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Hydraulic Fluid Influence on Piston Pump Efficiency

Komatsu 35+35 Piston Pump Study

Fuels and Lubes Asia
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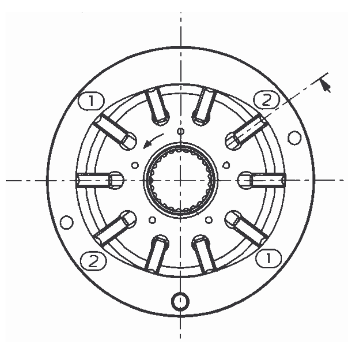

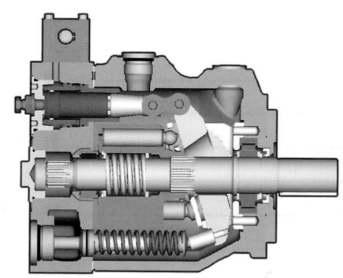

Presentation Overview

Fundamental Effect of Viscosity in Hydraulic Equipment

- Previous results in Gear and Vane Pumps

New Piston Pump Test Stand

- Komatsu 35+35 piston pump
- Test Protocol

Test results

- Standard Monograde (HM, VG46)
- High Viscosity Index (HV, VG46W)

Conclusions

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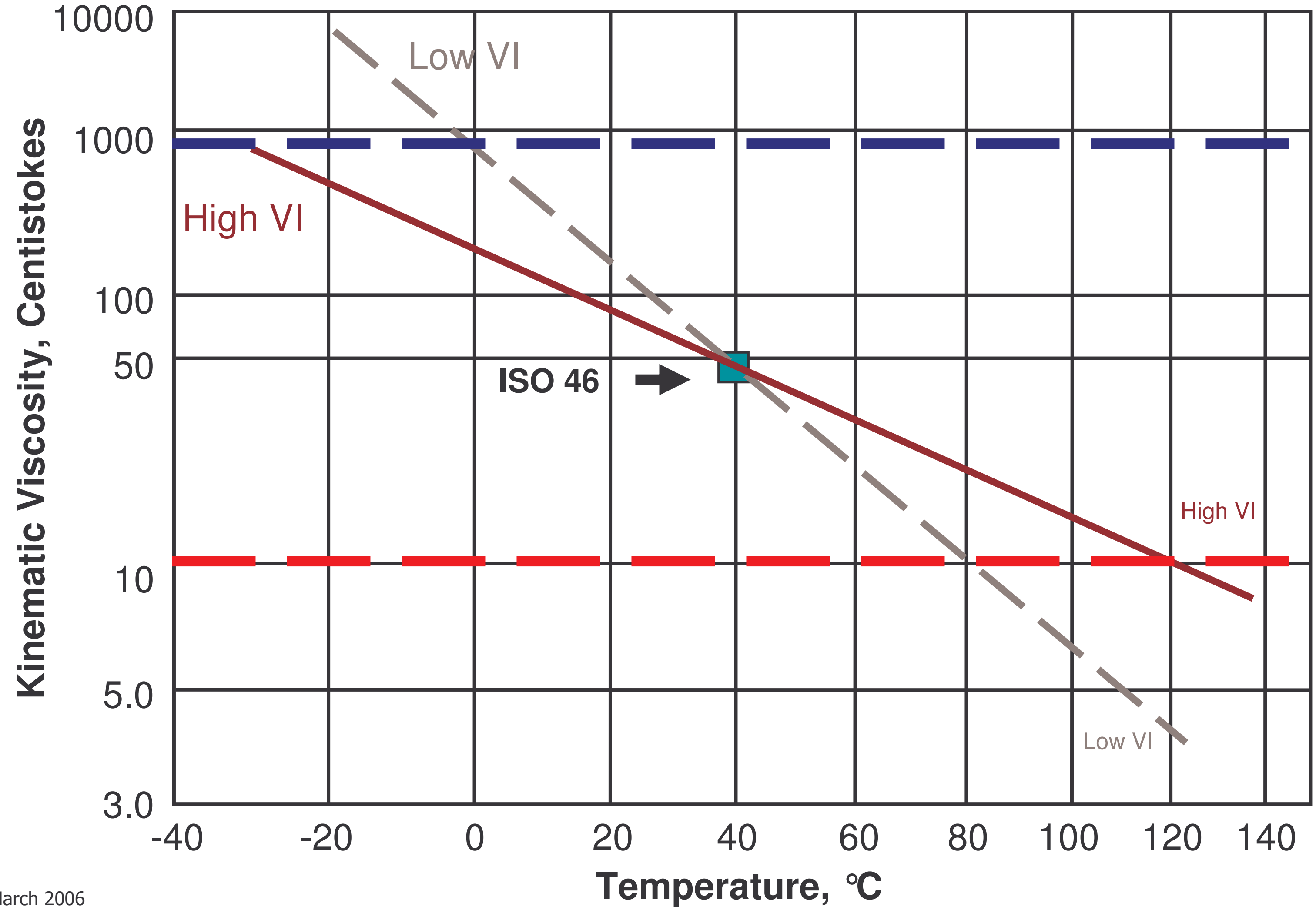
High VI Expands the fluid Temperature Operating Window



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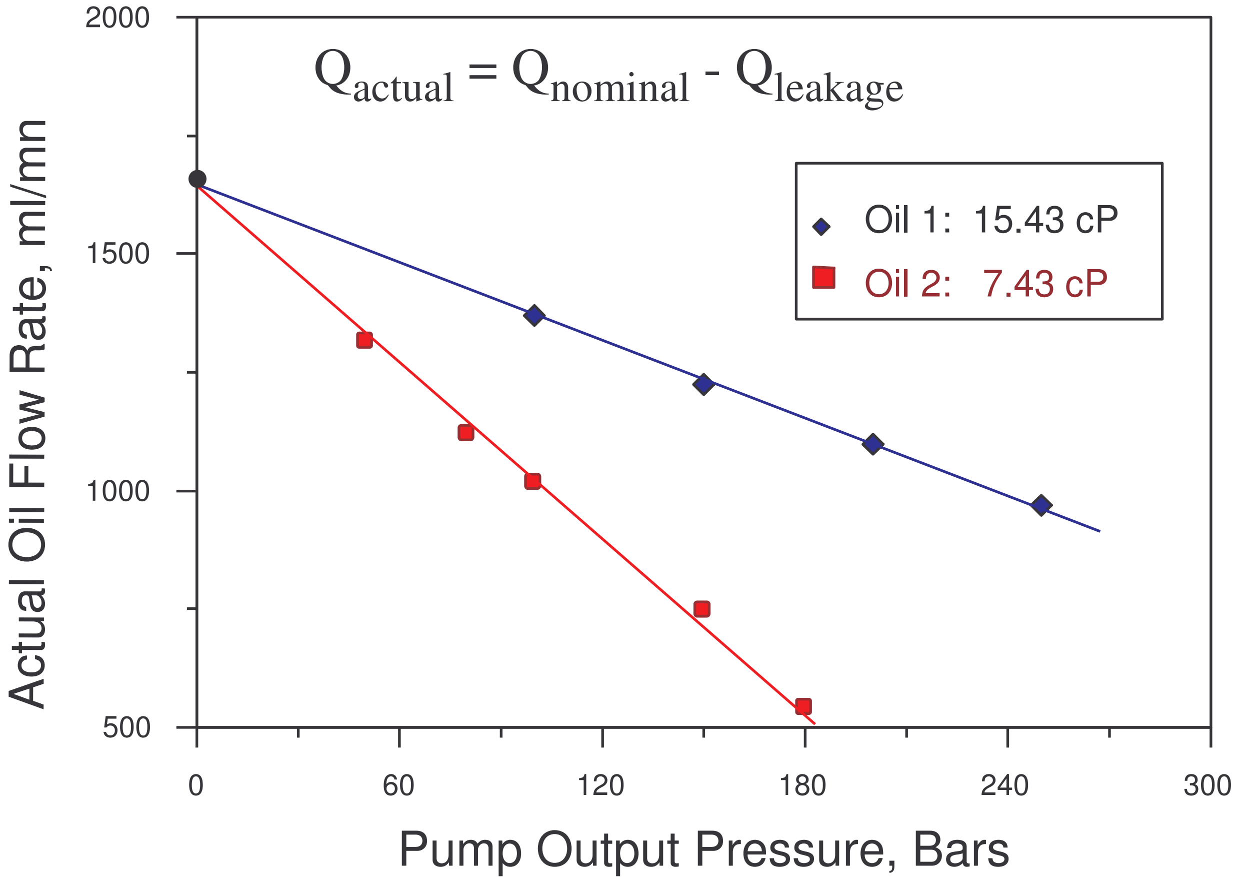
Principal Pump Flow Rate vs. Outlet Pressure

For Newtonian Oils in a **Gear Pump**



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Previous Results describing influence on Kinematic Viscosity on pump volumetric efficiency

- In literature, a model is often given to describe the leakage $\mathbf{Q_l}$ in a vane or a gear pump:

$$Q_l = \alpha \frac{\Delta P}{\eta}$$

- As the volumetric efficiency, η_V, of a pump is defined as the actual flow rate $\mathbf{Q_a}$ divided by the nominal flow rate $\mathbf{Q_n}$. The following model could be used to describe the volumetric efficiency:

$$\eta_V = \frac{Q_a}{Q_n} \times 100 = \frac{Q_n - Q_l}{Q_n} \times 100 = 1 - \alpha \frac{\Delta P}{Q_n \times \eta}$$

- In previous papers, the validity of this model was verified in two vane pumps and one gear pump using monograde mineral oil fluids.

Type / Pump	**Volumetric Efficiency in %**	**R^2**
Vane Pump / Eaton Vickers V-104	$\eta_v = 100 \cdot (1 - 0{,}0173 \cdot \Delta P/KV)$	0,96
Vane Pump / Eaton Vickers V-20	$\eta_v = 100 \cdot (1 - 0{,}0138 \cdot \Delta P/KV)$	0,96
Gear Pump / Bosch	$\eta_v = 100 \cdot (1 - 0{,}027 \cdot \Delta P/DV)$	0,99

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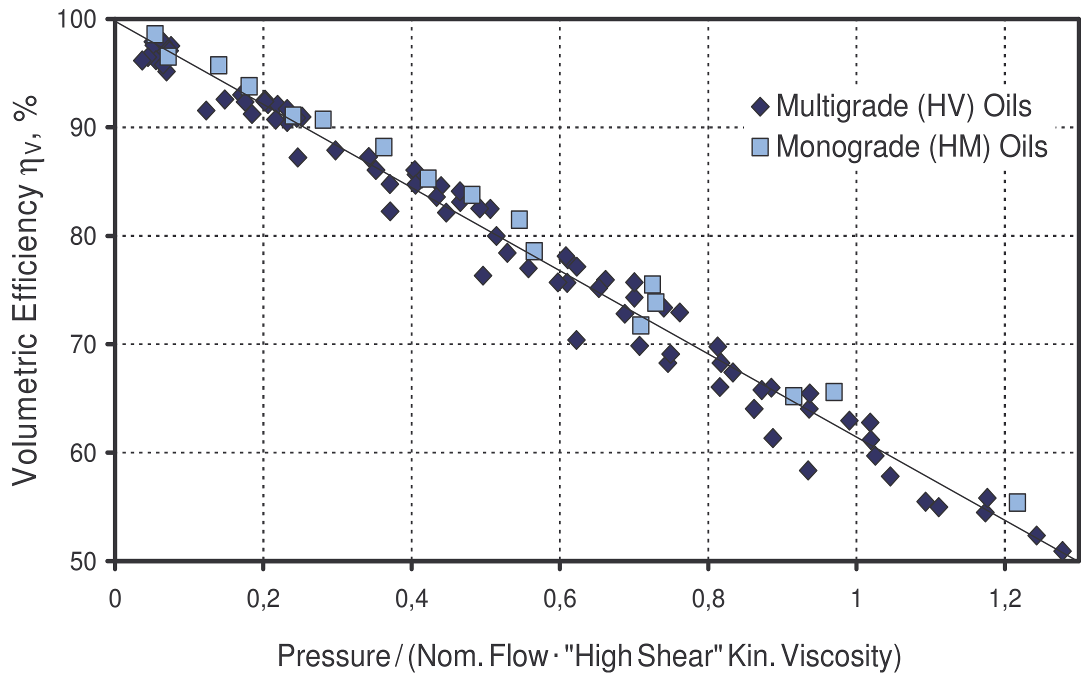
Kinematic Viscosity and “in service“ viscosity

Models such as describe before could not be apply to high VI fluids formulated with viscosity index improver additives due to the viscosity shear losses occurring during the use of such fluid.



Previous work has demonstrated that applying pump efficiency models to HV fluids formulated with viscosity index improver require the use of high temperature high shear viscosity, or after shear kinematic viscosity in a shear test with the proper severity.

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Do Piston Pumps Follow the Same Trends in Fluid Viscometrics?

Komatsu – RohMax Program

- Ø Build new test rig with Komatsu 35+35 dual piston pump
- Ø Evaluate various monograde and multigrade oils
- Ø Determine impact of “In-service” viscosity
  - § Identify benefits of higher viscosity index
  - § Identify impact of shear stability at 350 bar

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Hydraulic Fluid Test Stand

Evaluation of:

Ü Efficiency
Ü Viscosity in Service
Ü Shear Stability
Ü Cold Start

Pump Types:

Ü Vane-
Ü Axial Piston-

Procedures:

Ü Efficiency-
Ü Heat up-
Ü Cycle-
Ü Cold Start-

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

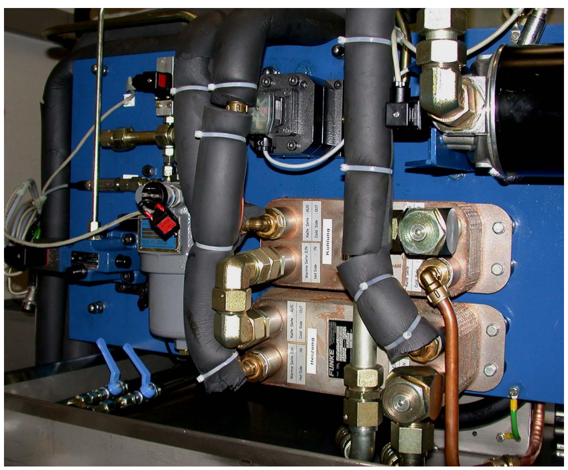
Operating conditions :

Speed: 2100 RPM

Drive performance: 22 kW (30 HP)

Pressure range: 0 to 350 bar (5000 Psi)

Fluid Temperature range: 60 - 80 - 100° C



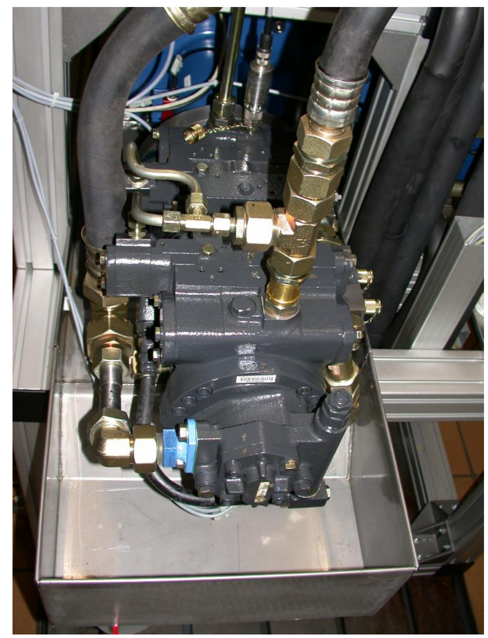


Diagram Komatsu Pump Test Rig

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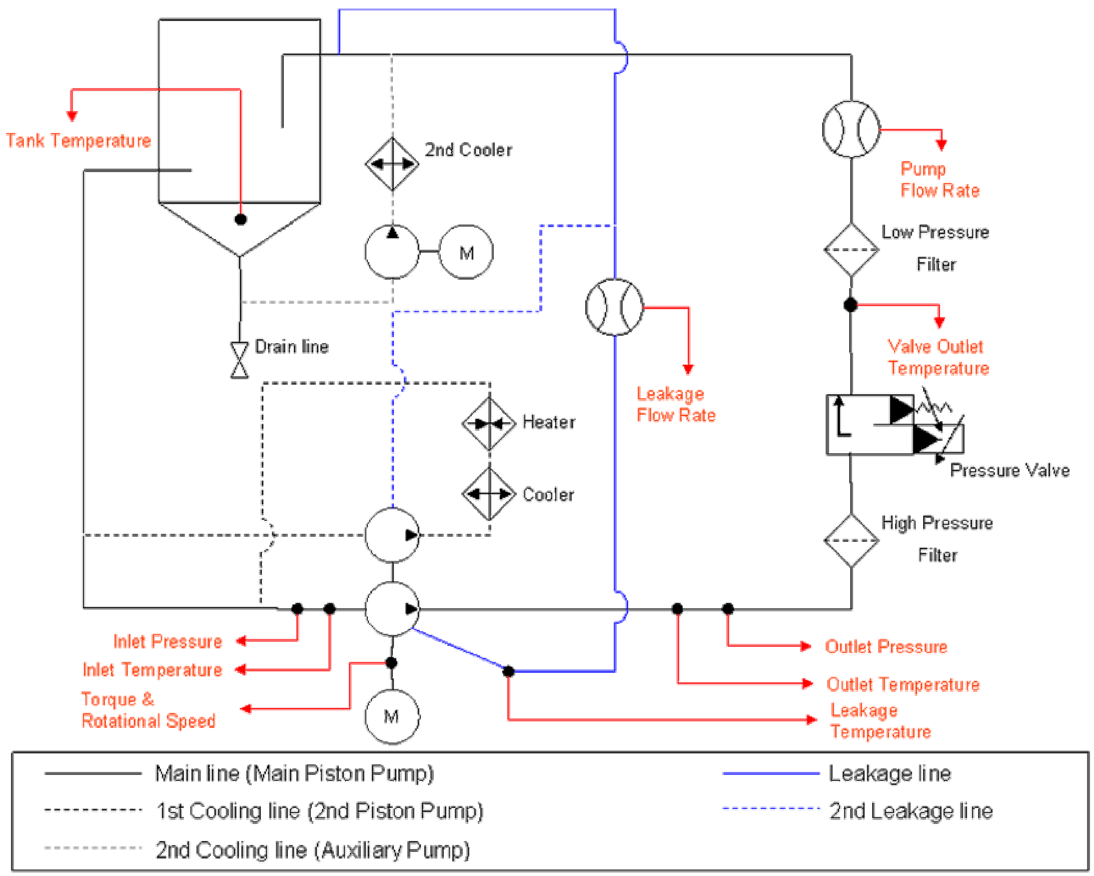

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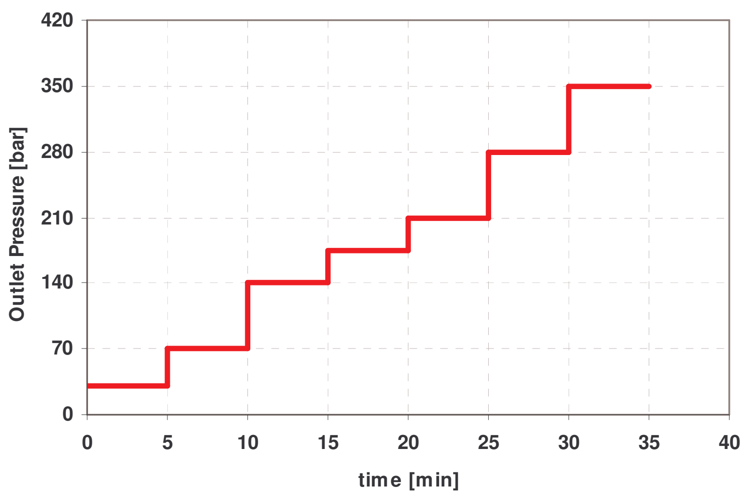
Efficiency Test Procedure



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, Tinlet 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, Tinlet 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, Tinlet 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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Variables in Fluid Test Matrix

		Fresh Oil			After 40min sonic shear test (ASTM D 5621)		
	Polymer	KV 40 °C cSt	KV 100 °C cSt	VI	KV 100 °C cSt	%KV 100 °C losses	PSSI
ISO 46	-	44,98	6,81	105	-	-	-
ISO 46	D	44,69	7,20	122	6,87	4,7	79
ISO 46	B	46,08	7,89	141	7,18	8,9	39
ISO 46	A	47,75	8,57	158	7,79	9,0	20
ISO 46	E	46,01	9,66	202	9,01	6,7	10
ISO 46	F	45,99	8,40	160	7,85	6,5	18
ISO 46	G	45,16	8,33	162	7,13	14,5	44

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Variables in Fluid Test Matrix

Study of the VI impact

Fluids formulated to meet the Parker-Denison HF-0 requirement, 15% KRL loss, max.

Fluid	Polymer	KV 40	KV 100	VI	KRL, % KV100 losses 20h	Sonic Shear, % KV100 losses, 40 minutes
ISO 46 VI 100	---	**45.9**	**6.8**	**103**	**-**	**0,0**
ISO 46 VI 120	D	**44.7**	**7.2**	**122**	**9.6**	**4,7**
ISO 46 VI 140	B	**46.1**	**7.9**	**141**	**14.8**	**8,9**
ISO 46 VI 160	A	**47.8**	**8.6**	**158**	**13.8**	**9,0**
ISO 46 VI 200	E	**46.0**	**9.7**	**202**	**13.5**	**6,7**
SAE 10W (L46-46)	10W	**42.8**	**6.9**	**120**	**?**	

Shear Stability Study

Fluid	Polymer	KV 40	KV 100	VI	KRL, % KV100 losses 20h	Sonic Shear, % KV100 losses, 40 min.
ISO 46 VI 160	F	46.0	8.4	160	10.1	6.5
ISO 46 VI 160	A	47.8	8.6	158	13.8	9.0
ISO 46 VI 160	H	45.4	8.4	162	17.5	12.1
ISO 46 VI 160	G	45.2	8.3	162	23.9	14.5

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Example of Measurement Data

DEVELOPED DATA, Efficiency Test @ Tin = 80 °C											
Measurement Results											
set	Temperatures					Pressures		Pump Values			
pressure	reservoir	pump in	pump out	after press. valve	pump leakage	pump in	pump out	torque	speed	flow rate	leakage rate
[bar]	[°C]	[°C]	[°C]	[°C]	[°C]	[bar]	[bar]	[Nm]	[RPM]	[l/min]	[l/min]
30	89.6	80.0	84.6	85.5	84.0	0.1	29.6	30.3	2108.1	60.9	4.3
70	90.3	80.2	85.5	88.2	84.9	0.1	69.8	49.6	2107.7	59.1	4.6
140	92.1	80.4	87.7	93.2	87.6	0.1	140.2	77.6	2105.1	51.7	5.2
175	93.3	80.1	88.1	95.2	89.5	0.1	175.4	82.5	2103.8	43.0	5.5
210	93.9	80.0	88.6	97.3	90.7	0.1	210.5	85.1	2103.0	35.8	5.9
280	95.2	79.8	90.8	102.5	94.2	0.1	280.8	83.0	2102.9	22.3	6.6
350	94.3	79.8	88.6	103.5	95.4	0.1	347.0	79.4	2103.0	13.4	7.2

The results shown are calculated averages of all the measurement data obtained during 5 minutes for each stage of operation.

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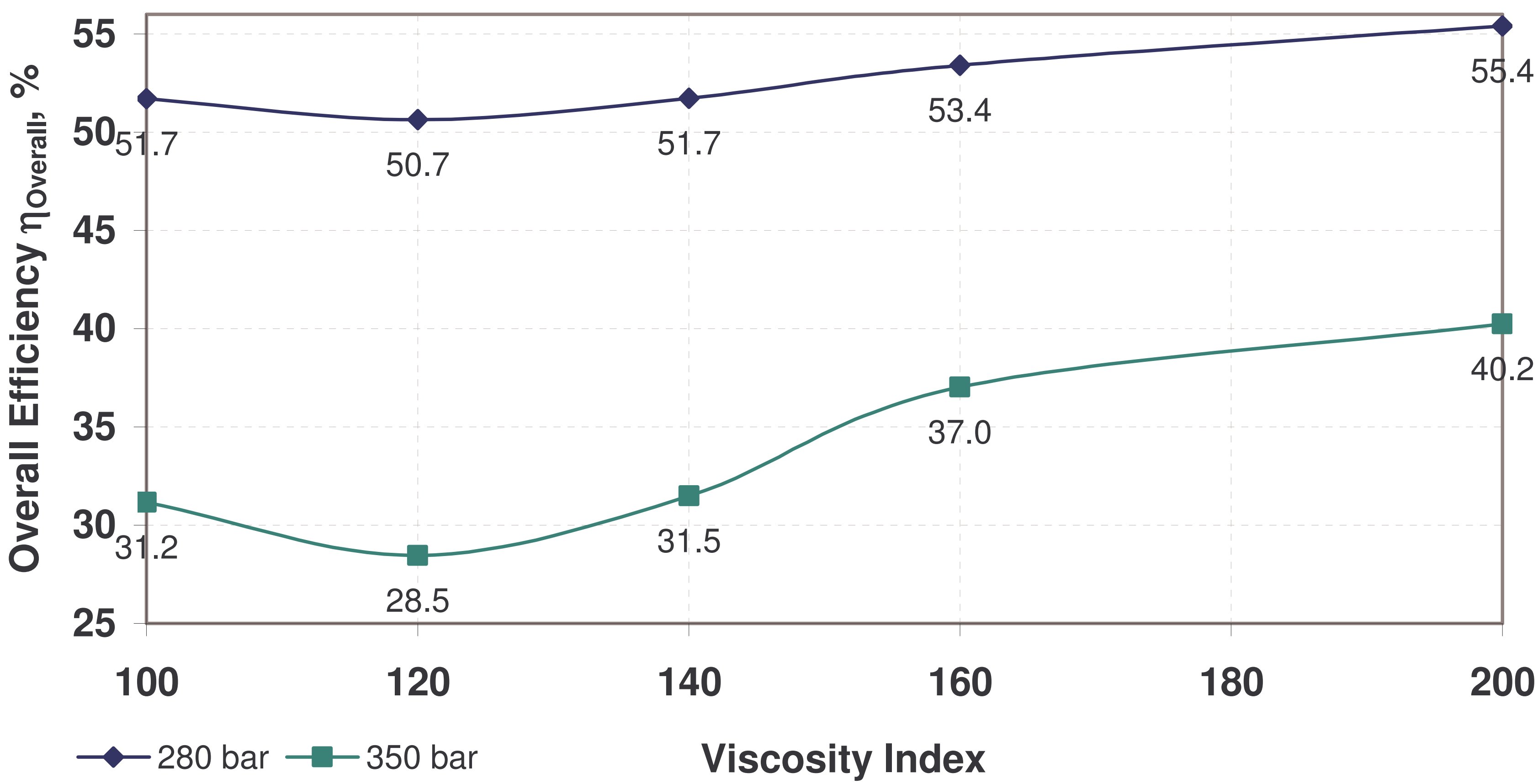
Impact of Viscosity Index and Shear Stability on System Efficiency



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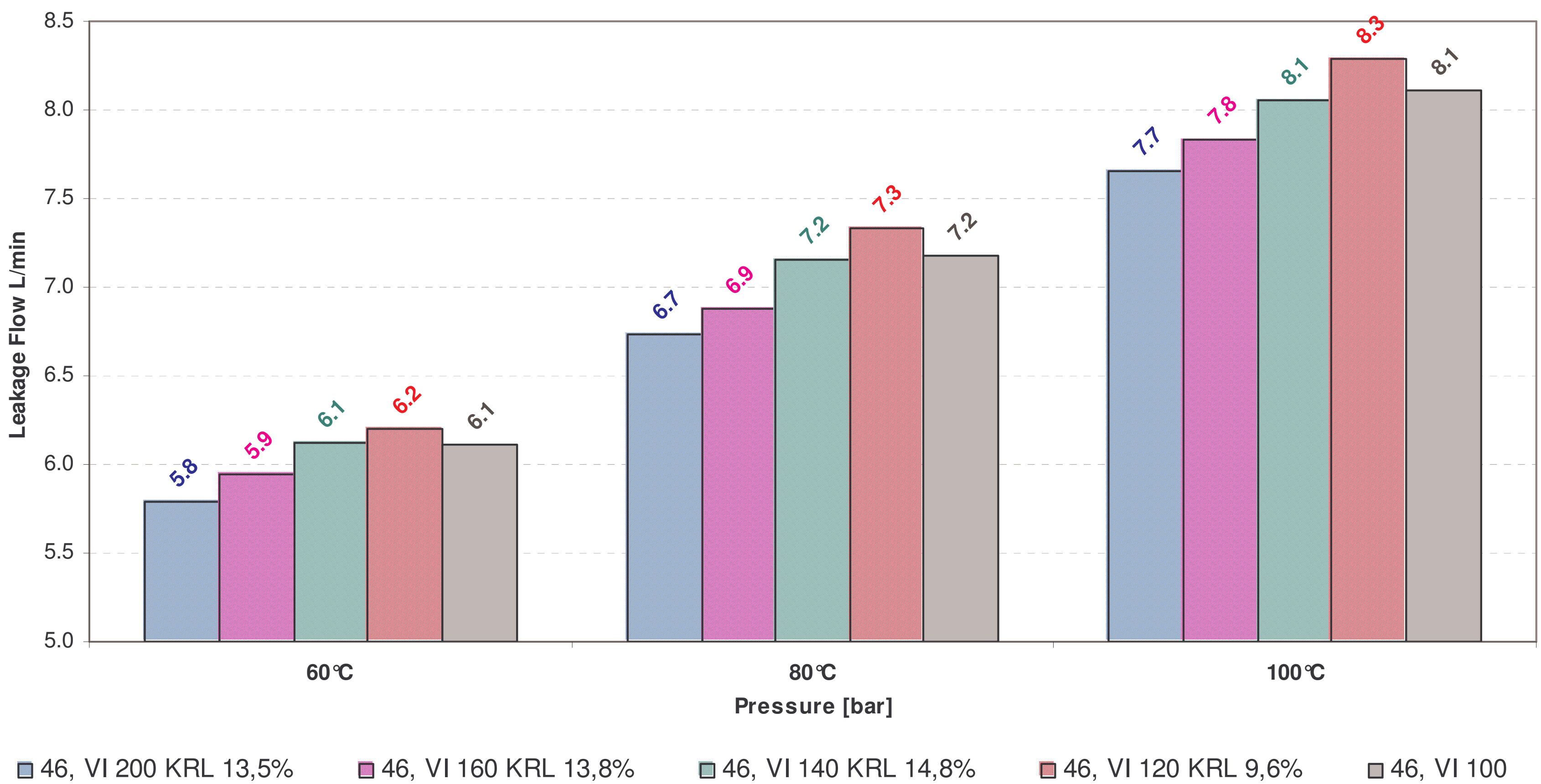
Impact of Viscosity Index on Pump Leakage

Leakage Flow Rate vs. Temperature at 350 bar



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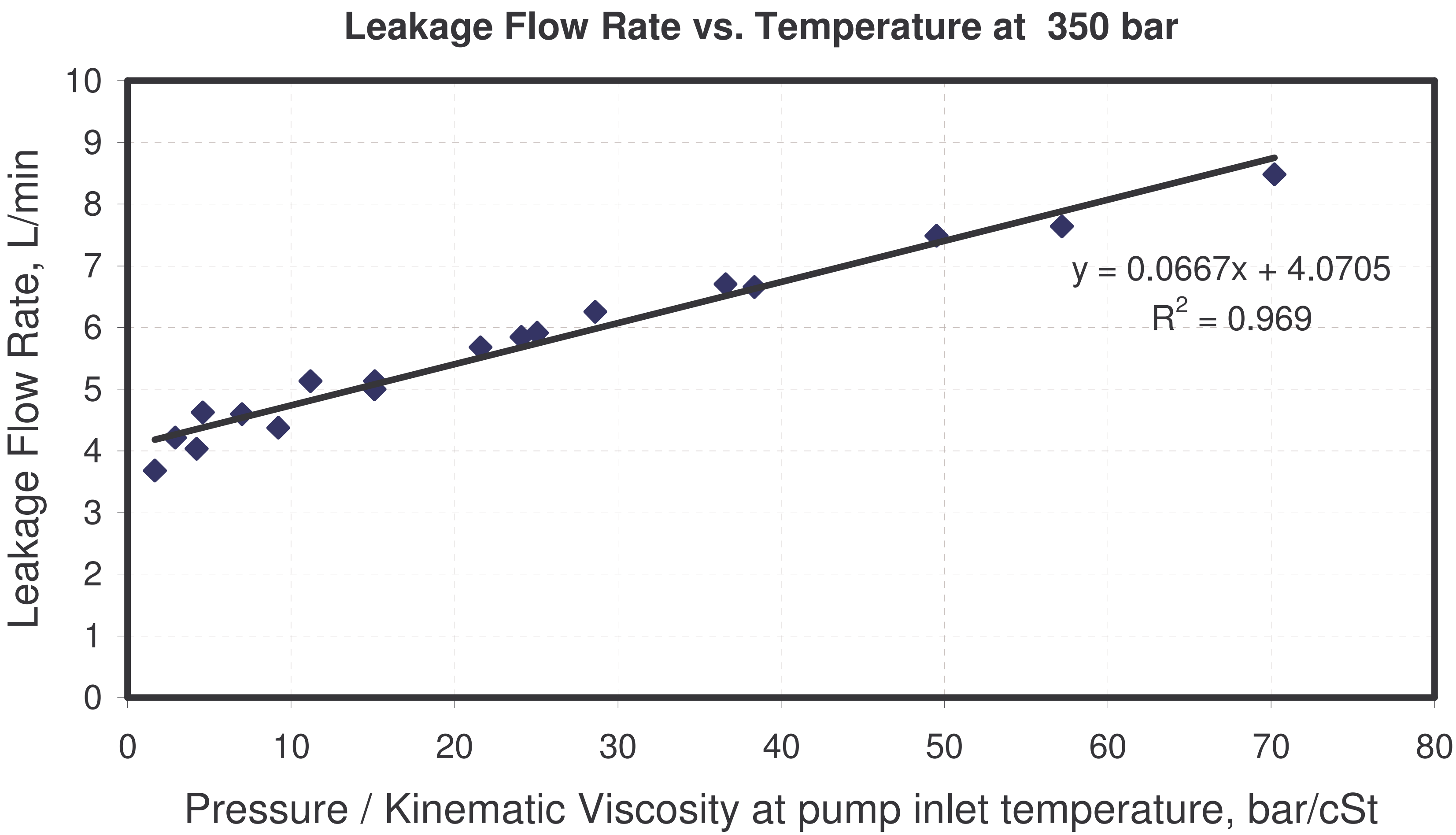
Impact of Viscosity Index on Pump Leakage



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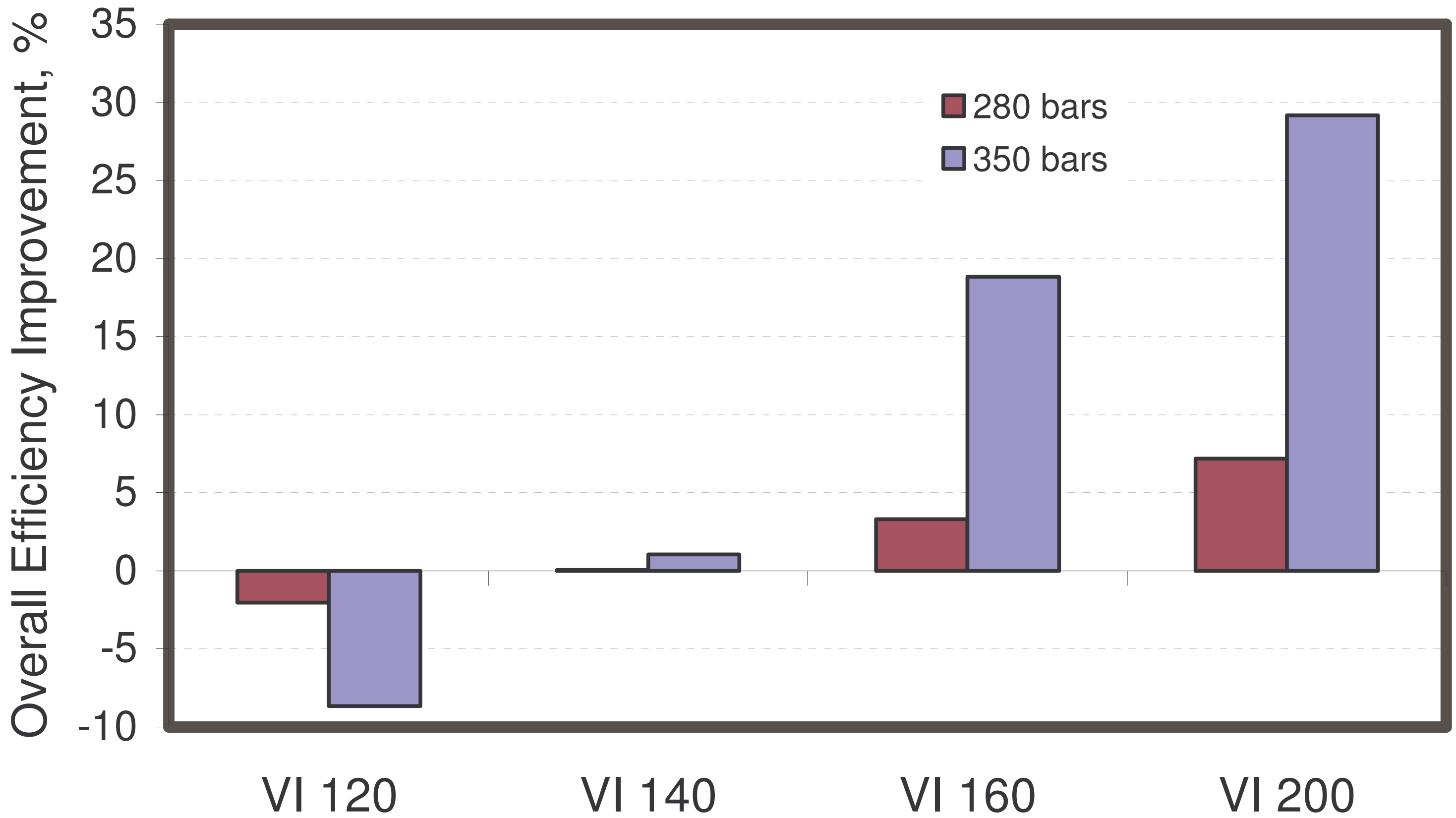
Overall efficiency improvement provided by the ISO 46 HV fluids compared to the HM fluid

at a pump inlet temperature of 100°C



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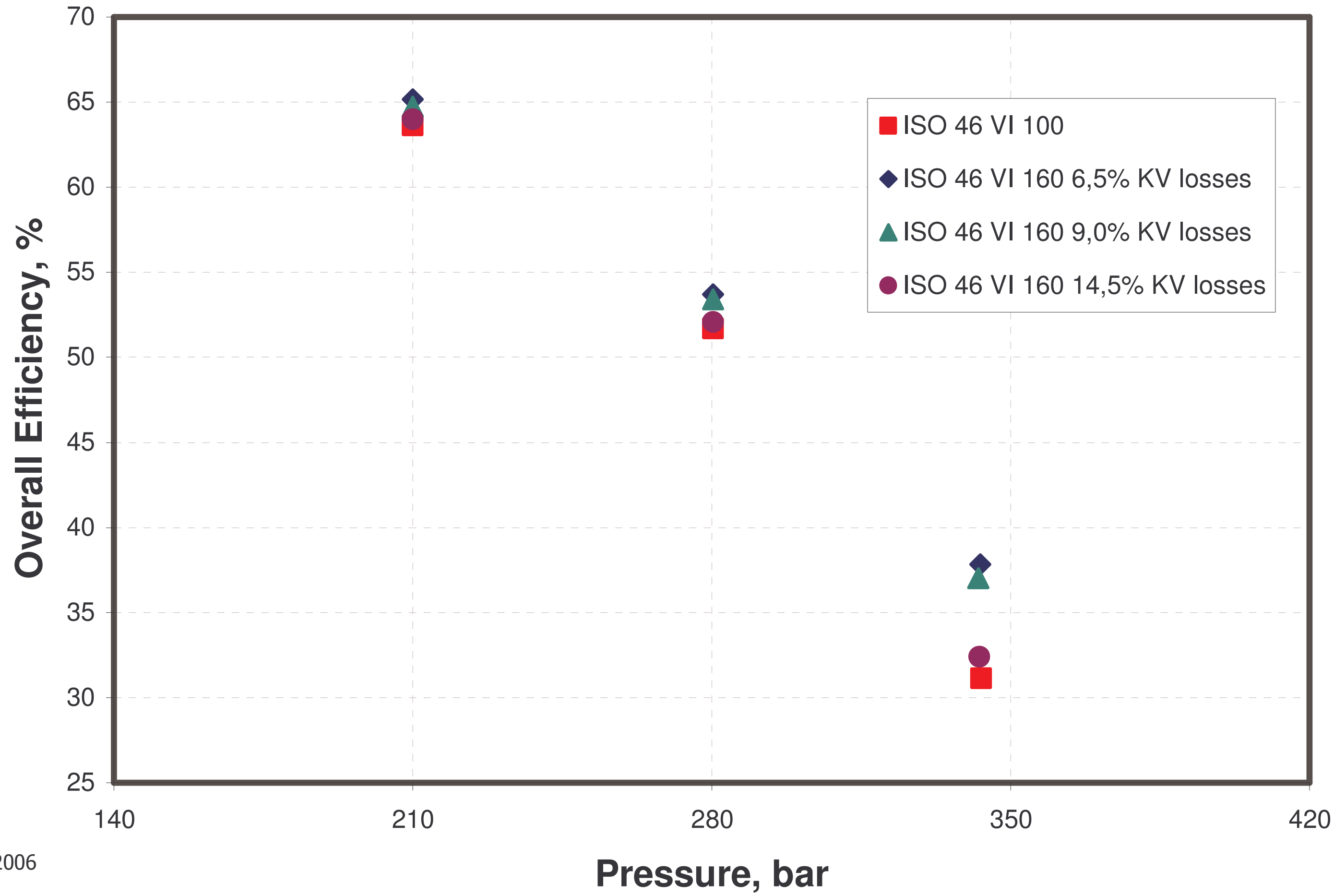
Dependence of overall efficiency on Shear Stability level for a same value of Viscosity Index

at a pump inlet temperature of 100°C



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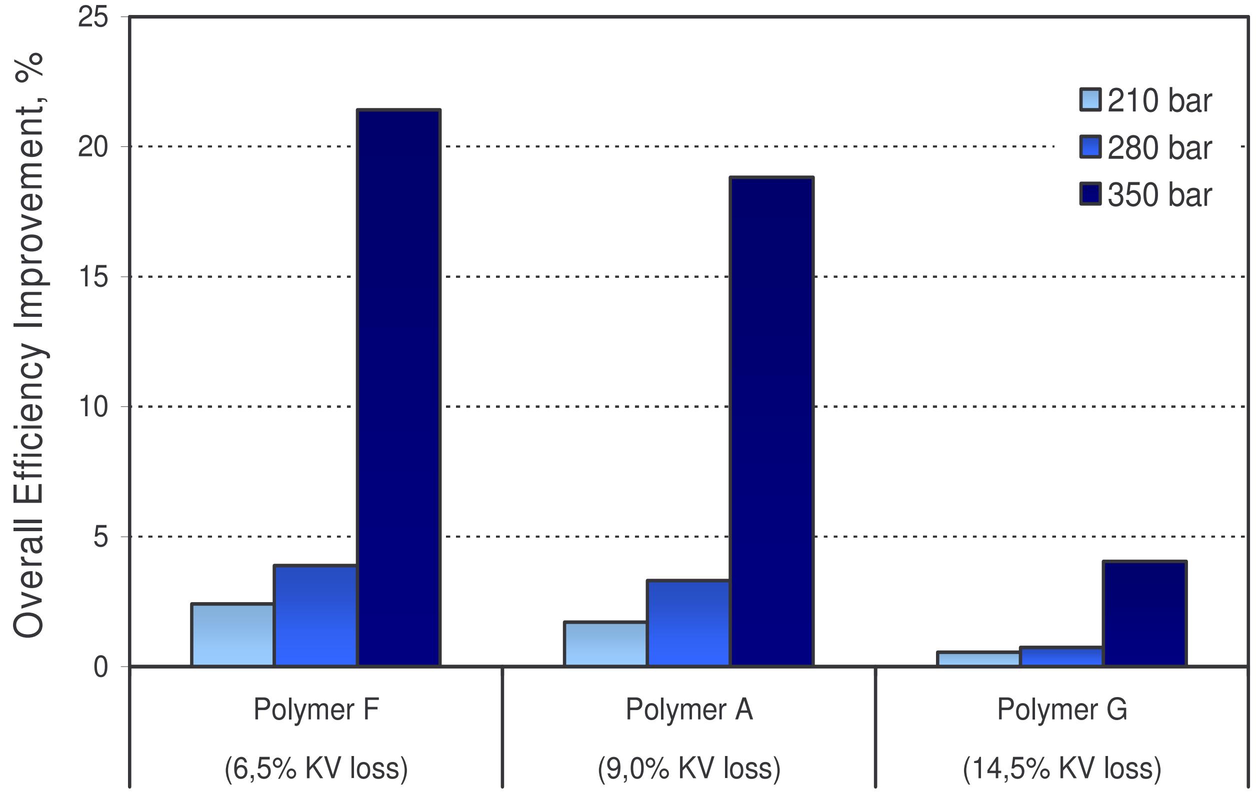
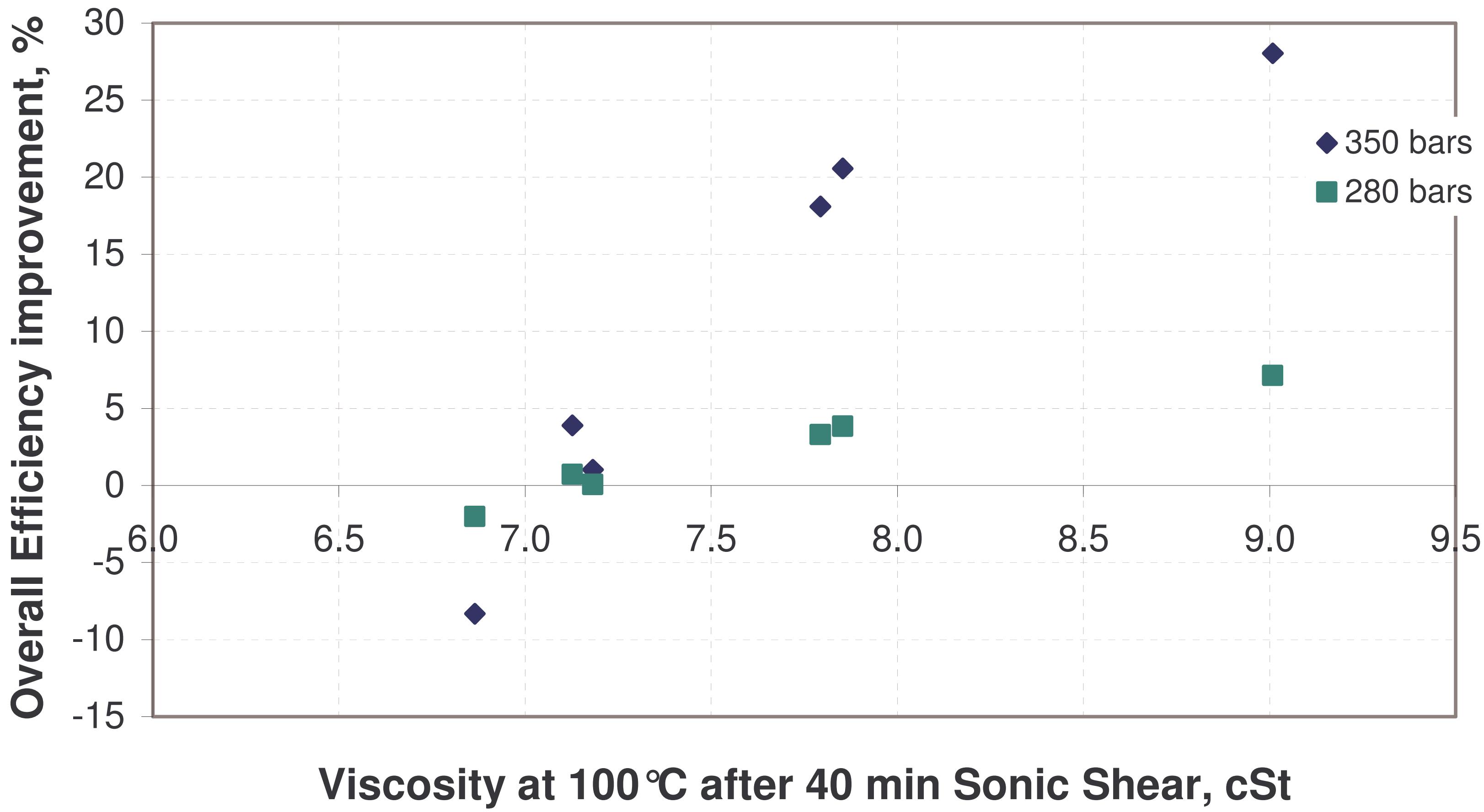
Overall efficiency improvement provided by the ISO 46 VI 160 fluids compared to the HM fluid

at a pump inlet temperature of 100℃



Influence of kinematic viscosity after sonic shear on overall efficiency improvement

at a pump inlet of 100℃



Conclusions

Ü The Komatsu 35+35 piston pump shows a clear response to fluid viscometrics.

- Higher “In-Service” viscosity reduces leakage

Ü The efficiency of a piston pump is a function of fluid viscosity and system pressure

- Relationship is similar to that found in gear and vane pumps

Ü Hydraulic fluids with high VI and shear stability improve volumetric and global efficiency.

F Equipment Efficiency/Productivity/Power can be increased
F Fuel consumption can be reduced
F Engine emissions can be reduced (CO2, HC, NOx, PM)