technology

High performance biohydraulic fluids use synthetic esters due to their high biodegradability, and low toxicity, making them particularly suitable for use in environmentally sensitive areas. Ester-based fluids can improve energy efficiency by reducing component wear, and minimizing energy losses caused by friction. Carefully formulated fluids offer excellent low-temperature properties, making them ideal for mobile equipment operating in cold climates.

To meet the rising demand for efficiency, energy savings and precision, OEMs are designing smaller, more powerful hydraulic systems. This trend is driven by industries that require light-weight, agile machinery and reduced operational costs. Two key challenges in the design of future fluids are managing the thermal performance of hydraulic systems and optimizing air release times.

Fast air release times of fluids is essential in smaller, more powerful hydraulic systems due to the higher pressures, faster flow rates, and increased precision. Effective air release ensures consistent performance and protects components from damage. This becomes even more critical when using bio-hydraulic fluids, which are more susceptible to air-related issues such as cavitation.

Figure 7: Example of the Performance of a Bio-Hydraulic Fluid using VBASE 46S versus ISO-15380 Specification

Formulation	Weight %	Property	Method	Typical Limits	Bio-Hydraulic Fluid
VBASE 46S	98.746	Kin. viscosity at 40°C, (cSt)	ASTM D445	Report	45.1
EL Additive Pack	1.25	Kin. viscosity at 100°C, (cSt)	ASTM D445	Report	8.7
Foam control additive	0.004	Kin. viscosity at 0°C, (cSt)	ASTM D445	780 max	402
EL Additive Pack is an ashless package containing antioxidants, anti-wear and corrosion inhibitors.		Viscosity Index	ASTM D2270	Report	174
		Pour point, °C	ASTM D97	-15 max	-40
Bio-hydraulic fluid using VBASE 46S fulfils key test requirements of ISO-15380 for HEES Fluids.		Acid number (mg KOH/g)	ASTM D974	Report	0.18
		Air release at 50°C (min)	ASTM D3427	7 max	0.1
		Copper corrosion (3h at 100°C)	ASTM D130	2 max	1A
		Demulsibility at 54°C (min)	ASTM D1401	Report	40-37-03 (25)
		Foam sequence I (mL)	ASTM D892	150-0 max	0-0
		Foam sequence II (mL)		80-0 max	0-0
		Foam sequence III (mL)		150-0 max	0-0
		TAN change (mg KOH/g)	ASTM D2619	n/a	0.09
		Water acidity (mg KOH/g)		4 max	2.30
		Cu weight loss (mg/cm²)		0.2 max	-0.1
		Rust (Salt)	ASTM D665B	Pass	Pass
		Dry TOST Lifetime (h)	ASTM D943 (dry)	Report	2500

Figure 8: Example of the Performance of a Bio-Hydraulic Fluid using VBASE 46S

Elastomer Compatibility per ISO-15380 Specification (HEES)				
Formulation	Weight %	Elastomer	Property	Bio-Hydraulic Fluid
VBASE 46S	98.746	HNBR, 1008h, 80°C	Hardness Change	-1
EL Additive Pack	1.25		Volume Change (%)	1
Foam control additive	0.004		Tensile Strength Change (%)	1
			Elongation Change (%)	6
Bio-hydraulic fluid containing VBASE 46S exhibits good elastomer compatibility		FKM, 1008h, 80°C	Hardness Change	-2
			Volume Change (%)	1
			Tensile Strength Change (%)	-6
			Elongation Change (%)	9
		NBR1, 1008h, 80°C	Hardness Change	-5
			Volume Change (%)	7
			Tensile Strength Change (%)	-3
			Elongation Change (%)	1

At VBASE, we've developed bio-hydraulic fluids designed to meet these challenges. Figure 7 illustrates the performance of a formulated bio-hydraulic fluid (ISOVG-46) tested according to ISO-15380. It uses VBASE 46S and additized (1.25% by weight) with an environmentally acceptable additive package. It demonstrates an excellent viscosity index and low-temperature properties, good oxidation stability, and outstanding ferrous and non-ferrous corrosion protection. The fluid also meets the specification requirements for hydrolytic stability and exhibits an excellent air release time. Many bio-hydraulic fluids made from synthetic base oils have significantly higher air release times. Furthermore, unlike some ester-based synthetics that are incompatible with common elastomers, it shows excellent compatibility with NBR, HNBR, and Viton (Figure 8).

Bio-hydraulic fluids formulated using VBASE SPE® base oils are capable of exceeding both OEM requirements and international specifications. Key attributes, such as superior thermal management and optimized air release times, provide innovative solutions for the industry. The VBASE team is currently

conducting a study to evaluate the hydraulic energy efficiency of bio-hydraulic fluids derived from SPE® base oils, comparing them to conventional petroleum oils and alternative ester fluids. Initial results, which will be published soon, further validate the significant energy efficiency advantages offered by these fluids.

Summary

Formulations using VBASE® Secondary Polyol Ester® base oils offer OEMs an effective solution for managing heat and are engineered to meet the evolving performance demands of future equipment while complying with emerging environmental standards and regulations.

REFERENCES

1. Secondary Polyol Ester® Technology. Novel, High Performance & Sustainable Base Oils, Tribology & Lubrication Technology, Nov. 2024.
2. Exploring the functionality of oxygen-rich Secondary Polyol Ester Base Oils, Lube Magazine No. 183, Oct. 2024.

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ALL PERFORMANCE. NO COMPROMISE.™



Advancing Lubricant Performance with VBASE® SPE® Base Oils ISO Viscosity Grades 32–460

Lubricant demands are evolving rapidly. Higher operating temperatures, tighter tolerances, and extended service intervals require base oils with exceptional stability and thermal management. Conventional petroleum oils can't keep up — but VBASE® Secondary Polyol Ester® (SPE®) technology can.

Why Formulators Choose VBASE® SPE® Base Oils:

- **Superior Thermal Management** – Oxygen-rich chemistry delivers higher **Volumetric Heat Capacity** for cooler, safer operations.
- **Improved System Efficiency** – Advanced **Friction Control and Shear Stability** enable decreased flow losses and torque losses.
- **Environmental Performance** – **Biobased, Readily Biodegradable**, and designed for regulatory compliance.



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