

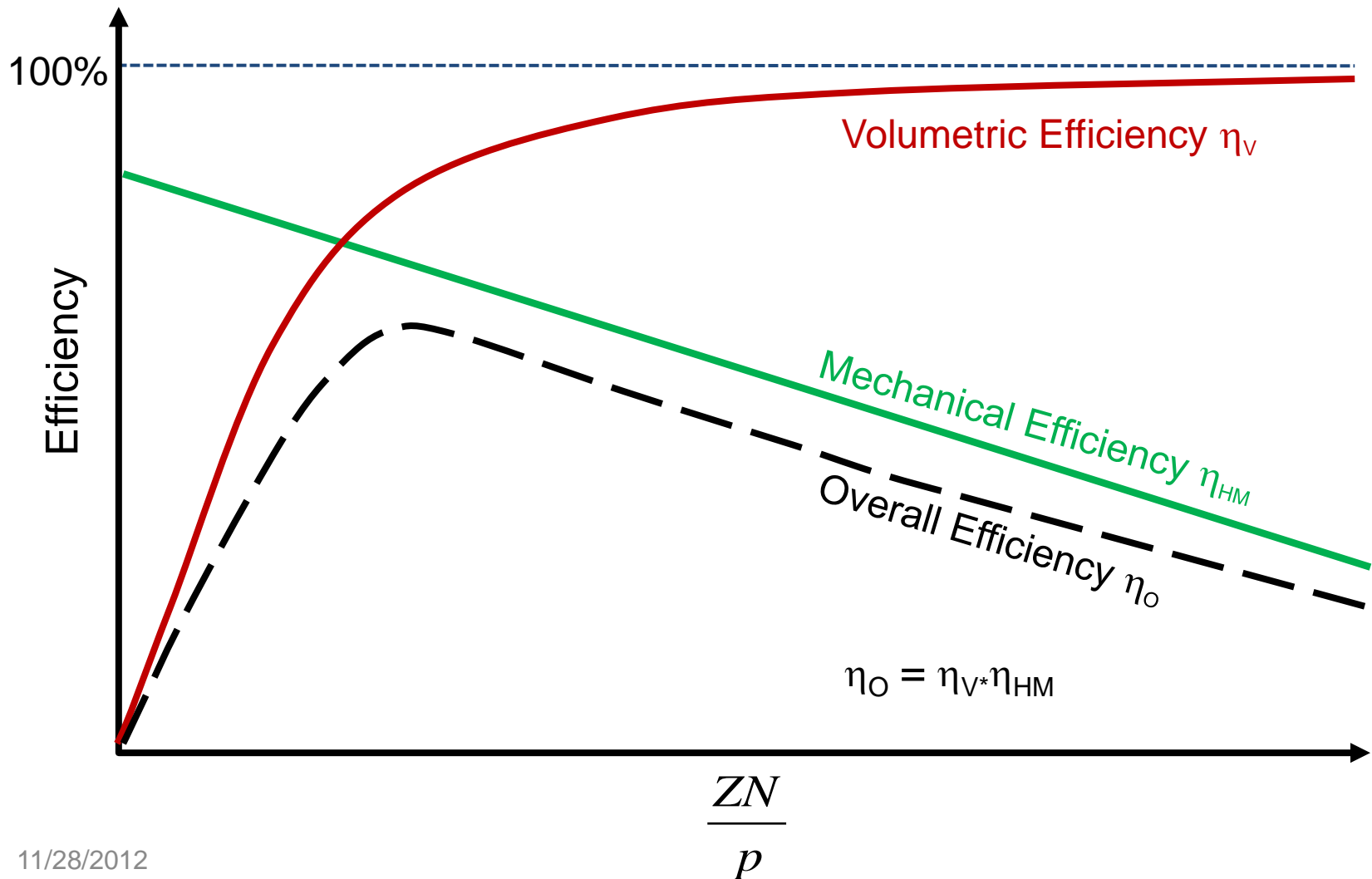


# **Energy Efficient Hydraulics and Pneumatics Conference, 2012**

**Paul Michael**  
**Milwaukee School of Engineering**

**Energy Efficient Fluids**

# Theoretical Pump Efficiency Curve



# 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

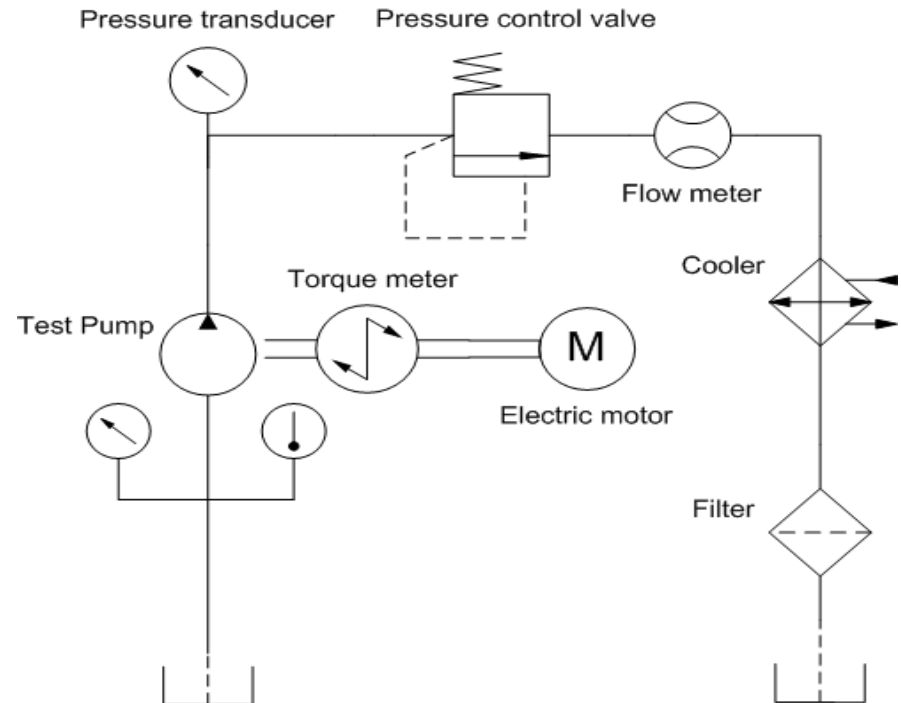
Maximum pressure

- 172 to 276 Bar  
(2500 to 4000 psi)

## ISO 4409 Method

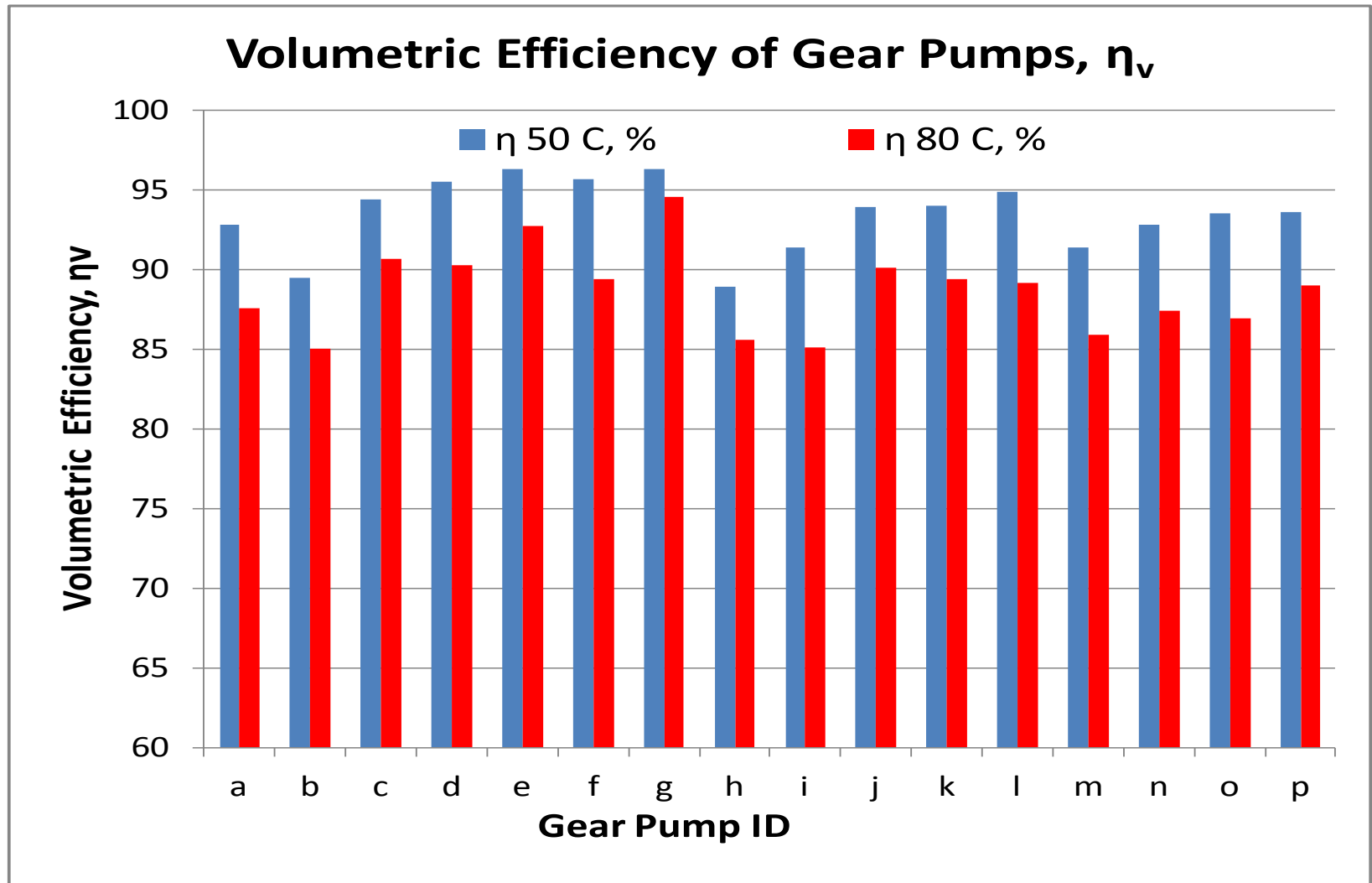
Vary input shaft speed and  
pump outlet pressure

Measure input shaft torque  
and pump flow rate



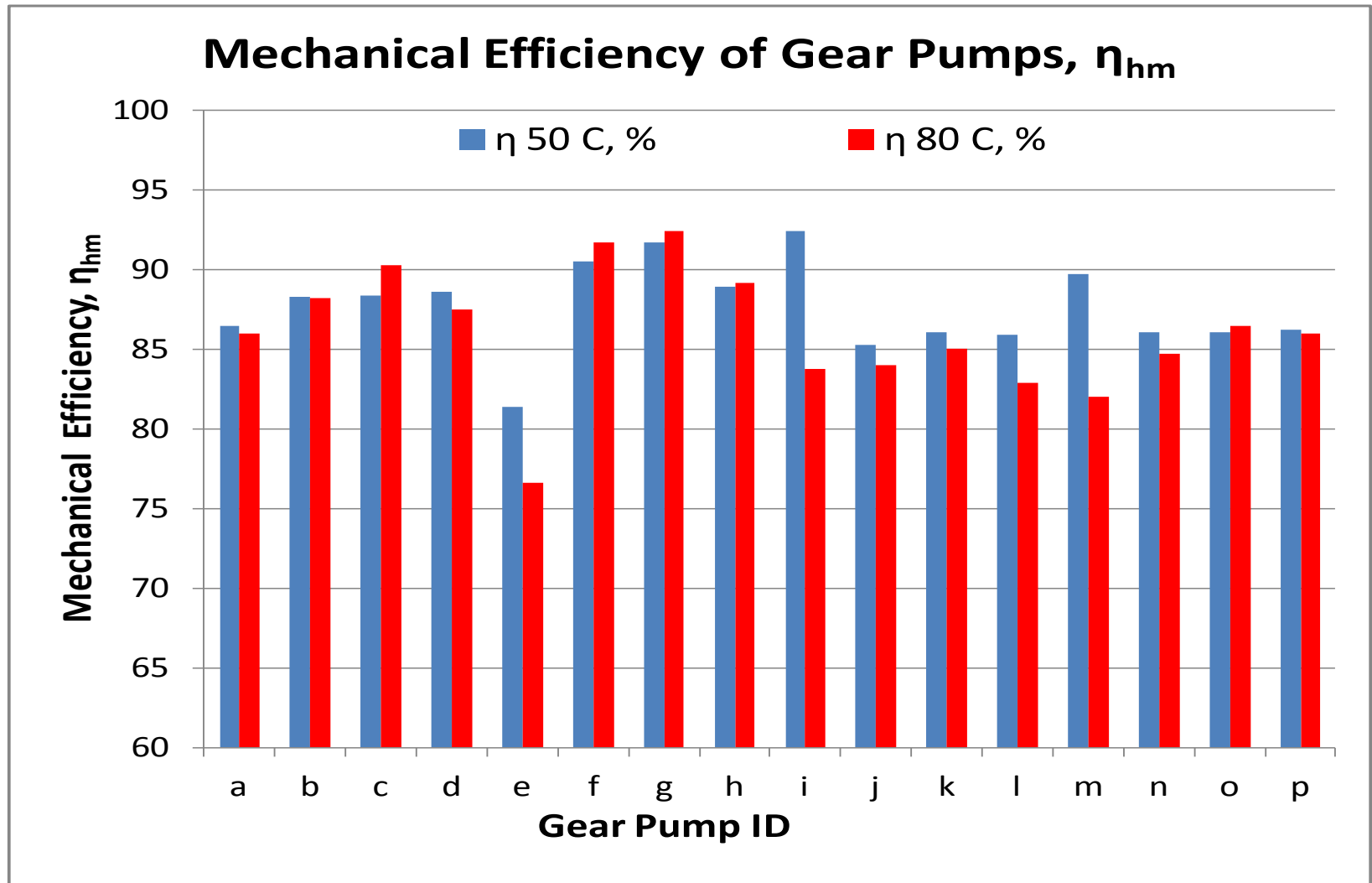
# Average Volumetric Efficiency

## 16 Pumps

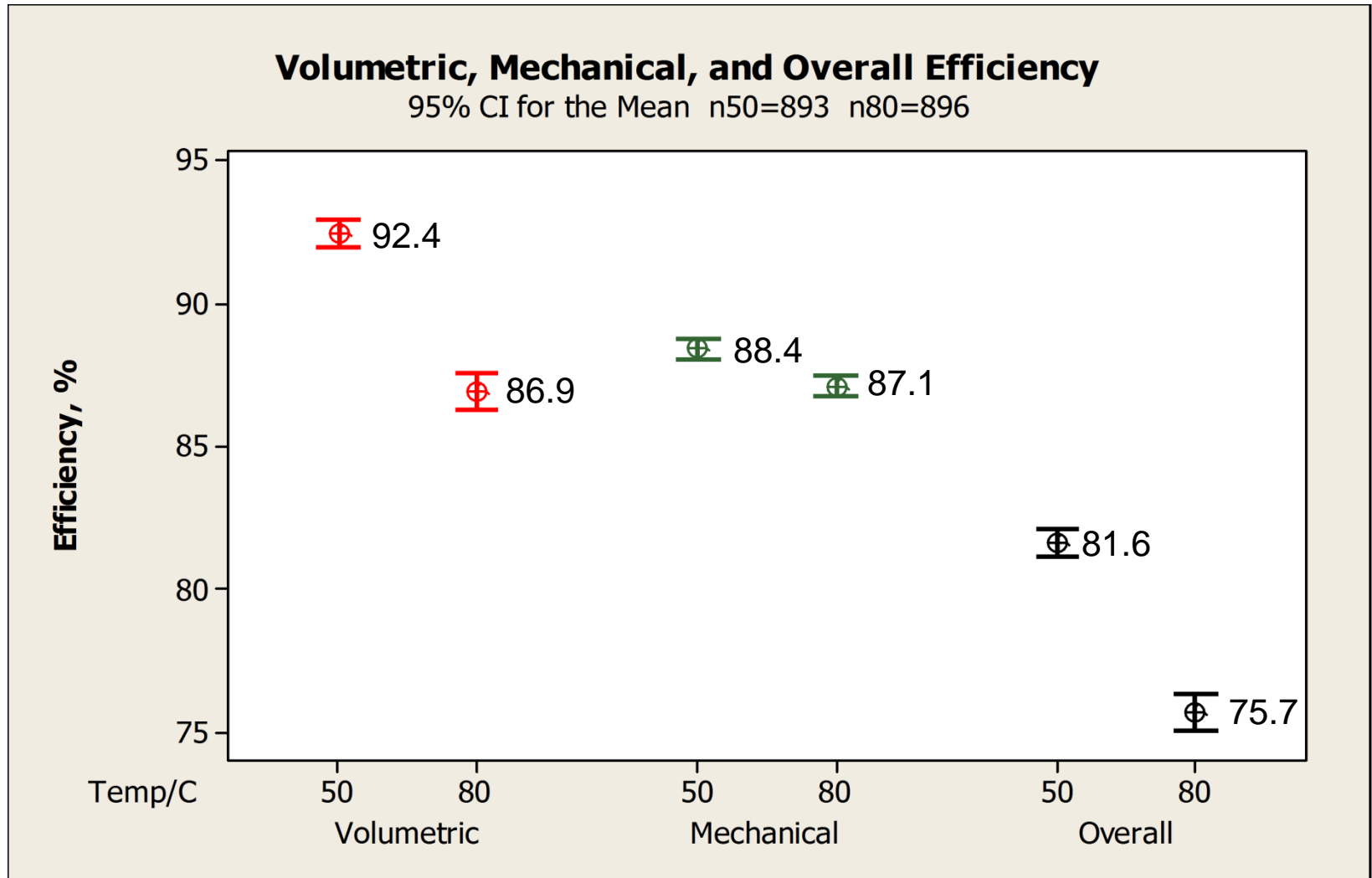


# Average Mechanical Efficiency

## 16 Pumps

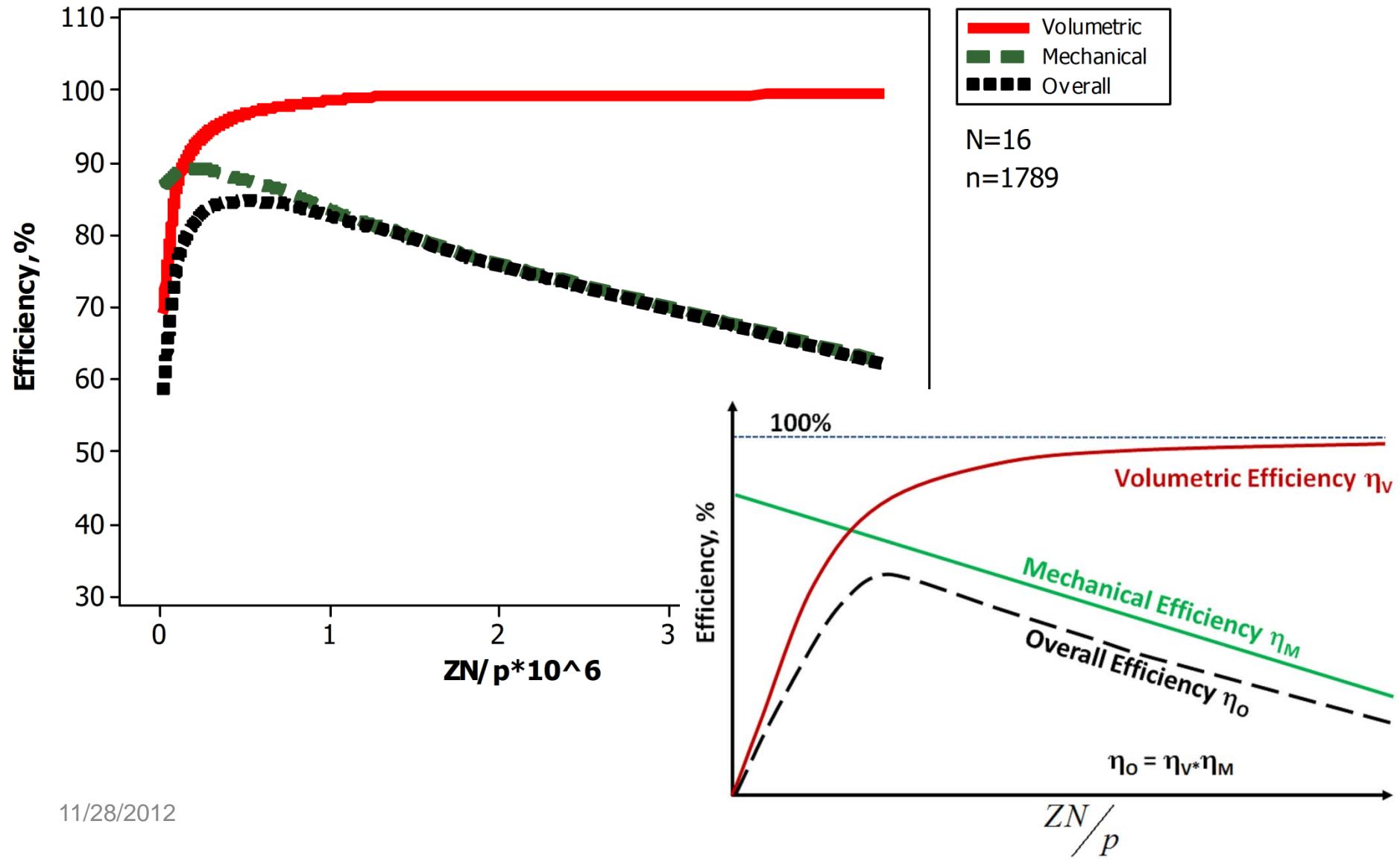


# Confidence Intervals for Mean Efficiency



# Experimental Pump Efficiency Curve

## Volumetric, Mechanical, and Overall Efficiency Curves



# Motor Efficiency Analysis

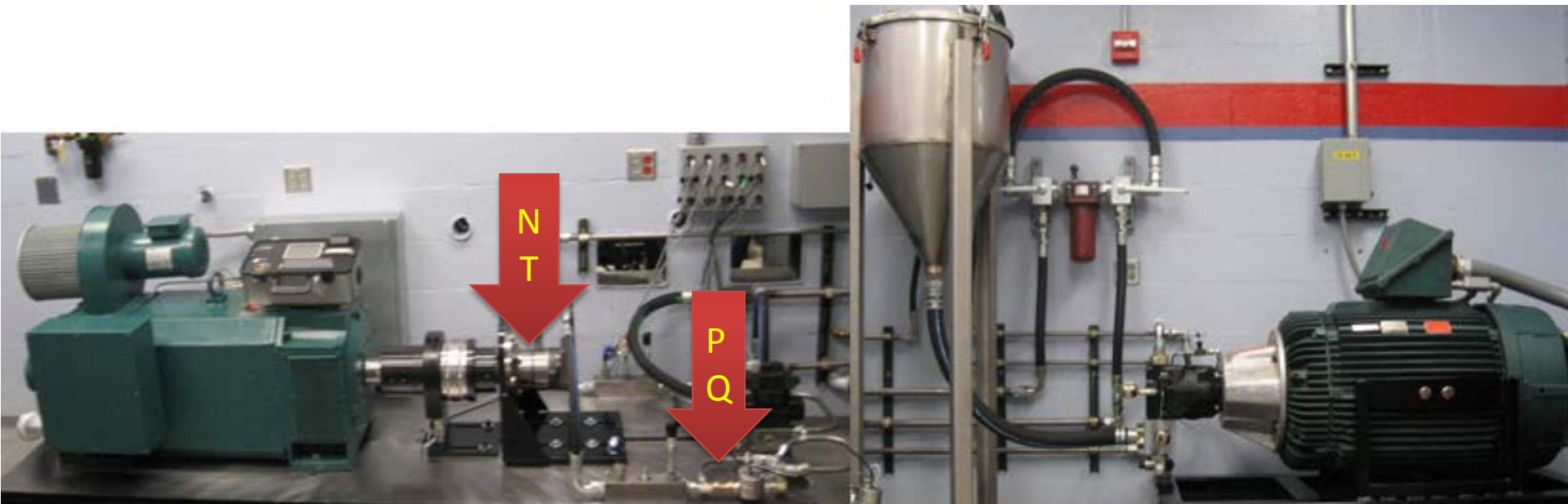
Fluid	Vis @ 40°C (mm <sup>2</sup> /s)	Description	Vis Index	Traction Coefficient	Friction Coefficient
HM46-1	46	Group I mineral oil plus S-P Ashless AW additive	100	0.048	0.156
HM46-5	46	HM46-1 plus 0.5% alkyl phosphonate	100	0.039	0.133





# Motor Efficiency Analysis

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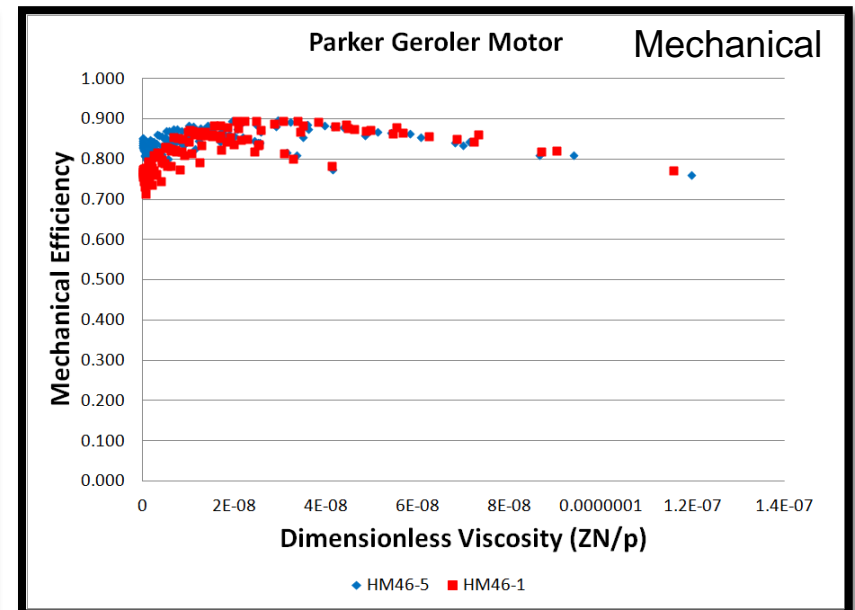
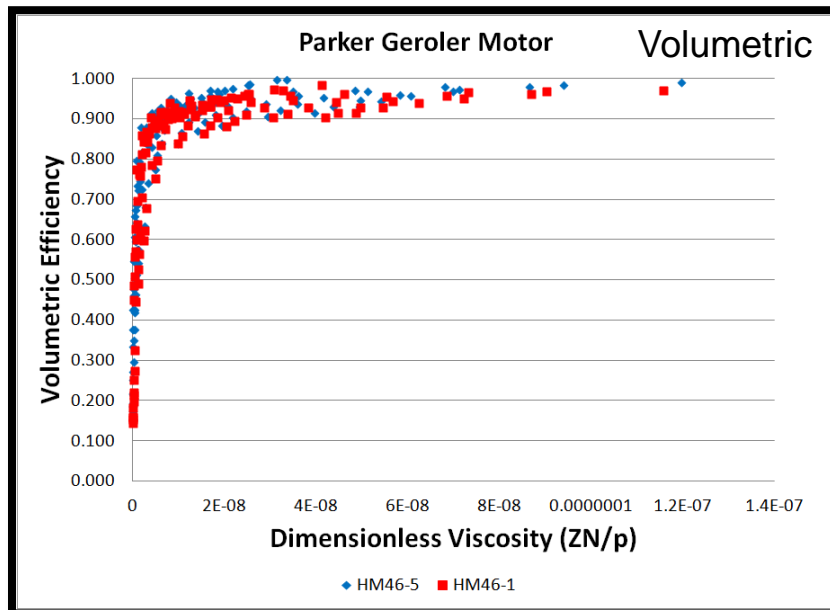
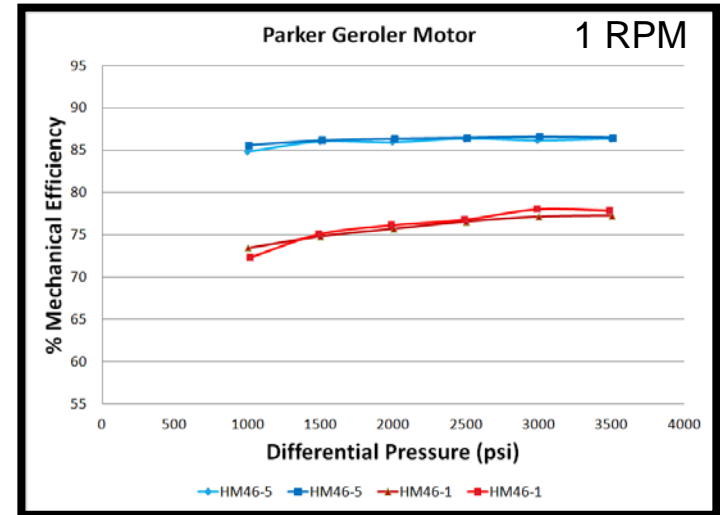
# Geroler Motor



## 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)



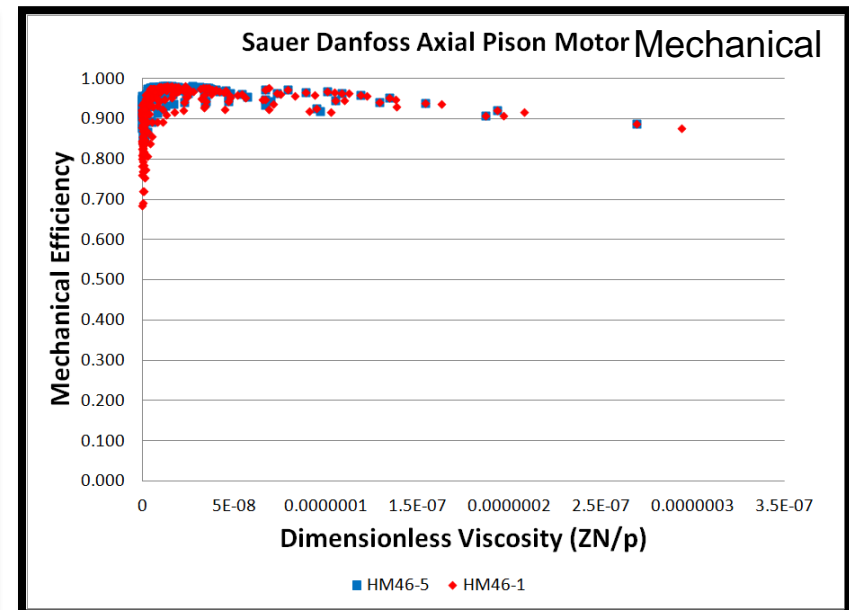
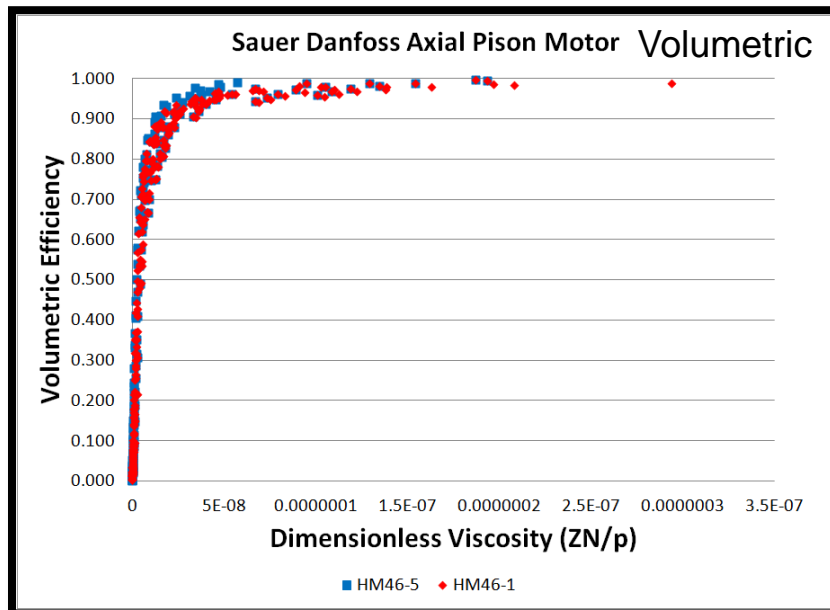
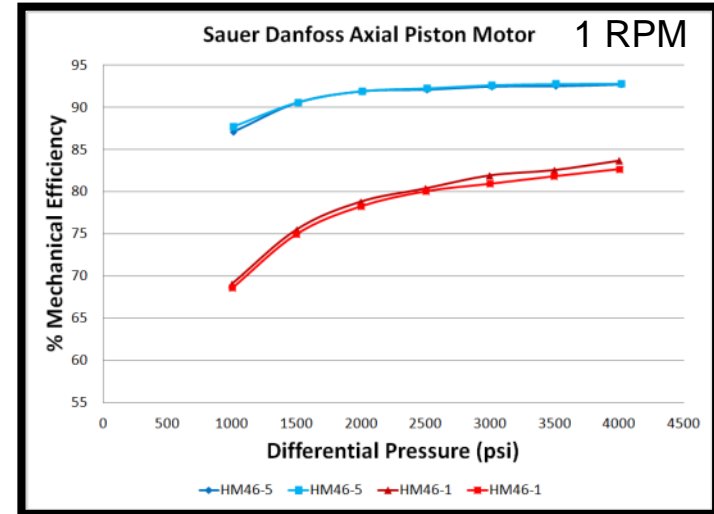
# Axial Piston Motor



## 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)



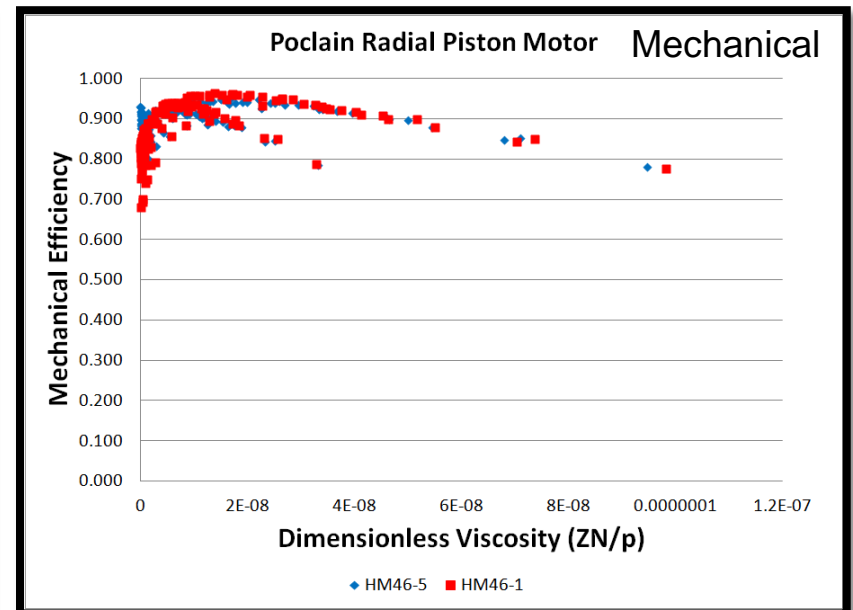
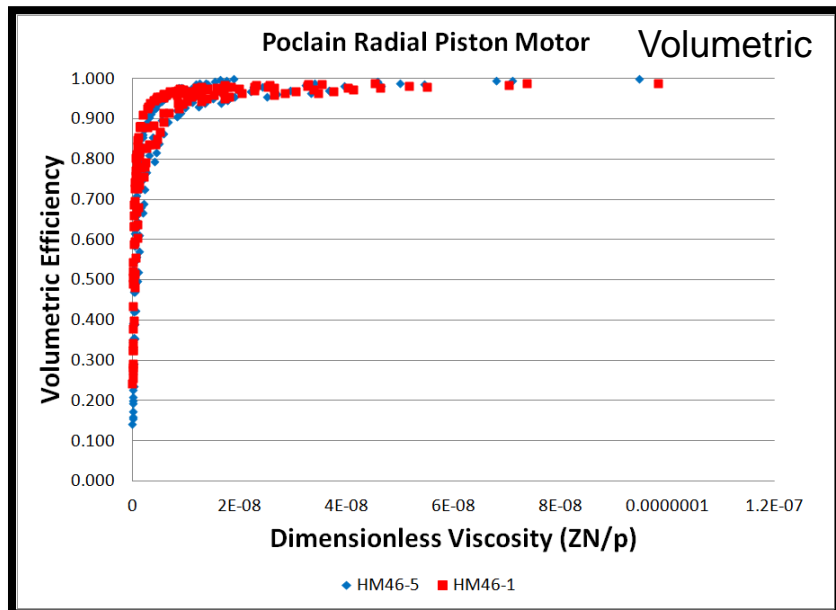
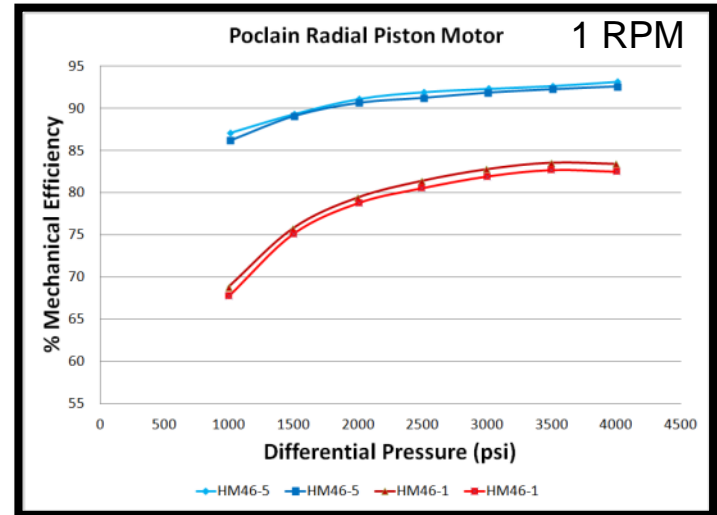
# Radial Piston Motor



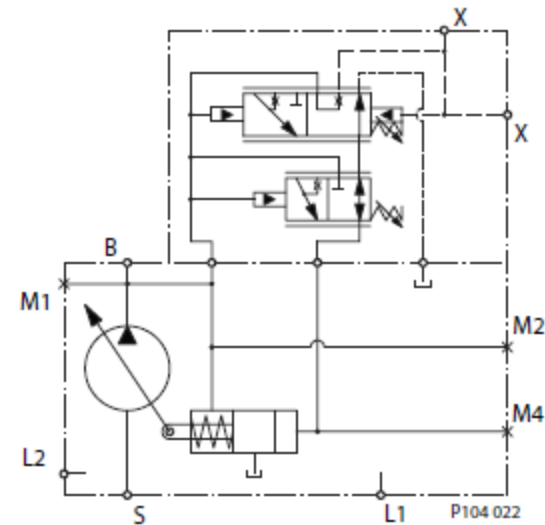
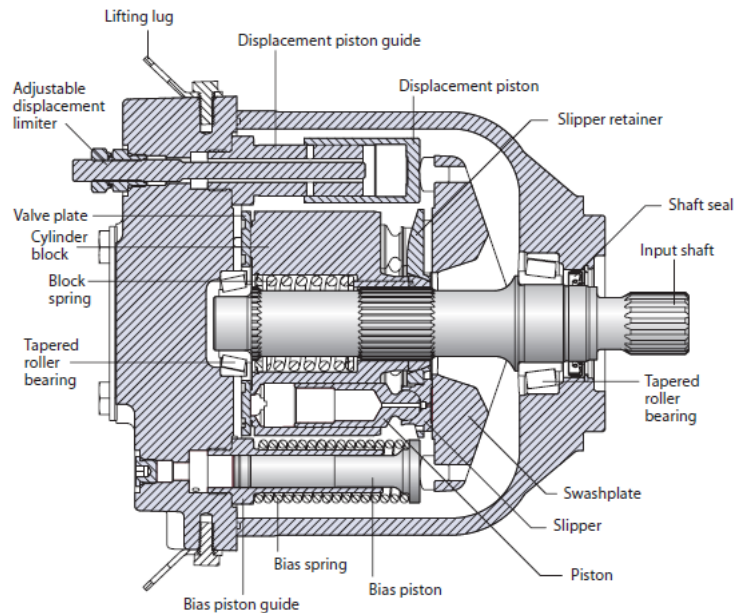
## Radial Piston Motor

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)



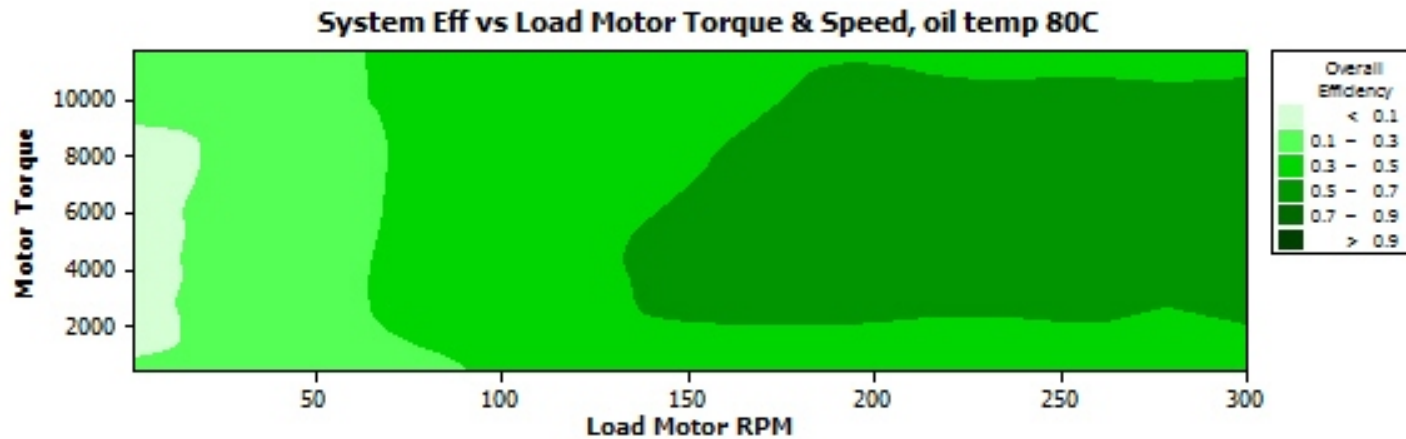
# System Efficiency Test



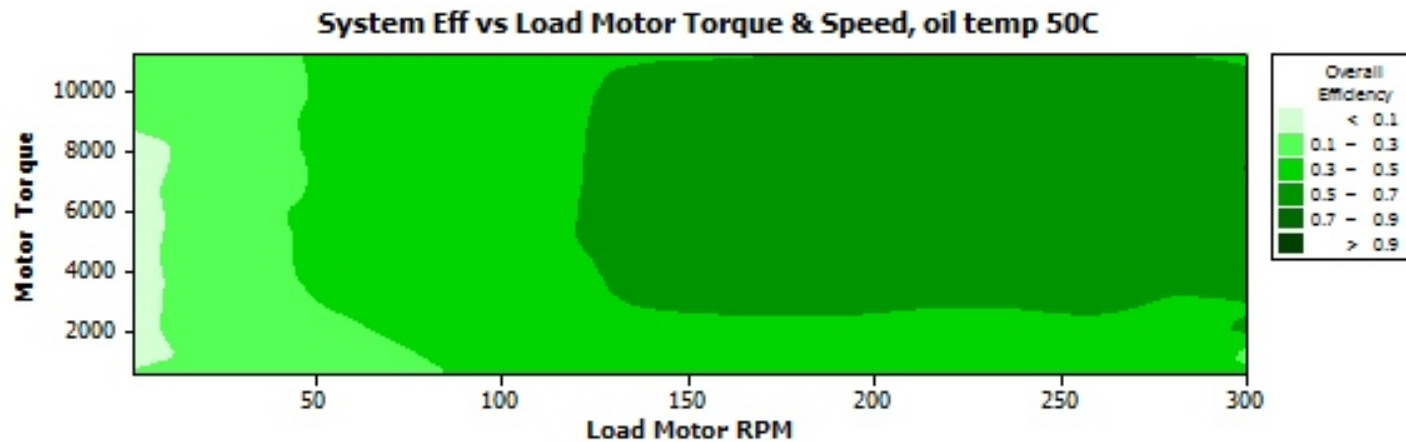
# System Efficiency Map

Axial Piston pump and Geroler Motor with oil at 50 & 80°C

80°C

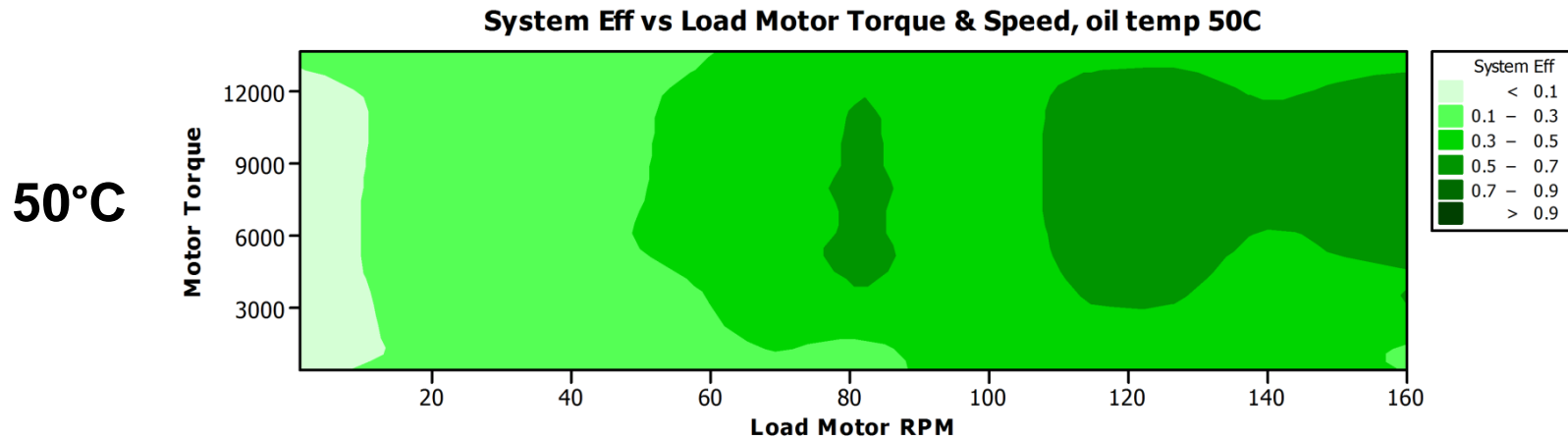
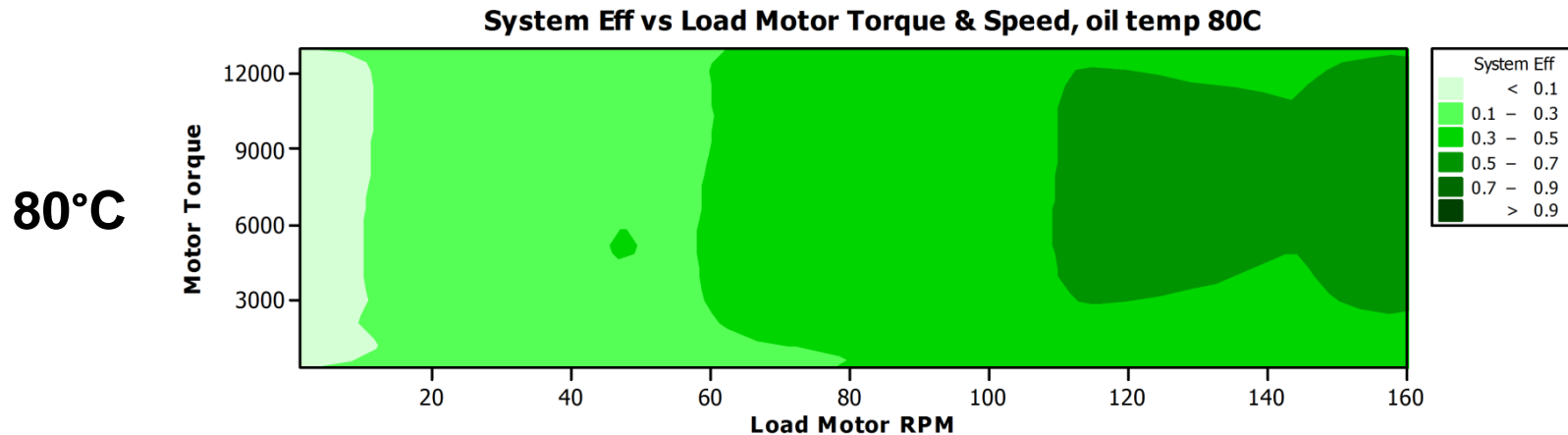


50°C



# System Efficiency Map

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

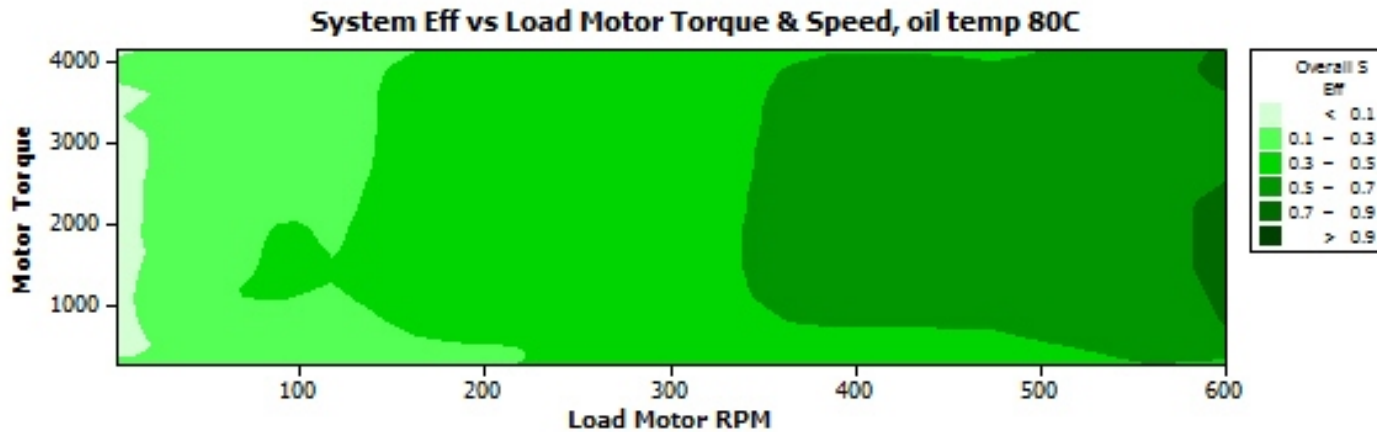




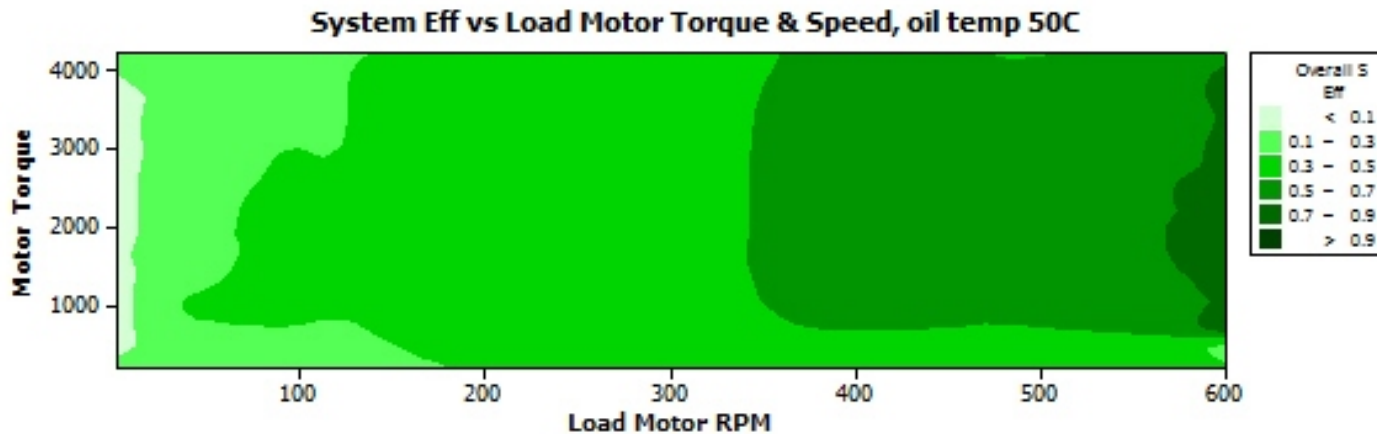
# System Efficiency Map

Axial Piston pump and Axial Piston Motor with oil at 50 & 80°C

80°C



50°C

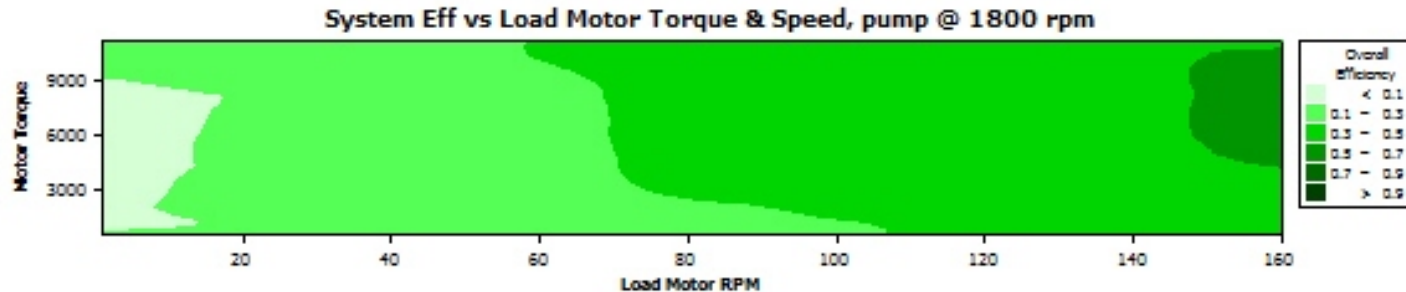




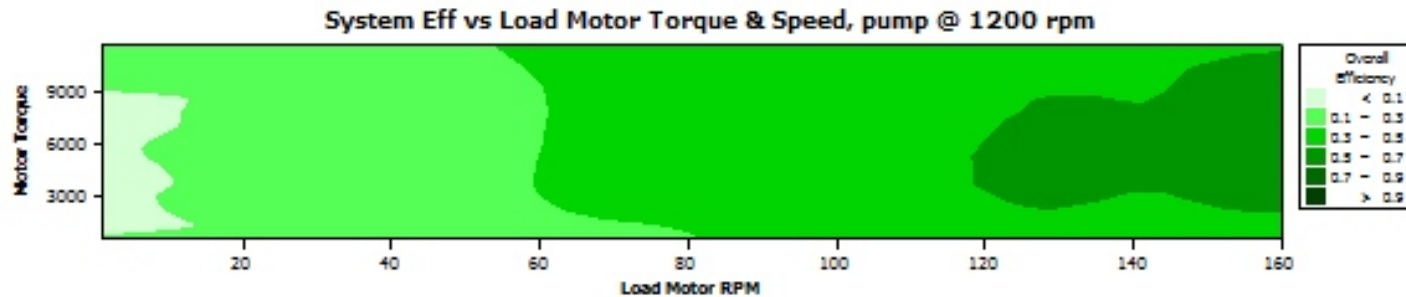
# System Efficiency Map

Axial Piston pump and Geroler Motor at different pump speeds

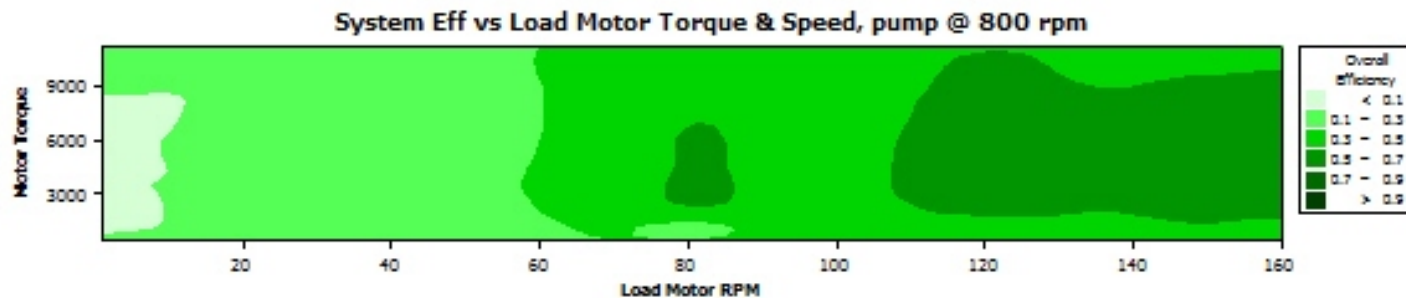
**1800  
RPM**



**1200  
RPM**



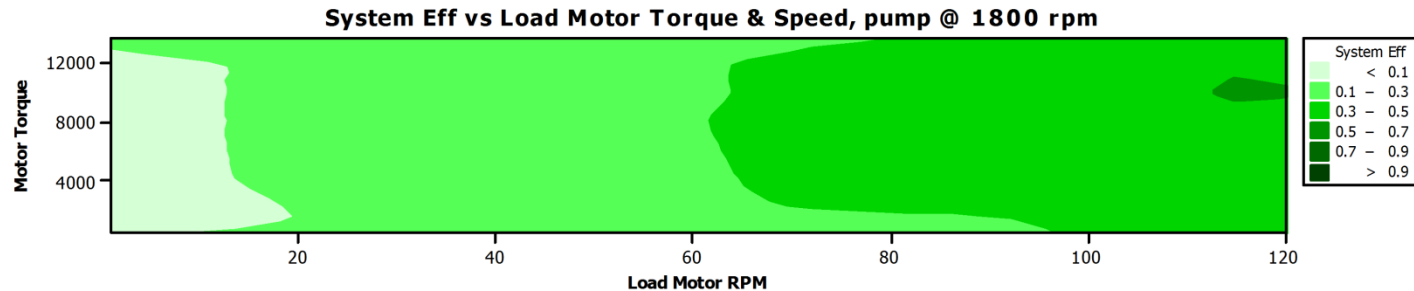
**800  
RPM**



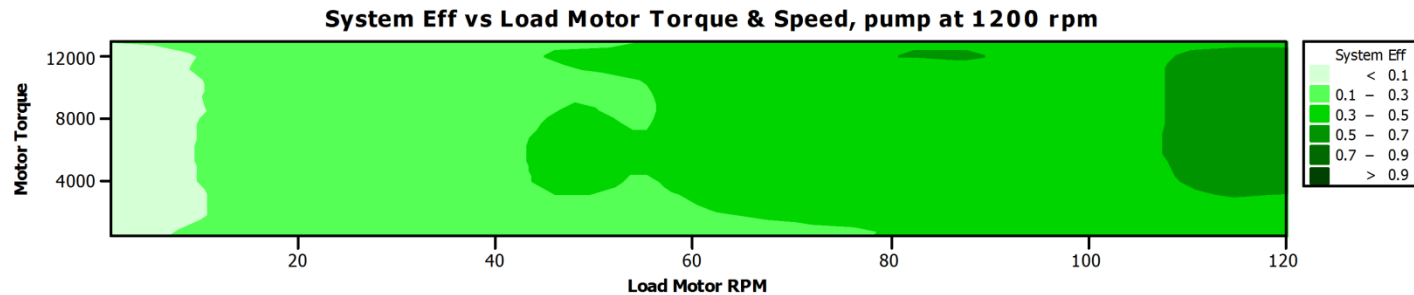
# System Efficiency Map

Axial Piston pump and Radial Piston Motor at different pump speeds

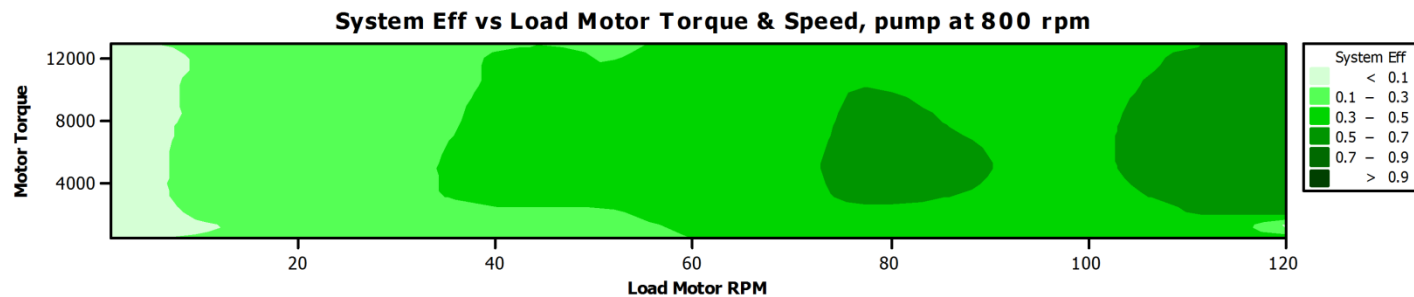
**1800  
RPM**



**1200  
RPM**



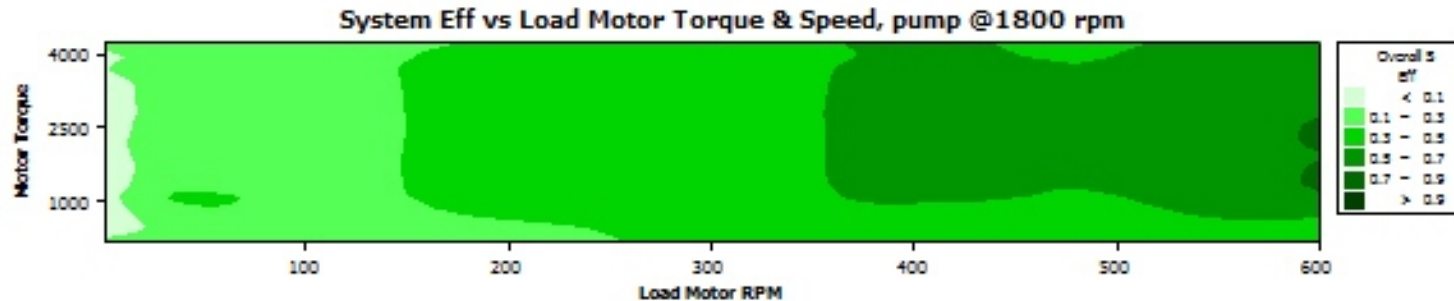
**800  
RPM**



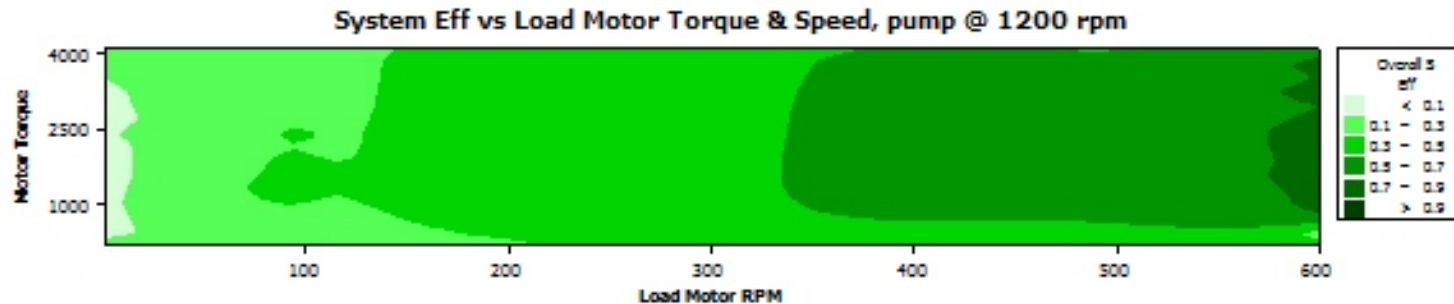
# System Efficiency Map

Axial Piston pump and Axial Piston Motor at different pump speeds

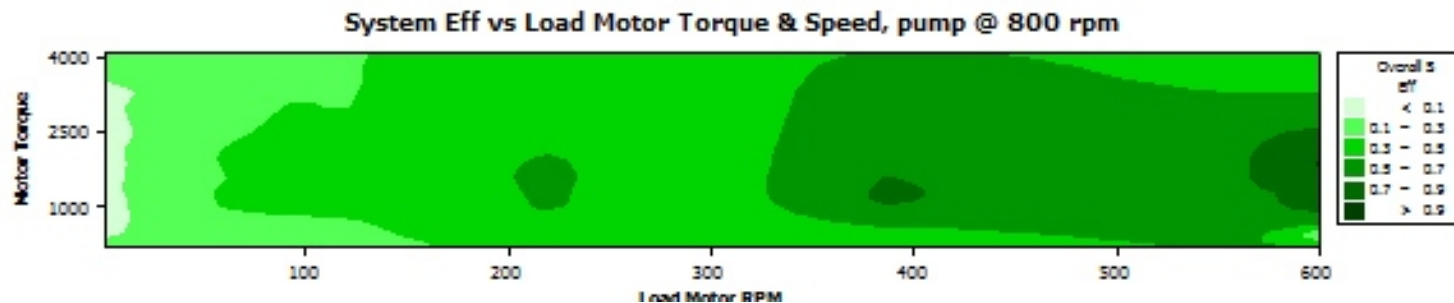
**1800  
RPM**



**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)