QUALITY WORKS.

Formulating with synthetic base oils for improved lubricant performance

STLE – Toronto Section

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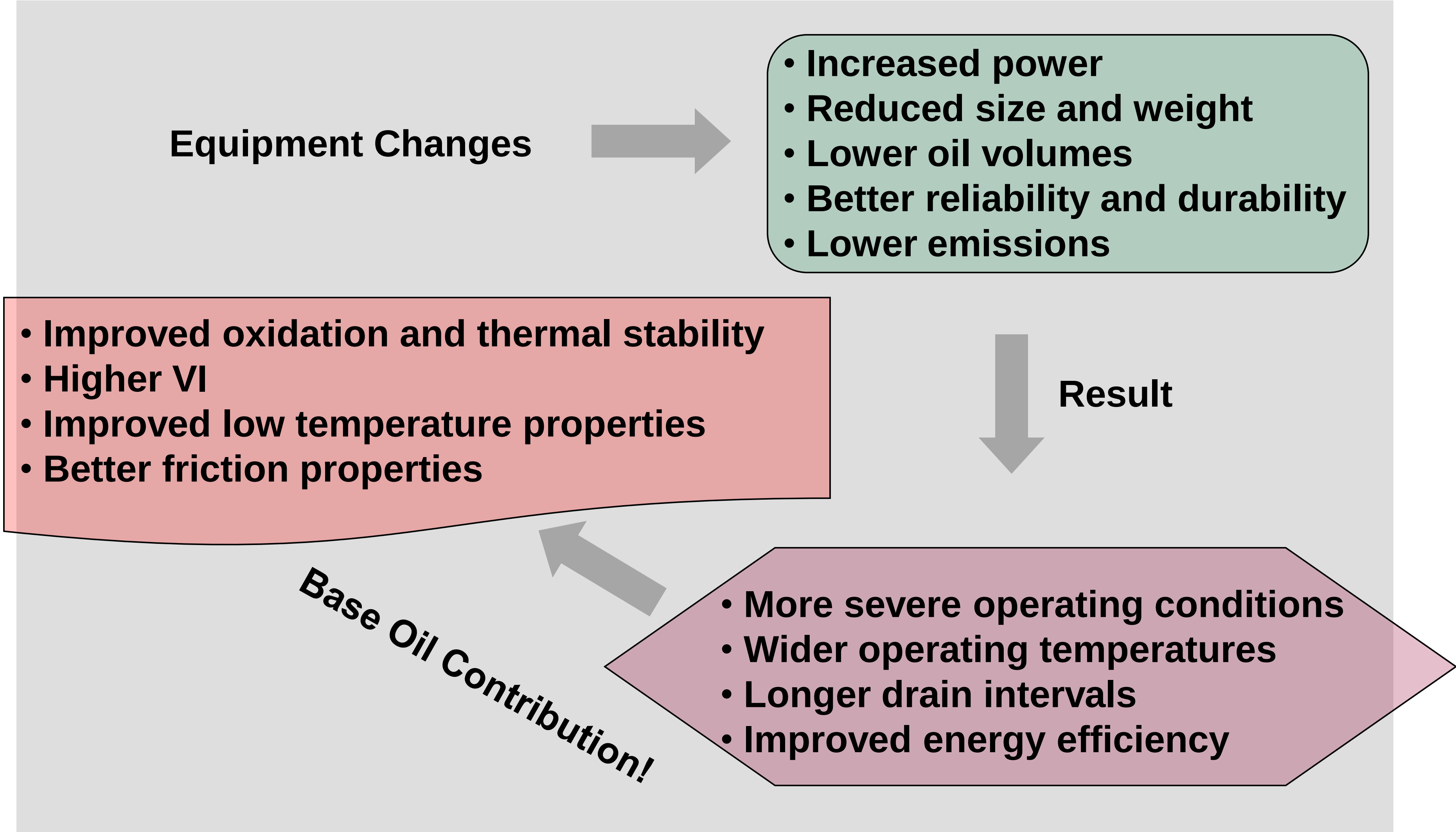
Energizing Chemistry

Outline

- Lubricant Trends
- History
- Why Synthetics
- Energy Efficiency and How Synthetic Base Oils Can Impact

Lubricant Trends



Equipment Changes

- Increased power
- Reduced size and weight
- Lower oil volumes
- Better reliability and durability
- Lower emissions

Result

- More severe operating conditions
- Wider operating temperatures
- Longer drain intervals
- Improved energy efficiency

Base Oil Contribution!

- Improved oxidation and thermal stability
- Higher VI
- Improved low temperature properties
- Better friction properties

Brief History of Synthetics

- Synthetics used in lubricants for many years
  - 1937 – PAO first produced
  - 1938-44 – many esters prepared/evaluated in Germany
  - 1940’s – US development of esters started
    - Both PAO and Esters developed and used in certain applications during the war. Mainly for aviation and hot/cold climates
  - 1958 – first polyol ester developed and used in jet engine oil
  - 1972 – first 100% diester automotive engine oil meeting API standards
  - 1973 – PAO based engine oil commercialized in Europe
  - 1975 – PAO based engine oil commercialized in US
- Products continued to expand / grow taking advantage of properties / performance the synthetic oils provide

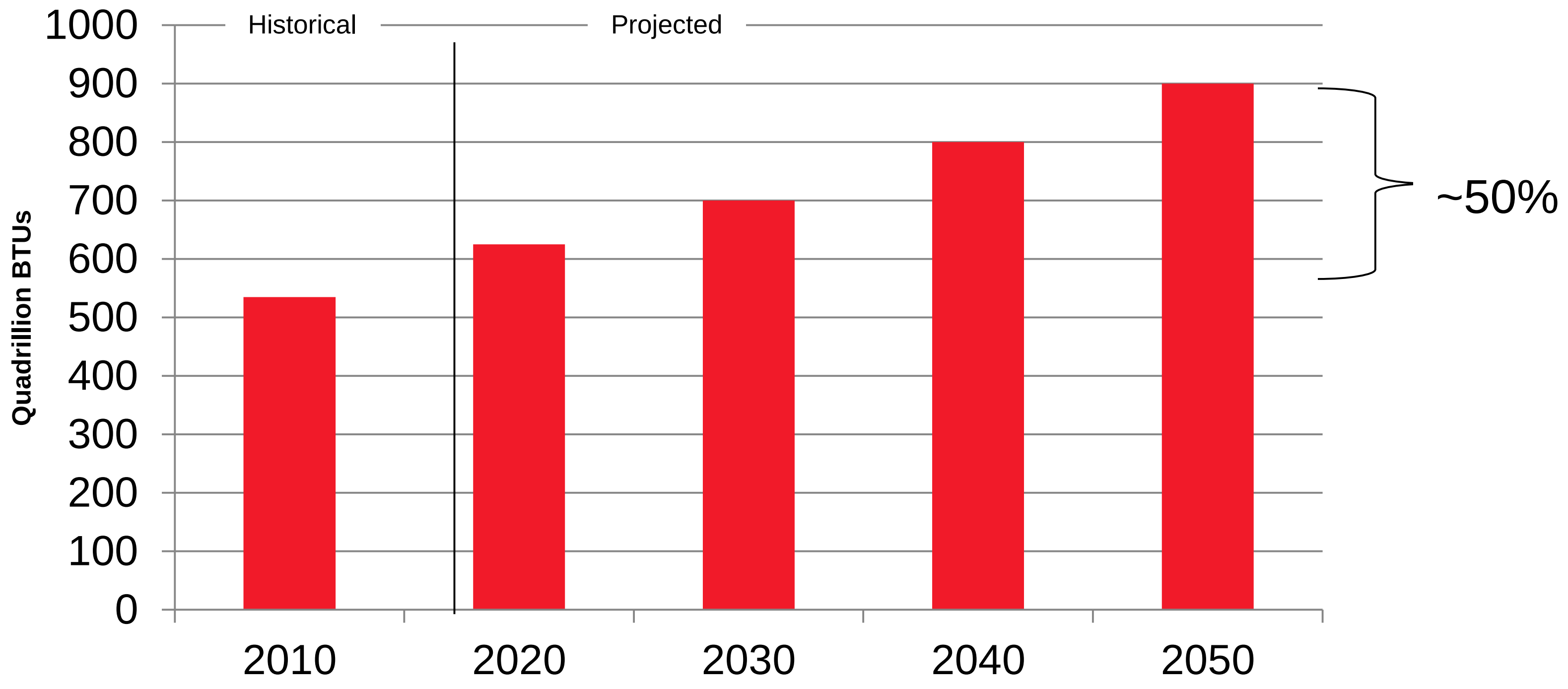
Why Synthetics?

- Broader operating temperature range
- **Increased service life of the lubricant**
- **Less lubricant consumption**
- Reduced deposit formation
- Increased wear protection
- **Reduced energy consumption**
- Reduced fire hazards
- Higher productivity, lower manufacturing costs and less downtime
- **Longer machinery life**

Energy Efficiency

Global Energy Consumption

Consumption Continues to Rise



- Source: U.S. Energy Information Administration – International Energy Outlook 2019

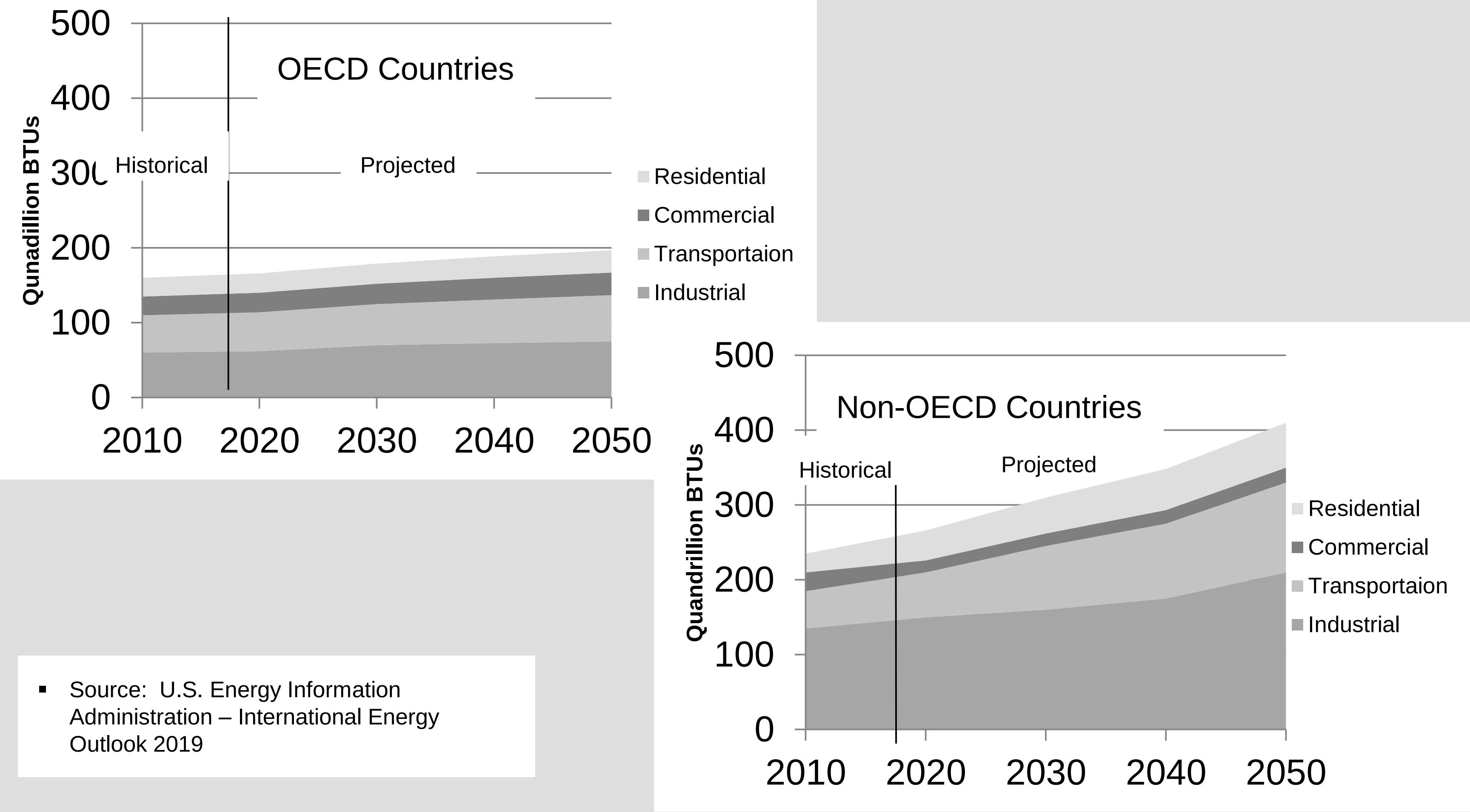
Global Emissions Reductions

Climate change concerns pushing lower emissions!

- Kyoto Protocol (1997)
  - An international agreement that aimed to reduce carbon dioxide (CO_2) emissions and the presence of greenhouse gases (GHG) in the atmosphere. The main goal was to lessen the amount of CO_2 emissions in the industrialized nations
  - Ended in 2012 but extended to 2020 for participating countries
- Paris Agreement (2015)
  - Central aim is to strengthen the global response to the threat of climate change by keeping a global temperature rise this century well below 2 ^{o}C above pre-industrial levels and to pursue efforts to limit the temperature increase even further to 1.5 ^{o}C.
  - Minimize / reduce greenhouse gas emissions!

Energy Consumption by Sector

Where is the energy going?



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Energy Efficiency

How can synthetic lubricants help?

- Minimize metal to metal contact and resultant friction and energy losses.
- Reduced churning losses due to improved hydrodynamic friction behavior.
- Improved internal friction under pressure.

Do they work?

- Anderol reported 1-8% energy benefits when using synthetics vs mineral oil.
- Interflon case studies report improvements of 5-20% depending on equipment / application being studied.
- ExxonMobil demonstrated 3.6% efficiency improvement in a conveyor application when using advanced synthetics.
- Many more in literature!

Energy Efficiency

Mechanism for improvement

- Correct viscosity
- Correct film thickness
- Hydrodynamic / elastohydrodynamic friction performance

Why is Viscosity Important?

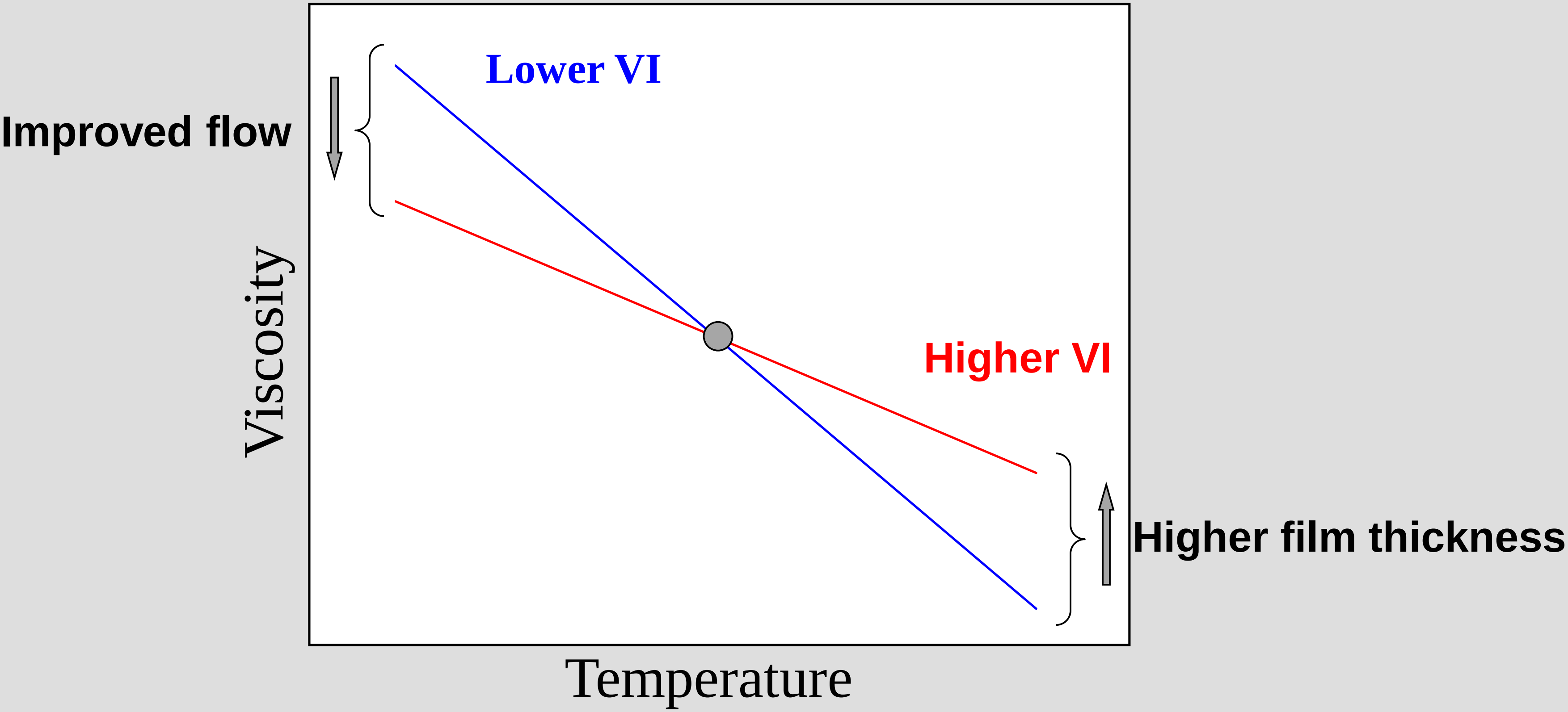
It Is the Single Most Important Basic Property Of A Lubricant

- Too Little Viscosity
  - Poor Lubrication
  - Excessive Heat
  - Increased Wear And Friction

- Too Much Viscosity
  - Poor Flow
  - Waste Of Energy
  - Start-Up Problems

VI Effect

Synthetics tend to have higher VI and a more consistent viscosity profile



Higher VI - more consistent Viscosity with Temperature
ie. better film thickness at higher temperatures, more fluid at low temperatures

Film Thickness

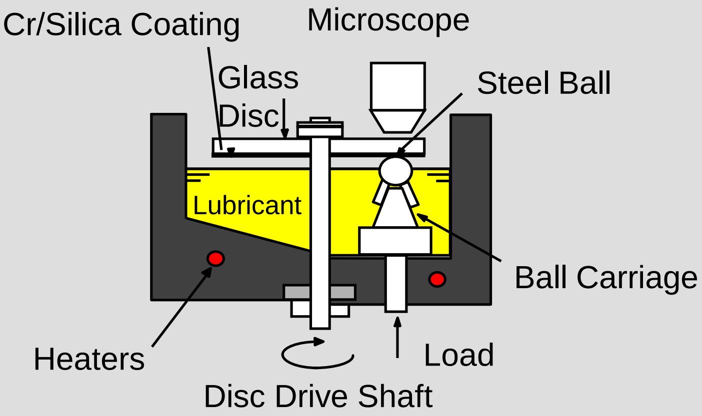
Need thick enough oil film to completely separate working surfaces

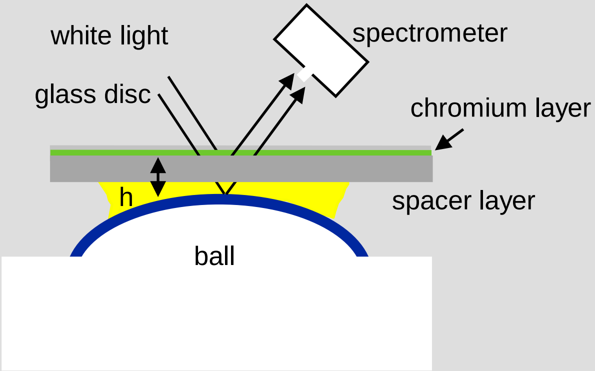
- Too Thin of a Film
  - Poor Lubrication
  - Excessive Heat
  - Increased Wear And Friction

Film Thickness – Under Pressure

Testing Protocol

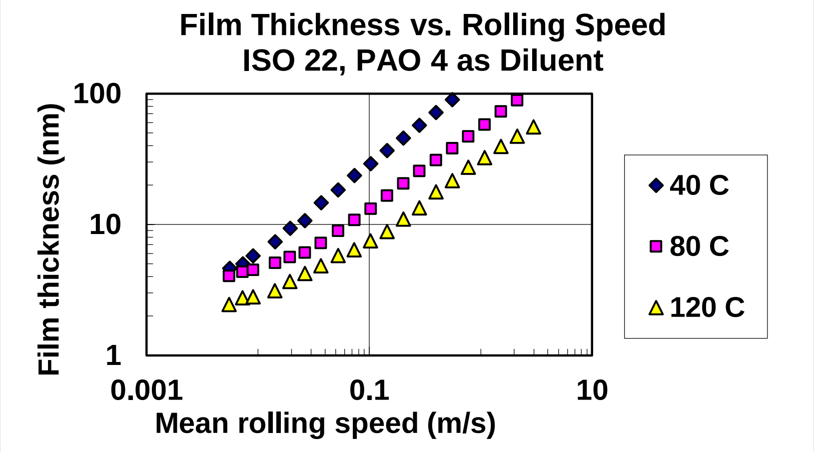
- ISO 22 and 220 Blends
- Temperature: 40, 80 and 120 ºC
- Load: 20 N, 0.54 GPa max Hertz contact pressure
- Slide-to-Roll Ratio: 0, Pure Rolling
- Specimens:
  - 19 mm Diameter AISI 52100 Steel Ball
  - Flat Glass Disc coated with 5 nm chromium layer covered by a 500 nm thick silica layer.



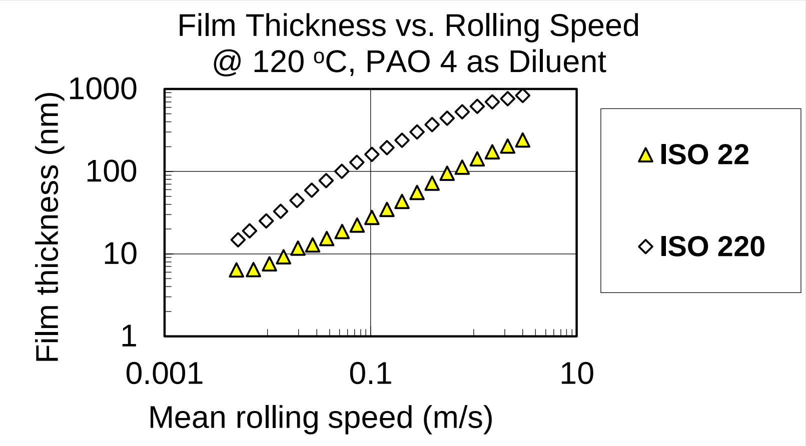


Film Thickness

Viscosity and Temperature Impact



- As temperature increases, film thickness decreases.



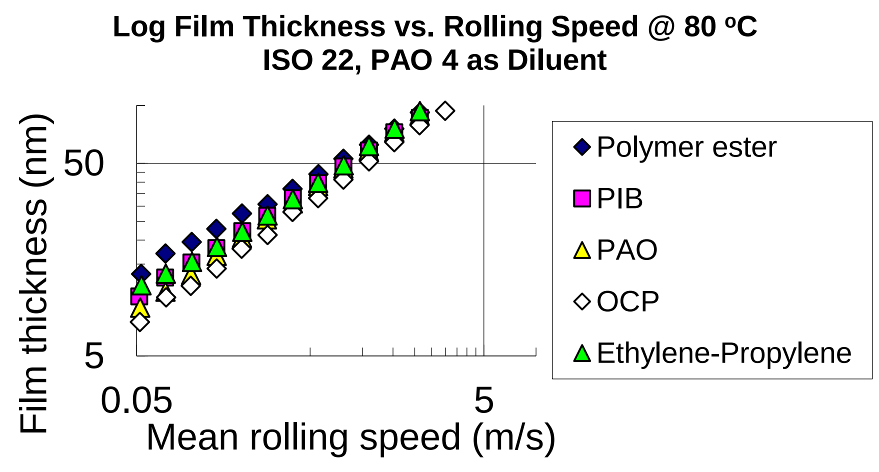
- As viscosity increases, film thickness increases.

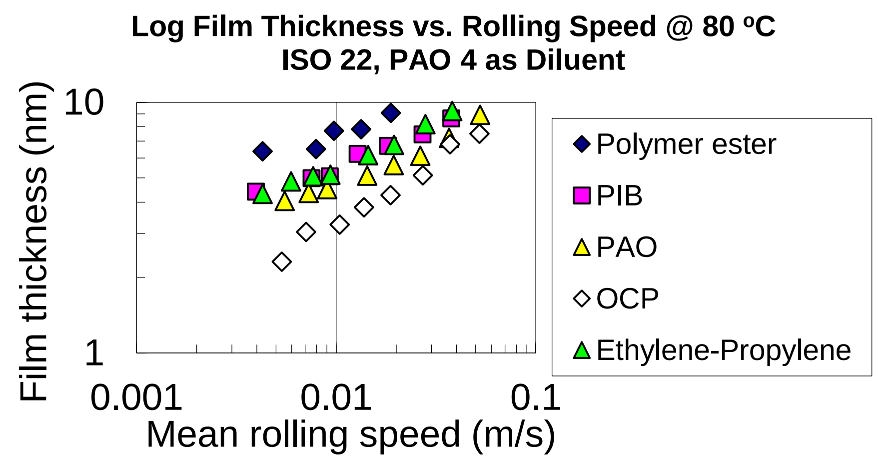
- Low Viscosity fluids at low rolling speeds tend to form boundary “films”, non-linear behavior.
- Higher Viscosity fluids tend to “level out” at higher speeds, possibly due to inlet shear heating effects.

Film Thickness

Synthetic oil comparisons

- At high rolling speeds (EHD lubrication), all polymers gave similar film thicknesses.
- At low rolling speeds (boundary lubrication range), some “film formation” seems to be occurring in all thickener types except the OCP polymer.
- The polymer ester seems to form a modestly thicker film vs. the PIB, EP and PAO thickened blends.





Elastohydrodynamic Friction

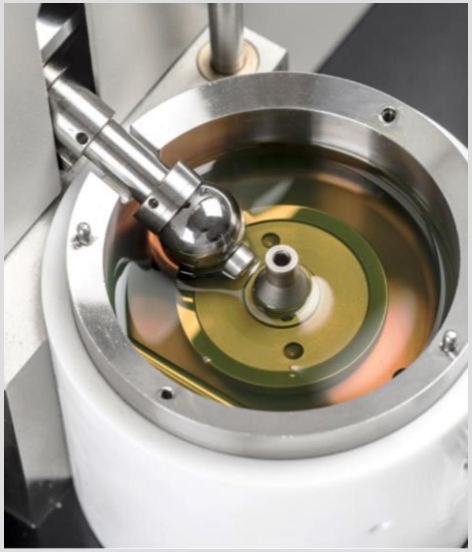
Good Internal molecular flow properties provides lower friction

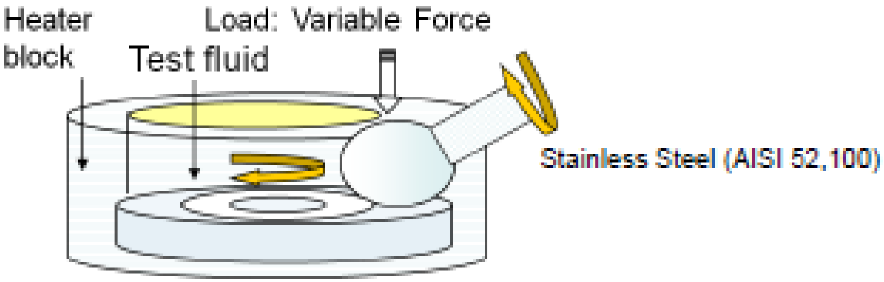
- Proper molecular structures provide inherent benefits
  - Lower traction coefficients => lower friction
  - Film formation at low speeds => improved lubricity

Mini-Traction Machine

Testing Protocol

- ISO 22, 68 and ISO 220 Blends
- Temperature: 40, 80, 120 °C
- Load: 30 N, 0.93 GPa max Hertz contact pressure
- Slide-to-Roll Ratio: Variable (5-70%)
- Speed: Variable (0.006-2 m/s)
- Specimens:
  - 19 mm Diameter AISI 52100 Steel Ball
  - Polished Flat Steel Disc.

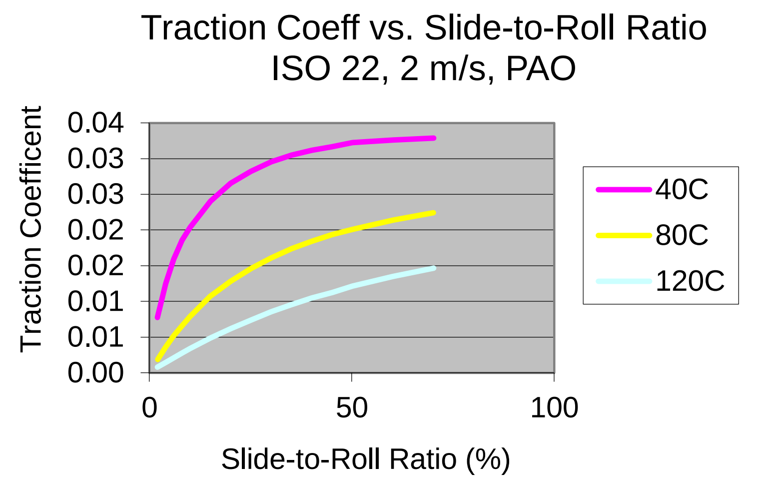


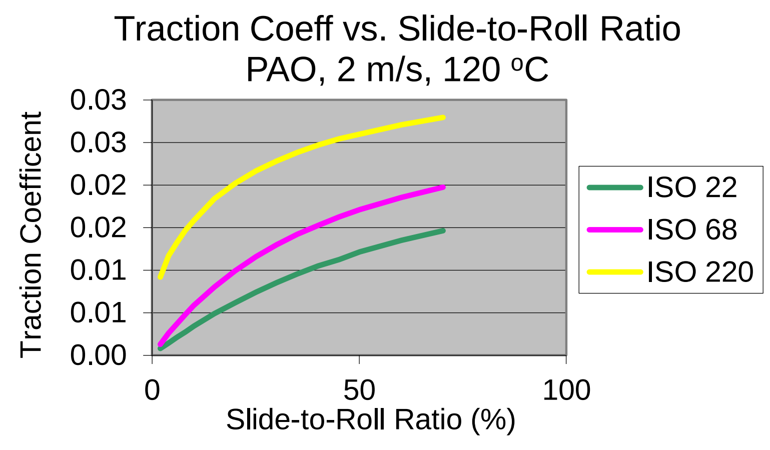


Traction

Friction – EHD Conditions

- Higher Temperature gives Lower Traction over the range of slide-to-roll tested
- Higher Viscosity gives Higher Traction over the range of slide-to-roll tested

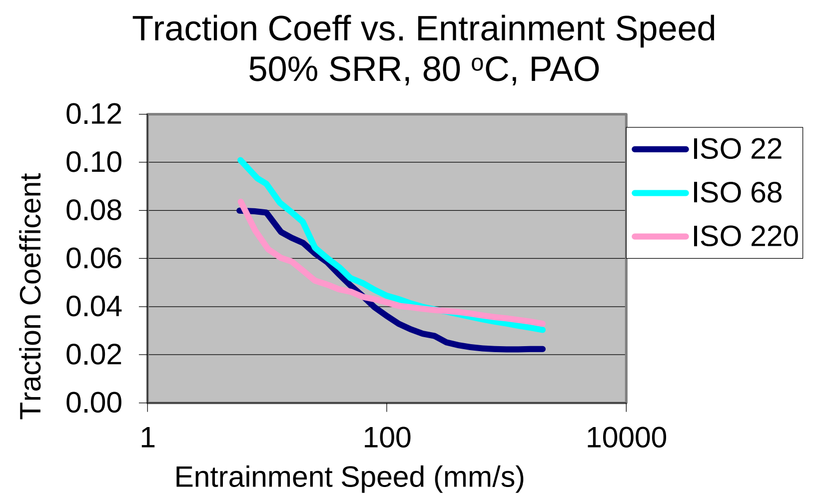


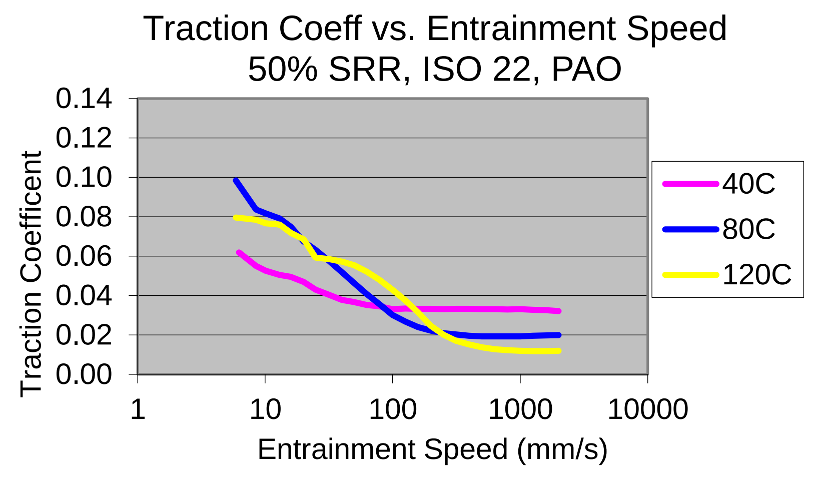


Traction

Lubricity – EHD to Boundary

- Lower vis oils start with lower traction due to lower film thickness but increase more quickly as fluid film thickness gets closer to the surface roughness and boundary conditions are seen.
- Higher temps act like lower viscosity.

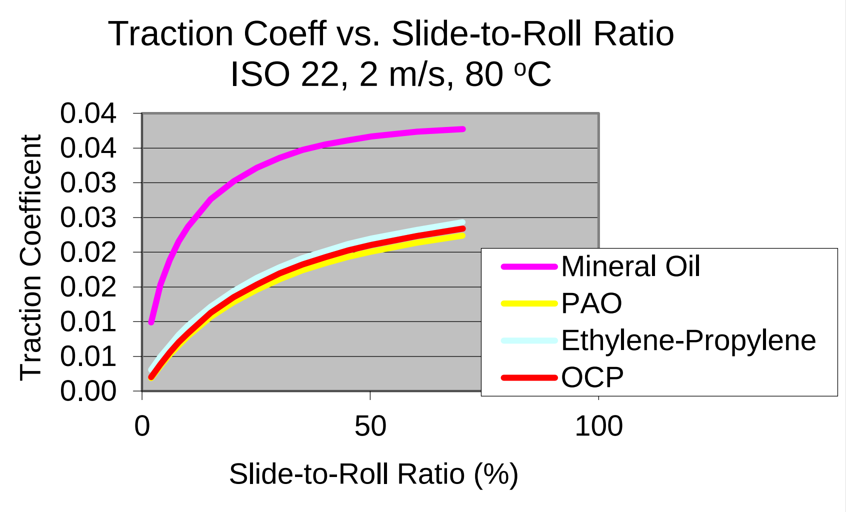


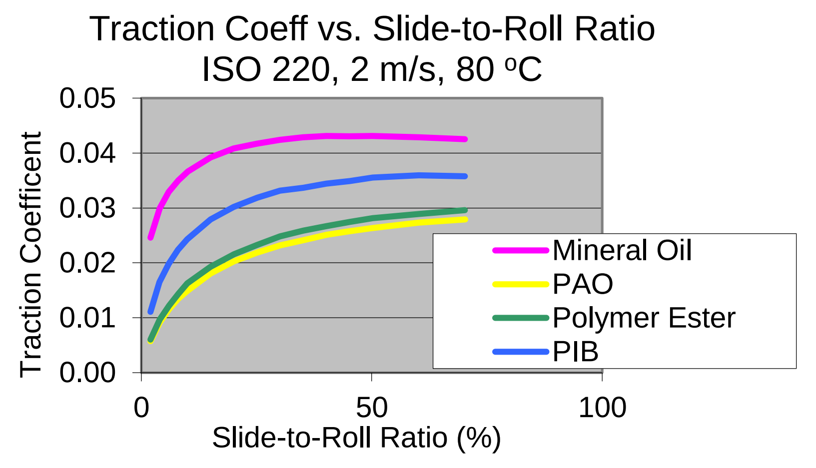


Traction – Different Thickener Types

Friction – EHD Conditions

- Mineral Oil (Group I) gives the highest traction numbers.
- Of the synthetics, only the PIB gives a modestly different curve, having higher traction coeff. than the other synthetics, but lower than the mineral oil.

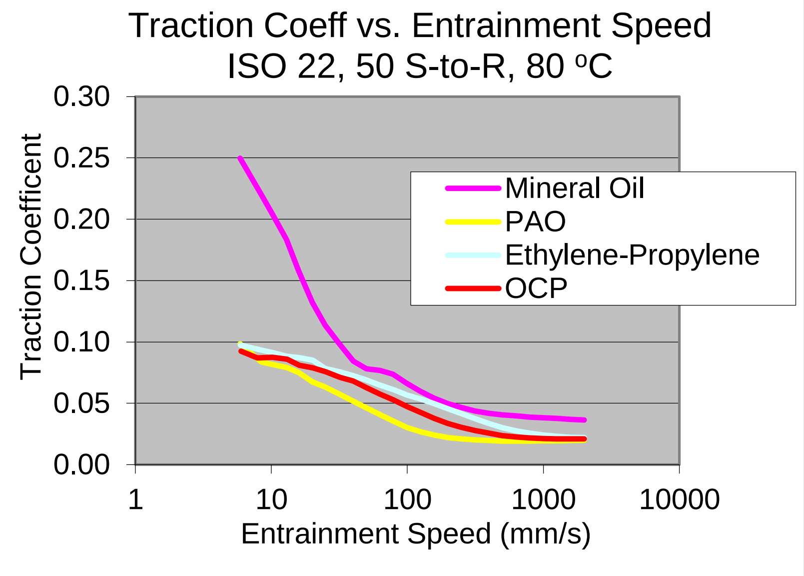




Traction

Lubricity – EHD to Boundary

- Mineral Oil (Group I) gives the highest traction numbers over the range of speeds and shows film breakdown at lower speeds.
- Synthetics are similar with PAO marginally lower.



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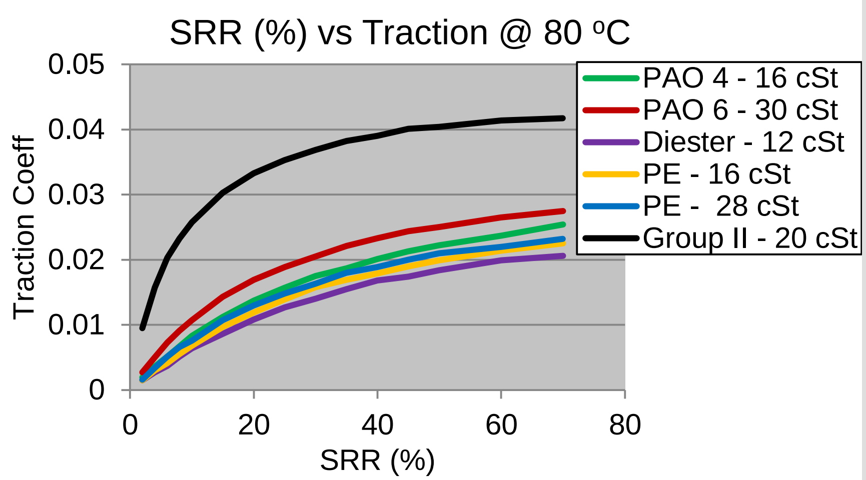
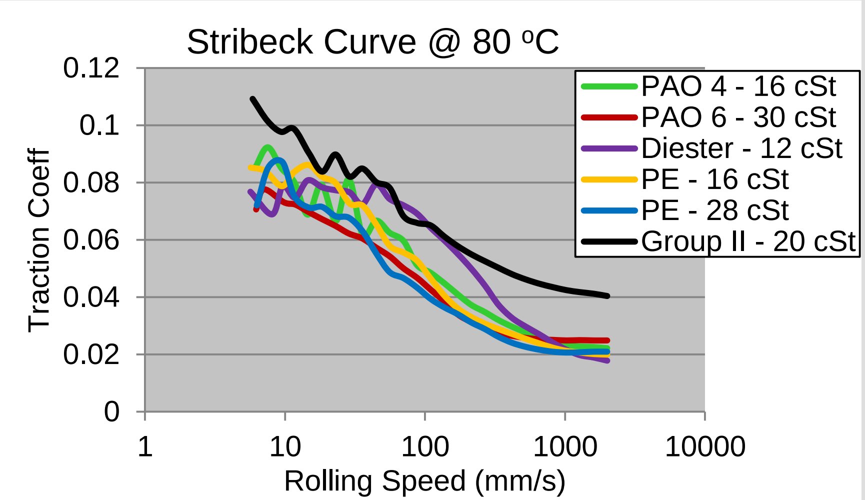
Traction – Straight oil

Friction and Lubricity

- Synthetics are superior to mineral oils in general

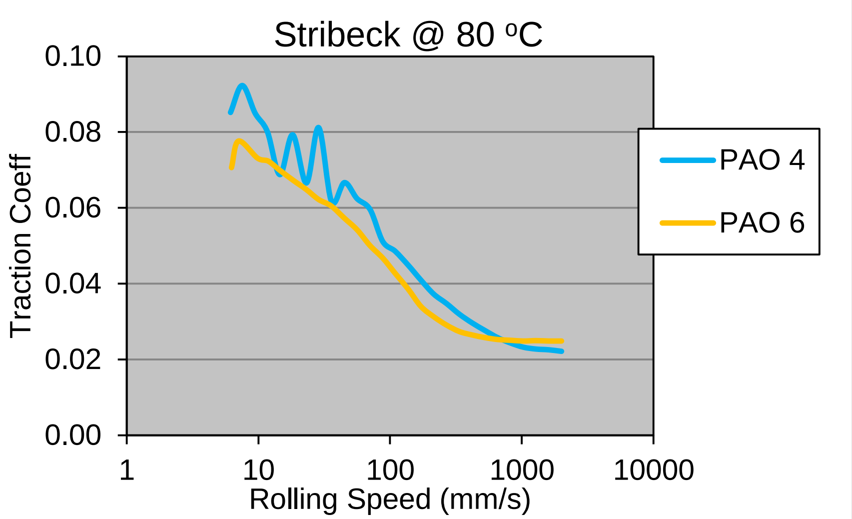


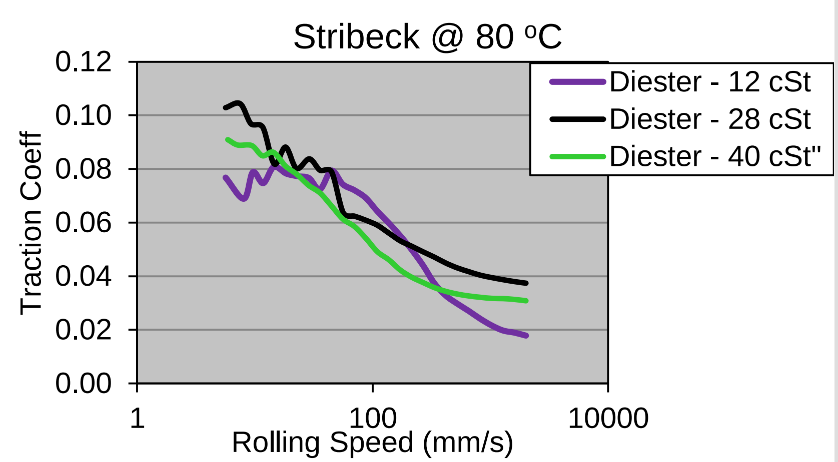


Traction – Straight oil blends

Structure Matters!

- While PAO follows the expected viscosity effect of better EHD friction at high speeds but higher friction at low speeds, esters are not so simple as the structures can be very different, even in the same ester “type”.
- Esters may allow customization options for tailored performance.



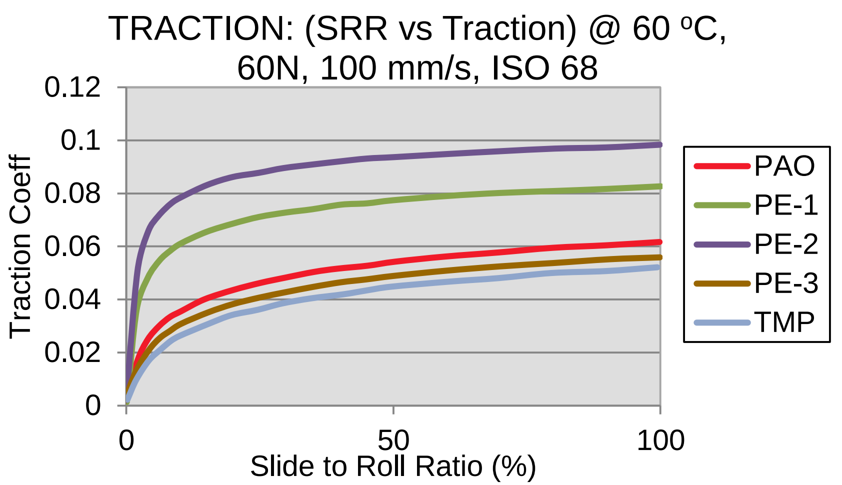


Traction – Straight oil blends

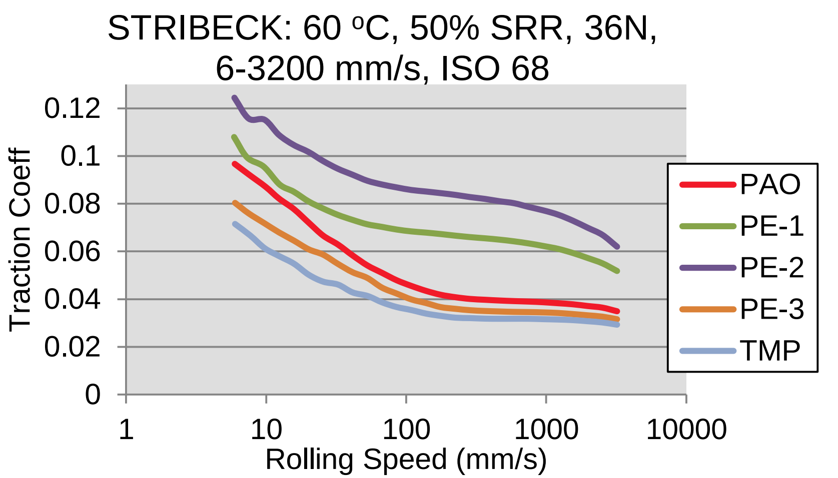
(using modified conditions)

Structure Matters!

- Comparing several ISO 68 esters made from different raw materials, we confirm differences are apparent.

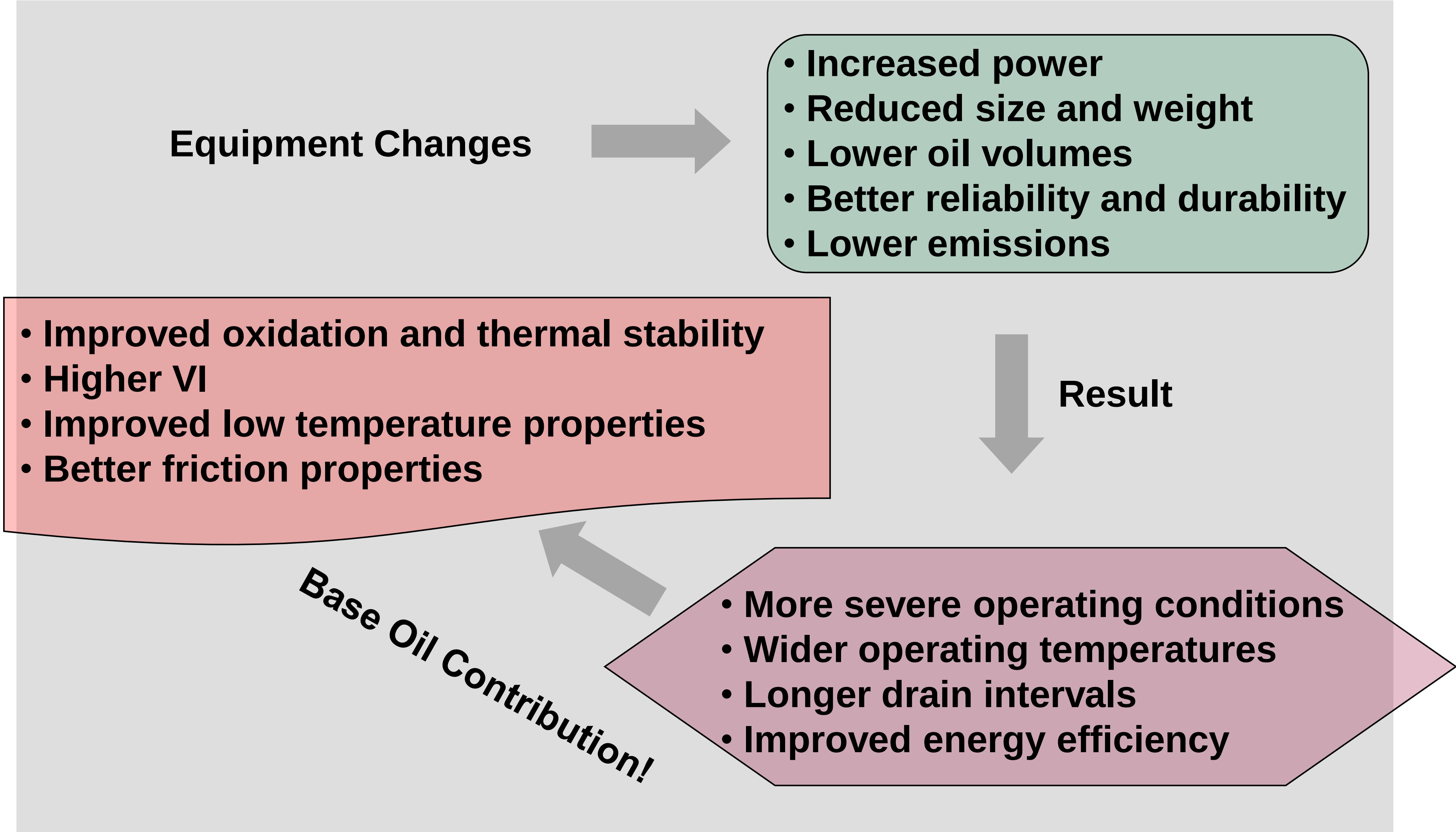


TRACTION: (SRR vs Traction) @ 60 ^{o}C, 60N, 100 mm/s, ISO 68



STRIBECK: 60 ^{o}C, 50% SRR, 36N, 6-3200 mm/s, ISO 68

Lubricant Trends



Equipment Changes

- Increased power
- Reduced size and weight
- Lower oil volumes
- Better reliability and durability
- Lower emissions

Result

- More severe operating conditions
- Wider operating temperatures
- Longer drain intervals
- Improved energy efficiency

Base Oil Contribution!

- Improved oxidation and thermal stability
- Higher VI
- Improved low temperature properties
- Better friction properties

Conclusions

- Synthetic base oils can provide both physical and tribological benefits that address the equipment needs of the future
- Synthetic base oils can contribute significantly to energy efficiency needs
  - Both Group IV (PAO) and Group V (ester) base oils show benefits
  - The energy efficiency properties can help address emission reduction needs and product use cost
- While energy efficiency benefits provided by the use of synthetic base oils is important, they also can help reduce costs by increase service fluid life, longer machine life and lower lubricant consumption.

Thank you for your attention….

Questions?