



# A new era in sustainable hydro-turbine lubrication

Zach Hunt, Martin Greaves, Jeff DiMaio, Ben Bergmann, VBASE Oil Company



Zach Hunt



Martin Greaves



Jeff DiMaio



Ben Bergmann

*Hydropower’s sustainability credentials are well established, but lubricant choice is becoming an increasingly important part of the equation. Focusing on*

*environmentally acceptable turbine oils, this feature highlights advances in ester-based chemistry and real-world trials, showing how operators can balance performance, reliability and environmental responsibility in modern hydroelectric systems.*

Hydropower is one of the most reliable and widely utilised renewable energy sources, playing a critical role in the global transition away from fossil fuels. While its low-carbon benefits are well established, the environmental footprint of hydroelectric operations extends beyond electricity generation. Central to turbine performance are lubricants, which reduce friction, control temperature, and ensure long-term reliability. Petroleum-based turbine oils have long been the industry standard, valued for their proven performance and ability to deliver extended service life under demanding conditions. However, when leaks or accidental discharges occur, these oils can persist in aquatic environments, posing risks to water quality and surrounding ecosystems.

As sustainability expectations rise, our industry is assessing the potential of environmentally acceptable hydro turbine oils as a safer alternative to conventional petroleum-based turbine oils.

These advanced fluids are designed to deliver the performance required for demanding turbine applications while offering a significantly improved environmental profile. Formulated to meet stringent criteria for biodegradability, low toxicity, and minimal bio-accumulation, and aligned with frameworks such as the U.S. Environmental Protection Agency (EPA) and the EU Ecolabel, they provide a more responsible option in the event of leaks or discharges. Beyond compliance, their adoption can help operators reduce environmental risk, potentially lower remediation costs, and strengthen the overall sustainability and public perception of hydropower operations.

In response to these evolving requirements, VBASE® Oil Company has developed a high-performance environmentally acceptable hydro turbine oil - VBASE® Hydro T-EL. Field performance insights are presented here to give turbine operators the confidence to safely and reliably transition to this technology.

## Technology behind Hydro T-EL™

Central to the formulation is the use of a novel Secondary Polyol Ester® (SPE®) base oil whose generic chemistry and functionality is highlighted in Figure 1. Traditional polyol esters are well established in the lubricant industry, with proven performance across industrial, aviation, marine, and automotive applications, where they address limitations associated with conventional petroleum oils. SPE technology represents a further advancement of this chemistry, engineered with a high degree of oxygen incorporation, as ether bonds, within their novel molecular structure.

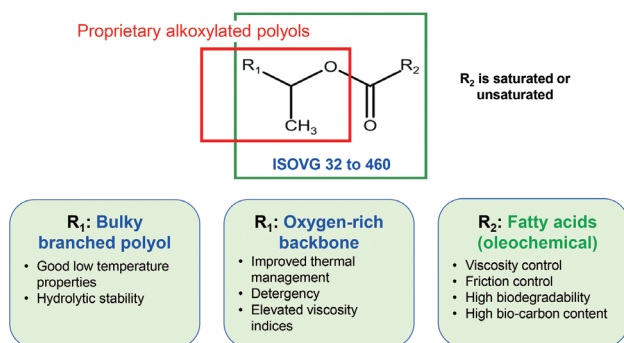


Figure 1: Generic structure of SPE base oils and key functionalities.

This molecular design imparts several functional advantages. The elevated oxygen content contributes to enhanced thermal management through increased volumetric heat capacity, while the inherent polarity of the ester structure promotes strong surface affinity and robust film formation. In addition, these fluids exhibit intrinsic detergency and provide effective control of deposits, varnish, and sludge formation under high-temperature operating conditions. The highly branched architecture of SPE base oils also provides favourable low-temperature properties and contributes to improved hydrolytic stability compared to conventional ester systems. Moreover, the base oils are readily biodegradable, non-toxic and non-bioaccumulating. They have the U.S. Department of Agriculture (USDA) Biopreferred status and are EU Ecolabel LuSC-listed. Collectively, these characteristics make SPE technology well suited to demanding hydro turbine environments.

## Equipment trials using Hydro T-EL™

Figure 2 illustrates the performance of the fluid in conventional laboratory tests. The product demonstrates a significantly elevated viscosity index compared to conventional petroleum-based turbine oils (typically 100-120), supporting stable viscosity

across a broad operating temperature range. It also exhibits outstanding oxidative stability, as evidenced by performance in both the dry turbine oil stability test (TOST) and the rotating pressure vessel oxidation test indicating strong resistance to oxidative degradation under prolonged thermal stress. In addition, the formulation provides effective corrosion protection for both ferrous and non-ferrous metals, alongside excellent demulsibility, ensuring efficient water separation in service. Load-carrying capability is confirmed by an FZG scuffing test failure load stage (FLS) rating exceeding 12, demonstrating robust film strength under high-load conditions.

Hydro Turbine Oil	Method	Result
Kin. Visc. at 40°C, mm <sup>2</sup> /sec	ASTM D445	57.7
Viscosity Index	ASTM D2270	182
Flash Point, °C	ASTM D93	254
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
Air Release, min	ASTM D3427	<2
Foaming, ml, 5 mins	ASTM D892	0-0-0
FZG Failure Stage	ASTM D5182	12+
Biodegradation, 28 days, %	OECD 301B	81
Biobased Carbon ( <sup>14</sup> C %)	ASTM D6866	57

Figure 2: Performance Testing.

From an environmental perspective, the product delivers excellent performance, being readily biodegradable, non-toxic, and exhibiting negligible bioaccumulation potential. This combination of technical performance and environmental compatibility positioned the fluid as a high-performance alternative to traditional petroleum-based turbine oils. To support its laboratory performance, equipment testing was scheduled in two phases.

The first phase was an initial validation study conducted through a pre-trial at the GE Hydro Solutions Global Centre of Excellence in Switzerland, using a combined thrust and guide bearing test rig (Figure 3). This study was designed as a preliminary assessment to establish the suitability of the fluid

prior to full-scale field evaluation. The lubricant demonstrated consistent performance across a range of operating conditions, including high-load and low-speed regimes representative of mixed lubrication. At rotational speeds of 400–800 rpm and applied contact pressures of up to 13 MPa, the fluid maintained a stable hydrodynamic film, effectively preventing surface-to-surface contact and mitigating wear of both bearing pads and runner surfaces. Post-test inspection confirmed the absence of any observable damage or distress on the bearing pad surfaces.

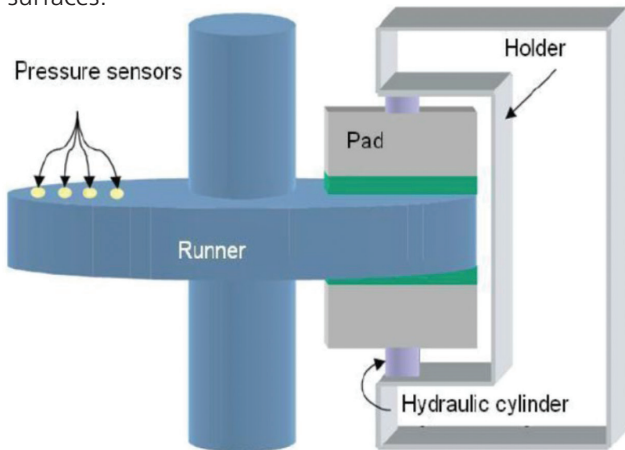


Figure 3: Combined thrust guide bearing test rig.

Further testing was undertaken to evaluate fluid film strength under increasingly severe loading conditions. Despite the application of loads exceeding standard test parameters, film breakdown could not be induced within the operational limits of the rig, indicating a high level of load-carrying capacity and film robustness.

The successful outcome of this controlled equipment testing provided the technical basis for advancing to a full-scale field trial, subsequently conducted at the Porjus Hydropower Centre Foundation in Sweden.

### Field trial performance of Hydro T-EL at Porjus, Sweden

The Porjus power station on the Lule älv river in Norrbotten, is owned by Vattenfall. The installation of Hydro T-EL is an extended field demonstration on the Unit 8 turbine which is operated by Porjus Hydropower Centre Foundation, a joint collaboration between ANDRITZ Hydro, GE Renewable Energy and Vattenfall. The U8 turbine is a 10MW Francis Turbine using a tilting pad thrust guide bearing (12 babbit pads), operating at 30 m/s (600rpm) with a mean bearing load of 4MPa. The trial began in January 2024

with the primary objectives to evaluate the fluid's stability, compatibility with equipment components and ensure a safe and reliable operation. The condition of the fluid over an 18-month period was measured periodically courtesy of Vattenfall. Over the trial period, the fluid accumulated 12,998 operating hours with 42 stops. Results are shown in Figure 4.

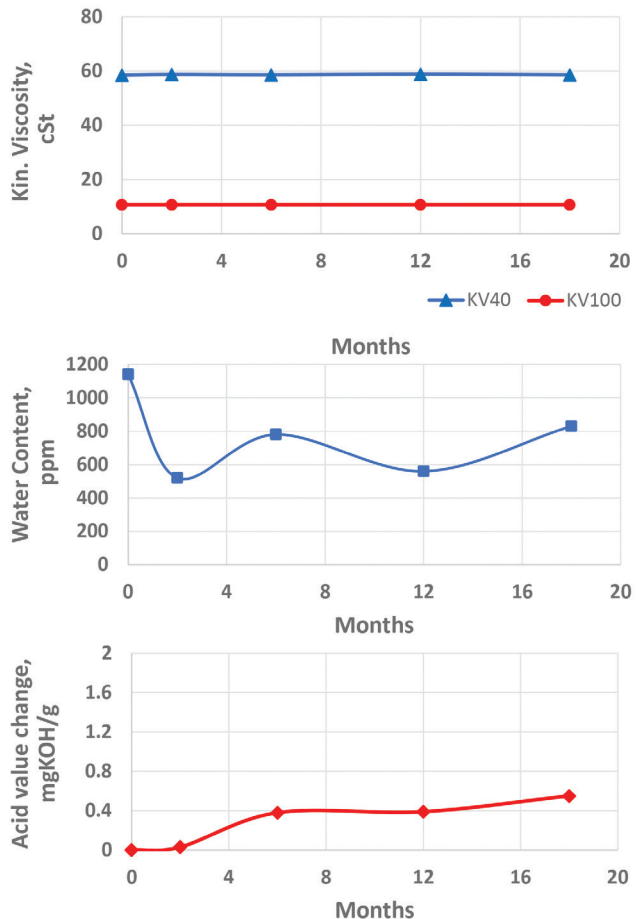


Figure 4: Fluid Condition Monitoring.

The viscosity of the fluid remained stable throughout the trial period. The water content varied between 500-1200ppm and is likely due to seasonal effects. There was a minor increase in the acid value of the fluid as expected as the fluid ages. Demulsibility and air release times remained unchanged. Finally, the ICP elemental analysis (Figure 5) showed no evidence of corrosion or wear metals, suggesting good equipment compatibility and excellent wear performance.

Interestingly the temperature of the fluid was also measured periodically during the trial and was recorded to be about 10°C lower than the petroleum-based product (ISO-68) that was previously evaluated in the equipment. Comparative analysis of the volumetric heat capacities of Hydro T-EL and

a common mineral-based turbine oil shows a 9% higher heat capacity for the SPE based fluid across the expected operational temperatures for a hydro turbine. (Figure 6) This suggests the frictional or heat management performance (or both) are superior for the new fluid, and this is considered to be the primary reason why a lower fluid temperature was observed in this trial. This observation could have much broader implications across our industry for those equipment users that are searching for improved heat management solutions.

ICP data	Initial	2 months	6 months	12 months	18 months
Al, ppm	<1	<1	<1	<1	<1
Ca, ppm	<1	<1	<1	<1	<1
Cr, ppm	<1	<1	<1	<1	<1
Cu, ppm	<1	<1	<1	<1	<1
Fe, ppm	<1	<1	<1	<1	<1
Mo, ppm	<1	<1	<1	<1	<1
Ni, ppm	<1	<1	<1	<1	<1
P, ppm	16	13	11	24	24
Sb, ppm	<1	<1	<1	<1	<1
Si, ppm	3	3	2	3	<1
Sn, ppm	<1	<1	<1	<1	<1
Zn, ppm	<1	1	2	1	<1

Figure 5: ICP Condition Monitoring.

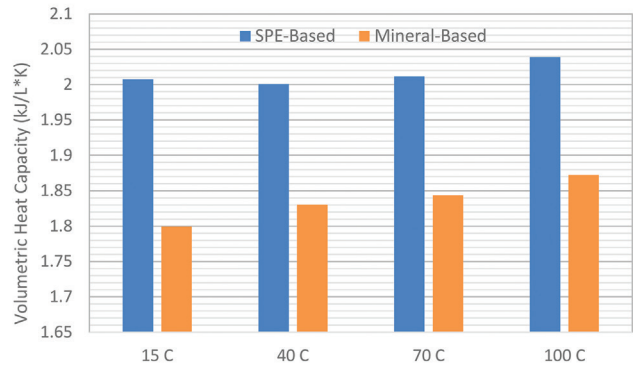


Figure 6: Volumetric Heat Capacities of Hydropower Turbine Oils.

### Summary

New turbine oil technology has emerged to support the global shift towards sustainable industrial operations. Implementing VBASE® Hydro T-EL into service represents a high-value innovation. For hydropower operators, it provides a practical, risk-mitigating path to achieving sustainability goals while maintaining peak turbine performance.

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