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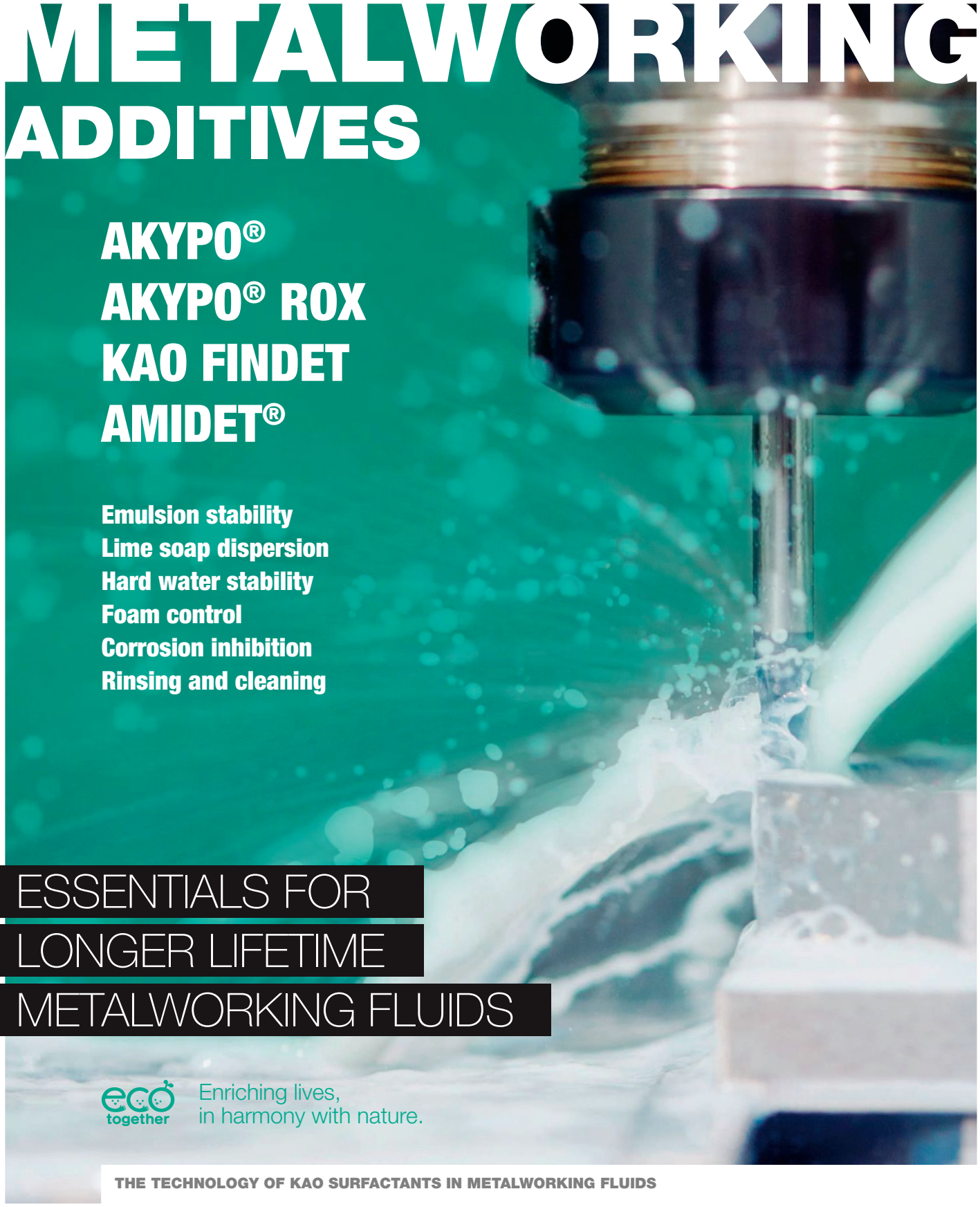

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Article by Bosch Rexroth; Authored by Karl-Heinz Blum, Fluid Validation - Germany, and Dipl.-Ing. Klaus Ellenrieder, Head of Department Testing - Germany

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Dipl.-Ing. Ralf Leonhardt, Head of Department Pumps & Motors Product Development – North America

Introduction
In this article Afton Chemical's CMF Key Driver Seminar guest speakers from Bosch Rexroth discuss how they are assessing and recognizing differentiated hydraulic fluid performance. This is very important as their OEM customers look to them to deliver continuous improvement in performance of their products. Differentiated performance demonstrates how fluids protect and extend the life of critical hydraulic system components and support increasing hydraulic system performance.

For more information about how Afton additives can help you provide differentiated hydraulic fluid performance to improve end-user productivity, reliability, and efficiency, contact your Afton representative at **www.AftonChemical.com/contact**

Pushing the Limits: The Pressures that Drive Hydraulic Fluids to New Heights
Over the past few years, the efficiency of hydraulic systems has again increased considerably. This also increases the demands made on the hydraulic fluids used, since they can have a crucial effect on the wear properties of hydraulic components. Relevant standards only define the minimum requirements of hydraulic fluids. They do not reflect further technical developments and do not make it possible to differentiate between the fluids. Bosch Rexroth offers the manufacturers of lubricants and additives a standardized assessment.

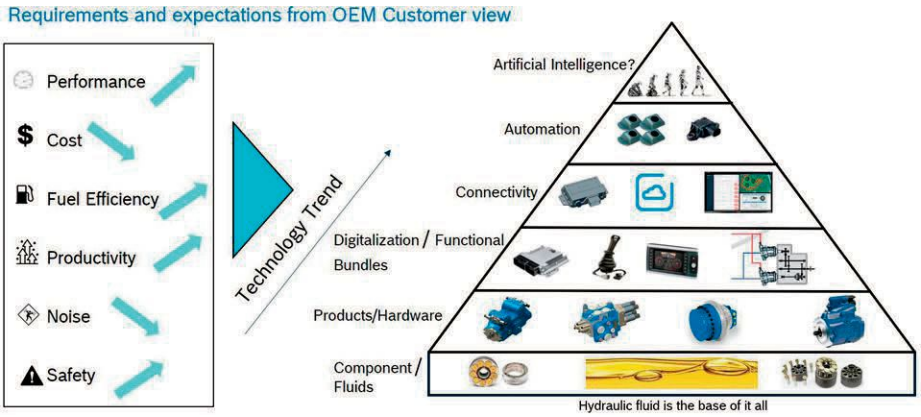

Figure 1. **From the Ground to the Cloud**

Bosch Rexroth's OEM customers have requirements and expectations of our hydraulic products to provide a continuous increase in product performance, fuel efficiency, productivity, and functional safety in combination with lower product cost and noise. The technology focus used to be the development of hardware only in combination with some electronics to control the products. Nowadays, the technology trend is digitalization, the need for connectivity of products with each other to establish more automation and ultimately more value for the end-user. We call this "from the ground to the cloud." *(Figure 1)*

Over the last few years power density has risen considerably to improve product performance, fuel efficiency, and productivity. This means that the power-to-weight ratio for axial piston pumps and motors has more than doubled over the last few decades. These increases in performance place demands on hydraulic fluids used more than ever before; therefore, the requirements for lubricant must increase as well *(Figure 2)*.

Hydraulic fluids have further developed as well. Developments of both lubricants and systems are not considered adequately in the relevant standards. Hydraulic fluids combined with the operating conditions have a crucial effect on the wear properties and consequently affect the lifetime of hydraulic components.

The standard requirements for hydraulic fluids (DIN 51524 or ISO 11158 for mineral oils; ISO 15380 for environmentally compatible hydraulic fluids and ISO 12922 for

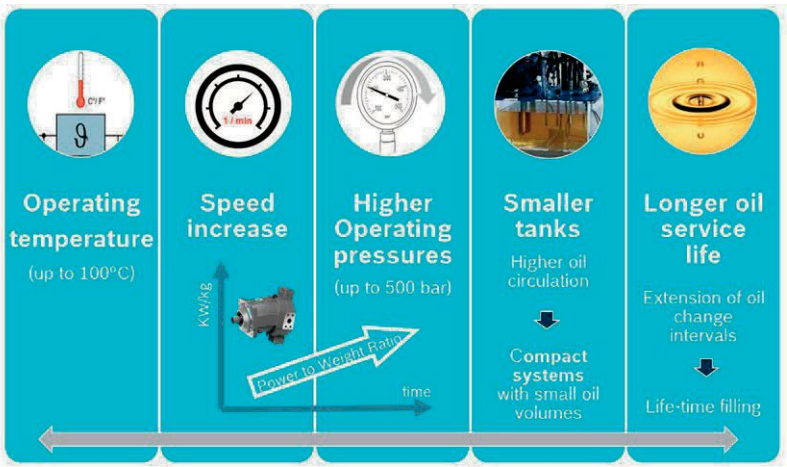

Figure 2. **Trends in Hydraulic Industries**

fire-resistance) only describe the minimum requirements of new and used fluids. These standard requirements do not take into account the chemicals used by lubricant manufacturers in the base oil and additives. Depending on the application and operating conditions, however, these chemicals can be highly relevant. This is the reason for component tests in addition to mechanical testing of vane pumps, which assess the suitability of the hydraulic fluid under real conditions on a product-specific basis.

Bosch Rexroth has gathered a wide range of experience in numerous tests with fluids. Some of the hydraulic fluids tested demonstrated very different wear properties after a relatively short operating time in recent motor and pump applications: For example, a fluid that complied with the minimum requirements of the standard led to significant wear in pumps and motors after less than 100 operating hours *(Figure 3)*.

Bosch Rexroth Rating Procedure

To meet the aim of reducing the risk of damage due to fluids and to increase operating safety for machine manufacturers and operators, Bosch Rexroth developed a neutral rating procedure based on existing DIN or ISO minimum requirements. This means Rexroth tests the behavior of fluids in a practical way as well as the reciprocal effects on the core components of the pump and motor. This is suitable for all mineral oil-based hydraulic media, related hydrocarbons, environmentally acceptable media as well as fire-resistant anhydrous hydraulic fluids.

To have the effectiveness of hydraulic fluids rated on an independent basis, manufacturers of lubricants and additives can register at **www.boschrexroth.com/fluidrating**. Rexroth data sheet 90235 describes the rating procedure in detail. Within the scope of the Rexroth Fluid Rating, the manufacturer tests the technical characteristics of the hydraulic fluid. Rexroth checks the values for plausibility and confirms for compliance with the standard. The additional requirements include stricter standard characteristic values, motor, and pump tests as well as a specified, static seal test that evaluates the suitability of the hydraulic fluid with defined Rexroth components and conditions. Depending on the fluid category and the Rexroth components that are used, the fluid test must pass before commissioning the fluid rating. In addition,

Figure 4. **Fluid Rating Quality Label**

samples of the base oils that are used and tested hydraulic fluids are stored for future reference.

If the hydraulic fluid meets all the requirements of RDE 90235, it is included in Bosch Rexroth Fluid Rating List 90245. The Fluid Rating List replaces current market overviews RD 90220-01 (mineral oils) and RD 90221-01 (environmentally acceptable hydraulic fluids).

In addition to this, Rexroth issues a quality label to the manufacturers of the hydraulic fluids listed in RDE 90245 *(Figure 4)*. This means users can recognize immediately that the hydraulic fluid in question has been qualified and is a high-quality fluid.

Figure 3. **Causes of failure due to fluid**

The Fluid Test

Bosch Rexroth currently offers one fluid test each for closed loops and open loops. Rexroth's "Fluid Test Axial Piston Unit Closed Loop" (RFT-APU-CL) represents the current requirements of a hydrostatic drive. It uses a combined unit consisting of a swashplate hydraulic pump (A4VG) and a swashplate hydraulic motor (A6VM).

Under real-world conditions, the hydraulic fluid goes through a break-in, a cyclic phase, and a full speed and pressure phase. At high loading levels, the unit runs for several hundred operating hours at 4000 RPM during the test and at an operating pressure of up to 500 bar.

Following the test, the test unit is disassembled, and the combination of effects between the hydraulic fluid and the components are examined. While doing this, changes in the weight of the components or their dimensions are measured, and a visual inspection is carried out for the component's surfaces. From this, Bosch Rexroth specialists derive material compatibilities and wear properties. In addition, Rexroth analyses the condition of the hydraulic fluid before, during, and after the test. This allows drawing valid conclusions about the continuous operation or wear properties. Depending on the pump/motor combination and the hydraulic fluid used, we envision further tests in the future, including cavitation and aging properties, for example.

Real-world experience indicated some fluids used in the field did not pass the Rexroth fluid test due to the insufficient wear properties. An optimized fluid demonstrates sufficient wear properties, which successfully passed the fluid test. This fluid replaced the original fluid in the field, leading to successfully solving the field problem.

Rexroth's "Fluid Test Axial Piston Unit Open Loop-HFC" (RFT-APU-OL-HFC) for hydraulic fluids in an open-loop represents the requirements for applications specifically with fire-resistant, aqueous hydraulic fluids of Category HFC. The fluid test consists of a constant conditions phase and a swivel cycle test. The test consists of a high-pressure A4VSO swashplate combined unit and a medium-pressure EA-10VSO swashplate unit. As previously, the test unit is disassembled after the test, and the components and hydraulic fluid are inspected for their effects according to similar rating criteria as with the "RFT-APU-CL" fluid test.

Figure 5. **Test Rig RFT-APU-CL**

Figure 6. **Test Rig RFT-OA and Oil Aging Gradation**

If desired, Bosch Rexroth offers the fluid test rig (RFT-APU-CL) manufacturers of lubricants and additives can use in test laboratories for their own development work *(Figure 5)*.

In addition, Rexroth also offers a fluid aging test rig (RFT-OA), which can represent real-life oil aging by the controlled addition of air, water, metal, and non-metallic particles to accelerate aging of the oil. *(Figure 6)* Both test rig models are available for purchase for new lubricants development or problem solving at lubricant manufacturer's site.

Conclusion

As Karl-Heinz Blum, the manager responsible for fluid validation at Bosch Rexroth, emphasizes, "Our results from fluid ratings demonstrate enormous differences between the hydraulic fluids that are available on the market, even though they all meet the minimum requirements of the standards. Machine manufacturers who use the Bosch Rexroth Fluid Rating List to orient themselves when selecting hydraulic fluids improve operational safety; reduce the probability of pump and motor failure and lower downtime and maintenance costs".

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A review of two Croda new product launches and an Ecolabel update

By Scott Davis,
US Sales Manager - Energy Technologies
Scott.Davis@croda.com

PERFAD™ 3500 Series organic friction modifiers for manual transmission motorcycles

As cities become more populated, there are even more vehicles on our roads. In some countries and cities, motorcycles comprise the majority of vehicles on the road. As a result, emissions regulation of motorcycles has become a larger priority and stricter requirements are being implemented globally.

Passenger car engine oils use a combination of lower viscosity lubricants and the addition of friction modifiers to meet fuel economy and emissions requirements. The use of friction modifiers in four-stroke motorcycles has been limited because most motorcycles utilize a "wet" clutch which uses the same oil used to lubricate the transmission and engine. The opposing needs of low friction in the engine and transmission while maintaining high clutch friction have not been previously addressed by traditional friction modifiers. Croda recently introduced the Perfad 3500 series of organic friction modifiers to address the unmet need of providing low steel/steel friction and high clutch friction for applications such as 4-stroke motorcycle oils.

To demonstrate the performance of the Perfad 3500 series of organic friction modifiers, we top treated seven commercially available motorcycle oils at 0.5% or 1% depending on the solubility of the four friction modifiers in each oil. We tested them in the JASO T903 clutch friction test and the mini traction machine (MTM) steel/steel friction test. MTM testing was conducted from 0.005 ms^{-1} to 3 ms^{-1} to achieve boundary and mixed lubrication. All seven top treated oils demonstrated a significant reduction in steel/steel friction. In two of the top treated oils, the Perfad 3500 series friction modifiers maintained or improved the clutch friction. There was a slight reduction in clutch friction in 3 oils, but the reduction was small enough that they still maintained their untreated T903 rating of MA2, MA, or MB. A typical result is shown in *Figure 1*.

Photo courtesy of Croda Lubricants.

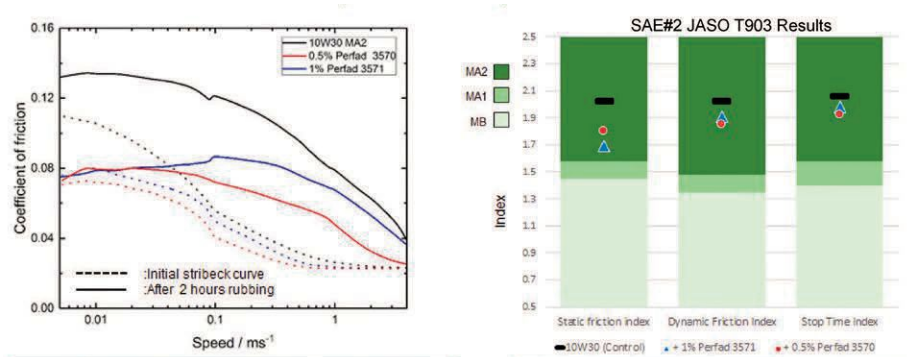
Croda has developed a line of organic friction modifiers for manual transmission motorcycles.

Priolube™ 3997: A new oxidatively stable thickener

Croda recently introduced a new oxidatively stable thickener called Priolube 3997. It is designed to replace other less oxidatively stable complex esters or bright stock. The properties of Priolube 3997 can be viewed in *Figure 2*. The high VI of 290 indicates the potential of Priolube 3997 to improve the VI of lubricants when used as a substitute for bright stock.

The oxidative stability of Priolube 3997 was evaluated using the Rapidoxy test (ASTM D7545) and compared to that of two other complex esters of similar viscosity. The Oxidation Induction Time (OIT) was determined, which is the time taken for 10% of the oxygen to be consumed and indicates the onset of rapid oxidation. Priolube 3997 gave an OIT of 245 minutes and significantly outperformed the other two products which gave OITs of 85 minutes and 72 minutes. We then tested a 10% treat rate of the thickeners in Chevron 600R, a Group II base oil. One of the complex esters caused a decrease in oxidative stability from 82 minutes for straight Group II. The other complex ester provided a slight increase in stability to 96 minutes. Priolube 3997 offered the best performance of 125

10W30 MA2 (LATAM)



Speed/ ms-1	Coefficient of friction reduction, vs untreated, %	
	Perfad 3570	Perfad 3571
0.01	-41	-41
0.1	-41	-29
1	-39	-11

Manufacturer's performance classification (T903: 2011)	MA2
Croda Control (JASO T903: 2016)	MA2
Perfad 3570 0.5%	MA2
Perfad 3571 1%	MA2

Figure 1. **(a) Shows the frictional performance of top treated motorcycle engine oils. (b) Shows the performance in the JASO T903 test.**

Priolube™ 3997 - Ester Viscosity Modifier

Property	Unit	Typical value
KV@ 40°C	mm²/s	40000
KV@100°C	mm²/s	2000
Viscosity Index	-	290
Iodine value	gl/100g	7
Pour point	°C	6

Figure 2. **Table showing the typical physical properties of Priolube 3997.**

Oxidation and Thermal Stability

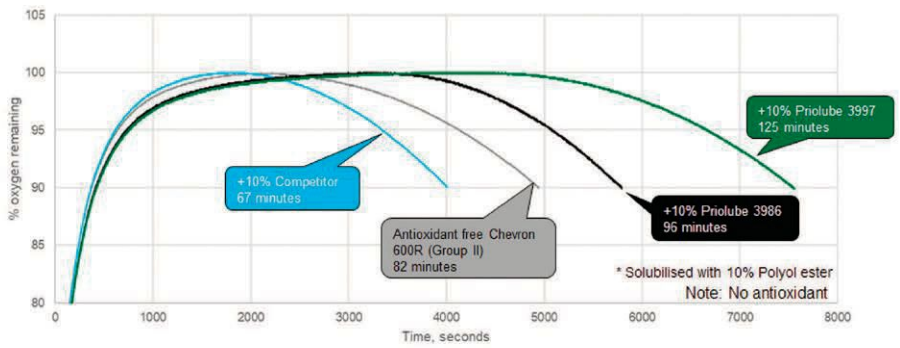


Figure 3. **Oxidation and thermal stability at 140°C: 10% in Chevron 600R Group II base oil.**

minutes, which was an improvement 3x better than the next best complex ester. *Results shown in Figure 3.*

Due to sulfur limits and the desire for lower viscosity base fluids for passenger car engine oils, manufacturers are decreasing their production of Group I base oils in favor of Group II. This has tightened the market for Group I base oils and caused lubricant manufacturers to consider alternate thickeners. In order to consider its suitability as a replacement, we compared the oxidative stability of Priolube 3997 to bright stock. Bright stock outperformed Priolube 3997 in the Rapidoxy test due to its high natural sulfur content which acts as an antioxidant. However, this sulfur also forms sulfur complexes that drop out as sludge and deposits. An oven test at 180°C demonstrates the ability of Priolube 3997 to prevent sludge and deposits compared to bright stock. *Results shown in Figure 4.*

Priolube 3997 also offers a lubricity benefit compared to other complex ester thickeners and bright stock. We evaluated ISO 150 gears oils made with a competitive complex ester, bright stock and Priolube 3997. We tested the gear oils in the mini traction machine at 0.05 m/s and 100°C using a 50:50 sliding to rolling ratio. The frictional performance was observed as contact pressure was increased from 1.25 GPa – 3.2 GPa. The Priolube 3997 thickened gear oil demonstrated lower friction across the contact pressure range. At 1.3 GPa, the Priolube 3997 containing gear oil offered an 11% friction reduction vs the gear oils containing bright stock or the competitive complex ester. *Results shown in Figure 5.*

Another benefit that Priolube 3997 provides compared to bright stock is superior wear performance. We evaluated ISO 150 gear oils made with Priolube 3997 and bright stock in a simulated FZG gear test using an SRV rig. The gear oil made with bright stock failed stage 13 while the gear oil made with Priolube 3997 was able to pass stage 13.

Because Priolube 3997 is a relatively large molecule, it was appropriate to test its shear stability. An ISO 150 gear oil formulation was made using 5% Priolube 3997. In a 20-hour KRL shear stability test, the gear oil made with Priolube 3997 had a viscosity

loss of only 4.1%. This result was superior to the viscosity loss of 4.7% and 8.5% for the gear oils made with competitive complex esters.

Priolube 3997 is a thickener that provides superior oxidative stability, lubricity, and lower friction than competitive complex esters. It creates less sludge and deposits than bright stock, while providing improved lubricity and lower friction. Priolube 3997 also has the potential to increase gear loading compared to formulations made with bright stock.

Changes to Ecolabel

There was a recent revision of the EU Ecolabel scheme. Three product groups replace the five groups that were used in the 2011 revision.

- Total Loss Lubricants (TLL) include chainsaw oils, wire rope lubricants, concrete release agents, total loss greases and other total loss lubricants.
- Partial Loss Lubricants (PLL) include open gear oils, stern tube oils, two-stroke oils and, partial loss greases.
- Accidental Loss Lubricants (ALL) include hydraulic systems, metalworking fluids, closed gear oils and, accidental loss greases.

Figure 6 summarizes the minimum readily biodegradable content required for each product group.

Ecolabel no longer specifies a renewability requirement unless the term "bio-based" or "bio-lubricant" is used. In order to be called "bio-based", the minimum bio-based carbon content in the final product must be 25% per EN 16807. Renewability content can no longer be calculated. It must be measured by ASTM D6866. Furthermore, renewable ingredients from palm kernel oil or palm oil must be obtained from a certified sustainable source.

The LuSC list will be adapted to reflect the new criteria in EU Ecolabel Revision November 2018. Croda has reapplied for all existing products to be added to the new LuSC list. Croda's updates to the LuSC list will continue to appear throughout 2019. Croda offers 17 esters that will be LuSC compliant in 2019. Viscosities available range from 15 cSt @40°C to 47,000 cSt @ 40°C.

Oven Test at 180°C: Differences in Color, Deposit and Sludge Formation, Neat

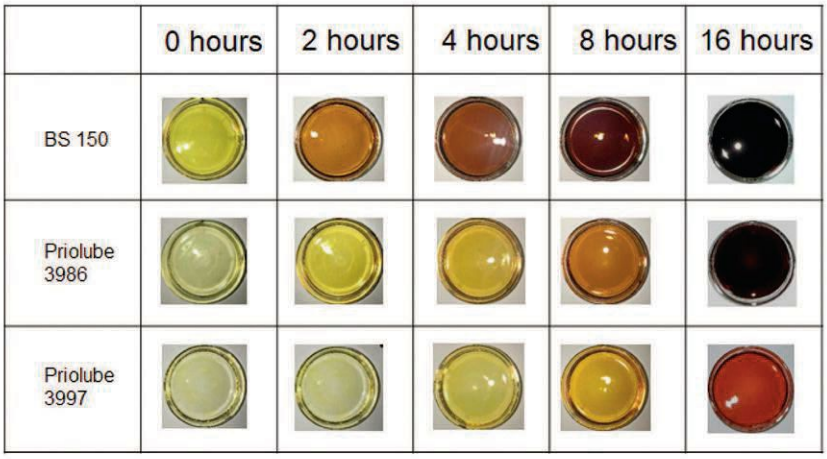


Figure 4. **Shows results of high temperature oven tests for Priolube 3997 versus brightstock 150 and Priolube 3986.**

MTM - Barrel on Disk

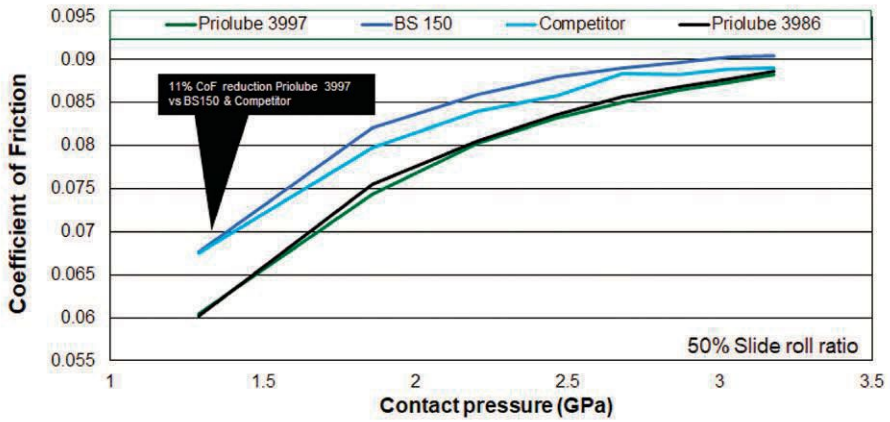


Figure 5. **Frictional performance of ISO 150 gear oil formulations with varying contact pressure.**

Biodegradability

	ALL	PLL	TLL	Greases (ALL, PLL, TLL)
Readily aerobically biodegradable	> 90	> 75	> 95	> 80
Inherently aerobically biodegradable	≤ 10	≤ 25	≤ 5	≤ 20
Non-biodegradable and non-bio accumulative	≤ 5	≤ 20	≤ 5	≤ 15
Non-biodegradable and bio accumulative	≤ 0,1	≤ 0,1	≤ 0,1	≤ 0,1

Cumulative mass percentage (%w/w) limits for substances present in the product with respect to their biodegradability and bio-accumulation potential

Figure 6. **Biodegradability guidelines for each lubricant class.**

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- Chainsaw oils
- Wire rope lubricants
- Concrete release agents
- Total loss greases
- Other total loss lubricants

Partial Loss Lubricants (PLL)

- Gear oils for use in open gears
- Stern tube oils
- Two-stroke oils
- Temporary protection against corrosion
- Partial loss greases
- Stern tube oils classified as partial loss lubricants

Accidental Loss Lubricants (ALL)

- Hydraulic systems
- Metalworking fluids
- Closed gear oils
- Accidental loss greases

In a world where awareness of our environmental impact is growing, we remain dedicated to meeting future legislation demands.

If you are formulating to any environmental regulation, contact us for the very best advice on Ecolabel compliance.

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CRODA

Cost saving synthetic solutions for the high-tier industrial gear oil market

David B Gray
NA OEM Manager
Evonik Oil Additives USA, Inc.

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In response to the changing dynamics of the Industrial Gear Oil (IGO) market, Evonik Oil Additives has developed NUFLUX™ technology; a collection of products, formulation concepts and services. When applied to industrial gear oil formulations it offers the benefits of improved efficiency and reduced operating temperatures at a lower cost versus the traditional synthetic solutions.

Evonik has been able to achieve these benefits by formulating NUFLUX™ industrial gear oils with VISCOBASE® synthetic base fluids. In addition, these formulations have been validated in a range of performance demonstrations across multiple applications. In all cases, improvements in gearbox efficiency and reductions in operating temperatures have been observed, resulting in extended fluid life versus mineral IGOs.

NUFLUX™ IGOs benefit from a combination of synthetic base oils, formulation concepts, OEM approvals, and technical services and are compatible with a comprehensive range of base fluids and additive systems. NUFLUX™ IGOs are applicable to a wide range of lubricant applications including industrial gearboxes and wind turbines.

In this article, we summarize data obtained on NUFLUX™ synthetic IGOs in real world comparisons to existing fluids and discuss the concepts, development, and performance benefits of this exciting new technology.

The Market:
The IGO market is relatively mature with an estimated 1,000,000 MT consumed in 2018 and a projected compounded annual

growth rate (CAGR) of 0.1%. However, due to recent changes in fluid requirements and a subsequent drive to synthetic solutions, top-tier products are enjoying significant growth.

The IGO market is split broadly into three classifications: mineral oil-based lubricants that meet basic requirements, enhanced mineral oil-based lubricants meeting specific OEM specifications, and top tier synthetic lubricants with a full slate of approvals and class-leading performance. At the expense of lower-tier mineral-oil based lubricants, demand for synthetic lubricants is increasing rapidly with market share increasing from 8% today to 12% share in 2025.

The growth in synthetic fluids demand is being driven by increasingly severe operating conditions and environment, changes in power density, and social trends focusing on sustainability. Equipment durability to limit downtime remains a critical and over-arching requirement.

Synthetic IGOs offer a wide range of advantages such as superior lubricity, lower volatility, oxidative stability, and extended drain intervals. In this article we will confine ourselves to the differences between mineral oil-based IGOs and synthetic IGOs with respect to low and high temperature performance and the associated changes in the viscosity/temperature relationship.

In *Chart 1*, we can see the general relationship between viscosity and temperature in ISO VG 320 Gear Oils. In simple terms the mineral oil-based fluid has a narrow temperature range of operation while the synthetic-based fluid has a broader range of operation. This offers reduced viscosity at colder temperatures and increased viscosity at higher temperatures. These optimized viscometrics ensure the benefits of efficient operation in cold conditions and satisfactory equipment protection at higher temperatures.

A typical synthetic IGO consists of an additive package, synthetic base oil such as Poly Alpha Olefin (PAO), and a compatibilizer, typically an Ester, to ensure the additive package remains in solution in the synthetic base oil. *(Chart 2)*

NUFLUX™ IGOs, utilize VISCOBASE® synthetic base fluids and Group III base oils, replacing the PAO and eliminating the com-

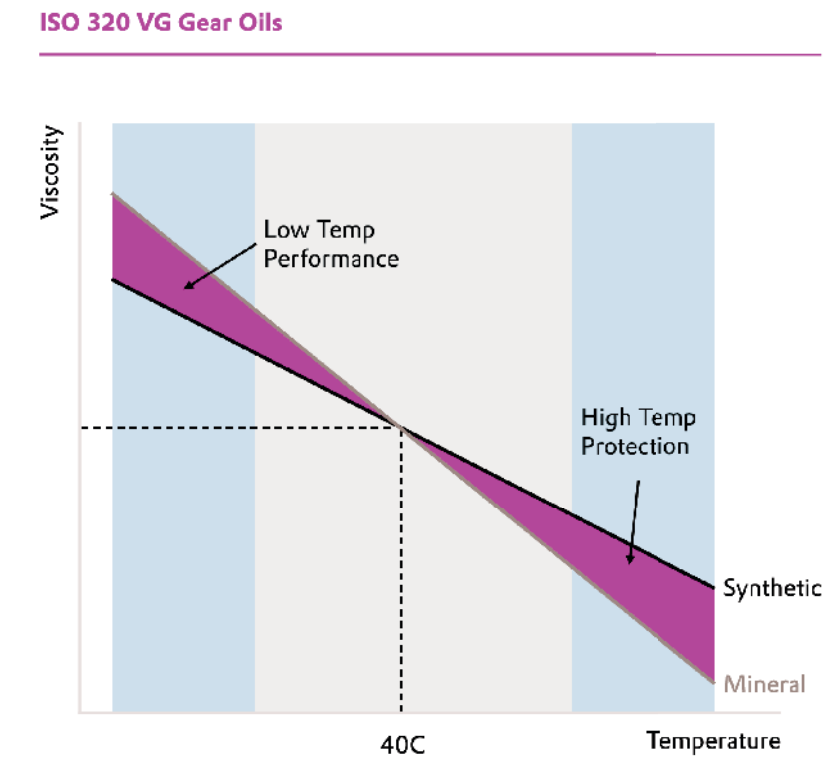


Chart 1. **loglog Viscosity vs Temperature**

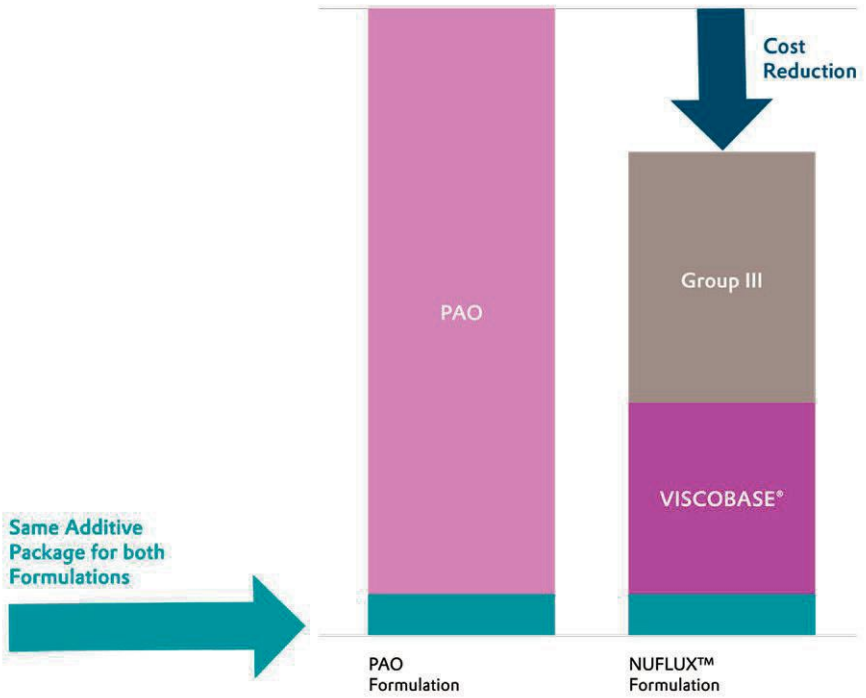


Chart 2.

patibilizer which reduces the cost of the formulation. This is possible as VISCOBASE® base fluids have a well-balanced polarity which results in good additive package solubility and excellent seal compatibility.

NUFLUX™ formulations have been tested extensively in a range of standard bench tests and meet (or exceed) industry standards and key OEM specifications. However, as Evonik has learned from developing other novel technologies, performance in the field under real world conditions is essential to confirm the findings of the laboratory.

Performance demonstrations

The *proof of the pudding* they say, *is in the eating,* so with that in mind, Evonik determined that relatable performance demonstrations were an essential part of conveying the advantages of NUFLUX™ technology. While the theory was proven and bench testing indicated significant advantages over mineral oils, testing in the field is essential and a universally recognized proof of concept.

Evonik learned from earlier development and testing of Efficient Hydraulic Fluids that robust testing protocols are essential. These were developed in conjunction with both OEMs and equipment operators to ensure meaningful data. At each site, the test equipment was instrumented, and the sites were visited on multiple occasions by Evonik's highly skilled operators from the Performance Test Laboratory based in Darmstadt, Germany.

Evonik identified sites for performance demonstrations in Africa, Asia, Europe and the United States. The focus was on wind turbines, mining, and water treatment applications including a controlled trial using a specially designed dynamometer test rig. This trial was conducted with a large gearbox similar to that used in both the mining industry and the water treatment plants. For wind turbine, the primary gearbox was selected while for the mining application, material conveyor gearboxes in a quarry were selected. In the water treatment plant, gearboxes used for agitation proved to be most applicable.

Controlled large scale trial

For the controlled trial, a large 3 stage bevel-spur gearbox (Jake KST II 250B) was installed on a custom test rig equipped with a 400kW motor, and a brake to record output power, a torque meter for input torque and an identical slave gearbox to reduce the very high torque levels. The low reference fluid selected was the OEM recommended VG 320 which was compared directly with NUFLUX™ VG 220, NUFLUX™ VG 320, and NUFLUX™ SYN VG 320. In addition to high reference VG 320 and VG 220 grades and testing was completed over 3 different load stages. The rig was instrumented for oil temperature, input bearing cooling and water temperature. Input and output torque were recorded to determine system efficiency.

NUFLUX™ IGOs were *found to reduce oil sump temperatures between 6°C and 10°C,* versus the OEM recommend mineral fluid. Similarly, *input bearing temperatures were reduced by 10°C to 13°C* with greater separation at increasing loads. Additionally, NUFLUX™ IGOs were proven to be equivalent in terms of efficiency gains to PAO based fluids while all synthetic IGOs were more efficient than the mineral oil IGOs. Further incremental gains could be found if moving to the VG 220 grades if the specific application permits.

Wind Turbine

Evonik has conducted performance demonstrations of NUFLUX™ VG 320 in more than 30 wind turbine gearboxes up to 2MW capacity over 6 years without oil changes or recorded performance or hardware concerns. More than 20 additional gearboxes are currently filled or being filled with NUFLUX™ VG 320, the longest running approaching 36 months with zero concerns. In the earlier demonstrations, *5°C lower temperatures were recorded* versus the previous PAO base formulation and in a different gearbox, *residues previously seen on the high-speed bearings and pinions were removed* after switching to the NUFLUX™ formulation. General oil analysis showed reduced ferrous particle counts and copper levels less than 2ppm with *no abnormal or excessive wear observed*.

Mining

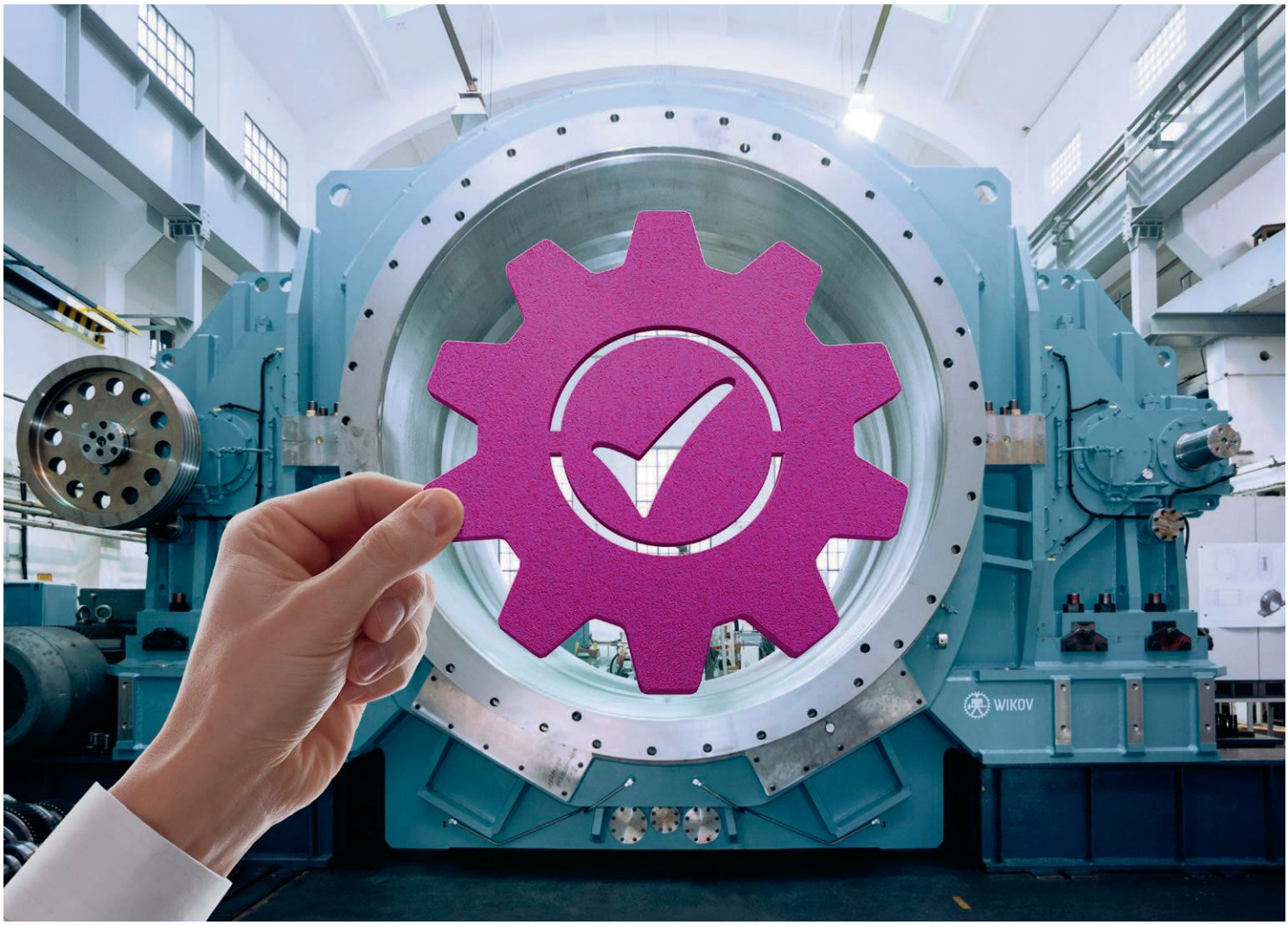
A dolomite quarry located in South Africa that utilizes Hansen RDF 33Q CRN transmission gearboxes for materials conveyors was selected. The gearboxes were filled with NUFLUX™ VG 320 and instrumented to measure relative gearbox efficiency, vibration, and heat profiles. While loads are relatively steady, the environment is especially harsh with high ambient temperatures and abrasive, airborne particulate matter from the mining process. This 6-month demonstration is nearing completion with data indicating *improved efficiency versus the incumbent fluid and reduced vibration* in addition to zero incidences of abnormal wear despite the harsh environment.

Water Processing

A water processing plant located in South Africa that uses Hansen P4, 3 stage gearboxes to agitate sewage effluent was selected. The recommended fluid was an ISO VG 220 fluid, so the gearboxes were filled with NUFLUX™ VG 220. The gearboxes were instrumented for oil sump temperature, vibration, and energy consumed versus power delivered to establish relative gearbox efficiency. The loads in the application are very steady and ambient temperatures consistent, which make for accurate comparisons. By comparing the measured energy consumption and power delivery, the efficiency of both the incumbent VG 220 and the NUFLUX™ VG 220 were calculated. Over the 2-month period of the demonstration, the NUFLUX™ fluid measured an *efficiency improvement of 2.9% percent versus the incumbent mineral oil-based fluid.* When multiplied by the large number of gearboxes employed in the plant a 2.9% improvement represents a significant energy savings.

Summary

Evonik has developed a new formulation technology for industrial gear oils that has proven to provide increased efficiency and reduced operating temperatures versus mineral based lubricants across a broad range of real-world applications. These IGOs formulated with VISCOBASE® synthetic base fluids offer comparable performance to traditional synthetic solutions at a reduced cost. As such, NUFLUX™ IGOs have the potential to reduce the cost of operations and improve the efficiency across a wide range of Industrial gearboxes.



Gear-up for efficiency.

NUFLUX™

Industrial gear oils are transformed with Evonik's NUFLUX™ technology. Geared for higher performance with lower formulation cost, Evonik additive technology provides a premium solution backed up by OEM approvals, industry standards and performance tests. With NUFLUX™ technology, you'll find a broad range of viscosity grades suitable for a variety of demanding industrial gear applications.

The Oil Additives specialists at Evonik — Let it flow.
www.evonik.com/oil-additives

EVONIK
POWER TO CREATE

Why sacrifice wear protection for energy efficiency?

By Michael P. Sheehan
Senior Staff Chemist, Marketing Technical Services
ExxonMobil Chemical Company

Today's industrial sector accounts for nearly half of the world's energy consumption. Improved energy efficiency in this sector obviously can have a major impact on the world's energy use, which is predicted to grow as much as 25 percent by 2040.*

To help lower industrial energy consumption, lubricant formulators have increased their use of synthetic base stocks, which have been known to improve energy efficiency. But limited test data existed to measure this improvement.

That's why ExxonMobil commissioned a series of tests at the Institute of Energy of the University of Porto (INEGI). Our goals:

- Verify and quantify the energy efficiency gained by using synthetic base stocks.
- Assess the concern of some equipment builders and owners that low-viscosity, synthetic-based lubricants may result in lower wear protection.

Our SpectraSyn™ polyalphaolefin (cPAO) and SpectraSyn Elite™ metallocene polyalphaolefin (mPAO) synthetic base stocks have demonstrated excellent wear protection capabilities, but we wanted specific rig data.

- Compare the performance of SpectraSyn Elite mPAO base stocks with conventional PAO, measuring energy efficiency and wear protection.

With this data, we could better guide formulators with solutions that help them innovate energy-efficient industrial lubricants for today's changing marketplace.

mPAO makes a difference

Created using a proprietary metallocene catalyst process, SpectraSyn Elite mPAO offers much higher viscosity index (VI), better low-temperature fluidity, enhanced film thickness and much lower foaming than conventional high-viscosity cPAO.

The differences between mPAO and cPAO can be seen at the molecular level *(Figure 1)*. Metallocene PAO has a uniform, comb-like structure and lacks random short side chains, while conventional PAO

has short and long side chains in a random orientation on either side of the main backbone. These differences help explain the enhanced performance properties of mPAO.

Through the INEGI test program, we wanted to answer a key question: Does the higher VI and enhanced film thickness properties in SpectraSyn Elite mPAO enable formulators to reduce lubricant viscosity to improve energy efficiency without impacting wear protection?

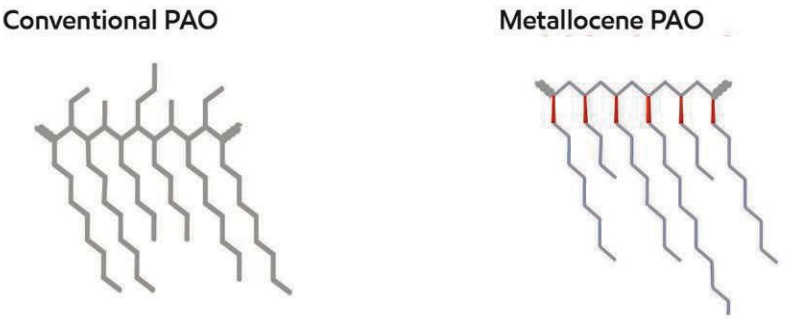


Figure 1.

How did we prove it?

We compared formulations using mineral and synthetic base stocks (cPAO and mPAO) by measuring EHL film thickness, traction curves, energy efficiency and wear protection performance.

The rig test program evaluated roller thrust bearing and FZG gear tests. The program tests measured:

- EHL film thickness at 40°C, 80°C and 120°C, calculating viscosity using ASTM D341
- Traction coefficient at 80°C
- Roller bearing temperature and friction torque at rotational speeds of 75.0, 150.0, 300.0, 600.0, 900.0 and 1,200.0
- FZG power loss at 500 rpm, 1,000 rpm and 1,750 rpm
- FZG gear set wear (mass loss, mg)

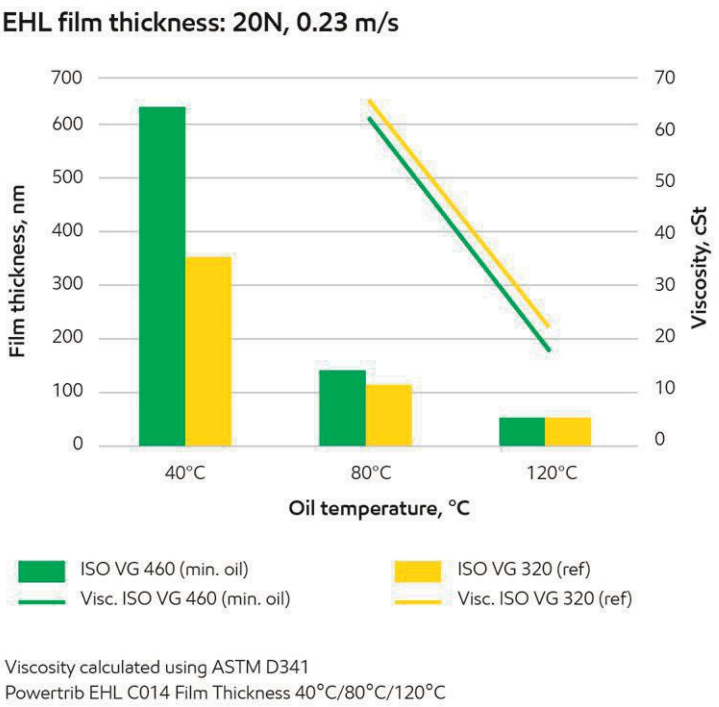


Figure 2.

Mineral vs. cPAO synthetic

The first set of tests compared an ISO VG 460 mineral oil formulation with an ISO VG 320 (58.90 percent cPAO) conventional synthetic PAO reference oil formulation. The synthetic oil demonstrated equivalent film thickness at higher temperatures (80 and 120°C) typical of industrial equipment in operation *(Figure 2)*, along with lower traction properties, which can enable energy efficiency.

In the roller bearing test, the synthetic showed 14 percent less power loss and operated at a 21 percent lower temperature. In the FZG test, the synthetic demonstrated lower power consumption while maintaining equivalent wear protection.

Overall, the synthetic formulation provided the same level of wear protection as the mineral-based lubricant, even as it delivered substantial energy savings through reduced power consumption.

cPAO vs. 7 percent mPAO

The second set of tests compared the ISO VG 320 reference oil with a similar formulation that substituted 7 percent of the high viscosity cPAO with SpectraSyn Elite™ 300 mPAO.

The oil formulated with mPAO demonstrated enhanced film thickness at 80 and 120°C and equivalent traction properties. The oils were roughly the same in terms of power consumption and wear protection.

The differences were much clearer in the roller thrust bearing test *(Figure 3)*. Without sacrificing wear protection, the oil with mPAO reduced power loss by 11 percent, proving energy efficiency, and lowered operating temperature by 10 percent.

cPAO vs. mPAO formulations

The final study compared the ISO VG 320 reference oil with two lower viscosity oils that included roughly 50 percent mPAO — an ISO VG 270 (53.40 percent mPAO) and an ISO VG 220 (49.34 percent mPAO).

The mPAO oils demonstrated lower traction properties, which translate to greater energy efficiency. Despite their lower viscosity, these oils maintained roughly equivalent film thickness with the reference oil at 80°C and 120°C *(Figure 4)*.

In the roller thrust bearing test, the ISO VG 220 operated at a 9 percent lower temperature, while all three demonstrated the same level of power loss, as they did in the

FZG test. They also showed no significant difference in wear protection.

Breaking barriers

We now have more specific data to measure how SpectraSyn Elite™ mPAO base stocks can offer enhanced film thickness and energy efficiency while also maintaining wear protection. Lubricants formulated with mPAO base stocks also can operate at lower temperatures, delaying oxidation degradation to help oil stay in grade longer.

The tests confirm: SpectraSyn Elite mPAO base stocks give formulators the flexibility to create innovative lubricants that meet the changing demands of their customers.

**Source for energy statistics: ExxonMobil's Outlook for Energy.*

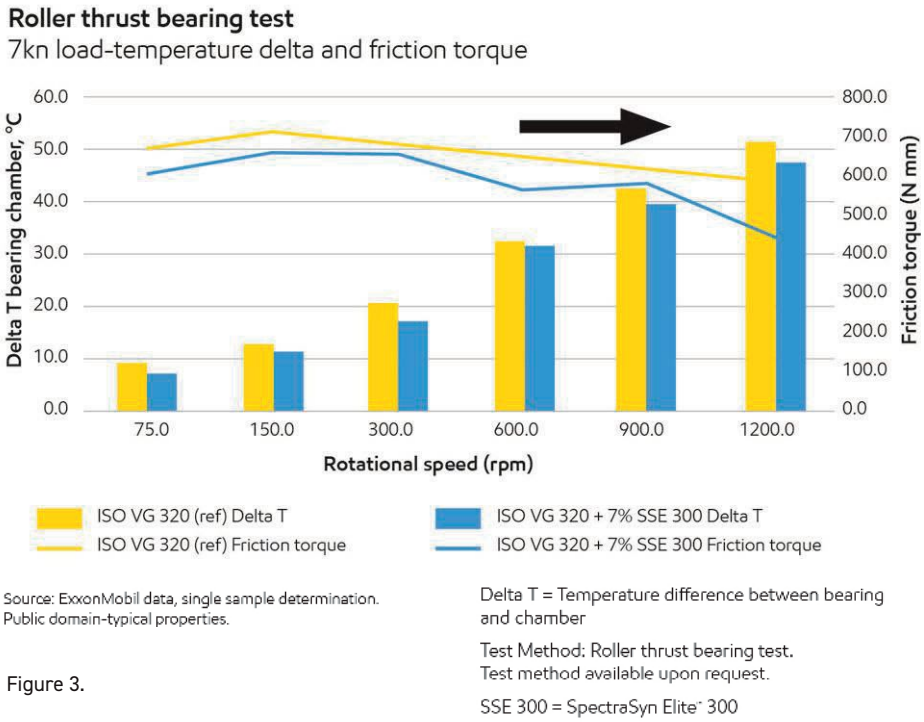


Figure 3.

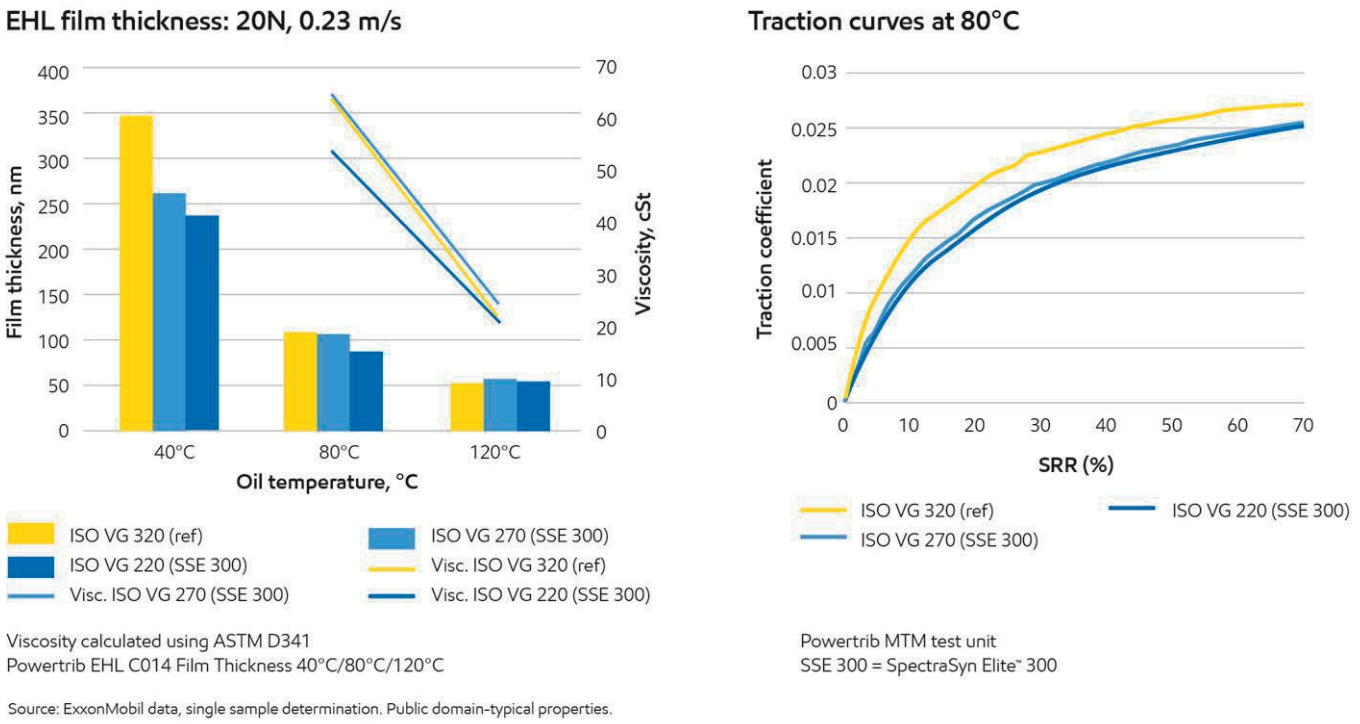


Figure 4.

When reliability counts, count on us.

Your company relies on you for timely procurement to meet ever-tighter production deadlines. You can rely on us for consistent, high-quality synthetic base stocks, a world-class global supply network and exceptional support. What you need when you need it.

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High Temperature Performance with NA-LUBE® KR Alkylated Naphthalenes

By Ross Dworet, MBA
Technical Marketing Engineer
King Industries, Inc.

Industrial fluid markets continue to push towards extended life fluids capable of improving both equipment life and production uptime to provide optimal operational efficiency. As such, fluids experience increased flow, higher temperatures, thinner films, reduced volumes, and sealed-for-life systems. More refined base stocks and synthetics have contributed to significant strides in satisfying industrial demands. There are limitations in these fluids' performance in areas such as additive and elastomer compatibility as well as thermal properties. To meet growing demands in industrial lubricants, automotive oils, e-fluids, and greases, optimized combinations of highly refined petroleum oils and synthetic base stocks have become the mainstay in driving base stock performance.

Properties

NA-LUBE® KR alkylated naphthalenes, classified as Group V base fluids by the API, are typically utilized in lubricant formulations as co-base stocks to replace a portion of Group II, Group III, and/or Group IV oils. Incorporation of NA-LUBE KR enhances thermo-oxidative stability and functional additive response while simultaneously extending fluid operating life especially in dynamic fluid systems. The range of NA-LUBE KR Series products provides several formulating options through a combination of viscosities, aniline points, and volatilities with HX-1 grade alkylated naphthalenes also available.

The structure of alkylated naphthalenes *(Figure 1)* consists of alkyl chains attached to a core of two fused six member rings with a highly stable electron rich conjugated π system.

NA-LUBE KR alkylated naphthalenes are supplied as mono alkylated and poly alkylated products and feature properties as shown in *Table 1* including mid-range aniline points, good VI, outstanding hydrolytic stability, and exceptional high performance thermo-oxidative stability.

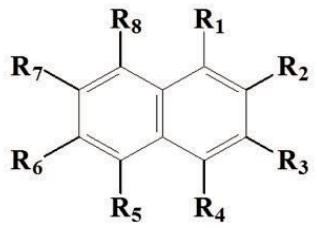


Figure 1. **Alkylated Naphthalene Structure**

The aniline point range is at a midpoint between traditionally polar esters and non-polar Group II, III, and IV fluids. This improves additive response through solvency, or compatibility, in a formulated lubricant without competing for the surface with functional additives. In dynamic systems, NA-LUBE KR has both bench and field proven varnish control through prevention and solubilizing mechanisms to contribute to long term system cleanliness between fluid change intervals.

This study features the key benefits of NA-LUBE KR:

- Reduction in system volatility
- Improvement of thermal and thermo-oxidative stability
- Prevention of varnish formation.

High Temperature Performance

Key features of NA-LUBE KR products are thermal and thermo-oxidative stability. The balanced composition imparts desirable high-performance properties to lubricant formulations for systems requiring durability under high temperatures.

Previous results of a pan volatility test, where mass loss was measured over a fixed period, evaluated the fluid volatility and mass deposits. The fluid film in the pan was tested under static conditions. At 240°C for 42 hours, a selected polyol ester designed for oven applications exhibited 83% evaporation loss and resulted in a brittle solid varnish remaining in the pan. By modifying the polyol ester with 20% NA-LUBE KR-019, the evaporation loss of the fluid was reduced by 35% and the residue remained fluid *(Figure 2)*.

Table 1. **NA-LUBE KR Alkylated Naphthalene Typical Properties**

NA-LUBE KR Series Products - Typical Properties

NA-LUBE	Viscosity @ 40°C ASTM D445	Viscosity @ 100°C ASTM D445	Viscosity Index Calculated	Aniline Point ASTM D611	Noack Volatility CEC L40 ASTM D6375	Pour Point ASTM D97	Flash Point ASTM D92
KR-007A	22 cSt	3.8 cSt	22	40°C	39 wt%	< -48°C	206°C
KR-008	36 cSt	5.6 cSt	90	42°C	12 wt%	-33°C	236°C
KR-015	114 cSt	13.5 cSt	115	94°C	2.2 wt%	-39°C	260°C
KR-019	177 cSt	18.7 cSt	119	103°C	1.4 wt%	-26°C	285°C
NSF KR-006FG	36 cSt	5.6 cSt	90	42°C	11 wt%	-33°C	236°C
NSF KR-015FG	114 cSt	13.5 cSt	115	94°C	2.2 wt%	-45°C	260°C
NSF KR-029FG	177 cSt	18.7 cSt	119	103°C	1.4 wt%	-26°C	285°C

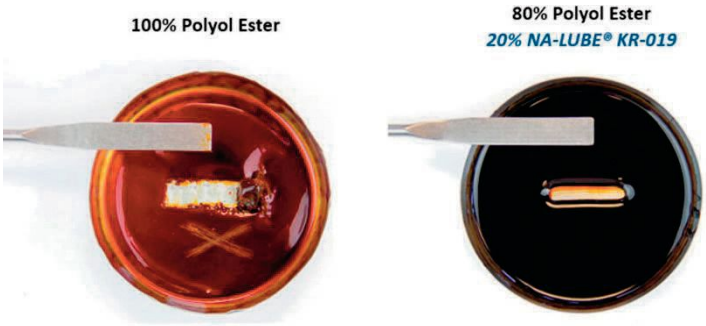


Figure 2. **Evaporation Loss Results 42 Hours at 240°C**

High Temperature Study

In this study, the goal was to demonstrate improvements in thermo-oxidative performance under static and dynamic conditions of two model formulations modified with NA-LUBE KR alkylated naphthalenes.

The two model formulations were designed with different additive treat rates corresponding to the operating conditions for the intended applications.

1. Bakery Oven Model Formulation (ISO VG 220): H1 Formulation based on PAO with a total HX-1 additive treat of 2.5% wt.
2. Industrial Model Formulation (ISO VG 220): Ashless High Temperature Chain Lubricant based on ester with a total additive treat of 6.75% wt.

Equipment for food grade applications often requires a less robust additive formulation to accommodate varying loads, speeds, and environmental conditions, such as humidity or foreign contaminants. In both formulations, the base fluid component, PAO or ester was replaced with 0%, 10%, 20%, and 30% NA-LUBE KR-029FG or NA-LUBE KR-019, respectively. Both NA-LUBE KR-019 and the HX-1 grade analogue, NA-LUBE KR-029FG, demonstrate excellent thermal performance.

Thermo-oxidative testing was done using PDSC (ASTM D6186) and a newly developed in-house panel coker test rig to demonstrate the benefits of the NA-LUBE KR modification in each formulation.

PDSC

Both the Bakery Oven and Industrial Model formulations displayed the advantages of the incorporation of the NA-LUBE KR-029FG and NA-LUBE KR-019 in PDSC performance. In addition to extended onset times, the heat flow of the oxidizing sample was significantly reduced with each increasing incorporation of NA-LUBE KR *(see Figures 3 and 4)*. To measure the onset point of the fully formulated Industrial Model within a reasonable time, the PDSC test temperature was increased from 210°C to 240°C. Both formulations were run under 500 psi O_2 with a 100 mL/min O_2 purge.

The PDSC results show that NA-LUBE KR-029FG and NA-LUBE KR-019 base fluid substitution can extend and improve thermo-oxidative stability under demanding conditions.

In-house Panel Coker Method

To provide a suitable thin film dynamic test system, an in-house panel coker was designed to better quantify fluid performance at a high temperature. The in-house panel coker method determines deposit evaluation after a set volume of fluid has passed over the surface of a stainless-steel panel at a predetermined temperature. The delivery mechanism of the test rig consists of a thin walled 1 meter long stainless-steel tube that allows rapid heat transfer to the fluid inside the tube as it is transported to the surface of the panel. After 18 hours, the panel is removed for evaluation of the deposit mass and flow pattern. After the panel has been evaluated, the panel is placed in a heptane vapor degreaser for an hour and evaluated again.

For the purposes of this study, fixed conditions were set regarding the configuration of the test rig, flow rate, fluid volume delivered to the panel surface, and duration. Test panels were placed at 35° with a flow rate of 0.8 mL/hr delivered to the surface of the

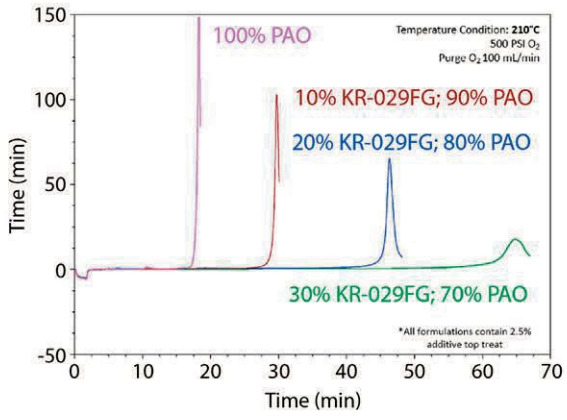


Figure 3. **PDSC (ASTM D6186) Bakery Model Formulation**

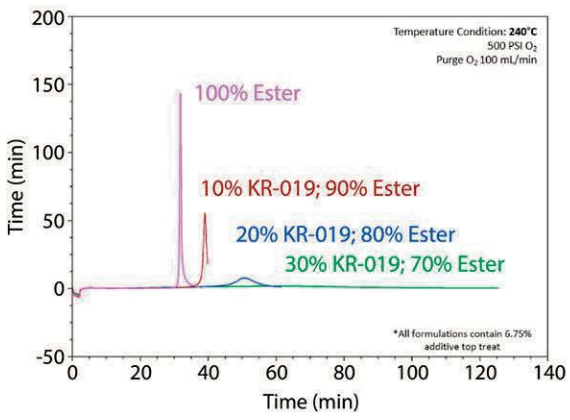


Figure 4. **PDSC (ASTM D6186) Industrial Model Formulation**

Table 2. **Chain Lubricant Market Application by Temperature**

Temperature	Application	Suitable Base Fluids
<150°C	Transport, agriculture, and mining equipment	Mineral Oil, Vegetable Oil, Diester, PAO, PAG
150 – 220°C	**Bakeries** (including H1 lubricants)	Water Soluble PAG, PAO, Ester, ***NA-LUBE® KR***
180 – 250°C	Automobile & beverage can painting	Trimellitate / Dimer Esters, PAO, ***NA-LUBE® KR***
220 – 300°C	**Industrial** (plywood/textile/ceramic)	Dimer / Polyol Esters ***NA-LUBE® KR***
>600°C	Pottery/brick/cement kilns	PAGs as carrier for solid lubricants (e.g. graphite)

panel for 18 hours maintained through a built-in pump controller. The evaluation temperatures for the model formulations were selected to be appropriate for the intended application, shown in *Table 2*.

The coke deposits remaining on the panel were classified into two categories, hard and soft, and quantified into total and cured deposits. Soft deposits are solid with a gummy to lacquer appearance with no flowability. These deposits are readily soluble in solvent and may or may not be soluble in oil. Hard deposits are dry in appearance with no flowability and may or may not be removed mechanically.

Total Deposit, as shown in *Equation 1*, is the combined soft and hard deposits remaining on the panel. The reported value is the mass difference of the initial panel ($m_{p,i}$) and coked panel ($m_{p,f}$) reported as a percentage of the mass of fluid delivered (m_{FT}).

$$Total\,Deposit,\ \%wt. = \frac{m_{p,f} - m_{p,i}}{m_{FT}}(100)$$

Equation 1. **Total Deposit Quantifying Formula**

The Cured Deposit, as represented in *Equation 2*, is the remaining deposit on the panel after heptane vapor degreasing. The reported value is the mass difference of the initial panel ($m_{p,i}$) and degreased panel ($m_{d,f}$) relative to the calculated mass of total deposits (m_{TD}).

$$Cured\,Deposit,\ \%wt. = \frac{m_{d,f} - m_{p,i}}{m_{TD}}(100)$$

Equation 2. **Cured Deposit Quantifying Formula**

As the fluid flows down the surface of the panel, a wetting pattern emerges based on the characteristics of the fluid.

Wetting is an important feature to a fluid's ability to create a tribological film. A fluid with good wetting has been observed to create a wide inverted parabola. High performance fluids with excellent thermo-oxidative stability and good wetting will typically result in an open pattern with faint or low deposits outlining the inverted parabola. At high temperatures, a lack of thermo-oxidative stability or wetting will cause the pattern to close at the bottom of the panel leading to coke build-up.

In-house Panel Coker Results

The Bakery Model Formulation was run at 220°C to evaluate the panel coker performance of the fluids in triplicate. The increasing base fluid substitution with NA-LUBE KR-029FG reduced the Total Deposit *(Figure 5)*. The Cured Deposits, based on the composition of hard deposits to the Total Deposit, were also reduced *(Figure 6)*.

The coking pattern of the fluid *(Figure 7)* displayed an increased opening at the bottom of the panel in addition to a lower 3-dimensional build of the solids along the periphery of the wetted flow route. The lower build of coke suggested both improved thermo-oxidative stability and solubilization of pre-formed and/or formed deposits.

The Industrial Model Formulation was run at 270°C to evaluate the panel coker performance of the fluids in triplicate. The Industrial Model Formulation fluids were robustly formulated to provide the highest potential performance combined with an ester specifically designed for high temperature applications.

The increasing base fluid substitution with NA-LUBE KR-019 did not demonstrate a significant difference or reduction in the Total

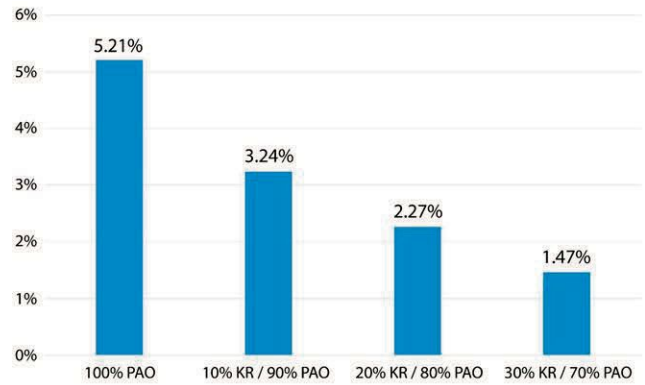


Figure 5. **Total Deposit (% wt.) Bakery Model Formulation**

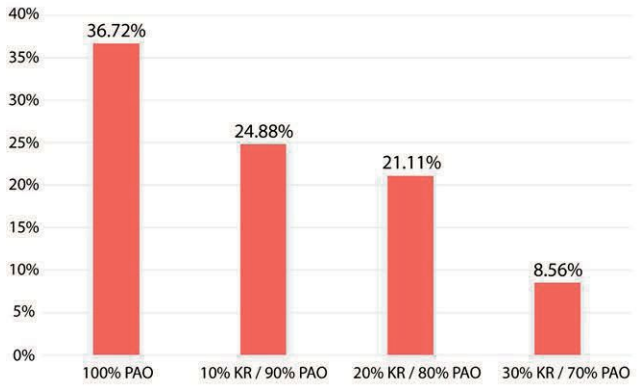


Figure 6. **Cured Deposit (% wt.) Bakery Model Formulation**

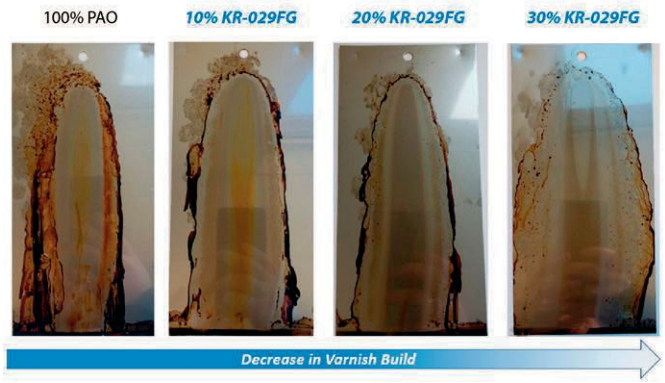


Figure 7. **Degreased panels from Bakery Model Formulation Panel Coker Tests**

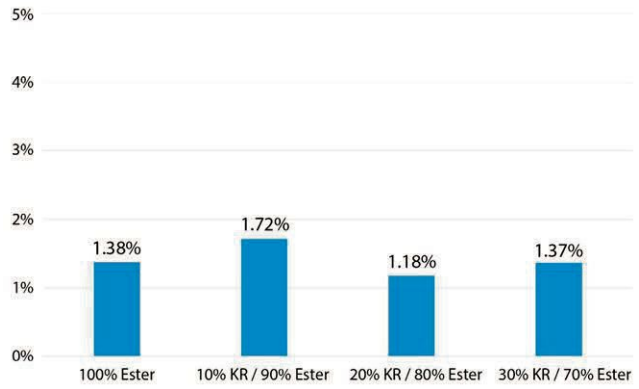


Figure 8. **Total Deposit (% wt.) Industrial Model Formulation**

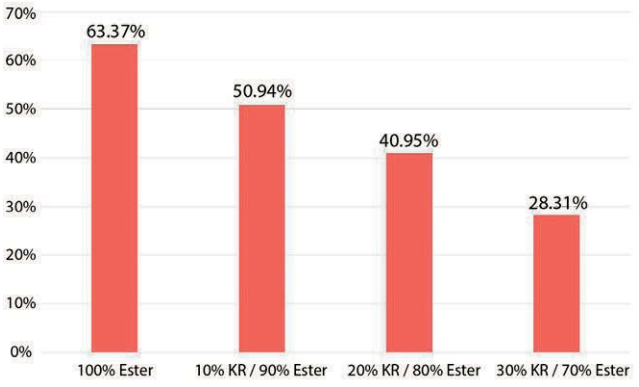


Figure 9. **Cured Deposit (% wt.) Industrial Model Formulation**

Deposit under the 270°C condition *(Figure 8)*, but all results were very low. However, the Cured Deposits results demonstrated a clear reduction in hard deposits *(Figure 9)*.

The coking pattern of the fluid *(Figure 10)* again displayed an increased opening at the bottom of the panel in addition to a lower 3-dimensional build of the solids along the periphery of the wetted flow route. The observed pattern and visual deposit flattened with the increased incorporation of the NA-LUBE KR-019. The Cured Deposit data provided support for the visual observation.

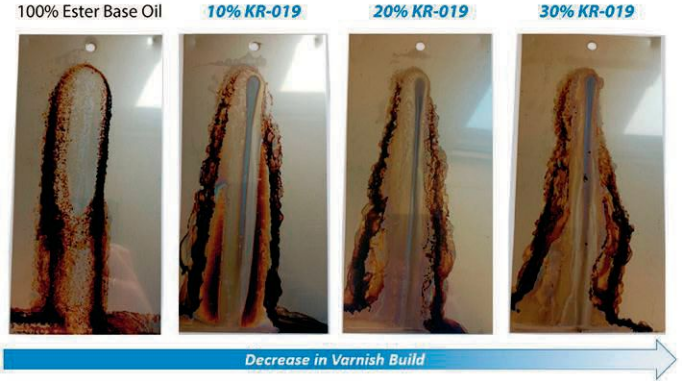


Figure 10. **Degreased panels from Industrial Model Formulation Panel Coker Tests**

Field Performance

Overall, the static PDSC and dynamic in-house panel coker results support the improved thermo-oxidative performance imparted by the NA-LUBE KR-019 and NA-LUBE KR-029FG. In the field, the NA-LUBE KR series performance has correlated to the observed laboratory performance. In a continuous hot press for plywood or MDF manufacturing, the in-service belt lubricant required frequent replacement intervals. The equipment operates continuously at temperatures between 240°C to 260°C and pressures near 5000 kPa moving pressed parts at speeds up to 2 meters per second. NA-LUBE KR-019 was formulated into a new belt lubricant formulation as a co-base stock and put into service. After six months, the fluid had darkened significantly. However, the friction liners used to drive the belt *(Figure 11)* were observed to be free of deposits that had built up from the previous oil.

Figure 11. **Continuous Hot Press Friction Liners after First Fluid Change Interval**

The fluid change interval was completed again with NA-LUBE KR-019 incorporated fluid and this time the fluid did not darken and the friction liners remained deposit-free. The equipment operators observed a reduction in noise and vibration that had previously impacted equipment's maintenance interval.

Summary

The data generated by static and dynamic laboratory testing supported by field performance demonstrated that NA-LUBE KR alkylated naphthalene formulated into a base fluid delivers a clear benefit in reducing varnish formation, limiting system deposits, and prolonging service life of a dynamically stressed fluid. With a diverse viscosity range, NA-LUBE KR products provide excellent flexibility in designing lubricants for a broad range of applications.

Additin® RC 3502
New Organic Friction Modifier Additive

By Mary Moon
Presque Isle Innovations, LLC

Like an acrobat poised on a tightrope, a unique organic friction modifier has a perfect balance of properties to give outstanding performance in lubricants for internal combustion engines. This new engine oil additive delivers more miles per gallon of gasoline, which means less fossil fuel consumption and fewer carbon dioxide emissions – a perfect choice for customers concerned with climate change and environmental regulations.

Combustion converts energy in fuel to do work and propel a vehicle, pump lubricant through the engine and overcome friction between pistons and cylinders. Lubricant companies are formulating engine oils with lower viscosities to reduce the work needed to pump the fluid and, thus, improve fuel economy.

Friction modifier additives play a vital role in the development of these new engine oils, and organic additives provide further performance advantages without adding metals, sulfur and phosphorous to lubricant formulations.

LANXESS Additin® RC 3502

LANXESS (Cologne, Germany) is a leading global specialty chemicals company. The Lubricant Additives Business supplies more than 660 synthetic base fluids, additives and fully-formulated lubricants to over 800 customers worldwide. The lubricant additive portfolio includes antioxidants, detergents, anti-wear compounds, extreme pressure additives, corrosion inhibitors, friction modifiers and automotive and industrial additive packages.

According to Caroline Davison, Strategy and Business Development Manager, Lubricant Additives Business, LANXESS Solutions UK LTD, "LANXESS is committed to the long-term growth of the global lubricants industry. Our objective is to help lubricant formulators extend oil life, protect equipment, conserve energy and resources and grow in their markets. In the Automotive market, energy efficiency continues to be a major priority for lubricating traditional internal combustion engines (ICEs) as well as hybrid and electric vehicles (EVs). In response, LANXESS is developing unique additive chemistries for next generation lubricants.

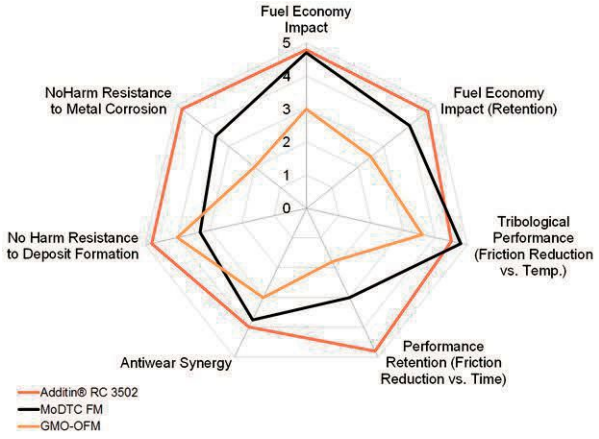


Figure 1. **Key attributes of Additin® RC 3502, MoDTC and OMC friction modifiers**

"Our new, patented Additin® RC 3502 lubricant additive reduces friction to improve fuel economy. Adding as little as 0.5% by weight of Additin® RC 3502 enables motor oils to exceed the minimum specification limits for fuel economy relative to a 20W-30 baseline oil in the ASTM D8114 Sequence VIE test. This test measures effects of automotive engine oils on fuel economy using a 3.6 L engine on a dynamometer test stand in a certified laboratory. First, fresh engine oil is conditioned by running in an engine for 16 hours, and fuel economy improvement (FEI-1) is measured. Second, FEI-2 is measured after extended oil aging (109 hours), which models higher mileage driving. The total fuel economy improvement is calculated as FEI-sum = FEI-1+FEI-2 .

In typical measurements of formulations with Additin® RC 3502, Sequence VIE test results for FEI-sum and FEI-2 were as high as 5.2% and 2.8%, respectively, and surpassed requirements for next generation ILSAC GF-6 fuel efficient motor oils (FEI-sum and FEI-2 of 4.5% and 2.8%, respectively). Additin RC® 3502 provided comparable performance to a molybdenum dithiocarbamate (MoDTC) friction modifier at 1.0% treat (400 ppm Mo).

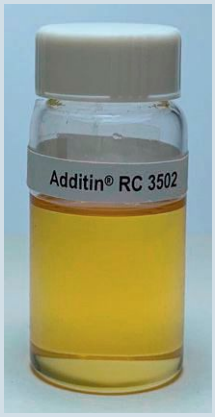
"Moreover, Additin® RC 3502 provides a balance of performance properties necessary for lubricating ICEs. In tests of performance retention or friction reduction versus time, as well as resistance to metal corrosion and deposit formation, Additin® RC 3502 excelled. *(Figure 1)*

"Engine oil formulators will appreciate that Additin® RC 3502 is 'zero SAPS'– contains no sulfated ash, metals, sulfur or phosphorous. The European Automobile Manufacturers' Association (ACEA) and automotive OEMs placed limits on the use of additives that can 'poison' catalytic converters or react with sulfuric acid in exhaust gases to form sulfated ash that clog filters. Formulators can blend Additin® RC 3502 with detergents and other additives that contain these elements and keep their formulations below required limits on SAPS. In our laboratory studies, Additin® RC 3502 demonstrated excellent compatibility with other additives and was synergistic with MoDTC and zinc dialkyldithiophosphate (ZDDP). We are truly excited by the performance capability of Additin® RC 3502 and proud of the commitment and expertise of our scientists that created such great chemistry.

A Molecule by Design

Frank J. DeBlase, Ph.D., Lanxess Fellow, Lubricant Additives Business, Lanxess Solutions US Inc., explained the LANXESS strategy to design a new organic friction modifier. "Lighter oils form thinner lubricating films, so formulators add friction modifiers such as MoDTC and glycerol monooleate (GMO) to reduce friction with the added benefit of lessening wear. To design a new molecule, we considered the behavior of inorganic friction modifiers such as MoDTCs and molybdenum disulfides. When lubricant gets hot enough, all of the MoDTC molecules adsorb on metal surfaces and form hard, 'glassy' tribofilms. The friction decreases as these atoms easily shear away - until tribofilms are oxidized or depleted, and the friction increases.

"This loss of retention of friction reduction performance was also found with GMO and some other commercial organic friction modifiers. GMO tends to break down with sufficient heating, likely through oxidative changes of its structure both in bulk oil and its tribofilm. It's necessary to use higher treat rates to obtain longer drain intervals. But if the concentration of GMO (and other polar organic friction modifiers) exceeds the solubility limit, the molecules separate from the oil. Additin® RC 3502 does not have this treat rate limitation. *(Figure 2)*



- 2% in SAE 5W-30 (-20C) remains clear after 6 weeks
- Enhanced solubility acts as a co-solvent to increase additive treat flexibility
- Additin® RC 3502 neat, can be stored for 5 years if kept cool, dry, heat and moisture free

Figure 2. **Excellent solubility of Additin® RC 3502 in mineral and synthetic motor oils**

"We designed our Additin® RC 3502 molecule with the perfect chemistry to be soluble in oil and adsorb on metal surfaces at low and high temperatures. In technical terms, the molecules are in dynamic equilibrium between the oil and a protective, self-assembled tribofilm on metal. Self-assembled molecules organize themselves like musicians or soldiers marching in a parade.

"We can use enough Additin® RC 3502 in a formulation to replenish the protective films after they wear away because Additin® RC 3502 does not separate from the lubricant. Formulators can use higher treat rates to increase drain intervals. We refer to this behavior as 'performance retention'.

Additin® RC 3502 can be used in the full range of oil types for engine crankcase and driveline gear lubricant applications. Our initial data show potential benefits for industrial lubricant applications as well.

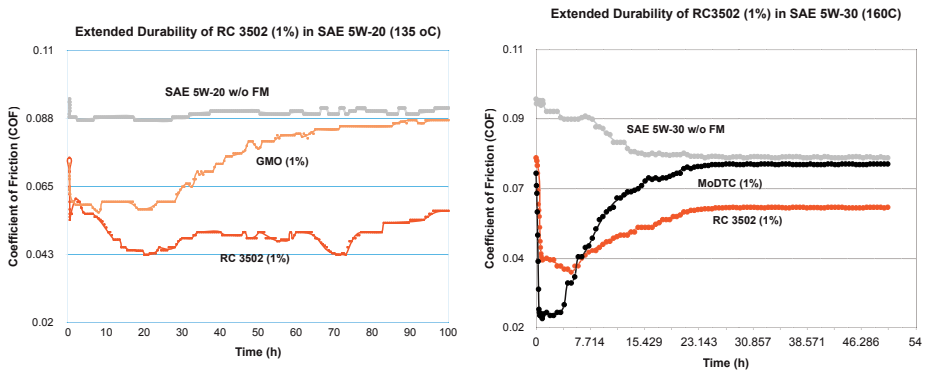


Figure 3. **Excellent durability performance of Additin® RC 3502 over time**

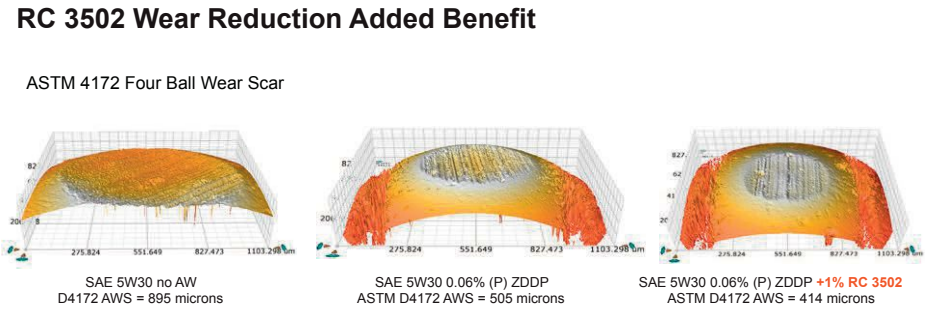


Figure 4. **ASTM 4172 Four Ball Wear Scar Optical Profilometry Analysis**

Friction and Wear

According to DeBlase, LANXESS measured effects of Additin® RC 3502 on friction using a Plint TE-77 High Friction Test Machine (Precision Tribology Ltd.) A round cylindrical pin was rubbed against a lubricated flat pin in reciprocating (back-and-forth) motion under 100 N applied load to simulate a line contact between a piston ring sliding against a cylinder wall in ICEs. In one study, SAE 5W-20 fluids were compared at 135 C. A 1% treat rate of Additin® RC 3502 reduced the coefficient of friction from 0.09 (no friction modifier) to approximately 0.045 during an extended test of 100 hours (more than 4 days). With a 1% load of GMO, friction was approximately 0.6 for the first 24 hours, but then steadily increased as the GMO effect diminished. *(Figure 3)*

Similar trends were observed for SAE 5W-30 oils at 160 C. A 1% treat rate of Additin® RC 3502 significantly reduced friction during a 52-hour test, while 1% MoDTC lowered friction only during the first 24 hours.

LANXESS also used the Plint to study fluids lubricating actual piston rings sliding on sections of cylinder walls. These results for engine parts supported those obtained with standard test specimens.

In another study, the ASTM D4172 Four-Ball Method was applied to measure effects of Additin® RC 3025 on wear preventive properties of lubricating fluids in a sliding contact. A single steel ball under a 40 kg applied load was rotated at 1200 rpm against a trio of fixed balls for 60 minutes. Optical profilometry was used to visualize and measure wear scars.

The experimental control was an SAE 5W-30 fluid with no antiwear additives (wear scar diameter 0.895 mm). With ZDDP at a treat rate of 0.06% (P), wsd was 0.505 mm, and the scar was shallower and smoother than the control case. Adding both 1% RC 3502 and ZDDP gave the smallest (wsd 0.414 mm), shallowest, smoothest wear scar. These results showed that Additin® RC 3502 and ZDDP were compatible. *(Figure 4)*

To simulate combinations of sliding and rolling movements for cams and other components, LANXESS used a Mini-Traction Machine (PCS Instruments). Stribeck curves showed that Additin® RC 3502 reduced friction over a range of temperatures.

Additive Compatibility

A wide matrix of laboratory tests showed good compatibility and no harmful interactions between Additin® RC 3502 and other components of engine and gear lubricants.

Positive synergistic interactions were observed in several cases. In Plint measurements, friction was lower with 1% of a 1 : 1 blend of Additin® RC 3502 and MoDTC in SAE 0W-20 fluid than with 1% of either individual friction modifier. *(Figure 5)*

Additin® RC 3502 also displayed synergy advantages and no loss of any performance properties in blends with ZDDP, sulfur-containing antiwear additives and magnesium sulfonate detergents.

Hybrids and EVs

Davison concluded, "We are currently working with our customers who are formulating fluids with Additin® RC 3502 for next-generation vehicles. Hybrid vehicles require engine oils but present some special challenges compared to traditional ICEs. The ICE in a hybrid vehicle does not operate when its electric motor is running, and the engine oil must tolerate greater start-stop challenges than in a traditional ICE vehicle. Additin® RC 3502 performs well at both cold and warm temperatures and provides an antiwear benefit to protect ICEs under these harsh conditions. *(Figure 6)*

In fully electric vehicles, innovative fluids will be needed to lubricate new drive lines and cool batteries. These fluids will require high-performance additives that meet these new challenges and have excellent compatibility with the lubricant and other additive chemistries. SAPS-free, fully organic Additin® RC 3502 is a strong candidate for these new formulations."

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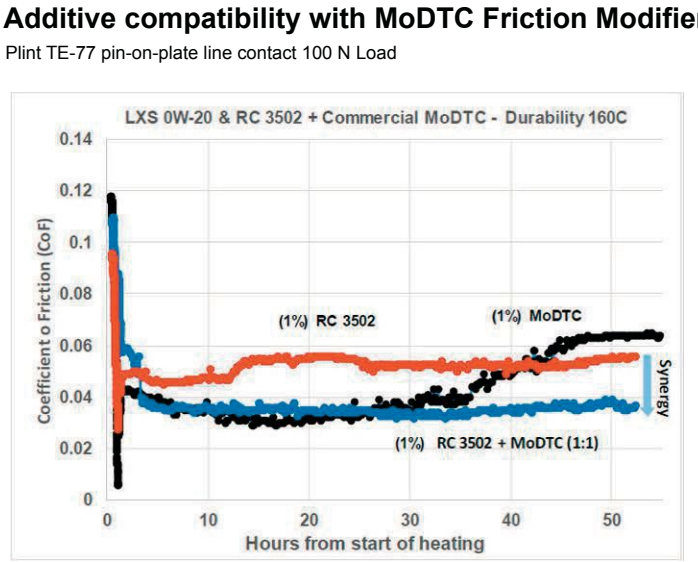

Figure 5. **Strong compatibility of Additin® RC 3502 and MoDTC Friction Modifiers**

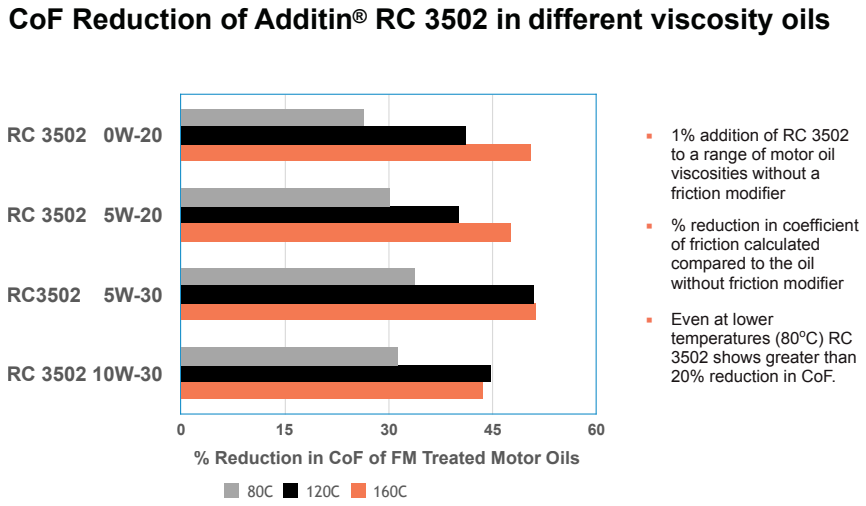

Figure 6. **Additin® RC 3502 reduces friction in four different SAE viscosity grades at 80, 120 and 160 C**

QUALITY DRIVES.

Effective lubrication plays a critical role in fuel efficiency. LANXESS is introducing a new, patented organic friction modifier that delivers significantly enhanced friction reduction, performance retention and antiwear protection. LANXESS quality and innovation supports the automotive industry in its challenge to improve fuel economy and lower emissions. **lab.lanxess.com**

Additin® RC 3502

QUALITY WORKS.

LANXESS
Energizing Chemistry

Additive Packages for Challenging Hydraulic Applications

By Mary Moon
Presque Isle Innovations, LLC

Like the beating heart in a human body, the mechanical pump is the single most critical (and valuable) component of an industrial hydraulic system.

Mechanical pumps circulate hydraulic fluid, which is essential for precise, continuous and efficient operation of systems for processing plastics, manufacturing steel and making paper, as well as operating assembly lines, machine tools and robots. Pump failure not only disrupts production, it spews debris that can damage valves, actuators and hoses.

High quality hydraulic fluids (and its proper maintenance) are the most effective insurance to prevent catastrophic pump failure. Many commercial hydraulic fluids meet basic national and international standards. Conventional oil analysis tests can reveal the presence of contaminants and moisture to signal the need for preventive maintenance. Additive packages from LANXESS provide lubricant suppliers with the performance they need to blend hydraulic fluids to meet national and international specification and to qualify as top tier products.

Top tier hydraulic fluids have the highest quality formulations and receive approvals from leading pump OEMs. These premium products pass rigorous testing in pumps under severe operating conditions as well as meet standard technical criteria. Formulation development and pump testing present a double challenge to lubricant manufacturers.

LANXESS Additin® RC 9200 N and 9300

LANXESS (Cologne, Germany) is a leading global supplier of specialty chemicals. The Lubricant Additives Business supplies more than 660 synthetic base fluids, additives and fully-formulated lubricants to over 800 customers. Mannheim, Germany is the principal facility for the development, production, and distribution of additive packages for the lubricant industry. In 2018, LANXESS commissioned a new manufacturing line for producing Additin® brand dimercaptothiadiazole (DMTD) derivatives at Mannheim. The business unit is globally positioned, with its headquarter in Shelton (CT, USA), and additional production facilities as well as sales and customer service organizations in all regions of the world.

According to Dr. Steffen Sandhoefner, Senior Manager Application Technology, Lubricant Additives Business, LANXESS Deutschland GmbH, "LANXESS provides a portfolio of additive packages to target three hydraulic fluid segments. First, we sell Additin® RC 9207 and Additin® RC 9305 for 'basic' hydraulic fluids that meet national and international specifications (e.g., DIN, ISO, ASTM, ….) Second, the LANXESS premium performance segment - Additin® RC 9200 N and Additin® RC 9300 – covers all of the basic requirements plus approvals obtained from pump testing. And third, we customize specialty additive packages to meet unique requirements of individual customers, regional conditions, and so forth."

Top tier Additin® packages were developed to provide reliable performance in state-of-the-art pumps, which operate at higher pressures and faster speeds than prior generations. Warranties for new hydraulic systems entail warranties for pumps, and pump OEMs write warranties that require the use of top tier hydraulic fluids meeting their proprietary requirements (or specifications).

Dr. Sandhoefner explained, "There has been a progression from the Eaton (Vickers) V-104C vane pump (1440 rpm / 140 bar), which was used since the 1970s in standard wear tests for hydraulic fluids, to testing with the Parker Denison T6H20C (1750 rpm / 280 bar) and the Bosch Rexroth RFT-APU-CL (4000 rpm / 500 bar) pumps. So, LANXESS started to develop new Additin® packages to provide the exceptional fluid performance that these new pumps demand. But there were unanticipated challenges. *(Figures 1 and 2)*

Pump Tests

Parker Denison and Bosch Rexroth had developed separate qualification tests for hydraulic fluids using their respective pumps.

Figure 1. **The Parker Denison T6H20C hybrid (piston + vane) pump**

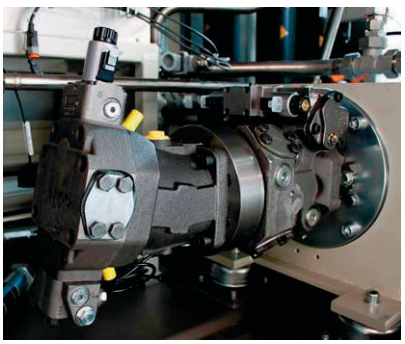

Figure 2. **The Bosch Rexroth RFT-APU-CL piston pump and motor**

Each pump test of a hydraulic fluid involves many steps and typically requires about two months:

- run-in to condition the fluid and the pump
- phase 1 test
- stop the pump, take the pump apart, photograph, measure and document wear on pump components
- reassemble the pump and put the fluid back into the pump
- run-in
- phase 2 test
- stop the pump, take the pump apart, photograph, measure and document wear on pump components
- prepare an extensive, standardized report
- expert evaluation of worn parts and report

According to Dr. Sandhoefner, the pressure and temperature conditions and duration in the first phase of each OEM test challenge the performance of premium hydraulic fluids. *(Figure 3)*

The second phase increases the severity of the operating conditions. In the case of the Parker Denison T6H20C test, it is necessary to add 1% water to the hydraulic fluid. The Bosch Rexroth (RFT-APU-CL) test requires operators to increase the pressure from 450 bars in phase 1 to 500 bars in phase 2.

Operating data	Parker Denison T6H20C	Bosch Rexroth RFT-APU-CL
1. Test cycle	Dry phase	Swivel cycle
Oil volume	180 L	60 L
Rotational speed	1750 rpm	4000 rpm
Operating pressure	250 bar / 280 bar	450 bar
Temperature	110 °C	100 °C
Test duration	300 h	300 h
2. Test cycle	Wet phase	Corner power
Oil volume	180 L + 1% water	60 L
Rotational speed	1750 rpm	4000 rpm
Operating pressure	250 bar / 280 bar	500 bar
Temperature	80 °C	100 °C
Test duration	300 h	200 h

Figure 3. **Comparison of both test procedures**

To accelerate the development of Additin® packages for top tier hydraulic fluids, LANXESS purchased test rigs from Bosch Rexroth and Parker Denison and installed them in their laboratory in Mannheim.

Additin® RC 9200 N Approvals

LANXESS has two additive packages in their portfolio that perfectly fit the top tier hydraulic fluid requirements of pump OEMs.

Additin® RC 9200 N is a premium metal containing performance additive package with a low level of zinc. Performance strengths include high thermal and hydrolytic stability, excellent filtration properties and a balance of anti-wear, antioxidant and corrosion protection properties. Recommended treat rate of Additin® RC 9200 N for premium fluids is 0.6%, which provides less than 300 ppm zinc in the finished fluid.

Already, Additin® RC 9200 N has been approved for stationary hydraulic machinery and mobile hydraulic traction drive systems. *(Figure 4)*

LANXESS also obtained the Bosch Rexroth RDE 90235 approval to a formulation of 0.6% Additin® RC 9200 N (by weight) in an API Group II (ISO 32) neutral base oil from Chevron.

Sandhoefner explained, "This approval automatically covers all hydraulic fluids formulated with Additin® RC 9200 N in this specific base oil. LANXESS received a letter

Primary application: **Hydraulic fluids**

Product characteristics	
Zn content	approx. 4.7%
P content	approx. 4.2%
S content	approx. 9.2%
Viscosity (40°C)	approx. 145 mm²/s
Density (20°C)	1.03 g/cm³
Main application	premium performance hydraulic fluids

General information	
Lead time	30 working days
REACh status	all components in registered
Inventory status	global (US, CA, CH, AU, JP, CN, KR, PH, TW)

Technical properties & specific applications

- Premium performance low zinc containing additive package for the formulation of top tier hydraulic fluids
- High thermal and hydrolytic stability
- Excellent filtration properties
- Balanced formulated additive package with anti-wear, antioxidant and corrosion protection properties
- Good demulsifying properties

USPs

- Approved for both, stationary hydraulic machinery and mobile hydraulic traction drive systems
- High performance at low treat rates (≥ 0.45%)
- Low zinc content (< 300 ppm in the finished fluid)

OEM Approvals / Pump tests

- Bosch Rexroth RD 90235 approved in group II base oil at 0.6% treat rate
- HF-0 approved in group I and group II base oils at 0.6% treat rate
- HF-0 read-across possible for gp I and II oils
- Eaton ATS-373 (35VQ25 pump test) passed

Meets the following specifications

- DIN 51524 p. 2 and p. 3 (HLP @ 0.45% / HVLP @ 0.6%)
- Eaton E-FDGN-TB002-E
- ISO 6743/4 (HM)
- ASTM D6158-05 (HM)
- ISO 11158 (HM)
- AFNOR NF E 48-603
- SS 155434
- VDMA 24318
- SEB 181 222
- U.S. Steel 127 and 136
- Fives P-68, P-69, P-70

Figure 4. **Premium Additive Package: Additin® RC 9200 N**

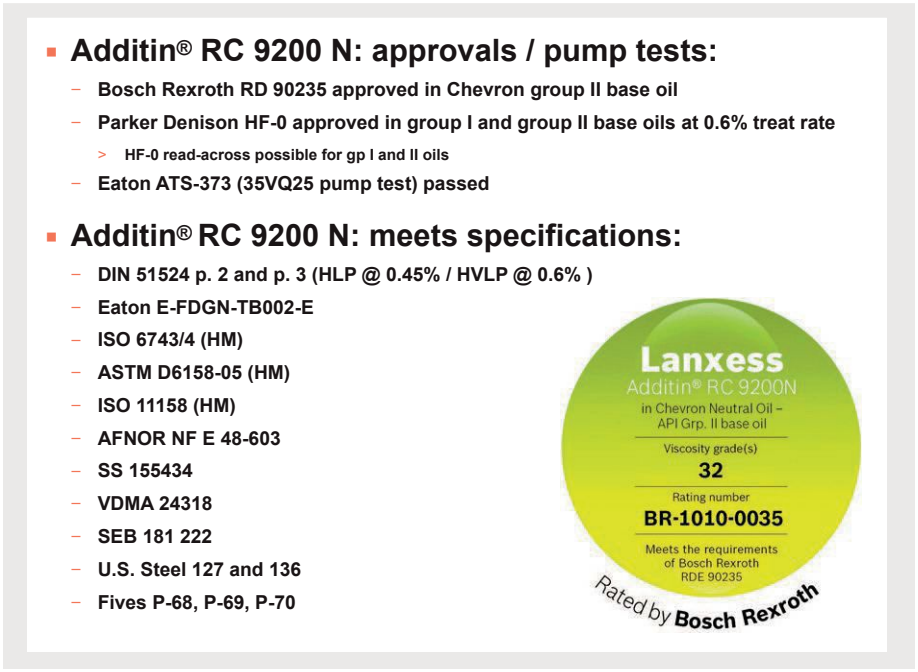

Figure 5. **Approvals for Additin® RC 9200 N**

of approval from Bosch Rexroth with an approval rating number in the 4th Quarter of 2018. Our customers can use this approval rating number to gain their own reblend approval for their hydraulic fluids formulated with Additin® RC 9200 N in the Chevron Group II oil. Work is underway at LANXESS to obtain Bosch Rexroth approval of Additin® RC 9200 N formulated in a second base oil." *(Figure 5)*

LANXESS has also received a series of HF-0 approvals from Parker Denison for hydraulic fluids formulated with Additin® 9200 N in Group I oil and Group II oils.

Additin® RC 9300

LANXESS has also commercialized Additin® RC 9300 for the formulation of top tier ashless hydraulic fluids. Additin® RC 9300 meets all major hydraulic specifications and is suitable for use in API Group I, II, III, and IV (PAO) base oils. Formulations made with Additin® RC 9300 in several base oils have received HF-0 approval from Parker Denison. *(Figure 6)*

LANXESS also recommends Additin® RC 9300 as a multifunctional additive package for various applications including compressors.

LANXESS seeks to obtain full read across approvals based on hydraulic fluids formulated with Additin® RC 9200 N and Additin® RC 9300 from Bosch Rexroth and Parker Denison. Full read across approvals provide automatic approval of hydraulic fluids formulated with these Additin® products and any type of mineral base oil.

Economical

LANXESS premium hydraulic packages provide a high economic efficiency due to their very low treat level of 0.6% by weight.

Net treat costs as well as necessary stock volume are reduced compared to many other hydraulic additive packages commercially available.

LANXESS supports its customers in testing, qualifying and obtaining OEM approvals.

All LANXESS products are sold in accordance with LANXESS General Conditions of Sale and Delivery and without warranty unless otherwise expressly stated.

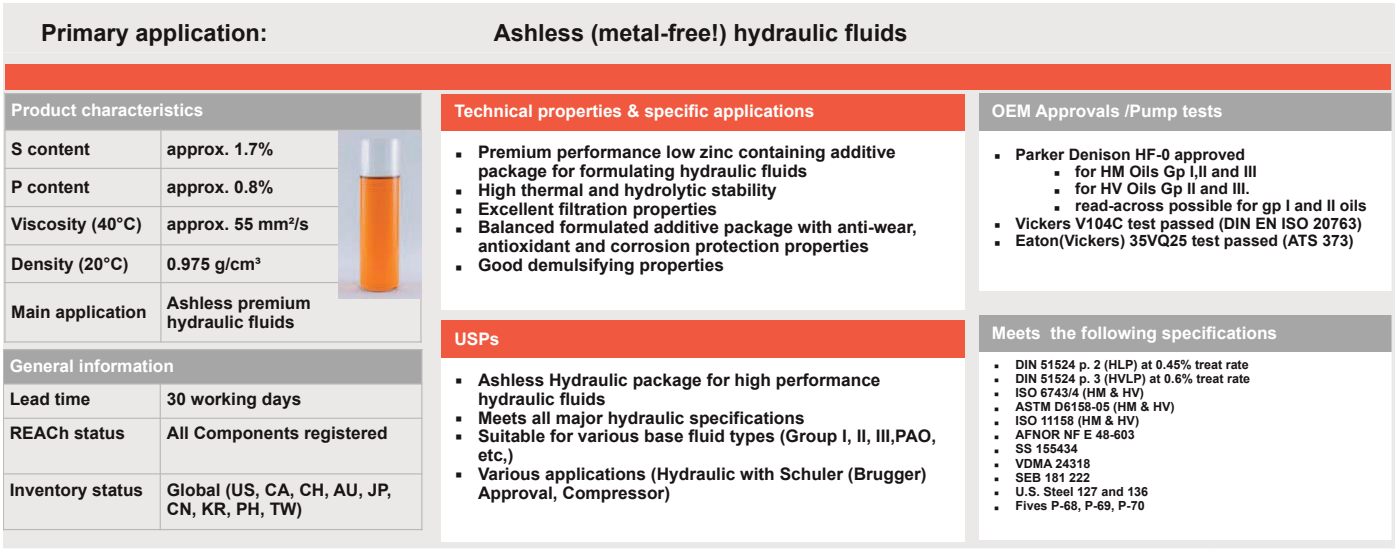

Figure 6. **Premium Additive Package: Additin® RC 9300**

QUALITY PERFORMS.

Approved for the Bosch Rexroth RDE 90235 and Parker Denison HF-0, **Additin® RC 9200 N** is ideally suited to formulating all types of high-performance hydraulic fluids for stationary equipment as well as mobile traction drive systems. Formulators benefit from its low dosage rate of only 0.6% **Additin® RC 9200 N** in mineral oils and get outstanding performance for a very economical net treatment cost. This is how LANXESS quality helps you to meet the highest industry standards. **lab.lanxess.com**

Additin® RC 9200 N

QUALITY WORKS.

LANXESS
Energizing Chemistry

Continuous Improvement of Münzing's FOAM BAN® Defoamers

By Justin Mykietyn
Manager – Industrial Fluid Applications

Defoamers must be insoluble in the fluid in order to provide foam control but need to remain dispersed in the concentrate to avoid instability. This often results in a trade off where products with better compatibility provide less foam control and vice versa.

More than 3 decades ago it was identified that a crosslinked, 3-dimensional (3D) siloxane provided superior foam control in metalworking fluids than previous technologies. Many products were developed to successfully utilize this technology. *(Figure 1)*

A defoamer's foam control property includes foam collapse, persistence to prolonged shear, persistence to age and filter-

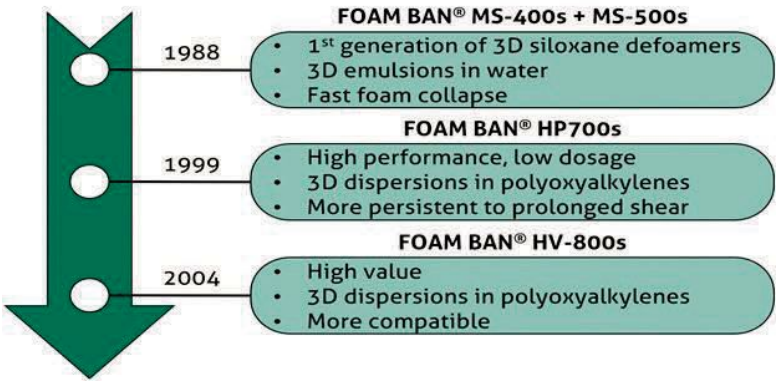

Figure 1.

ability. The compatibility property includes concentrate compatibility upon aging at different temperatures, compatibility with the dilution and the defoamer's ability to be washed off to avoid defects in painting. The balance of these two properties can be visualized as a plot of foam control vs. compatibility. *(Figure 2)*

Standard defoaming technologies are not effective enough in metalworking fluid applications. Silicone (PDMS) emulsions create defects in painting. Oil based, non-Si, defoamers have compatibility and filterability concerns. Molecular defoamers do not provide a fast foam collapse.

The traditional 3D siloxane technology has been used to overcome the limitations of these standard technologies. However, there remains an opportunity for further improvement.

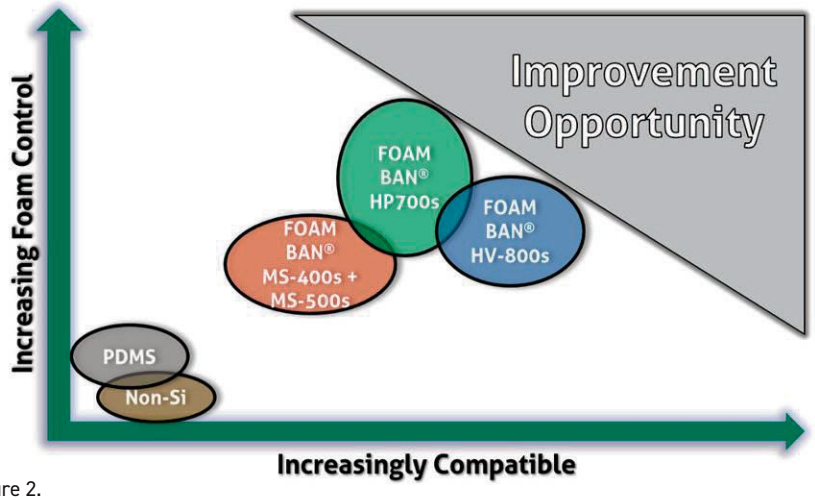

Figure 2.

Münzing's Next Generation 3D Siloxane Technology Based Defoamers

Foam is always a concern in metalworking fluid operations. It has become especially challenging as fluids are:

- Used at higher pressures
- Used in smaller sumps
- Expected to last longer with less make up
- Reformulated to meet new regulatory and safety requirements

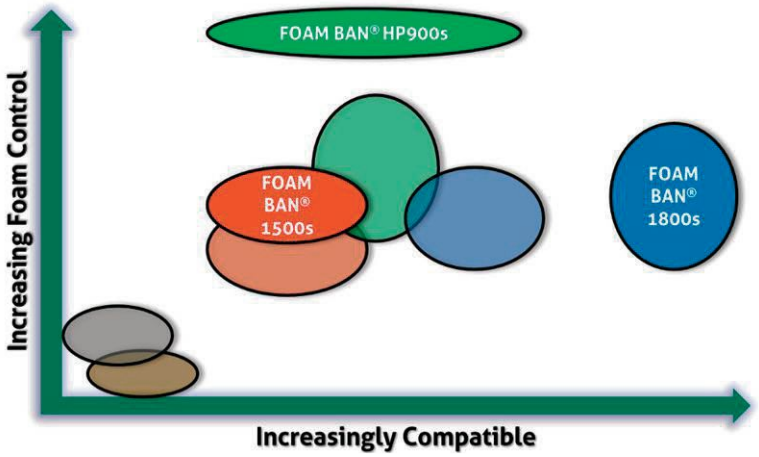

Figure 3.

Understanding where we've been, allows us to know where we are going. The traditional product lines represent many individual products that were tailor made to solve a problem in different metalworking fluids. Münzing looked to these past products and used it as a road map to develop a breadth of new products, the FOAM BAN® HP900, 1800 and 1500 series, similarly tailored to different fluids. *(Figure 3)*

For these reasons there has been a perpetual need for a better defoamer. To improve the defoamer Münzing identified the next generation 3D siloxane technology that is exceptionally resistant to shear providing drastically more persistent foam control. The next step was to reinvent the emulsifier package and create a range of packages tailored to provide enhanced concentrate compatibility.

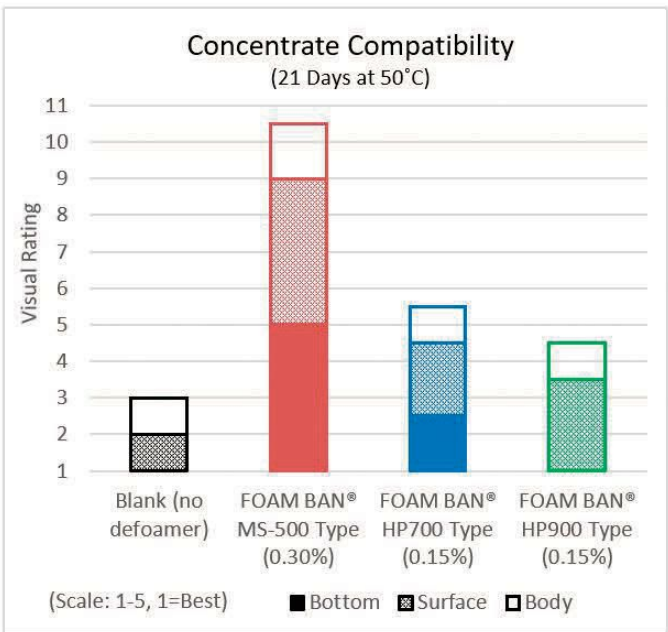

Figure 4.

While all formulated defoamers need to be mixed prior to use to achieve optimal results, these next generations of defoamers were designed to be inherently more stable than previous generations making them easier to handle.

The performance properties of the products are evaluated on a laboratory scale using a combination of different test methods.

- Hand and mechanical shake tests: provides insight into foam collapse.
- Recirculation testing (w or w/o filters): gives information on the defoamers persistence to prolonged shear.
- Compatibility: visually assessing separation, sediment or haze during aging at 5°C, 25°C and 50°C.

Example: Semi-Synthetic Metalworking Fluid

Objective: Historically, a FOAM BAN® MS-500 Type defoamer has been used in a metalworking fluid concentrate with 15% oil content. The goal of this testing is to identify a more compatible and persistent solution to foam control.

Conclusion:

- The FOAM BAN® HP900 Type defoamers displayed better concentrate compatibility as no sedimentation at the bottom was observed after 21 days of aging at 50°C. *(Figure 4)*
- All product types provided a fast foam collapse in shake testing. *(Figure 5)*
- FOAM BAN® HP900 Type products provided the most persistent foam control under prolonged shear and 30um polypropylene filtration. *(Figure 6)*
- This indicates they are more effective than the previous product types.
- Münzing is a service driven company. This example represents the type of testing Münzing's technical service laboratory performs.
- We welcome the opportunity to provide you with an improved foam control solution by evaluating the new product lines or tailor making a new defoamer to achieve optimal foam control and compatibility, if needed.

Handshake Test
(10% of 7-Day Aged Concentrate in DI Water)

Defoamer	Time (s)	Foam (cm)
Blank (no defoamer)	15 30 60	4.8 4.6 4.5
FOAM BAN® MS-500 Type (0.30%)	15 30 60	0.1 0.1 0.0
FOAM BAN® HP700 Type (0.15%)	15 30	0.1 0.0
FOAM BAN® HP900 Type (0.15%)	15 30	0.1 0.0

Figure 5.

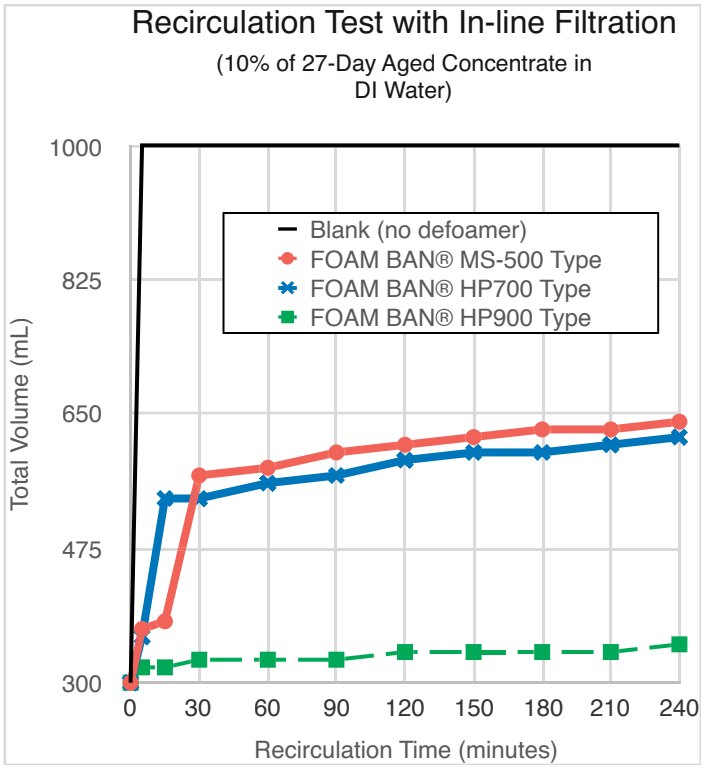

Figure 6.

Think beyond the foam

Foam control is the foundation. Additive innovation is our future.

At Munzing, we're more than defoamer experts. We help our customers craft the perfect defoamer for their individual industrial needs, including metalworking fluids, industrial cleaners, antifreeze coolants and industrial lubricants. In addition to our FOAM BAN® technology, we offer innovative solutions in wetting agents, dispersants, rheology modifiers and waxes. Munzing delivers exceptional technical expertise for your foam control and additive solutions.

MÜNZING

CREATING ADDITIVE VALUE

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A Changing Environment For Corrosion Protection

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For decades, steel manufacturers, metal fabricators and parts manufacturers have coated metal coils, sheets and components with a temporary rust preventive film to protect against corrosion. This has made traditional, wax-based rust preventives essential in thin-film corrosion protection.

However, with increased regulatory pressures and feedstock supply concerns, paired with performance and durability demands, members of the industry are seeking better solutions. Over time, this has led many formulators to challenge current rust preventives and demand new, sustainable solutions that maintain or exceed the performance of traditional technologies.

Setting the standard for additives, ALOX® has used 90 years of industry expertise to test and supply proven solutions that meet ever-changing demands. Understanding the latest industry regulations and the challenges they bring, ALOX is proud to introduce a new, revolutionary product, ALOX® MT1000.

A Next Generation Solution

A calcium-based rust preventive, ALOX MT1000 serves as a new solution to industry challenges. Reducing complexity and mitigating supply risk, all without compromising exceptional performance, it is unlike any traditional rust preventive formulation in market.

Compatible with an extensive range of oil and solvent diluents, ALOX MT1000 provides formulators with the opportunity to meet the increasing demands placed on transportation and industrial markets. All while reducing inventory requirements and extending the performance of their rust preventives.

Focused on delivering operational efficiency, ease of handling and superior solubility, ALOX MT1000 can reduce heating time with its lower melting point at room temperature. This allows for a reduction of energy used, as well as in operational costs.

Advanced Corrosion Protection

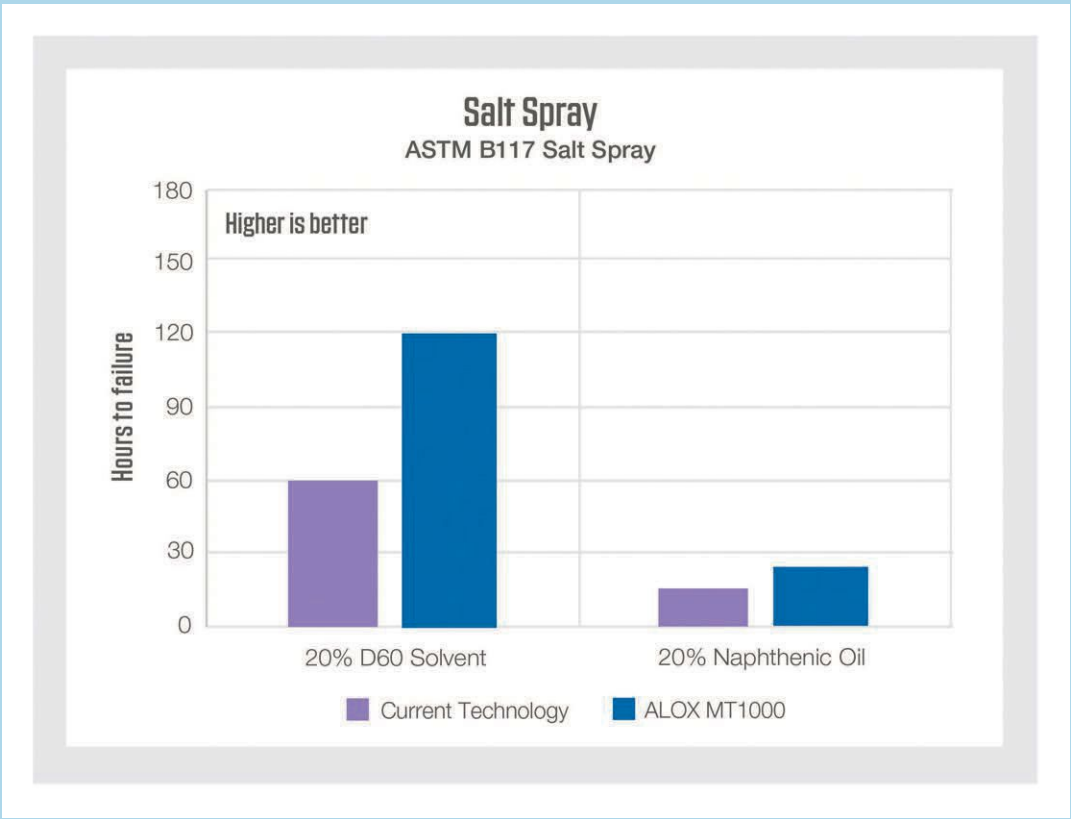
Within the automotive and industrial markets, corrosion is the most common cause of component failure. Currently, the World Corrosion Organization reports that the annual cost of corrosion worldwide is over 3% of the world's GDP. This has led many manufacturers, formulators and fabricators to seek preventive and protective solutions. Specifically, ones that optimize corrosion protection.

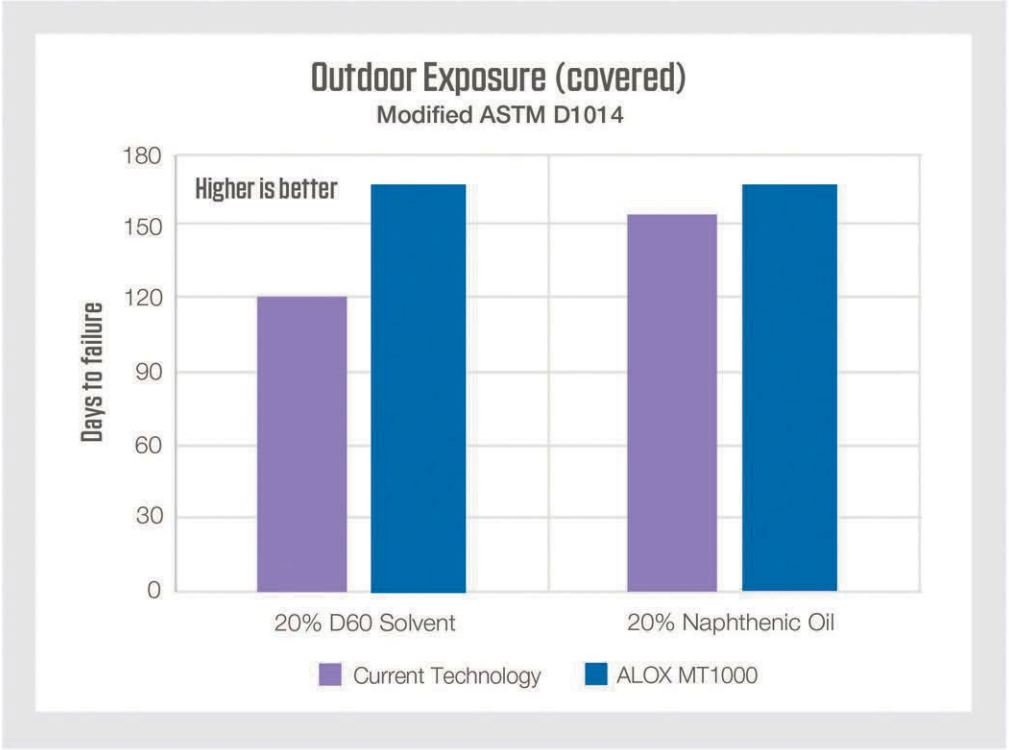
Corrosion protection is difficult to measure as it is impacted significantly by the surrounding environment. Controlled testing is therefore completed in both traditional salt-spray testing and outdoor testing to replicate real-world conditions and identify early signs of rust formation. ALOX MT1000 is proven in real-world testing conditions to achieve high levels of corrosion protection using a variety of corrosion measurement techniques. All while consistently delivering excellent protection in diverse environments against current technologies.

Increased Operational Efficiency

As blenders and formulators are looking for new ways to improve operational efficiency and reduce costs, many seek alternatives to traditional rust preventive additives, as they require special equipment and extended planning time for heating and handling.

Unlike traditional technologies, ALOX MT1000 is a semi-fluid paste at room tem-





perature, featuring a lower melting point that allows for lower maintenance costs, storage capacity and processing time. All while reducing the handling of hot materials and the risk of spills, which drastically improves worker safety and reduces waste. Ultimately, reducing energy used and total operational costs.

Registered & Regulated Across The Globe

Greater global awareness of health, safety and environmental impacts have led to increased global regulations on volatile organic compound (VOC) exposure levels and driven the replacement of traditional volatile solvent-based rust preventives.

VOC regulations combined with the increased usage of Group II+ base oils with more demanding solubility are being selected by formulators to reduce their operational complexity. ALOX MT1000 is compatible with a wide range of solvents and base oils while delivering consistent corrosion performance, reducing risk of exposure from high VOC solvents and stability during storage.

Available in key geographical areas, ALOX MT1000 is a solution fit for the global marketplace. By removing the complexity that comes with new registration requirements and changes to product labels, ALOX MT1000 minimizes supply complexity while meeting the demands of OEMs.

A Sustainable Solution For New Technologies

The ability to ensure exceptional corrosion protection and stain resistance using a thin, film rust preventive provides an advantage in today's competitive marketplace. ALOX MT1000 not only delivers on key performance benefits, but it also reduces the number of additives needed for formulation and is compatible across a wide range of metals. Making it a sustainable solution fit for emerging technologies and new environmental regulations.

As an addition to a proven, additive family that has been setting the standard for over 90 years, ALOX MT1000 serves as the superior solution for rust prevention by not only delivering on ever-changing industry demands, but maintaining or exceeding the performance of traditional technologies.

ALOX® MT1000

A New Generation of Corrosion Protection

For over 80 years, ALOX® has been the trusted source of reliable rust prevention products to industrial markets. To expand on our product line, ALOX has adopted new technologies and advanced materials that ensure a more sustainable future for the rust preventives of today and tomorrow.

Lubrizol

Lubrizol Unlocks Hydraulic Efficiency with Durability

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Fluid power drives the world around us. From the mobile construction, mining, agriculture and forestry industries to all manner of stationary manufacturing, hydraulic power is there doing work. The hydraulic circuits carrying this power are continuously expected to provide higher throughput and deliver greater productivity. To move more earth, plant more crops, or manufacture more parts, hydraulic equipment is forced to operate under increasing stress and without unexpected failure.

The cost of unplanned downtime can be significant—service and repairs for one pump failure can reach $20,000. This figure doesn't include productivity losses, costs of missed deadlines, or reputation damage. A case study on unplanned downtime in a gold mine showed a commodity value loss can be anywhere between $75,000 - $113,000 per hour, depending on the current gold price.

As the market trends towards more compact systems, increased productivity expectations, coupled with higher operating pressures and greater power densities, provide an opportunity for the lubricant to deliver enhanced efficiency performance while still critically protecting against unexpected downtime. Incorporating a hydraulic fluid that provides proven durability and reliability while increasing productivity can provide fuel or energy savings and reduce the overall total cost of ownership of equip-

ment. End users need a fluid that can offer reliable performance, increase productivity and maintain uptime without compromising oil drain life.

Lubrizol's Solution

Balancing durability and productivity is critical when designing an energy-efficient hydraulic fluid. The combination of Lubrizol® 5703 and Lucant™ in a high-quality base oil unlocks efficiency with durability.

The premium antiwear hydraulic additive package, Lubrizol 5703, has been tested extensively in the lab and offers proven, robust equipment protection in the most demanding operating conditions in the field. Lubrizol 5703 is formulated to deliver excellent antiwear protection with high thermal and oxidative stability, coupled with excellent hydrolytic stability and rust protection. This additive package has been approved by global hydraulic equipment leaders Bosch Rexroth, Denison, Eaton and others.

Lucant is a specially-developed performance polymer for multigrade hydraulic fluids. It offers many performance benefits over conventional viscosity modifiers including:

- Excellent thickening efficiency for optimizing treat rate
- Outstanding shear stability to keep your fluid in-grade
- Low fluid traction to keep operating temperatures down
- Reduced flow losses to save you fuel and money

Together with Lubrizol 5703, Lucant delivers lower total cost of ownership with durable, worry-free operation.

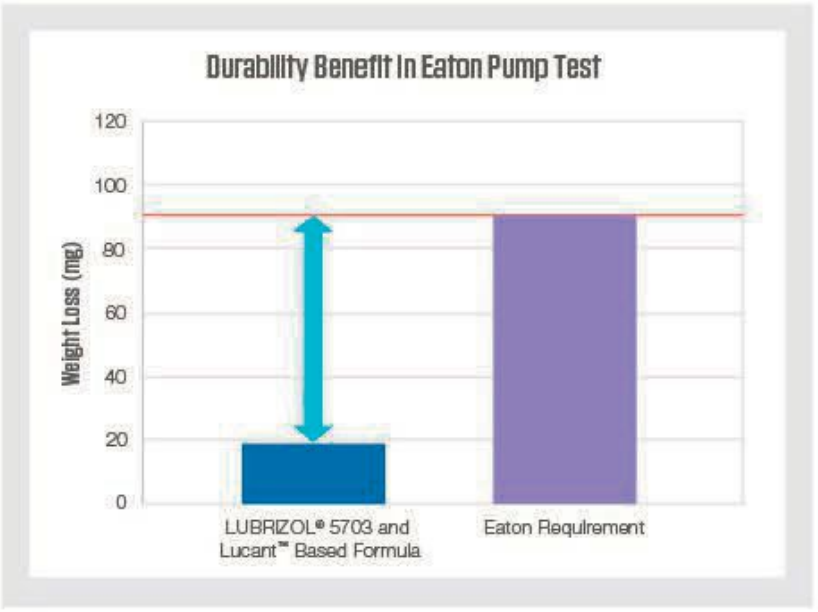

Figure 1: Performance in Eaton 35VQ Pump Test

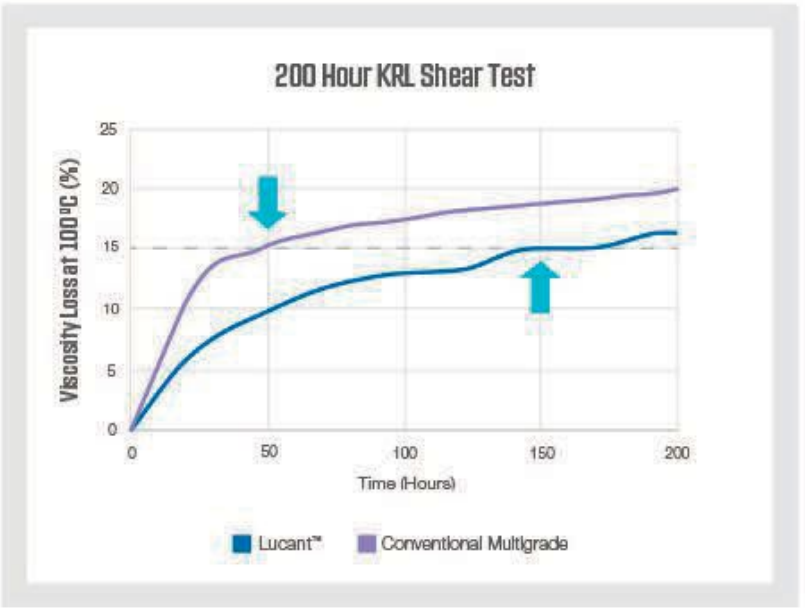

Figure 2: 200 Hour KRL Shear Stability Test

Performance Demonstration – Durability Testing

When developing hydraulic fluids, Lubrizol formulators run a gamut of bench and pump tests to ensure reliable field operation.

Pump Performance

Standardized pump tests recommended by leading hydraulic pump manufacturers are an important tool for evaluating hydraulic lubricants. The combination of Lubrizol 5703 and Lucant has been tested and approved by both Eaton and Denison. Lubrizol's energy efficient solution provides excellent antiwear performance in the Eaton 35VQ pump test *(Figure 1)*.

Extended Shear Stability

Shear stability testing is also recommended by pump manufacturers for multigrade hydraulic fluids to ensure that they can maintain viscosity and thick, part-protecting lubricant films. In the lab, fluids are often evaluated after 20 hours of bench shear testing, but in the field, multigrade fluids are subject to harsh environments for much longer intervals. Multigrade lubricants can continue to lose viscosity

leading to thinner protective lubricant films, damaged parts, and downtime. Running longer shear stability tests can indicate the extended shear behavior of lubricants.

In addition to the standard 20-hour KRL shear stability test (CEC-L-45-A-99), Lubrizol scientists run extended, 200-hour, KRL shear testing and monitor the loss of kinematic viscosity at 100°C. *Figure 2* compares the percentage of viscosity loss of two fluids of equal starting viscosity grade. The first is Lubrizol's energy efficient solution containing Lucant, while the second, is a conventional multigrade fluid. The fluid formulated with Lucant maintains its viscosity longer and remains within the 15% viscosity loss limit allowed by the OEMs, again affording equipment owners and operators peace of mind.

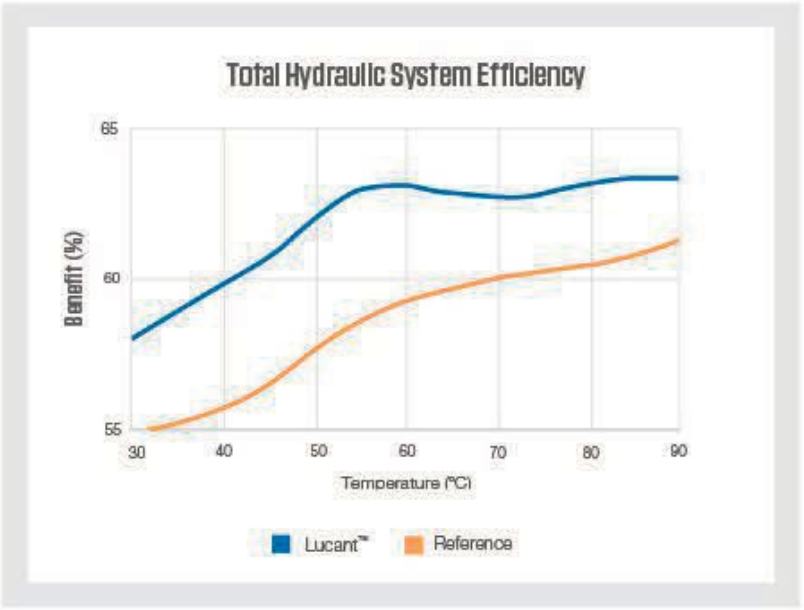

Figure 3: Performance in Total Hydraulic System Efficiency Test

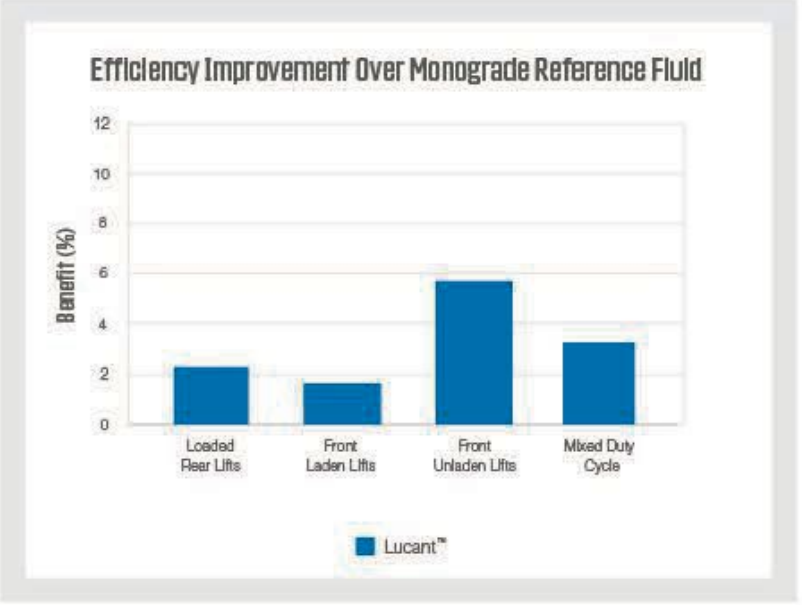

Figure 4: Performance in Field Test on a Backhoe Loader

Performance Demonstration – Efficiency Testing

For hydraulic equipment, efficiency in the field is measured by fuel consumption and/or time needed to perform work. In the lab, efficiency is calculated from test inputs, like torque and flow in a controlled system. Unlike the automotive industry, there is no standardized industry testing or specification to measure off-road hydraulic efficiency.

Total System Efficiency Testing Rig

In the absence of an industry standard test, Lubrizol has developed a total hydraulic system efficiency rig, consisting of a hydraulic pump and motor joined by conventional hydraulic hoses, lines and valves. This tool, unlike a simple pump test, can evaluate the efficiency of different lubricants in an entire hydraulic circuit and was designed to mimic real-world mobile hydraulic equipment. The efficiency results for Lubrizol's energy efficient solution containing Lucant as compared to a monograde fluid are shown in *Figure 3*. In this testing, Lucant provides significant improvement.

Real-World Field Efficiency

To compliment efficiency gains observed total system lab testing, a controlled field evaluation under real-world conditions was conducted on a backhoe loader equipped with sensors to measure pressure, temperature, flow and fuel usage. Fuel saving benefits were calculated for the same test fluids under a variety of duty cycles. Again, the Lucant-containing lubricant delivered efficiency gains over the monograde reference fluid *(Figure 4)*.

Temperature Reduction in Hydraulic Applications

In addition to improving efficiency and du-

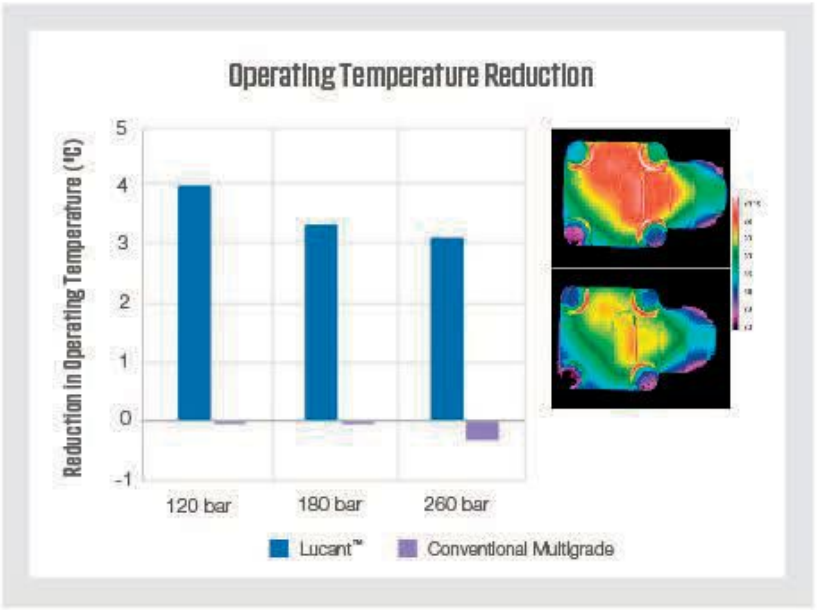

Figure 5: Reduction in Operating Temperature in a Hydraulic System

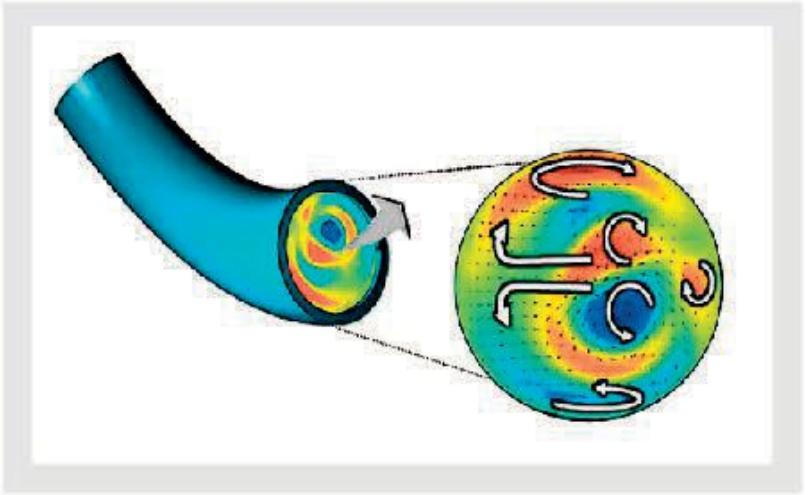

Figure 6: Secondary Flow Losses

rability, the combination of Lubrizol 5703 and Lucant can reduce operating temperatures of hydraulic fluid. The above testing in Lubrizol's total system efficiency rig also revealed that the Lucant-based fluid can reduce the operating temperature by 3-4 °C compared to both the conventional multigrade and the monograde reference *(Figure 5, left)*. Thermal imaging of Eaton 20VQ testing also reveals a reduction in pump surface temperature *(Figure 5, right)*. With current equipment sump size trending smaller than before, fluids are expected to face hotter temperatures. Lucant can reduce fluid temperature, affording consistent hydraulic actuation and longer fluid life.

Lucant and Secondary Flow

The efficiency, durability, and operating temperature data above speak volumes, but how does Lucant "work?"

Like all things hydraulic, the key lies in flow.

Hydraulic power is the product of flow and pressure. Increase flow and you can increase power. Hydraulic circuits, particularly in compact mobile equipment, inevitably contain a multitude of lines, twists, turns and valves, all there waiting to reduce flow. Some of this flow loss comes in the form of secondary flow. Any flow not in line with the main flow direction is secondary flow, and secondary flow effectively means lost power. *Figure 6* shows a model of the complex flow patterns a fluid experiences simply by going around a bend. The bright blue and red areas depict significant secondary flows. Lubrizol researchers developed a technique for measuring the severity of these parasitic flows using lasers, a high-speed camera, and reflective particles. Using this capability, it was observed that Lucant dramatically reduces secondary flow around 90° and 180° bends.

Conclusion

It is essential to balance durability and efficiency of a hydraulic fluid to maximize uptime and reduce total cost of ownership. Hydraulic fluids comprising Lubrizol 5703 and Lucant combine trusted durability performance with a measurable improvement in efficiency in both total system lab testing and real-world field evaluations. This energy-efficient formula maintains its viscosity longer in extended shear testing compared to a fluid formulated with other viscosity modifiers. This combination was observed to increase efficiency and reduce operating temperature in lab and field testing. Lastly, the Lucant-based formula increases efficiency by reducing secondary flow losses seen around bends in hydraulic lines and, together with Lubrizol 5703, helps unlock efficiency with durability.

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