

New Methodology for Selecting the Proper Viscosity of Hydraulic Fluids

Update on Global Trends and Standards

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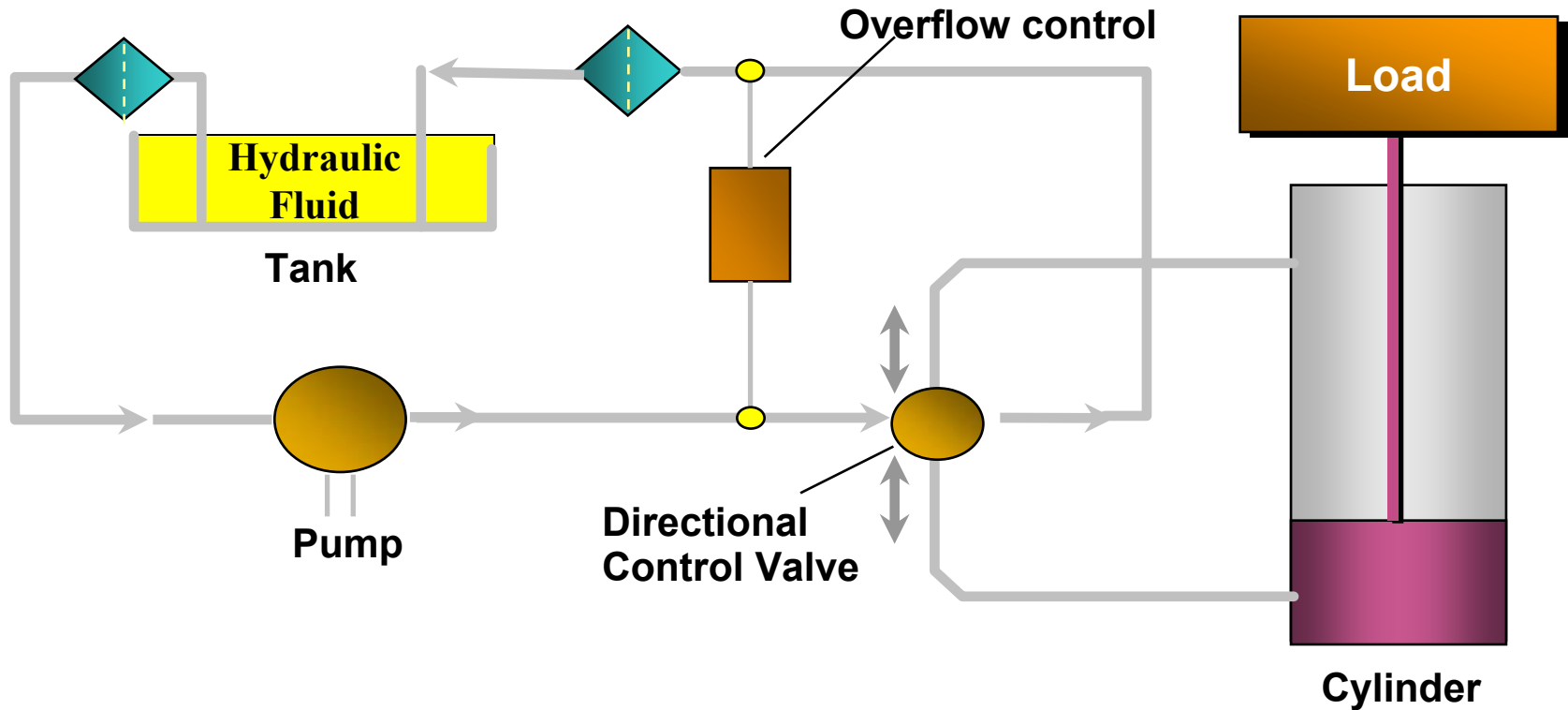
RohMax Oil Additives

Information Updated August 2004

Overview

- **Primary Functions of Hydraulic Fluids**
- **Consequences of Improper Viscosity Selection**
- **HF Viscosity Classification Systems**
- **Viscosity Selection Criteria**
- **Advantages of Multigrade Hydraulic Fluids**

Simple Hydraulic Circuit



Major Components of an Hydraulic Circuit

Pump	Provides force to cause fluid flow through system
Valves	Provide fluid direction control and, maintains fluid pressurization
Reservoir	Stores fluid not within the “working system”
Actuator	Converts hydraulic energy into mechanical energy and thus useful work <ul style="list-style-type: none">- Linear / Cylinder- Rotary / Hydraulic Motor
Hydraulic Fluid	Provides media for power transmission and lubrication

Functions of Hydraulic Fluids

Transmits pressure (energy)

- Compressibility/bulk modulus and **viscosity** are important power transmission properties

Lubricates/Protects

- **Viscosity** is an important lubricating property

Eliminates heat generated in service

- The more **viscous** the oil the less it can exchange heat

Serves as a sealing agent

- The lower the **viscosity**, the higher the leakage

Accepts and minimizes the effect of minor amounts of contamination

- Oxidation products, particles and dust, air and water

Selecting an Appropriate Hydraulic Fluid

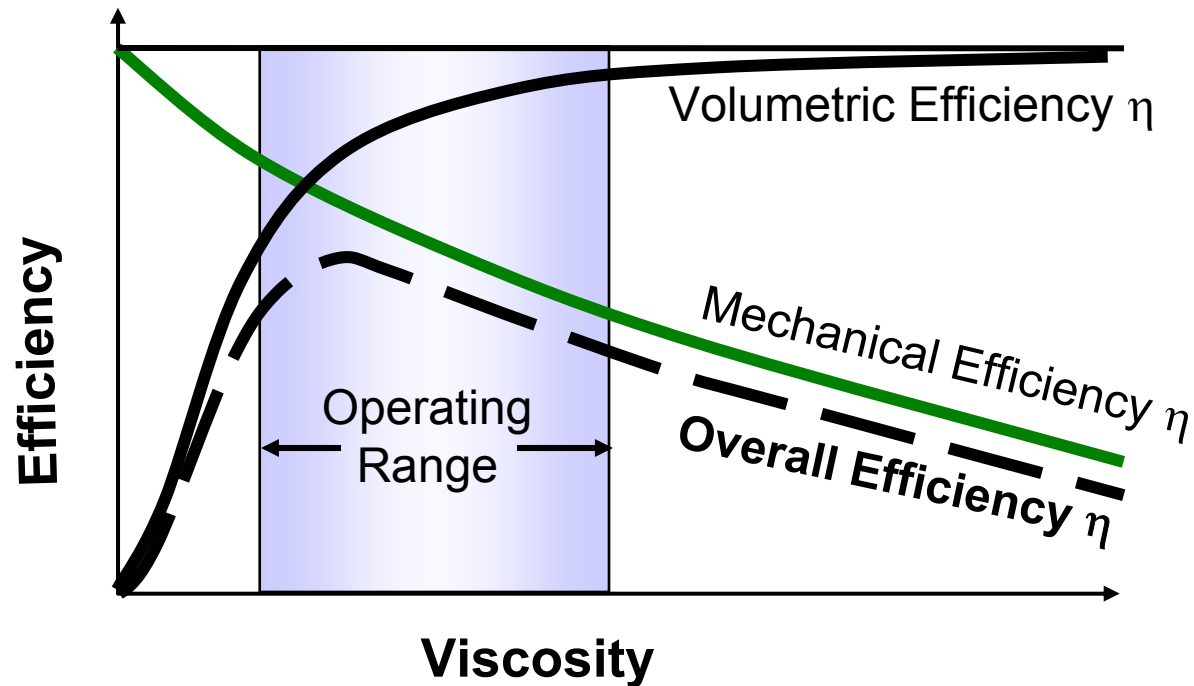
Fluid selection depends on many factors, such as:

- Design of the equipment
 - Pump type (gear, vane, piston)
- Total temperature operating range:
 - From start-up
 - To maximum expected under high load and high ambient temperature.
- **Viscosity** is one of the most important selection criteria.
- **Viscosity** directly influences the efficiency of the power transmission.

Effects of Viscosity on System Efficiency

Mechanical Efficiency

Volumetric Efficiency



Importance of Fluid Viscosity

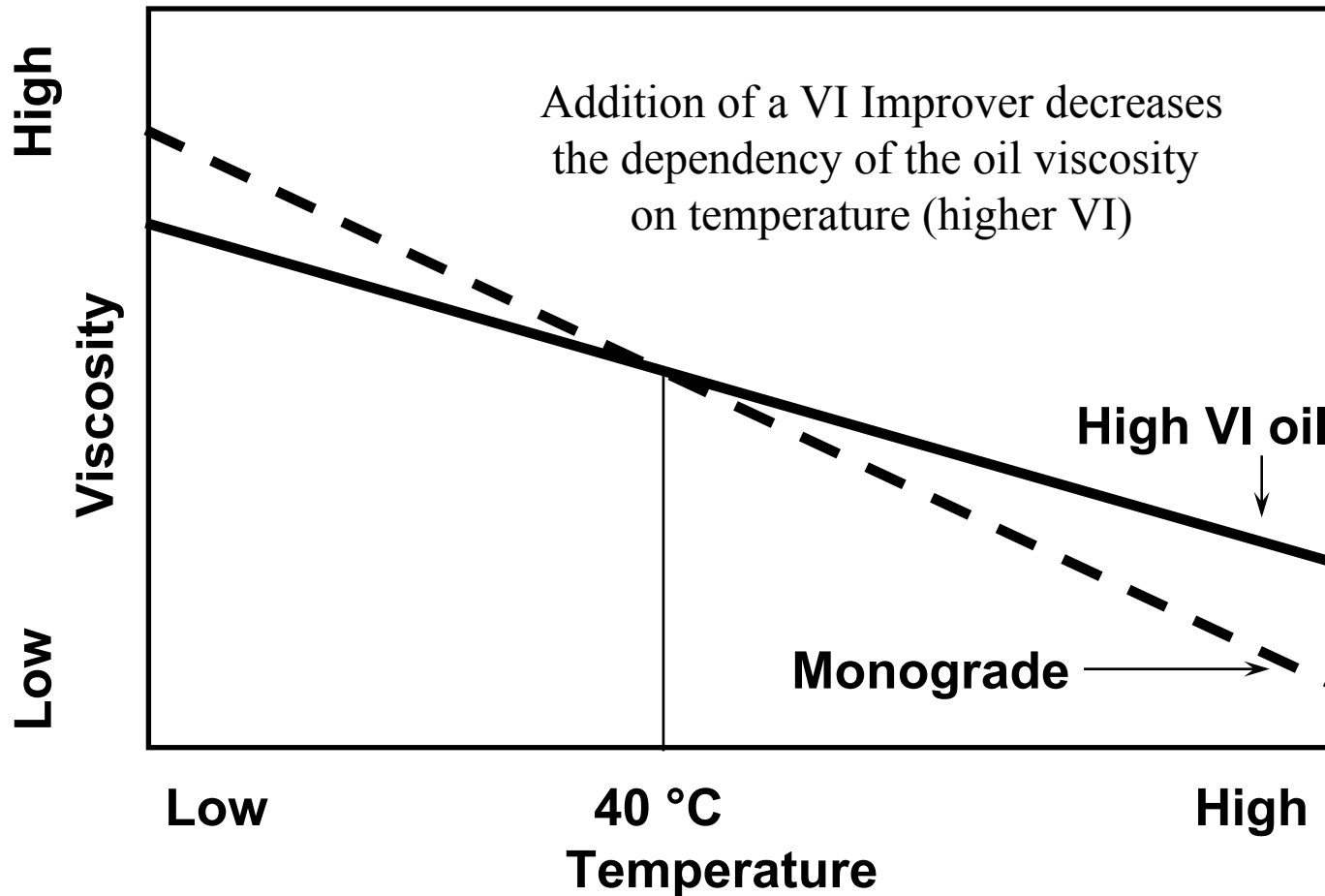
Too high viscosity at start-up results in inadequate oil flow:

- Air entrainment
- Cavitation
- Noisy operations
- Sluggish response
- Energy loss
- Pump breakage in extreme cases.

Too low viscosity under high load and high ambient temperature:

- High wear rates
- Excessive pump leakage
 - Loss of system efficiency
- Excessive seal leakage
- Overheating
 - Further reduction of the viscosity
 - Acceleration of fluid degradation.

Viscosity - Temperature Behaviour



Hydraulic Fluid Classifications

Several viscosity classification systems are currently used or under development.

Their objective is to provide suppliers, lubricant users and equipment manufacturers a common, meaningful basis for specifying and selecting lubricants for use.

Viscosity Grades	ISO 3448:1992	ASTM D 2422-97
High VI + Shear Stability	CETOP G6.20.08.SEC*	ASTM D 6080-97
Performance Grades	ISO 11158:1995	ASTM D 6158-99
HF for Mobile Equipment	JCMAS HK and HKB (biodegradable)	

*CETOP specification is currently in project committee review

Hydraulic Fluid Selection Criteria

The NFPA (National Fluid Power Association- USA) has developed a “Recommended Practice” for selecting hydraulic fluids that meet pump OEM viscosity requirements.

NFPA/T2.13.13-2002

The standard is useful in identifying the fluid grade needed to deliver optimum pump efficiency, over the temperature operating window of the equipment in service.

ISO 3448

In the mid-seventies, a co-operative effort between ASTM, ASLE, BSI and DNA resulted in the ISO 3448 1975(E) Viscosity Classification for Industrial Liquid Lubricants.

ISO 3448 was designed in order to cover the entire range of kinematic viscosities of liquid lubricants normally used with only a limited numbers of discontinuous grades.

- The viscosity grade width was set to be not more than 10% on either side of the nominal value.
- The reference temperature was selected to be close to average service experience.
- 40° C was selected as the reference temperature
 - Middle of the operating temperature range.

ISO 3448 Viscosity Grades (ASTM D 2422)

ISO VG	MID-POINT	MINIMUM	MAXIMUM
10	10.0	9.0	11.0
15	15.0	13.5	16.5
22	22.0	19.8	24.2
32	32.0	28.8	35.2
46	46.0	41.4	50.6
68	68.0	61.2	74.8
100	100.0	90.0	110.0
150	150.0	135.0	165.0

Deficiencies of ISO 3448

ISO viscosity grades not continuous

Only one viscosity at one temperature

- Does not describe viscosity at low startup temperatures
- Does not describe viscosity at high operating temperatures

Does not address used oil viscosity

ASTM D 6080 addresses these problems!

New Designation of Fluids According to ASTM D 6080

ISO VG xx Lyy-zz (VI)

- **xx** is the fresh oil viscosity grade as per ASTM D 2422
- **Lyy** is the low temperature grade based on the temperature at which the fresh oil viscosity reaches 750 mPa.s
- **zz** is the viscosity at 40° C after shearing in D 5621
- **VI** is the viscosity index as per D 2270 after shearing in D 5621.

Example: **ISO VG 32**
L22-30 (150)

ASTM D 6080 Low Temp Viscosity Grades

Temperature, ° C for
Brookfield Viscosity
Of 750 cP Maximum

ISO VG	
L10	-33 TO -41
L15	-23 TO -32
L22	-15 TO -22
L32	-8 TO -14
L46	-2 TO -7
L68	4 TO -1
L100	10 TO 5
L150	16 TO 11

Hydraulic Fluid Performance Grades ISO 11158, ASTM D 6158

<u>Grade</u>	<u>Characteristics</u>
HH	Non-inhibited mineral oils for light duty use
HL	Mineral oils with rust and oxidation inhibition
HM	HL oils with improved antiwear protection
HR*	HL oils with high VI for wide temp. operating range
HV	HM oils with high VI for wide temp. operating range
HG*	HM oils with improved stick/slip performance

**ISO 11158 standard only, not included in ASTM 6158*

Hydraulic Fluid Performance Grades ISO 11158, ASTM D 6158

Each grade has unique specifications, and is subdivided by ISO viscosity grades (ISO 10 to ISO 150)

HH	Flash point, pour point, acid number, water
HL	HH + antirust, oxidation, copper corrosion, antifoam air release, demulsibility
HM	HL + antiwear (ASTM = Vickers vane pump, ISO = FZG)
HR*	HL + VI >130, shear stability
HV	HM + VI >130, shear stability
HG*	HM + low speed stick/slip performance

**ISO 11158 standard only, not included in ASTM 6158*

JCMAS HK (Japan)

- ⊗ **Hydraulic fluids for earth moving equipment**
- ⊗ **Activity of SAE F&L Div., Steering Committee for Asia**
- ⊗ **Work Group mainly composed by Japanese equipment manufacturers and lubricants / parts / additives suppliers**
- ⊗ **Two performance categories and four viscosity grades**
 - ***Performance Categories***
 - ***HK*** ***High friction for parking brake system***
 - ***HKB*** ***Moderate friction for preventing stick-slip***
 - ***Viscosity Grades***
 - ***Multi grade*** ***VG32W and VG46W***
 - ***Single grade*** ***VG32 and VG46***
- ⊗ **Timeline:**

Jan. 2002	Publish as JCMAS* HX-1 draft Spec.
Mar. 2004	Release final Specification

**JCMAS: Japanese Construction Machinery Association Standard*

JCMAS HK Important Requirements

Viscosity Grade	VG32W	VG46W	VG32	VG46	Test Method
KV100, mm ² /s	> 5.3	> 6.8	> 5.0	> 6.1	ASTM D 445
Viscosity Index	> 120	> 120	> 90	> 90	ASTM D2273
Brookfield Viscosity, mPa.s	< 5000 @-25° C	< 5000 @-20° C	-	-	ASTM D2983
Shear Stability	< 5%	< 10%	-	-	ASTM D5621
Oxidative Stability	TAN Increase < 1.0 mgKOH/g				ASTM D4310
Seal Compatibility	Pass (NBR and Urethane)				CEC-L39-T-96
Piston Pump Test	Pass (Komatsu HPV35+35)				Komatsu Met.
Vane Pump Test	Pass (Vickers 35VQ25)				Vickers M2950-S
Friction	HX-1A	$\mu > 0.13$			Micro Clutch or SAE#2
	HX-1B	$\mu > 0.09$			
Bearing Fatigue	Better than REO-A				JEC Method
Chlorine	< 50 ppm				ASTM D6443

Swedish Standard SS 15 54 34

Edition 4

Viscometric Requirements for the V Grades

	VISCOSITY GRADES		
Viscosity	V32	V46	V68
KV @ 40 °C, mm ² /s	28.8 – 39.0	>39.0 – 57.0	> 57.0 – 74.8
KV @ -20 °C, mm ² /s After 72 hr soaking	---	≤2400	≤5000
KV @ -30 °C, mm ² /s After 72 hr soaking	≤4000	---	---
KV @ 100 °C, mm ² /s After 20 hr KRL	>4.5	>6.0	>7.0

Examples of Fluids Formulated to SS 15 54 34

CHARACTERISTICS	GRADES		
	V32	V46	V68
KV @ 40 °C, mm ² /s	31.5	44.2	67.9
KV @ 100 °C, mm ² /s	7.48	9.05	12.30
Viscosity Index (fresh oil)	216	192	181
KV @ 100 °C after KRL 20 hr, mm ² /s	5.11	6.27	7.75
KV @ 100 °C after 40 minute Sonic, mm ² /s	5.21	6.66	8.86
KV @ -20 °C after 72 hr of soaking, mm ² /s	---	2115	4805
KV @ -30 °C after 72 hr of soaking, mm ² /s	3420	---	---
Temperature for 860 mm ² /s, °C	-21	-13	-6

Comparison of Global Viscosity Grading Systems

Swedish Standard Grade	V32	V46	V68
NFPA Grading	L22-32	L32-46	L46-100
ASTM D 6080 Grading	VG 32 L22-22 (170)	VG 46 L32-33 (160)	VG 68 L46-51 (160)
ISO 3448 Grading	VG 32	VG 46	VG 68

Conclusions - 1

**The Four Major Viscosity Classification Systems are Valuable Tools:
Each Provides Different Information.**

ISO 3448

- Viscosity at 40 °C only

ASTM D 6080

- Fresh & sheared (Sonic 40') oil Viscosity at 40 °C and VI after shear

NFPA T2.13.13.2002

- Selection Criteria based on OEM Guidelines and In-Service temperatures
 - High temperature grades are defined by a range of viscosity at 100 °C
 - Uses the same low temperature grades as ASTM D 6080
 - No shear stability requirement

Swedish Standard 15 54 34

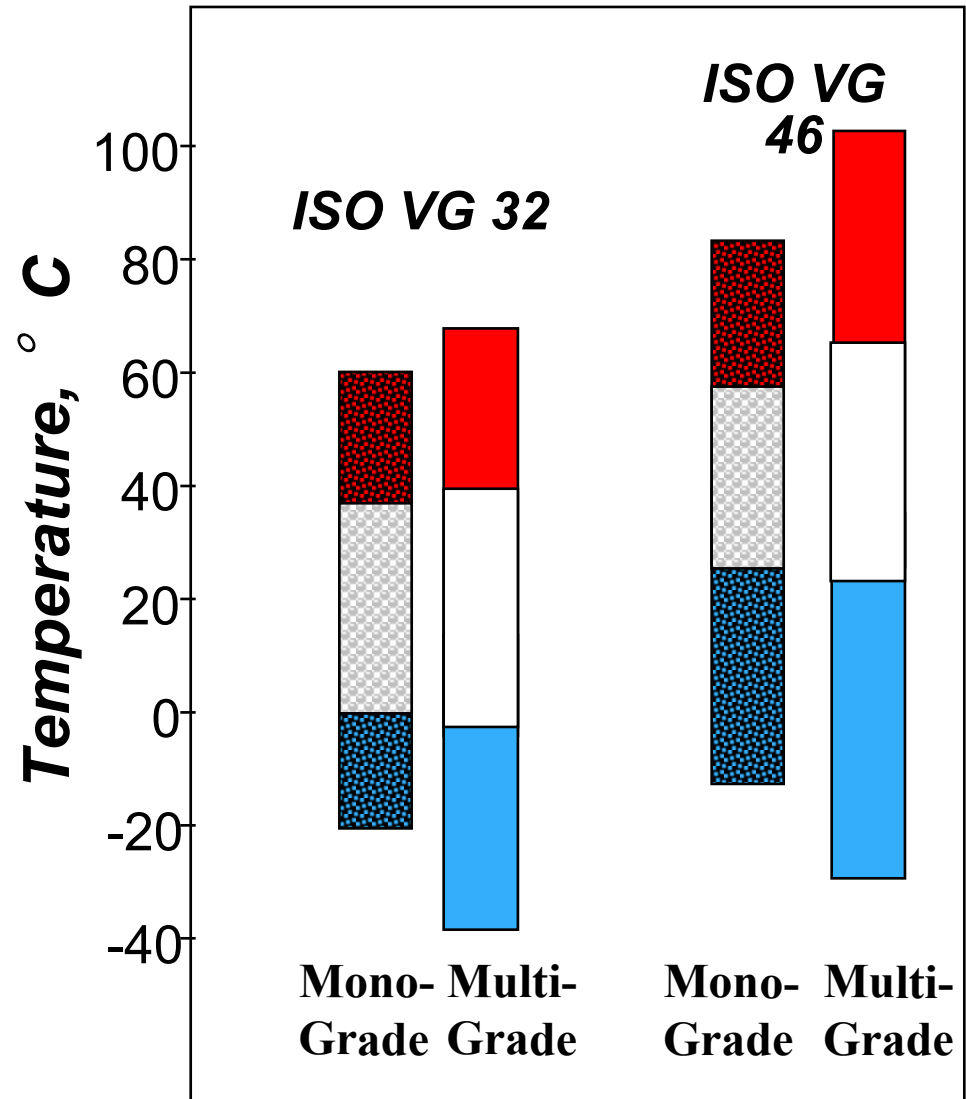
- Full fluid specification for use in cold climates
- Sheared (KRL 20 hr) oil Viscosity @ 100 °C

High Viscosity Index Fluids have a Wider Operating Temperature Range

Multigrade hydraulic fluids are especially favorable in ISO grades 32 and higher.

The total operating range increases with the VI of the fluid and the ISO grade

White Bar: range of optimal operating temperature

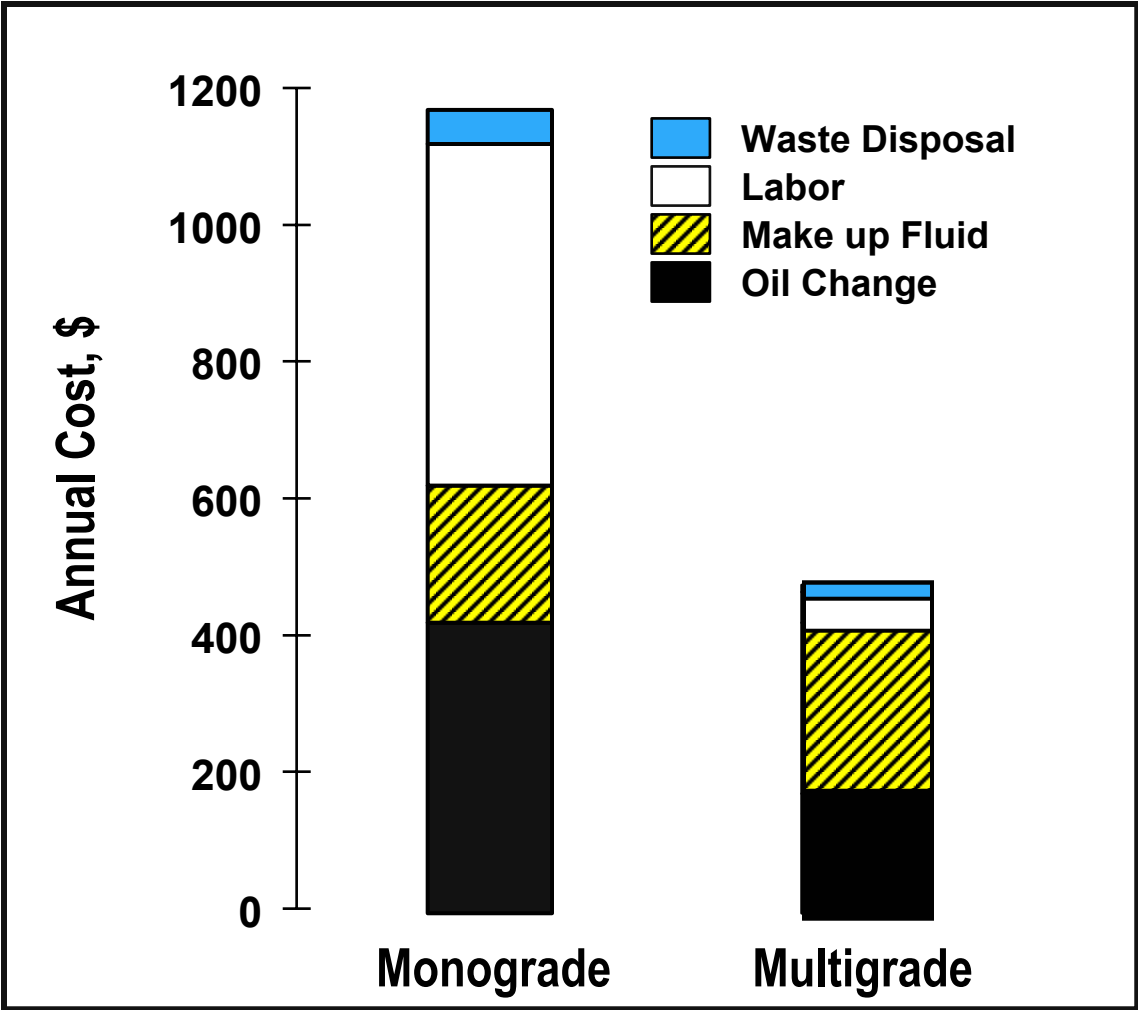


Forest Machinery, Feric Field Test - Canada, all year -



Estimated Operating Costs of Outdoor Hydraulic System

RohMax Oil Additives



Conclusions

- **A variety of specifications are available to describe hydraulic fluid viscosity and performance characteristics**
- **NFPA has introduced a system for optimizing hydraulic fluid grade selection. Recommended Practice T2.13.13-2002**
- **JCMAS HK specification for mobile hydraulic equipment is approved**
- **Multigrade hydraulic fluids offer a wider temperature operating window**
 - Improves pumping efficiency
 - Can reduce maintenance and fluid disposal costs
 - Better operational response of the equipment
 - Correct oil viscosity offers less wear and longer component life