Hydraulic equipment trends

**Sustainability**
- Increased efficiency and productivity
- Reducing emissions and noise
- Hybridization and electrification

**Higher power density**
- High efficiency pumps
- Higher pressures
- Smaller size

**Reliability**
- Digital automation
- Connectivity and smart systems
- Data analytics and condition monitoring
Changes in the Hydraulic Equipment Market

Equipment Sophistication
• Higher power densities
• System complexity
• Downsizing
• Running hotter and at higher pressures for longer

Fluid Performance Needs
• Increased wear protection
• Wider operating temperature range
• Lower energy consumption
• Need for extended oil life

Hydraulic fluid performance must meet the needs modern systems demand
Hydraulic efficiency and end user needs

Total cost of ownership = purchase + maintaining + running

Efficiency
There are no industry standard tests to measure hydraulic efficiency.

How to describe efficiency?
- Productivity or cycle time
- Energy consumption per unit time
- Work done per amount of fuel
- Temperature reduction

Value and definition of efficiency vary by end user

Durability
There are many industry standard tests for hydraulic durability.
Energy Efficiency in Today’s Market

• Understanding total system efficiency is critical
  – Pump efficiency is only one element of hydraulic system efficiency
  – Energy losses occur in pumps, motors, hoses, filters, valves and coolers

• Thorough understanding of both hardware and fluid is key to delivering real efficiency

• Total lubricant formulation works together enable real efficiency without compromising durability.

Delivering real world efficiency is a valuable proposition to industrial end users
Designing Durable Efficient Fluids

Lubricant performance validation

1. Bench testing
   - Tribology
   - Rheology

2. Total system efficiency rig
   - Benchmarking
   - Candidate screening
   - Fundamental knowledge

3. Whole vehicle testing
   - Whole system analysis
   - Benchmarking
   - Final candidate selection

4. Field testing
   - Real world proof of performance
Stage 1
Bench Testing
Bench Testing

Polymer choice affects fluid traction

- Fluid traction is the internal friction of the squeezed lubricant film
- Low fluid traction contributes to efficiency
- Different viscosity modifiers can affect traction coefficient

![Graph showing traction coefficient at 80 °C](image)
Stage 2
Lubrizol Total Hydraulic System Efficiency Rig
Hydraulic Efficiency – Pump vs Total System

**Hydraulic pump efficiency**
- Volumetric efficiency ($\eta_v$)
- Mechanical efficiency ($\eta_m$)

**Total hydraulic system efficiency**
- Volumetric efficiency ($\eta_v$)
- Mechanical efficiency ($\eta_m$)
- System losses

- Volumetric efficiency
  - Internal leakage

- Mechanical efficiency
  - Friction
  - Pumping

- Overall efficiency
  \[ \eta_o = \eta_v \times \eta_m \]

* Green, D. A. World Tribology Congress 2009, Japan, B2-212
Lubrizol Total Hydraulic System Efficiency Rig

• Lubrizol’s laboratory based hydrostatic transmission rig
  − Representative of real world mobile equipment
  − Uses a hydraulic motor for the working load
  − Instrumented to measure efficiency across multiple parts of the hydraulic system
  − Flow, temperature, pressure sensors installed around motor, lines, pump, filter, cooler
  − Most other studies have focused only on pump efficiency
Lubrizol fixed hydraulic efficiency rig

Total hydraulic system efficiency

- Small difference in pump efficiency, large difference in motor efficiency
- Total system efficiency shows VM1 to be more efficient
Stage 3
Whole Vehicle Testing
Controlled Whole Vehicle Testing

Proof of performance

- Total system field trial
  - Extensive instrumentation
  - Robust structured testing protocol
  - Big data approach – millions of data points
  - Statistical analysis
- Quantification of efficiency by duty cycle
  - Loaded and unloaded front lifts
  - Loaded and unloaded rear lifts

Measured fuel consumption of two candidates
Whole Vehicle Testing – Test Method

Rear boom lift course

Front lift laden
Controlled Whole Vehicle Test Results

Efficiency Improvement Over Monograde Reference Fluid

VM1 offers superior improvements in hydraulic energy efficiency
Stage 4
Field Testing
Field Trial

Local Excavating Company
• 2015 980M Caterpillar Wheel Loader
• Trial over 3 months
  – Data logged for 120 hours

Fluids on test
Factory fill: Monograde (Baseline)  ISO VG 46
Test Fluid: VM1  ISO VG 46
Shop Oil: Service Fill  SAE 10W-30
How VM1 improves efficiency?
Measuring Secondary Flow: Data Acquisition

**Particle image velocimetry (PIV)**

- Tracer particles with sizes (~5-20μm) are added to the fluid
- The light scattered by the particles is recorded at ~ 30,000 frames per second by a high-speed camera
- The displacement of the particle images between the successive frames allows the measurement of the planar 2-dimensional velocity field
Particle Image Velocimetry Data

- Vorticity at the apex of the 180° channel was similarly examined.
- For the degree of curvature in the test piece the maximum vorticity was anticipated at the apex.
- Profile at high flow rates becomes increasingly distorted, maximum vorticity shifting to inner wall.

![Image of Particle Image Velocimetry Data with graphs and color scale for vorticity at the apex of a 180° bend at 38 L/min⁻¹, showing Monograde, VM2, and VM1 profiles.]
Particle Image Velocimetry Data

- Quantification of magnitude and area of vorticity can be done for each vertical region.
- VM1 fluid was compared to VM2 fluid and shows noticeable differences.
- VM1 reduces the magnitude of vorticity by ~10%.
- VM1 reduces the area of vorticity by ~18%.

![Graph showing local average magnitude and area of vorticity for VM1 vs VM2.](image)
Summary

• VM1 substantially reduces secondary flows under hydraulic operating conditions
• Multigrade fluid containing VM2 does not significantly reduce secondary flows

<table>
<thead>
<tr>
<th>In comparison to monograde fluid</th>
<th>Reduction in magnitude of vorticity</th>
<th>Reduction in area of vorticity</th>
</tr>
</thead>
<tbody>
<tr>
<td>VM 1</td>
<td>11%</td>
<td>20%</td>
</tr>
<tr>
<td>VM 2</td>
<td>1%</td>
<td>4%</td>
</tr>
</tbody>
</table>

These results support all of our hydraulic efficiency testing where VM2 and monograde fluids appear to perform similarly whilst VM1 containing fluids are overwhelmingly the most energy efficient.
Durability Testing
No Compromise on Durability

Strong pump performance ensure fluid durability and equipment protection for a longer time

Eaton E-FDGN-TB002-E and Parker Denison HF-0 approved
Bench testing

Extended shear stability

- Commercially relevant formulations.
- Comparison to shear stable Bosch Rexroth capable VM1 fluid and competitor example.
- VM1 substantially more shear stable out to 200 hours by KRL.
Conclusion
Conclusion

• Fluid flow behaviour is a key variable in understanding hydraulic energy efficiency that does not correlate to viscosity index.

• Careful selection of viscosity modifier can deliver real world efficiency improvements.

• A balanced hydraulic oil formula can give both durability and efficiency.
Your trusted source for market trends, industry insights and the lubrication challenges of today’s advanced hardware

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