Demonstrating Hydraulic Efficiency Improvements Using VBASE® SPE® Base Oils

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EXECUTIVE SUMMARY

Modern hydraulic systems operate under increasing pressures, tighter tolerances and higher temperatures, placing exceptional demands on lubricants to maintain energy efficiency, cleanliness, and durability. Hydraulic fluids formulated with mineral oils can degrade under high thermal and shear stresses resulting in poor hydraulic response and decreased system efficiencies, leading to reduced equipment and operational reliability.

VBASE® Secondary Polyol Ester (SPE®) base oils provide formulators with an advanced synthetic fluid engineered to improve the thermal management and energy efficiency of demanding hydraulic systems. In independent testing by the Fluid Power Institute at the Milwaukee School of Engineering (MSOE), a hydraulic fluid formulated with SPE® base oils demonstrated lower motor torque loss, lower system flow loss, and higher overall system efficiency than a leading industrial hydraulic fluid formulated with mineral oil.

The reduction of torque and flow losses translates directly into higher equipment productivity such as, more tons moved per hour for an excavator and less fuel burned per ton of material moved. These results show that VBASE SPE technology enables machines to deliver more power to the final operation. These key benefits can contribute to lower total cost of ownership, longer equipment life and increased productivity rates for equipment users.

INTRODUCTION

Hydraulic systems transmit power through pressurized fluid flow. Efficiency losses -either mechanical (frictional/torque losses) or volumetric (flow losses from leakage and compression) - reduce the system's energy transfer and lead to excess heat generation. These inefficiencies directly affect productivity, operating temperature, and component life.

VBASE® SPE® base oils are advanced synthetic esters engineered for both performance and sustainability. Their unique oxygen-rich structure can enable low wear rates and provide robust oxidative and thermal stability. Moreover, their thermo-physical properties, such as their high volumetric heat capacities, are excellent and this inherent functionality can offer a solution to improve heat management in equipment. Their potential to improve hydraulic efficiency over conventional fluids has been explored and described in this paper.

MSOE Hydraulic Efficiency Study

The Fluid Power Institute at the Milwaukee School of Engineering (MSOE) (led by Paul Michael) conducted a comprehensive hydraulic efficiency evaluation to measure the performance impact of a VBASE®-formulated EAL (environmentally acceptable lubricant) hydraulic fluid compared to a mineral oil-based reference fluid. The goal was to isolate and quantify differences in frictional (torque) and volumetric (flow) losses under realistic operating conditions using a closed-loop hydraulic dynamometer test stand.

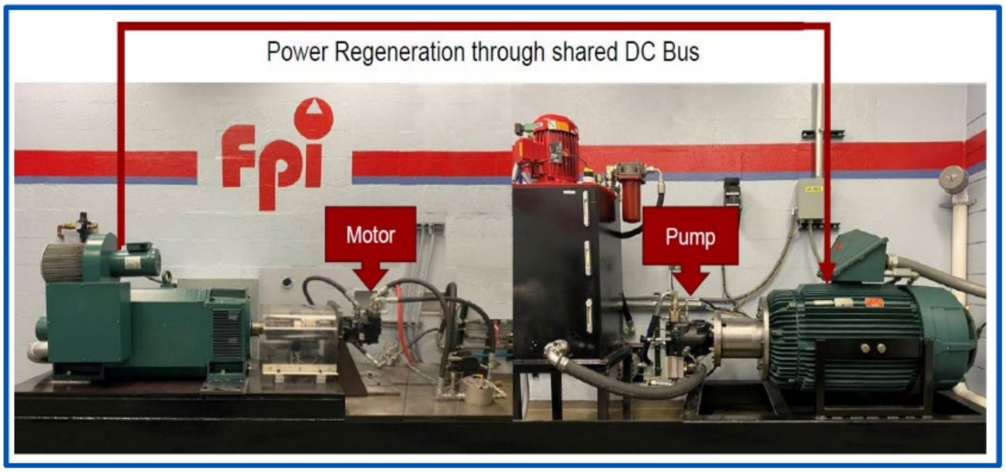


Figure 1. MSOE Fluid Power Institute hydraulic efficiency test stand showing pump–motor loop and instrumentation setup.

Test Stand and Equipment

Testing was conducted using a closed-circuit hydraulic test stand (Figure 1). The system consisted of:

- **Pump:** Linde HPR-75 axial piston pump (load-sensing configuration)
- **Motor:** Poclain radial piston motor
- **Reservoir:** 25-gallon capacity with inline heating and cooling for temperature control
- **Instrumentation:** High-accuracy torque transducers, flow meters, pressure sensors, and thermocouples to record torque, flow rate, pressure, and temperature
- **Control:** Proportional relief and load valves to regulate system pressure and maintain repeatable load conditions

The circuit was designed to simulate typical mobile hydraulic operation with precise control over pressure, flow, and temperature. Data were logged through MSOE's automated data acquisition system at steady-state operating points.

Test Conditions

- **Temperature:** Maintained at 80 °C ± 1 °C (bulk oil) (measured at reservoir or pump inlet)
- **System Pressure:** 13.8, 20.7, and 27.6 MPa (2,000, 3,000, and 4,000 psi)
- **Motor Speed:** 400, 600, and 800 rpm test points
- **Pump Speed:** Varied to achieve target Motor speed (rpm) and system pressure (MPa) (flow rates and torque demands)

Each test condition was repeated six times for reproducibility. Torque, flow, and temperature data were measured and averaged across steady-state intervals.

Typical Physical Properties of Test Fluids

Two fluids were tested (Table 1 compares the typical properties of both fluids):

1. **Industrial Hydraulic Reference Fluid:** This is a leading SAE 10W (ISOVG-46) mineral oil hydraulic fluid meeting typical OEM specifications.

2. **VBASE EAL Hydraulic Fluid:** This is a formulated hydraulic fluid using **SPE® base oils**, blended to an ISOVG-46 and comprises an ashless anti-wear additive package with components that are EU-LuSC listed. The formulation is targeted to meet ISO-15380 (specifies the requirements for environmentally acceptable hydraulic fluids).

Property	Industrial Hydraulic Fluid	VBASE EAL HF*
Kinematic Viscosity, 40 °C (cSt)	42.0	**45.1**
Kinematic Viscosity, 100 °C (cSt)	6.7	**8.7**
Kinematic Viscosity, 0 °C (cSt)	Not listed	**402**
Viscosity Index	114	**174**
Pour Point (°C)	-39	**-42**
Flash Point (°C)	227	**>250**
Pumping Viscosity, -30 °C (cP)	15,000	**< 10,000**
Air Release, 50 °C (min)	< 4	**0.1**
Copper Strip Corrosion	1A	**1A**
Rust Protection	Pass (A/B)	**Pass (B)**
Foam Sequence I (ml)	Not listed	**0 - 0**
Foam Sequence II (ml)	Not listed	**0 - 0**
Foam Sequence III (ml)	Not listed	**0 - 0**
Demulsibility (54 °C)	Not listed	**40-37-03**
Zinc Content (wt.%)	~0.090	**0 (ashless)**
Phosphorus Content (wt.%)	~0.073	**<0.05**

Table 1. Mineral Oil Hydraulic Reference Fluid compared to VBASE EAL HF (formulated to meet ISO 15380)

The mineral oil reference fluid exhibits good low temperature properties and has a comparatively low viscosity index, typical of mineral oils. It is speculated that it contains no viscosity index (VI) improver due to the risk of shear degradation under high pressure conditions.

VBASE EAL hydraulic fluid offers a significantly higher viscosity index and does not contain any VI Improvers. It also exhibits good low temperature properties. Interestingly, this fluid exhibits a remarkably low air release time and low foaming. As equipment reservoirs are designed to be smaller in the future, in part to reduce capital costs, even greater stresses will be imparted to the hydraulic fluid. Its ability to rapidly release air and avoid issues such as cavitation, will be a key functional requirement of future fluids.

In addition, it should be emphasized that recent measurements of the volumetric heat capacities of SPE® base oils show significantly higher values than mineral oils which supports their ability to manage heat more effectively.

RESULTS AND DISCUSSION

Motor Torque Loss

Motor torque loss represents energy loss due to friction and component drag within the hydraulic motor. Lower torque loss indicates reduced internal friction and higher mechanical efficiency.

Across all speeds and pressure conditions, VBASE® EAL hydraulic fluid consistently exhibited **lower torque loss** than the reference oil (Figure 2). The difference was most pronounced at high pressure and low speed—conditions where boundary and mixed lubrication regimes dominate, and up to a 25% difference was measured. This improvement is attributed to the lower friction coefficients of VBASE® SPE® base oils even under these thin-film or mixed lubrication conditions.

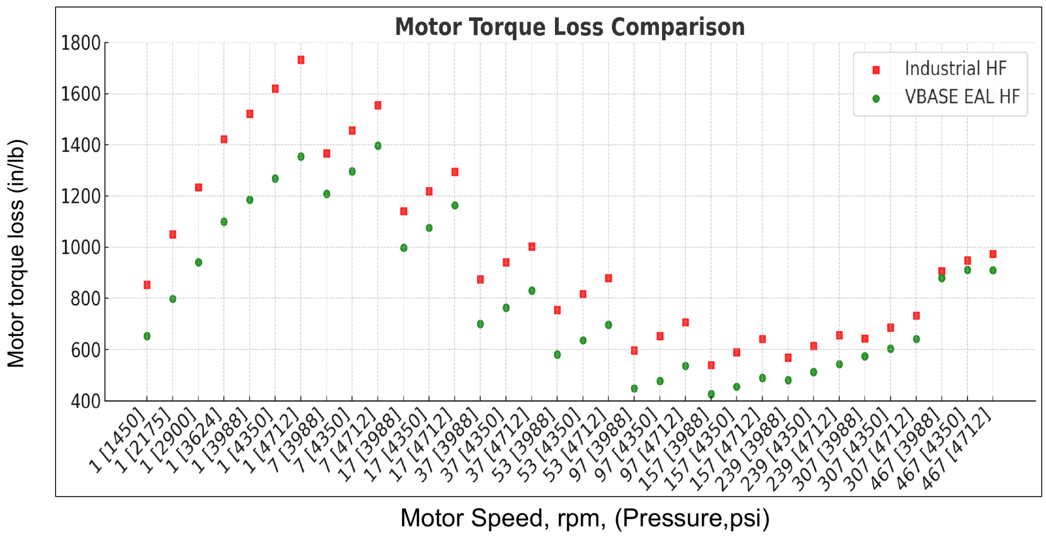


Figure 2. Motor torque loss comparison between VBASE® EAL hydraulic fluid and reference fluid at multiple speeds and pressures.

System Flow Loss

System flow loss encompasses leakage, compression, fluid resistance and shear losses within the pump and system plumbing. VBASE®-EAL fluid demonstrated **10–20% lower flow loss** than the reference oil over the entire duty cycle (Figure 3). The advantage remained consistent across all pressures and speeds, suggesting improved sealing efficiency, and reduced fluid leakage under load resulting in improved system responsiveness.

Lower compressibility and improved film strength of the VBASE formulation contributed to tighter volumetric control and reduced internal flow loss.

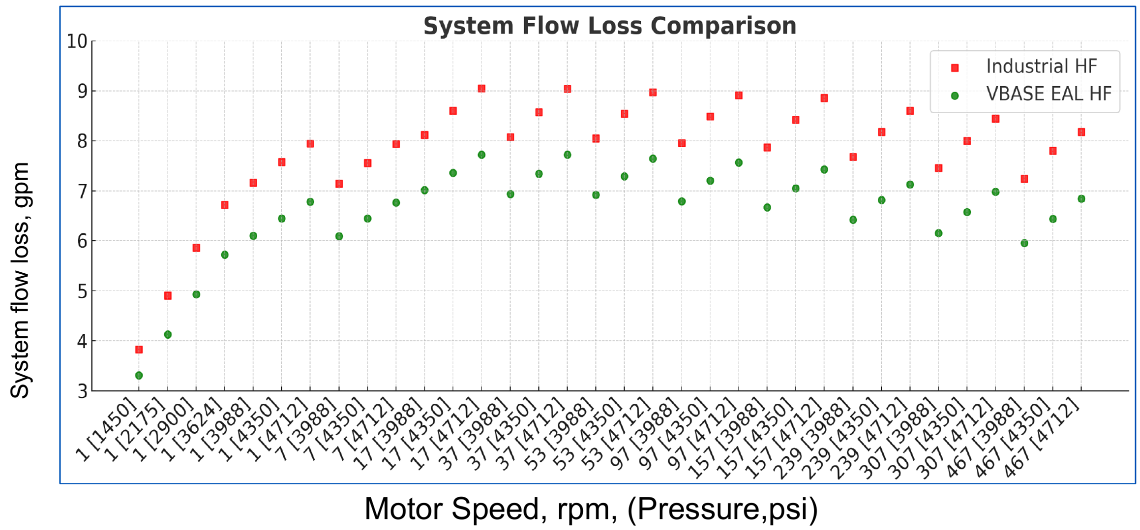
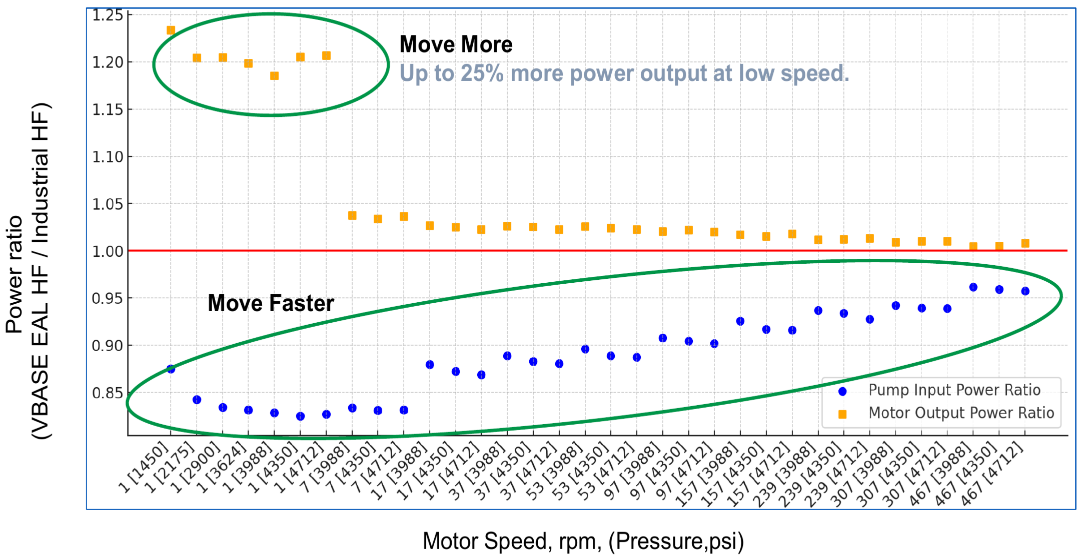


Figure 3. System flow loss reduction observed with VBASE® EAL fluid versus reference fluid.

Overall Energy Efficiency and Power Ratio

When torque and flow data are combined, they define total hydraulic efficiency. “The Motor Output Power Ratio” divided by “Pump Input Power Ratio” at each point gives the **relative efficiency compared to the reference fluid.**

Figure 4 illustrates the Power Ratio analysis showing higher motor output and lower pump input power with the VBASE® formulation normalized against the reference fluid. In the low-speed range, there is **up to 25% higher** overall efficiency compared to the reference fluid. **In the mid- to high-speed range, the efficiency gain is ~ 5–12%.** In practical terms, this means more useful work delivered at the actuator per unit of input power at the pump, leading to measurable reductions in fuel or power consumption.



Motor Output - Ratio > 1 = greater power output vs. Industry HF. **Higher productivity in the high work zone**

Pump Input - Ratio < 1 = power savings vs. Industry HF. **More flow available to do work**

Figure 4. Power ratio analysis showing higher motor output and lower pump input power with the VBASE® formulation.

INTERPRETATION AND PRACTICAL IMPLICATIONS

The MSOE results confirm that a hydraulic fluid built on VBASE® SPE® base oils delivers measurable performance improvements in both mechanical and volumetric efficiency.

Operational implications:

- **Higher productivity:** More effective work delivered at the tool or actuator.
- **Lower energy use:** Reduced pump power demand, translating into energy cost savings.

The inherently higher volumetric heat capacities of SPE® base oils compared to mineral oils can also significantly contribute to a **cooler operation.** Superior heat management can also reduce oxidation rates and can extend fluid life.

For OEMs and fluid formulators, these results demonstrate the potential of SPE® technology to meet increasingly stringent efficiency and sustainability goals without sacrificing protection or durability.

Chemistry Behind the Performance

VBASE® SPE® base oils are alkoxylated polyol esters and are designed to optimize energy efficiency and long-term stability. These functional and environmental performance advantages provide OEMs with novel energy-efficient hydraulic fluid solutions:

- **Low traction coefficients:** Minimizes internal friction in elastohydrodynamic and mixed lubrication regimes.
- **High viscosity index:** Formulations do not need to include viscosity index improvers that are prone to shear degradation.
- **Polarity-balanced structure:** Ensures strong film formation and wear protection.
- **Thermal and oxidative stability:** Supports extended drain intervals.
- **Built-in Detergency:** Ability to keep the fluid and equipment clean preventing equipment reliability issues.
- **Biobased and biodegradable:** Enables sustainable, environmentally responsible fluid design.

CONCLUSIONS

Independent third-party testing at the Milwaukee School of Engineering confirmed that a hydraulic fluid formulated with a **VBASE® SPE® base oil** delivers quantifiable improvements in both efficiency and operating stability. By reducing torque and flow losses, the VBASE® formulation allows machines to transmit **more power to the tool while requiring less power at the pump**—improving total energy utilization across the hydraulic circuit.

This efficiency can translate into **greater work output per unit of input energy**, enabling operators to move more material with less fuel or power consumption. These advantages drive a measurable reduction in **total cost of ownership**, achieved through improved machine productivity, extended service life, and lower overall energy consumption.

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