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Energy Efficient Fluids
Theoretical Pump Efficiency Curve

Volumetric Efficiency $\eta_V$

Mechanical Efficiency $\eta_{HM}$

Overall Efficiency $\eta_O$  

$\eta_O = \eta_V \cdot \eta_{HM}$

ZO/N  

P
Test Procedure

**Test Conditions**
16 External Gear Pumps
- 7 Manufacturers
Mineral oil hydraulic fluids
- ISO VG 32 & 46
- 50 & 80C
Size (displacement)
- 32.3 to 56.6 cc
Maximum speed
- 2600 to 3200 rpm
Maximum pressure
- 172 to 276 Bar (2500 to 4000 psi)

**ISO 4409 Method**
Vary input shaft speed and pump outlet pressure
Measure input shaft torque and pump flow rate

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11/28/2012
Average Volumetric Efficiency
16 Pumps

Volumetric Efficiency of Gear Pumps, $\eta_v$

<table>
<thead>
<tr>
<th>Gear Pump ID</th>
<th>$\eta$ 50 C, %</th>
<th>$\eta$ 80 C, %</th>
</tr>
</thead>
<tbody>
<tr>
<td>a</td>
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<tr>
<td>b</td>
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Average Mechanical Efficiency
16 Pumps

Mechanical Efficiency of Gear Pumps, $\eta_{hm}$

- $\eta$ 50 C, %
- $\eta$ 80 C, %

Mechanical Efficiency, $\eta_{hm}$

Gear Pump ID

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Confidence Intervals for Mean Efficiency

Volumetric, Mechanical, and Overall Efficiency

95% CI for the Mean  n50=893  n80=896

- Volumetric: 92.4%
- Mechanical: 86.9%
- Overall: 88.4%

Temp/C

Efficiency, %
Experimental Pump Efficiency Curve

Volumetric, Mechanical, and Overall Efficiency Curves

- Red: Volumetric
- Green: Mechanical
- Black: Overall

N = 16
n = 1789

\[ \eta_o = \eta_v \cdot \eta_m \]
## Motor Efficiency Analysis

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<th>Fluid</th>
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<th>Description</th>
<th>Vis Index</th>
<th>Traction Coefficient</th>
<th>Friction Coefficient</th>
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<td>0.048</td>
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Geroler Motor

Orbital (Geroler) Motor

Parker TG240
14.5 cu. in.
390 RPM
3000 psi

ISO 46 Straight Grade Group I Mineral Oil (HM46-1)
HM46-1+ 0.5% Friction Modifier (HM46-5)
Axial Piston Motor

Sauer-Danfoss Series 90
6.1 cu. in.
5350 RPM
6000 psi

ISO 46 Straight Grade Group I Mineral Oil (HM46-1)
HM46-1+ 0.5% Friction Modifier (HM46-5)
Radial Piston Motor

Radial Piston Motor

Poclain MS0E2
20.2 cu. in.
200 RPM
5800 psi

ISO 46 Straight Grade Group I Mineral Oil (HM46-1)
HM46-1+ 0.5% Friction Modifier (HM46-5)
System Efficiency Test
System Efficiency Map
Axial Piston pump and Geroler Motor with oil at 50 & 80°C

80°C

50°C

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System Efficiency Map
Axial Piston pump and Radial Piston Motor with oil at 50 & 80°C

80°C

System Eff vs Load Motor Torque & Speed, oil temp 80°C

50°C

System Eff vs Load Motor Torque & Speed, oil temp 50°C
System Efficiency Map
Axial Piston pump and Axial Piston Motor with oil at 50 & 80°C

80°C

50°C
System Efficiency Map
Axial Piston pump and Gearler Motor at different pump speeds

1800 RPM

1200 RPM

800 RPM
System Efficiency Map
Axial Piston pump and Radial Piston Motor at different pump speeds

1800 RPM

1200 RPM

800 RPM
System Efficiency Map
Axial Piston pump and Axial Piston Motor at different pump speeds

1800 RPM

1200 RPM

800 RPM
Conclusions

• **Gear pump efficiency** can be enhanced by increasing the oil viscosity

• **Hydraulic motor efficiency** can be enhanced by improving lubricity

• **System efficiency** can be enhanced by reducing fluid temperature and pump speed

• **Hydraulic fluid** that exhibits a minimum change in viscosity with temperature (High VI) and improved lubricity (Low boundary friction)