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FLUID POWER IN ACTION

Study examines multigrade fluids for forestry equipment

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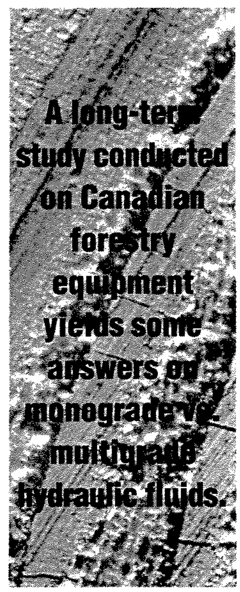


Balancing performance and cost is a challenge when selecting any product, including hydraulic fluid. Identifying low price is simple, but other questions can be complex:

- Will the fluid meet the application's performance guidelines?
- Will it work at the temperature extremes the system might see?
- Will it minimize maintenance costs?

How can designers find meaningful answers to these questions? A good starting point is determining proper fluid viscosity — a critical factor in hydraulic system performance. The fluid must transmit power and lubricate moving parts over the system's entire operating temperature range. The fluid must be thin enough to flow at cold start-up temperatures, and thick enough to maintain a protective lubricating film in the pump at peak operating temperatures. A system operating with fluid that is too thick or too thin will experience sluggish response — or failure.

A long-term study was conducted on Canadian forestry equipment to compare the performance of monograde (seasonal) and multigrade (year-round) hydraulic fluids[1]. This environment and application offer a challenging mixture of ambient and operating temperatures where proper viscosity is critical for minimizing downtime and maximizing profitability.

Monograde vs. multigrade

Monograde fluids typically are the low cost option. They are a good choice for indoor operations, or systems where mild operating conditions produce only small variations in fluid temperature. Narrow temperature operating windows are desirable, as fluid viscosity will change very little and the system can operate very efficiently.

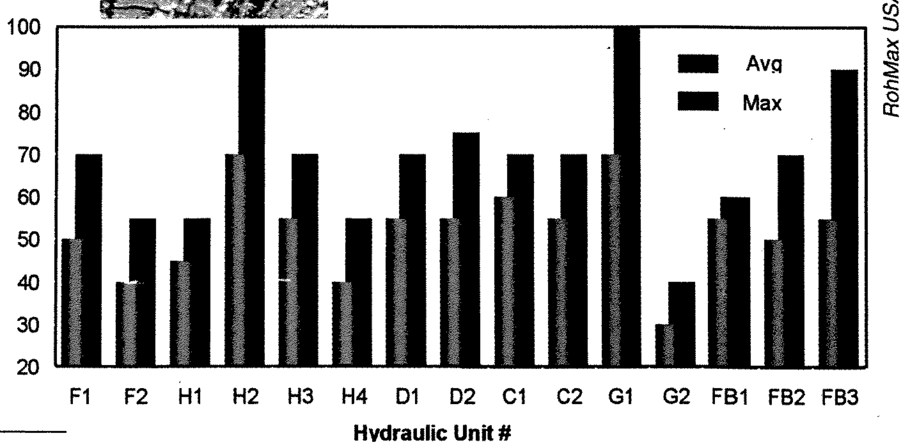
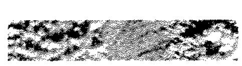


Fig. 1. Oil-ambient air temperature difference, °C.



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Multigrade fluids tend to be slightly higher in cost, but can offer savings when maintenance and disposal costs are considered. Multigrade fluids have a much wider temperature operating window (TOW), which is often required in outdoor operations or in hard-working systems where the fluid absorbs and holds heat.

A typical hydraulic pump converts about 20% of its input horsepower into heat[2]; therefore, most fluids run at elevated temperatures. There are many system design factors that determine if the fluid can properly get rid of heat to maintain optimum viscosity, with other factors such as air release, foaming, water absorption, and filtration playing a role. A good system is designed with these considerations in mind, but aggressive field conditions can sometimes compromise a good design. High or low ambient air temperatures present a tough challenge, as well as demanding workloads that stress system design capabilities.

In the study conducted by the Forest Engineering Research Institute of Canada (FERIC) over year-round operations in Kapuskasing, Ont.[3], interviews with area contractors indicated that there was no problem in selecting a fluid to meet OEM guidelines, but it was unclear if these fluids were truly optimum, considering local operating conditions and maintenance practices. A variety of equipment from a number of major suppliers was monitored, including: harvesters, delimbers, graders, forwarders, cleaning machines, and feller-bunchers.

Contractors were surveyed to identify the major types of hydraulic fluid that were available and widely used. Three commercially available hydraulic fluids from major North American suppliers were selected for detailed evaluation. These fluids are described in Table 1 below.

The TOW for any hydraulic system can be determined by examining pump requirements. This information can be obtained by contacting the pump manufacturer, or a summary of many pump fluid specifications can be found in a recent technical paper by Herzog[4]. Typical specifications for hydraulic fluids used in Canadian forestry equipment require that the fluid never get thicker than 5000 cSt, or thinner than 10 cSt. These criteria lead to the operating temperature limits presented in Table 1.

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Real-world temperatures

Ambient temperatures in Kapuskasing occasionally reached -40° C on winter nights, and peaked at 35° C on summer afternoons. In general, fluid operating temperatures typically ran 40° to 60° C above ambient temperatures, but it was not uncommon for the fluid to peak at 100° to 115° C above ambient temperatures in both winter and summer operations. Oil temperatures were measured in the range of -29° to 135° C over the course of the year, Figure 1. These fluid-temperature extremes dictate that several monograde hydraulic fluids need to be rotated in service, or a single multigrade be used year-round.

Winter monograde fluids offer quick start-up and excellent response at low temperatures. Unfortunately, they cannot provide adequate lubrication protection if fluid temperatures rise above 65° C. Most of the hydraulic systems studied had average winter operating temperatures around 50° to 60° C, but there also were extended daily periods of higher temperatures where the fluid was too thin.

Does this matter? The equipment didn't seize up or shut down operations, but there were both productivity losses and undesirable stress on equipment. Hydraulic pumps need fluid with a minimum level of viscosity to prevent significant internal leakage (backflow), which results in a decrease in fluid transmission to the hydraulic actuators. Slow fluid flow means sluggish response and a decrease in equipment productivity. When the flow rate slows down, the operator will typically push the pump to work harder, creating more heat so the fluid becomes even thinner. This nasty cycle leads to high wear and tear, and, ultimately, decreased life of the pump.

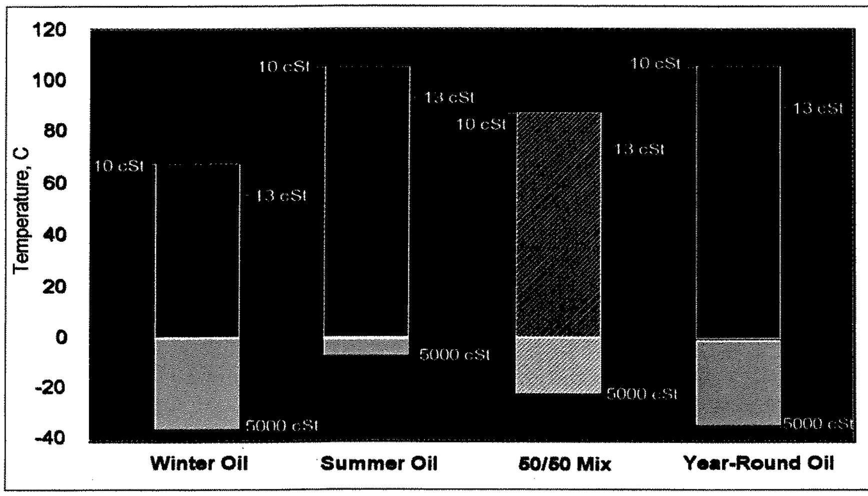
The study showed that hydraulic fluid runs much hotter than anticipated in most of the forestry equipment monitored. The problem can be solved if the system provides adequate cooling capacity, and fluid with the right viscosity is selected to minimize heat generation due to internal

Table 1 — Test fluids

Type	ISO Grade	Viscosity @ 40° C	Temperature @ 5000 cSt	Temperature @ 10 cSt
Monograde "seasonal" Winter grade	ISO VG 22	22 cSt	-37° C	67° C
Monograde "seasonal" Summer grade	ISO VG 100	100 cSt	-8° C	104° C
Multigrade "year-round" variety	ISO VG 46	46 cSt	-33° C	106° C

pump leakage.

Conversely, the use of summer-grade hydraulic fluid can be a problem in fall and spring, when evening temperatures occasionally drop below freezing. At this temperature, the summer grade fluid thickens above 5000 cSt making morning start-ups a problem. Hydraulic pumps require sufficient fluid flow to maintain 70- to 80-kPa suction pressure. When the fluid is too thick, there can be cavitation at the inlet port, resulting in high pump wear and sluggish system response. Operators reported that it was common to experience slow start-ups on cold mornings that required 15 to 30 minutes of slow speed control valve shifting to warm the fluid and maintain suction pressures above the minimum limit.



RohMax USA

Fig. 2. Viscosity profile of new monograde fluids, along with the 50/50 mix typically found after a fluid change.

Multigrade hydraulic fluids offer a wide TOW because they contain polymers that act as viscosity-index improvers. A quality multigrade hydraulic fluid is formulated with shear stable polymers that do not degrade in hydraulic fluid service. A shear-stable fluid will have long life in high-pressure service. Other multigrade fluids, such as engine oil or automatic transmission fluid (ATF), are not designed for high-pressure service, and will not perform well in hydraulic systems. (Some operators indicated that they sometimes used ATF fluid in their hydraulic systems, but this practice is not recommended.) All of the hydraulic fluids evaluated in this study exhibited good shear stability and constant viscosity characteristics over the test period.

One of the challenges in using lower-cost monograde fluid is scheduling the fluid changes. When does winter end and summer start? It is often undesirable to take equipment out of service due to seasonal weather patterns. However, it is far more desirable to conduct maintenance when it fits the work schedule or other planned maintenance events. Some operators attempt to perform fluid changes in the field in order to minimize downtime, but this creates other problems, such as fluid spills and waste disposal. Oil changes performed in the field are rarely as thorough as those performed in the maintenance garage.

When fluid changes are performed at any location, it is extremely difficult to drain the fluid from the entire system. This study revealed that only 45 to 55% of the fluid was drained when changing monograde fluids, which means that the fluid in the system becomes a blend of viscosities with unknown operating limits. Figure 2 shows the viscosity profile of new monograde fluids, as well as the 50/50 mix typically found after a fluid change. It is certainly possible to drain the remaining fluid out by manipulating the cylinders and lines, and by flushing the systems several times with new fluid. However, this practice is costly, time consuming, and rarely done.

Given the measured make-up rates, the study also showed that it took approximately six months of leakage and top-off additions to get the fluid back to its new-fluid viscosity range. However, once this point was reached, the

Table 2 — Cost for fluid maintenance

	Delimber 1	Delimber 2	Delimber 3	Grader 1	Grader 2	Grader 3
Monograde fluid changes	$1590	$1590	$1590	$953	$953	$747
Monograde top-off	$1680	$960	$1320	$204	$204	$180
Total	*$3270*	*$2550*	*$2910*	*$1157*	*$1157*	*$927*
Multigrade fluid change	$374	$374	$374	$231	$231	$141
Multigrade top-off	$2380	$1360	$1870	$289	$289	$255
Total	*$2754*	*$1734*	*$2244*	*$520*	*$520*	*$396*
Multigrade Savings/Year	$516	$816	$666	$637	$637	$531
% Cost Reduction	16%	32%	23%	55%	55%	57%

weather dictated that it was time to change the to fluid again. This is a very undesirable cycle of continued inefficient fluid performance. In addition, when multiple fluids are in use, there is an increased risk of cross contamination during weekly top-off additions.

While the volume of fluid consumed during normal operations is constant for monograde or multigrade fluids, two to three times the volume of monograde fluid must be disposed of yearly due to more frequent fluid changes (each change requiring the additional use of flushing fluid in order to minimize viscosity-dilution effects). The higher cost and environmental impact associated with this practice is undesirable.

Real costs

At the conclusion of the test, it was possible to calculate the cost of using each type of fluid. Three tree delimbers and three graders were selected for detailed evaluation. Each unit saw use of all three types of hydraulic fluid, and the leakage/make-up rate for each unit was documented. Table 2 shows the total cost of hydraulic fluid, maintenance, and disposal for each unit.

Monograde economics assume two fluid changes per year (summer and winter grades), fluid purchased at $1.20/l, double labor charges ($35/hr), and double fluid disposal charges ($0.0873/l). Additional costs due lost production time and increased equipment wear are significant, but were not accounted for in this analysis. Multigrade economics assume one fluid change per year, with fluid purchased at $1.70/l.

Conclusions

The FERIC study concludes that the use of multigrade hydraulic fluid was a factor in keeping forestry equipment operating in an optimum viscosity range, and offered consistent response and lubrication protection. The use of a single fluid guarantees predictable viscosity temperature performance, as fluid mixtures are avoided.

Monograde fluids are an acceptable low-cost option if the hardware can provide excellent fluid cooling and constant temperature control. Monograde fluids may also be used temporarily if there is a high leakage rate and lower cost fluid is required prior to service.

Multigrade hydraulic fluids are the preferred low-cost/high performance option when wide operating range temperatures are encountered. Maintenance, disposal, and downtime costs can be significantly reduced by eliminating semi-annual fluid changes in favor of a yearly (or longer) fluid-change interval. H&P

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