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Maximum Efficiency Hydraulic Fluids

M.E.H.F

Advantages at High Temperature Operation

October 18, 2004

RohMax
OIL ADDITIVES

Maximizing Pump Efficiency at High Temperature and High Pressure

- At high temperature and high pressure, low fluid viscosity will result in high internal pump leakage which :
  - Reduces the actual flow rate and thus the hydraulic power
    - Increases the amount of fuel/electricity required to achieve a desired amount of hydraulic work
    - Increases the amount of time needed to obtain a desired amount of hydraulic work
    - Increased fuel consumption means higher exhaust emissions
  - Increases the rate at which the temperature of the fluid increases, since the energy that is lost is converted into heat
  - Reduces pump life due to wear and potential damage
  - Increases the rate at which oxidation takes place reducing fluid life
    - Anti-oxidant additives are consumed faster
    - Formation of lacquers and varnishes

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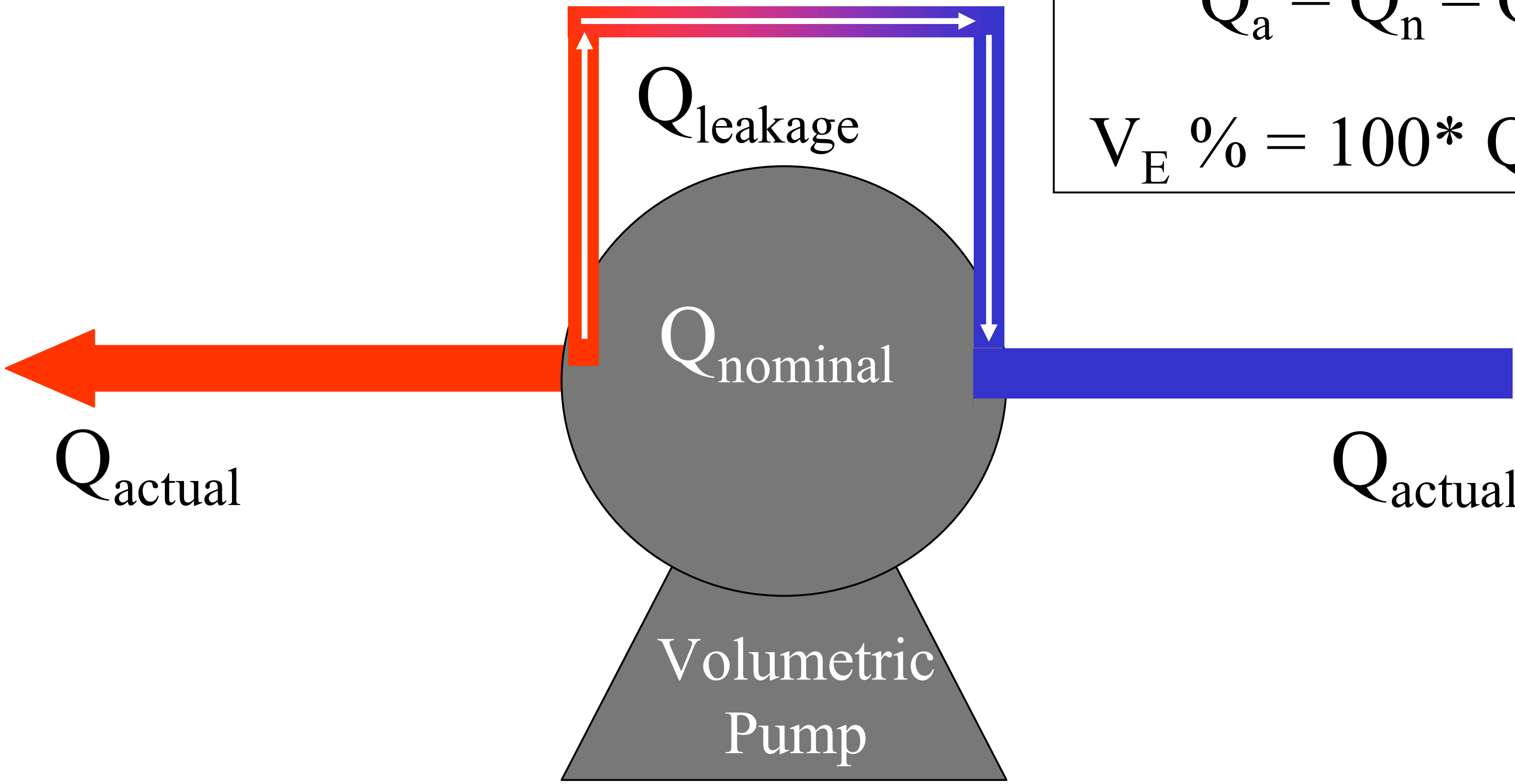
Actual versus Nominal Flow Rate in a Volumetric Pump



$$Q_a = Q_n - Q_l$$

$$V_E \% = 100 * Q_a / Q_n$$

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Influence of Oil Viscosity on Pump Efficiency at High Temperature

- Work completed with HM oils (VI=100) in Vane and Gear pumps has shown that leakage is:
  - Proportional to pressure
  - Inversely proportional to viscosity.

$$\text{Leakage} = \alpha * \text{Pressure/Viscosity}$$

In this equation, α is a function of the geometry of the pump

- Therefore, the higher the pressure and the lower viscosity the higher the leakage.
- The energy lost in the leakage stream increases the temperature of the oil entering the pump and further reduces its volumetric efficiency.
- In a volumetric pump, if leakage is higher than 50%, the volume of oil that stays in the pump is larger than the flow of oil entering the pump resulting in overheating.

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Performance of High VI Fluids in High Pressure Pumps
Definition of MEHF

- High VI hydraulic fluids were evaluated in a variety of volumetric pumps:
  - High Pressure Gear pump - constant displacement
    - *Bosch-Rexroth* -1 ml per revolution – 250 bar maximum
  - Medium Pressure Vane Pumps - constant displacement
    - *Eaton-Vickers* V20 and V 104C – 140 bar maximum
  - High Pressure Vane Pump - constant displacement
    - *Denison* T6C Mobile – 250 bar maximum
  - High Pressure Piston Pump - variable displacement
    - *Komatsu* HPV 35 + 35 dual piston pump – 350 bar maximum

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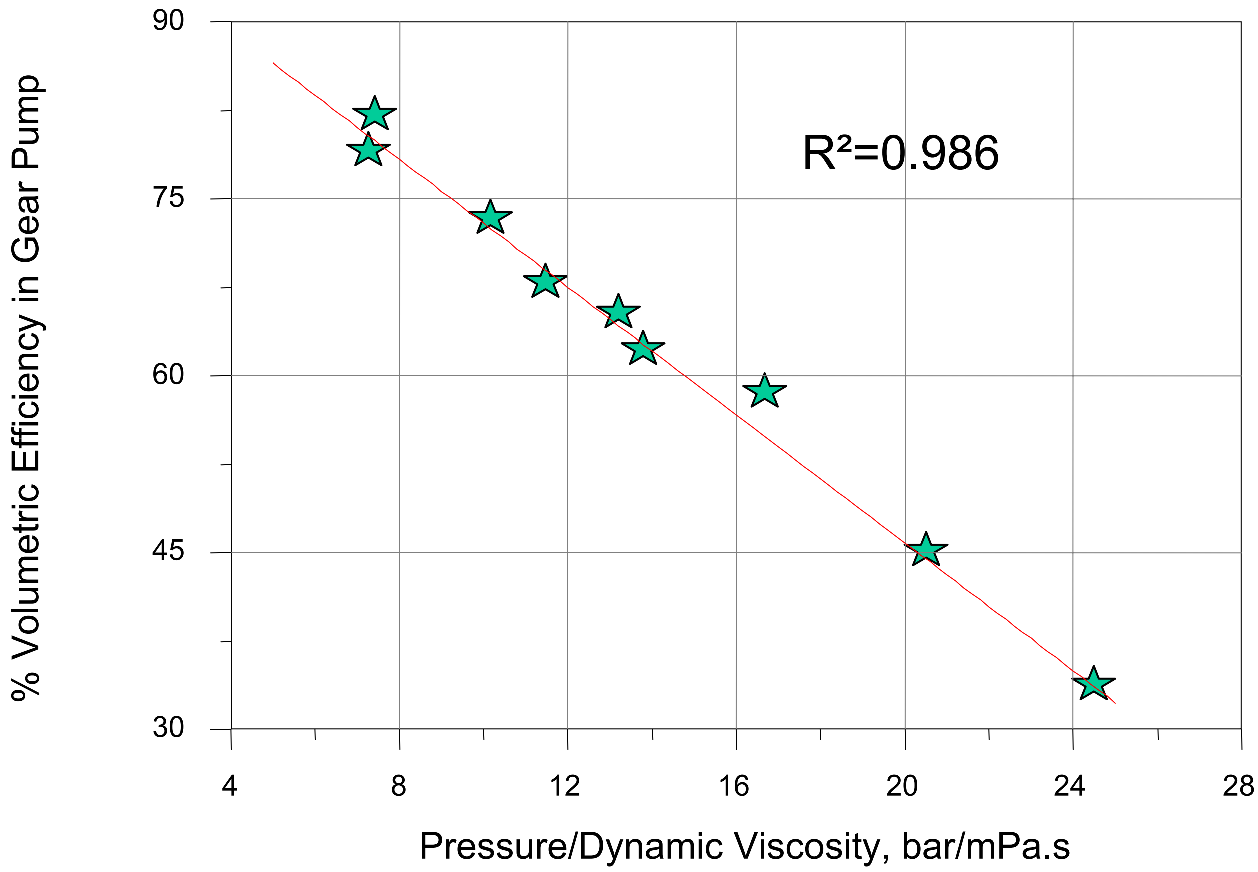
Flow Rate of HM Oils in a High Pressure Gear Pump Bosch -1 ml/rpm (250 bar Max.)



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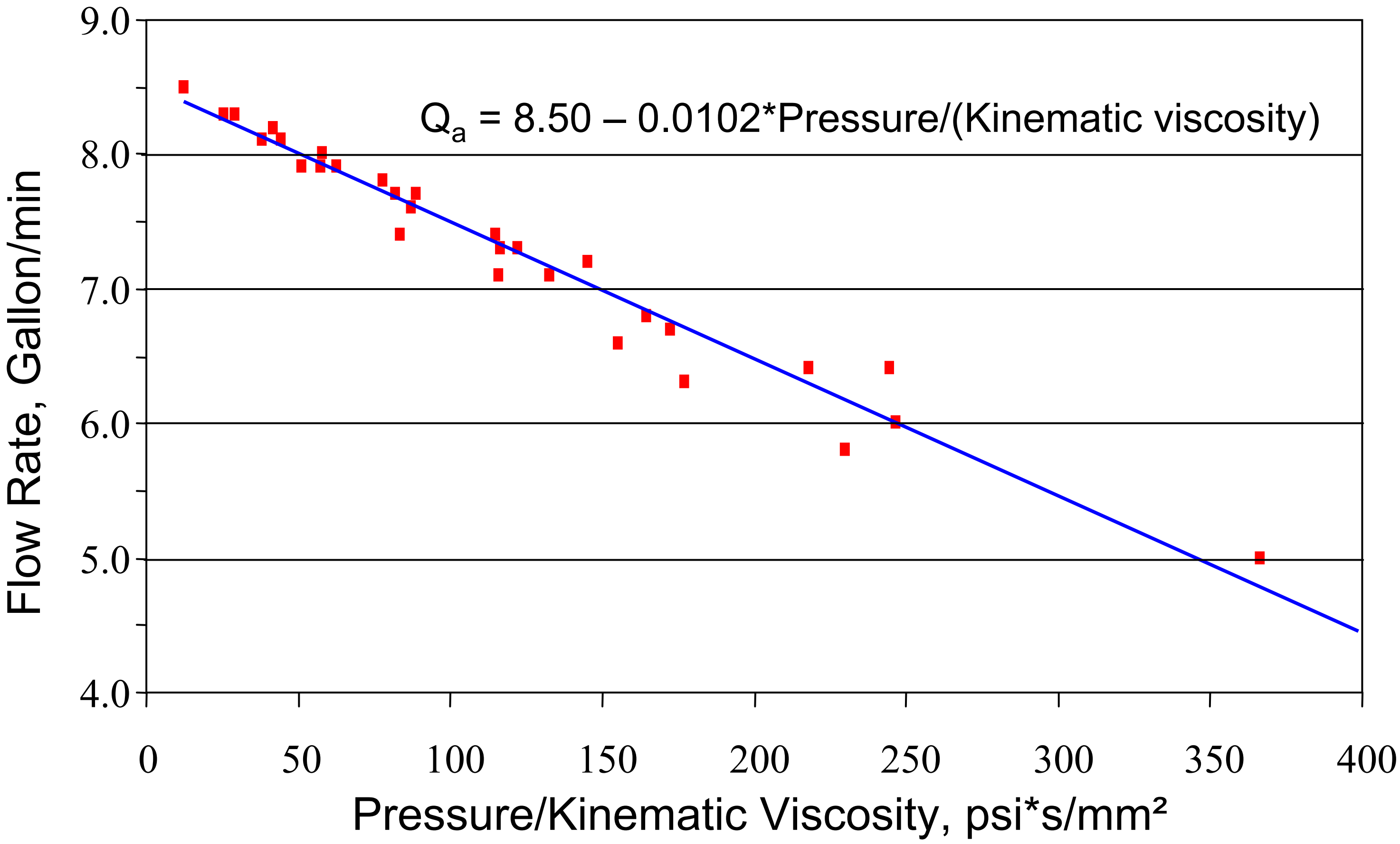
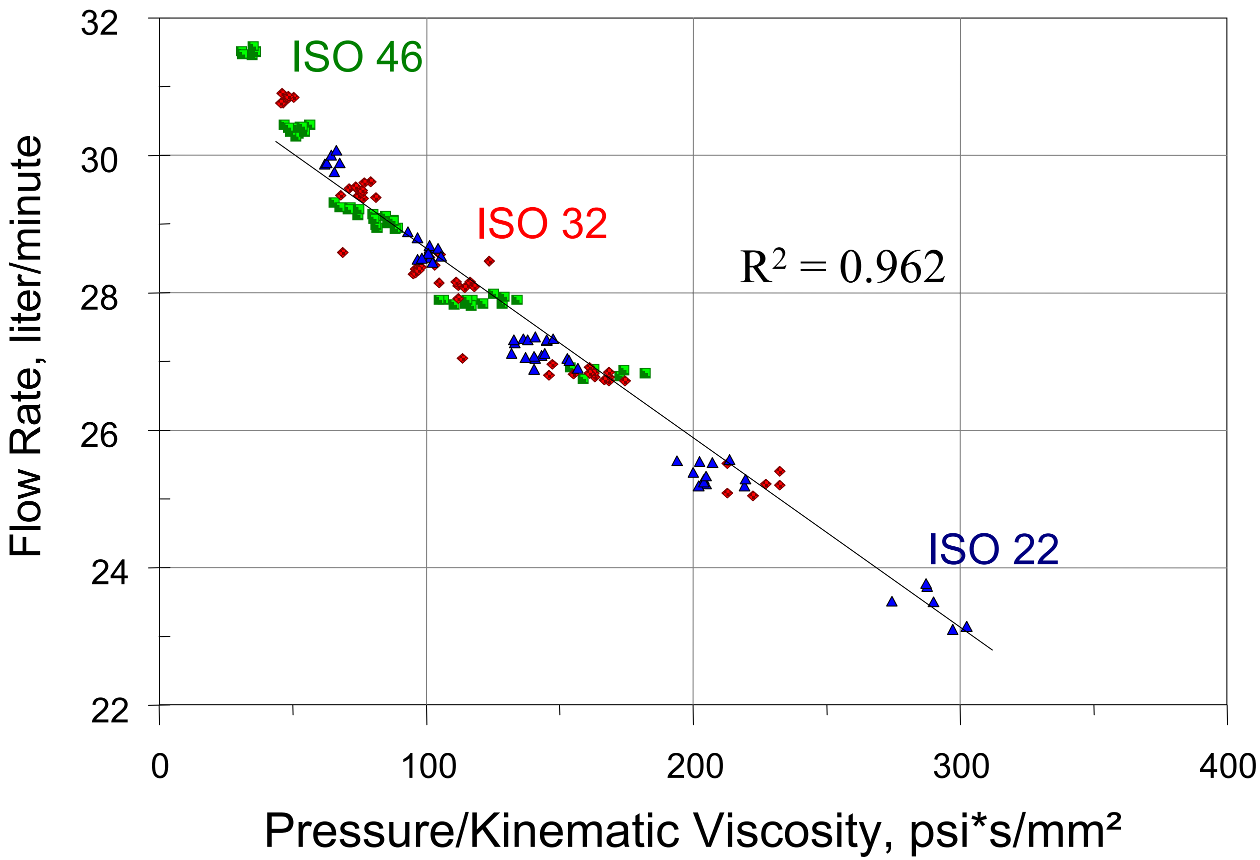
Flow Rate of HM Oils in a Medium Pressure Vane Pump Eaton-Vickers 104C (140 bar Max.)



Flow Rate of HM Oils in a Medium Pressure Vane Pump Eaton-Vickers V20 (140 bar Max.)



Modeling Vane Pump Volumetric Efficiency

- For the Eaton-Vickers Vane Pumps used in this study:

Pump	Flow rate, liter/minute Pressure in psi	Volumetric Efficiency at 2000 psi, %
V-104	Qa = 32.2 – 0.0384*P/KV	V_E = 100*(1-2.4/KV)
V-20	Qa = 31.70 – 0.0302*P/KV	V_E = 100*(1-1.9/KV)

Volumetric Efficiency = Actual Flow Rate / Nominal Flow Rate:

$$V_E = 100 * Q_a/Q_n$$

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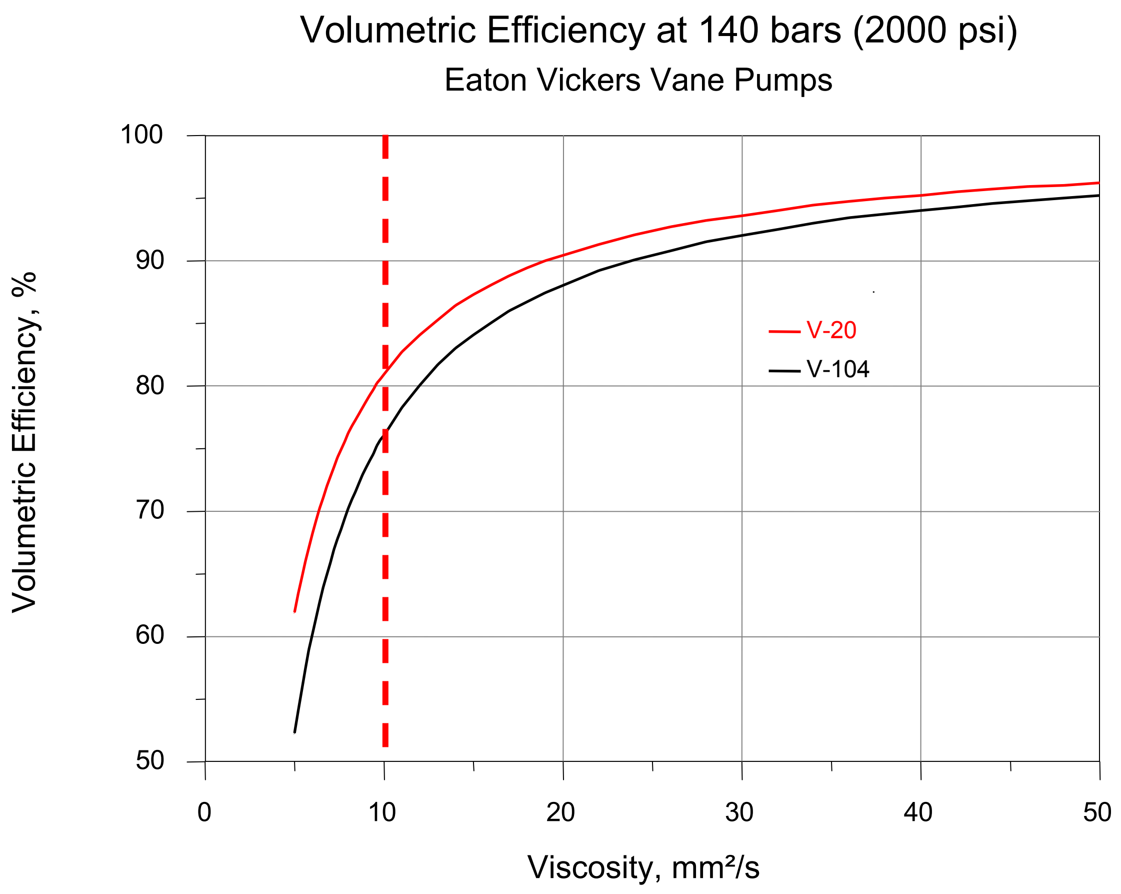
Effect of Kinematic Viscosity on Volumetric Efficiency Eaton-Vickers Vane Pumps at 140 bar (2000 psi) -



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Maximizing Efficiency in a High Pressure Vane Pump Denison T6CM Mobile with MEHF Fluids

- Vane Pump used for Efficiency Tests:
  - Denison T6CM
    - Cartridge B06
      - 31.9 litre/minute at 1500 rpm

Operating conditions :

- Speed: 1500 RPM
- Drive performance: 15 kW (20 HP)
- Pressure range: 0 to 250 bar (4250 Psi)

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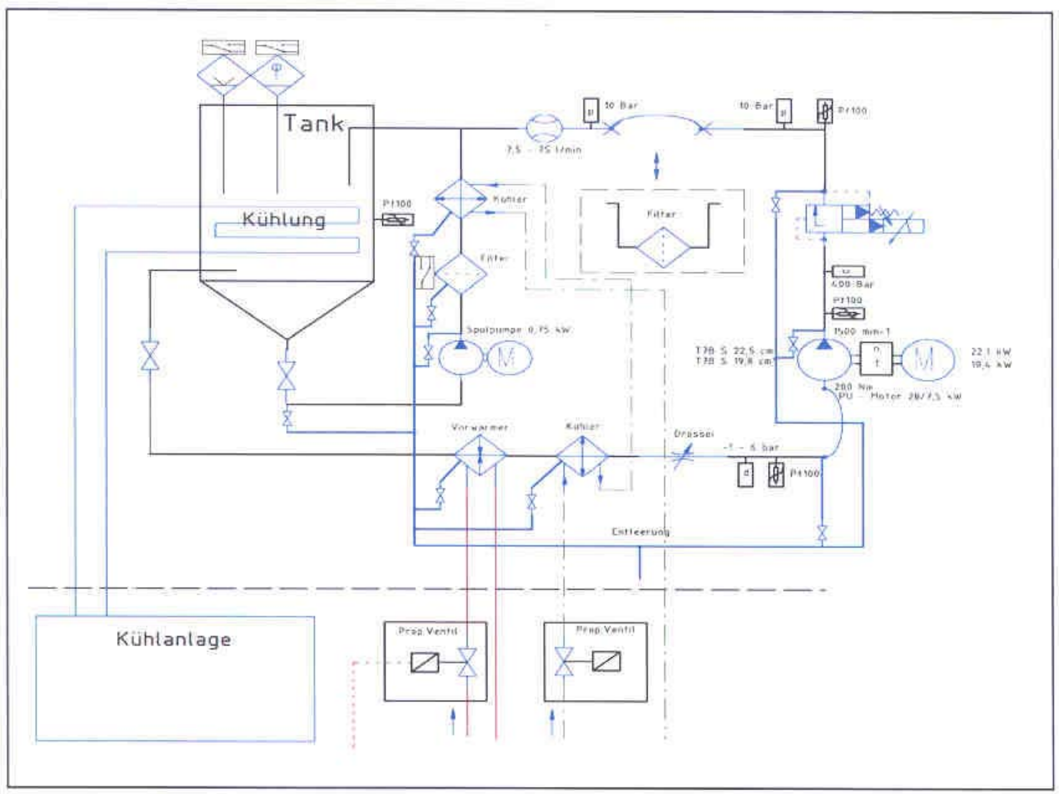
RohMax Hydraulic Fluid Test Stand

Evaluation of:
- Efficiency
- Viscosity in Service
- Shear Stability
- Cold Start

Pump Types:
- Vane
- Axial Piston

Procedures:
- Efficiency-
- Heat up-
- Cycle-
- Cold Start-

Schematic of the Test Rig
Denison T6C Mobile Pump – Cyclic Operations



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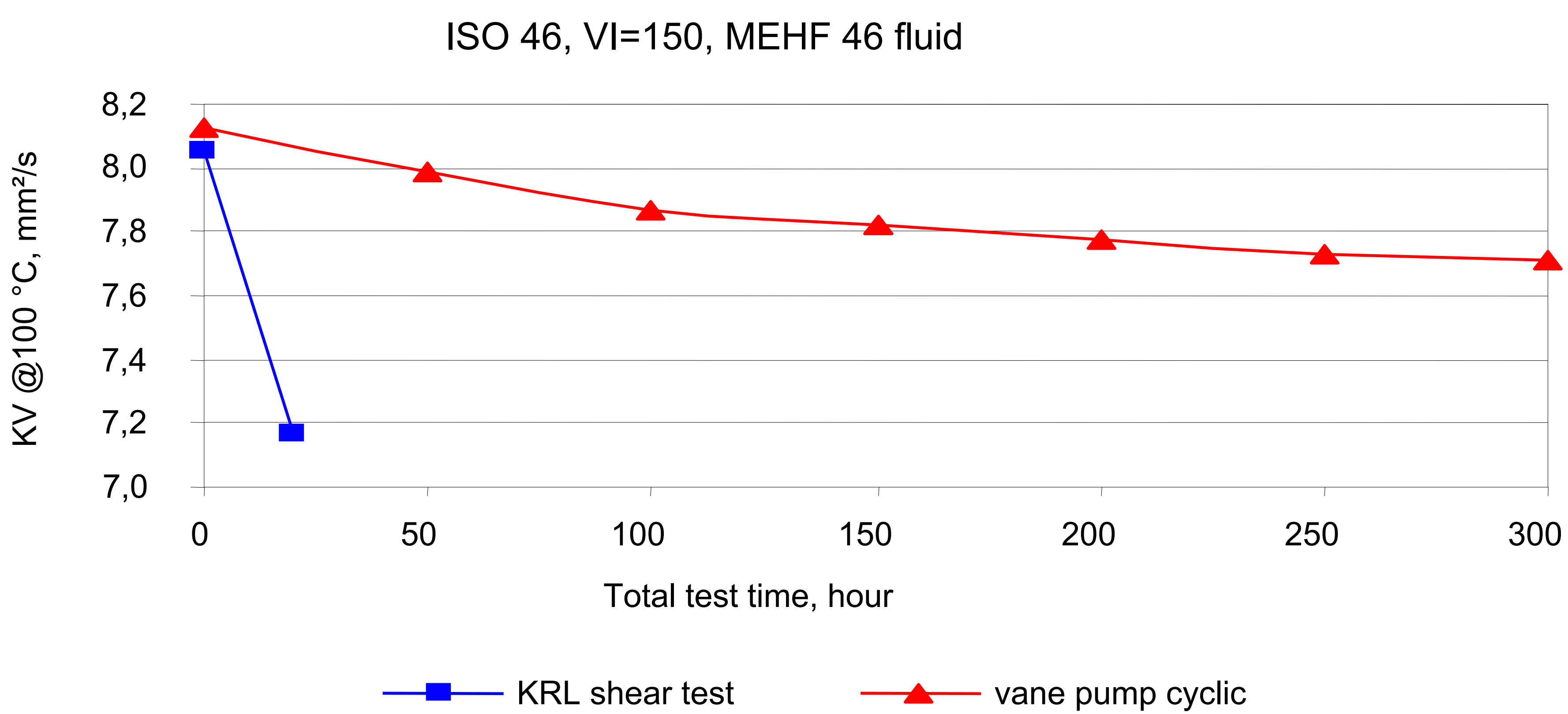
Change in Kinematic Viscosity in Service
Denison T6C Mobile Pump – Cyclic Operations



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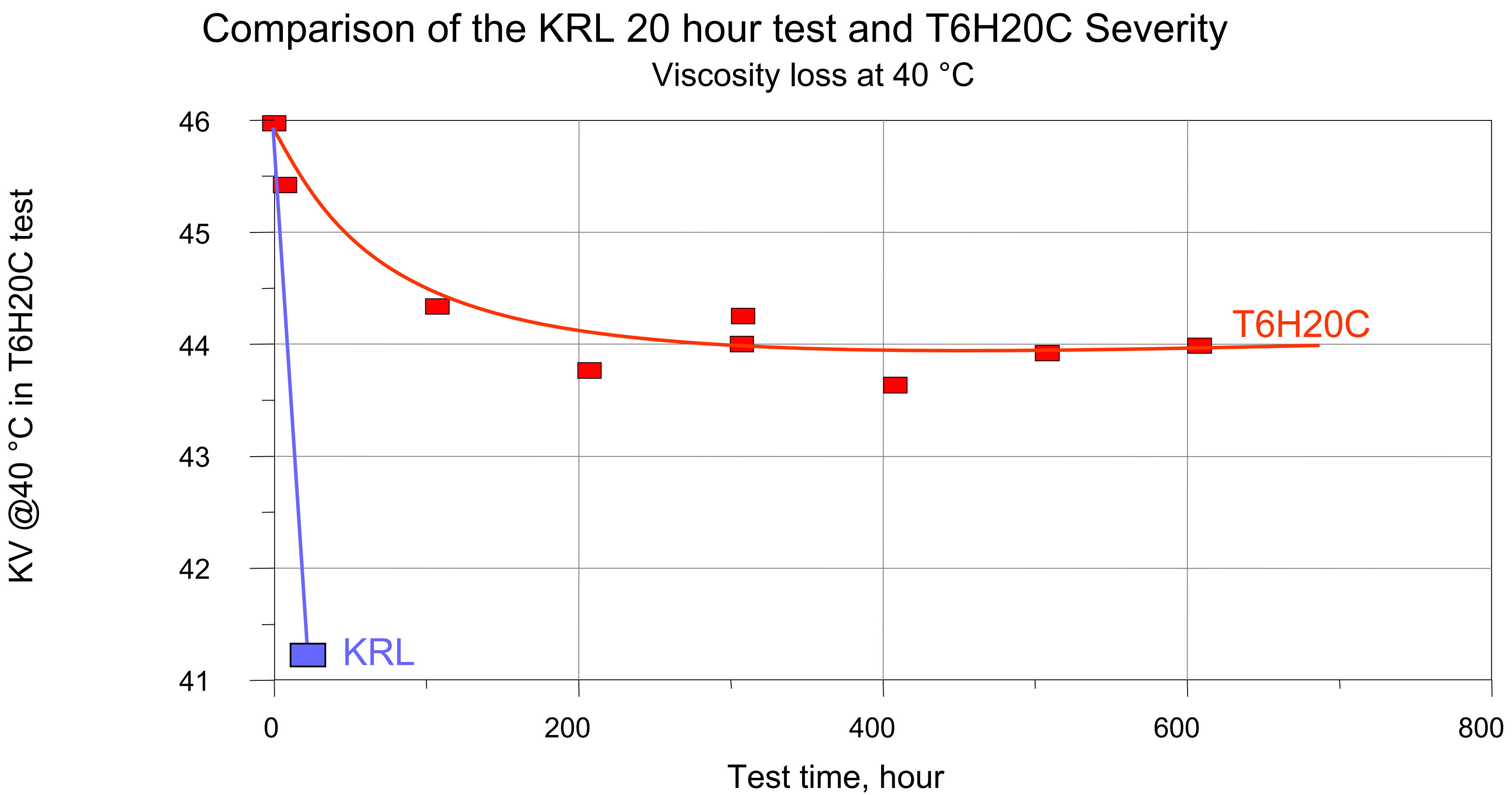
Comparison of the KRL 20 hour test and T6H20C ISO 46, VI=150, MEHF 46 fluid



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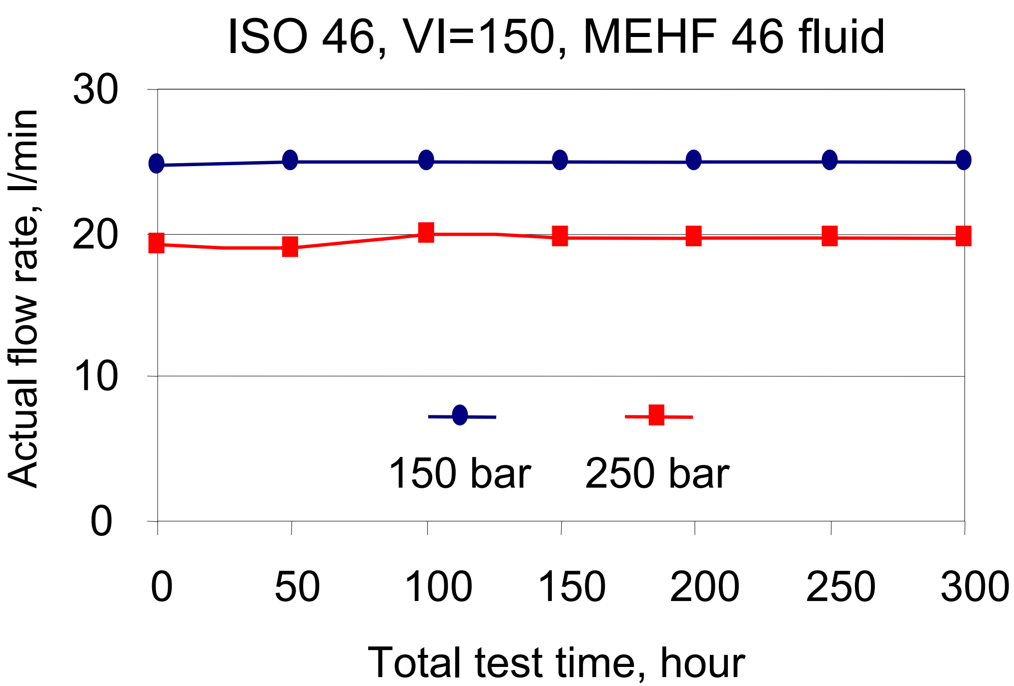
Change in Actual Flow Rate as a Function of Time Denison T6C Mobile Pump – Cyclic Operations



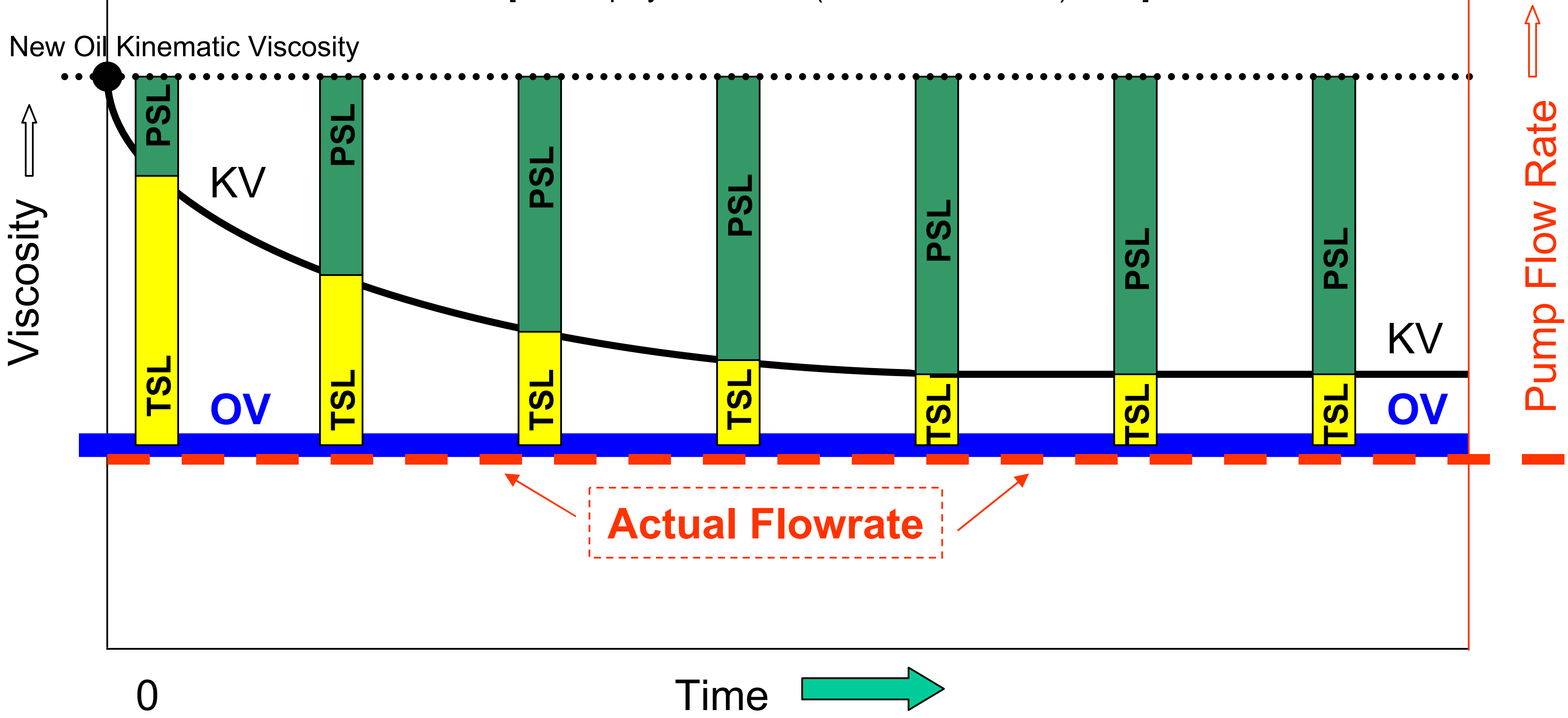
Flow Rate and Volumetric efficiency are constant irrespective of the kinematic viscosity

The viscosity in service (under the shear rate encountered in the pump) remains constant

Flow rate is a function of temporary and permanent shear loss, the net result is constant flow rate

Kinematic vs. Dynamic Viscosity

[with VI polymer treated (i.e. non-Newtonion) fluids]



KV = Kinematic Viscosity, changes with time due to permanent shear loss

OV = Operating Viscosity, constant over time, due to sum of permanent and temporary shear loss, equal to dynamic viscosity at the high shear rate pump conditions

PSL = Permanent Shear Loss, determines Kinematic Viscosity loss, irreversible process

TSL = Temporary Shear Loss, determines Operating Viscosity, reversible process

PSL and TSL are a function of shear rate in the pump and polymer type

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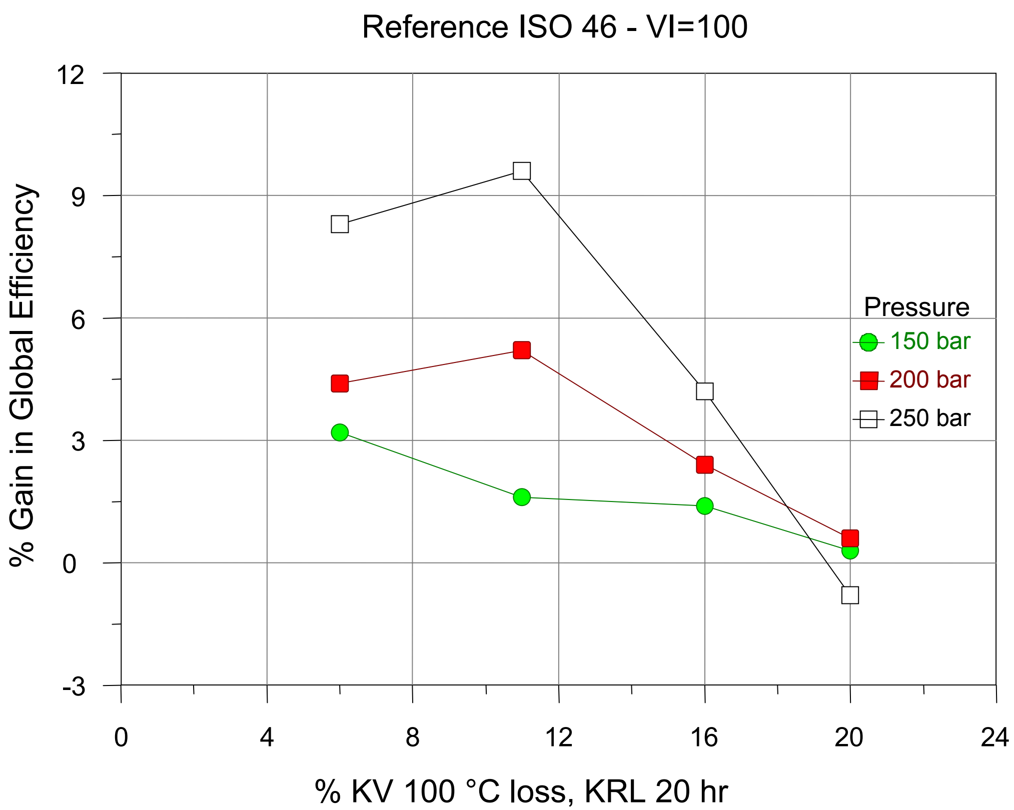
High VI Test Oils Evaluated in Denison Vane Pump – T6C Mobile Pump Cyclic Operations

- **Grades:**
  - ISO 46 and 68
- **VI:**
  - 150 and 200
- **VI Improvers:**
  - Four VIIs with different molecular weight were used to formulate ISO 46 oils with a VI=150.

VII	% KV 100°C loss in KRL 20 h test, ISO 46 VI=150
A	6
B	11
C	16
D	20

Effect of VII and Pressure on Global Efficiency
Denison Vane Pump – T6C Mobile Pump
ISO <u>46</u>, 150 VI Oils vs. monograde, VI = 100 oil



The higher the pressure and the more shear stable the VII, the larger the gain in global efficiency

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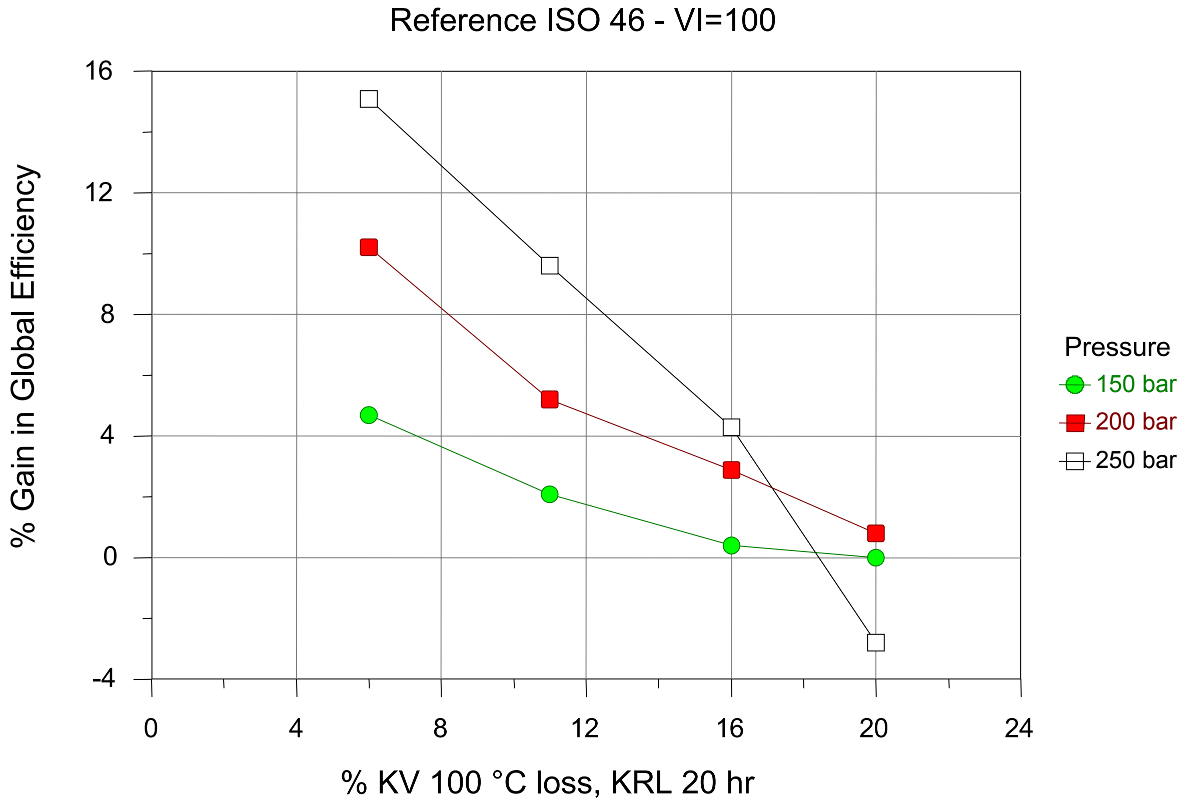
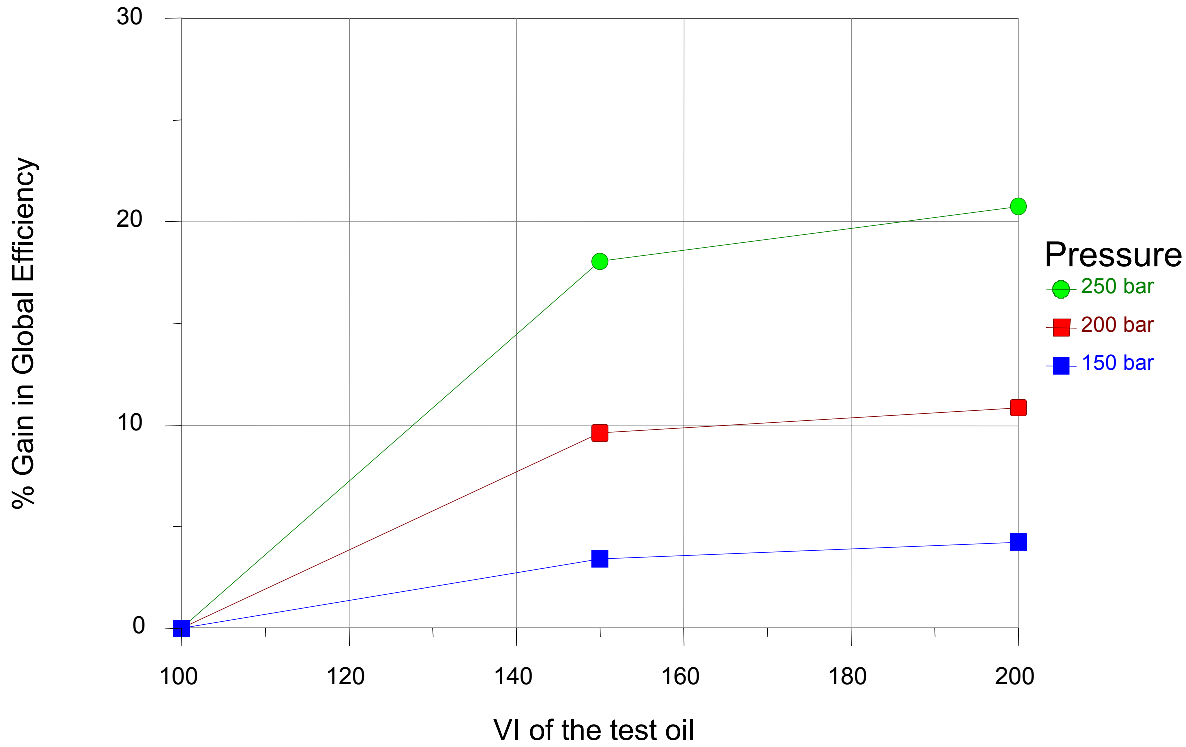
Effect of VII and Pressure on Global Efficiency Denison Vane Pump – T6C Mobile Pump ISO 46, 200 VI Oils vs. monograde, VI = 100 oil



Effect of VI and Pressure on Global Efficiency
Denison Vane Pump – T6C Mobile Pump
ISO 68, 150 & 200 VI Oils with PAMA A

Reference ISO 68 - VI=100



Temperature Operating Window Based on 860 to 10 mm²/s

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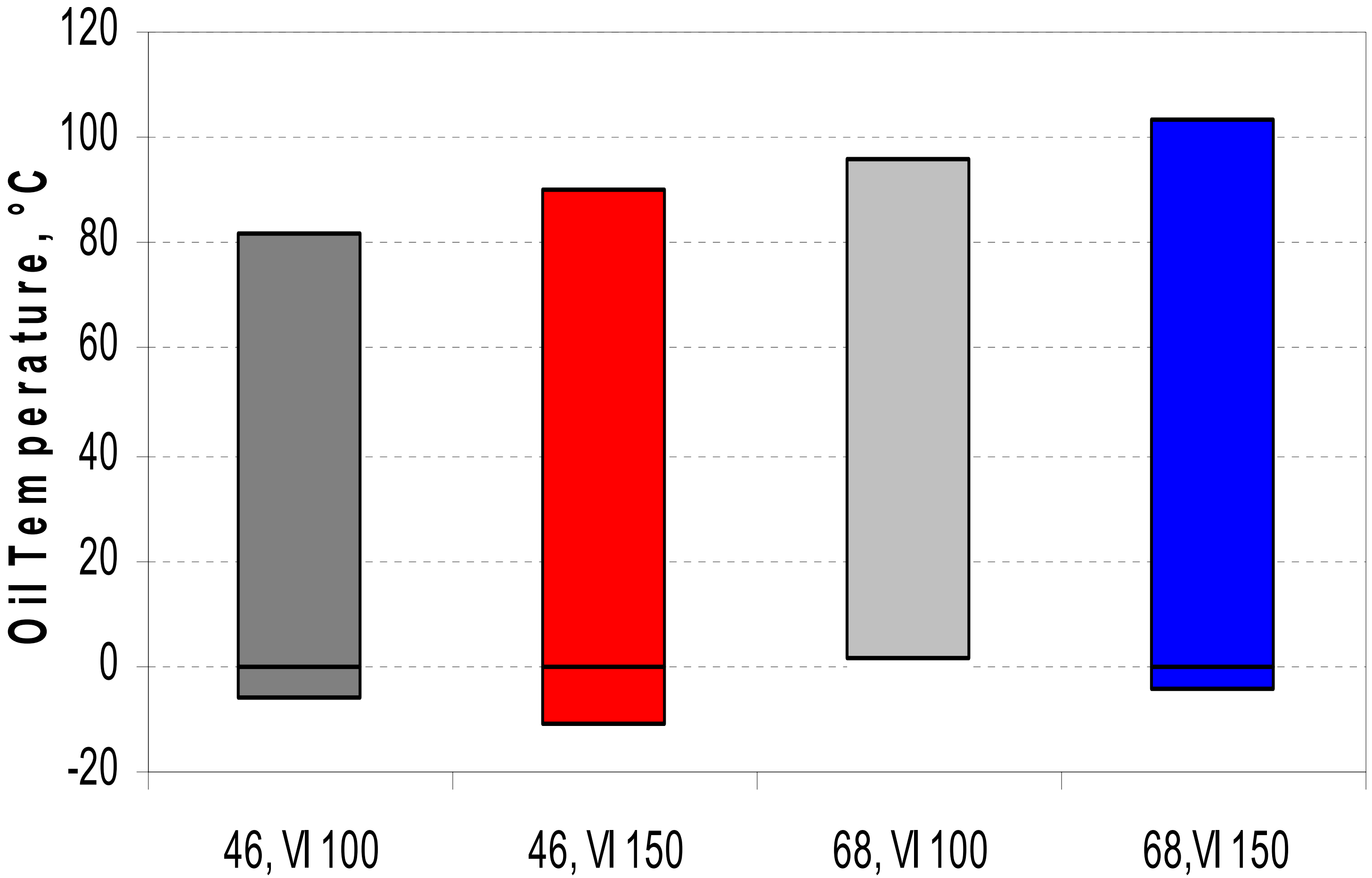

An ISO 68 VI=150 has about the same Minimum Start-up Temperature as an ISO 46 VI=100

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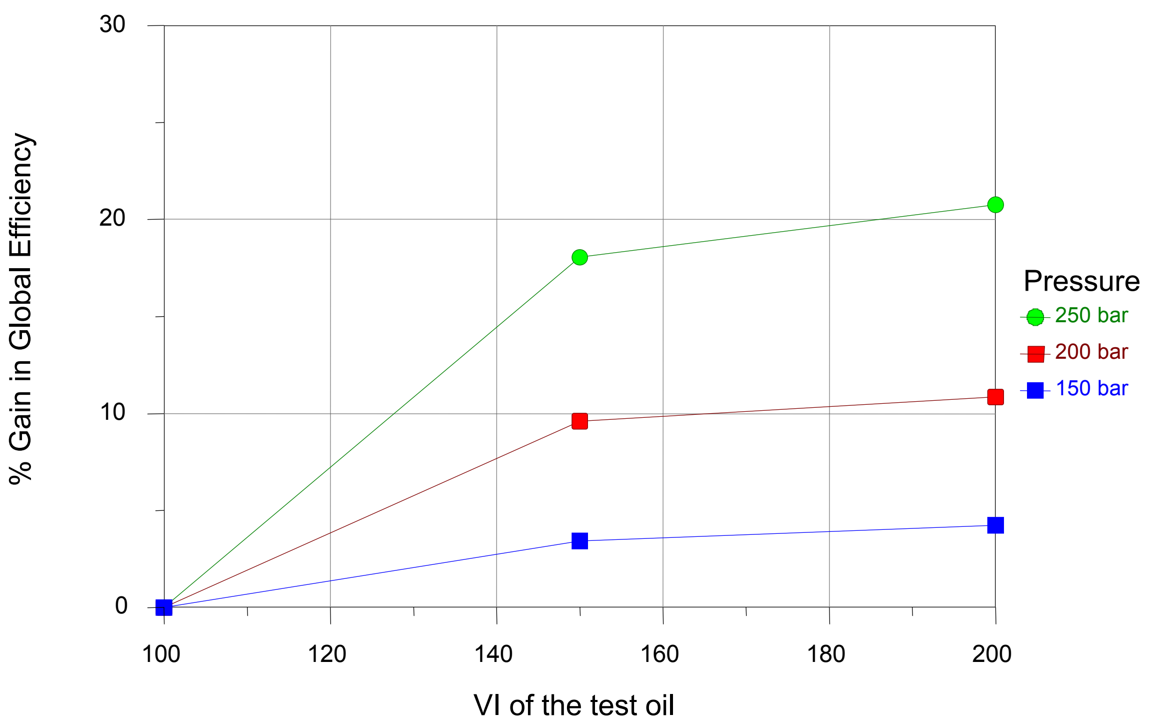
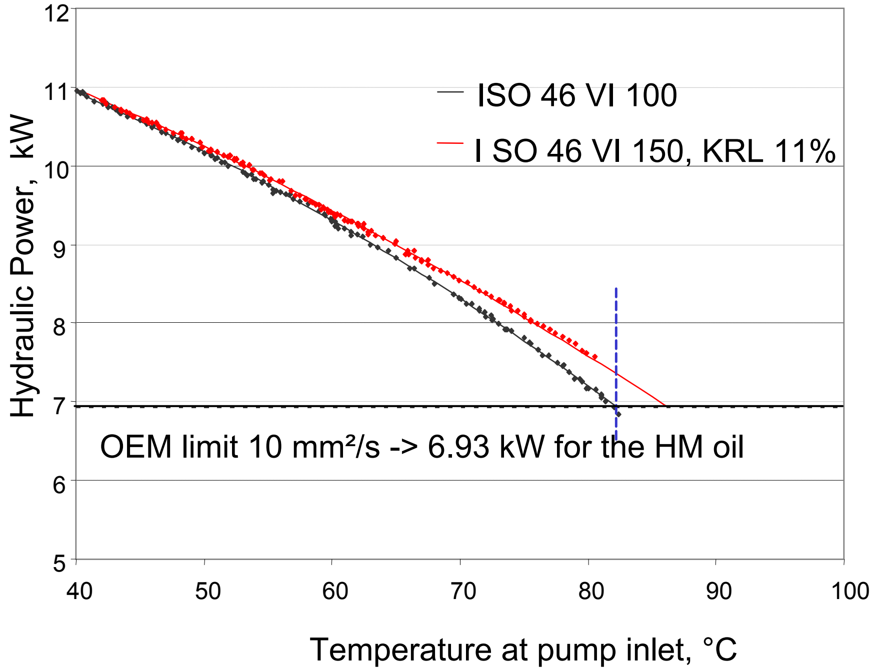
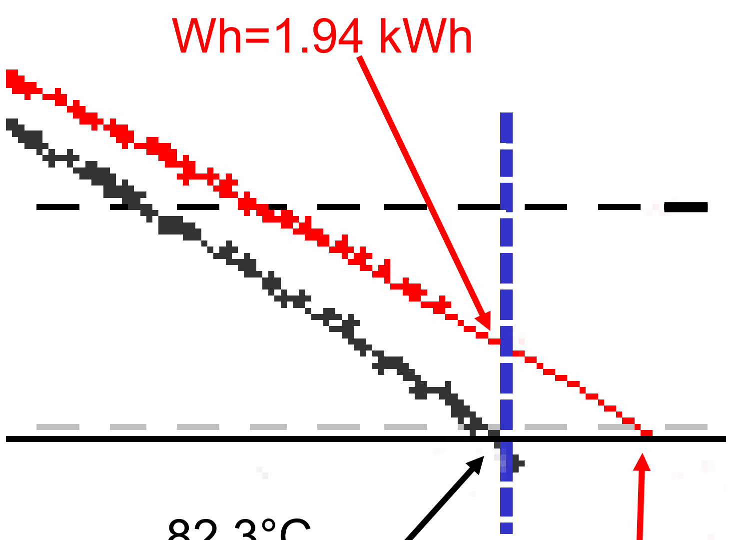
Effect of VI and Pressure on Global Efficiency
Denison Vane Pump – T6C Mobile Pump
ISO 68, 150 & 200 VI Oils with PAMA A

Reference ISO 46- VI=100

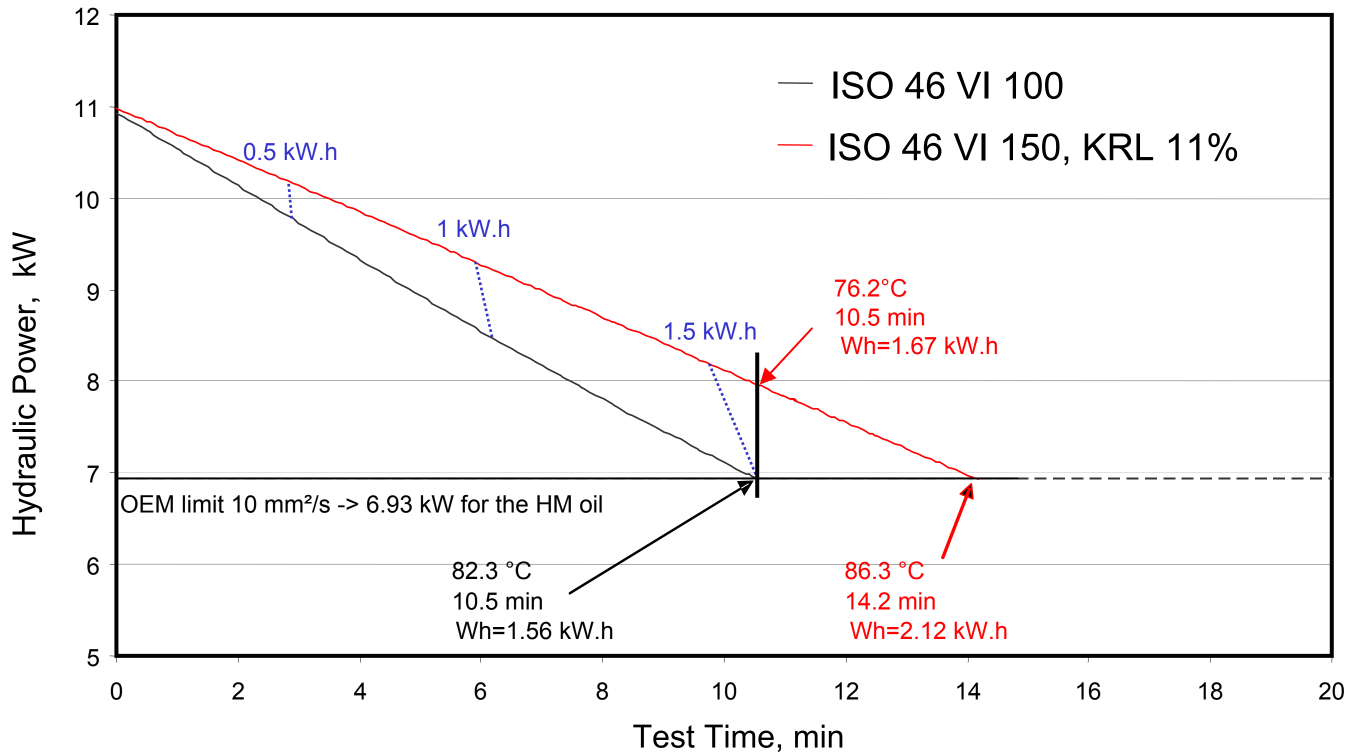


Effect of Oil Temperature on Hydraulic Power at 250 bar Denison Vane Pump – T6C Mobile Pump ISO 46, VI=150





Gain in Hydraulic Power at 250 bar, no Cooling
Denison Vane Pump – T6C Mobile Pump
ISO 46, VI=150



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Conclusions
Denison Vane Pump – T6C Mobile

- All fluids formulated with a shear stable VII (<20% viscosity loss at 100 °C following the KRL 20 hour test) provide global efficiency gains over an HM fluid of the same ISO grade.

- Fluids meeting the Denison HF-O shear stability requirement (<15% viscosity loss in the KRL 20 hour test) will thus provide significant benefits in the Denison pump over a monograde HM fluid.

- The actual flow rate does not vary with test time under severe cyclic conditions, indicating that the viscosity seen by the pump is constant.
  In the case of a VII containing fluid, this demonstrates that the sum of the permanent and temporary viscosity loss is constant.

- The benefits achievable with a MEHF in a high pressure vane pump will thus remain constant even after extended service.

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Maximizing Efficiency in a High Pressure Piston Pump Komatsu HPV 35 + 35 with MEHF Fluids

- Piston Pump used for Efficiency Tests:
  - Komatsu HPV 35 + 35 dual piston pump

- Operating conditions :
  - Speed: 2100 RPM
  - Drive performance: 22 kW (30 HP)
  - Pressure range: 0 to 350 bar (5000 Psi
  - Flow rate depends on pressure

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Piston Pump installation for Efficiency Tests: Komatsu HPV 35 + 35 Dual Piston Pump

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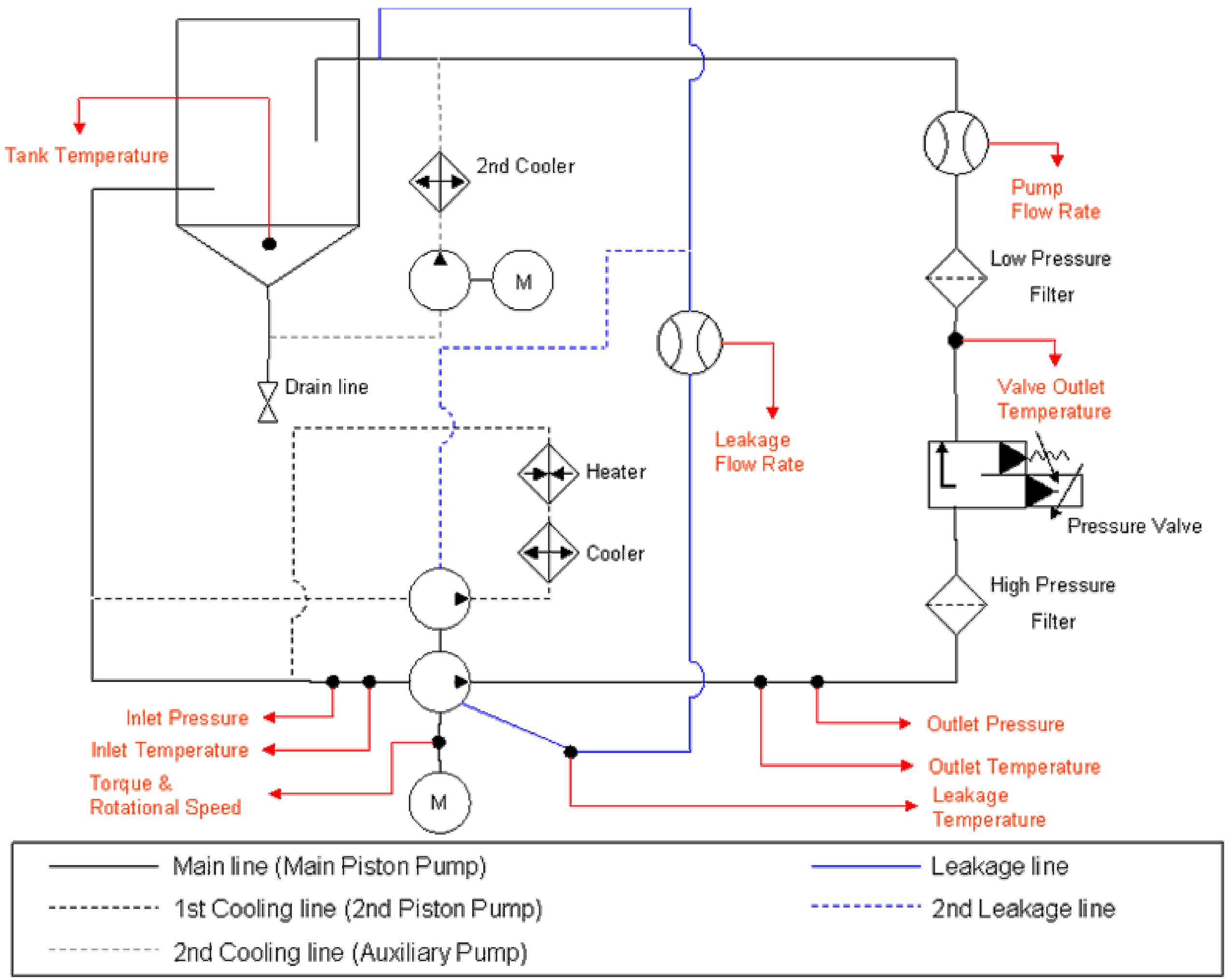
Schematic of the Test Rig
Komatsu HPV 35 + 35 Dual Piston Pump



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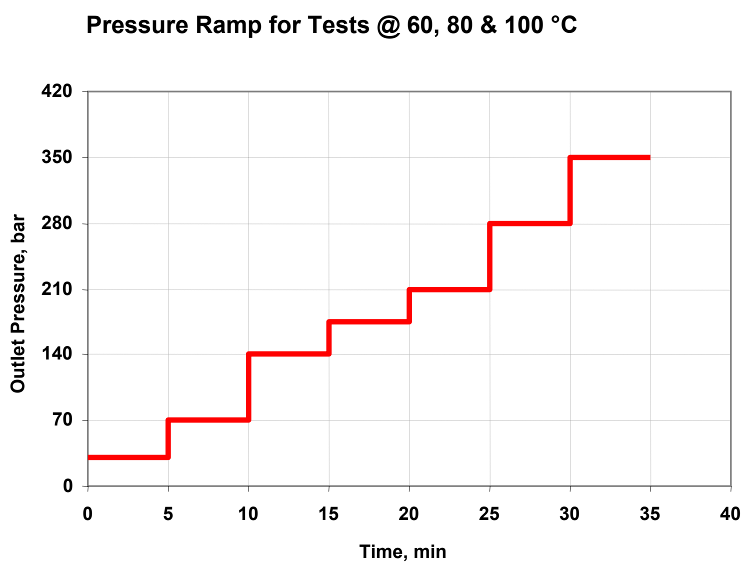
Efficiency Test Procedure
Komatsu HPV 35 + 35 Dual Piston Pump



Install High and Low Pressure Filter Fill in 55 kg Flush Oil from Blending Container
Flush Run, at 1500 rpm, at 50bar, 80°C
Drain Flush Oil, Remove and Drain Filters
Install High and second Low Pressure Filter Fill in 80 kg Test Oil from Blending Container
Heat up to 60°C, all Circuits, 1000 rpm, 30 bar
Efficiency Test @ 2100 rpm, T-inlet 60°C and 30, 70, 140, 175, 210, 280 & 350 (5 min for each step)
Heat up to 80°C, all Circuits, 1000 rpm, 30 bar
Efficiency Test @ 2100 rpm, T-inlet 80°C and 30, 70, 140, 175, 210, 280 & 350 (5 min for each step)
Heat up to 100°C, all Circuits, 1000 rpm, 30 bar
Efficiency Test @ 2100 rpm, T-inlet 100°C and 30, 70, 140, 175, 210, 280 (5 min for each step)
Drain Test Oil, Remove and Drain Filters

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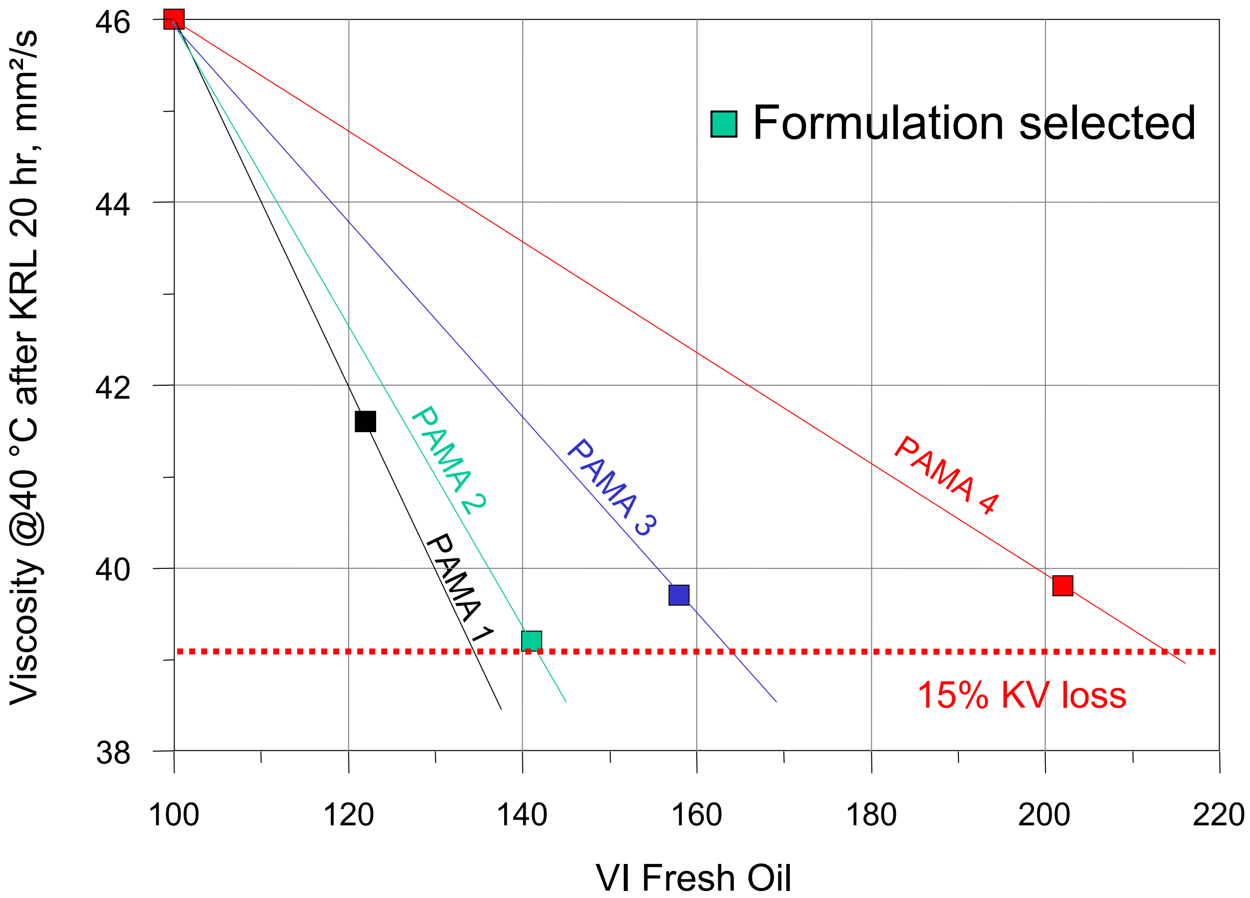
Optimization of the VI and of the VII Shear Stability Komatsu HPV 35 + 35 Dual Piston Pump

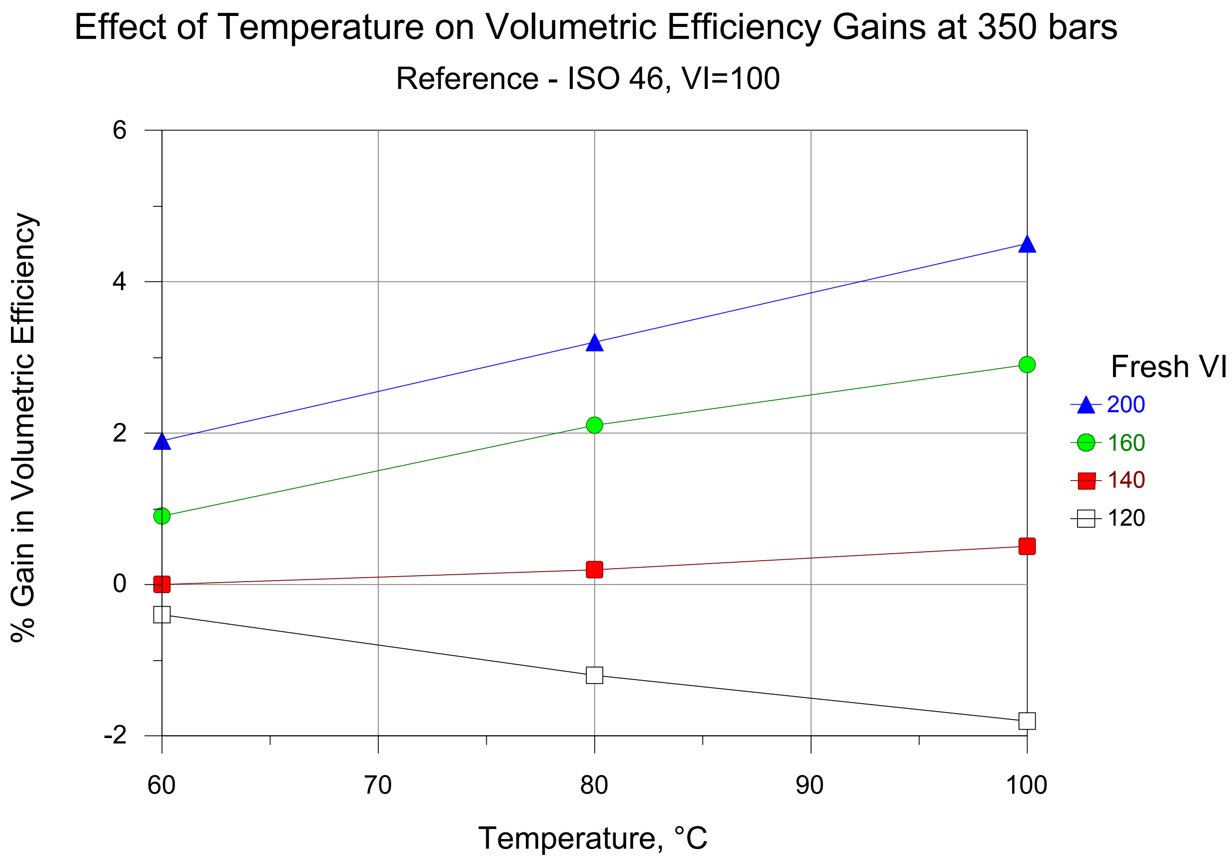
Fluid	VII	KV 40 °C mm²/s	KV 100 °C mm²/s	VI	KRL 20h % KV loss
ISO 46 VI 100	None	45.9	6.8	103	-
ISO 46 VI 120	PAMA 1	44.7	7.2	122	9.6
ISO 46 VI 140	PAMA 2	46.1	7.9	141	14.8
ISO 46 VI 160	PAMA 3	47.8	8.6	158	13.8
ISO 46 VI 200	PAMA 4	46.0	9.7	202	13.5

Oils were blended to have a maximum viscosity loss of 15% after the KRL 20 hour test (CEC L-45-A-99)

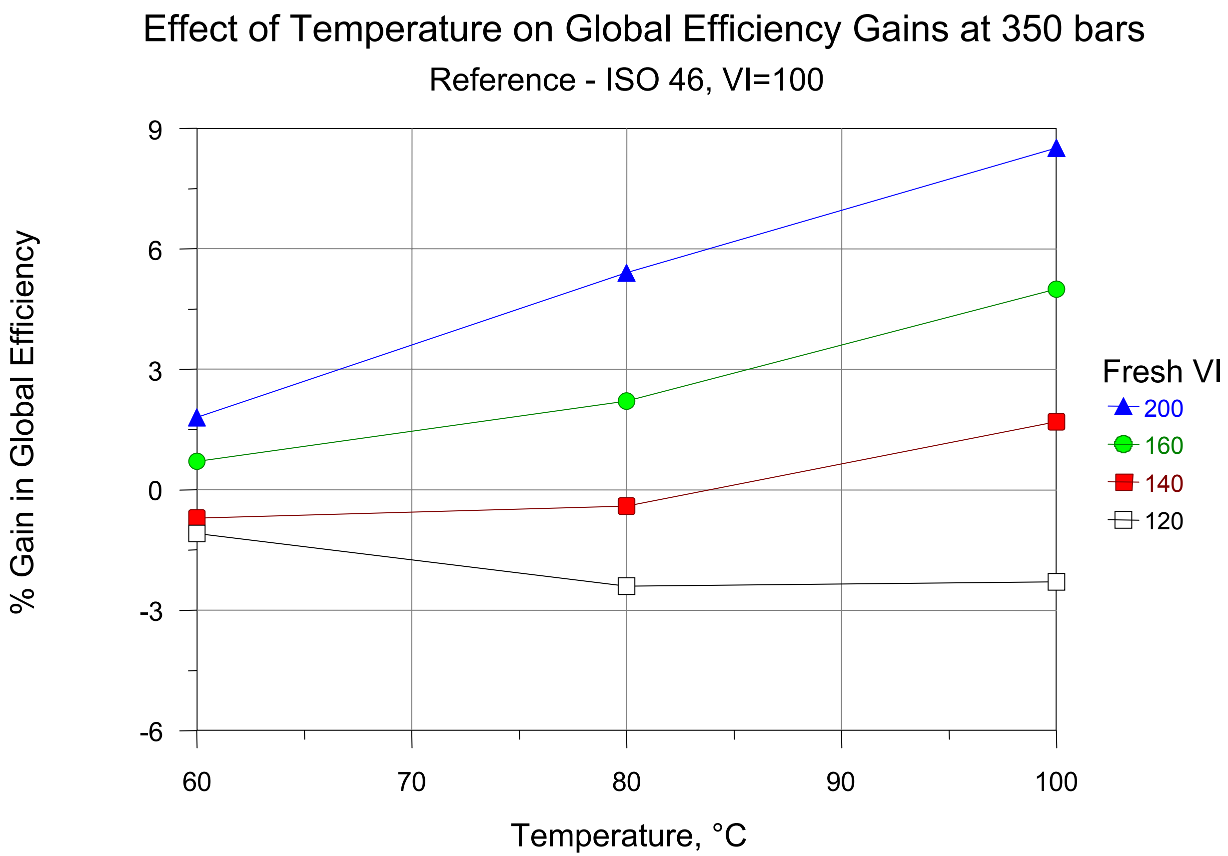
Optimization of the VI of the Formulation for a KV loss of 15% Max. in the KRL Test



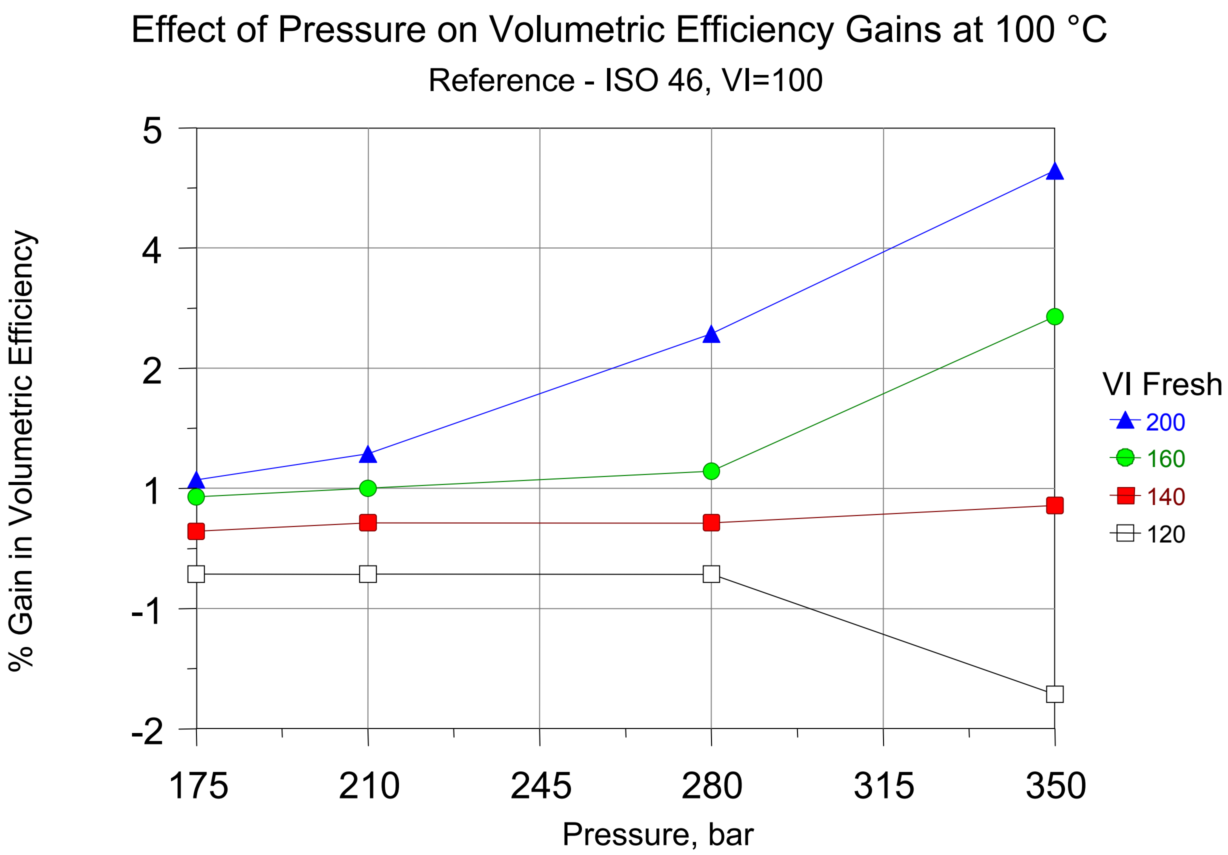
Effect of Temperature on Volumetric Efficiency at 350 bars Komatsu HPV 35 + 35 Dual Piston Pump



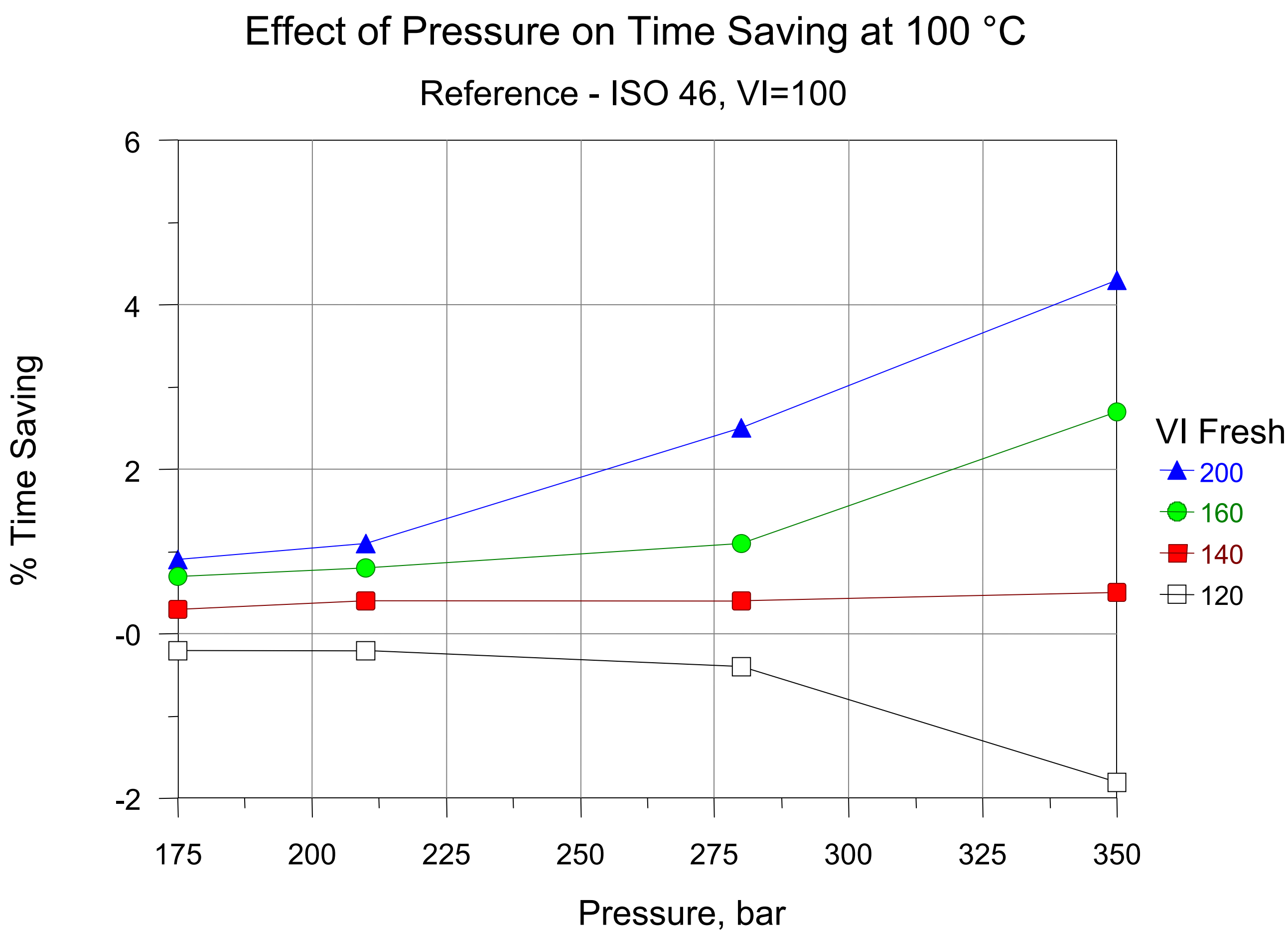
Effect of Temperature on Global Efficiency at 350 bars Komatsu HPV 35 + 35 Dual Piston Pump



Effect of Pressure on Volumetric Efficiency at 100 °C Komatsu HPV 35 + 35 Dual Piston Pump



Effect of Pressure on Time Savings at 100 °C
Komatsu HPV 35 + 35 Dual Piston Pump



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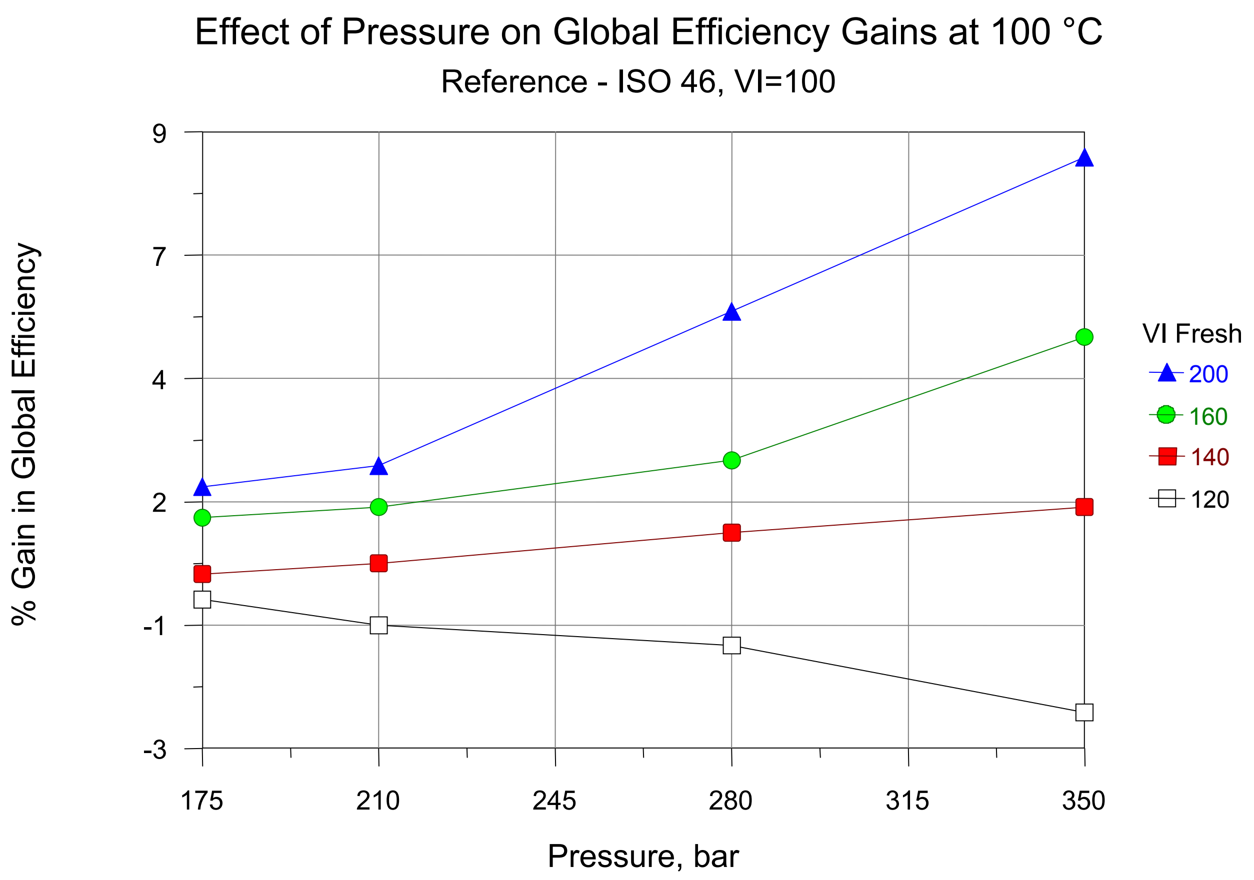
Effect of Pressure on Global Efficiency Gains at 100 °C Komatsu HPV 35 + 35 Dual Piston Pump



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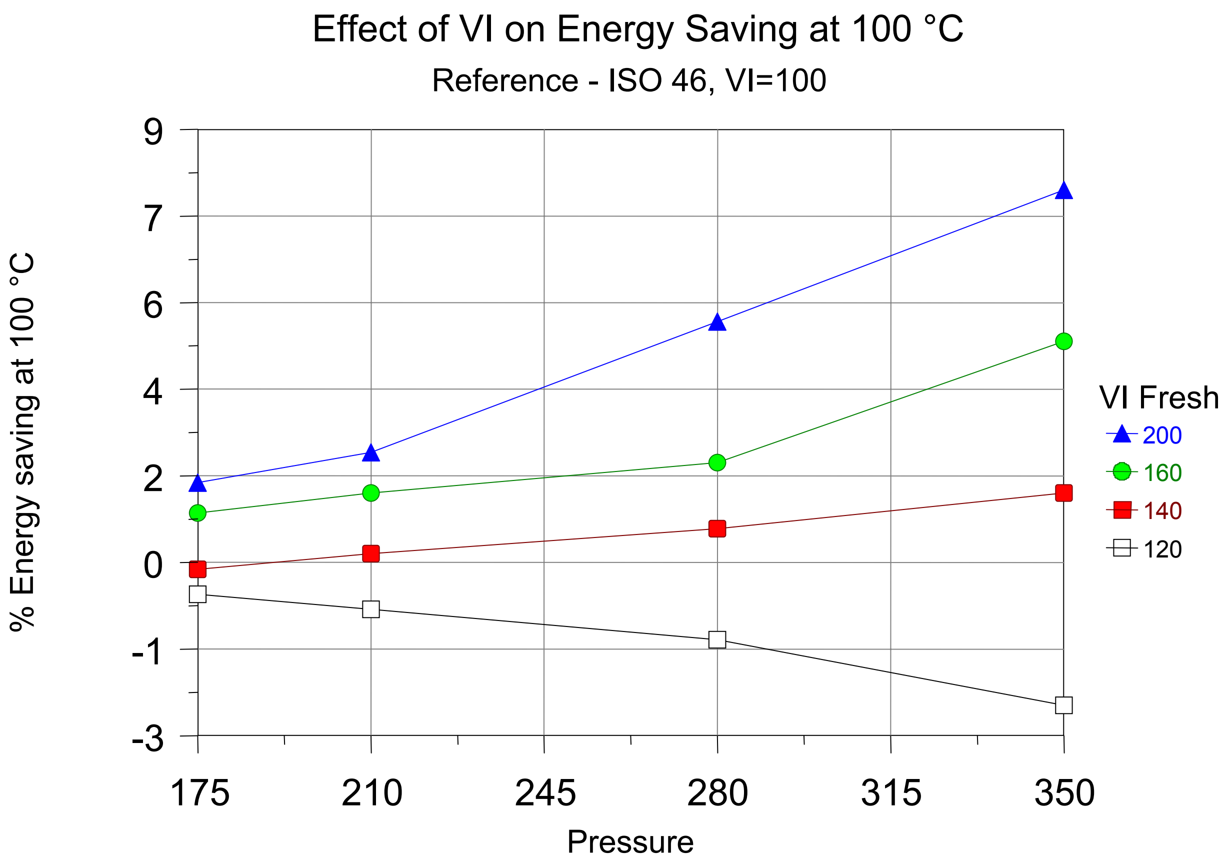
Effect of Pressure on Energy Savings at 100 °C
Komatsu HPV 35 + 35 Dual Piston Pump



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Partial Conclusions
Komatsu HPV 35 + 35 Dual Piston Pump

- ISO 46 fluids formulated with different VI Improvers to a maximum KV loss of 15% maximum show different performance in the Komatsu pump.

- Only the polymers that can reach a VI of 160 show significant benefits and would meet the MEHF performance requirements

- The rest of the program will be run on oils having a VI of the 160.

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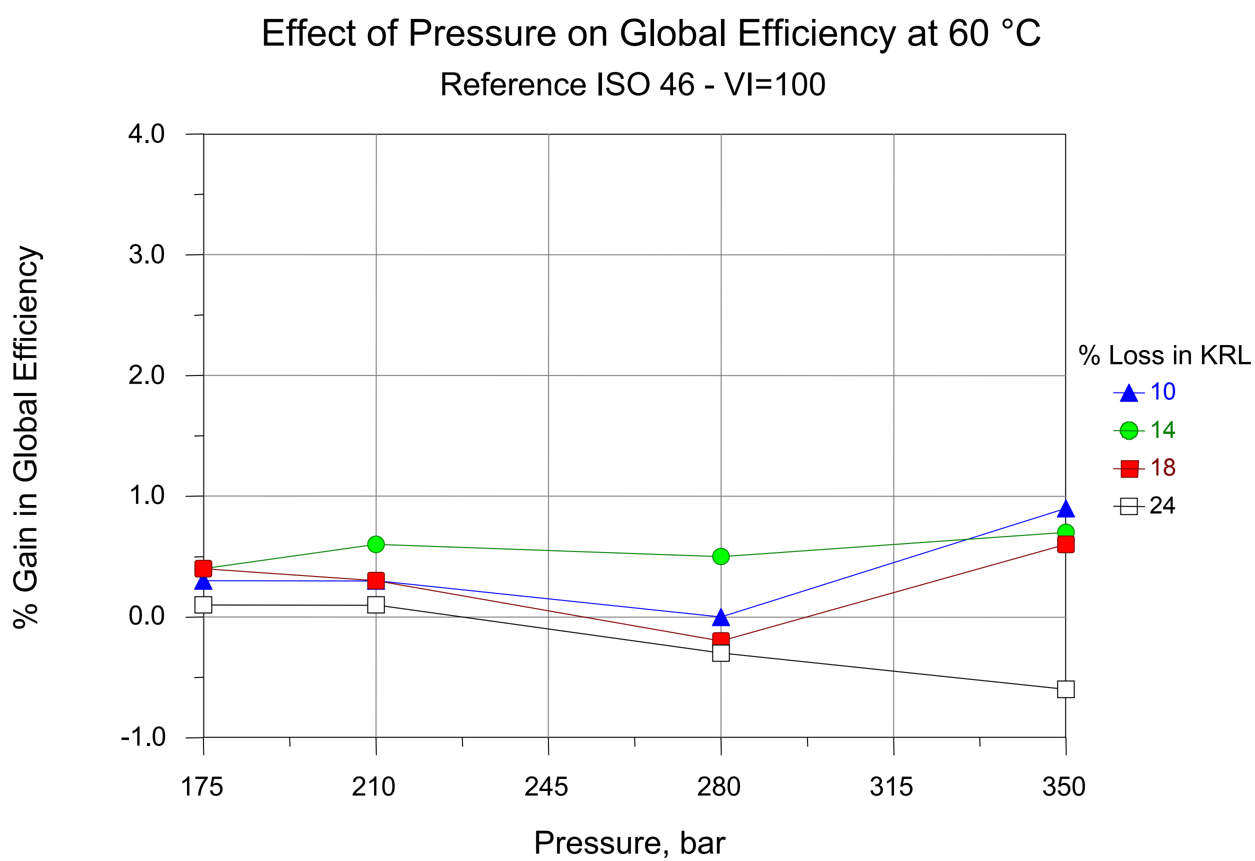
Optimization the VII Shear Stability for MEHF Komatsu HPV 35 + 35 Dual Piston Pump

VII	KV 40 °C mm²/s	KV 100 °C mm²/s	VI	KRL 20h % KV loss
None	45.9	6.8	103	-
PAMA A	46.0	8.4	160	10.1
PAMA B	47.8	8.6	158	13.8
PAMA C	45.4	8.4	162	17.5
PAMA D	45.2	8.3	162	23.9

ISO 46 oils were blended with different VIIs to have a VI of 160 and a % viscosity loss between 10 and 24 after the KRL 20 hour test (CEC L-45-A-99)

Effect of Pressure on Global Efficiency at 60 °C ISO 46 VI=160 in Komatsu Piston Pump



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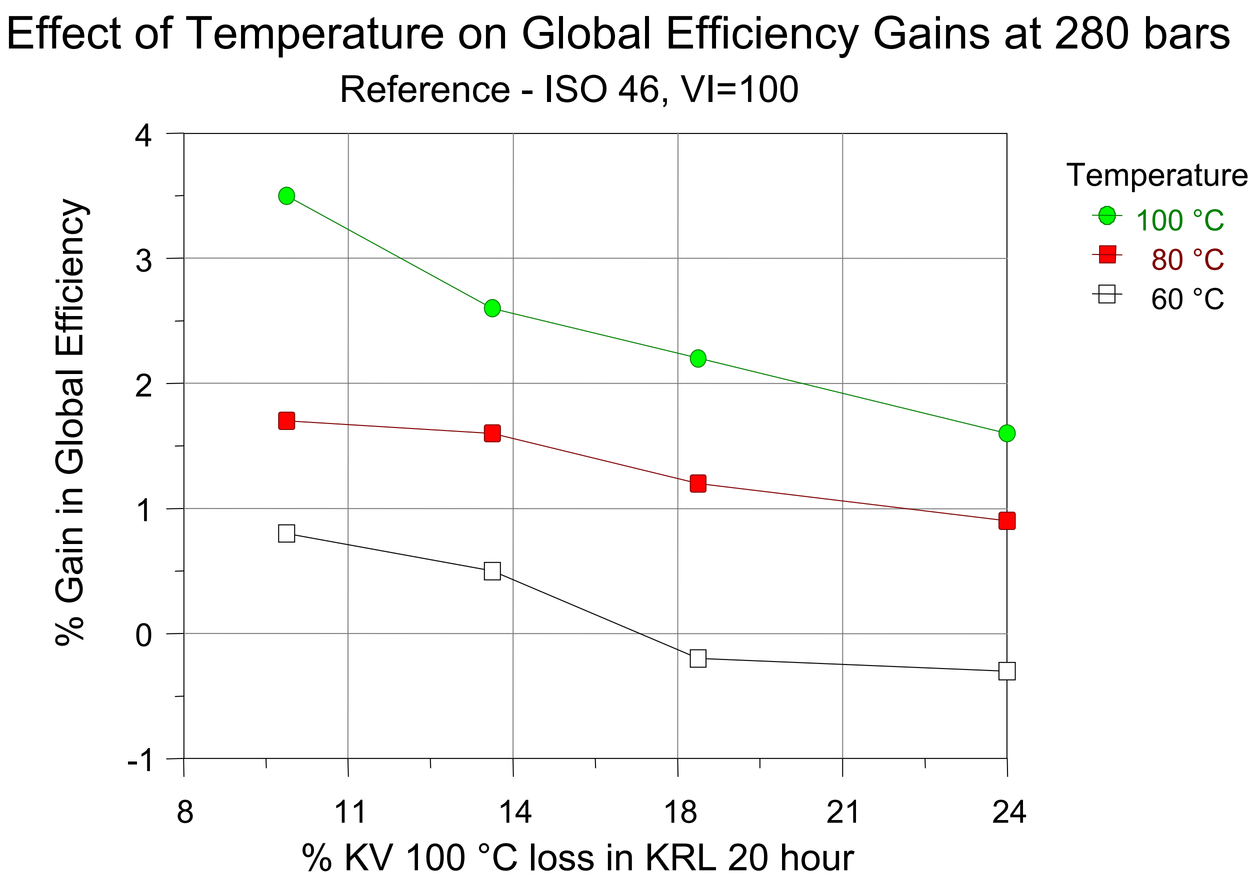
Effect of Shear Stability on Global Efficiency at 280 bars ISO 46 VI=160 in Komatsu Piston Pump



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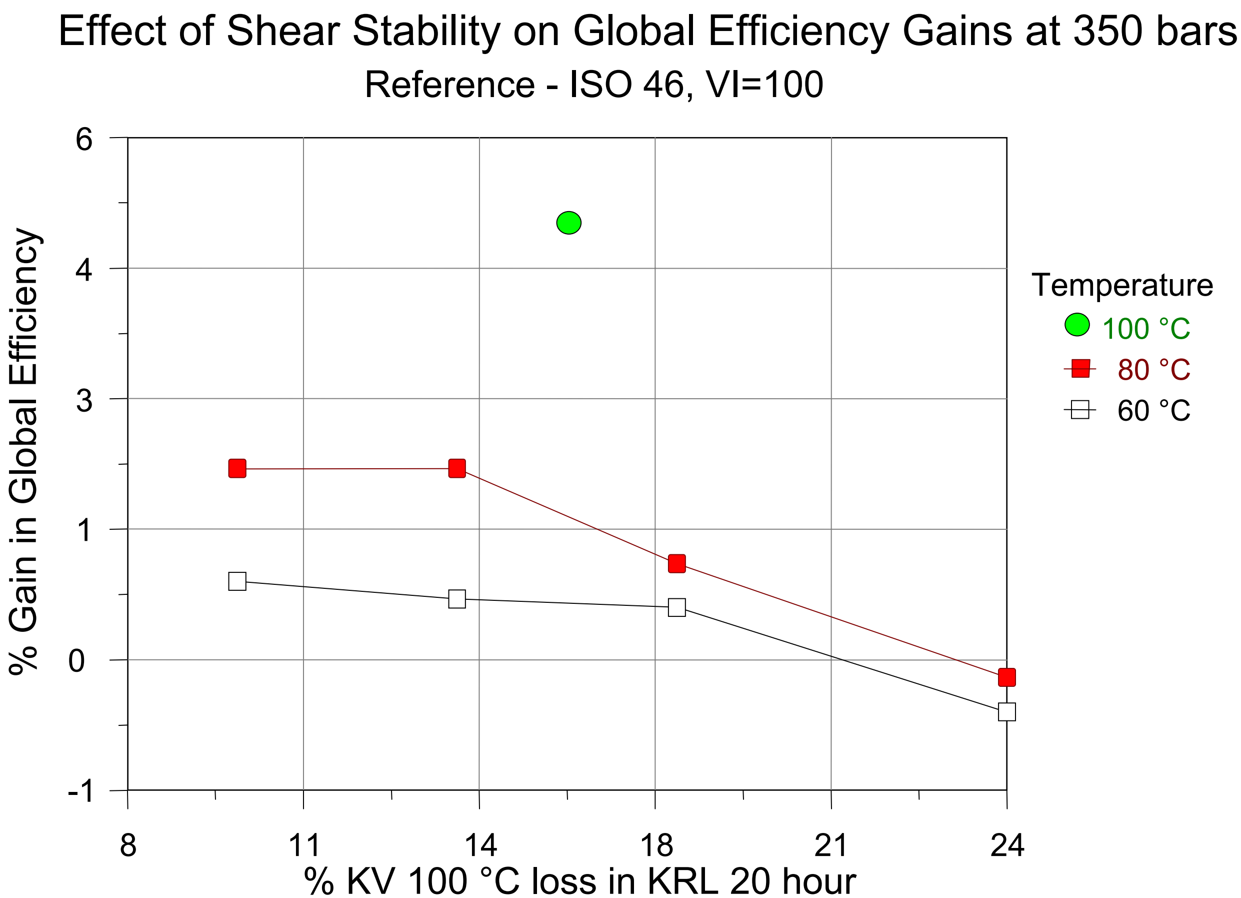
Effect of Shear Stability on Global Efficiency at 350 bars ISO 46 VI=160 in Komatsu Piston Pump



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Maximum Operating Temperature Viscosity of MEHF Oils after Shear

Fresh oils

Grade	KV @ 40 °C	KV 100 °C	VI
32	32.26	6.50	160
46	46.30	8.44	160
68	68.49	11.32	160

After Sonic Shear 40' (ASTM D 5621)

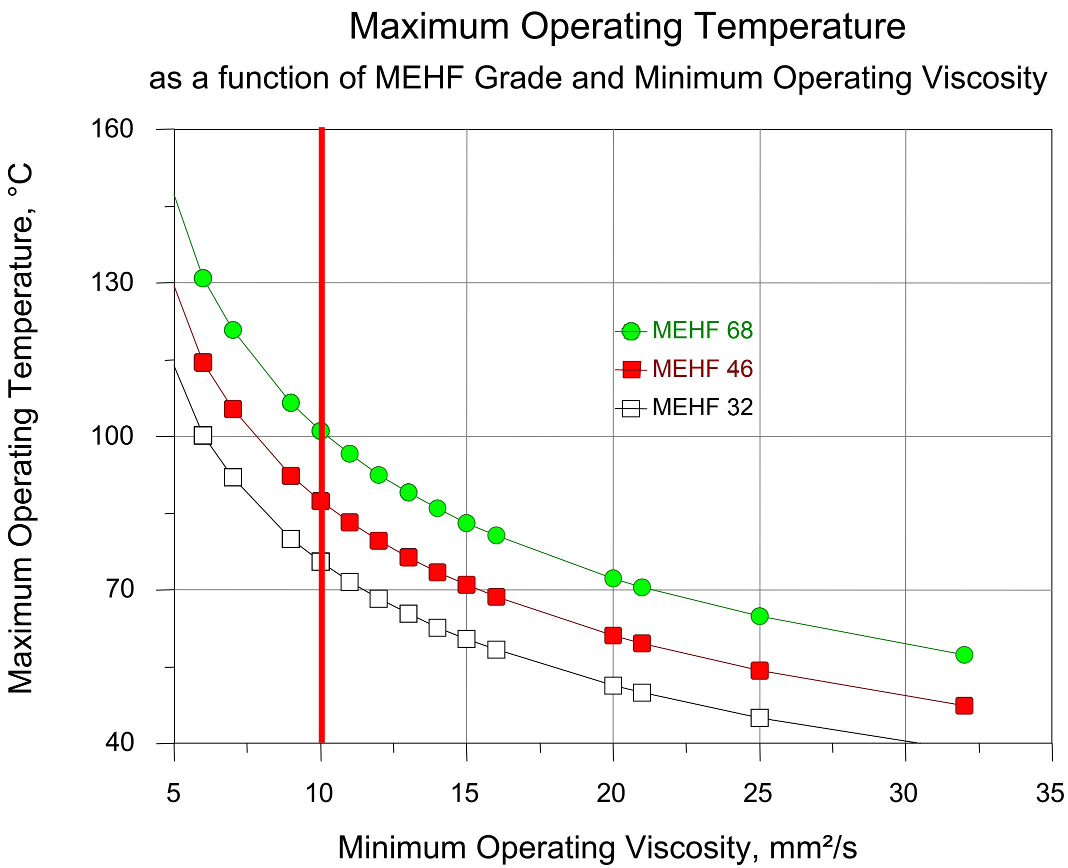
Grade	KV @ 40 °C	KV 100 °C	VI	% KV 100 °C loss
32	30.93	6.08	148	6.5
46	43.31	7.75	150	8.2
68	62.92	10.24	151	9.5

After KRL 20 hour (CEC L-45-A-99)

Grade	KV @ 40 °C	KV 100 °C	VI	% KV 100 °C loss
32	28.74	5.69	141	12.5
46	39.34	7.01	139	16.9
68	55.00	8.30	138	26.7

All viscosities in mm^2/s

Maximum Operating Temperature
MEHF Oils after Sonic 40’ Shear (ASTM D 5621)



MEHF	T for 10 mm²/s after Sonic Shear, °C
22	65
32	75
46	85
68	95
100	110

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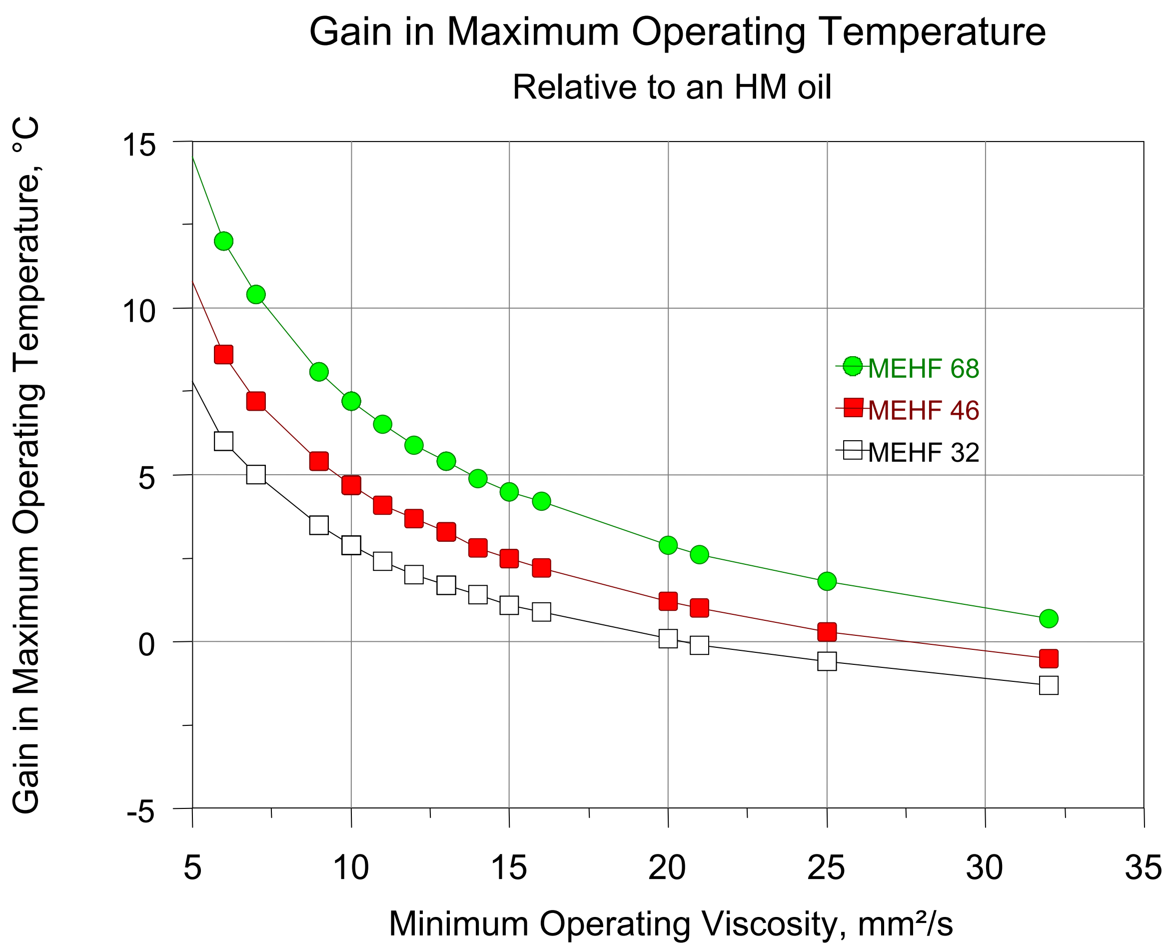
Gain In Maximum Operating Temperature MEHF Oils after Sonic 40’ Shear (ASTM D 5621)



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Average Gain In Maximum Operating Temperature MEHF Oils after Sonic 40' Shear (ASTM D 5621)