Mobil SHC Gear Technical Presenter

May 12th, 2011

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Contents

- Performance Overview vs. Mobilgear SHC XMP series
- Energy Efficiency Benefits
- Competitive Assessment
- Conclusion and Next Steps

Mobil SHC Gear - Summary

Key Features

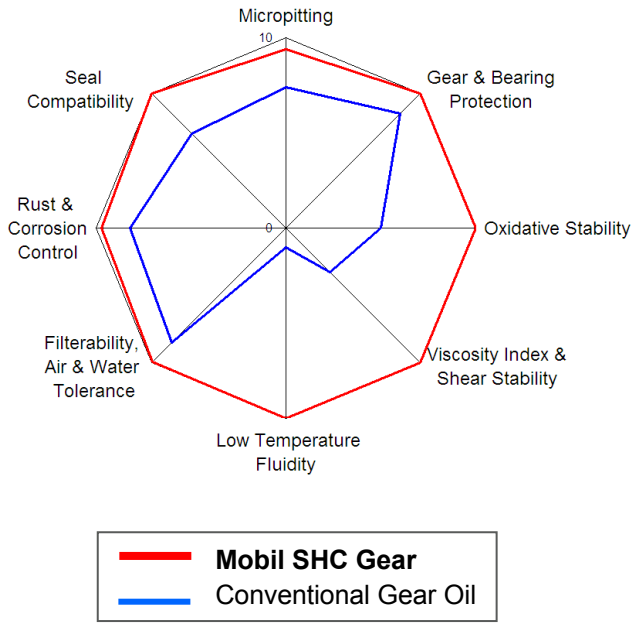
- Excellent balanced performance
- Energy efficiency benefit vs. conventional gear oils
- Superior viscometrics
- Low temperature performance
- Seal compatibility
- ISO VG 150 to 680

Energy efficiency relates solely to the fluid performance when compared to conventional (mineral) reference oils of the same viscosity grade. The technology used allows up to 3.6% efficiency compared to the reference when tested in a worm gearbox under controlled conditions. Efficiency improvements will vary based on operating conditions and application.

Industry Specifications

Viscosity Grade	150	220	320	460	680
AGMA 9005 E02	✓	✓	✓	✓	✓
DIN 51517-3 CLP (June 2009)	✓	✓	✓	✓	✓
ISO 12925-1 CKT (Dec 1996)	✓	✓			
ISO 12925-1 CKD (Dec 1996)	✓	✓	✓	✓	✓
Approved: Siemens T 7300, Table A-3, Rev. 11	✓	✓	✓	✓	✓

Relative Performance



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Mobil SHC Gear versus Mobilgear SHC XMP

Objective

- Develop next generation gear oil to replace Mobilgear SHC XMP*

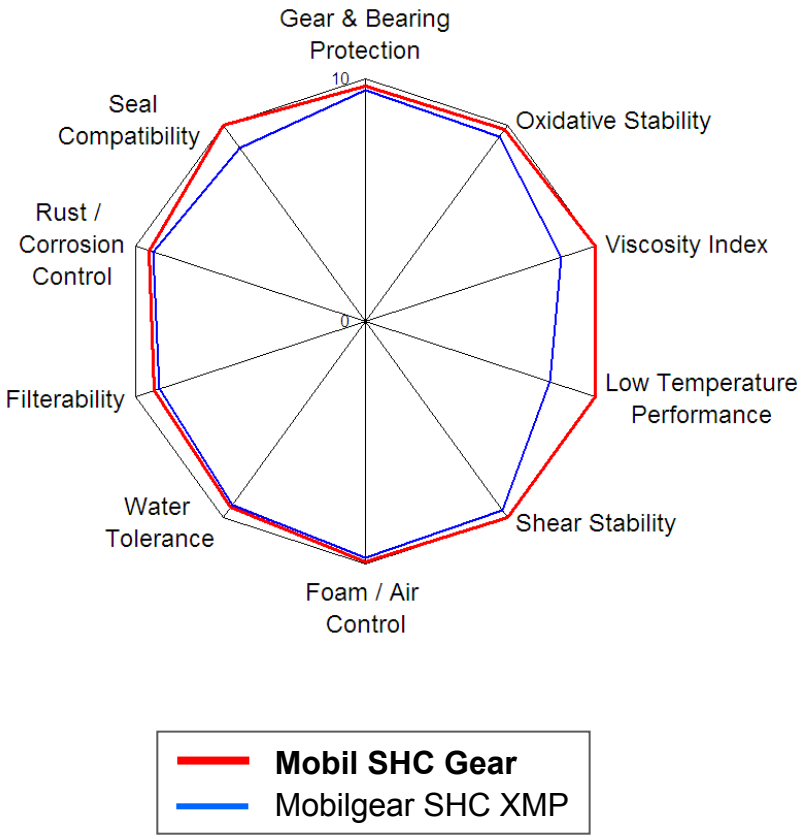
Key Features & Benefits

- Mobil SHC Gear delivers excellent balanced performance:
  - Supports customer efforts to reduce total cost of ownership and improve productivity.
- Mobil SHC Gear maintains excellent balanced performance of Mobilgear SHC XMP while providing some additional benefits:
  - Superior Viscometrics (higher VI) and Low temperature performance for for a wider operating temperature range.
  - Enhanced Seal compatibility.

Status

- Product commercially available from May 2011

Relative Performance



* Mobilgear SHC XMP 320/460 have OEM approvals and proven performance for use in wind turbine gearboxes and will remain for wind sector

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Mobil SHC Gear versus Mobilgear SHC XMP

- **<u>Improved Performance:</u>**
  - Viscometrics:
    - VI
    - Low Temperature Viscometrics
  - Shear Stability
  - Foam & Air Release
  - Seal Compatibility

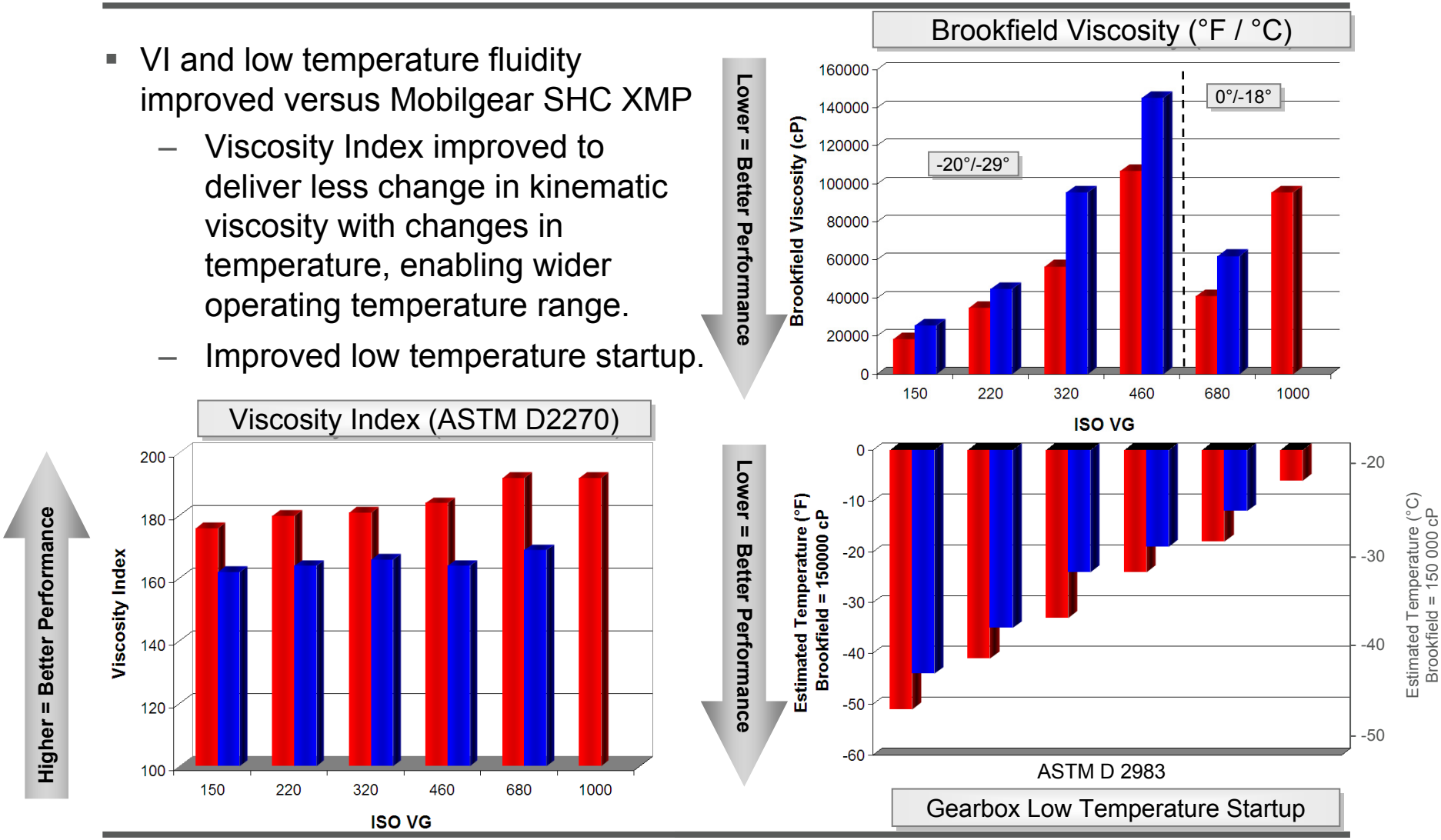
- **<u>Same Performance Level:</u>**
  - Gear & Bearing Wear Protection
  - Oxidation stability
  - Water tolerance:
    - Rust & Corrosion
    - Water separability
    - Filterability

Viscosity Index and Shear Stability - Background

- Viscometrics are among the primary advantages of synthetic lubricants and are critical to performance at both high and low temperatures.
- Shear stability is critical for an oil to maintain its viscosity in service.
- Viscosity Index and Shear Stability were compared based on results of:
  - Viscosity Index – ASTM D 2270
    - **Indicates resistance of a lubricant to change viscosity with temperature. Higher VI indicates less change in viscosity with changes in temperature.**
  - Shear Stability (CEC L-45-99 modified)
    - **Measures permanent shear loss after 20 hours of operation in a tapered roller bearing operating at 60° C.**
    - **Test duration was extended by a factor of five, to 100 hours to increase severity.**
    - **Test temperature was increased to 90° C so that the viscosity of the test oils (ISO VG 460 to 1000) would be in a suitable range for the test rig.**

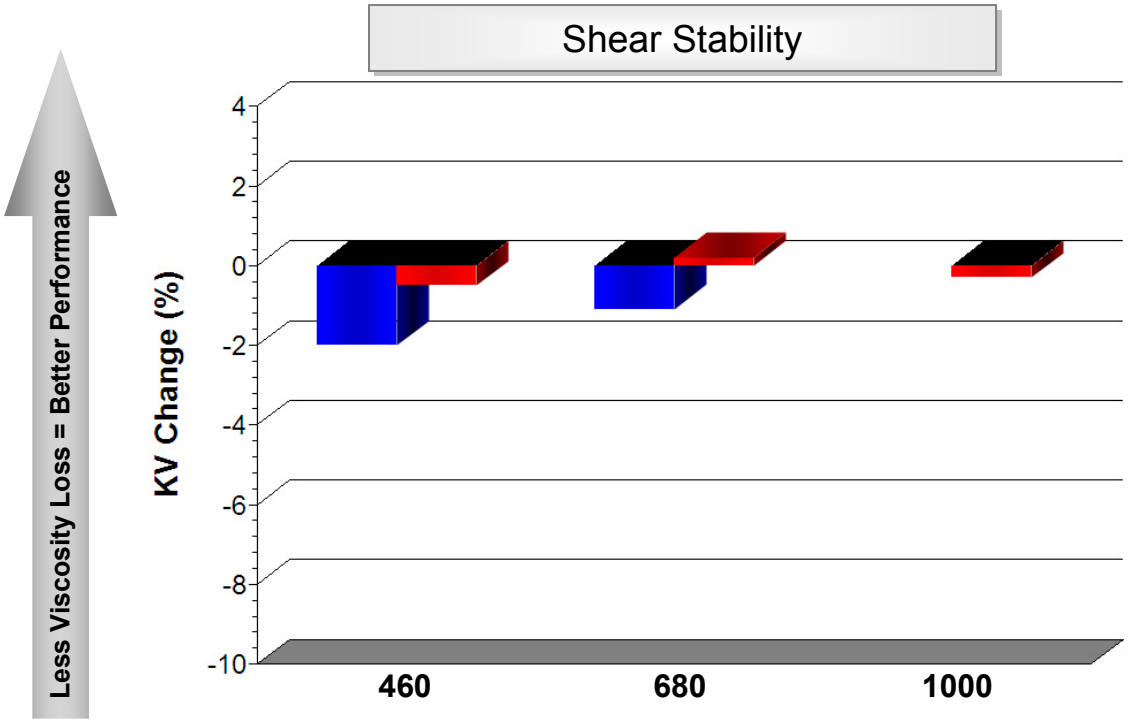
Mobil SHC Gear - Viscosity Index and Low Temperature Fluidity

- VI and low temperature fluidity improved versus Mobilgear SHC XMP
  - Viscosity Index improved to deliver less change in kinematic viscosity with changes in temperature, enabling wider operating temperature range.
  - Improved low temperature startup.



Mobil SHC Gear - Shear Stability

- Current product has “stay in grade” performance
- Mobil SHC Gear shows excellent shear stability under severe conditions
  - Virtually no shear loss below ISO VG 460
  - Comparable performance for grades below ISO VG 460



KRL Tapered Roller Bearing: CEC L-45-99 (modified – 90°C, 100hr)

Mobil SHC Gear
Mobilgear SHC XMP

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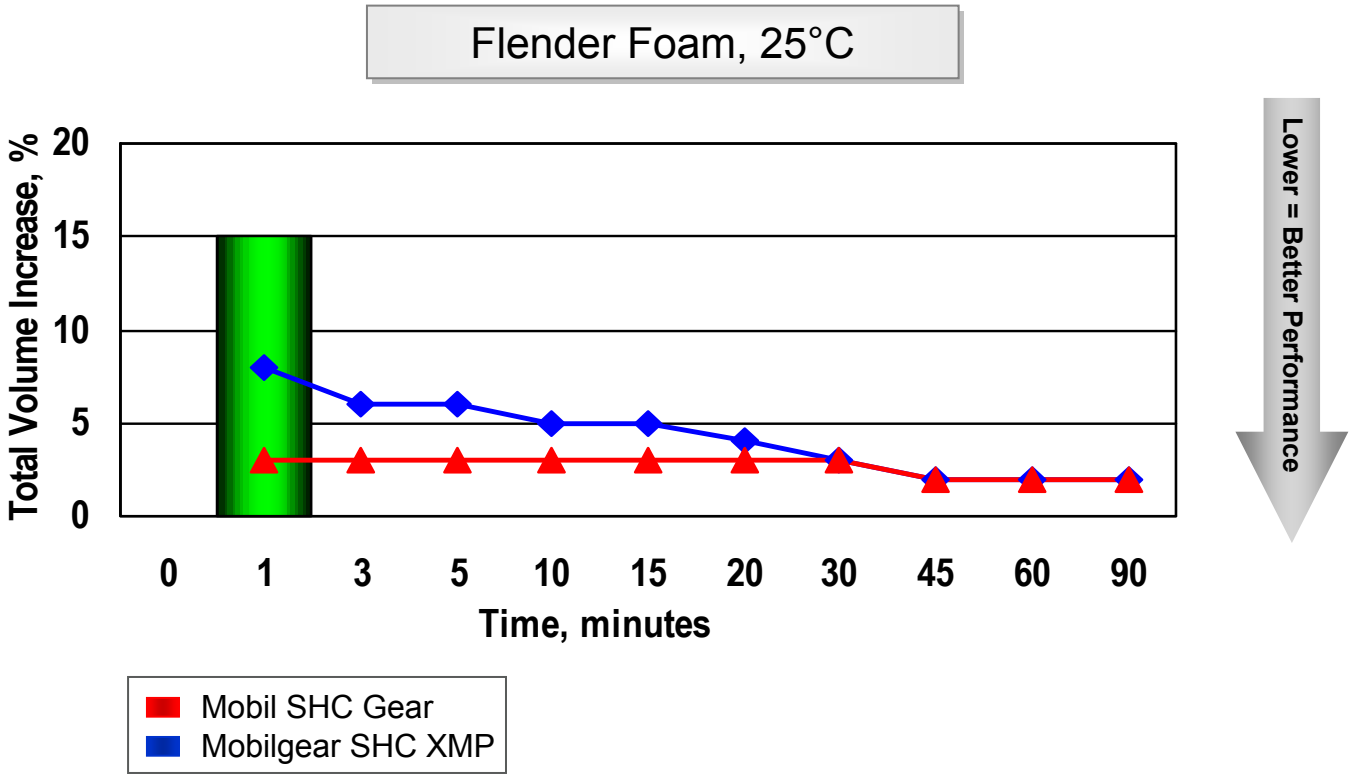
Foam & Air Release - Background

- Separation of air from oil consists of two steps:
  - Release of air from the bulk fluid, including agglomeration of smaller bubbles to form larger ones is “air release”.
  - Release of air at the oil / air interface is “foam”.

- These properties are important for gear oils:
  - Oil with moderate amounts of entrained air will generally provide adequate lubrication.
    - Tribology testing has shown that entrained air does not enter the contact zone under EHL or mixed/boundary lubrication conditions.
  - Oil with excessive amounts of entrained air will not provide proper lubrication and can lead to cavitation in pumps.
  - A layer of foam on top of a gear oil is generally not a problem.
  - In severe cases, poor foam performance could lead to difficulty in determining oil level and even oil leakage from seals and breathers.

Mobil SHC Gear - Foam and Air Release

- ASTM foam performance equivalent
- Flender Foam performance slightly improved



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Energy Efficiency Benefits

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Overview

- Objective of this discussion is to summarize energy efficiency claims for Mobil SHC Gear ISO VG 150 through to 680.

- Testing Programme completed at EMRE:
  - MTM Traction data.
  - MSWG data and thermographs.

- Conclusion and claim disclaimer.

Energy efficiency relates solely to the fluid performance when compared to conventional (mineral) reference oils of the same viscosity grade. The technology used provides up to 3.6% efficiency compared to the reference when tested in a worm gearbox under controlled conditions. Efficiency improvements will vary based on operating conditions and application.

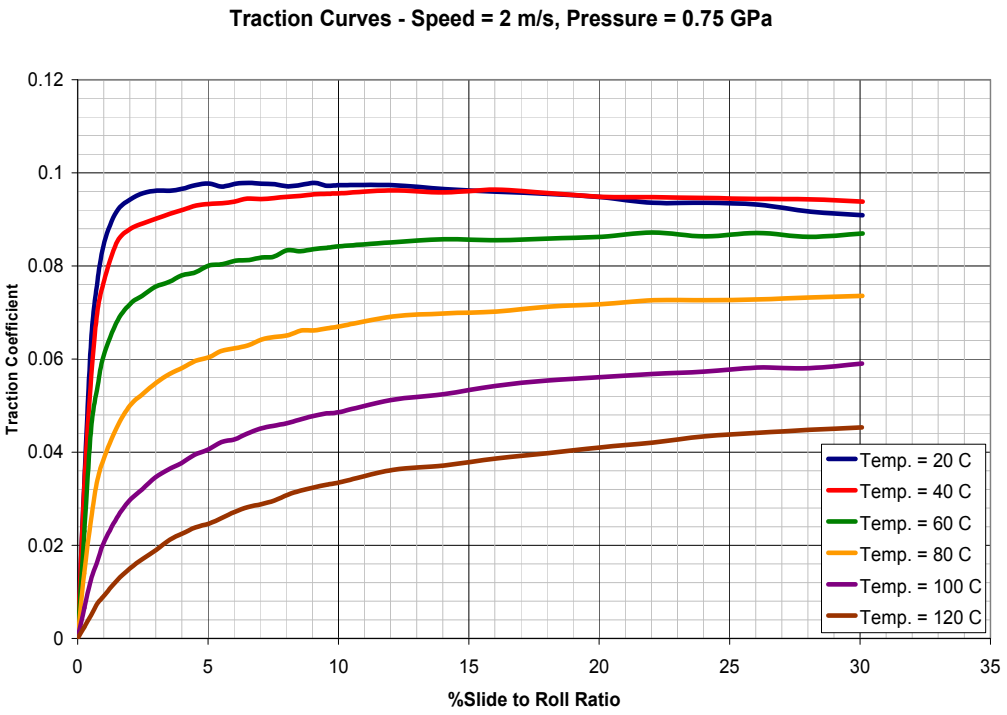
Mini Traction Machine (MTM)

- PCS Mini Traction Machine is a commercial instrument and is widely accepted as a flexible instrument for performing tribological experiments.

Objective	Reproduce a lubricated contact under highly controlled EHL (elastohydrodynamic lubrication) conditions.
Measure	Traction forces transmitted across a lubricant film under varying amounts of sliding while controlling load, speed, and temperature.
Output	Traction curve which is essentially a plot of these forces as a function of sliding speed, often characterized as slide to roll ratio.
Relevance	MTM system reproduces conditions that exist in tribological contacts that occur in common engineering components such as rolling element bearings and gears of all types. MTM is widely accepted as the most convenient and accurate method to quantify losses in EHL contacts. Correlates well with gear testing performed both internally and by 3rd parties (e.g. Afton and PARC rear axle gear testing).

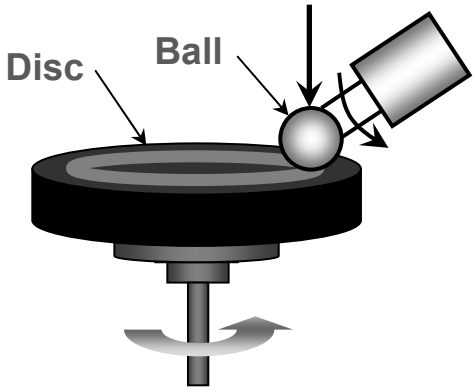
Mini Traction Machine (MTM)

Traction Curves at Various Conditions

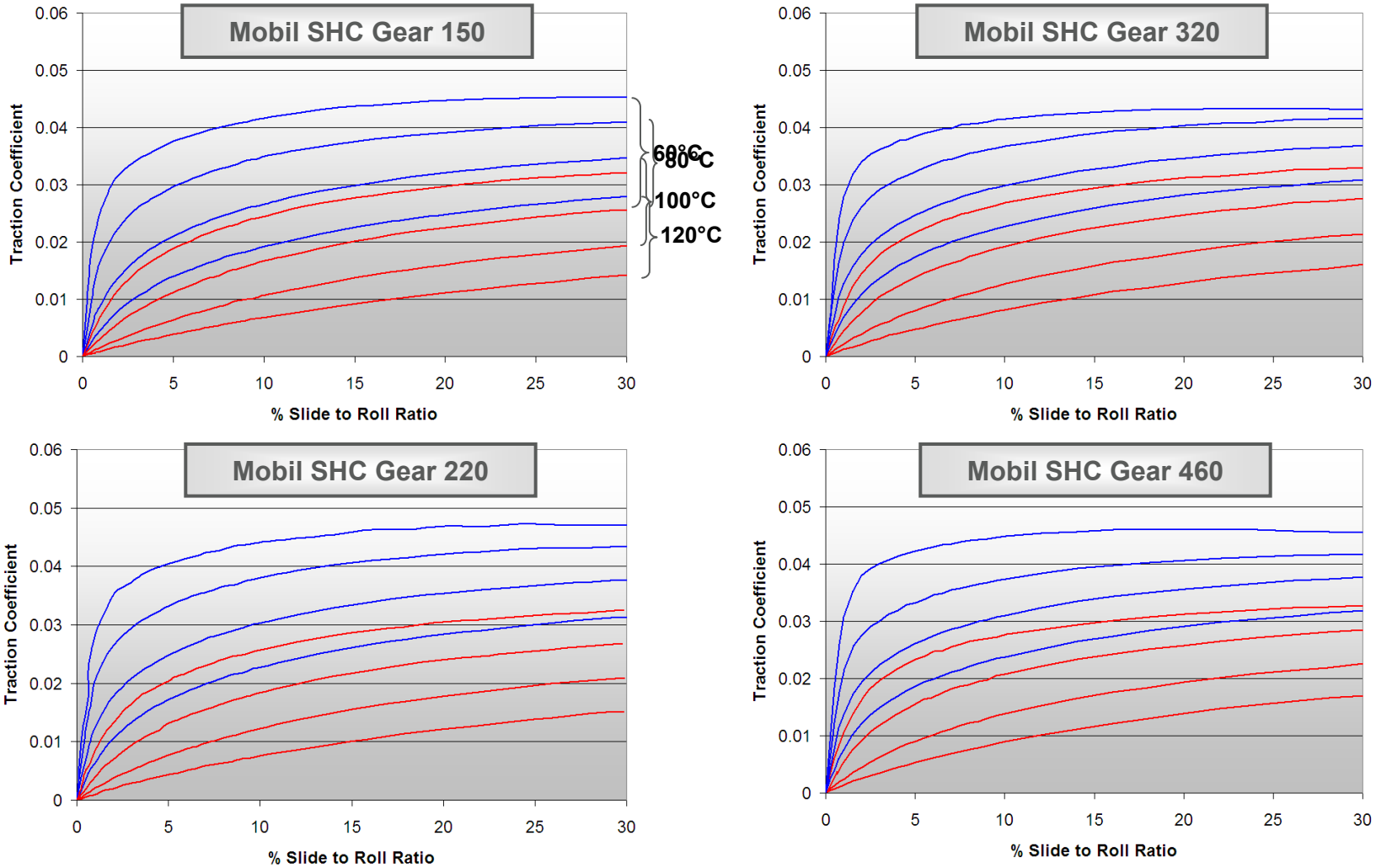


EHL Traction Curves are constructed under High Contact Load and Contact Pressure

Mini Traction Machine (MTM)



Low Traction Benefit Mobil SHC Gear 150 to 460



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Low Traction Benefit Mobil SHC Gear 680

Reference
Mobil SHC Gear

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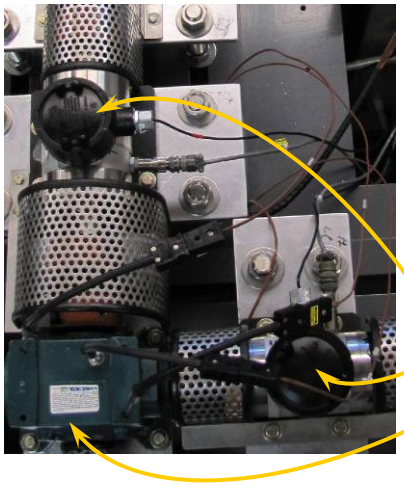
Modular Small Worm Gear Test (MSWG)

- MSWG test uses a commercial 1 Hp right angle, worm gearbox with a 20:1 reduction ratio to measure impact of lubricants on worm gear operation.

Objective	Measure impact of worm gear oil on operation of a commercial worm gearbox at full speed and rated load.
Measure	Data acquisition system collects input and output torque, speed, and power and lubricant temperature under controlled conditions. Test protocol requires equilibration period followed by sequence test period and frequent reference oil test runs.
Output	Mechanical efficiency versus test hours and oil temperature at 95% confidence interval. Gearbox thermographs.
Relevance	Gearbox is commercial and test was developed based on extensive interactions with several key US worm gear builders. Development of data analysis approach by EMRE statistician.

The data supports an energy efficiency potential of up to 3.6% improvement of PAO-based lubricants over mineral-based lubricants at 95% confidence level

Modular Small Worm Gear Test Rig (MSWG)



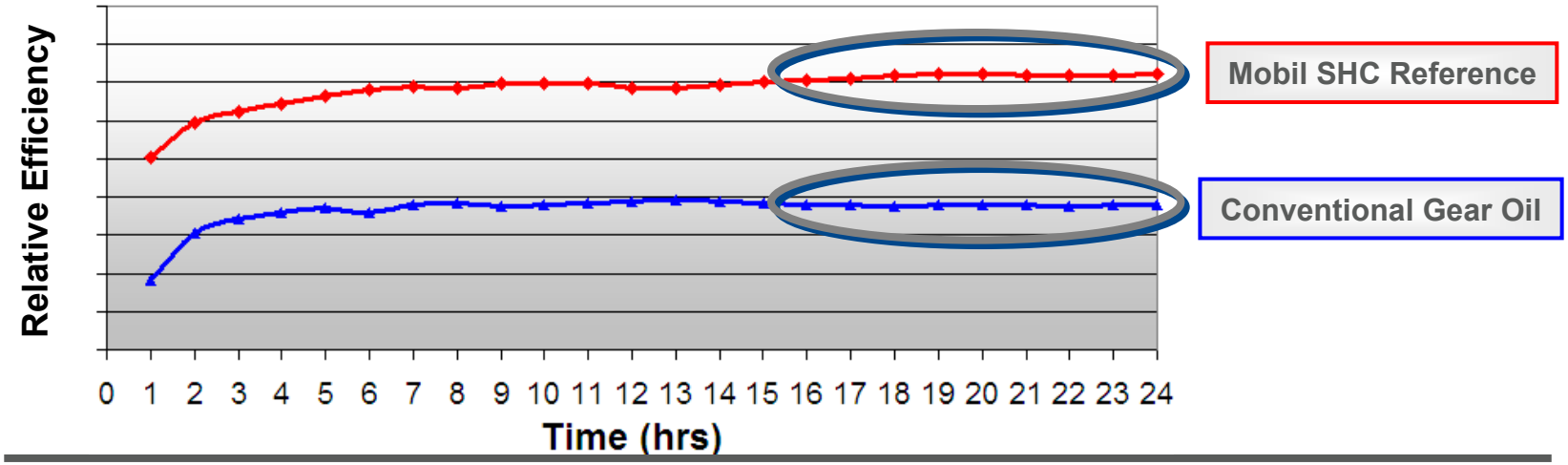
20:1 Reduction Gearbox, 1.00 HP

Test Flexibility:

- Builder-specific gearboxes
- Power assessment
- Reduction ratios
- Break-in/Wear-in

Assessment Capabilities:

- Mechanical Efficiency
- Sump Temperature



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Lubricant Effects on Gearbox Efficiency

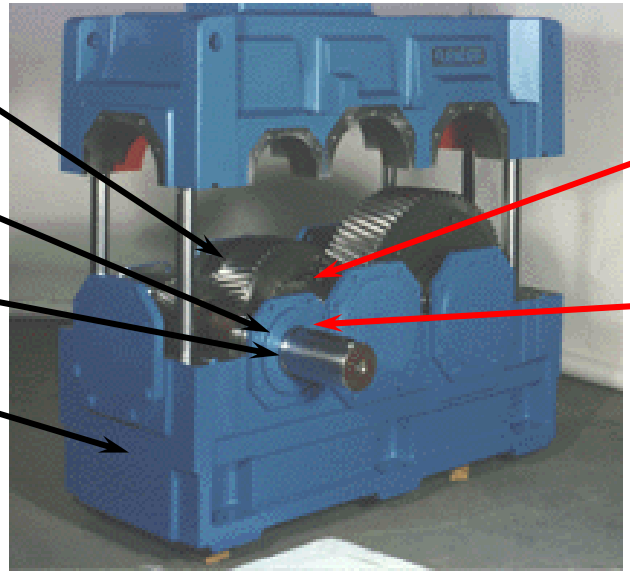
Speed-dependent Losses

Gear mesh churning loss

Shaft bearing churning loss

Seal drag loss

Circulation and sump churning



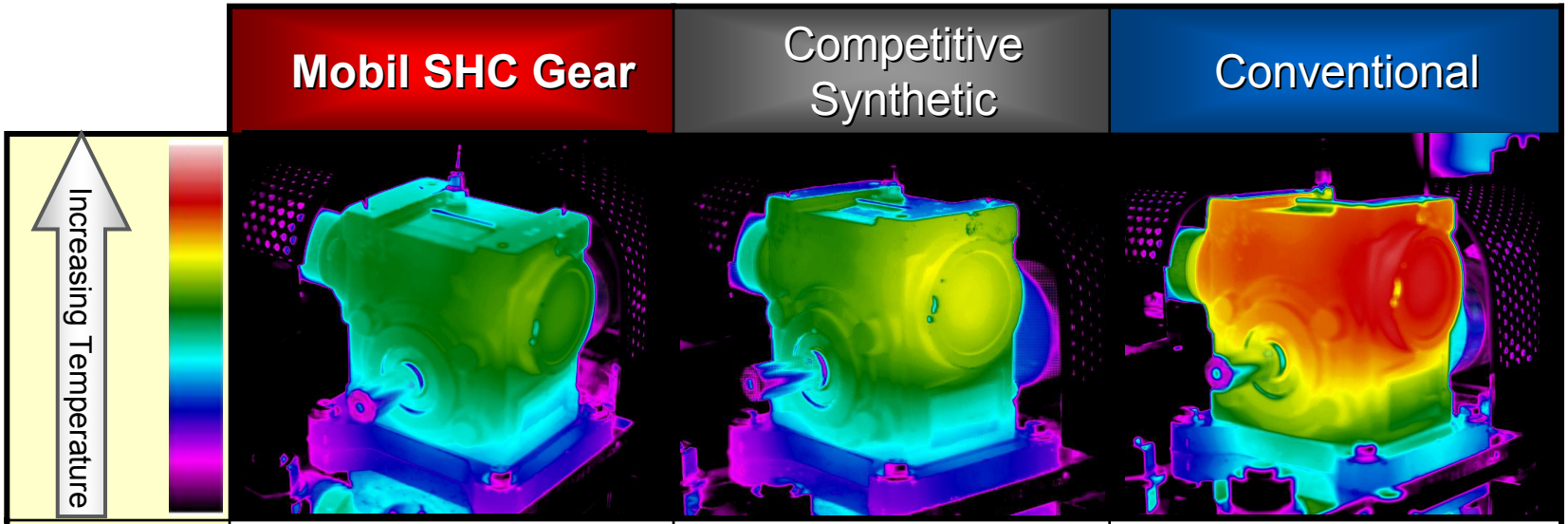
Load-dependent Losses

Traction loss in gear mesh and rolling element bearings

Hydrodynamic loss in shaft bearings

- Fluid bulk viscosity affects speed dependent losses.
- Fluid traction and boundary friction affect load dependent losses.

MSWG Testing Confirms Energy Efficiency Benefit



	Mobil SHC Gear	Competitive Synthetic	Conventional
Sump Temp	**74.5° C / 166° F**	**83° C / 182° F**	**91° C / 196° F**
Efficiency	**77.0%**	**75.2%**	**74.0%**

- Mobil SHC Gear runs ~16°C cooler than a conventional mineral gear oil, leading to:
  - Increased equipment life
  - Increased efficiency
  - Reduced maintenance cost

  and delivers almost 2% energy efficiency advantage vs. competitive synthetic gear oil in controlled worm gear testing.

Mobil SHC Gear – Energy Efficiency Summary

- Many lubricated contacts in Industrial equipment operate under EHL conditions.
- Losses in EHL contacts depend on fluid traction (internal friction) properties.
- Mobil SHC Gear has lower traction than conventional gear oils.
- Potential gear oil energy efficiency benefit depends on gear types, number of gear reduction stages, duty cycle, and lubrication conditions.
- Tribological testing, including MTM, EHL thermal mapping, and controlled worm gear rig testing, demonstrates the energy efficiency benefit of Mobil SHC Gear.

Mobil SHC Gear delivers up to 3.6% energy efficiency benefit versus conventional gear oil

Energy efficiency relates solely to the fluid performance when compared to conventional (mineral) reference oils of the same viscosity grade. The technology used provides up to 3.6% efficiency compared to the reference when tested in a worm gearbox under controlled conditions. Efficiency improvements will vary based on operating conditions and application.

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Competitive Assessment

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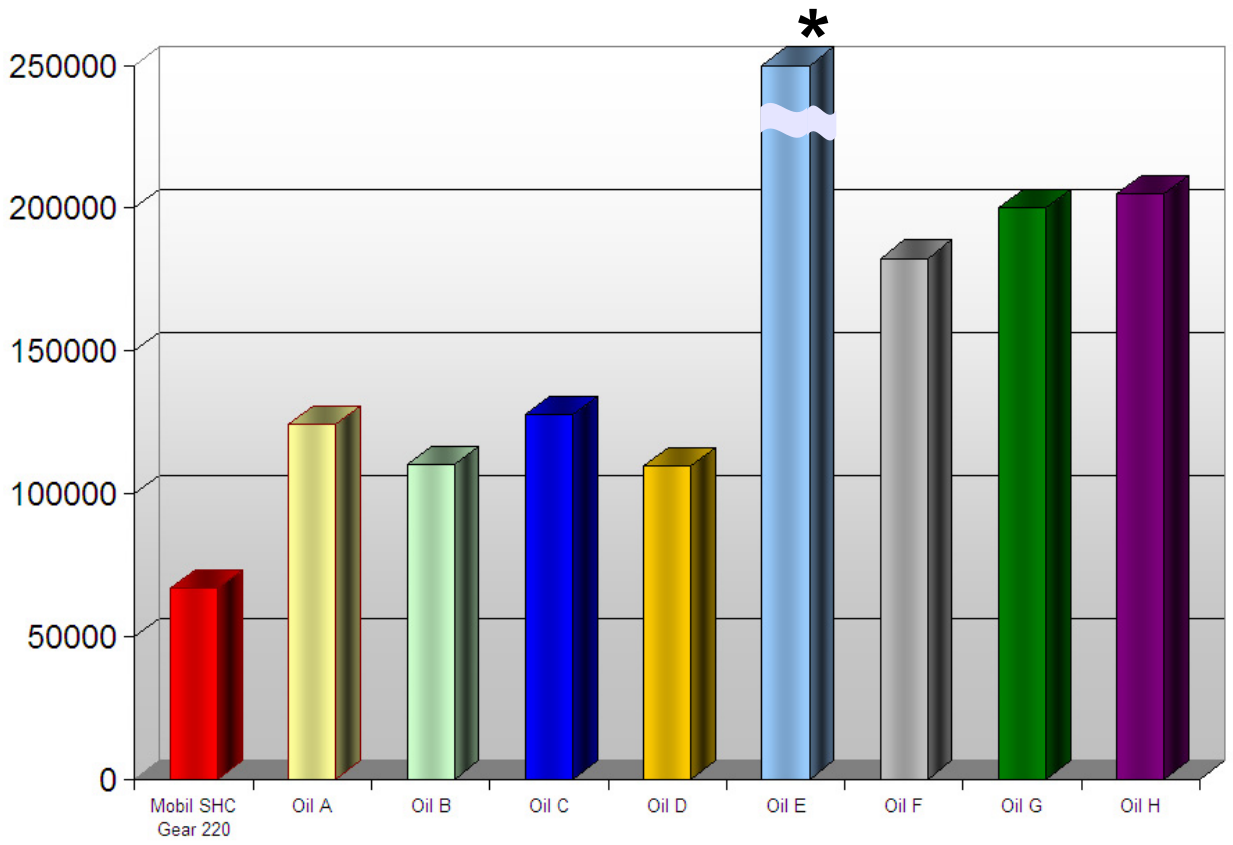
Mobil SHC Gear – Competitive Assessment Introduction

- Mobil SHC Gear was compared with eight competitive products recommended for use in Industrial gearboxes.
- The oils were evaluated in a rigorous testing programme:
  - 7 key performance areas.
  - 19 performance tests including in-house and industry standard testing:
    - Industry standard glassware and rig tests
    - Proprietary in-house rig tests
  - Tests were performed ExxonMobil Research & Engineering or approved third party laboratories.
- Oils were purchased commercially in their local markets in North America, Europe, and Asia.
- Seven competitive brands are represented.
- The data in the following slides:
  - Represent a snap shot in time.
  - Are assumed to be representative of the competitor's brand.

Mobil SHC Gear – Competitive Assessment

- Low Temperature Fluidity
  - Brookfield Viscosity at -35°C / -31°F



*325000 cP

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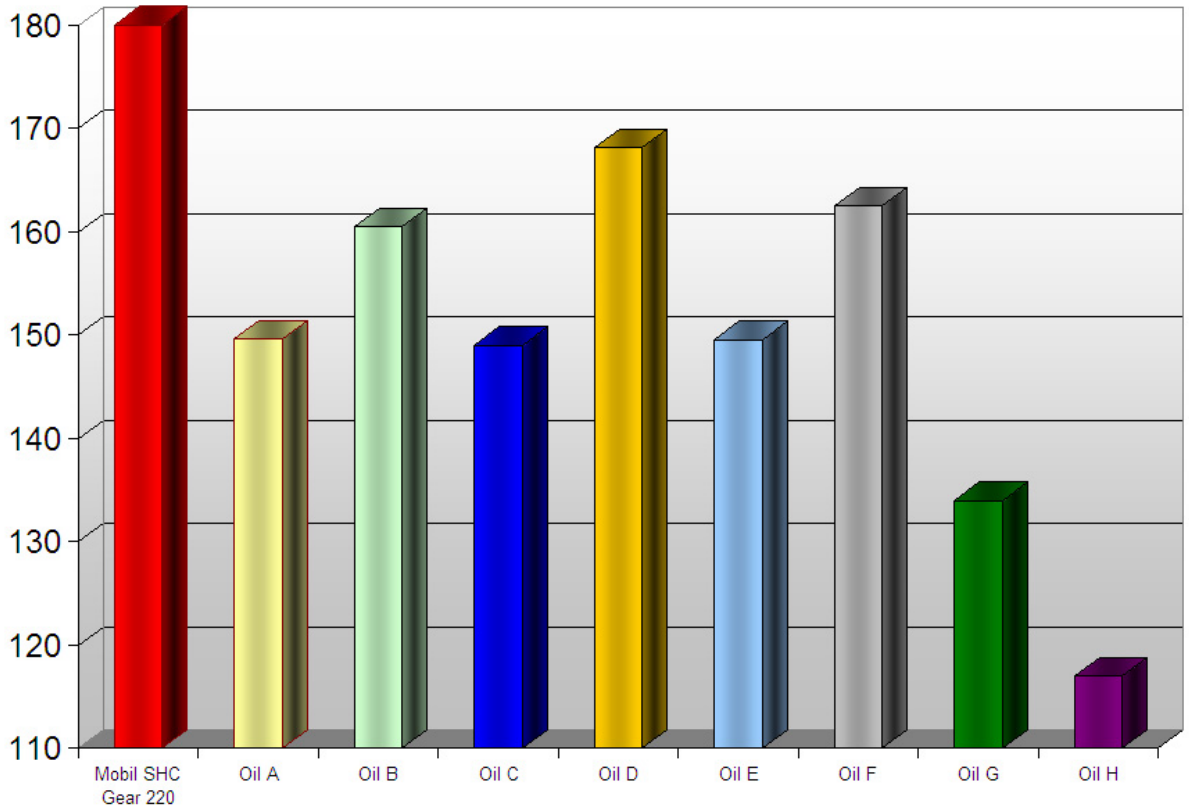
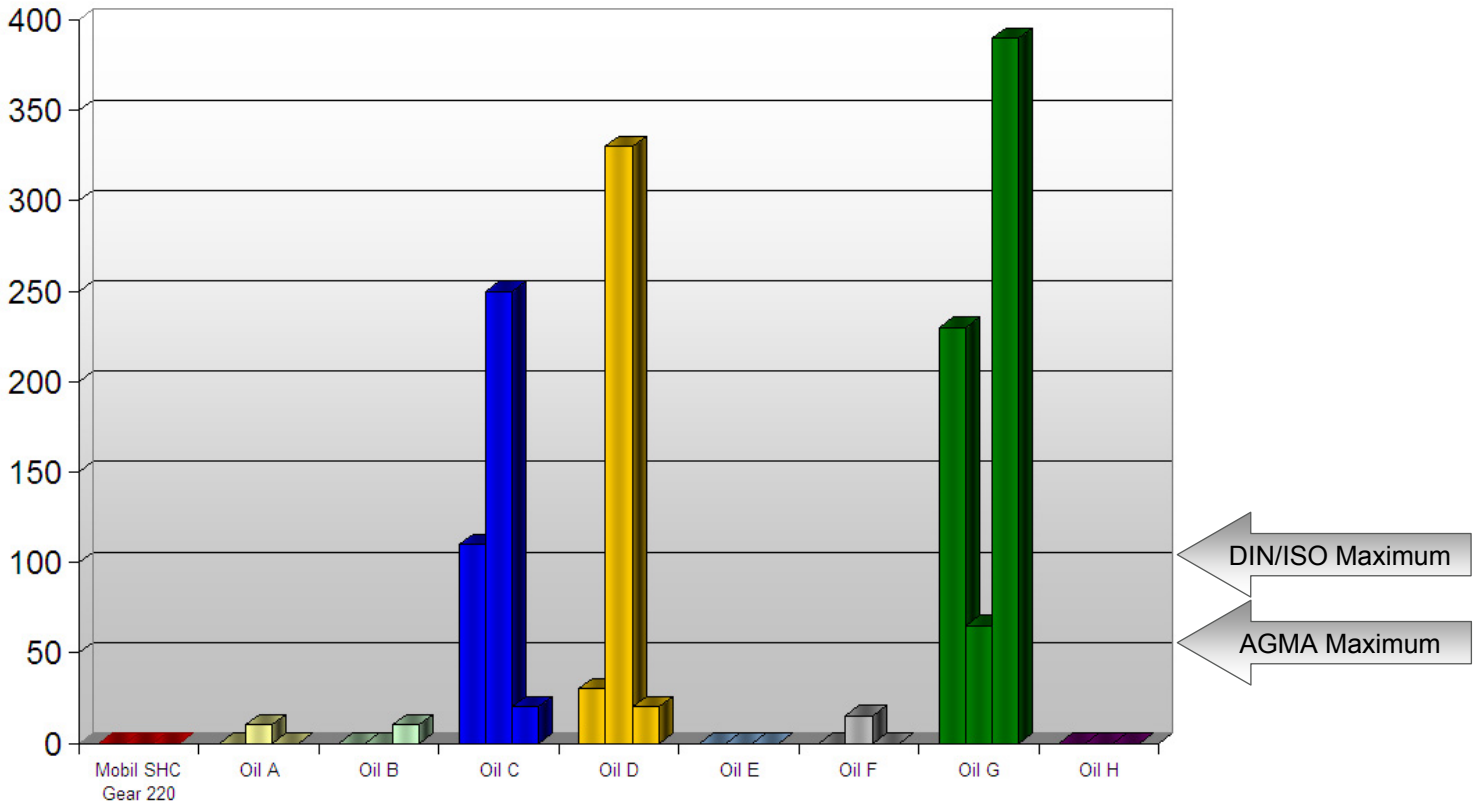
Mobil SHC Gear – Competitive Assessment

- Viscosity Index



Mobil SHC Gear – Competitive Assessment

- Foam Tendency



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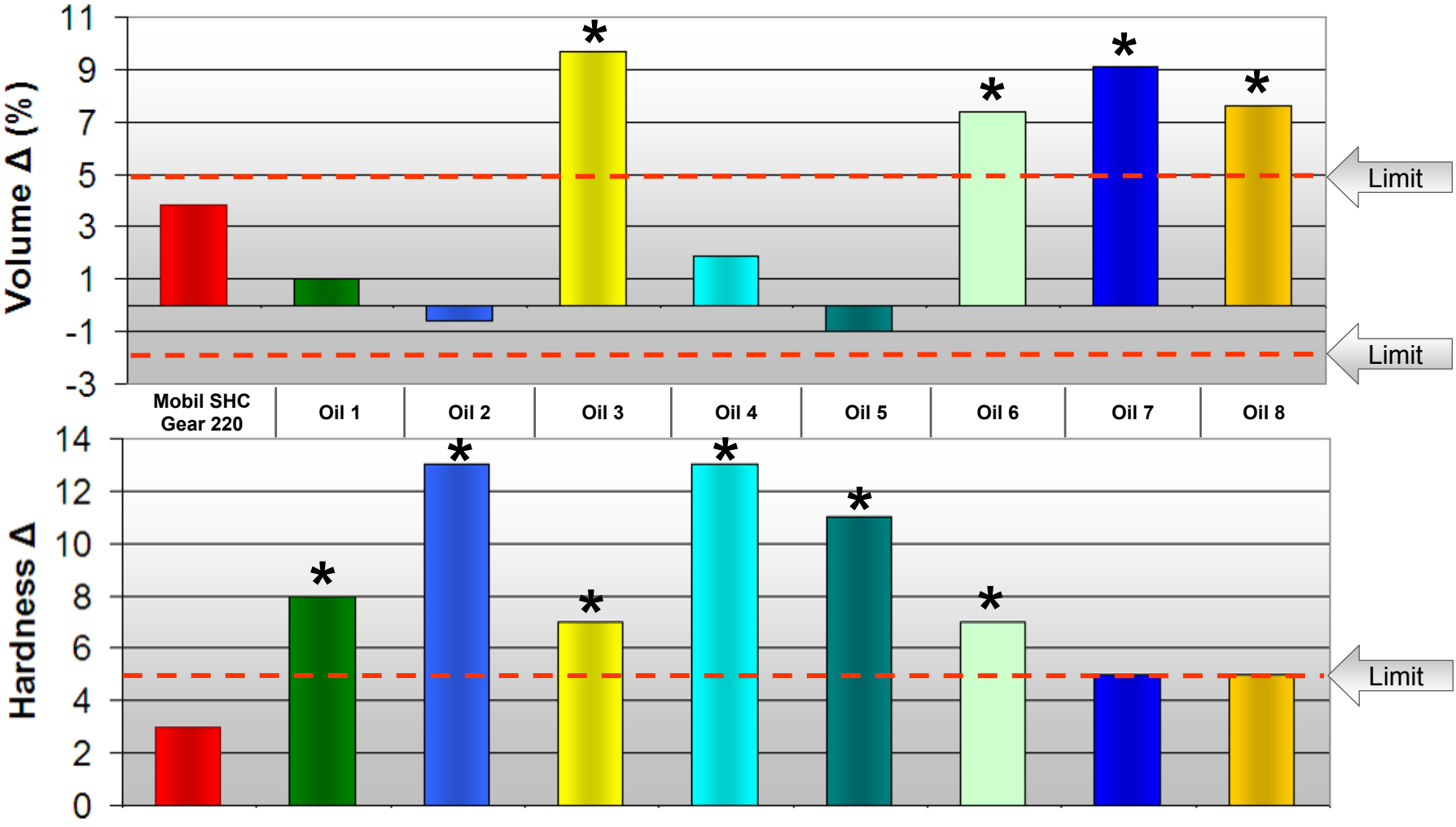
Freudenberg Static Seal Compatibility

FB 11 73 008
72 NBR 902, 1000hr at 100°C



* Failing Result

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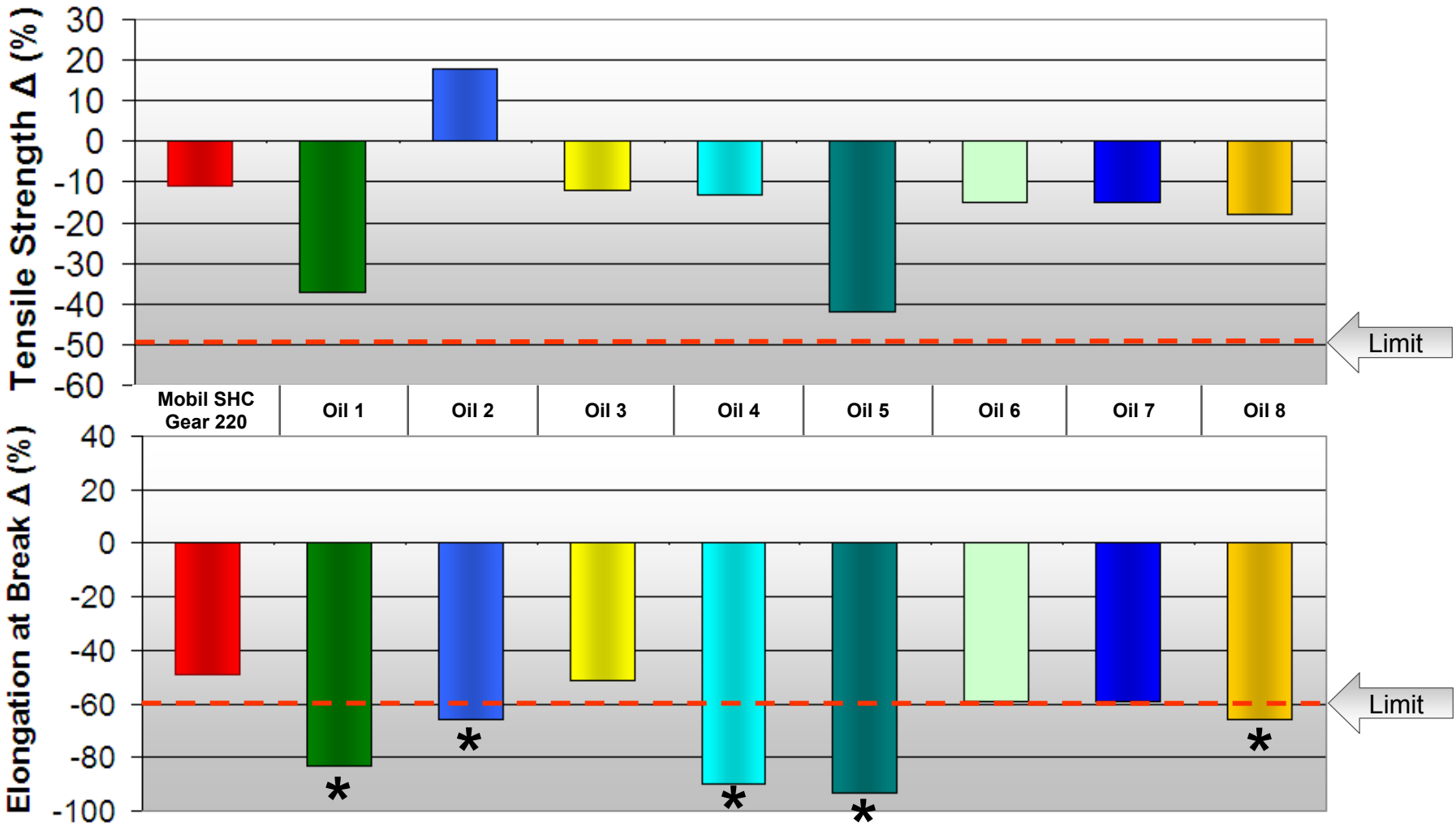
Freudenberg Static Seal Compatibility

FB 11 73 008
72 NBR 902, 1000hr at 100°C



*Failing Result

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Freudenberg Static Seal Compatibility - Summary

	Mobil SHC Gear	Oil 1	Oil 2	Oil 3	Oil 4	Oil 5	Oil 6	Oil 7	Oil 8
72 NBR 902									
Volume Δ%									
Hardness Δ									
Tensile Strength Δ%									
Elongation at Break Δ%									
Overall Evaluation	**Pass**	**Fail**	**Fail**	**Fail**	**Fail**	**Fail**	**Fail**	**Fail**	**Fail**
75 FKM 585									
Volume Δ%									
Hardness Δ									
Tensile Strength Δ%									
Elongation at Break Δ%									
Overall Evaluation	**Pass**	**Pass**	**Pass**	**Pass**	**Pass**	**Pass**	**Fail**	**Fail**	**Pass**

All of the Flender-approved oils tested fail versus Freudenberg static seal compatibility requirements with NBR elastomer

Mobil SHC Gear – Competitive Assessment Summary

- Mobil SHC Gear delivers balanced performance that is unmatched by the competitive synthetic gear oil products tested.
- Mobil SHC Gear outperforms all oils tested in most key performance areas.
- Many competitive oils do not deliver balanced performance:
  - Almost all show acceptable gear and bearing protection
  - However they have deficiencies in other performance areas
    - Some even show failing results for some parameters
- The excellent, balanced performance of Mobil SHC Gear would be expected to outperform these competitive oils in service, supporting customer efforts to reduce total cost of ownership and improve productivity.

Mobil SHC Gear - Conclusion and Next Steps

- Mobil SHC Gear is an excellent replacement for Mobilgear SHC XMP in Industrial gearbox applications:
  - Excellent balanced performance for reliable operations.
  - Superior viscometrics and low temperature performance enabling wide operating temperature range.
  - Enhanced seal compatibility.

→ Supports customer efforts to reduce total cost of ownership and to improve productivity.

- Approved by Siemens for use in Flender gearboxes.
- Key Equipment Builder evaluations and field demonstrations underway.
- Commercially available from May 2011.

Questions?

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Back-ups

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Mobil SHC Gear – Elastomer Compatibility

- Static Tests:
  - Meets DIN 51517-3: 2009-06 requirements for SRE NBR 28 seals.
  - Meets Freudenberg limits for 72 NBR 902, 75 FKM 585 and 75 FKM 170055.

- Freudenberg Dynamic Tests:
  - Meets all requirements for 72 NBR 902, 75 FKM 585 and 75 FKM 170055.

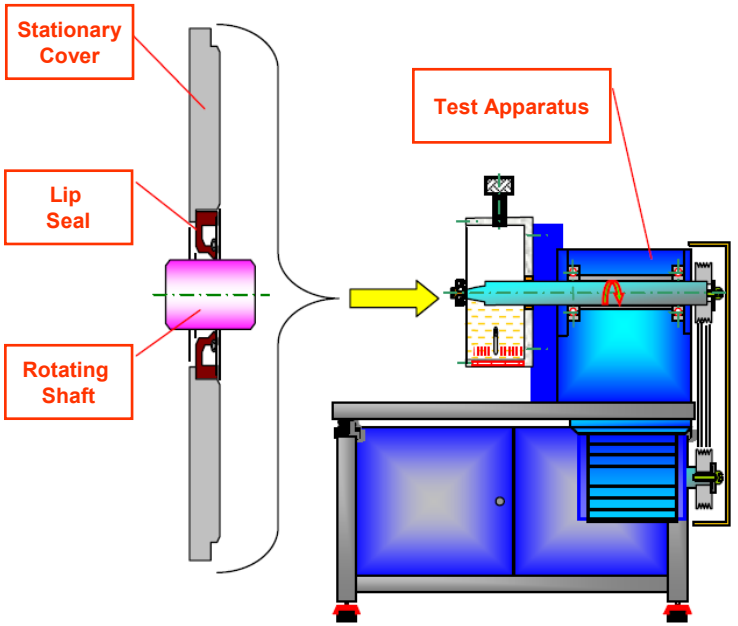
DIN Static Seal Compatibility - Summary

	Mobil SHC Gear	Oil 1	Oil 2	Oil 3	Oil 4	Oil 5	Oil 6	Oil 7	Oil 8	Oil 9	Oil 10	Oil 11
Volume Δ%												
Hardness Δ												
Tensile Strength Δ%												
Elongatiion at Break Δ%												
Overall Evaluation	**Pass**	**Fail**	**Fail**	**Pass**	**Fail**	**Pass**	**Pass**	**Pass**	**Pass**	**Fail**	**Fail**	**Pass**

More than half of the oils tested fail versus basic DIN seal compatibility requirements with reference NBR elastomer

Freudenberg FB 73 11 008 Dynamic Seal Compatibility - Summary

- Excellent compatibility demonstrated with Freudenberg elastomers in dynamic seal tests.
- A radial shaft seal is mounted on a shaft rotating at 1500 rpm for 20 hrs per day for 42 days on a standardized rig.
- Likely more relevant than static seals testing due to interaction of oil, elastomeric radial lip seal, and rotating shaft



Elastomer	Test Method	Conditions	Result
72 NBR 902	Freudenberg FB 73 11 008 (PAO-based lubricants)	80° C / 1008 hrs.	PASS
75 FKM 585		110° C / 1008 hrs.	PASS
75 FKM 170055		110° C / 1008 hrs.	PASS