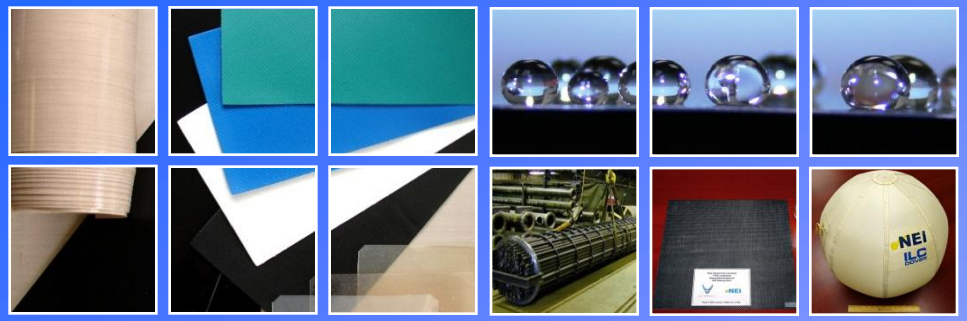
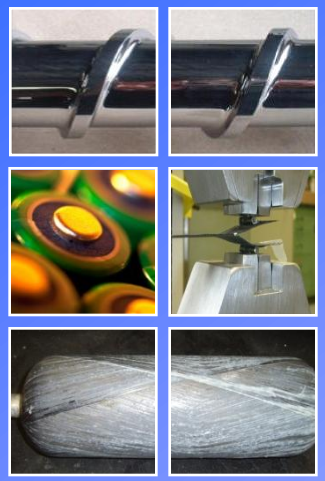
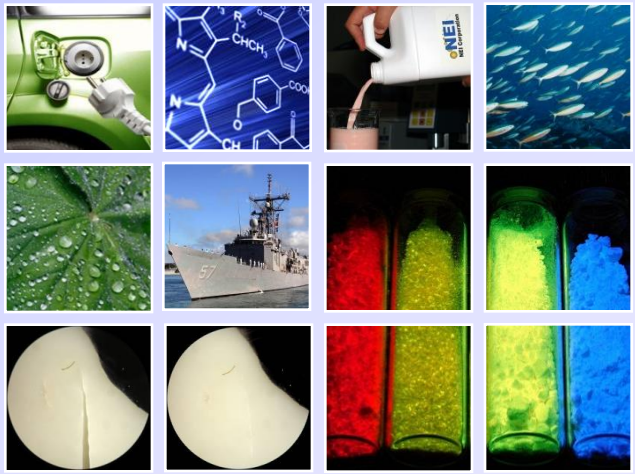




Nanotechnology for Lubricants to Improve Performance and Reliability of Army Systems

October 15, 2013

Ken Eberts, Mohit Jain
and Ganesh Skandan
NEI Corporation – Somerset, NJ
and
Kristin B. Walker
RAM & System Assessment Division, Redstone Arsenal



Program Sponsored by US Army SBIR Program
W31P4Q-11-C-0194

NEI Corporation
400 Apgar Drive – Suite E
Somerset, NJ 08873
V: (732) 868-3141; F: -3143
www.neicorporation.com

About Us

- Founded in 1997
- Today, conducting R&D, manufacturing and marketing diverse Advanced Materials products
- Two facilities in New Jersey (15,000 ft^2 space)
- Products sold under NANOMYTE® trademark

NEI building
400 E Apgar Drive

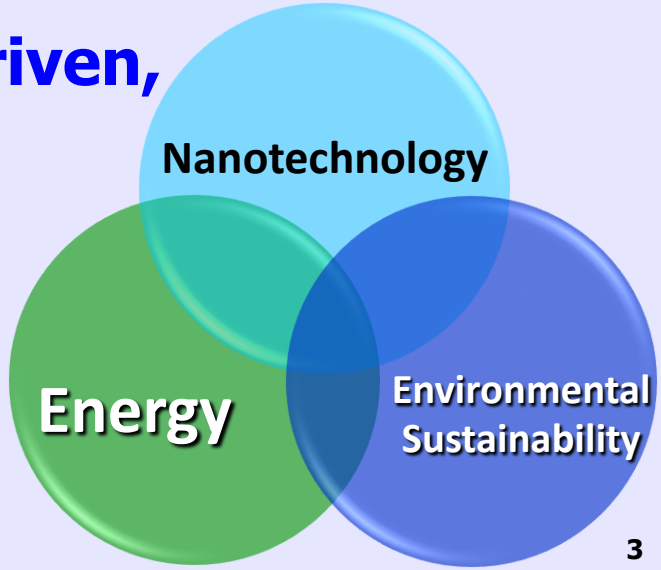
Shop floor

Analytical Laboratory

NEI building
14C Worlds Fair Drive

Core Competency

- **Nanotechnology expertise**
  - Bridge gap between basic and applied science by relating material properties to product performance
  - Design and develop products (nanoparticles, nanocomposites and nanostructured materials)
- In-house capabilities to ***prove concept*** and ***demonstrate prototype*** in relevant environment
- **Technology based, application driven, customer focused**



Nanomaterial Products

Nanomyte® Series for:

- Advanced Protective Coatings
- Energy Storage Materials
- Environmental Nanomaterials
- Nanoparticle Fluids

Application Need

- **Lubricants** used in the Army's ground and airborne vehicles

- Lubricants with more efficient **heat transfer** can lead to:

  - Reduced erosion of the gears
  - Reduced downtime
  - Reduced maintenance costs
  - Extended operation

- Engineer the lubricant (oil/grease) to enhance heat transfer properties

Challenge

Heat Transfer Correlation for Forced Convection in a Tube

$$h \propto k^{2/3} \cdot C_p^{1/3} \cdot \rho^{0.8} / \eta^{0.467}$$

h = heat transfer coefficient
k = thermal conductivity of the fluid
C_p = heat capacity
ϱ = density of the fluid
η = viscosity of the fluid

- **Maximize Increase in Thermal Conductivity**
- **Minimize Increase in Viscosity**
- **Minimize Decrease in Heat Capacity**
- **Maintain or Improve Lubricity**

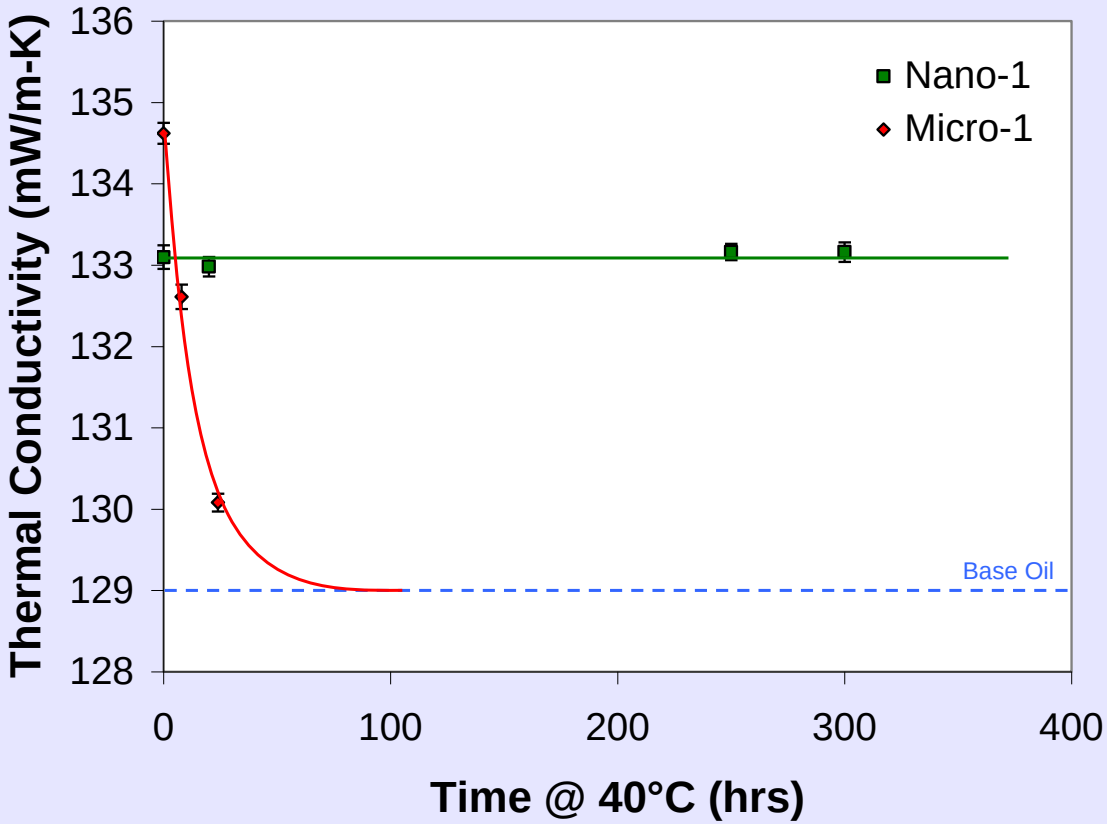
Initial Work

- **Base Fluid:**
  - Valvoline *Synpower* 75W90 (VV975) Gear Oil

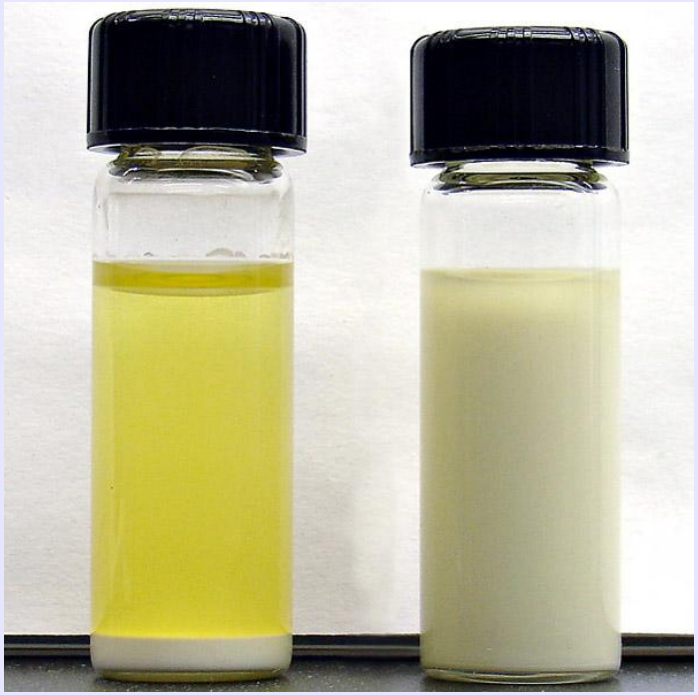
- **Additives**
  - Commercially available, Micron-Scale Additive: **Micro-1**
  - NEI-Synthesized, Nanostructured Additive: **Nano-1**
  - Commercially available, Micron-Scale Additive: **Micro-2**
  - NEI-Synthesized, Nanostructured Additive: **Nano-2**

Results:

Comparison of Dispersion Stability Over Time (without agitation)



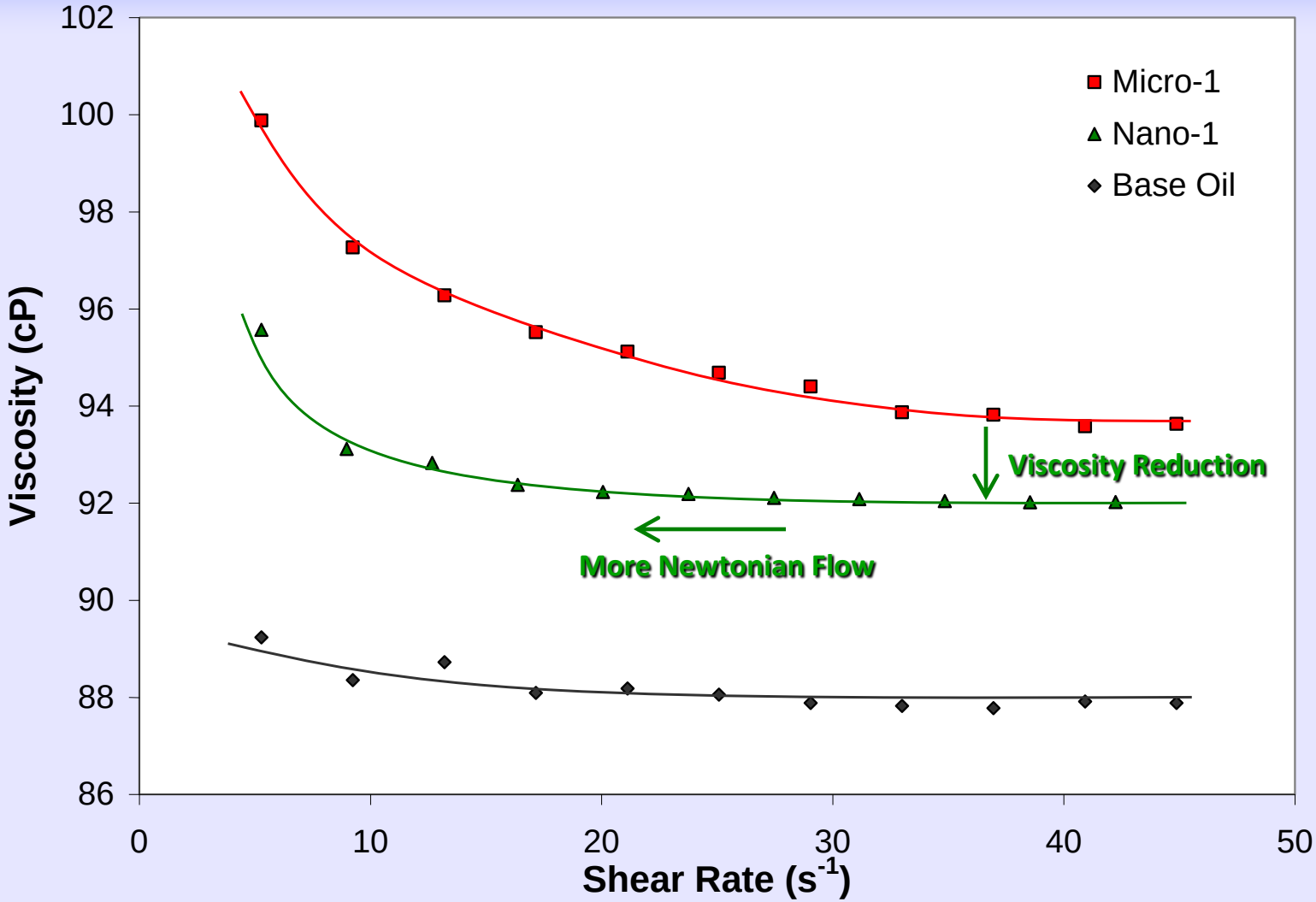
Dispersions After ~1 Week



Micro-1 Nano-1

➡ Nanostructure allows for highly stable dispersions

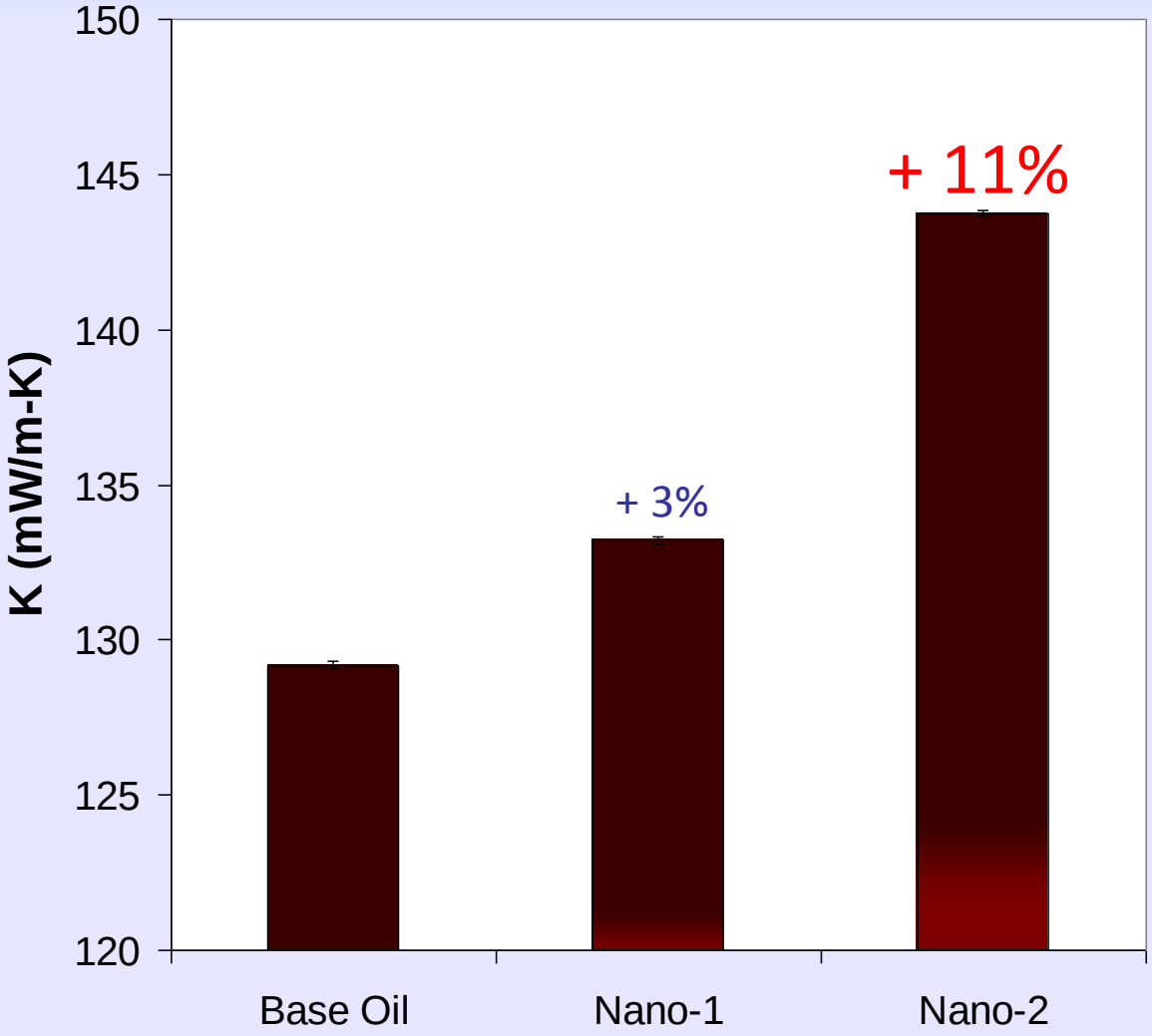
Results:
Viscosity Measurements at 40°C



Results:

Comparison of Additive 1 and Additive 2

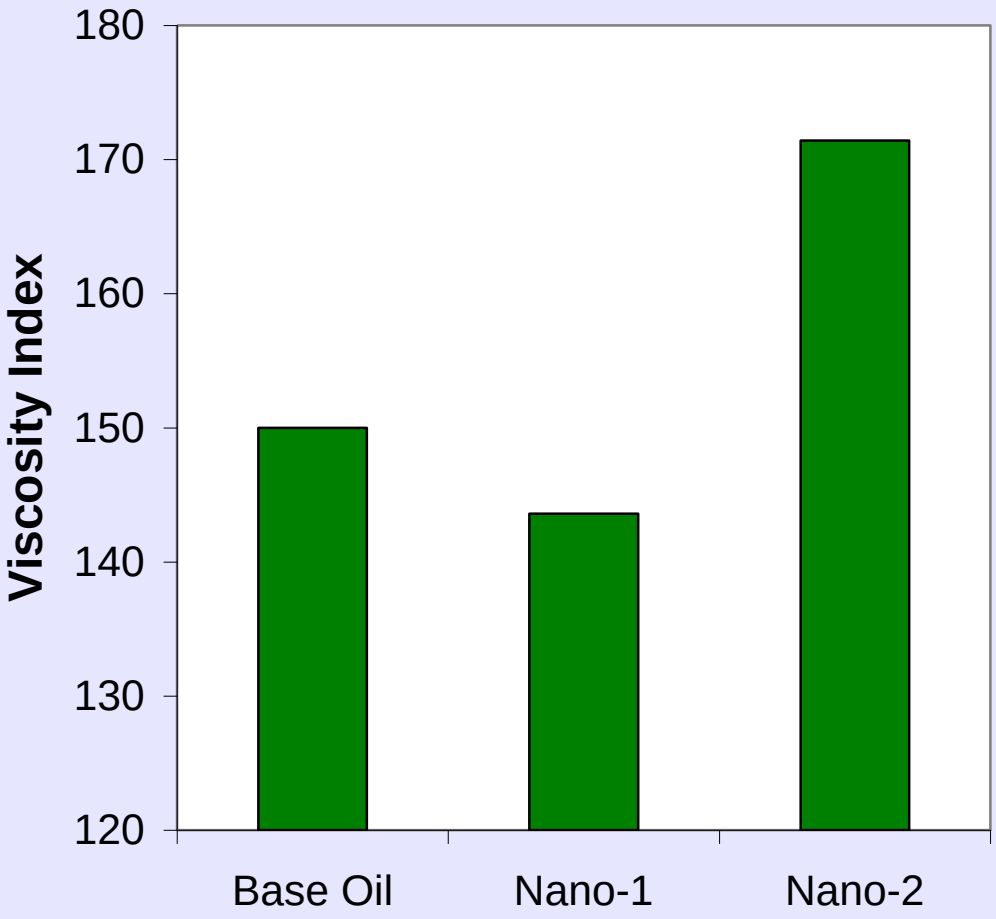
Thermal Conductivity of Dispersions in Oil at 40°C



Results:

Effect of Dispersed Solids on Viscosity Index (VI)

ASTM D2270 - Kinematic Viscosity Calculated from Absolute Measurements



- Some reduction in VI for Nano-1
- Significant increase in VI for Nano-2

Potentially Allows for
Wider Operating Temperature Range

Scale-up and Independent Standardized Testing:

- **Base Fluid:** Valvoline Synpower VV975

  "Base Oil"

- **Base Fluid + Commercial Nano Additive:**

  "Commercial" (using recommended amount)

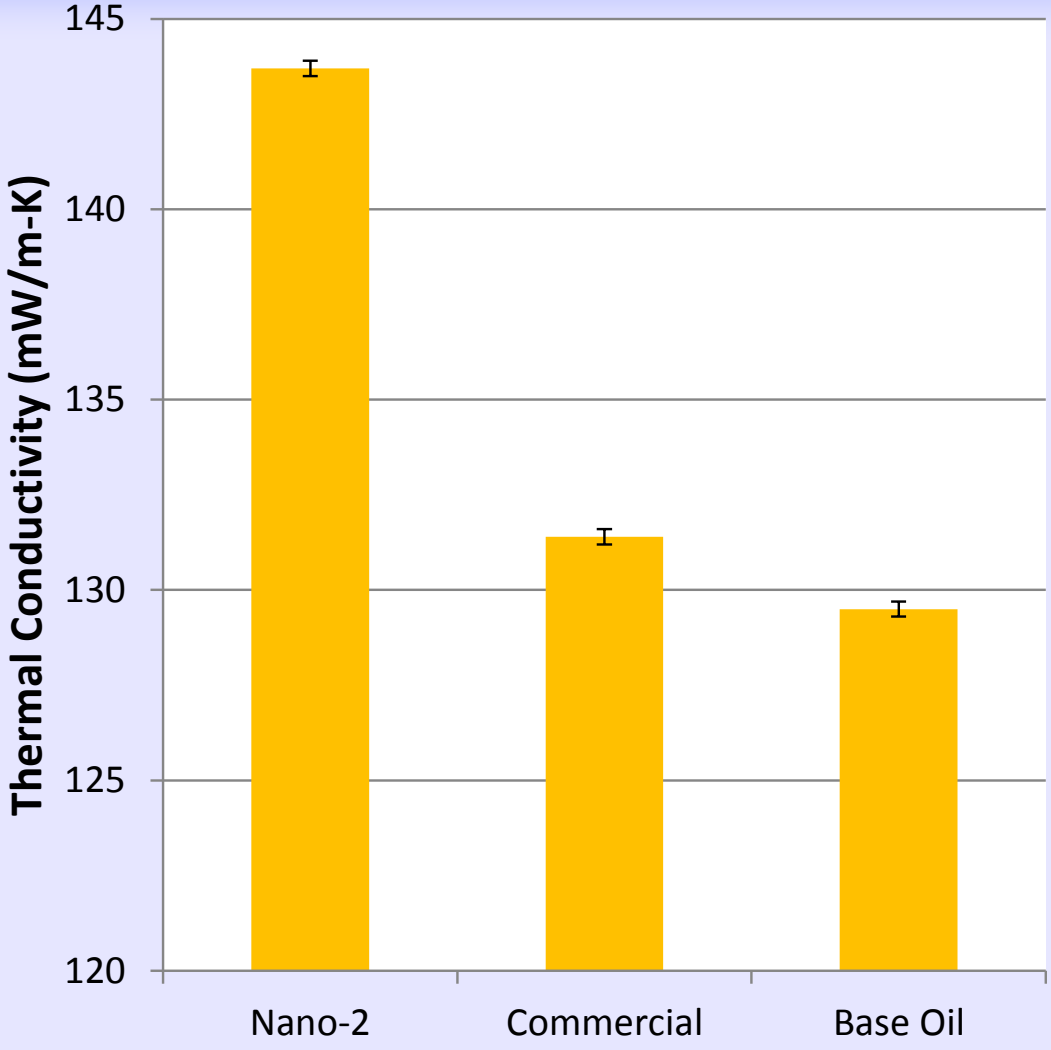
- **Base Fluid + NEI Nano Additive:**

  "Nano-2"

Results:

Comparison of Oil Additives

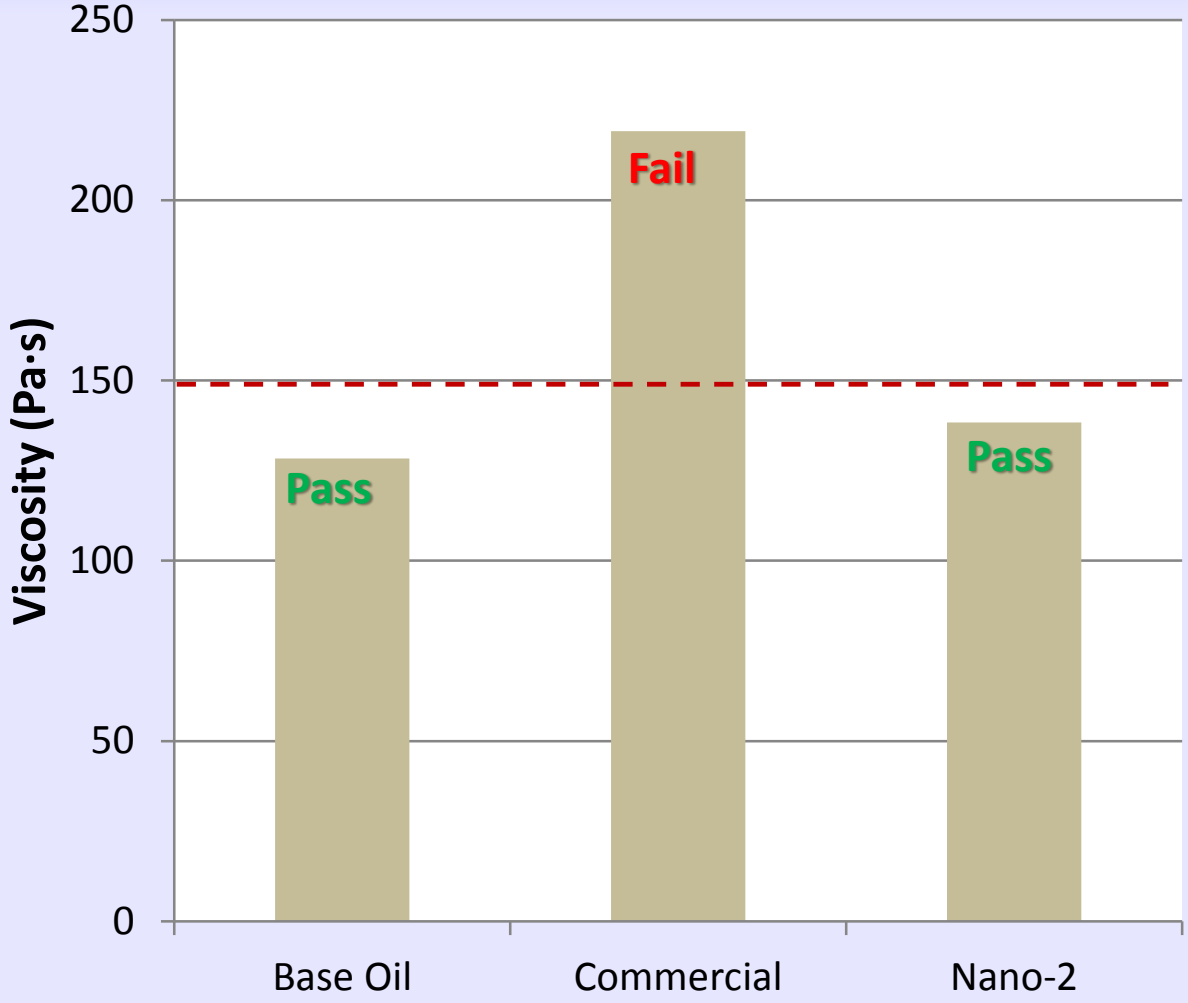
Thermal Conductivity of Oil Dispersions at 40°C



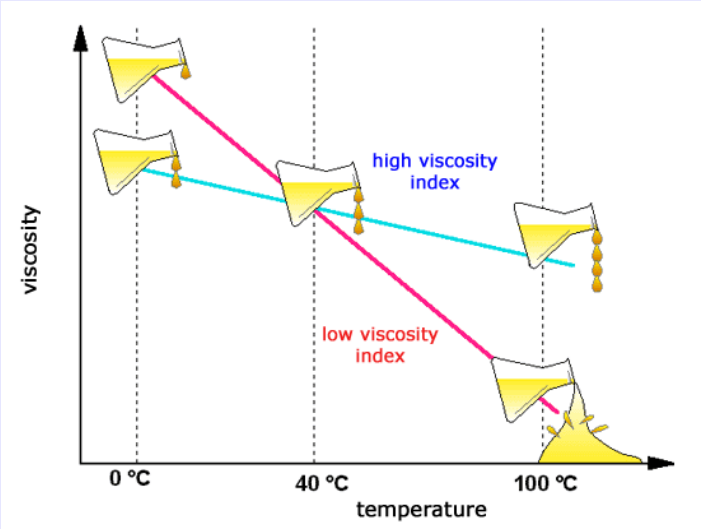
Results:

ASTM D2983 Low Temperature Viscosity, -40°C

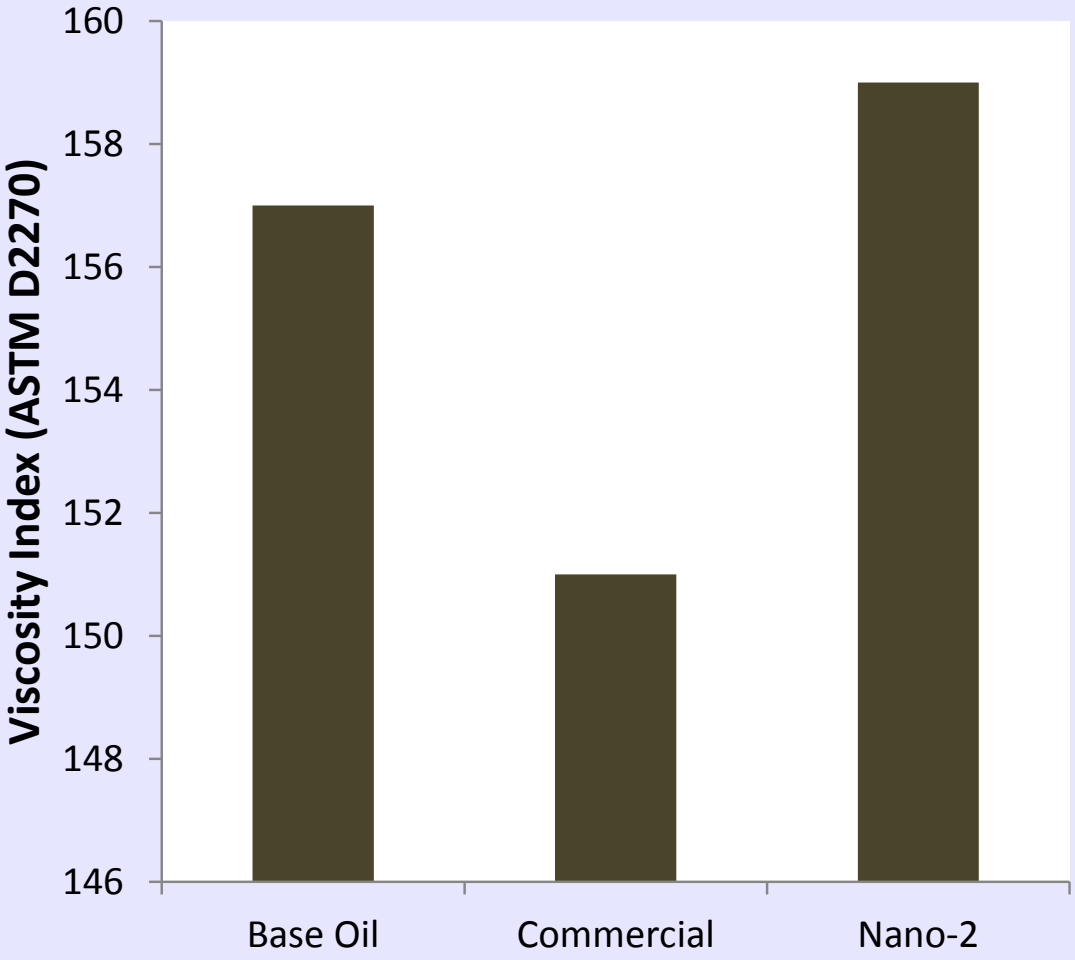
http://www.synthetic-oil-tech.com/Gear%20Lube%20White%20Paper.pdf



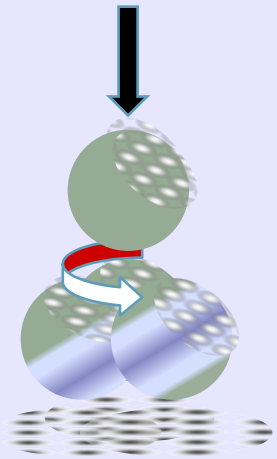
Results:
ASTM D2270 Viscosity Index



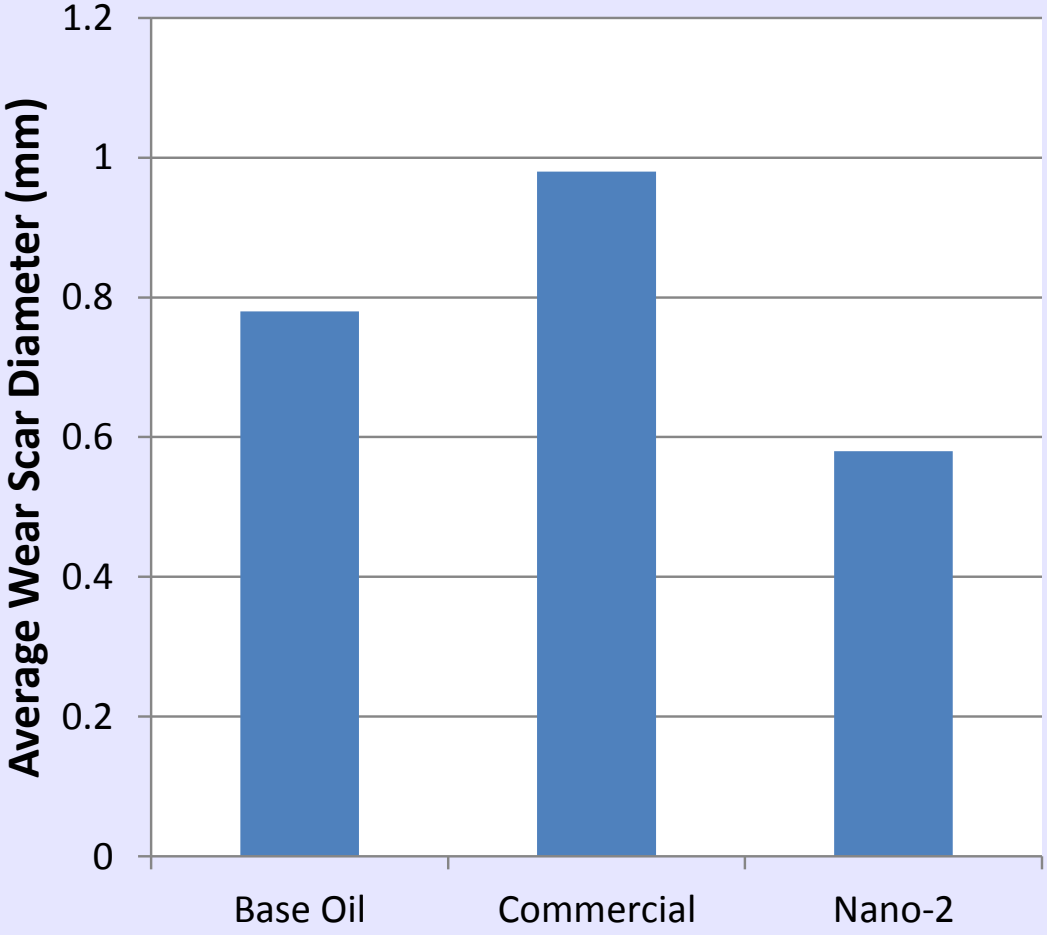
http://www.flitalia.it/en/fl/manuale/en/trasm_0103.htm



Results:
ASTM D4172 4 Ball Wear Test



Scars form at contact points



Extreme Pressure Testing:

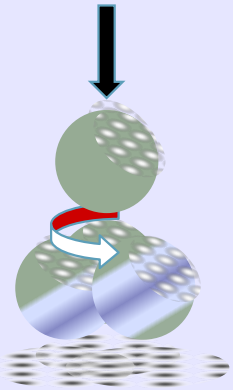
ASTM D2783 4 Ball EP Test
ASTM D3733 Falex EP Test

Example:

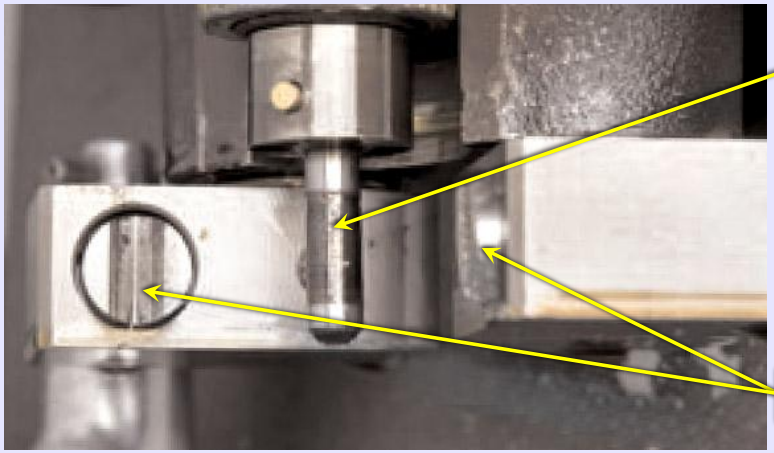
Hypoid Gears

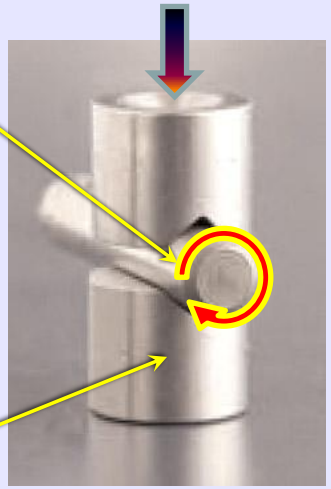
http://www.synthetic-oil-tech.com/Gear%20Lube%20White%20Paper.pdf

ASTM D2783 4 Ball EP Test



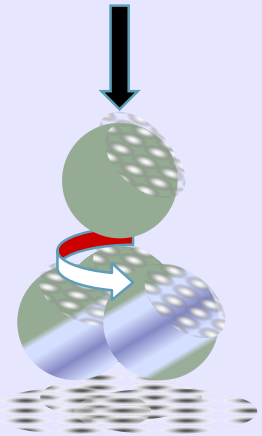
ASTM D3733 Falex EP Test



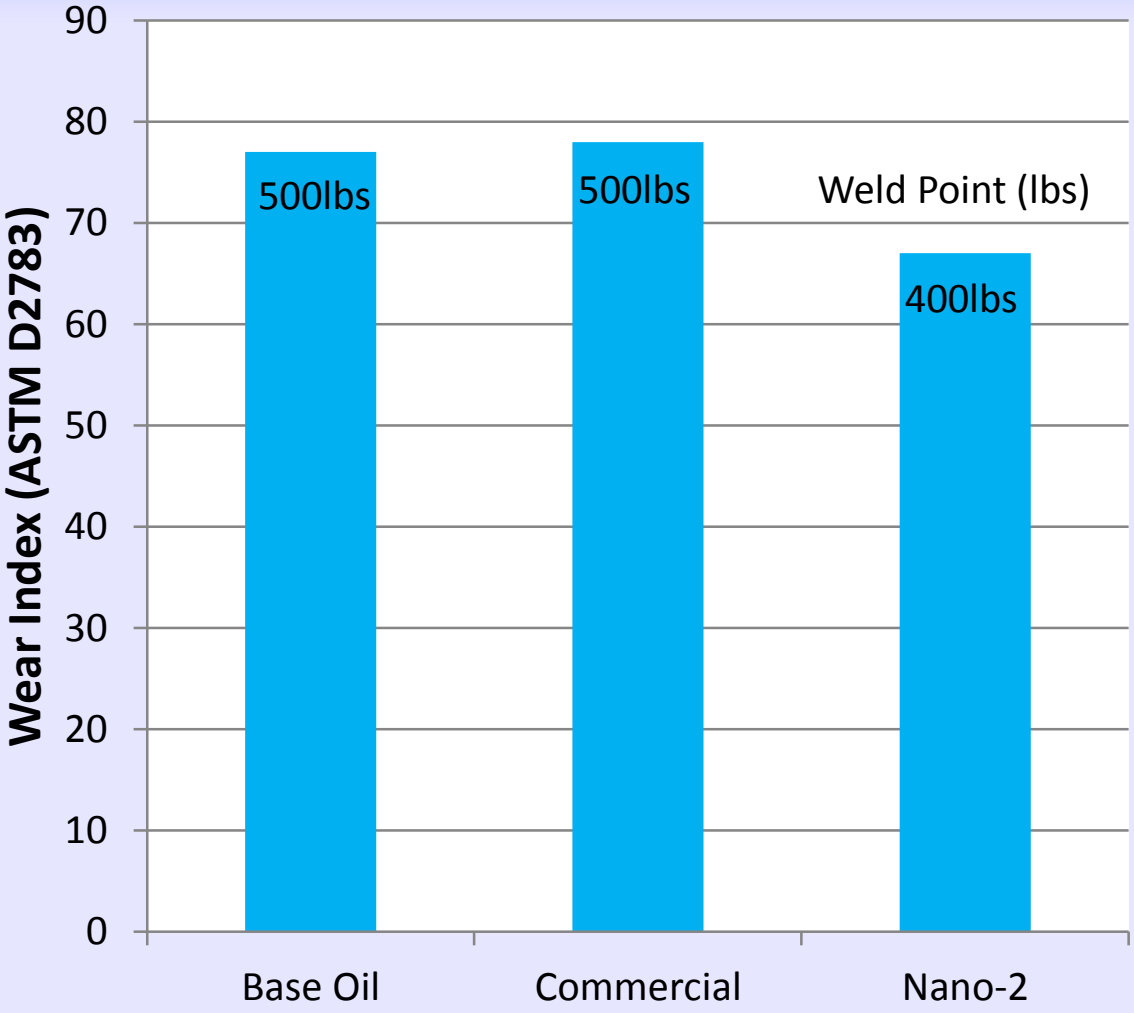


Results:

ASTM D2783 4 Ball EP Test
Wear Index and Weld Point



High index indicates reduced friction



Weld

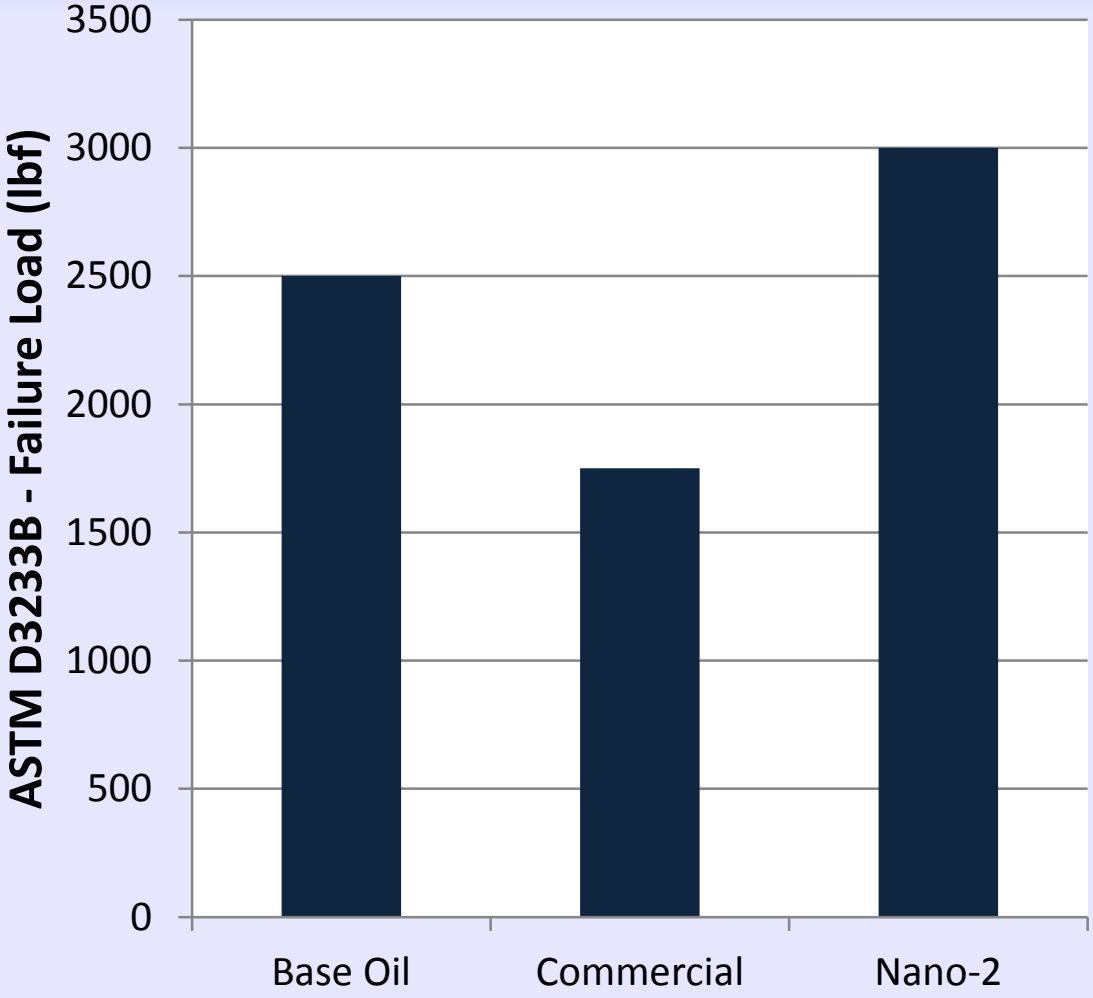
http://www.synthetic-oil-tech.com/Gear%20Lube%20White%20Paper.pdf

Results:

ASTM D3733 Falex EP Test
Load to Failure

Load to failure
(pin seizes)

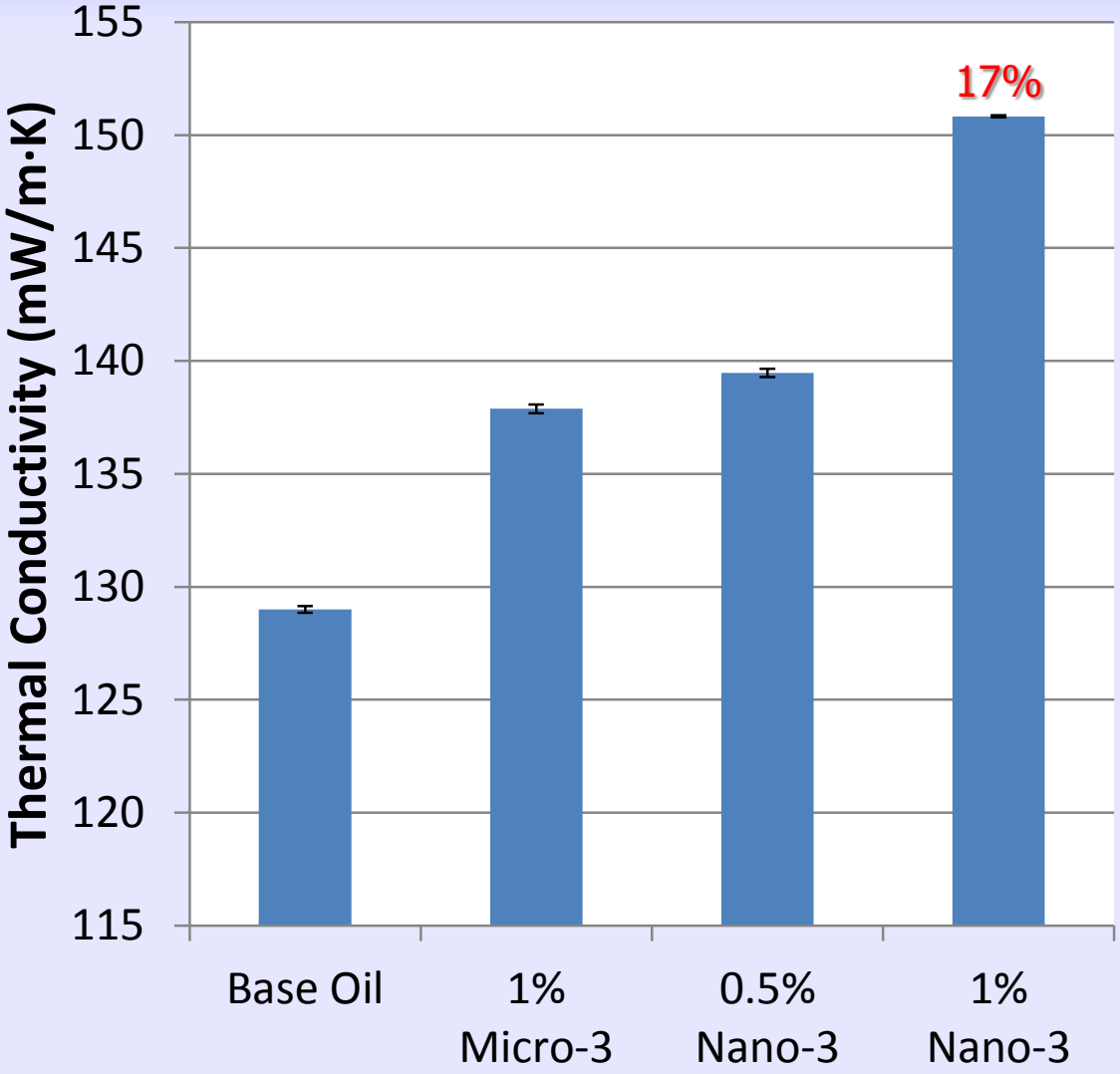
http://www.synthetic-oil-tech.com
/Gear%20Lube%20White%20Paper.pdf



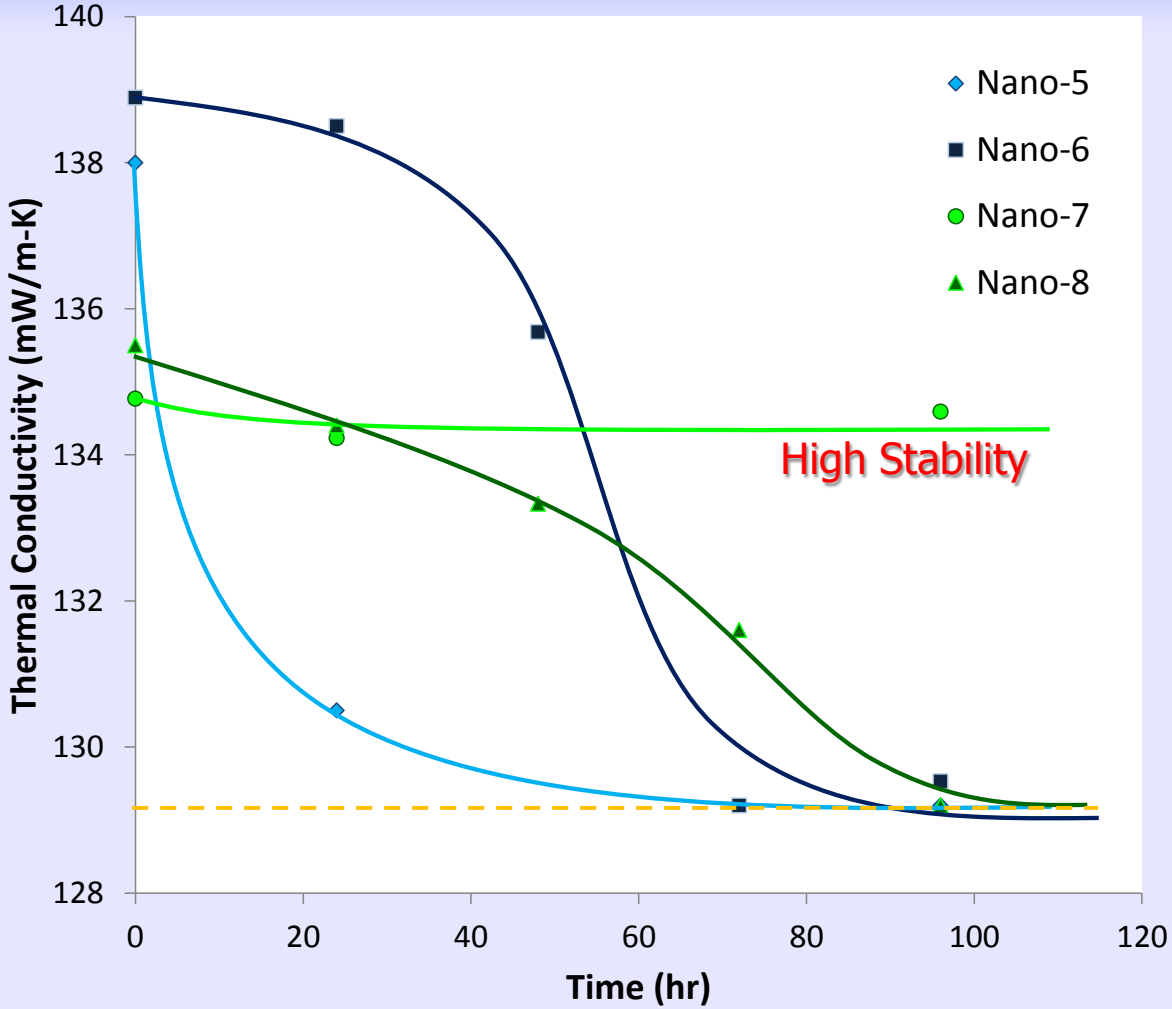
Product Development and Demonstration

- Further Optimization of High Conductivity Additives
- Surface Functionalize for Dispersion in Aviation Oils
  - MIL-PRF-23699F Turbine Oil
  - Aviation Gear Oil
- Performance Testing
  - In-House
  - USC Apache Drivetrain Facility

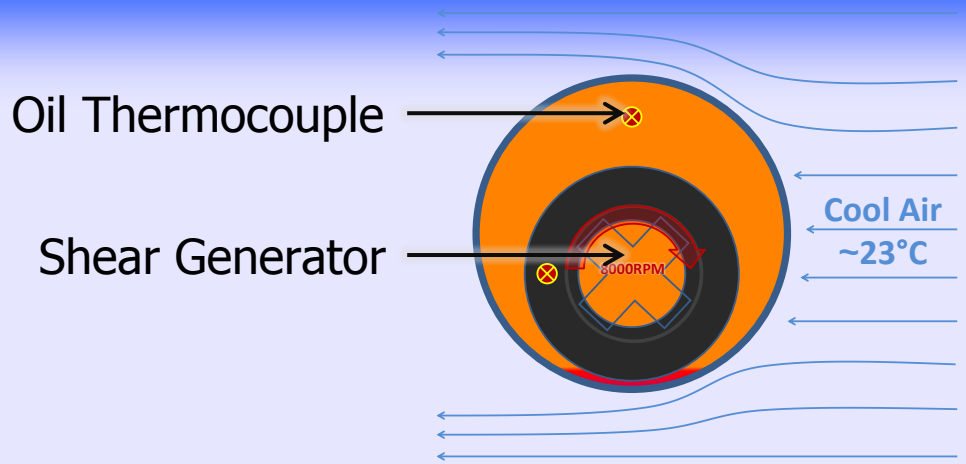
Optimization of Thermal Conductivity

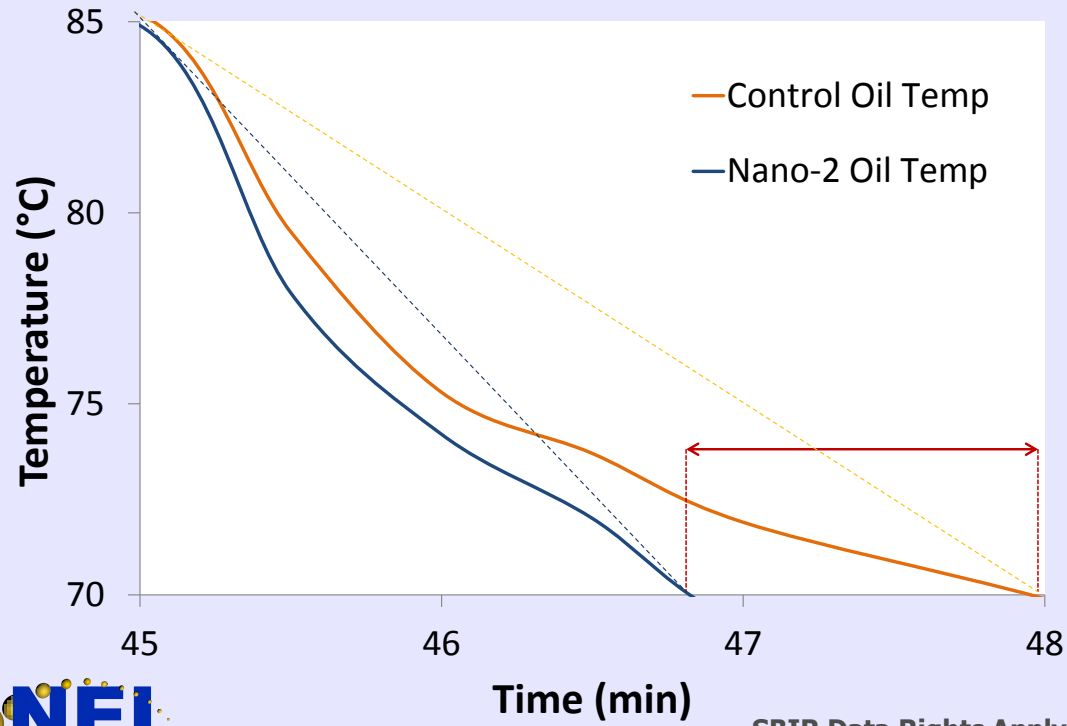


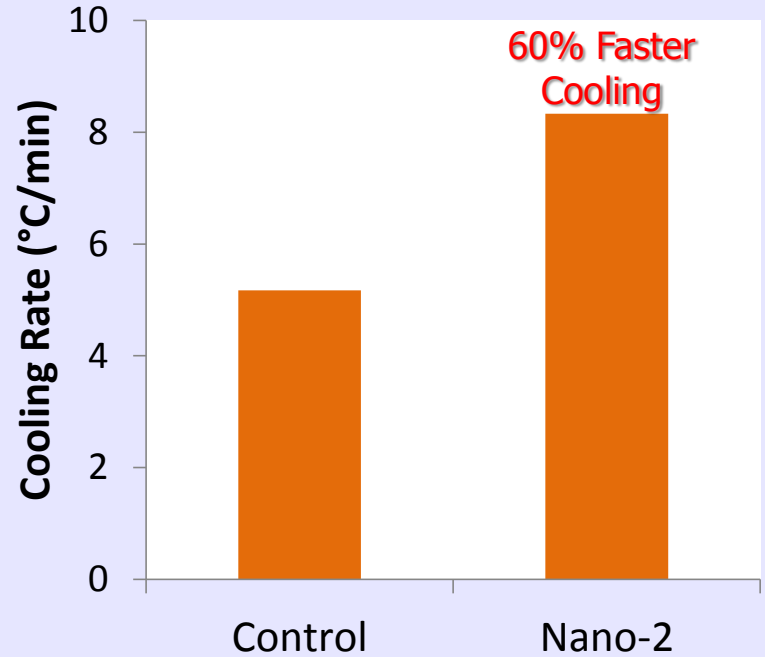
Optimization of Stability



In-House Performance Testing







Simulated Use Conditions

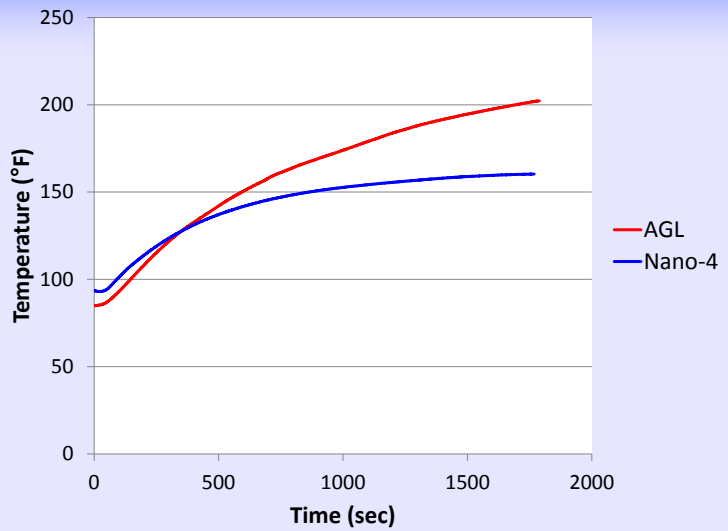
USC Apache Tail Rotor Drivetrain Facility

Intermediate Gear Box (IGB)

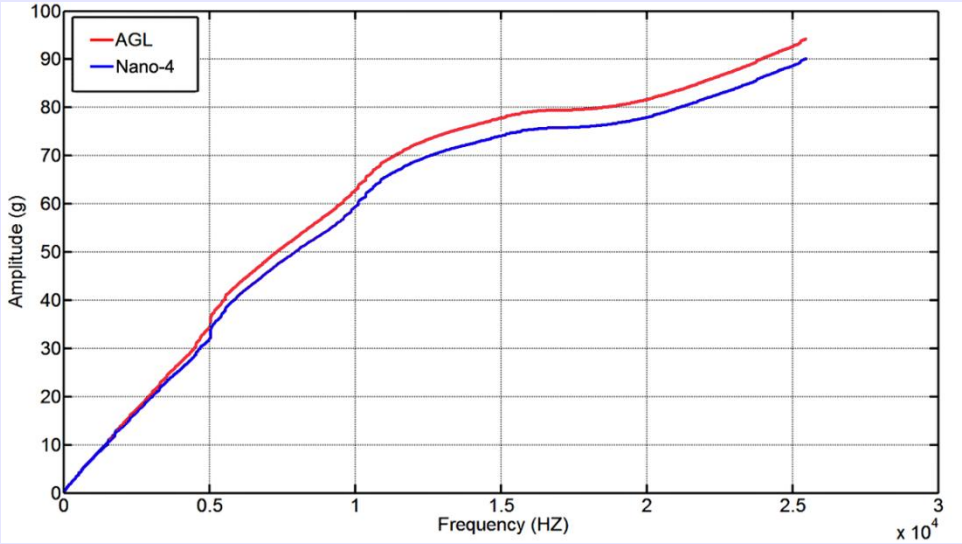
Simulated Use Conditions

Gearbox Operated Without Load

Average Gearbox Temperature



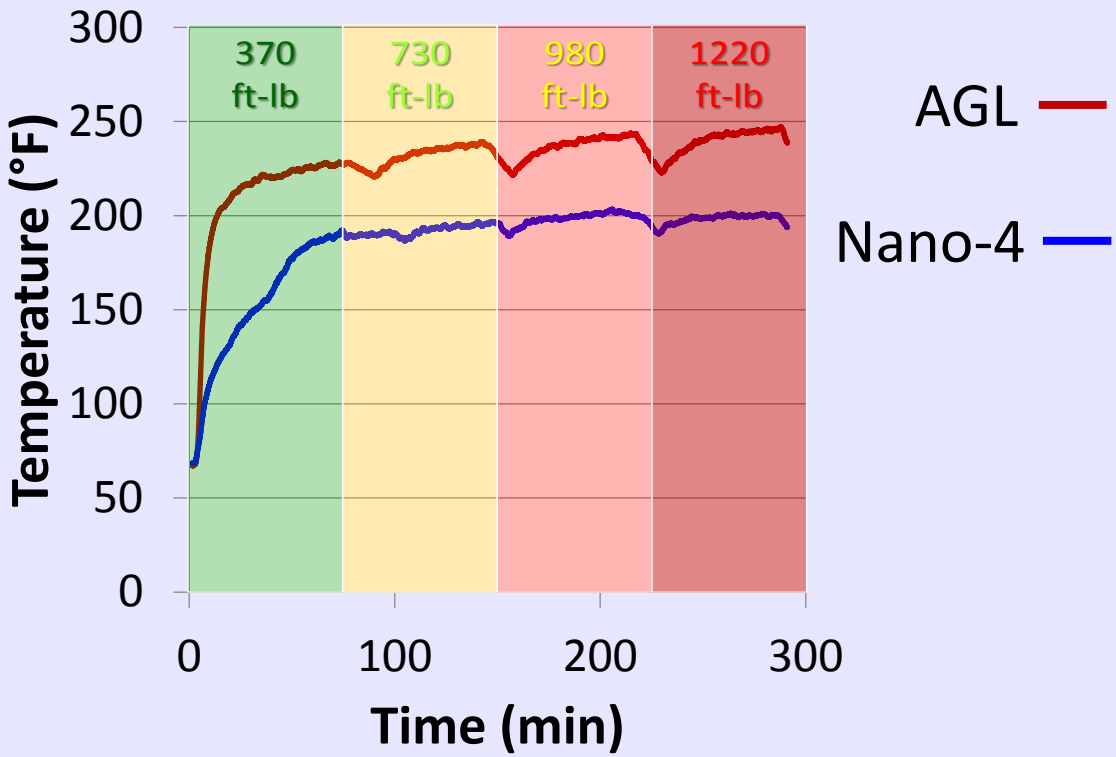
Cumulative Vibrational Energy



Simulated Use Conditions

Gearbox Operated WITH Load

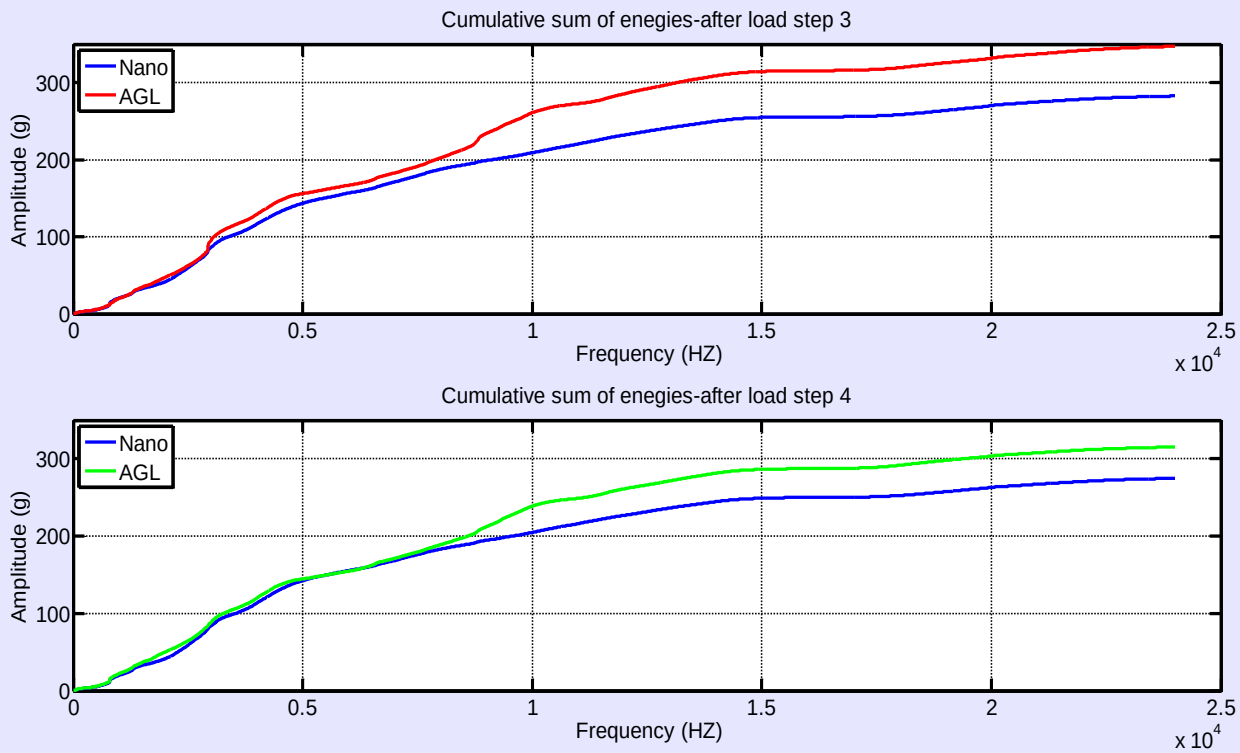
Average Gearbox Temperature



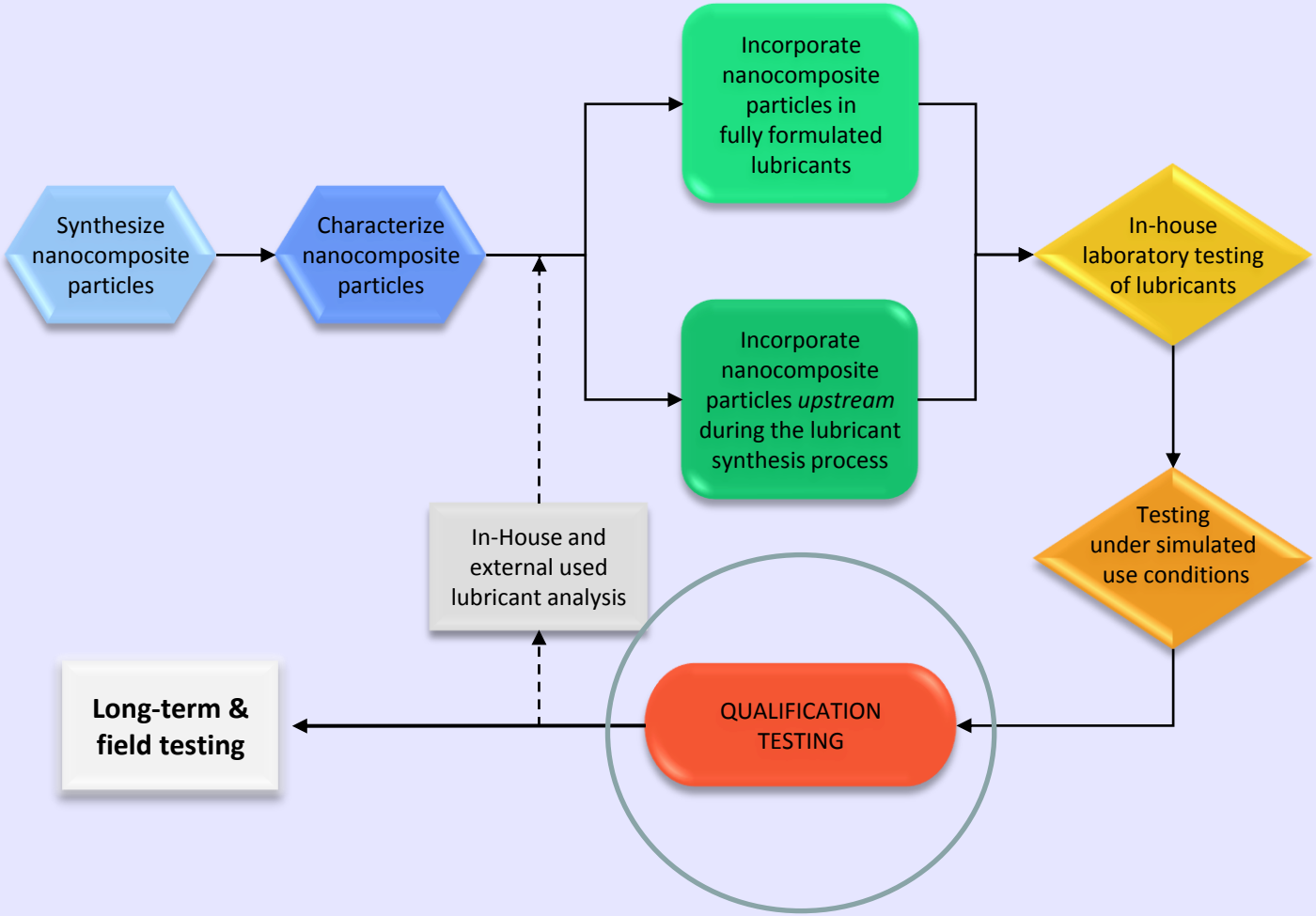
Simulated Use Conditions

Gearbox Operated WITH Load

Cumulative Vibrational Energy



Future Development



Qualification Testing

- Viscosity Grade, per ASE and ISO
- Viscosity Index, ASTM D2270
- Pour Point, ASTM D97
- Flash Point, ASTM D92
- Oxidation Resistance, ASTM D943, D2272
- Rust Protection, ASTM D665
- Water Separability, ASTM D1401
- Copper Corrosion, ASTM D130
- Foam Test, ASTM D892
- FZG Scuffing, ASTM D5182, DIN 51534

Thank You