KING INDUSTRIES
SPECIALTY CHEMICALS

NA-LUBE® KR

Alkylated Naphthalenes

For High Performance Lubricants and Greases

The ***NA-LUBE® KR Series*** consists of synthetic alkylated naphthalene fluids available in diverse viscosities. Alkylated naphthalenes are typically incorporated into lubricant formulations to ***replace*** a portion of Group II, Group III or PAO ***base oil***, where additional benefits are needed to meet the increasingly demanding requirements of high performance applications.

Because of our ***proprietary processing technology,*** NA-LUBE KR alkylated naphthalenes have emerged as high performance base oil performance boosters that ***provide formulators with flexibility*** in designing lubricants that meet their ***demanding requirements.***

For over 50 years, King Industries Inc. has been a leader in the alkylation of naphthalenes. Today, King is the producer of the world's broadest line of alkylated naphthalene synthetic fluids for lubricants. Designated the ***NA-LUBE® KR*** Series, these products are the ideal choice as base stocks or co-base stocks for high performance applications.

Whether working to develop an innovative new product or to improve an existing product, NA-LUBE KR alkylated naphthalenes can help formulators meet the ever-increasing demands placed on today's lubricants and greases. They provide superior thermo-oxidative stability, excellent hydrolytic stability, and greater film thickness compared to alternative base fluids.

King offers three ***NSF HX-1*** registered products that meet the requirements for incidental food contact as prescribed by FDA 21 CFR 178.3570 - ***NA-LUBE KR-006FG, KR-015FG*** and ***KR-029FG.***

Synthetic Base Oils

Base Oil Modifiers

Specialty Additives

Halal & Kosher Approvals

HX-1 Approvals
For incidental food contact

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-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
KR-006FG	36 cSt	5.6 cSt	90	42°C	11 wt%	-33°C	236°C
KR-015FG	114 cSt	13.5 cSt	115	94°C	2.2 wt%	-45°C	260°C
KR-029FG	177 cSt	18.7 cSt	119	103°C	1.4 wt%	-26°C	285°C

Introduction to Alkylated Naphthalenes

NA-LUBE® KR Series alkylated naphthalenes are high performance, synthetic base stocks that are used primarily to boost performance and to overcome deficiencies associated with other synthetic base oils or Group II & III mineral oils. Benefits of NA-LUBE KR products include:

- **Improved thermal & thermo-oxidative stability**
- **Excellent varnish control**
- **Improved solvency and dispersancy**
- **Improved system cleanliness**
- **Improved seal swell**
- **Excellent hydrolytic stability**
- **No surface competition with additives**
- **Increased service life**

	Applications	*Benefits of using NA-LUBE KR*
Lower Viscosity Grades *(4-14 cSt @100°C)*	Automotive Engine and Transmission Oils	Imparts excellent thermal and oxidative stability. Excellent varnish control.
		Provides excellent hydrolytic stability.
		Improves additive solubility and enhances additive performance.
		Imparts enhanced film flexibility, toughness, chemical resistance and detergent resistance.
	Compressor Oils Hydraulic Oils R&O & Turbine Oils	Boosts thermal and oxidative stability.
		Imparts seal swell.
		Improves additive response.
Higher Viscosity Grades *(14-20 cSt @ 100°C)*	Industrial Gear Oils	Results in good film thickness and film strength to reduce friction.
		Imparts excellent thermal and oxidative stability.
		Imparts seal swell.
	Windmill Oils	Increases cleanliness and service life.
		Provides excellent hydrolytic stability.
		Results in good film thickness and film strength to reduce friction.
	High Temperature Oven and Chain Lubes	Imparts excellent thermal and oxidative stability.
		Reduces volatility.
		Inhibits varnish formation and prevents lubricant failure (flaking).
	Greases	Requires less thickener in lithium greases, improving low temperature properties.
		Results in superior thermo-oxidative stability.
		Acts as a bridging solvent, reducing opaqueness.
		Acts as a highly effective dispersant, producing a smooth grease.

Panel Coker - Federal Test Method 791-3462 - In this test, a sample of oil is splashed against a test panel at an elevated temperature and the amount of coke deposited on the panel is determined by weight. Modifying a PAO fluid with 10% ***NA-LUBE® KR-008, KR-015 or KR-019*** significantly reduced the amount of coke formed.

Shown below, the neat PAO resulted in 9 mg of coke, while the PAO modified with the NA-LUBE KR resulted in significantly lower amounts of coke and cleaner panels.

Panel Coker (FTM 791-3462)

	100% PAO (ISO VG 220)	*10% KR-008* 90% PAO	*10% KR-015* 90% PAO	*10% KR-019* 90% PAO
Coking Value (mg)	9	**1**	**3**	**2**

Temperature Conditions: Test Panel (200°C), Oil Sample (140°C)

100% ISO VG 220 PAO

PAO + ***10% NA-LUBE KR-008***

The table below shows the benefits of using ***NA-LUBE KR-008*** to boost the RPVOT performance of a Group III oil containing 0.7% of an R&O package. ***NA-LUBE BL-1208*** is a multifunctional ashless R&O package also available from King Industries, Inc. Replacing 15% of the Group III oil with NA-LUBE KR-008 increased the RPVOT oxidation lifetime from 1339 to 1926 minutes. It also significantly reduced the sludge in the Cincinnati Milacron (CM) test.

	0.7% BL-1208 99.3% Group III	0.7% BL-1208 *15.0% KR-008* 84.3% Group III	Improvement
RPVOT (ASTM D2272) Lifetime (minutes)	1339	**1926**	+44%
CM Thermal Stability (ASTM D2070)			
Condition of Steel Rod: Color	2	**2**	
Condition of Copper Rod: Color	5	**5**	
Total Sludge (mg/100ml)	10.7	**5.3**	-49%

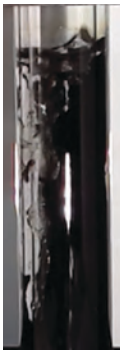
Thermal Stability

Federal Test Method 3411 - In this test, the samples are held at 274°C for 96 hours in the presence of a steel coupon, in a sealed glass tube, in the absence of moisture and oxygen. Measurements include the changes in viscosity and acid number, steel coupon weight loss and the appearance of the oil.

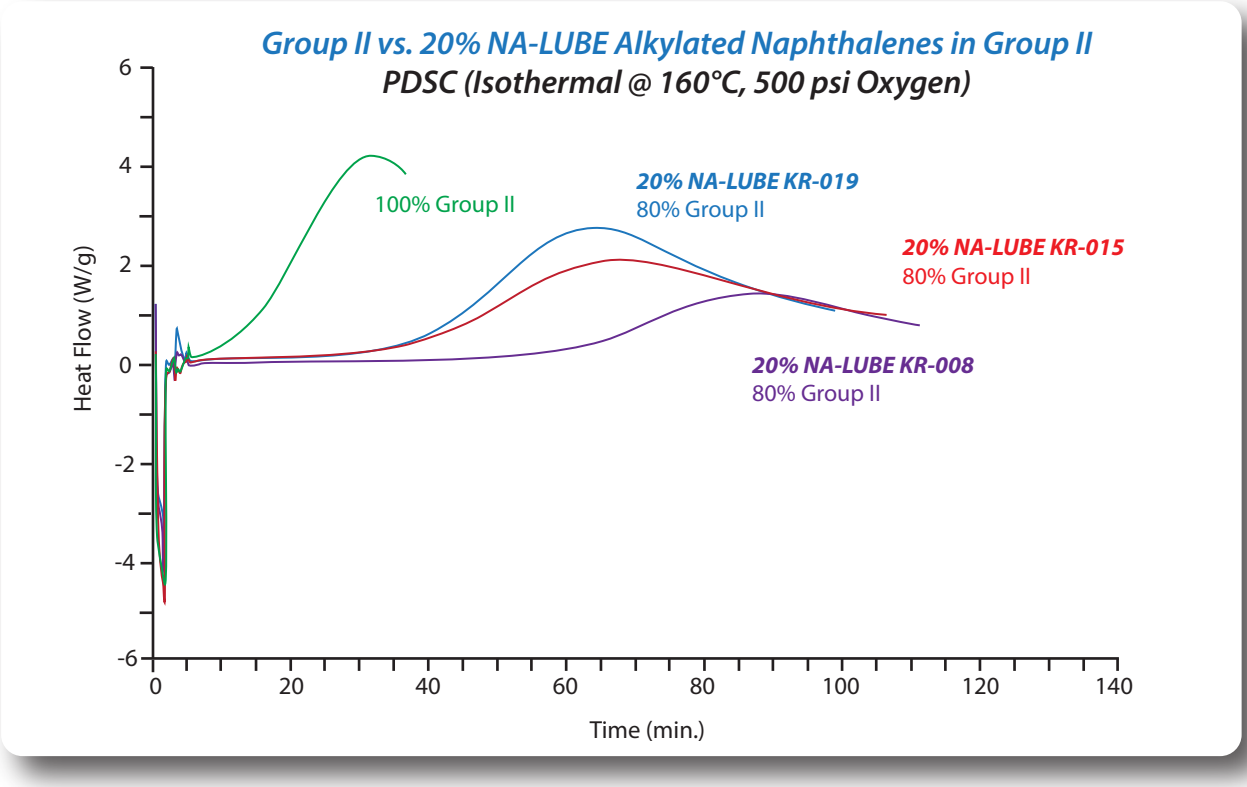
Using this test, a 7 cSt Group III base oil was compared to 20% modifications with ***NA-LUBE® KR-015***, a TMP ester and a diester. The oil containing NA-LUBE KR-015 showed excellent performance, while the oils containing the esters resulted in thick, dark deposits, and in the case of the TMP ester, extensive degradation of the metal.

FTM 3411 - Thermal Stability and Corrosivity of Aircraft Turbine Engine Lubricants

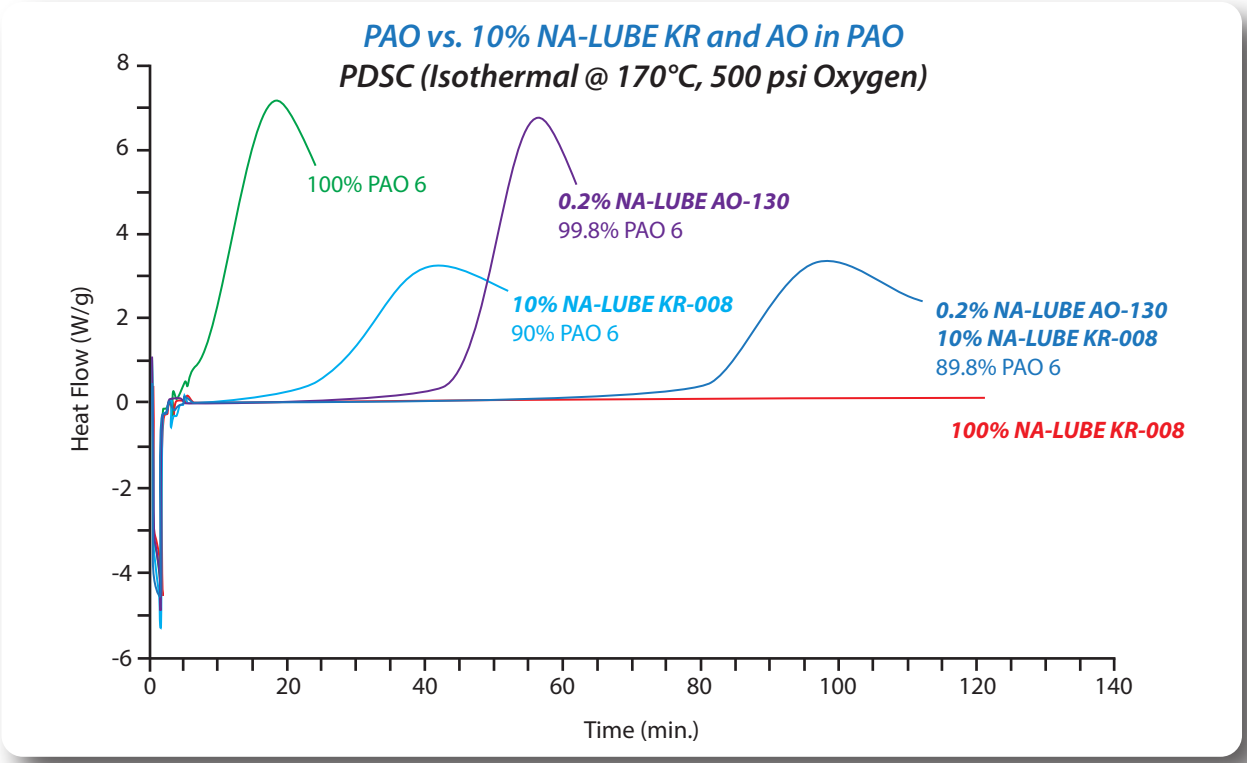
274°C for 96 hours with steel coupon in sealed glass tube

	7 cSt Group III	*20% KR-015* 80% 7 cSt Group III	20% TMP Ester 80% 7 cSt Group III	20% Diester 80% 7 cSt Group III
Percent Change in Viscosity	0	**0**	-10.0	-15.8
Change in Acid Number (mg KOH/g)	0	**0**	6.0	0.5
Change in Metal Weight (mg/cm^2)	0	**0**	-3.0	0
Metal Appearance	Clean	**Shiny**	Etched	Etched / Black
Oil Appearance	Clean	**Clear / Slight Amber**	Very Dark Amber	Black
Test Cell Appearance	 Clean	 **Clean**	 Light Staining	 Heavy Black Stains

ASTM D6186 - This test measures the oxidation induction time (OIT) to an onset of an exotherm. The curves below show the improvement in the oxidative stability of a Group II base oil (ISO VG 46) when modified with 20% ***NA-LUBE® KR-019, KR-015*** or ***KR-008***.



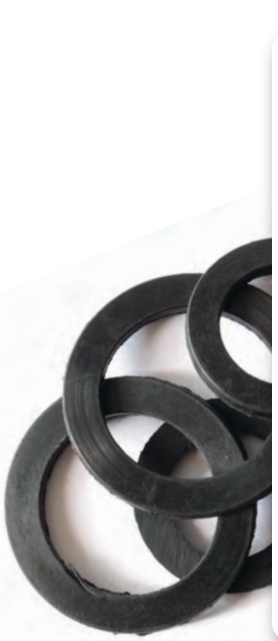
The curves below show the improvement in the oxidative stability at 170°C of a 6 cSt PAO when modified by 10% ***NA-LUBE KR-008***. Also shown is the positive effect of adding 0.2% of an aminic antioxidant, ***NA-LUBE AO-130***, to the blend.

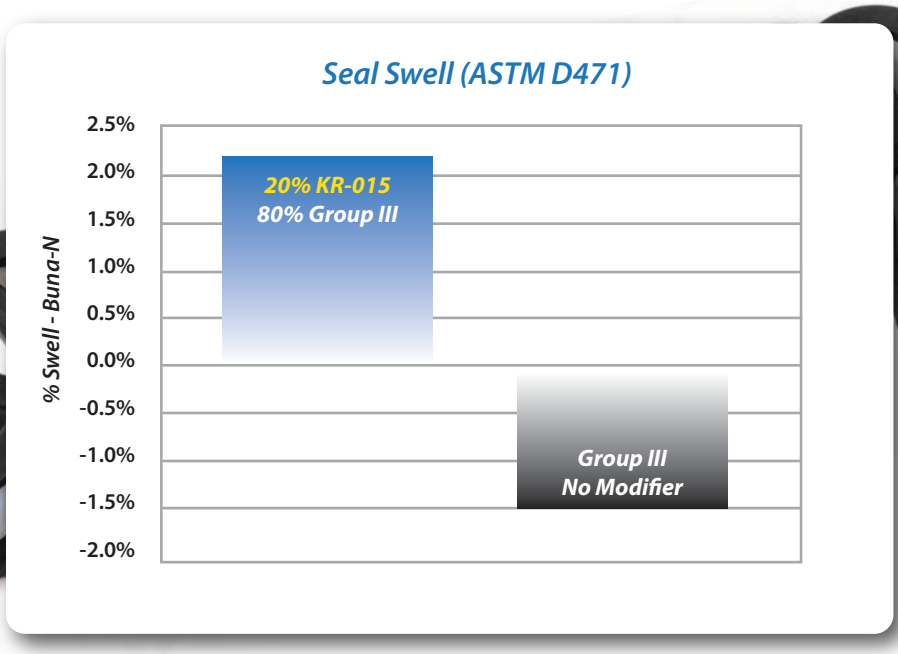


Seal Swell

Seal Swell - The addition of 20% ***NA-LUBE® KR-015*** to a 7 cSt Group III oil resulted in 2% seal swell.

- **Balanced polarity**
- **Imparts seal swell**
- **Effective in most rubber types**





Thin Film Volatility

Thin Film Volatility - In this test, 2g of fluid was held in an aluminum pan for 24 hours at temperatures of 200°C, 225°C and 250°C. The table below shows that when 20% NA-LUBE KR-019 is added to a 40 cSt PAO, the volatility of the PAO containing fluid was significantly reduced. For comparison, a diisotridecyl adipate ester at 20% in the PAO resulted in significantly higher volatility.

Thin Film Volatility

(2 grams in aluminum pan for 24 hours)

	Weight Loss, %		
	200°C	225°C	250°C
PAO 40 cSt	17.9	29.8	45.4
NA-LUBE KR-019	***8.5***	***19.7***	***41.6***
20% Ester / 80% PAO	28.5	43.1	56.7
20% NA-LUBE KR-019 / 80% PAO	***9.4***	***20.2***	***39.6***

NA-LUBE® KR alkylated naphthalenes exhibit excellent performance properties when used as either the sole or co-base oil for grease applications.

The table below shows that ***NA-LUBE KR-015*** significantly reduces the amount of lithium soap required to prepare NLGI #2 lithium 12-hydroxystearate (Li-12-OH) greases, while imparting excellent performance properties. ***NA-LUBE KR*** products impart similar performance when used in polyurea or aluminum complex greases. Data is available upon request.

NA-LUBE KR-015

Neat Grease Comparison

PAO 10 (89%)
Li-12-OH (11%)

KR-015 (93%)
Li-12-OH (7%)

Neat Base Oil Comparison

in Lithium 12-OH Grease (NLGI#2)

	89% PAO 10 11% Li-12-OH	93% ***KR-015*** 7% Li-12-OH
P (60) **P (100K)** **% Change**	273 350 28	288 366 27
Oil Separation	4.1%	2.8%
Dropping Point	202°C	200°C
TGA	233°C	304°C

- **Requires less thickener - improves low temperature properties**
- **Imparts superior thermo-oxidative stability**
- **Acts as a bridging solvent - reduces opaqueness**
- **Acts as a highly effective dispersant - produces a smooth grease**

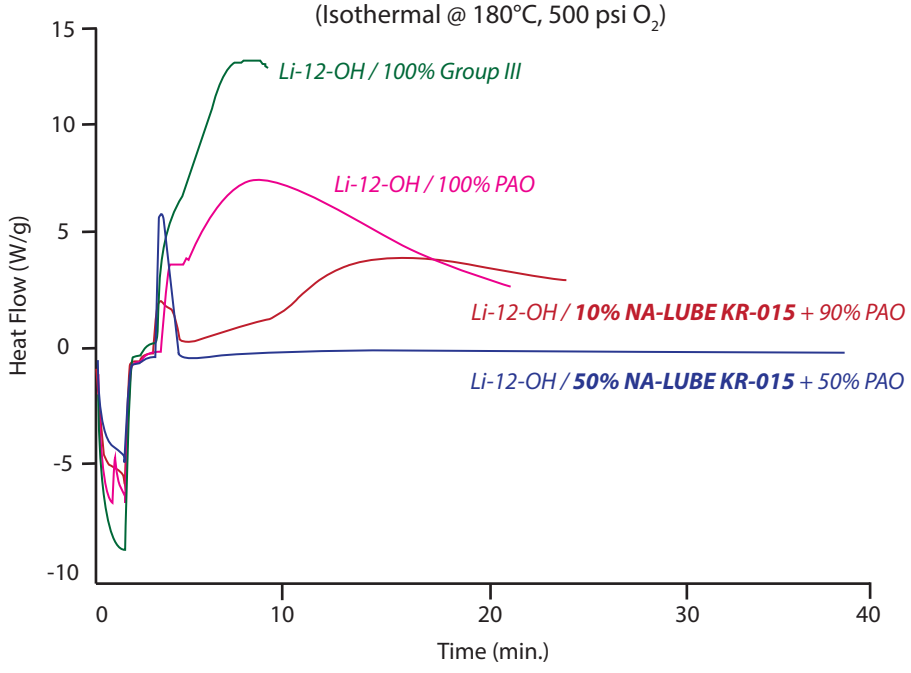
Thermo-oxidative Stability

PDSC - ASTM D5483

The PDSC curves on the right show the thermo-oxidative stability at 180°C of greases made with Group III oil and PAO as well as the improvements that can be gained by modifying the PAO grease with ***NA-LUBE KR-015.***

PDSC - ASTM D5483

(Isothermal @ 180°C, 500 psi O_2)



High Temperature Chain Lubricants

High temperature applications place severe demands on lubricating oils and additives. ***NA-LUBE® KR*** alkylated naphthalenes are especially suited to these applications. Low volatility and excellent thermo-oxidative stability are two of the attributes that help extend the functional life of high temperature lubricants.

- **Lowers volatility to retain fluid longer - Noack 2% or less for *NA-LUBE KR-015* & *KR-019***
- **Thermo-oxidative stability inhibits fluid degradation and varnish formation**

High temperature chain lubrication is a prime example for the benefits of the ***NA-LUBE KR*** series. The following examples show the benefits of modifying a polyol ester with ***NA-LUBE KR-019***.

The table below shows how the addition of 20% NA-LUBE KR-019 to a polyol ester chain lubricant can extend the functional life. After eight hours at 260°C, the polyol ester is a solid varnish. The sample modified with ***NA-LUBE KR-019***, although darkened, remains fluid and functional.

NA-LUBE KR - High Temperature Performance

3 grams of fluid in aluminum pan for 8 hours @260°C

	Polyol Ester ISO VG 68	80% Polyol Ester ISO VG 68 *20% KR-019*
Original Weight (g)	3.0	3.0
Weight After 8 hours (g)	0.2	0.9
Evaporation Loss (%)	94%	70%
Appearance *INITIAL*		
Appearance *AFTER* 8 hours @ 260°C		
	Solid Varnish	Viscous Liquid

The example below further demonstrates the benefits of ***NA-LUBE® KR-019*** in a chain lubricant fluid. The chain lubricant containing the polyol ester froze after 8 hours at 260°C. The fluid modified with ***NA-LUBE KR-019*** continues to lubricate post-bake.

NA-LUBE KR - High Temperature Performance

Extended Service Life of a *NA-LUBE KR Modified POE*

Color has NO effect on performance

100% Polyol Ester ISO VG 68

Solid Varnish

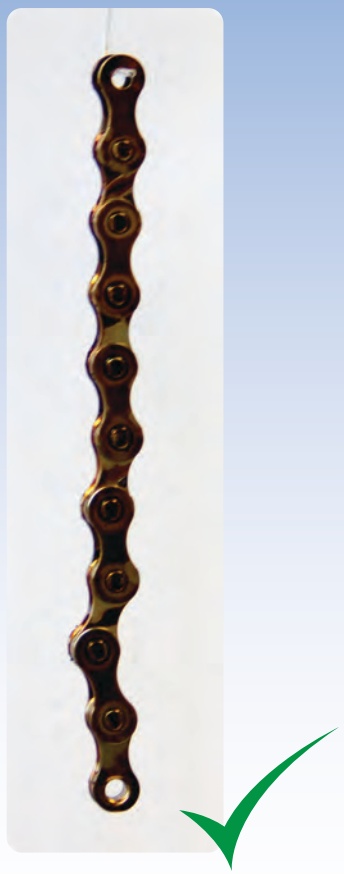
No Extension
Chain Seized

Coated and baked for 8 hours @260°C

Post-bake hanging performance

80% Polyol Ester ISO VG 68
20% KR-019

Dark Viscous Liquid



Full Extension **- 2 sec.**

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