HYDRAULIC EFFICIENCY IMPROVEMENTS

For: Toronto STLE Section
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PETRO-CANADA LUBRICANTS

Maximize The Opportunity – Select the Right Lubricant

The purpose of today's presentation is to review the opportunities in obtaining **energy efficiencies** which can lead to **prolonging equipment and oil life.**

OPPORTUNITIES FOR CHANGE

- The trends and more severe requirements for today's hydraulic systems can and are met with existing high quality mono-grade (straight AW) oils.
- However, further improvements in performance, as well as an added bonus in **energy efficiencies** is possible through the use of multi-grade oils.

FUNCTIONS OF A LUBRICANT

- Reduce Friction
- Minimize Wear (Keep Moving Surfaces Apart)
- Cool Parts (Carry Away Heat)
- Prevent Corrosion
- Disperse Combustion or Oxidation by-products
- Act as a Sealant
- Transmit Power

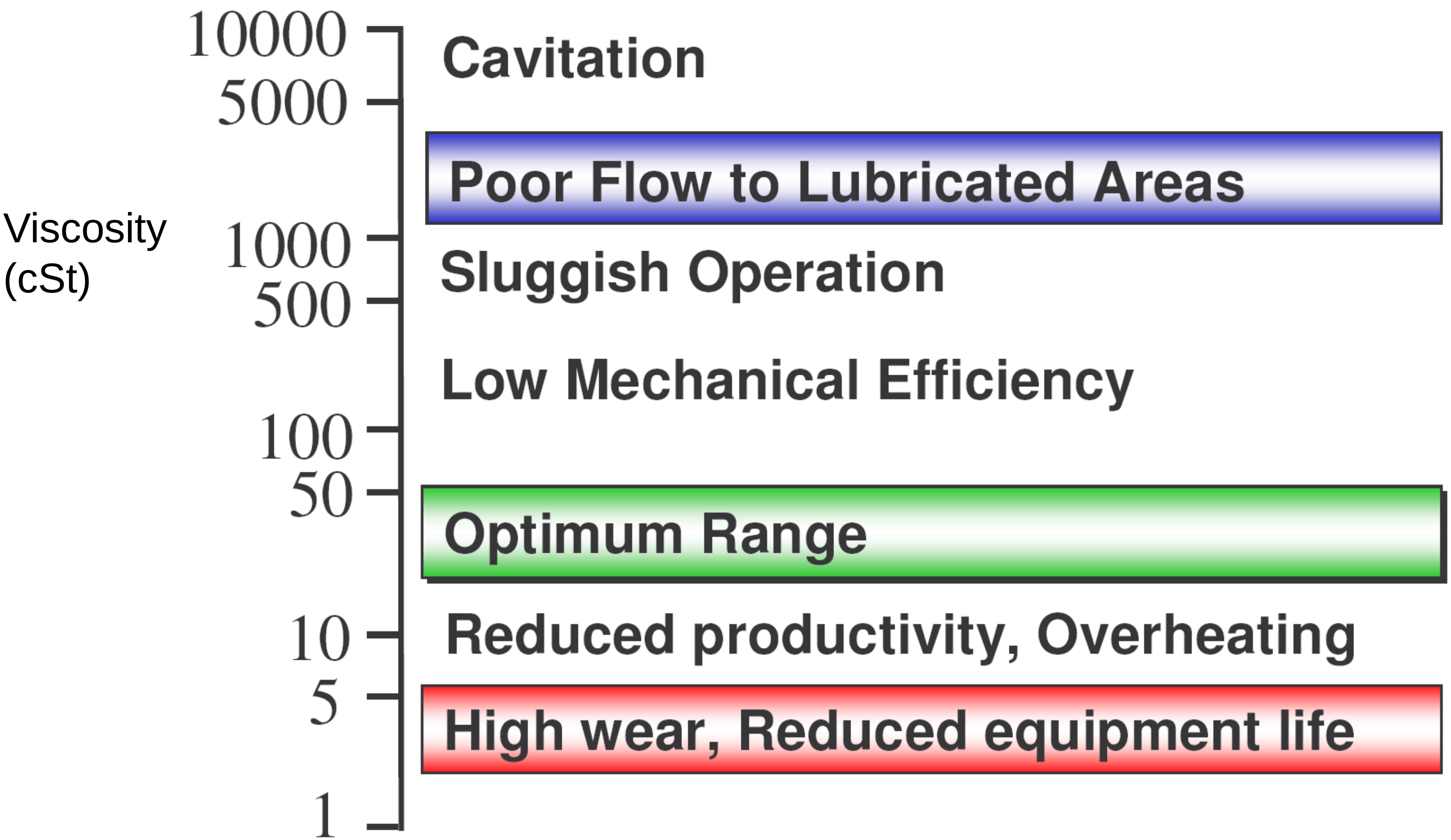
LUBRICANT PROPERTIES

Viscosity is a measurement of resistance to flow at **one** temperature.

Viscosity Index (VI) is a measurement of the rate of change of viscosity over a **range** of temperatures. In simple terms: it measures how fast the oil thickens up as it gets colder or how fast it thins out as it gets hotter.

Generally the higher the Viscosity Index the more "all-season" the product

VISCOSITY IMPACT - HYDRAULICS



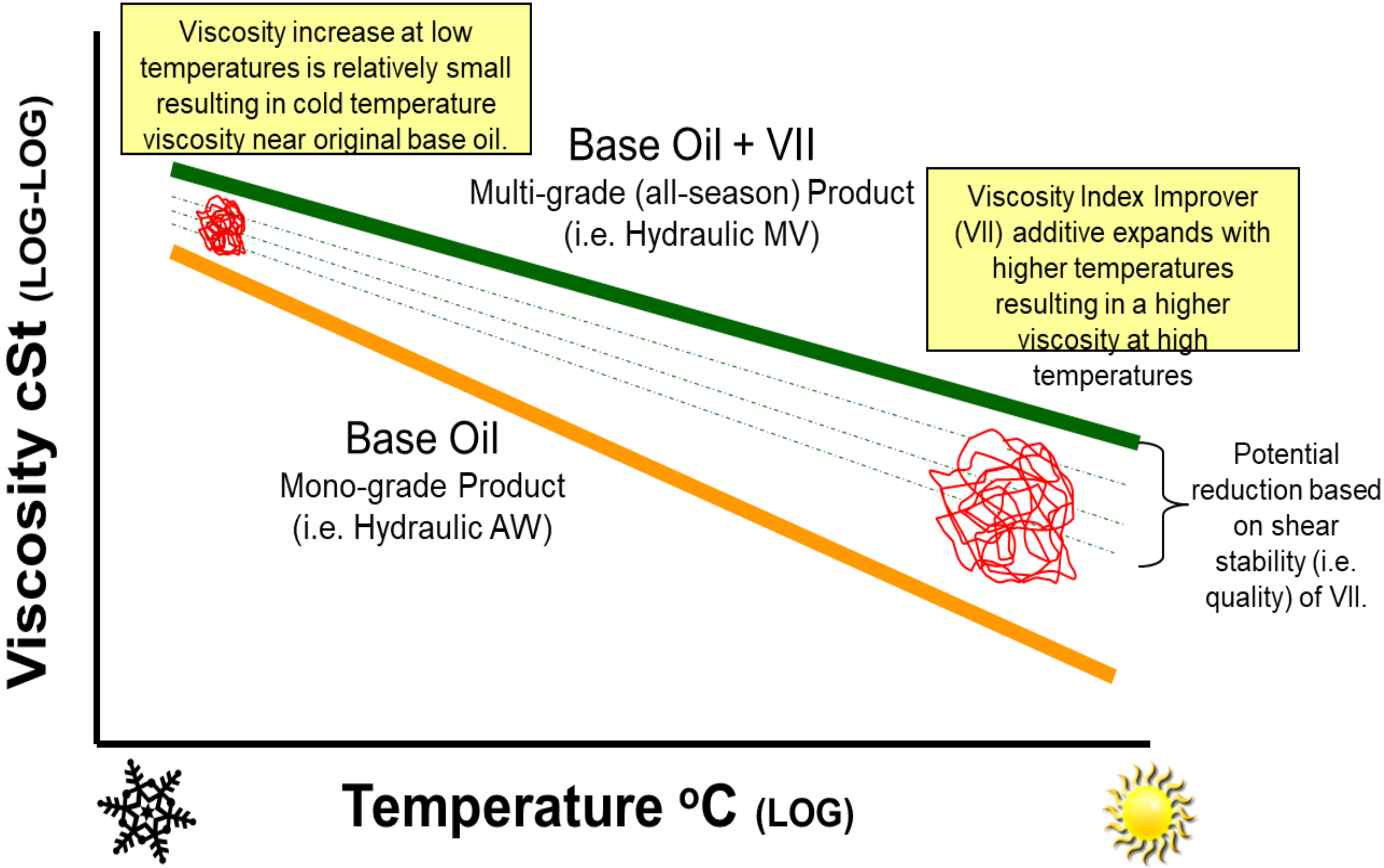
VISCOSITY INDEX

- **V**iscosity **I**ndex is an **inherent property of the base oil** used to blend a lubricant.
  - Some oils have naturally higher VI than others (i.e. Group II or synthetics)

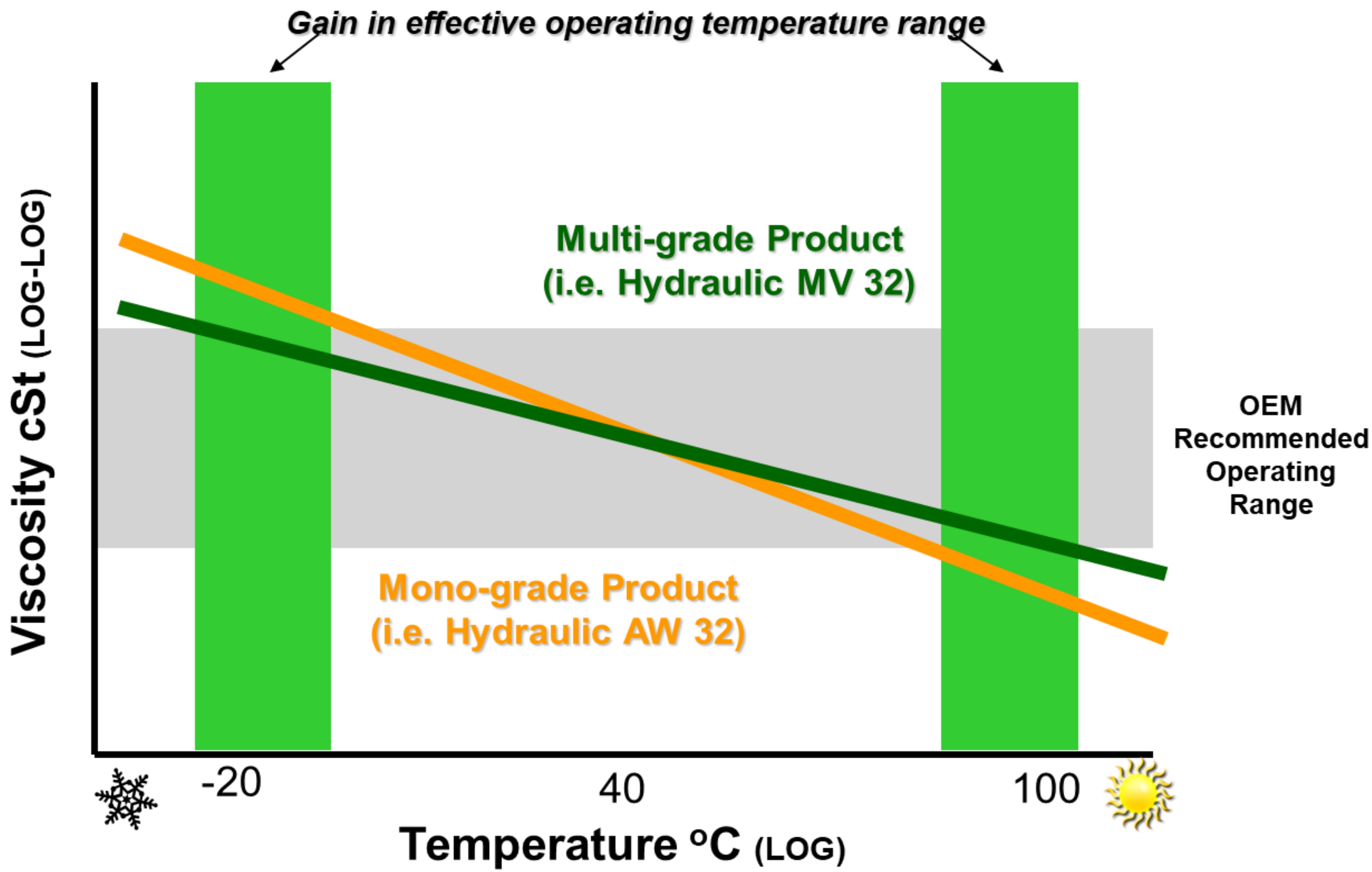
- **VI can be improved** significantly by blending soluble additives called **VI I**mprovers (VII) into the oil.

- These additives are long polymer molecules which uncoil at high temperatures to increase viscosity, while at low temperatures they form tight "balls" which no longer contribute much to viscosity.

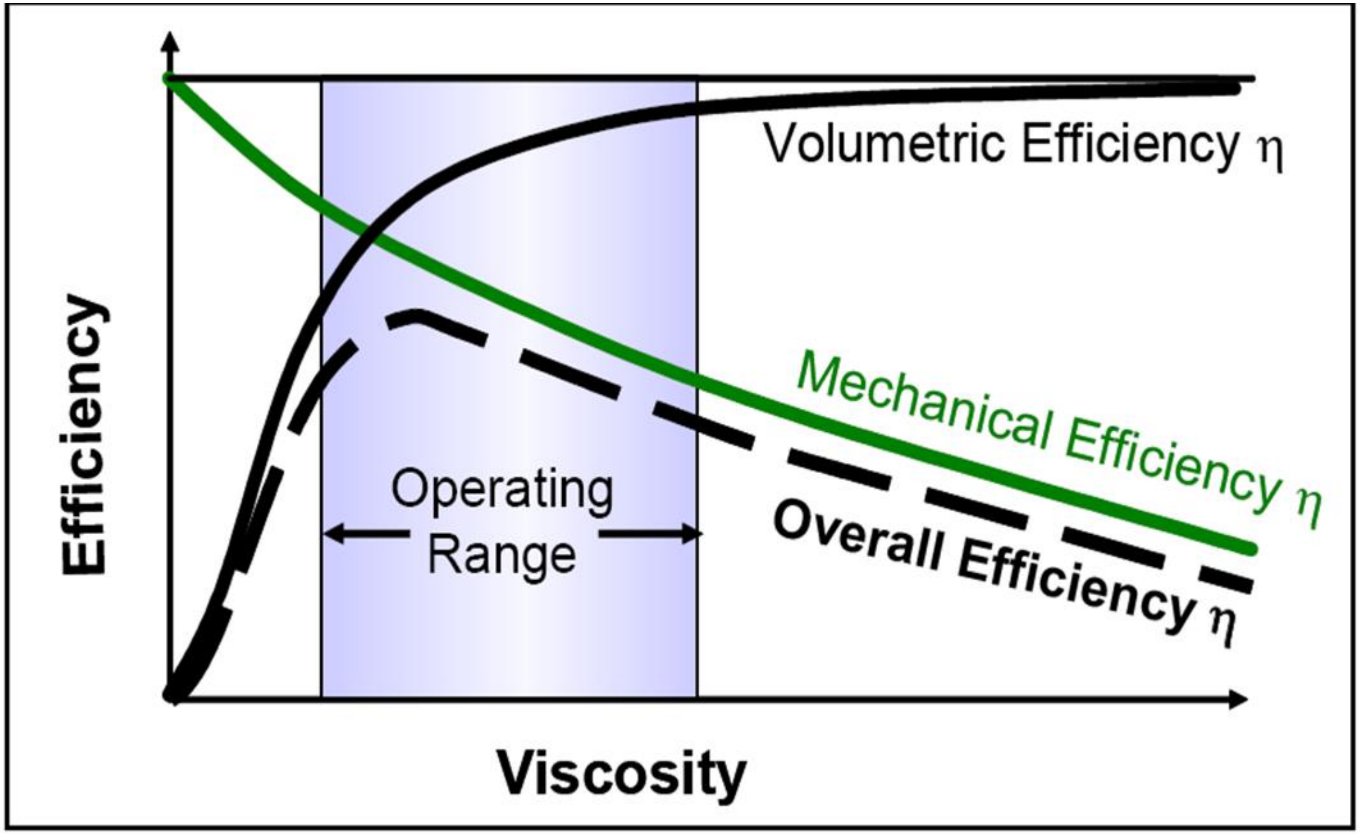
VISCOSITY INDEX IMPROVER (VII)



VISCOSITY INDEX IMPROVER (VII)

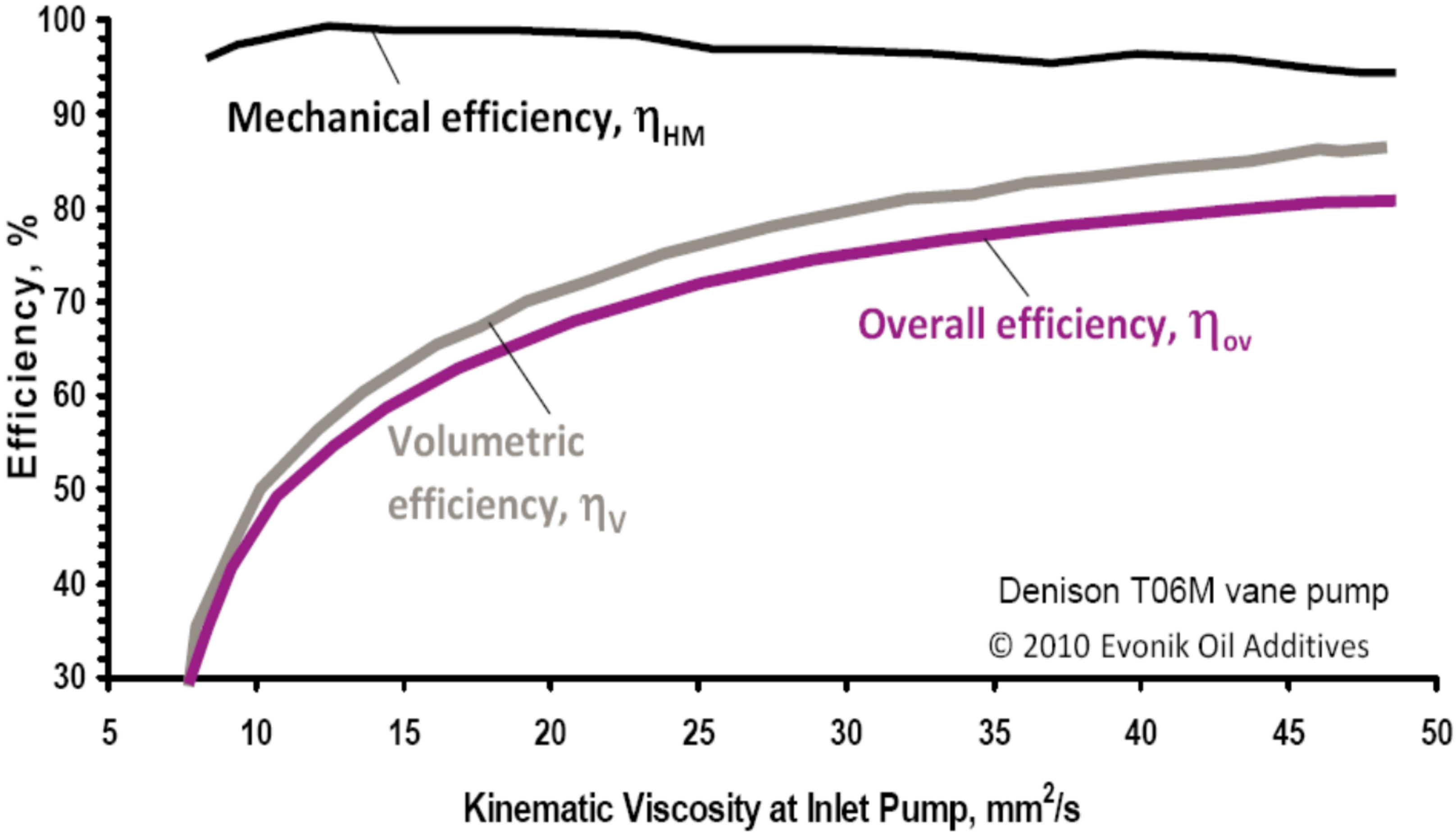


HYDRAULIC PUMP EFFICIENCY



Volumetric Efficiency: All pumps have internal leakage paths.
Mechanical Efficiency: Energy is consumed to rotate pump and overcome fluid frictional losses.
The amount of mechanical and volumetric loss in a pump is **primarily a function of the fluid's viscosity and lubricity properties**.

HYDRAULIC PUMP EFFICIENCY



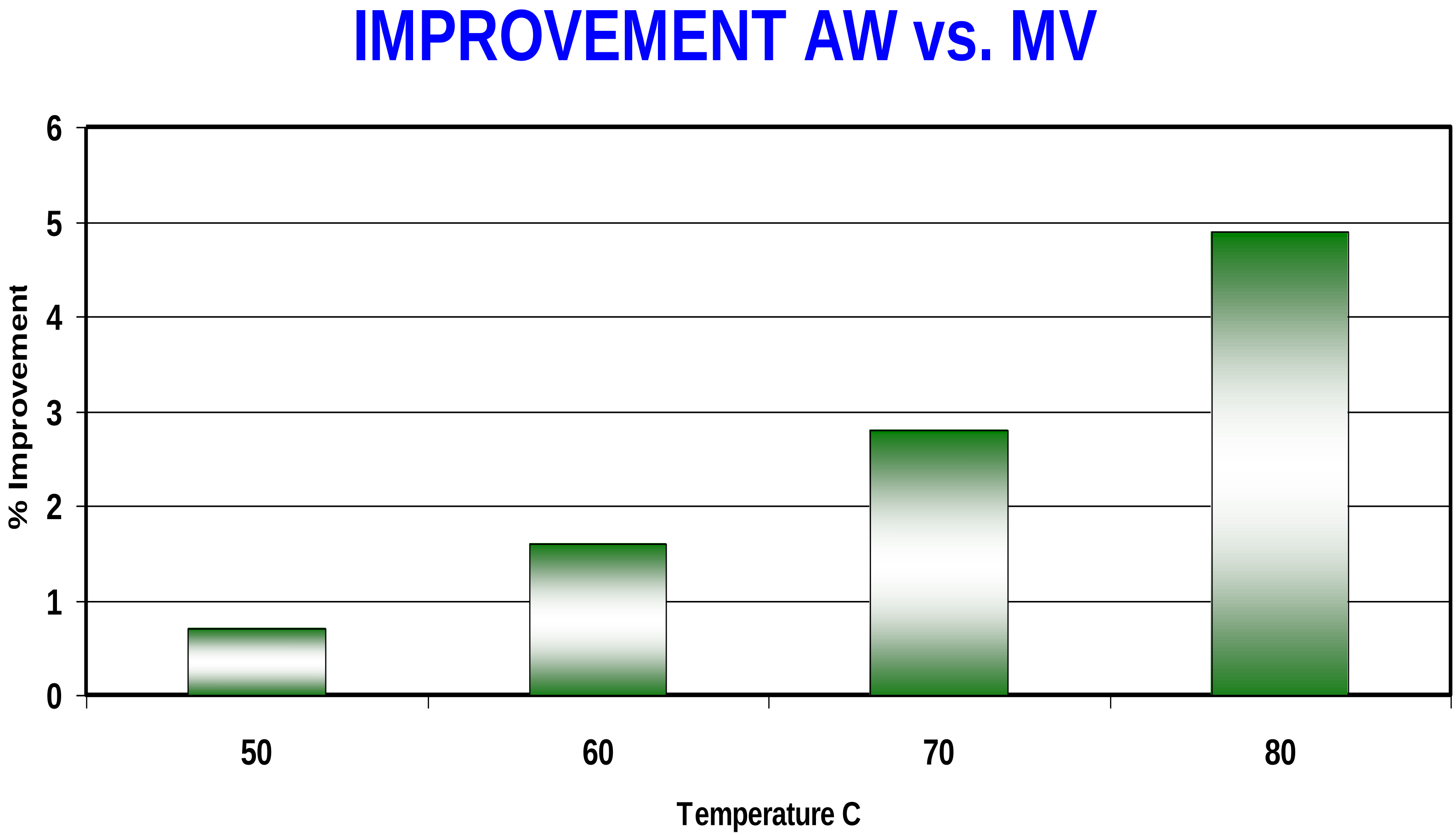
Overall efficiency is more dependent on volumetric efficiency

INDUSTRY – TEST RESULTS

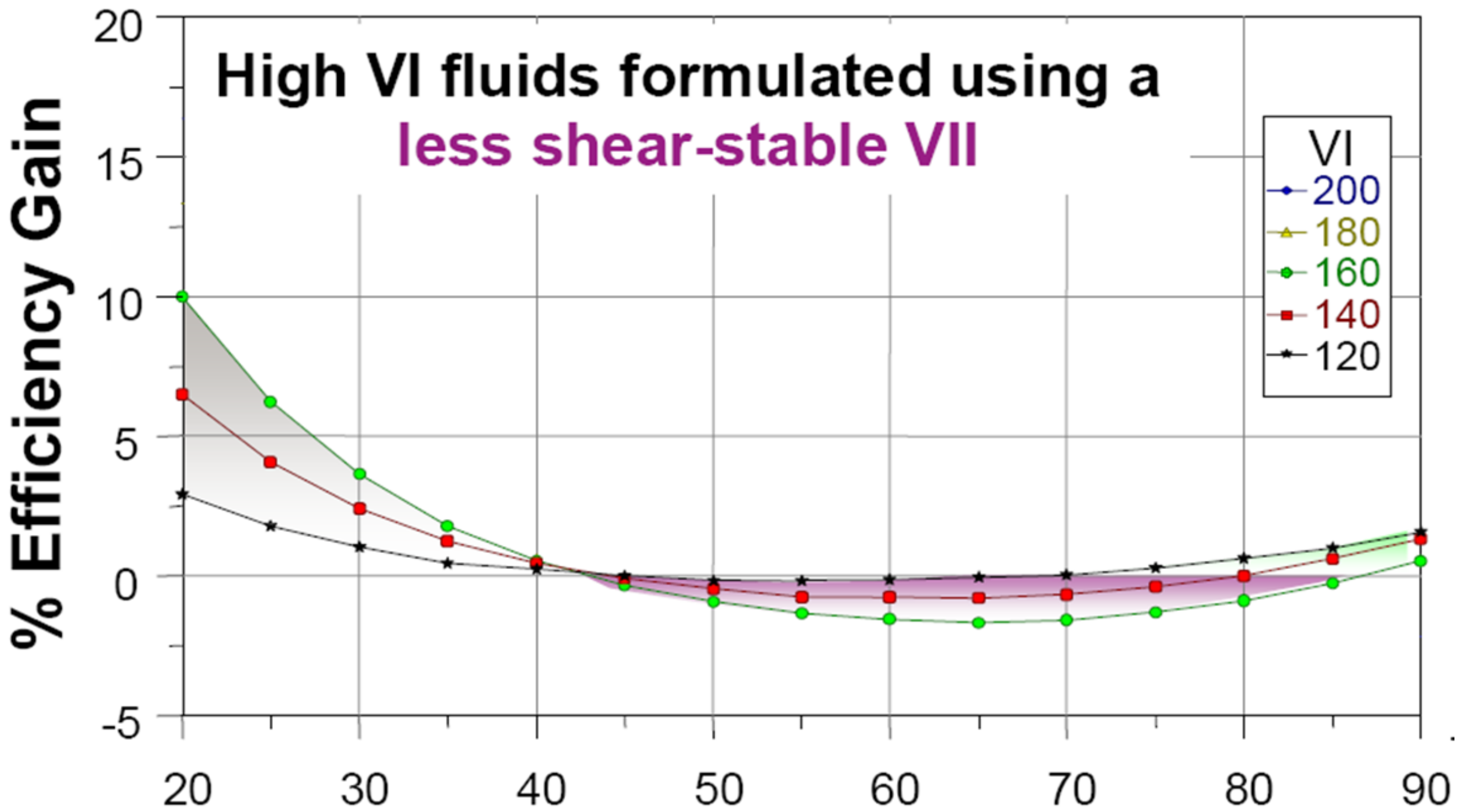
Lead author	Firm name	Forum	OEM Equipment	Reported efficiency improvement
Herzog	Evonik Oil Additives	STLE 2007	Mid sized excavator	Up to 18 %
Herzog	Evonik Oil additives	IFPE 2008	Skid steer loader Compact excavator	13-16 % 14-15 %
Guerzoni	Shell Oil	Hydraulics and Pneumatics, 2009	Injection molding	13.9 %
Hannon	ExxonMobil	STLE 2010	Small excavator, Injection molding Skid steer loader	Up to 6 % Up to 2.2 % Up to 4 %
Anon	Hydrotex	Press release 2010	Injection molding	Average 13.5 %
Battersby	Shell Oil	NFPA 2011	Telehandler	4 %

Source: Evonik Industries

INTERNAL HYDRAULIC OIL TESTS



SHEAR STABILITY IS IMPORTANT



Operating Temperature ºC

Conditions: Denison T6C-B06 vane pump, 2000 rpm, 200 bars

Ref: Evonik Industries

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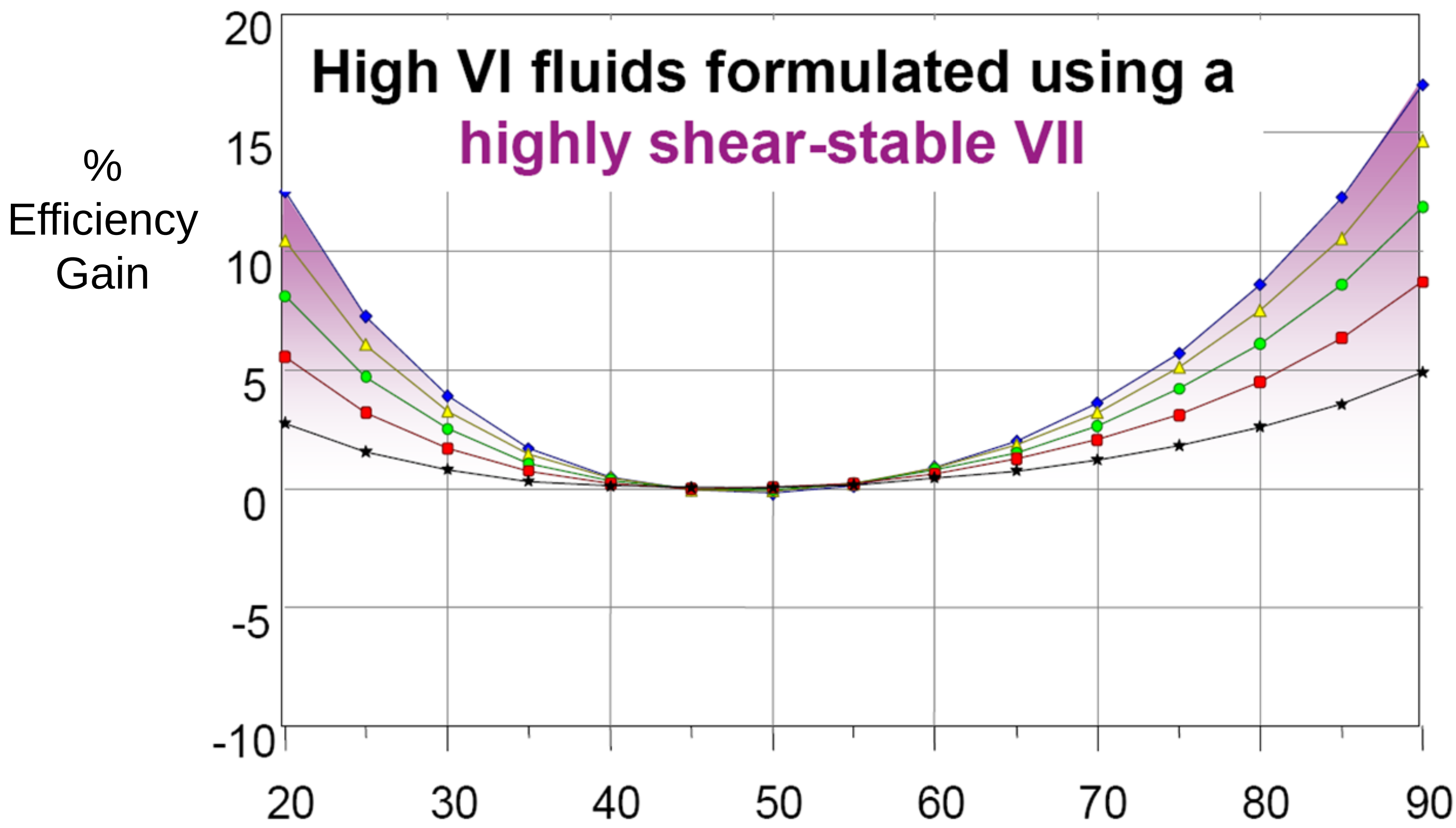

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1. Test Case at Cruickshank Construction

CAT Crawler Excavator 336E L
Weight: 39,100 kg
Engine Output: 224 kW / 300 HP
Bucket Capacity: 2.3 m^3

Three Tasks That Were Evaluated

- ❑ **Digging**
- ❑ **Truck loading**
- ❑ **Travelling**

These tasks were evaluated under the parameters below:

- Two operators with different experience levels
- Start oil temperature at more than 50ºC/122ºF
- Engine mode at "High Power" (100% throttle fixed)
- Excavator test mode at "fast" for travelling
- Large bucket of 2.3 m^3 (travelling was done with the same bucket size)

5 Globally-Recognized Oils Were Tested

1) Mono-grade ISO 46 hydraulic fluid with VI of 122 as reference fluid
2) 10W-30 engine oil with VI of 142
3) Mono-grade ISO 46 hydraulic fluid with VI of 99
4) Multi-grade ISO 32 hydraulic fluid with VI of 148
5) Multi-grade ISO 46 hydraulic fluid with VI of 194

Multiple Parameters Were Measured and Monitored During The Test

- Ambient temperature
- Hydraulic oil reservoir temperature
- Hydraulic driven fan speed
- Hydraulic pump output pressure
- Fuel consumption rate
- Hydraulic pump inlet temperature
- Fuel inlet and outlet temperature

Note: a robust drain and flushing procedure was used after each product sequence to ensure negligible product carryover.

DIGGING

Digging & Truck Loading

Fuel Consumption (L/h)
Measured value

Efficiency (t/L)
Average amount of moved mass /
Average amount of used fuel

Productivity (t/h)
Average amount of moved mass /
duration of the operation

TRUCK LOADING

Digging & Truck Loading

Fuel Consumption (L/h)
Measured value

Efficiency (t/L)
Average amount of moved mass /
Average amount of used fuel

Productivity (t/h)
Average amount of moved mass /
duration of the operation

TRAVELLING

Travelling

Fuel Consumption (L/h)
Measured value

Efficiency (m/L)
Average travelled distance / Average amount of used fuel

Productivity (m/h)
Average travelled distance / duration of the operation

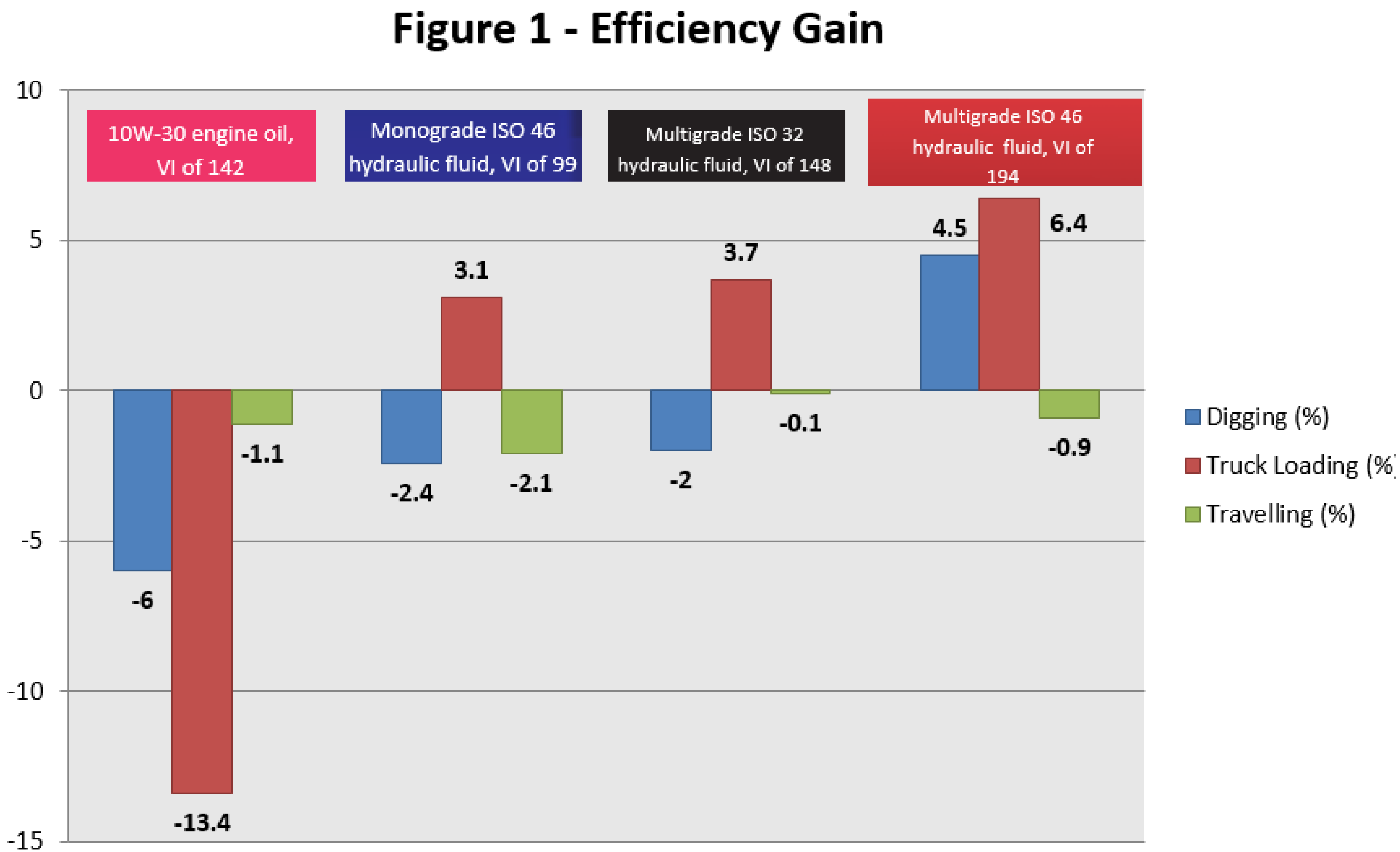
RESULTS

Table 1 – Efficiency Gain † (t/L for digging and truck loading, m/L for travelling, compared to reference fluid)				
Competitor	10W-30 engine oil, VI of 142	Monograde ISO 46 hydraulic fluid, VI of 99	Multigrade ISO 32 hydraulic fluid, VI of 148	Multigrade ISO 46 hydraulic fluid, VI of 194
Digging (%)	-6.0	-2.4	-2.0	+4.5
Truck Loading (%)	-13.4	+3.1	+3.7	+6.4
Travelling (%)	-1.1	-2.1	-0.1	-0.9

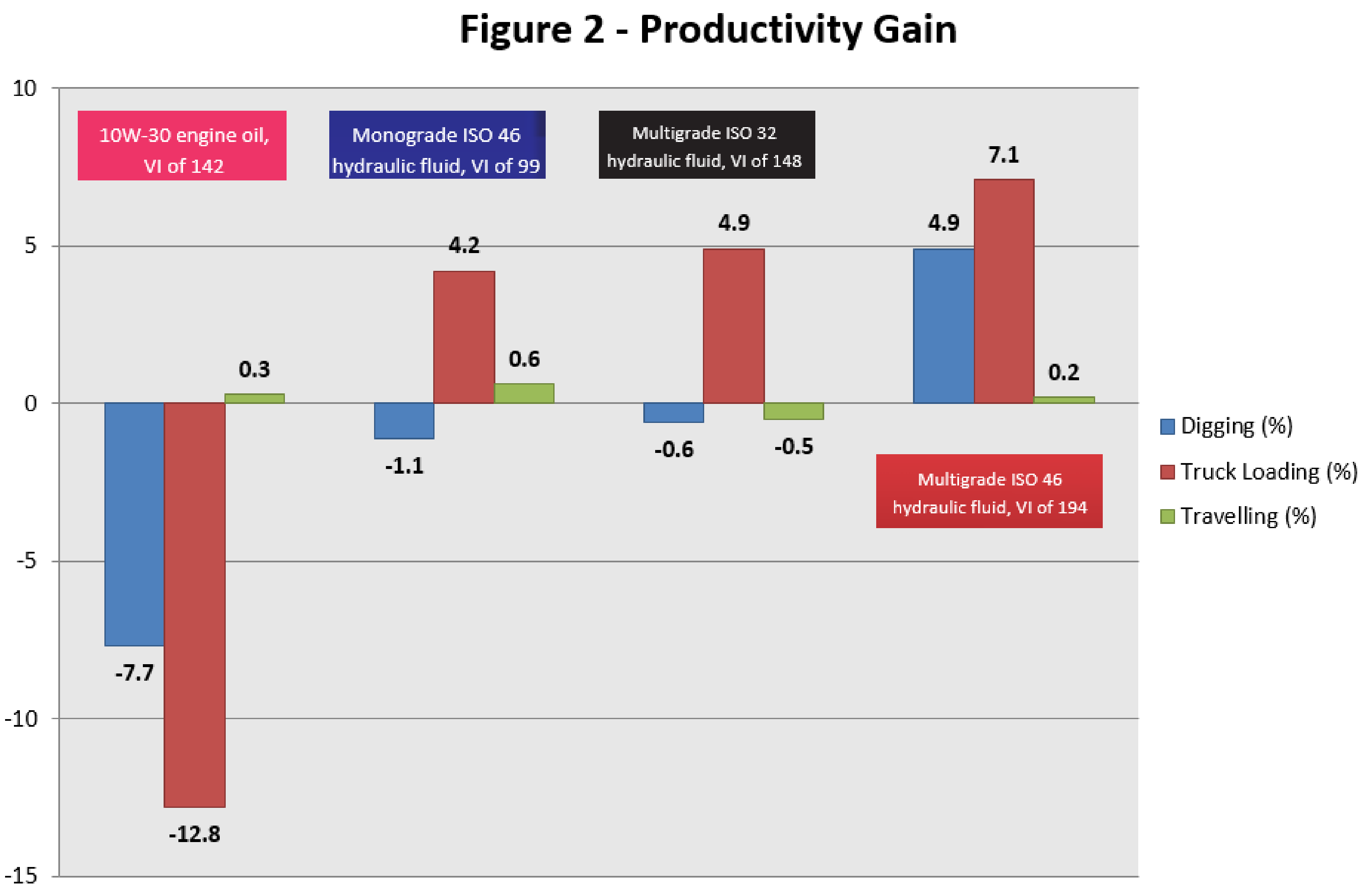
Table 2 – Productivity Gain † (t/h for digging and truck loading, m/h for travelling, compared to reference fluid)				
Competitor	10W-30 engine oil, VI of 142	Monograde ISO 46 hydraulic fluid, VI of 99	Multigrade ISO 32 hydraulic fluid, VI of 148	Multigrade ISO 46 hydraulic fluid, VI of 194
Digging (%)	-7.7	-1.1	-0.6	+4.9
Truck Loading (%)	-12.8	+4.2	+4.9	+7.1
Travelling (%)	+0.3	+0.6	-0.5	+0.2

† Because each sample was tested once with the exception of Multi-grade ISO 46 with VI 194, not all results are deemed statistically significant, based on the data sample size and actual results versus the standard deviation of our test procedure.

GRAPHIC RESULTS OF EFFICIENCY GAIN



GRAPHIC RESULTS OF PRODUCTIVITY GAIN



OPERATOR COMMENTS

- Beyond the evidence found in the data, both operators who undertook the tasks of digging, truck loading, and travelling mentioned that they *felt* a noticeable difference when using the Multi-grade ISO 46, with a VI of 194 – that is, the machine operated more smoothly and quickly.

CONCLUSION OF TEST CASE

- Across all oils tested, the data for travelling showed minimal variation from product to product, and insignificant differences when compared statistically to the reference fluid.
- The other monograde AW fluid (VI of 99) is common of many mono-grades fluids and showed some efficiency benefits during loading. However, these were nearly offset by the inefficiencies in digging so that fuel savings versus the reference fluid are statistically insignificant at a 90% confidence interval.
- The multi-grade 32 (VI of 148) performed slightly better than the mono-grade VI 99 in both digging and loading, but yet again, the deviation to the reference fluid proved insignificant at a 90% confidence interval.
- A 10W-30 engine oil was evaluated as industry practice sometimes substitutes engine oil for hydraulic oil to simplify material handling. The results were statistically significant in that performance was very poor versus the reference fluid.
- In truck loading specifically, the multi-grade ISO 46 (VI 194) showed a benefit in efficiency of 19.8% compared to the engine oil. This was the only fluid that showed strong, positive gains in efficiency and productivity.

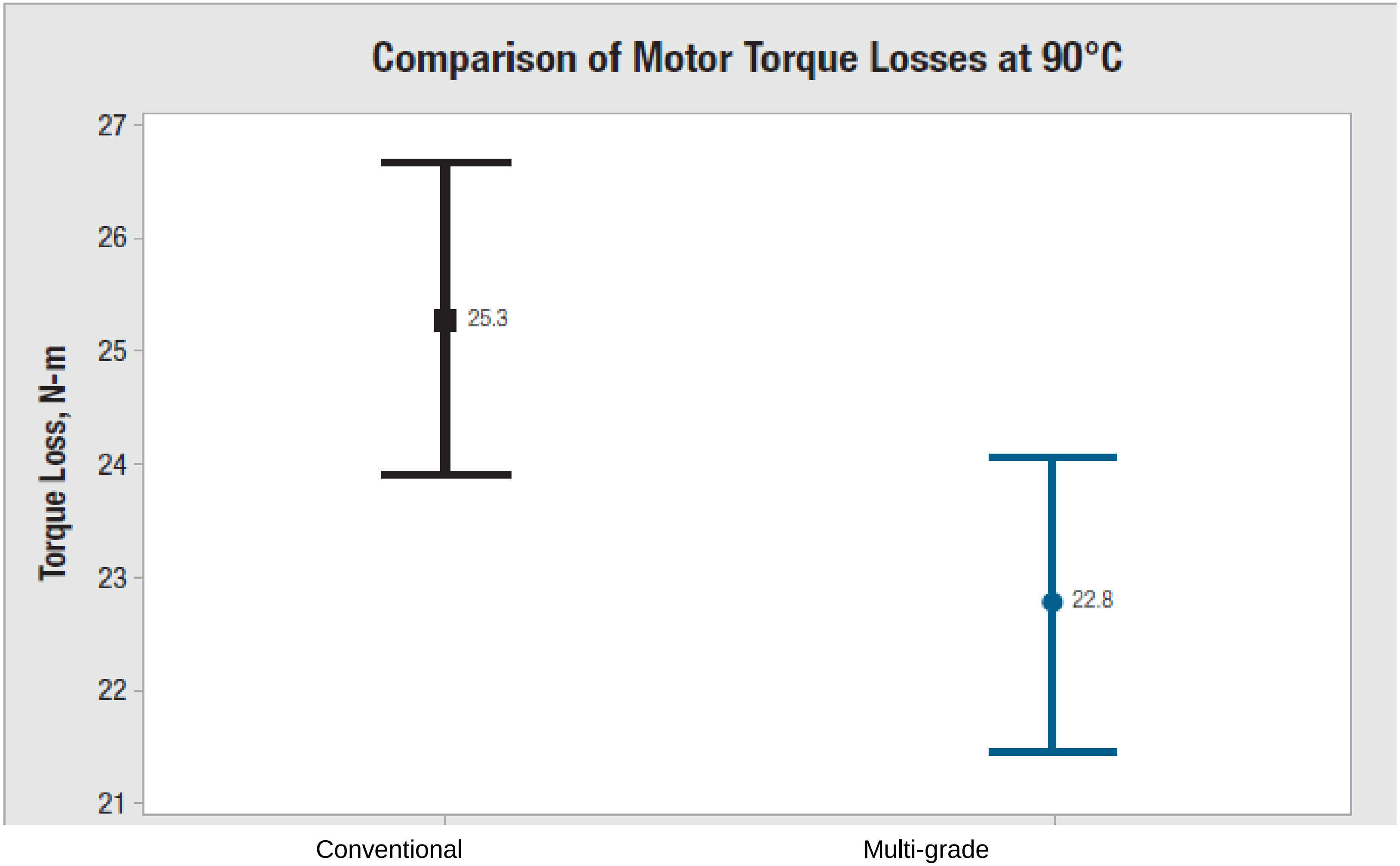
Putting Fluid Efficiency to the Test

Hydraulic System Losses as Compared to Automobile Inefficiencies

PRODUCTS EVALUATED & TEST PARAMETERS

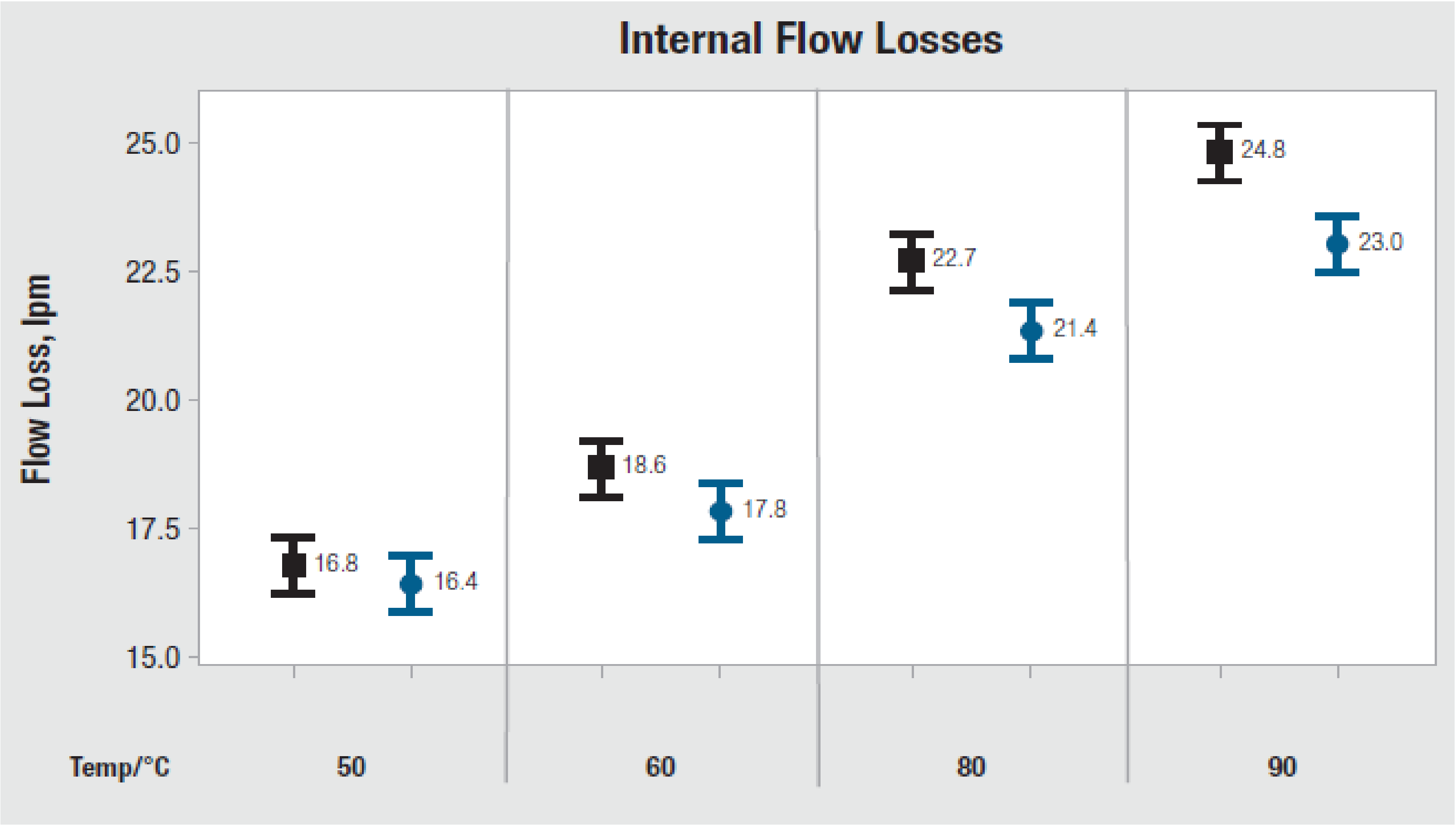
- 2 fluids were evaluated: a conventional mineral oil-based mono-grade and a semi-synthetic multi-grade hydraulic fluid.
- The fluids were tested at 50, 60, 80 and 90^{o}C.
- The hydraulic pump speeds were 800, 1200, and 1800 rpm, while the hydraulic motor speeds ranged from 1 to 600 rpm.
- The system pressure was regulated from 67 to 276 bar in 34 bar intervals by a proportional electrohydraulic compensator control.
- A total of 1782 data points were collected for each fluid during this demonstration.

HIGHER FRICTION, HIGHER FUEL CONSUMPTION



Comparison of axial piston motor torque losses at 90ºC.
Machines using multi-grade generate more torque to engage the payload due to reduced friction.

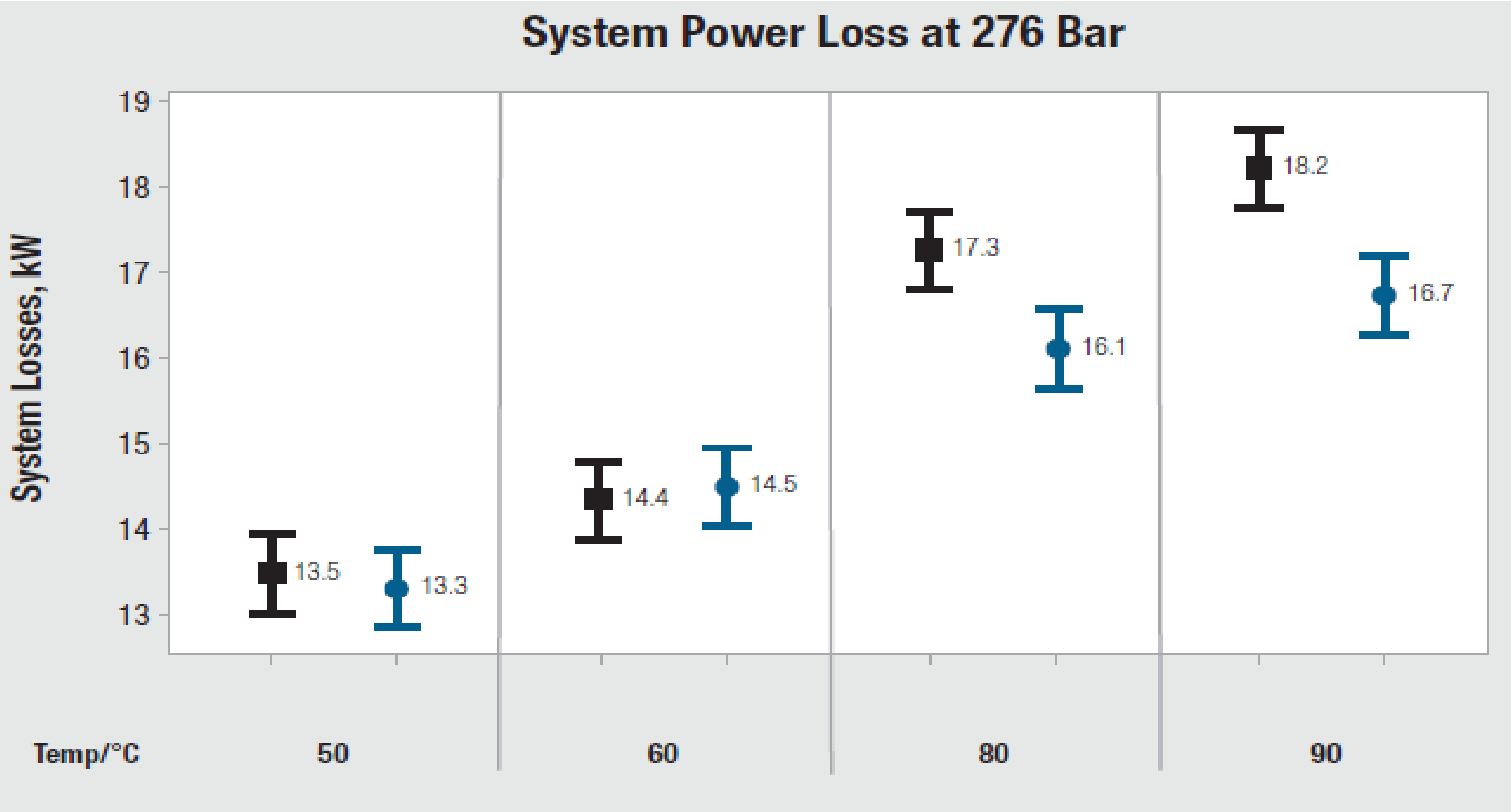
LOWER FLOW, LOWER SYSTEM EFFICIENCY



Conventional **Multi-grade**

Comparison of the internal leakage flow of the hydraulic system.
Multi-grade generates more flow to move actuators and perform work due to reduced flow losses

POWER LOSS



Conventional **Multi-grade**

Comparison of system power losses.
Machines that use multi-grade are more productive, require less fuel and operate at a lower temperature.

SUMMARY OF TEST DATA

- Using an energy efficient multi-grade will get you where you are going faster while using less energy by increasing the hydraulic system flow rate and motor torque output, while reducing energy loss and consumption.
- On mobile equipment, this will inevitably lead to reduced fuel consumption to drive the hydraulically controlled functions of the machine.
- These benefits are greatest when the machine is working hard and power is needed the most at peak loads and elevated temperatures.
- When heavy equipment is often being pushed to the limit, using an energy efficient multi-grade fluid will create a significant energy savings opportunity with the right fluid.

DON'T LET THE WRONG HYDRAULIC FLUID SLOW YOU DOWN

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