# *New Developments with NA-LUBE® KR Alkylated Naphthalene*

**3B | Commercial Marketing Forum III**

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KING INDUSTRIES SPECIALTY CHEMICALS

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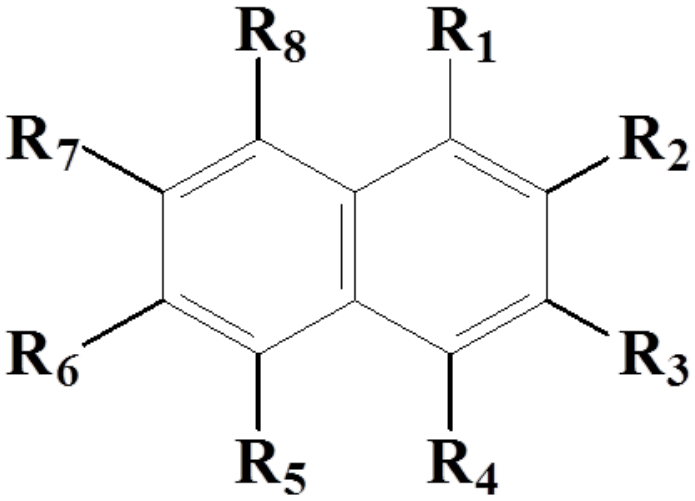
# *Presentation Outline*

- Alkylated Naphthalene Background
- Physical / Chemical Properties
- Lubricant Trends
- Performance data focusing on High Temperature Applications
- Summary

# *Alkylated Naphthalenes*

- High Performance Group V Base Oils
- Co-Base Oil
  - with other synthetics or Group II and Group III oils
  - to enhance thermal and oxidative stability, varnish control and additive response
  - to extend the lifetime of high performance lubricants

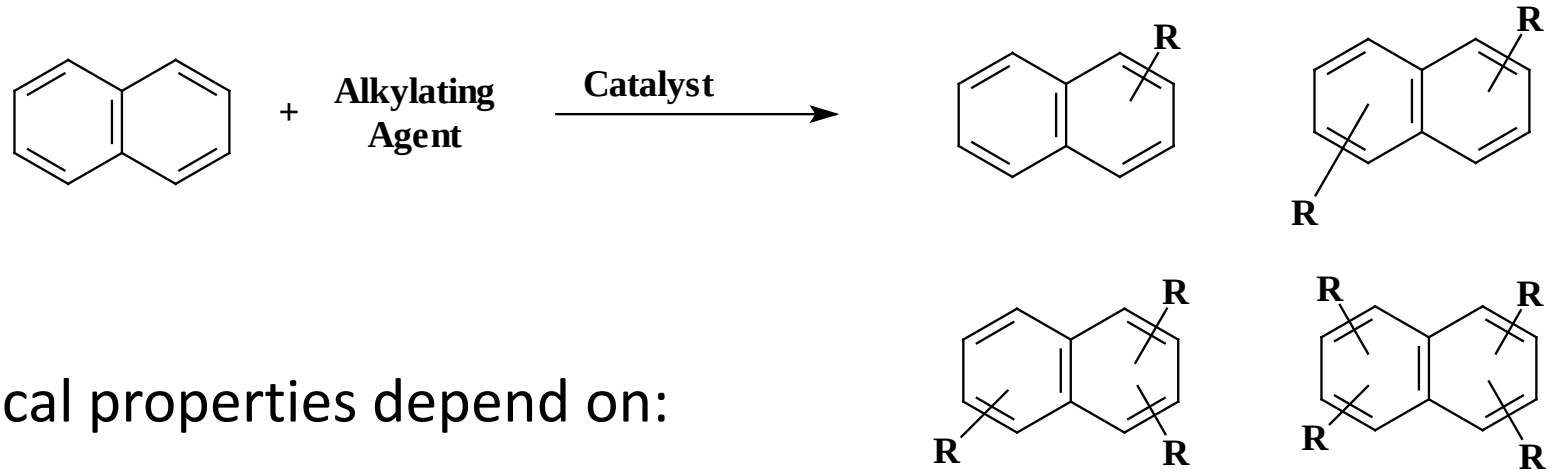
# *Alkylated Naphthalene Structure*




R1 to R8 are independently a linear or branched alkyl group or hydrogen.

The core naphthalene system consists of two fused six-membered rings with a electron rich conjugated π system.

# *Alkylated Naphthalene Synthesis*




Physical properties depend on:

Number of *carbons* in the alkyl group
(Controlled by raw material selection)

Degree of branching of the alkyl group
(Controlled by raw material selection)

*Number* of alkyl groups on the naphthalene ring
(Controlled by chemical processing)

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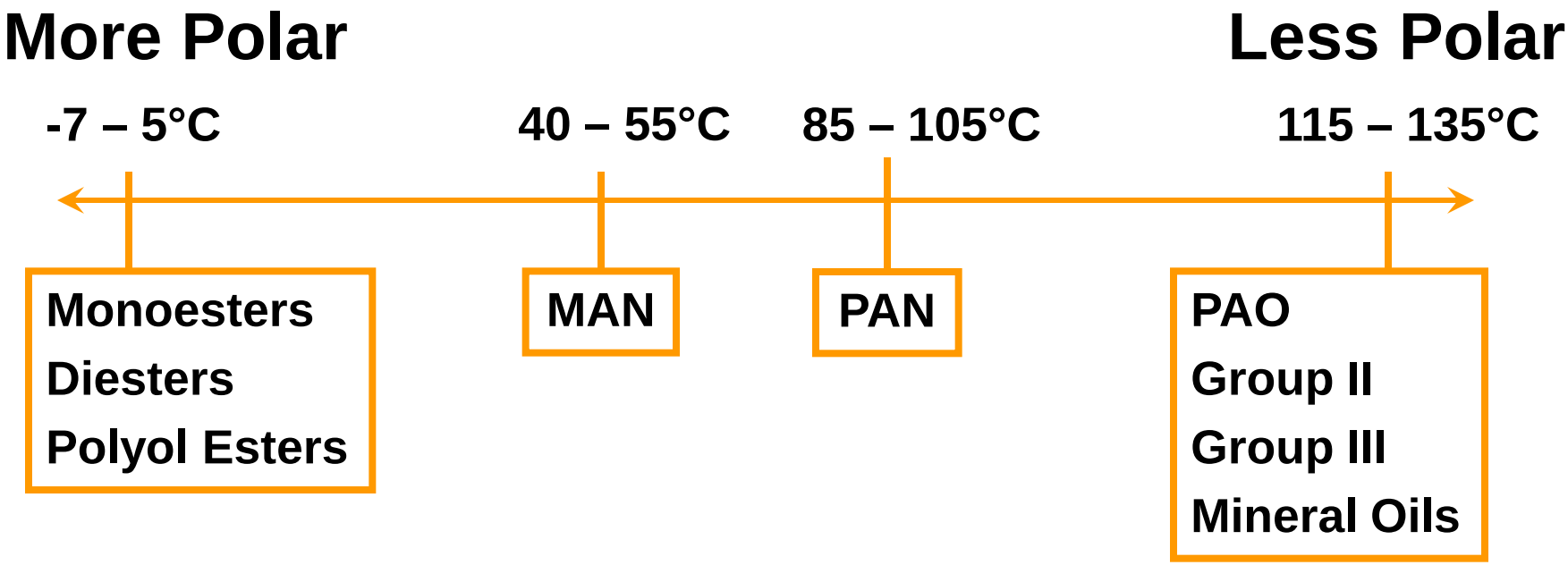
# *Aniline Point*




Alkylated naphthalenes can aid in solubilizing additives in non-polar base stocks

# *Alkylated Naphthalene Properties*

| NA-LUBE | Viscosity @ 40ºC ASTM D445 | Viscosity @ 100ºC 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 | 40ºC | 39 wt% | <-48ºC | 206ºC |
| KR-008 | 36 cSt | 5.6 cSt | 65 | 42ºC | 12 wt% | -33ºC | 236ºC |
| KR-009 | 37 cSt | 5.7 cSt | 90 | 50ºC | 8 wt% | -36ºC | 240ºC |
| KR-015 | 114 cSt | 13.5 cSt | 115 | 94ºC | 2.2 wt% | -39ºC | 260ºC |
| KR-019 | 177 cSt | 18.7 cSt | 119 | 103ºC | 1.4 wt% | -26ºC | 285ºC |
| KR-023 | 193 cSt | 19.8 cSt | 118 | N/A | <1.0 wt% | -21ºC | 310ºC |
| KR-006FG | 36 cSt | 5.6 cSt | 90 | 42ºC | 11 wt% | -33ºC | 236ºC |
| KR-015FG | 114 cSt | 13.5 cSt | 115 | 94ºC | 2.2 wt% | -45ºC | 260ºC |
| KR-029FG | 177 cSt | 19 cSt | 119 | 103ºC | 1.4 wt% | -26ºC | 285ºC |

# *General Performance Features of Alkylated Naphthalenes*

- **Thermo-oxidative stability**
  - Excellent performance because of the electron-rich naphthalene ring
- **System Cleanliness**
  - Excellent Varnish Control
- **Volatility**
  - Low volatility as compared to other base stocks

# *General Performance Features of Alkylated Naphthalenes*

- **Solvency**
  - An intermediate aniline point that has the right balance of polarity
  - Good additive response
  - No surface competition with the additives
- **Viscometrics and VI**
  - A variety of viscosities with low pour points and a good VI
- **Base Oil Modifying Properties**
  - Excellent compatibility with other base stocks to achieve balanced and enhanced performance
- **Hydrolytic stability**
  - No functional groups that can hydrolyze

# *General Performance Features of Alkylated Naphthalenes*

- **Good Lubricity / film thickness / reduced friction**
- **Good seal swelling properties**
- **Nuclear radiation resistance**
- **Good air release properties**
- **HX-1 Approvals – “Food Grade”**

# *Main Application Areas*

- Automotive and Stationary Engine Oils
- Automotive and Industrial Gear Oils
- High Temperature Chain Lubricants
- Paper Machine Oils
- Hydraulic Oils
- Circulating Oils/Turbine Oils/R&O Oils
- Screw Compressor Oils
- Heat Transfer Oils
- Windmill Oils and Greases
- Automotive and Industrial Greases

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# General Lubricant Trends
## Industrial, Auto Engine & Driveline, Greases

- Higher operating speeds & temperatures
- Longer life lubricants; extended drain intervals
- Reduced lubricant volumes
- Sealed-for-life systems

Lead to the requirements for:

- Improved thermo-oxidative stability
- Improved thermal stability
- Improved additive response
- Improved compatibility with seals & housings

# *Fluids Evolve to Meet These Trends*

Meeting the demanding trends in industrial lubricants, automotive engine oils, driveline fluids, and greases is the driver to the growth of optimized combinations of highly refined petroleum oils and synthetic base stocks:

- Group II hydrotreated mineral oils
- Group III severely hydrocracked oils
- Group IV polyalphaolefins (PAO)
- Esters
- Alkylated naphthalenes

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# *New Results for High Temperature Applications*

- High Temperature Chain
- Plywood Manufacturing
- In-house Panel Coker

# High Temperature Chain Lubricants

# *High Temperature Chain Lubricants*

Alkylated naphthalenes extend fluid lifetime by:

- Reducing the volatility to retain the fluid longer
- Imparting thermal and thermo-oxidative stability to inhibit viscosity increase and varnish formation

# *Chain Lubricant Market*
## *Application and Base Fluid 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 | Water Soluble PAG, PAO, Ester, **Alkylated Naphthalene** |
| 180 – 250°C | Automobile & beverage can painting | Trimellitate / Dimer Esters, PAO, **Alkylated Naphthalenes** |
| 220 – 300°C | Plywood/textile/ceramic/ plastic film manufacturing | Dimer / Polyol Esters **Alkylated Naphthalenes** |
| >600°C | Pottery/brick/cement kilns | PAGs as carrier for solid lubricants (e.g. graphite) |

# *Typical Chain Lubricant Formulation*

- Base fluid with:

0 – 20% Thickener / Tackifier / Adhesion Improver

- PIB, VI improvers

1 – 5% Antioxidant(s)

- Combinations of aminics , phenolics

0 – 5% Extreme Pressure / Antiwear

- Phosphates, amine phosphates, S/P type (triphenyl ZDP, thiophosphate)

0 – 1% Corrosion Inhibitor

- Ferrous: organic acids, partial esters, amides, sulfonates
- Copper: triazoles, thiazoles

0 – 0.1% Defoamer

- Organics, silicones, modified siloxanes

# *Test Procedure*

- Testing was conducted to determine if the addition of alkylated naphthalene to chain lubricant formulations would help with the high temperature performance.

- Test Method:
  - 3 g of test fluid are place in an aluminum pan
  - Sample is heated at 260°C for 8 hours
  - Report:
    - % Evaporation Loss
    - Condition of fluid

# *Evaporation Loss Reduction to Retain Fluid*

| | POE 1963* | 97% POE 1963<br>3% AO Blend† | 80% POE 1963<br>20% NA-LUBE KR-019 | 77% POE 1963<br>20% NA-LUBE KR-019<br>3% AO Blend |
|---|---|---|---|---|
| **Blend Number** | **1** | **2** | **3** | **4** |
| **Evaporation Loss**<br>8 Hours @ 260°C | **94%** | **94%** | **71%** | **68%** |

**NA-LUBE KR-019 alone has an evaporation loss of 43%.**

* Priolube 1963 is an ISO VG 68 polyol ester recommended for high temperature chain lubricants (180–300°C).

† AO Blend is a 50:50 mixture of alkylated diphenylamine with phenyl-alpha naphthylamine.

# *Evaporation Loss Reduction to Retain Fluid*

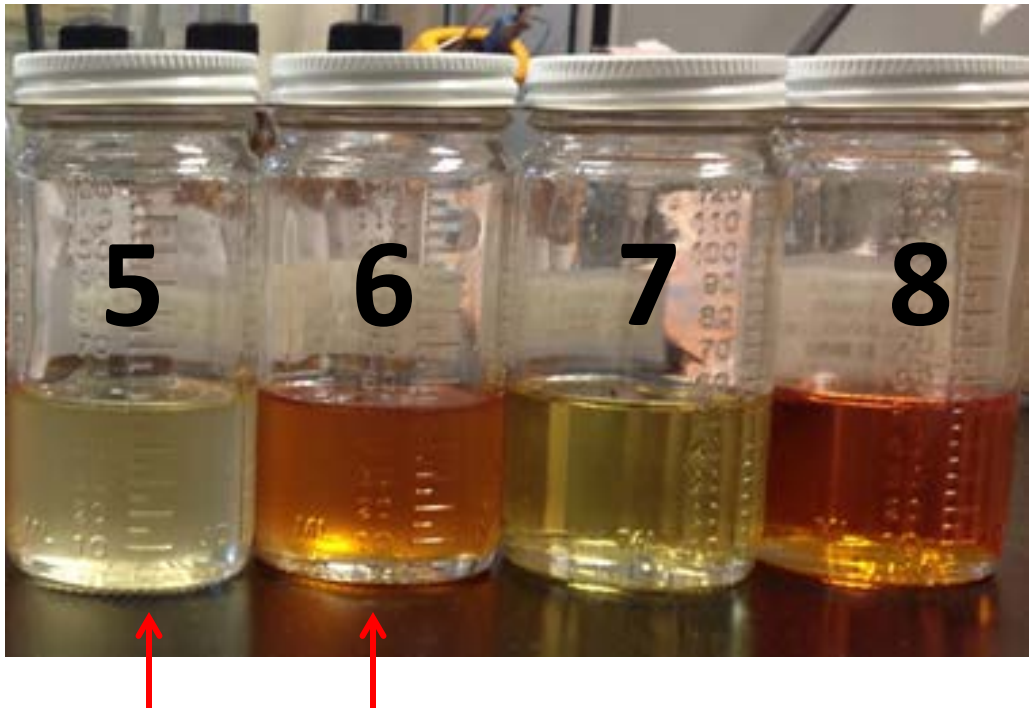
| | POE 1963 | NA-LUBE KR-019 | 80% POE 1963<br>20% NA-LUBE KR-019 |
|---|---|---|---|
| **Evaporation Loss**<br>8 Hours @ 260°C | **94%** | **43%** | **Theoretical: 84%**<br>**Actual: 71%** |

# *Evaporation Loss Reduction to Retain Fluid*

| | 88% POE 1963<br>12% PIB 950 | 85% POE 1963<br>12% PIB 950<br>3% AO Blend | 68% POE 1963<br>12% PIB 950<br>20% NA-LUBE KR-019 | 65% POE 1963<br>12% PIB 950<br>20% NA-LUBE KR-019<br>3% AO Blend |
|---|---|---|---|---|
| **Blend Number** | **5**<br>**Hazy** | **6**<br>**Hazy** | **7**<br>**Clear** | **8**<br>**Clear** |
| **Evaporation Loss**<br>8 Hours @ 260°C | **95%** | **96%** | **69%** | **69%** |

**POE 1963 alone has an evaporation loss of 94%.**

# *Appearance of Blends*




- **Blends 5 and 6 containing PIB with no alkylated naphthalene are hazy.**
- **Blends 7 and 8 are the same formulations with 20% alkylated naphthalene. These blends show no haziness.**

# *Samples Before Aging*

# *Samples After Aging* at 260°C for 8 Hours

- **The lighter brown samples do not contain NA-LUBE KR-019 and resulted in thin, hard varnish.**
- **The darker samples contain NA-LUBE KR-019 and resulted in less evaporation leaving thicker/ viscous but still liquid samples.**

# *Alkylated Naphthalene Blends After Aging*

- **The viscosity of the samples that <u>contain</u> NA-LUBE KR-019 increased after being heated, but the remaining samples were self-healing when scratched.**

# *Alkylated Naphthalene Blends After Aging*

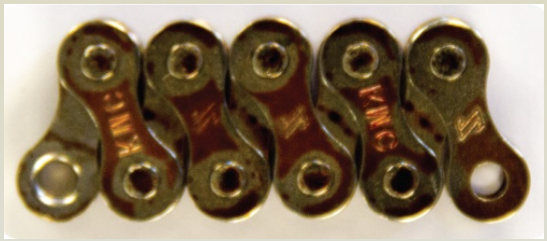
- **The samples that <u>contain</u> NA-LUBE KR-019 flow after aging.**

# *Varnished Blend Without Alkylated Naphthalene*

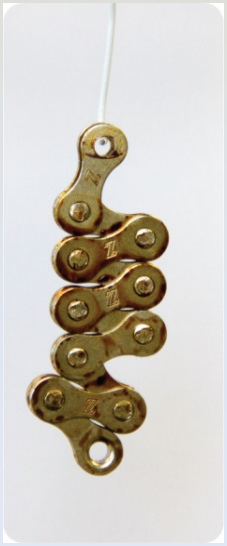
- **The samples <u>without</u> NA-LUBE KR-019 created a thin, hard varnish on the metal surface and were not self-healing when scratched.**

# *Extended Service of a NA-LUBE® KR Containing POE*

**100% Polyol Ester ISO VG 68**



**Solid Varnish**

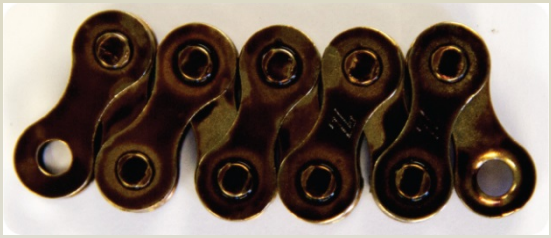


**No Extension**
**Chain Seized**

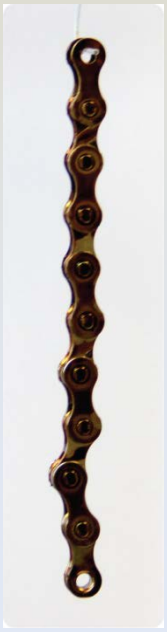
**Coated and baked for 8 hours @ 260°C**

**Post-bake hanging performance**

**80% Polyol Ester ISO VG 68**
***20% NA-LUBE KR-019***



**Dark Viscous Liquid**



**Full Extension - 2 Seconds**

# *High Temperature Chain Lubricants*

- The addition of NA-LUBE KR-019 resulted in:
  - less evaporation loss
  - sample clarity
  - superior varnish control

- The samples containing NA-LUBE KR-019 remained liquid:
  - retaining lubrication
  - avoiding varnish flake off

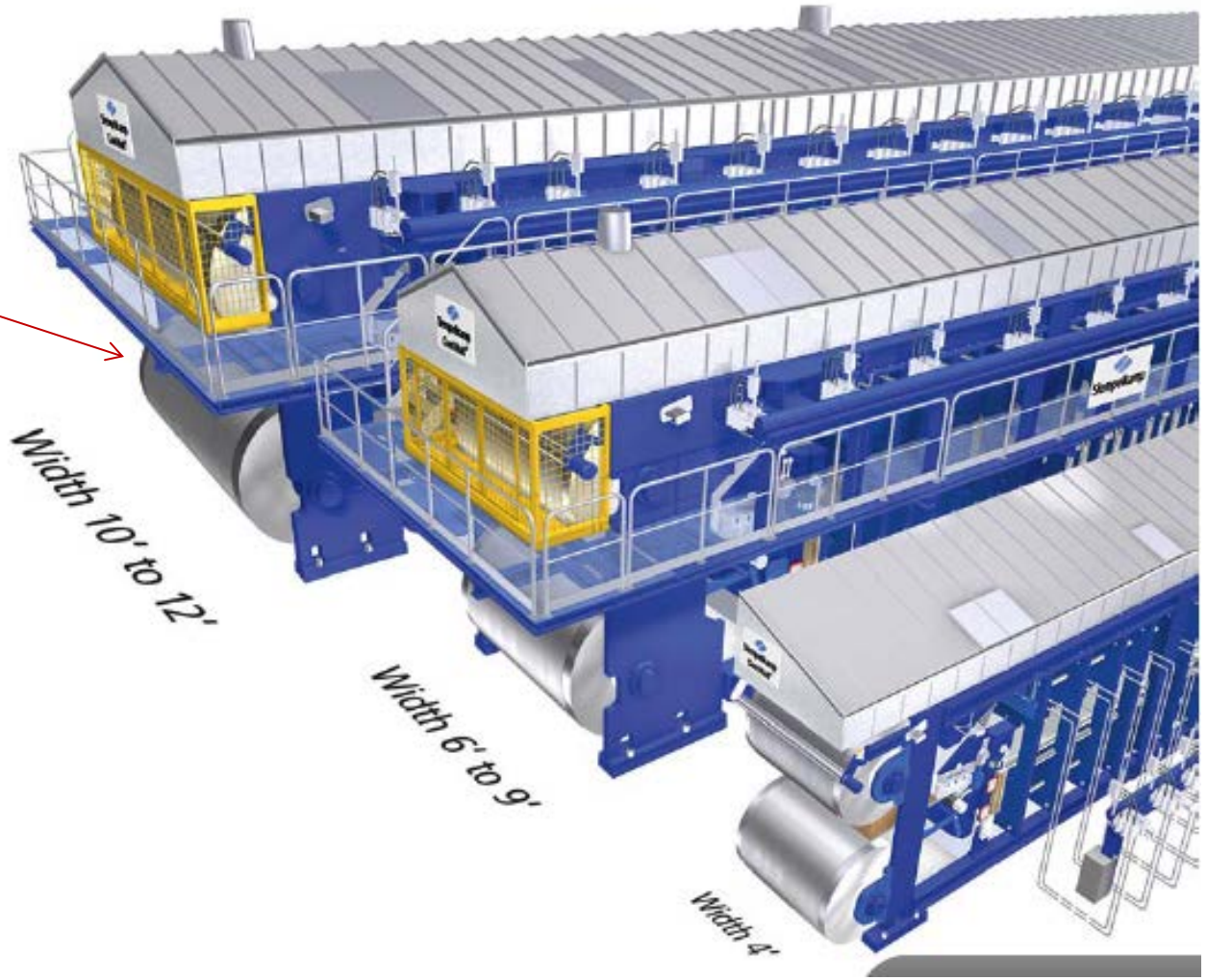
# Plywood Manufacturing

# *Conveyor Belt Oil for Plywood Manufacturing*

Alkylated naphthalenes:

- When used for the first time in a press, dissolved the deposits on drive roller friction liners that had formed from an oil previously used.

# *Plywood Manufacturing – Hot Presses*




**240°C – 260°C**

# *Cleaning of Equipment*

**High Temperature Belt Oil for Plywood Manufacturing**

- Prior to using the oil containing the NA-LUBE KR-019, pictures were taken of the friction liners showing heavy deposits from oxidation products of the previously used oil.
- After 6 months of using the oil containing the NA-LUBE KR-019, it was observed that the oil was very dark and the friction liners were completely clean.
- When the darken oil containing the NA-LUBE KR-019 that had dissolved the deposits was exchanged for fresh oil, the deposit formation and oil darkening did not reoccur.

# *Removal of Deposits*

Friction liners before and after 6 months of NA-LUBE KR-019 containing product use.

# *Plywood Manufacturing*

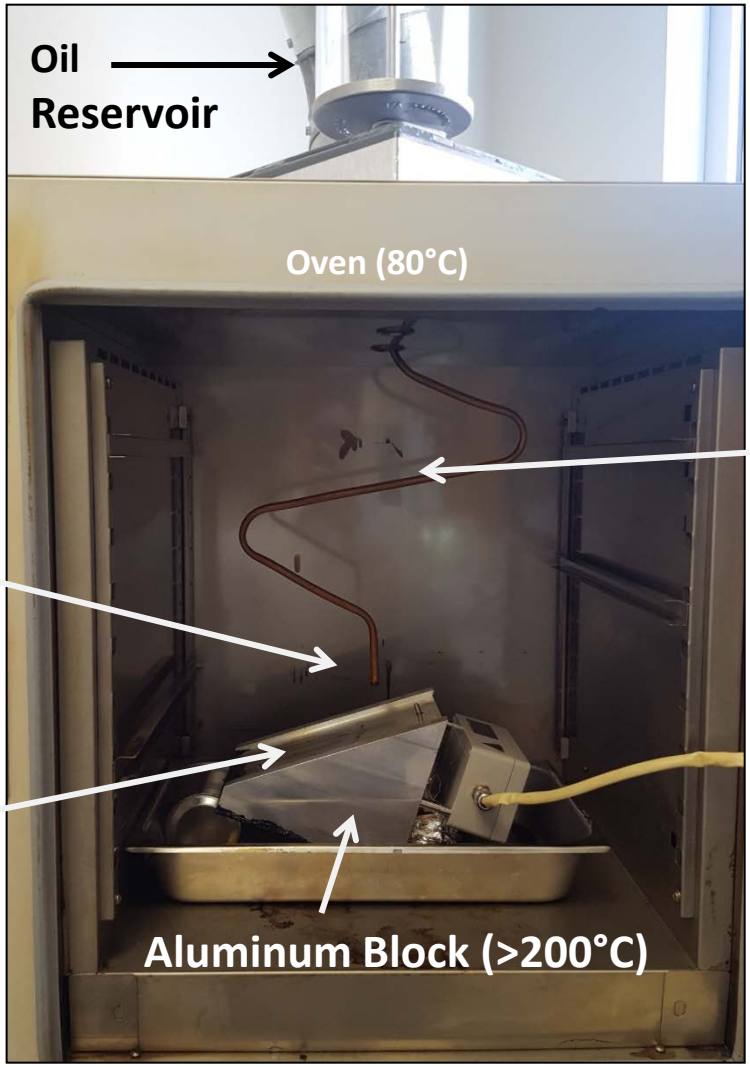
**Cleaning of equipment by NA-LUBE KR-019**

- reduced unwanted noise, vibration and wear of the equipment
- greatly reduced maintenance cost

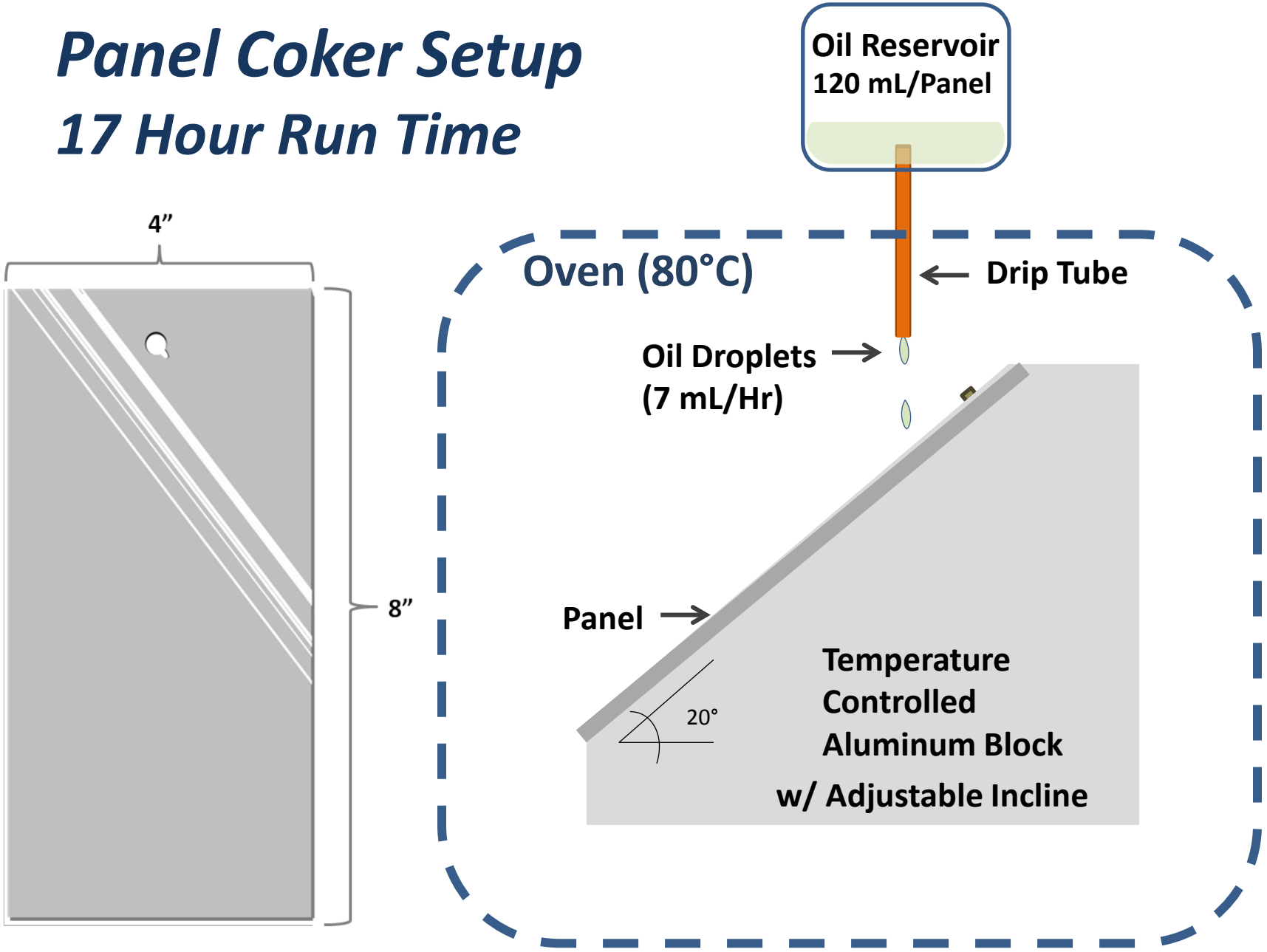
# In-House Panel Coker Test

To determine tendencies of oils to form coke in a moving system when in contact with a hot metal surface.

# *In-house Panel Coker*



# Panel Coker Setup
## 17 Hour Run Time



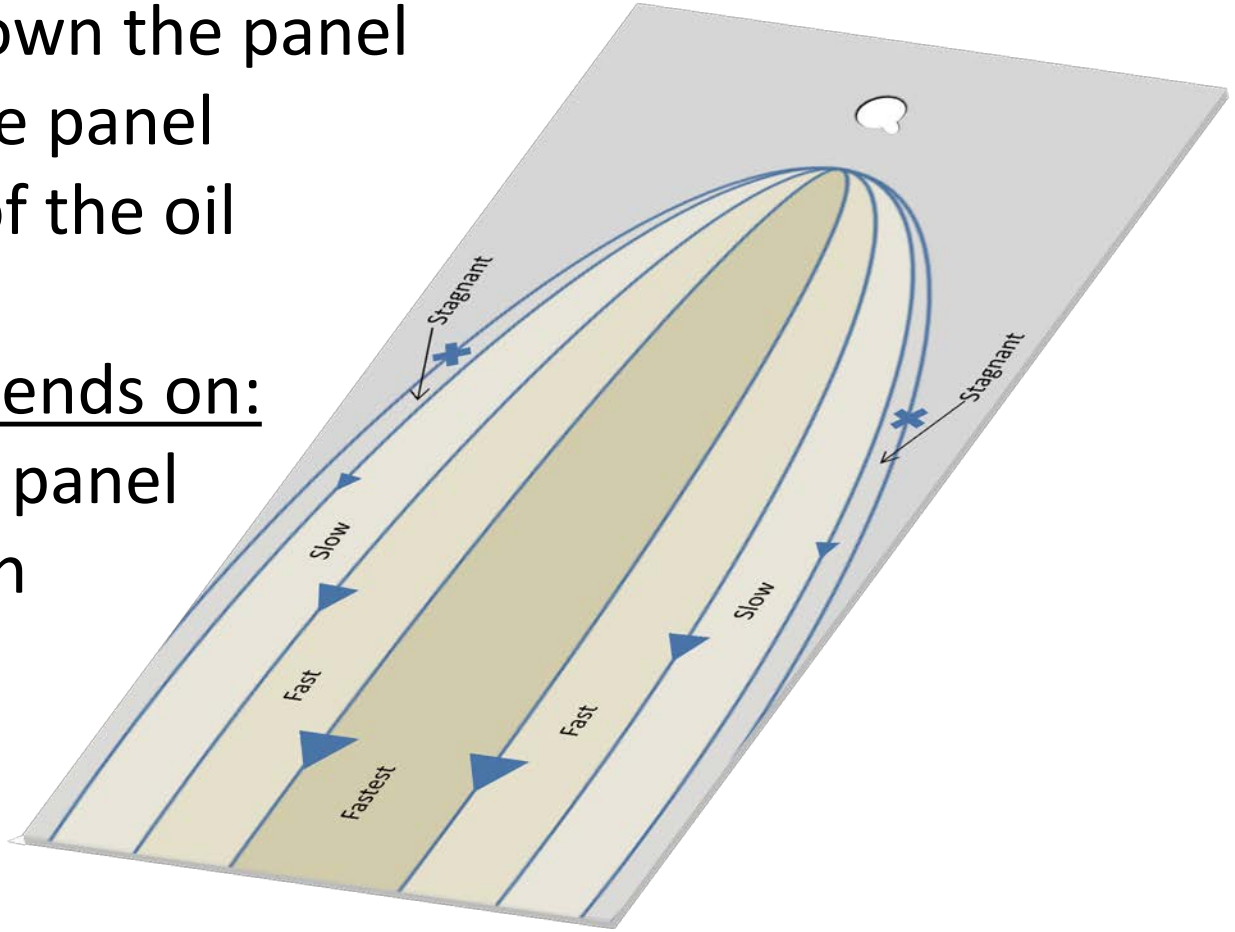
# *King Panel Coker Test*

Coking pattern depends on:

- Oil flow pattern down the panel
- Temperature of the panel
- Thermal stability of the oil

Oil Flow pattern depends on:

- Dimensions of the panel
- Panel surface finish
- Pitch of the panel
- Viscosity of the oil



# *King Panel Coker Test*

If:

- all reasonable parameters are controlled
- the flow pattern of oil is understood

Then:

- the thermal stabilities of oils can be compared by qualitatively evaluating their coking patterns at various temperatures

# *King Panel Coker Test*

**After 2 drops of PAO 8 cSt at 230°C**

# *Flow Pattern and Coke Pattern*

**Panel A**

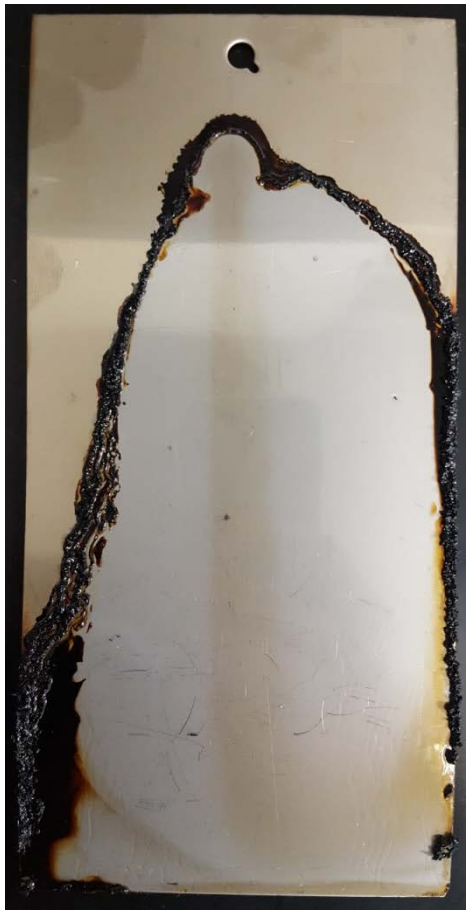
At surface temps below the *Coking Temperature,* the oil flows over the bottom edge and off of the panel

**Panel B**

At surface temps at or above the *Coking Temperature,* the oil cokes before reaching the bottom edge of the panel

**An oil's *Coking Temperature* is the lowest panel temperature at which a closed coke pattern is observed.**

**Panel A**



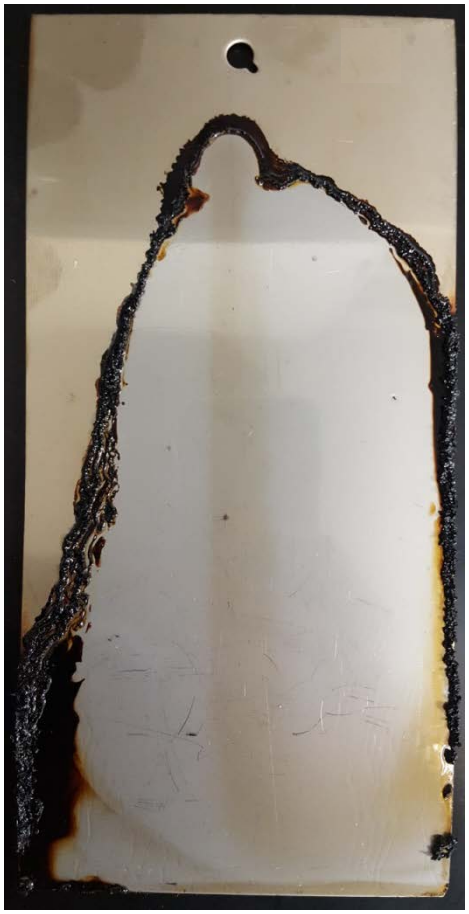
**Open Coke Pattern**
**Passed at 220°C**

**Panel B**

**Closed Coke Pattern**
**Failed at 230°C**

*100% PAO 8*

# *Coking Patterns at 220°C*



**Open Coke Pattern**
**100% PAO 8**

**Open Coke Pattern**
**80% PAO 8**
**20% NA-LUBE KR-019**

# *Coking Patterns at Different Temperatures*

**220°C**

**Open Coke Pattern**

**240°C**

**Open Coke Pattern**

**250°C**

**Closed Coke Pattern**

**80% PAO 8 / 20% NA-LUBE KR-019**

# *Coking Patterns at Different Temperatures*

**220°C**

**Open Coke Pattern**

**Good Repeatability**

**220°C**

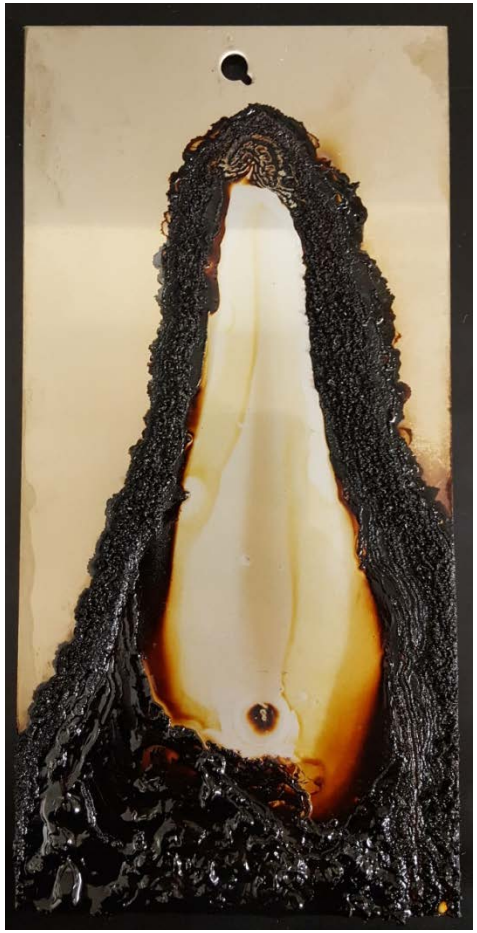
**Open Coke Pattern**

**230°C**

**Closed Coke Pattern**

**100% ISO VG 46 Group III**

# Coking Patterns at 230°C

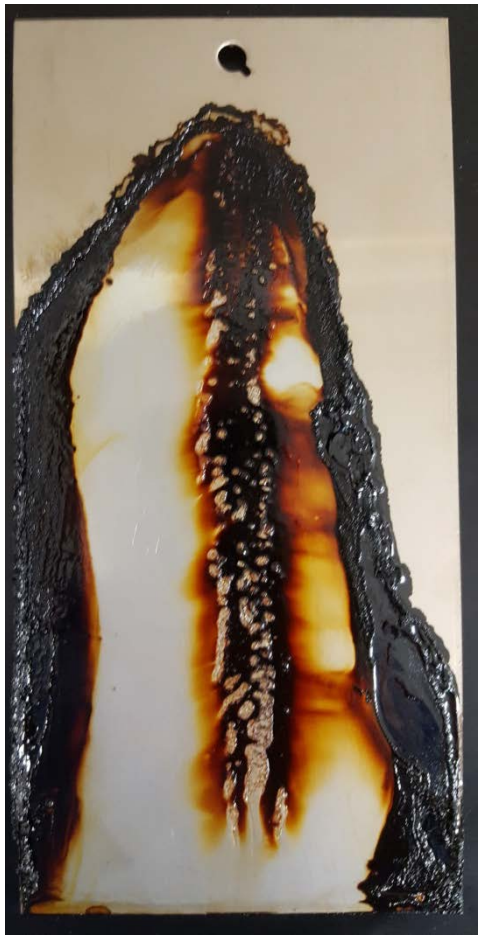


**Closed Coke Pattern**

**100% ISO VG 46**
**Group III**

**Closed Coke Pattern**

**90% Group III**
**10% NA-LUBE KR-019**



**Open Coke Pattern**

**80% Group III**
**20% NA-LUBE KR-019**

# *Coking Patterns at Different Temperatures*

**230°C**

**Open Coke Pattern**

**240°C**

**Open Coke Pattern**

**250°C**

**Closed Coke Pattern**

**80% ISO VG 46 Group III / 20% NA-LUBE KR-019**

# *In-house Panel Coker – Current Results*

- **For PAO 8:**
  - The Coking Temperature was 230°C.
  - 20% NA-LUBE KR-019 addition increased the Coking Temperature to 250°C.

- **For ISO VG 46 Group III:**
  - The Coking Temperature was 230°C.
  - 20% NA-LUBE KR-019 addition increased the Coking Temperature to 250°C.

# *In-house Panel Coker – Future Testing*

- Collect the fluid flowing off the panel and conduct analytical and performance testing.
- Evaluate the ability of alkylated naphthalene to dissolve deposits formed by other oils.
- Evaluate the coking patterns and temperatures of fully formulated high temperature fluids with and without alkylated naphthalene.

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# *Summary*

***Why Use Alkylated Naphthalenes***

- Diverse viscosity range for flexibility in designing lubricants for a variety of applications
- Excellent thermal & thermo-oxidative stability
- Excellent varnish control
- Low volatility with higher viscosity
- Superior solubility characteristics than Group II, Group III, and Group IV (PAO)

# *Summary*

***Why Use Alkylated Naphthalenes***

- Inherent hydrolytic stability
- Excellent additive response
- Good low pour point
- Good film thickness and film strength
- Good seal swelling

# King Industries Offers


- Alkylated Naphthalene
- Blends/Packages
- Friction Modifiers
- Antiwear
- Antioxidant
- Extreme Pressure
- Corrosion Inhibitors
- Rust Inhibitors
- Rust Preventive
- Technical Product Support