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High Temperature Wheel Bearing Testing – an Electrifying Improvement

Barbara Carfolite and Autumn Chadwick
ExxonMobil Research and Engineering Technology Center Clinton, NJ 08809 USA

Initial Steps of Lithium Soap Grease Thickener Agglomeration

Paul Shiller, The University of Akron
Akron, OH 44325

Let the Games Begin: New trends in industrial grease lubrication

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Dr. Mary Moon - Technical Editor, The NLGI Spokesman - Yardley, PA 19067 US
Dr. George S. Dodos - Eldon’s S.A.  - 14343 Athens, GR

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Industry Calendar of Events

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Thank you to all those who joined us in Las Vegas for the 86th NLGI Annual Meeting! It was a great event packed with education, networking and fun! Of the record 470+ attendees who joined us this year, 92 attendees were from abroad continuing a trend of international interest and active global participation in NLGI. The NLGI Annual Meeting offered 29 technical presentations, two grease courses, a CLGS exam and various networking opportunities including receptions, breakfasts, lunches and a spectacular closing party on Tuesday evening. We’ve included an excellent recap of the highlights of the meeting in a separate article in this issue.

The following board positions renewed their terms for the next three years (2018-2021):

<table>
<thead>
<tr>
<th>Member Representing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Barbara Bellanti ...................... Battenfeld Grease &amp; Oil Corp. of NY (Active)</td>
</tr>
<tr>
<td>Chuck Coe................................ Grease Technology Solutions, LLC. (Technical)</td>
</tr>
<tr>
<td>Chad Chichester ..................... Molykote Lubricants (Manufacturer)</td>
</tr>
<tr>
<td>Anoop Kumar ........................... Chevron Global Lubricants (Active)</td>
</tr>
<tr>
<td>Jim Hunt ............................... Tiarco Chemical (Supplier)</td>
</tr>
<tr>
<td>Tyler Jark ............................. AOCUSA</td>
</tr>
</tbody>
</table>

Please note that the following board members are not renewing their terms:

<table>
<thead>
<tr>
<th>Member Representing</th>
</tr>
</thead>
<tbody>
<tr>
<td>David Como................................ Molykote Lubricants</td>
</tr>
<tr>
<td>Dick Burkhalter ................................ Covenant Engineering Services, LLC</td>
</tr>
</tbody>
</table>

For those who weren’t able to join us in Vegas, we mentioned some organization highlights that have taken place since our last Annual Meeting as well as an upcoming event including:

**Re-designed website**

“Creative, colorful and easy to use”, the new [www.nlgi.org](http://www.nlgi.org) contains “quick links,” direct avenues to education and industry related information as well as a robust Members’ Only area. The Members’ Only area features NLGI’s annual Grease Production Survey, Membership Directory and more! Login today and start taking advantage of these benefits.

Additionally, the redesigned [www.nlgi.org](http://www.nlgi.org) features Technical Articles dating back to the 1960’s. These articles are searchable via Keyword(s), Title, Author(s), Presented Date and Published Date. Additionally, they are available for immediate download. Choose an article, view the first page to ensure you’d like to proceed, then add to cart. Articles from 1941-1960 will be added in the coming months.

We encourage everyone to explore the site, discovering the full spectrum of technical, education, membership, academic and industry information. We will continue to expand and deliver the most updated information for the lubricating grease industry.

*continued on page 4…*
2018 Research Grant Recipient
University of Akron was announced as the 2018 Research Grant recipient for their impressive research proposal titled “A Fundamental Examination of Grease Thickener Self-Assembly.” The University of Akron's research will take place over a one-year period and conclude later this fall.

Inaugural NLGI Hands-On Training
NLGI will be offering a hands-on education course September 17-19, 2019 in Holtzville, NY. This three-day, hand-on training course provides an excellent overview of the types of greases, thickeners, base oils and additives. The methods of manufacturing, testing methodology and their use in bearings and in industrial and automotive applications will also be covered.

The class is taught in a participatory atmosphere, comprising a Lecture section and a hands-on Laboratory Practical section where participants perform the prescribed test methods using a variety of test instrumentation. Each day following the morning lecture section, participants will perform a selection of test methods discussed during the day using the required instrumentation. This hands-on approach will reinforce the topics and subject matter discussed during the lecture session to enhance learning and retaining knowledge.

For a specific schedule, registration information and hotel information, please visit https://www.nlgi.org/education/september-education-course/.

As I enter the second year of my Presidency, I reflect on an outstanding past year. As an organization, we accomplished a lot and I look forward to watching NLGI continue to evolve and grow. In March, the NLGI Board of Directors redefined our strategic goals. As a global organization focused on delivering top notch technical information and member value, I’m confident these redefined goals will help achieve growth for both NLGI and the grease industry. Strategic goals for 2019-2021 include:

- Membership growth, engagement, and global outreach
- Providing expanded educational opportunities
  - Effective governance and leadership for NLGI (Financial growth and health)
  - Communication of NLGI knowledge-based resources and certification (Spokesman, marketing NLGI value)
- Certification upgrade - implementation, engagement, marketing
- Enhancing opportunities for networking and discussion on emerging industry trends/applications (webinars, panel discussion, Spokesman, social media)

Additionally, I want to extend a thank you to our volunteers for all your efforts. We recognize that you have jobs in addition to everything you do for NLGI and I’m grateful for your dedication. We wouldn't be able to achieve our goals without incredible volunteer support. So THANK YOU!

And thanks again to all of those who attended this year's Annual Meeting. We look forward to seeing everyone next year in Miami.

Joe Kaperick Afton Chemical
NLGI President 2018-2020
Soltex is now the named distributor for Imerys natural and primary synthetic graphite in lubricant applications throughout the Americas!

Soltex SA
Manufacturer
Brazil

SantoLubes LLC
Supplier
USA

GEO Specialty Chemicals
Supplier
USA

Quatrinvest
Technical
Brazil

5th Order Industry
Technical
USA

Reprolon Texas
Supplier
USA

Lone Star Grease
Manufacturers
USA

S & S Chemical
Supplier
USA

Tulstar Products, Inc.
Supplier
USA
Total Lubrifiants is a major, internationally recognized player in the development, production, and marketing of a full range of high performance lubricating greases.

With over 90 years of field experience Total Lubrifiants offers a variety of innovative lubricating grease solutions tailored for demanding applications in all industry segments.

Total Lubrifiants, your preferred lubricating greases partner.

lubricants.total.com/business
Worldwide Student Poster Contest

Celebrating STLE’s 75th Anniversary

Four Age Categories
4-8  9-11  12-14  15-18

Winners in Each Category Receive Cash Prizes!

Contestants Should Submit a Poster Showing How

**Tribology***
Can Affect the Future World.

*The science and engineering of interacting surfaces in relative motion.

**Poster submission period**
July 1-Dec. 31, 2019

Contest information and entry form available at [www.stle.org](http://www.stle.org) on July 1.

**Questions?**
Contact Dr. Maureen Hunter:
[mhunter@kingindustries.com](mailto:mhunter@kingindustries.com)
A comparative study of high-pressure vs. low-pressure grease dispensing systems for applying rail curve grease

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Environmental Lubricants Manufacturing, Inc.
Grundy Center, IA 50638, USA

Abstract
This paper reports results from over a year of field test investigation of two grease dispensers on a short line railroad. Testing took place in the northern Iowa region that offers extremes of hot and cold temperatures. These conditions are suitable for investigation of the effectiveness of systems for applying grease at both temperature extremes.

Grease dispensing equipment, also called lubricators, is typically operated by batteries that are charged on location by solar collectors. A wheel sensor placed ahead of a lubricator senses the arrival of the train wheels and signals the battery-operated electric motor to run the pump to force the grease into the grease delivery bars attached to the inside of the gauge faces of the track.

In this study, two grease lubricators from two OEMs were placed in the middle of an S-shaped track curve. Each lubricator delivered grease to one of the tracks. Then, using a tribometer, engineers collected friction readings on the tracks at different distances from the lubricators in both directions. Additionally, the collected data included daily temperature readings, grease flow via an automated flow recorder, and other pertinent information.

The results of this study should be helpful to railroad friction management personnel, grease manufacturers, and grease lubricator designers and manufacturers.

Railway Curve Lubricants
Lubricants and friction modifiers for railroad tracks are available in several forms including grease, oil, water, and polymer-based mixtures. Solids such as graphite, molybdenum disulfide, solid stick lubricants, pastes, and sprays are also applied to the track or to the wheel flange via various applicators.

The established methods for lubricating railway tracks or wheel flanges include wayside, on-board, and high-rail lubrication methods.

In the wayside method, track lubricant or friction modifier, typically a grease, is applied to each wheel flange. The lubricated flange rubs the grease on the inside part of the track's profile known as the gauge face. This is where the track curves and wheel flanges exert lateral forces.

The high-rail method relies on a small truck with flanged wheels that drives on the portions of the track that need lubrication. The truck carries the grease in a reservoir and uses a pump to apply beads of grease to the gauge face of the track.

An on-board unit uses a pump and hoses to deliver the grease to a nozzle that applies a bead of grease to the gauge face of the track.

Figure 1 presents the basic components of a wayside lubricator. Wayside lubricators include a grease reservoir, a positive displacement pump operated by an electric motor that is triggered by a proximity sensor.
sensor, and a control system that modulates the duration of operation of the pump based on the number of wheels passing the proximity sensor. Hoses deliver the grease to the rail through wiper bars attached to the gauge face of the rail. Wheel flanges come in contact with grease on the gauge faces and carry it along the track curve and beyond.

- Wayside lubricator
- Trackside reservoir
- Battery, electric motor, and pump
- Solar Panel
- Wiper bars clamped to the inside rails

**Figure 1:** Basic components of a wayside grease dispenser (lubricator) and grease on gauge face

In principle, a rail curve grease seems simple because it is applied once and then is lost to the environment. But in practice, it requires a multitude of performance attributes that make it a complex product. While there are no internationally accepted standards for rail greases currently, desired attributes include the following:

1. High extreme pressure property
2. Adequate level of adhesion to wheel flanges and gauge faces of tracks
3. Adequate level of cohesiveness necessary for “carry” down the track and for preventing pump cavitation
4. Good cold temperature flowability in hoses and lines from the reservoir to the distribution bars
5. Adequate flowability within the reservoir for continued flow into the pump inlet at lower grease levels in the reservoir
6. Acceptable anti-rust and anti-corrosion properties
7. Desired level of conductivity so as to not interfere with electrical signals
8. High thin film strength for base oil
9. High viscosity index (VI) for base oil
10. High flash and fire points for base oil
11. Biodegradability so as to not accumulate in the ballast or layer of gravel on which the railroad ties are laid, which could render the tracks unstable.
Testing in an Environmental Chamber and Results
Before they were tested in the field, two OEM lubricators were first tested in an environmental chamber where the temperatures of the equipment and grease were changed from about 65 °C (149 °F) to -23 °C (-9.4 °F). The amount of grease pumped at various temperatures was documented. Figure 2 shows the two lubricators in the environmental chamber.

![Figure 2: The high-pressure Unit 1 (top right) and the low-pressure Unit 2 (top left) were tested in the environmental chamber (bottom).](image)

The two lubricators were tested in the environmental chamber to simulate the passing of 50 consecutive 25-car trains with 60 ft. (18.3 m) car centers running at 5 mph (8 kph). After each train passed, there was a 1 min delay before the next train arrived in the simulation.

a. Through experimentation with the simulation, it was determined that Unit 1 should be set to pump for 0.35 sec every 5 axles to output 0.3778 lb (0.1714 kg) of grease at 100 °F (30.5 °C) during the passage of one train. Unit 2 was set to pump for 3.5 sec on every axle to match the output of Unit 1. The settings on Unit 2 are such because a relay is used to simulate a wheel count every time the Unit 1 pump engages. It is also determined that these settings on the Unit 2 output 0.3908 lb (0.1773 kg) under the same conditions, above. The output for each lubricator was similar under the same conditions and close to a desirable 0.8 lb (0.4 kg) grease per 100 wheels. (One bar system should be half of that value.)

b. After each simulation, the environmental chamber was cooled to the next lower temperature and the grease allowed to acclimate to the new temperature for a minimum of 24 h. The same simulation was run at each temperature. Figure 3 shows the reservoir of each lubricator before the start of the test. The grease in each reservoir was leveled and the height of the grease in the tank was recorded. Figure 4 shows the grease dispensing bar from each manufacturer and the drum used to collect and determine the weight of the grease after each test.
In addition to determining the amount of grease pumped by each lubricator, other visual monitoring included observation of the shape of the grease in each reservoir and measurement of the level of the grease at the center and side wall of each reservoir. However, no distinguishable visual difference between the shape of greases in the reservoirs was observed.

Field Testing and Results
Two grease lubricators from two OEMs were placed in the middle of an S-shaped track curve where each fed grease to one of the tracks. Figure 5 shows the test set up at the Iowa Northern Railway test location. The two grease dispensers were placed next to each other, but the outlet hose from each one fed the grease to one track. The bi-directional traffic at the location allowed the grease to be carried in both directions. When the train travels around curves, the outside track (the high rail) and the inside track (low rail) are exposed to different loads and wear.
On an S-shaped curve, each track can be a high rail for the train going in one direction or a low rail when the train travels in the opposite direction. Figure 6 shows photos of the lubricators on location, on the left-hand side of the tracks facing north. Figure 7 presents the tribometer used for measuring the coefficient of friction at predetermined locations.

The main differences between the two lubricators are the pump and the means of distributing grease to the outlets of the lubricator bars.

In Unit 1, the high-pressure pump is a positive displacement mechanical shovel pump. The benefit of this pump design is that the mechanical shovel maintains a 98% prime of the pump when the grease gets stiff at cold temperatures.

In Unit 2, the low-pressure unit uses a gear pump, and priming of the pump can suffer when the grease is stiff at colder temperatures, thus reducing output.

Another difference is that the high-pressure Unit 1 uses positive displacement valves to evenly distribute grease at the lubrication bar outlets. The low-pressure Unit 2 used variable orifices to distribute the grease out of the lubrication bar. Lubricator bars were 1,400 mm (54 in) in length for both systems.
Figure 6: Test site facing north with the lubricators

Figure 7: Tribometer used for measuring the coefficient of friction
Over the test, 290,000 axles were counted. This location has a low travel rate. The direction of train travel was split evenly in the north and south directions.

The output from the low-pressure Unit 2 was applied to the far side (low rail) for trains travelling in the south direction, and the opposite (high rail) for trains going in the north direction. The output of the high-pressure Unit 1 was applied to the near side (high rail) for south-bound trains and on the low rail for north-bound trains.

The Data Measuring Technology - The On-Track Tribometer
The tribometer used in this study (Figure 7) operates based on stick slip mechanics and is different from the previous versions of tribometers, which were hand operated or truck mounted. This portable lightweight device obtains friction data by measuring lateral and vertical force values on a test wheel. The wheel is oriented from 1 to 3 degrees from the longitudinal path of the track to obtain lateral friction forces. The vertical friction force is obtained by applying force directly down on the test wheel.

The tribometer is fully self-contained, requiring only that the operator correctly sets the head with respect to the gauge corner of the candidate rail and locks the magnets that affix the beam to the top of the candidate rail. For safety, the beam can be grasped and quickly pulled off in case there are any approaching vehicles. Control is provided via a generic tablet with a Wi-Fi link and a standard browser.

The operator sets the head positions and the desired Hertzian forces for a given series of tests and touches the ‘Run’ button. Results are plotted on the tablet and document the location of measurement via GPS to a cell phone, notepad, or remote storage. A quick-release measuring wheel tread allows for easy removal and cleaning so that each new test location has a fresh surface condition on the measuring wheel. Figure 8 shows a close-up view of the measuring wheel.

![Figure 8: A close-up view of the tribometer’s measuring wheel at the measuring position](image)

According to Harrison (2015), “Determining the coefficient of friction ($\mu$) at the wheel/rail interface is a key diagnostic tool for optimizing the maintenance of freight and transit infrastructure, as well as improving the quality of analytical models used to predict vehicle performance.” Unlike some lubricants that are visible to the naked eye, solid friction management and lubricant products involve the deposition of a layer from 0.5 to 5 $\mu$m thick within the wheel-rail interface. At this thickness, it is impossible to visually confirm its presence. Hence, tribometers can be effective tools for objectively determining the presence of lubricant at the desired location on the rail.
Validation Testing of the On-Track Tribometer
Before field testing was performed, it was necessary to verify if the tribometer can measure L/V (lateral/vertical) friction data that can detect the presence of grease on a gauge face compared to a dry track (no lubricant). With test rails in the lab, 10 measurements were taken and recorded. Two rails were used, one smooth and one rough. Friction data were recorded for each rail in dry and lubricated states. The mean and standard deviation of the friction for each set of conditions were calculated with the following results:

<table>
<thead>
<tr>
<th></th>
<th>Mean</th>
<th>Standard Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dry smooth rail</td>
<td>0.261</td>
<td>0.009</td>
</tr>
<tr>
<td>Lubricated smooth rail</td>
<td>0.232</td>
<td>0.006</td>
</tr>
<tr>
<td>Dry rough rail clean</td>
<td>0.315</td>
<td>0.012</td>
</tr>
<tr>
<td>Lubricated rough rail</td>
<td>0.265</td>
<td>0.008</td>
</tr>
</tbody>
</table>

Table 1: The means and standard deviations of friction measurements in the lab

The results of the laboratory tests indicated that this tribometer can effectively detect the presence of lubrication on gauge faces.

Field Testing
The locations where the friction readings were taken are shown in Figure 9. Additionally, the collected data included daily temperature readings, grease flow via an automated flow recorder, and other pertinent information.

Figure 9: Example of markings on the track locations where friction was measured
Table 3 shows the axle counts throughout the test period. The axle counts represent the total axle count, which includes both directions. Approximately 50% of axle counts are in each direction.

A conventional mineral oil-based grease was used in both lubricators starting August 23, 2016. Then, the grease in both lubricators was changed to a biobased grease September 13, 2017. The grease was changed at the request of Iowa Northern Railway because the conventional grease was not being carried along the tracks to locations that were farthest from the applicators.

<table>
<thead>
<tr>
<th>Date</th>
<th>Axle Count</th>
</tr>
</thead>
<tbody>
<tr>
<td>8/23/2016</td>
<td>0</td>
</tr>
<tr>
<td>9/13/2016</td>
<td>15,000</td>
</tr>
<tr>
<td>10/19/2016</td>
<td>29,000</td>
</tr>
<tr>
<td>11/7/2016</td>
<td>53,000</td>
</tr>
<tr>
<td>2/16/2017</td>
<td>92,000</td>
</tr>
<tr>
<td>4/7/2017</td>
<td>115,000</td>
</tr>
<tr>
<td>5/31/2017</td>
<td>142,000</td>
</tr>
<tr>
<td>7/19/2017</td>
<td>174,000</td>
</tr>
<tr>
<td>9/13/2017*</td>
<td>205,518</td>
</tr>
<tr>
<td>10/26/2017</td>
<td>254,000</td>
</tr>
<tr>
<td>12/18/2017</td>
<td>290,000</td>
</tr>
</tbody>
</table>

* The grease was changed from a mineral oil-based to a biobased gauge-face formulation.

Figure 10 shows the friction coefficients as measured at the test locations for the high-pressure Unit 1 (top) and the low-pressure Unit 2 (bottom).

**Figure 10:** The friction coefficients as measured at the test locations for the high-pressure (top) and low-pressure (bottom) grease dispensers.
Figure 10 shows plots of the friction values recorded over the life of the testing. Each grouping of lines is a test location. From left to right, the south directions are S1, S2, and S3 with S3 being furthest from the lubricator. In the north direction, the locations are, from left to right, N1 to N6 with N6 being furthest from the lubricator.

Figure 9 shows an example of markings on the rail ties where friction measurements were taken on both tracks to determine the presence of grease. Generally, the friction readings were lower when the temperature was warmer, above 70 °F (21.1 °C). The charts in Figure 10 generally show this behavior.

Each test point in a group corresponds to the date the test was conducted. Eleven measurements were taken from July 2016 to December 2017. The date of each test is listed in Table 1. From September 2017, grease was changed to a biobased product. This grease tended to show better carry rate and carry over longer distances than the original grease, which was a mineral oil-based product.

It was observed that with a friction value below 0.25, there was some presence of grease on the gauge face. With friction below 0.20, there was a combination of smooth track often with some presence of grease. Readings above 0.30 were generally due to a dirty track or track with surface rail defects.

Grease carry was most noticeable on the high rail side. As shown in the lower graph in Figure 10, grease was present on the high rail (north side) out to N6, which was furthest from the lubricator. This indicated a better carry distance.

Figure 11 (below) shows the rate of grease carry on high and low rails. The general trend over the test was an average drop in friction on the gauge face of 14% on the low rail and 19% on the high rail.

Lower grease carry rates were observed below 30 °F (-1.1 °C), and higher grease carry rates above 70 °F (21.1 °C).

Grease yield stress was measured. A yield stress below 250 Pa is too thin for good carry as the grease drips off the lubricator bars. And a grease yield stress above 500 Pa is too stiff for the grease to adhere and be carried down the track. Figure 12 shows the temperature during the testing time.

<table>
<thead>
<tr>
<th>Effciency</th>
<th>on time</th>
<th>axles</th>
<th>Flow Rate per 1000 Axles (cubic inches)</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low</td>
<td>2</td>
<td>45</td>
<td>5.1</td>
<td>Lack of grease supply</td>
</tr>
<tr>
<td>Low</td>
<td>2</td>
<td>30</td>
<td>7.7</td>
<td>Lack of grease supply</td>
</tr>
<tr>
<td>Medium</td>
<td>2</td>
<td>15</td>
<td>15.5</td>
<td>Acceptable grease supply</td>
</tr>
<tr>
<td>Low</td>
<td>3</td>
<td>45</td>
<td>7.7</td>
<td>Lack of grease supply</td>
</tr>
<tr>
<td>Medium</td>
<td>3</td>
<td>30</td>
<td>11.5</td>
<td>Acceptable Grease Supply</td>
</tr>
<tr>
<td>Medium</td>
<td>3</td>
<td>15</td>
<td>23.3</td>
<td>Acceptable grease supply</td>
</tr>
<tr>
<td>Low</td>
<td>4</td>
<td>45</td>
<td>10.2</td>
<td>Lack of Grease Supply</td>
</tr>
<tr>
<td>Medium</td>
<td>4</td>
<td>30</td>
<td>15.3</td>
<td>Acceptable Grease Supply</td>
</tr>
<tr>
<td>High</td>
<td>4</td>
<td>15</td>
<td>31</td>
<td>Maximum Grease Supply</td>
</tr>
</tbody>
</table>

Table 2: Pump settings for optimal results. Higher than 4 sec on 15 axles caused grease run off from the lubricator bar.
Figure 11: Miles of coverage verses axle count

Figure 12: Output of each pump at different ambient temperature

Figure 13: Cumulative flow at measurement dates
Flow rate was consistent for the high-pressure Unit 1 over the temperature range. Flow settings increased in June of 2017. Output flow for low-pressure Unit 2 fluctuated over the temperature range with reduction in flow at colder temperatures.

**Temperature Effects**
During the cold months and lower temperatures during this study, the flowrate for the high-pressure Unit 1 stayed consistent. Whereas for the low-pressure Unit 2, the output flow fluctuated and presented noticeable reduction at low temperatures. Consequently, the grease coverage on the corresponding track was lower for Unit 2 in comparison to Unit 1.

**Ideal Grease Properties**
One of the most important properties of an effective rail grease is its adherence to the gauge face. Lubricant must stay on the gauge face in order to be carried along the track by the wheel flanges. It is crucial that grease not migrate from the gauge face to the top of the rail (the crown). If the grease migrates to the top of the track (due to overgreasing or inadequate formulation), then it could create problems with braking and wheel slippage going uphill.

For an appropriate level of adhesion, gauge face grease needs the right level of tackiness. Too much tackiness can cause the grease to remain on the applicator bars and not be carried by the wheel flanges. In other words, an effective rail grease must demonstrate a balance between adhesiveness and cohesiveness. This balance should be maintained within the operating temperature range of the grease.

In order to achieve the best grease performance during the course of this study, the grease was changed according to the seasonal temperatures so the operating temperature range of the rail grease was met. Therefore, at the beginning of each season, the lubricators’ reservoirs were emptied and the delivery lines were flushed. The lubricators’ reservoirs were filled with a rail grease that was rated for the season temperatures.

**Summary**
The results from this study showed that a high-pressure applicator performed better than a low-pressure applicator. The high-pressure applicator delivered grease more consistently over a wide temperature range, but especially at the extremely cold temperatures, in comparison to the low-pressure applicator. Total grease consumption of the two units was very close over the entire test period. Both lubricator systems used positive displacement pumps that were programmed properly to deliver the same amount of grease. At extreme cold temperatures, the high-pressure unit was better able to overcome the flow resistance of the grease. Hence it delivered a more consistent amount of lubricant at those temperatures than the low-pressure unit.

Grease was carried farther on the track treated with the high-pressure applicator than the low-pressure applicator, perhaps due to more continuous delivery at colder temperatures. This was detected on both north and south sides of the tracks.

**Reference**

**Acknowledgements**
The authors would like to thank Mr. Paul Conley, Chief Technologist - Lubrication Business Unit, SKF Industrial Market, Strategic Industries, for sponsorship and full support of this project. Additionally, the authors thank Mr. William Magee, Manager of Iowa Northern Railway, and his team for support in equipment installation and data collection throughout the project.
High Temperature Wheel Bearing Testing – an Electrifying Improvement
Barbara Carfolite and Autumn Chadwick
ExxonMobil Research and Engineering Technology Center
Clinton, NJ 08809 USA

Abstract
ASTM D3527 Standard Test Method for Life Performance of Automotive Wheel Bearing Grease has been in place since the 1970s. While several ASTM sponsored programs have been conducted over the past 30 years within ASTM Subcommittee D02.G0.05 Functional Tests - Temperature to address what has been identified as variability in results generated using this equipment across multiple laboratories, the method remains virtually unchanged from its original issue. This is currently the only high temperature dynamic test in ASTM D4950 Standard Classification and Specification for Automotive Service Greases developed by the National Lubricating Grease Institute (NLGI) for the assessment of greases. This article provides a new perspective on the impact of motor selection on the precision of the test, based on the experience of one laboratory.

Introduction
In the 1960s and 1970s, as automotive OEM’s (Original Equipment Manufacturers) started using higher speed roller bearings instead of ball bearings in combination with disc brakes, bearing operating temperatures increased and the industry needed a test to measure the high-temperature performance of lubricating grease used in these applications. Such a test was issued by the American Society for Test and Materials (ASTM) in the 1970s. This test method, ASTM D3527, Standard Test Method for Life Performance of Automotive Wheel Bearing Grease, uses a modified front wheel hub/spindle bearing assembly that is subjected to cycles of elevated temperature for an extended time period.1 ASTM D3527 was modified in 1985 to increase the severity and improve the test precision and accuracy. However, after several decades and numerous efforts to improve the precision and accuracy of this test by ASTM Subcommittee D02.G0.05 Functional Tests-Temperature, the method remains relatively unchanged.

An internal investigation was conducted by ExxonMobil Research and Engineering (EMRE) to evaluate means for improving the precision and accuracy of ASTM D3527. The findings are presented in this paper.

Background
ASTM D3527 was released over 40 years ago, and to this day, it remains one of the few, broadly available dynamic tests for measuring the high-temperature life of lubricating grease. However, due to the poor precision and accuracy of D3527, ASTM issued a ballot in 2017 to withdrawal this standard. The ballot was unsuccessful, mostly due to the fact that the test was included in several industry and military specifications. In addition, ASTM D4950 Standard Classification and Specification for Automotive Service Greases includes ASTM D3527 as one of the key tests for measuring the upper operating temperature limit of grease.2

However, the accuracy and precision of D3527 are limited.3 In addition, the D3527 method uses small tapered roller bearings that that are no longer used by the automotive industry. NLGI is evaluating alternative test options to replace D3527.
ASTM Subsection D02.G0.05 investigated several of the D3527 test parameters in an effort to improve the precision of the test:

- Cutoff sampling time
- Bearing torque load
- Chamber temperature control and insulation
- Alternate cutoff calculation
- Motor variability
- Bearing packing method variations
- Motor speed control

Despite the efforts of these investigations, D3527 precision and accuracy were still poor. This method remains unchanged.

**D3527 Method and Precision**

Below is a summary of D3527 test setup and operation:

- Two tapered roller bearings (LM67048-LM67010 inboard and LM11949-LM11910 outboard) are placed in a modified automotive wheel hub/spindle bearing assembly based on the 1970s Chevrolet Chevy II (renamed Nova) automobile.
- The inboard bearing is packed with 3 g of grease, and the outboard bearing is packed with 2 g of grease.
- The bearings are thrust loaded to 111 N, and the hub is rotated at 1,000 rpm.
- The assembly is operated through cycles of two conditions;
  - Rotation, 20 h, spindle maintained at 320 F ± 2.7 F (160 C ± 1.5 C)
  - No rotation, no heat, 4 h, spindle allowed to cool to room temperature
- The test ends when the electrical current driving the motor exceeds a cutoff value calculated on the basis of the steady state and the unloaded state of the motor.
- The accumulated on-cycle hours are recorded as the high-temperature life performance of the grease.

The precision of D3527 is defined in terms of Repeatability (r – measurements made with the same test rig and operator) and Reproducibility (R – measurements made with different test rigs and operators):

\[
  r = (0.8)x \quad (x = \text{average of 2 runs}) \\
  R = (1.2)x \quad (x=\text{average of 2 runs})
\]

Table 1 is an example of how to calculate the precision for this test. These data for three greases are available in Table X2.1 in the ASTM D3527 standard, and show that both the calculated Repeatability and Reproducibility can potentially exceed the measured total test hours, depending on the test outcome.

<table>
<thead>
<tr>
<th>Precision calculation example</th>
<th>Grease 1</th>
<th>Grease 2</th>
<th>Grease 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Result 1</td>
<td>80</td>
<td>40</td>
<td>20</td>
</tr>
<tr>
<td>Result 2</td>
<td>120</td>
<td>120</td>
<td>120</td>
</tr>
<tr>
<td>Average</td>
<td>100</td>
<td>80</td>
<td>70</td>
</tr>
<tr>
<td>Difference between results</td>
<td>40</td>
<td>80</td>
<td>100</td>
</tr>
<tr>
<td>Repeatability – r</td>
<td>x 0.8</td>
<td>80</td>
<td>64</td>
</tr>
<tr>
<td>Reproducibility – R</td>
<td>x 1.2</td>
<td>120</td>
<td>96</td>
</tr>
</tbody>
</table>

Table 1
Twice a year, ASTM conducts round robin testing to check the precision and accuracy of many of the grease tests listed in ASTM standards. Table 2 is a summary of the last ten round robins conducted on D3527. The test results generated in 2H15 showed a difference of 520 h between the lowest and highest results. Clearly, these results show that D3527 is out of control. ASTM Subsection D02.G0.05 ceased investigating means for improving the precision and accuracy of D3527.

Table 2

<table>
<thead>
<tr>
<th>Report Time</th>
<th># Participants</th>
<th>Result Range, h</th>
</tr>
</thead>
<tbody>
<tr>
<td>1H13</td>
<td>6</td>
<td>141 – 400</td>
</tr>
<tr>
<td>2H13</td>
<td>5</td>
<td>40 – 61</td>
</tr>
<tr>
<td>1H14</td>
<td>3</td>
<td>140 – 222</td>
</tr>
<tr>
<td>2H14</td>
<td>3</td>
<td>60 – 101</td>
</tr>
<tr>
<td>1H15</td>
<td>3</td>
<td>100 – 240</td>
</tr>
<tr>
<td>2H15</td>
<td>7</td>
<td>60 – 580</td>
</tr>
<tr>
<td>1H16</td>
<td>9</td>
<td>20 – 100</td>
</tr>
<tr>
<td>2H16</td>
<td>7</td>
<td>40 – 313</td>
</tr>
<tr>
<td>1H17</td>
<td>8</td>
<td>80 – 300</td>
</tr>
<tr>
<td>2H17</td>
<td>5</td>
<td>80 – 260</td>
</tr>
</tbody>
</table>

It was at this point that ExxonMobil Research and Engineering (EMRE) decided to take a closer look at improving the precision and accuracy of this test.

EMRE discovered that D3527 no longer reflected currently available equipment, as the originally specified motor was discontinued. ASTM Subsection D02.G0.05 is considering the development of a new test for measuring the high-temperature life of lubricating grease.

**Test Method Investigation**

EMRE decided to investigate the effects of temperature control and motor operation on the precision of D3527. ASTM Subcommittee D02.G0.05 previously investigated seven other test parameters (above).

The D3527 method states that a steady-state torque should be developed during the first 2 h of the test. But it was noticed that after 2 h, the target spindle temperature of 320 F (160 C) was not reached, and the torque continued to fluctuate. Extra insulation was installed in the test chamber box to enable a faster heat-up profile and steadier temperature control. However, as shown in Graph 1 (time-temperature heat-up profile), the extra insulation caused the spindle temperature to well exceed the test setpoint of 320¬ F (160 C) and fluctuate. Based on the inability to adequately control temperature, the extra insulation was removed from the chamber.
Next, EMRE focused on better control of the temperature through improved electronics. The use of computer control and upgraded software enabled the test temperature of 320°F (160°C) to be reached in under 2 h and maintained for the duration of the run cycle.

The next area of focus was the motor. The method states that the spindle drive motor is ¼-hp, 1,725 rpm, and 120 VDC. The initial ¼-hp motor received with the test rig has been discontinued by the manufacturer. This investigation compared replacement motors received from the original test rig manufacturer and off-the-shelf motors. Photo 1 illustrates the test rigs used for the motor investigation.
As stated in the method, when ASTM D3527 was developed, motor current (A) was used to measure the unloaded, loaded, and cutoff values. The motor cutoff value, or end-of-test value, was calculated as follows:

\[ C = 8(T-N) + N, \]

where:

- \( C \) = motor cutoff value, A
- \( T \) = loaded steady-state current, A
- \( N \) = unloaded motor current, A

Motor current is the key input into the calculation of the motor cutoff or end-of-test value. However, the test method does not specify the motor rating with regard to motor current capability. This is important, as the motor current can change based on the voltage of the motor:

\[
\text{Current} = \frac{\text{Power}}{\text{Voltage}}
\]

In addition, as the motor ages, it’s possible that the current will increase, thus causing the unloaded current to increase, which will lower the motor cutoff value.

Table 3 shows the power, speed, voltage and torque constant of the motors used for this investigation.

<table>
<thead>
<tr>
<th>Motor Type</th>
<th>Originally Supplied Motor (shown for reference)</th>
<th>Off Shelf Option 1 Motor (Used 2013-2017)</th>
<th>Off Shelf Option 2 Motor (Current)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Power (hp)</td>
<td>( \frac{1}{4} )</td>
<td>( \frac{1}{4} )</td>
<td>( \frac{1}{4} )</td>
</tr>
<tr>
<td>Speed (rpm)</td>
<td>1,725</td>
<td>1,750</td>
<td>2,500</td>
</tr>
<tr>
<td>Voltage (VDC)</td>
<td>115</td>
<td>90</td>
<td>130</td>
</tr>
<tr>
<td>Torque Constant (Kt)</td>
<td>91 (calculated)</td>
<td>70 (calculated)</td>
<td>60 (from motor data sheet)</td>
</tr>
</tbody>
</table>

Only Option 1 Motor and Option 2 Motor were used for the investigation, as the original motor supplied with the test rig was discontinued several years ago. The grease used for this investigation was the 2017 NLGI Reference Grease. The amount of motor current used to turn the spindle was measured at start-up and during the 2 h break-in period.

Graph 2 shows that Motor 1 required considerably more current than Motor 2 at start-up and during the 2 h break-in period. These differences were expected based on the voltage differences for these motors. Also, Motor 1 was in use for several years prior to this study, which could increase its current draw in this evaluation.
Since motor current is the key input for determining the cutoff value, the difference seen between the two motors has a significant impact on their cutoff values, as shown in Graph 2. Also, since torque is linearly proportional to motor current draw, operating at higher than rated torque can damage motor windings, leading to current fluctuations and decreased test accuracy.

The current values generated from the testing of the NLGI Reference Grease were then used to calculate torque values (Graphs 3 and 4) as follows:

\[ T \text{ (torque, Oz.In.)} = K_t \text{ (torque constant)} \times \text{Current (A)} \]

The estimated torque values show the linear relationship between motor current and torque. Although not clearly demonstrated in the motor current data shown in Graph 2 (due to scale limitations), Motor 2 did show fewer fluctuations during the 2 h break-in period. Graph 3 shows this more clearly when converted to torque values.

**Conclusions**
Addition of extra insulation in the test chamber did enable the chamber to reach the 320 F (160 C) test temperature in the required 2 h time limit for D3527. However, the temperature continued to increase and was difficult to control.

More efficient heat-up and improved temperature control were realized through the use of upgraded computer software and removal of the extra insulation from the test chamber.

Three motors meeting the ASTM hp and speed requirements for D3527, but with different voltages, gave different cutoff (end-of-test) results. The 90 VDC motor, which required more current to run than the 130 VDC motor, produced a much higher initial current spike and considerable current fluctuations during the 2 h break-in period.

Using torque, not current, to determine the cutoff value may be a more accurate means for determining the motor cutoff value and could improve the precision of the method.

**Acknowledgements**
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**References**
1 ASTM D3527-18, Standard Test Method for Life Performance of Automotive Wheel Bearing Grease
2 ASTM D4950-14 Standard Classification and Specification for Automotive Service Greases
4 ASTM Subsection D02.G0.05 Minutes – 1990 - Present
Initial Steps of Lithium Soap Grease Thickener Agglomeration

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Abstract
In lithium soap thickened greases, soap molecules form a fibrous network. This fundamental study investigated the arrangement of lithium 12-hydroxystearic acid molecules at the earliest stage of thickening in mineral oil. Experimental data suggested that an initial structure or arrangement of thickener molecules formed when about 4% soap thickener was dispersed in base oil. Rheological measurements showed that at this concentration, the mixture first exhibited viscoelastic properties with its solid-like storage modulus at about the same value as its liquid-like viscous modulus. This concentration was defined as the critical micelle concentration (CMC). Infrared analysis spectra were consistent with results from computer models that showed that the lowest energy arrangement for two lithium 12-hydroxystearic acid (Li-12HSA) molecules was a structure where the tails were opposite the head groups, due to a repulsion between the tail groups, and with the head groups in a planar arrangement.

Introduction: What do we know about grease?
The common understanding of how grease lubrication thickeners work is a “sponge” analogy. It is difficult to determine when this analogy started, but in 1951, Bondi et al. stated that the consistency of grease is due to the thin fibrous shapes of the soap particles forming a latticework that holds the oil by capillary action where the oil can easily flow into the small narrow spaces between the grease fibers.\(^1\) In 1954, Boner et al. reviewed the literature discussion about syneresis and bleed.\(^2\) Syneresis is the expulsion of liquid as the fibrous lattice structure collapses, and bleed is release of oil due to defects in the network. These terms (syneresis and bleed) are used interchangeably and are related to the effects of pressure on the lubricating grease; i.e., a sponge that can hold oil and release it under pressure. The fibrous structure of soap thickener in grease was known from the 1950s through electron micrographs produced by Brown, Huddson, and Loring.\(^3\)

Grease, as it is known today, is a three-dimensional network of thickener particles in oil. These thickener particles interact with each other and the oil, forming a matrix through physical forces. The pores of this network are filled with oil.

Recently, Saatchi et al. developed an oil bleed model that uses the grease thickener and its associated hydrodynamic volume; i.e., the volume of the thickener particles plus the oil bound with them, to calculate oil bleed amounts of grease.\(^4\) Saatchi et al. proposed a ‘point of structural opening’ in which the thickener particles, with their associated hydrodynamic volume, are spaced far enough apart to allow open channels and oil bleed. This model fit the data for oil bleed of lithium soap, polyurea, and calcium sulfonate thickened greases. It was particularly useful for predicting the increase in bleed for calcium sulfonate thickened grease. Figure 1 shows the ASTM D6184 data for bleed rate for greases as a function of percent oil in the grease.
Saatchi’s model depended on not only the size of the thickener particles but also their shape. Their measurements showed that lithium soap formed a fibrous structure (as was previously known), while polyurea thickeners formed plate-like structures, and calcium sulfonate formed spherical structures.

This paper builds on the work of Saatchi et al. to increase the fundamental knowledge of how grease thickener structures form. The findings in this paper shed light on how and why the thickener particles form into fibers. Further work will be extended to the formation of plates and spherical structures. Controlling the shape of the thickener particles may ultimately lead to methods that can control how the grease bleeds.

**Thickeners**

Grease is thickened using a number of different compounds, but generally these thickeners can be described as soap or non-soap. The soap thickeners can be simple, complex, or mixed. Soap is the metal salt of a fatty acid. The metal is usually from Group 1 (alkali metals lithium, sodium, etc.) or Group 2 (alkaline earth metals magnesium, calcium, etc.) of the periodic table. The fatty acid is a monocarboxylic acid that may contain carbon-carbon double bonds or -OH substituents and is typically from a plant and animal source. A simple soap results from the acid-base reaction of a single fatty acid and a metal hydroxide.

A complex soap results from the acid-base reaction of a single metal hydroxide with one fatty acid and a complexing agent. Complexing agents are fatty acids of different chain lengths, dicarboxylic acids, or other compounds. The addition of a complexing agent disrupts the crystallization of the soap particles, giving complex grease with higher operating temperatures than simple greases. Soap thickened grease is often referred to by the metal in the hydroxide used to make it, e.g., lithium grease for lithium metal soap thickened grease. Mixed soap grease combines soaps made from different metals to get the best properties from each of the metal soaps. Mixing lithium and calcium thickeners is a common practice. Non-soap thickeners are polymers like polyurea or polytetrafluoroethylene, inorganics like clay or silica, and others. Sulfonates as in calcium sulfonate thickener, are structurally similar to soaps in that they have a head and tail group.

![Figure 1](image-url) **Figure 1** Cone bleed versus percent of oil in grease for lithium complex (blue), polyurea (red), and calcium sulfonate (green) thickened greases. Structural opening refers to the point at which channels of flow open between previously isolated pores.
Soap and detergent molecules have a similar structure consisting of a polar ionic ‘head’ group and a non-polar hydrocarbon ‘tail’. This molecular structure allows these molecules to form ‘bridges’ between polar and non-polar phases. When the thickener concentration gets large enough, the soap molecules self-assemble into micelles; this concentration is known as the critical micelle concentration (CMC). Micelles are discrete particle-like structures as opposed to a three-dimensional fibrous network structure. Nagarajan defined a packing factor to describe the structure of micelles that self-assemble in an aqueous solution. In water, a polar solvent, the polar heads of the molecules are hydrophilic (compatible with water), and the nonpolar tails are hydrophobic (incompatible with water).

The packing factor was based on the length of the tail and the area of the head, assuming that the hydrophobic tails point towards each other and away from the polar water solvent. Packing factors predict spherical or cylindrical micelles, or even bilayer structures. Lubricating grease is a non-aqueous system, and the self-assembly of soap thickener molecules is not so straightforward because the hydrophobic tails face outward from the micelle to interact with the non-aqueous solvent. The self-assembled soap structure is described as a reverse or inverse micelle as shown in Figure 2.

![Figure 2](image.png)

**Figure 2** Stylized picture of an inverse or reverse micelle along with a 3D molecular model from a computer simulation.

Although micelles are pictured as spherical structures, there is a continuum of structures based on the concentrations of water, oil, and surfactant (soap). This continuum includes spherical, cylindrical, lamellar, bicontinuous, inverse, and other mixed structures. Because there is a continuum of shapes associated with thickeners in oil, what shape do the thickener particles actually have in greases? How do these shapes affect grease properties?

**Particle Shape Theory**

According to Saatchi et al., thickeners form cylindrical (fibrous), plate-like, or spherical structures in oil. How do these structures relate to grease bleed? As in the work by Saatchi et al., a thickener structure can be modeled as n independent spherical particles arranged in a simple cubic lattice and spaced a distance a apart. The particles have a radius of r with an associated hydrodynamic volume that increases the radius to r’. [ ] The oil held in this hydrodynamic volume moves, within the assumptions of this model, rigidly with the particles. Oil not associated with the hydrodynamic volume is free to flow. The parameters n, a, r, and r’ have not been set yet. The structure is given in Figure 3.
This model leads to three possible conditions:

- **Condition #1:** The particles with their associated hydrodynamic volume touch, and there are no connected pores for oil flow. See Figure 4.
- **Condition #2:** The particles move apart and some pores connect for limited oil flow. See Figure 5.
- **Condition #3:** The particles and the associated hydrodynamic volumes do not touch and there is free flow of oil in channels. See Figure 6.
Condition #1 is realized when \( \frac{a}{r'} < \sqrt{2} \) and when \( \frac{a}{r'} > 2\sqrt{3} \), and pores are isolated, see Figure 4. Jumping to Condition #3, the free flow of oil occurs when \( \frac{a}{r'} > 2 \), see Figure 6. The oil flow can then be described with the help of the Kozeny-Carman equation that describes an empirical relationship of fluid flow through a packed bed of solids:

\[
K = \frac{\varepsilon^3}{8(1 - \varepsilon)^2} D_p^2
\]

where \( K \) is the permeability, \( \varepsilon \) is the porosity and \( D_p \) is the sphere diameter.\(^7\)\(^,\)\(^8\) This porosity can then be used in Darcy’s equation to relate flow to pressure drop.

\[
q = -\frac{K}{\mu} \nabla p
\]

where \( q \) is the flux, \( \mu \) is the dynamic viscosity, and \( \nabla p \) is the pressure gradient.

In Condition #2, \( \sqrt{2} < \frac{a}{r'} < 2 \) and the particles with their associated hydrodynamic volumes are just touching. The isolated pores from Condition #1 become connected, and oil can flow, although it may be through a tortuous path. The permeability becomes:

\[
K = \frac{20\varepsilon^3 a^3}{(6\pi r(a - r') - 2\pi r'^2)\tau}
\]

where the variables are described above, and \( \tau \) is a factor related to the tortuosity or how twisted the paths are between solid particles.

For cylindrical particles such as the fibers found in lithium soap greases, the cylinders would have a radius of \( r \) and an effective radius with the associated hydrodynamic volume of \( r' \). Cylindrical shapes will also have a length, \( l \), and since \( l \) is very much larger than \( r' - r \) the associated hydrodynamic extension of \( l \) will be ignored. The Conditions now are given by:

\[
\text{Condition #1} \quad < \quad \text{Condition #2} \quad < \quad \text{Condition #3}
\]

\[
2(\sqrt{2} + 1) < \frac{a}{r'} < \frac{l}{r'}
\]

and the permeability is:

\[
K = \frac{\varepsilon^5}{20} r'^2
\]

The point of structural opening, or the point at which channels of flow open between previously isolated pores, is reached when \( a = l \).
The particle shape theory models how grease bleed is affected by the shape of the thickener particles.

The bleed properties of grease are important in the lubrication mechanism of rolling element bearings. This is particularly important in fretting; a damage mode caused by the inability of lubricant to re-enter a contact under small amplitude sliding motion. In Figure 7, plots of the bleed rate (ASTM D6184) of three greases versus bearing wear from a Fafnir test (ASTM D4170-16) show a relation between bleed and wear.9

![Figure 7](image_url)

**Figure 7** False brinelling wear versus bleed rate for three different greases in the Fafnir Friction Oxidation test. Results are for lithium complex (LiX, red), calcium sulfonate (CS, green) and polyurea (PU, blue) thickened greases.

The bleed of oil is important in grease applications, but can the bleed be controlled? How thickener particles self-assemble into spheres, fibers, or plates is not well known. Developing a model of the self-assembly of thickener particles requires knowing first, the concentration of the thickener at which the self-assembled particles form, the CMC, and second, the energetics of the thickener particle interactions. Once the CMC is found, can the mechanism for self-assembly be found based on the energy of interaction? Is there a way to verify the structure?

**Methods**

Grease was manufactured in an open kettle. ISO VG 68 mineral base oil with rust and oxidation inhibitors was heated to 200 °F (93 °C) in a mixing bowl and continuously stirred. 12-hydroxystearic acid (12HSA) was added to the oil and melted. The temperature was increased to 250 °F (119 °C), and a slurry of LiOH in water was slowly added. The mixture was left to react and was considered completely reacted when all of the water was removed, as indicated by the absence of bubbles and by performing Karl Fisher titrations. The mixture was cooled slowly to room temperature. The grease formed as the mixture cooled. The amounts of 12HSA and LiOH were measured to give the required percentage of soap in the final grease. This mixture was used as made or diluted to control the final thickener concentration.

Rheological measurements were performed on a TA Instruments AR-G2 cone on plate rheometer. The cone was 40 mm in diameter with a 2° cone angle. The cone rotated against an aluminum plate that was temperature controlled using a Peltier system. An oscillating procedure was used, an appropriate choice for viscoelastic materials such as greases. The oscillating procedure was used to measure the storage, G', and loss, G'', moduli as functions of applied stress. The storage modulus is the solid-like response and in-phase with the driving signal. The loss modulus is the viscous response and out-of-phase with the driving signal. When the storage and loss moduli cross, the nature of the material changes from either a solid-like to viscous or a viscous to solid-like material when plotted against the applied stress.
Computer models and calculations were used to study the behavior of individual thickener molecules. Computations of the interaction energies between lithium carboxylate groups were carried out using the Gaussian 03W program. Density Functional Theory (DFT) was used with a Becke, three parameter, Lee-Yang-Parr exchange correlation functional at the unrestricted level (UB3LYP). The basis sets are Pople’s 6-31+G(d,p) for the first two row elements and LANL2DZ for transition metals along with the corresponding LANL2DZ effective core potential. The goal for the calculations was to survey the energy surface to determine possible structures so the basis sets were not optimized for the structures. Binding energy, the energy needed to make or break a bond, was calculated as the difference in energy between the energy of a full structure and the energies of its component parts.

Infrared spectra were obtained with a Thermo-Scientific Nicolet 8700 FTIR. Samples were irradiated in the main compartment. Both the mid and far IR ranges were scanned, covering from about 100 to 4000 cm⁻¹. A KBr beam splitter was used for the mid IR range, and a solid substrate beam splitter was used for the far IR range. The samples were placed between KBr salt plates with a 0.1 mm spacer to give quantitative results.

**Rheological Results**
An oscillating stress sweep experiment ranged in stress from 10 to 8000 Pa at 40 °C, with 1 Hz oscillation. The measured values were the storage modulus, G', or the solid-like portion of the viscoelastic response, and the loss modulus, G'', or the liquid-like portion of the viscoelastic response. A typical curve is shown in Figure 8. Measured values of interest were the moduli (G' and G'') in the plateau region, the stress at the onset point where the linear range ended, and the stress at the flow point. At the flow point, the loss modulus, G'', exceeded the storage modulus, G', and the response of the material changed from solid-like to liquid-like. Values of stress in the plateau region will be used in subsequent rheological testing that requires the material to be in the linear viscoelastic region.

![Figure 8](image)

**Figure 8** Typical modulus data from a cone on plate oscillating stress sweep measurement for a grease, G' (red) is the elastic modulus and G'' (blue) is the viscous modulus.
The measurements on the grease samples were focused on the plateau region and the relative positions of the G’ and G” traces as the concentration of thickener was changed. For a fully formed grease, the G’ trace was above the G” trace, which indicated that the material acted solid-like. Performing the same analysis on the base oil was difficult, since the base oil was a Newtonian fluid and not viscoelastic. The result was a single G” trace, and low stress indicated a viscous material. These are shown in Figure 9.

Figure 9 Oscillating stress sweep results for the fully formed grease and base oil at 40 C for comparison.

The grease was diluted to 2, 4, and 5% concentrations of soap in oil for rheological testing. The measurements are shown in Figure 10. The 4% concentration showed G’ and G” with nearly equal values. With a little more soap, 5%, G’ > G” indicated a solid-like material. With a little less soap, 2%, showed G’ < G” indicating a viscous material. These results showed that the CMC was 4% soap in oil.

Figure 10 Oscillating stress sweep of the grease diluted to concentrations around the critical micelle concentration. Data are shown for 2 (red), 4 (blue), and 5% (green) Li-12HSA thickened in mineral oil at 40 C.
Calculation Results
The geometry of a Li-12HSA molecule was optimized to give the lowest energy, see Figure 11. Charges on the atoms were calculated using the Merz-Singh-Kollman (MK) scheme. The MK scheme gives charges that better fit the electrostatic potential. The binding energy of 12HSA$^+$ to Li$^{+1}$ was 8.2 eV. The energy stored in the CO$_2$Li atoms by electrostatic charges was calculated to be -12.15 eV. Of this, about 6 eV of electrostatic energy was in the binding of the Li atom to the COO group.

An additional Li-12HSA molecule was added to the one calculated above to make a system of two Li-12HSA molecules. The geometry of the two molecules was optimized to give the lowest energy as above, and the charges were calculated on this geometry as shown in Figure 12. In the arrangement of two molecules with the lowest energy, the axes of the hydrocarbon tails were skewed but seemed to remain linear. The Li on the top molecule sat among 3 O atoms. The Li on the bottom molecule seemed to be in a position to interact with a third molecule, placing it in the center of three O atoms. The O-Li-O-Li chain seemed to form a circle in 3D space related to the size of the initial aggregate. Calculating the radius gave about 3.6 Å (3.6 x 10$^{-10}$ m). The binding energy of the top Li atom to the complex was 9.9 eV. The energy of the top Li atom in this system of COO-LiCOO was about 5.7 eV and attractive. The binding energy of the top Li-12HSA to the bottom Li-12HSA was 1.3 eV.
In the optimizations performed above, the tail sections were positioned on the same side of the head groups. This increased the interaction between the tails. The tail-tail interaction had both an attractive and a repulsive component. The tails could also be positioned opposite from the head groups as in Figure 13. The calculated results gave a binding energy for the top Li atom to the complex that was 8.5 eV. The energy of the top Li atom in this system of COO-LiCOO was about 6.0 eV and attractive. The binding energy of the top Li-12HSA to the bottom Li-12HSA was 2.2 eV. In this configuration, the Li and O atoms were planar. The molecules could be arranged so that the Li and O atoms were not coplanar as in Figure 14. The binding energy of this configuration was -3.6 eV, indicating an unstable structure requiring energy to form.

![Figure 13](image13.png)

**Figure 13** Geometry and charges for two Li-12HSA molecules with their tails aligned opposite from their head groups, from computer models and calculations.

![Figure 14](image14.png)

**Figure 14** Geometry and charges for two Li-12HSA molecules arranged with non-coplanar head groups, from computer models and calculations.

Figure 15 plots the energy of the system as a function of the configuration. As the tail was rotated from the optimized structure (where they were on the same side of the head group) to the linear planar structure (with the tails opposite the head groups), there was a jump in energy. The energy stabilized (becomes lower) as the tails separated. This indicated that the tail-tail interaction was repulsive. These interactions occur in all micelle forming molecules with an attractive end (ionic head) and a repulsive end (hydrocarbon tail) and give rise to the various shapes of micelles.
Figure 15 Energy along the y-axis plotted as a function of geometry for two Li-12HSA molecules with their tail groups rotating around their head groups. Energy is in units eV.

Infrared Spectroscopy Results

The configurations calculated above showed another arrangement of the Li and O atoms where the Li and O atoms could form a staggered formation with a -Li-O-Li-O- configuration. Or, they could form a planar structure with two Li atoms surrounded by four O atoms. It may be possible to resolve the structural issue using infrared analysis.

Figure 16 shows the calculated infrared spectra from about 400 to 800 cm\(^{-1}\). The molecules used in the calculation were Li acetate instead of Li-12HSA. The calculations were performed with tails consisting of only two carbon atoms instead of the 18 in stearic acid to reduce the computation time and to simplify the calculated infrared structure. There were 3N-6 infrared modes of vibration, so this simplification removed about 96 infrared modes that would mainly have been in the C-H and C-C region. The hydrocarbon chains had a 720 cm\(^{-1}\) peak in this region, which was an overtone band of the C-H bonding. The images show the vibrations that correspond to the largest peaks in the spectra and have a large Li component to the vibration.

Figure 16 Calculated infrared vibration spectra and associated vibration modes for the peaks indicated. These calculations are for two Li-acetate molecules.
The spectra of 4% Li-12HSA in ISO 150 and neat ISO 150 oil were measured, overlaid, and shown in Figure 17. The spectra were obtained at 1 cm$^{-1}$ resolution from 400 to 800 cm$^{-1}$. The peak at 720 cm$^{-1}$ was due to the C-C vibration along with CH$_2$ and CH$_3$ overtone vibrations in the hydrocarbon oil. The peak at 667 cm$^{-1}$ was due to the CO$_2$ bending vibration. There was virtually no difference between the experimental spectrum for the grease and the calculated spectrum for two molecules, which suggested that the initial structure in the grease was the linear planar interaction (or arrangement) and the 720 cm$^{-1}$ peak, as calculated above, was buried in the hydrocarbon peak.

![Infrared vibrations - observed](image)

**Figure 17** Experimental IR spectrum for grease thickened with 4% Li-12HSA overlaid with the base oil spectrum.

**Conclusions**

- A Li-12HSA soap thickened grease began to show viscoelastic properties at about 4% soap concentration in ISO VG 68 mineral oil.
  - At this concentration, the solid-like or storage modulus was about the same as the viscous or loss modulus.
  - This 4% concentration was defined as the critical micelle concentration for Li-12HSA in this mineral oil.
- Interactions of two Li-12HSA molecules in several different arrangements were compared using computer models.
  - In the most stable structure (lowest energy), the Li and O atoms were in a planar structure, and the tails of the molecules were on opposite sides of the head groups.
  - This stable structure was supported by infrared analysis.
  - The tails had a repulsive interaction of about 0.9 eV, which was in the range of Van der Waals forces.
References


Density Functional Theory

Density functional theory or DFT is a method of computing the energy of a molecular structure. It is an *ab-initio* method in that the only information needed is the coordinates and types of the atoms in the molecule. The energy is calculated by solving Schrödinger’s equation:

$$H\psi = E\psi$$

where $H$ is the Hamiltonian operator and $E$ are the energy eigenvalues. $\psi$ is a wavefunction describing the positions of the electrons in the molecule. There are two main methods of solving this equation: choose a model wavefunction (molecular orbital theory) or choose the electron density (density functional theory).

But what does the term “functional” mean? Normally we think of a function as an operation that maps one number to another; i.e. $f(x) = y$. A functional maps a set of functions to a number; i.e. $\{f(x)\} \rightarrow R$. This is essentially a function of functions.

The Hamiltonian operator is simply the potential and kinetic energy operator of the electrons and nuclei of the molecule but it is the interactions of all of the particles that complicate the form. Mathematically the Hamiltonian is given by:

$$H = T_e + T_n + V_{e-e} + V_{n-n} + V_{e-n}$$

where the $T$ are the kinetic energy operators of the electrons and nuclei, respectively. $V$ are the potential energy operators of the electron–electron interactions, the nucleus–nucleus interactions, and the electron–nucleus interactions.

When constructing the Hamiltonian using the Born-Oppenheimer approximation keeps the atomic nuclei stationary so $T_n$ is zero and $V_{n-n}$ is constant. $V_{e-n}$ can be considered as an external field of the nucleus charge acting on the electron. What is left, $T_e + V_{e-e}$ is approximated in the various DFT methods. The approximations are given by functions of the electron density, $\rho(\vec{x})$.

In DFT, functionals are chosen that fit calculated energies of a test set of molecules with known energies. Density functional theory uses functionals of electron density to approximate the two-electron interaction when constructing Schrödinger’s equation. Wavefunctions comprised of a linear combination of basis sets are used to solve Schrödinger’s equation based on the Kohn-Sham method to calculate the energy of a molecule given the coordinates of and types of atoms.

The most popular functional is designated the B3LYP functional and is popular because it gives good energy calculations in a reasonable computational time. B3LYP combines a correlation functional with an exchange functional. The B3 is a 3
Regarding the selection and usage of Food Safe Lubricants

Q&A and making the right choices for food grade lubricants

In 1965 Kohn and Sham suggested an implementation of DFT to compute the energies. Their method was similar to the wavefunction method and relied on a linear combination of basis sets

$$\psi_j(\vec{r}) = \sum_a c_{j,a} f_a(\vec{r})$$

and a diagonalization of a matrix composed of the Hamiltonian and energy operators acting on the basis sets. Because the wavefunction method requires the calculation of electron-electron interactions but the DFT method accounts for this with the density functional so the electron-electron interactions do not need to be calculated, it is very much simpler.

For this project, a set of Gaussian type orbitals (GTO) were used as the basis set and designated as 6-31++G(d,p). This shorthand notation indicates that the orbitals on a heavy atom (anything heavier than H) is composed of a group of 6 GTOs for the S orbital, two groups of 3 GTOs and 1 GTO for the SP orbitals. The ++ adds additional P and D GTOs to polarize the orbitals. The (d,p) adds additional D and P GTOs to create larger orbitals that diffuse the electron density. These additions are used to increase the accuracy of the calculated energy.
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Let the Games Begin: New trends in industrial grease lubrication
Quimica Liposoluble, S.A. de C.V.
A brief summary of ELGI ’s Olympic Performance Meeting in Athens
Dr. Raj Shah - Koehler Instrument Company, Inc.- Holtsville, NY, 11742 US
Dr. Mary Moon - Technical Editor, The NLGI Spokesman - Yardley, PA 19067 US
Dr. George S. Dodos - Eldon’s S.A. - 14343 Athens, GR
June 4, 2019

The European Lubricating Grease Institute held its 31st Annual General Meeting in Athens, Greece (April 13-16, 2019). The AGM site at the Divani Caravel Hotel was located only several blocks from the National Gallery and the National Garden and a 10-minute drive from the historic Acropolis Temple and Museum that overlook the city of Athens. On the evening before the AGM, a formal welcoming reception was held on the rooftop terrace of the venue hotel. This reception gave all attendees the chance to socialize, talk with new and old friends, and enjoy the stunning view of the Acropolis.

Opening Ceremony
ELGI Chairman Terry Dicken, (Global Lubricants Ltd., UK) opened the AGM by welcoming a record-breaking 384 delegates from 32 nations who represented 180 organizations. Dicken reported that ELGI membership is stable with 150 members and a sound financial position operating within budget. He described ELGI as ‘progressive and expanding its scope’ by supporting joint ELGI-NLGI working groups to address topics relevant to the grease industry, establishing an industry-wide consortium for REACH registration of grease thickeners, and regularly publishing a digital technical journal, Eurogrease.

Andreas Adam (Fragol AG, DE), ELGI treasurer, provided a brief but clear review of the audit of the Institute's financial records. Constantin Madius (Axel Johnson International AB, SE), ELGI Technical Coordinator, discussed the significant work that is taking place within the Working Groups and presaged the possible revival of the Environmental WG, which has been inactive for several years. Each Chairman enlightened the audience about the progress and the outlook of their respective WG. Then, Joe Kaperick (Afton Chemical Corporation, US), NLGI Chairman, Sachdeva Siddharth (Siddharth Petro Products, IN), on behalf of the NLGI-India Chapter,
and Ray Zhang (Vanderbilt Chemicals, LLC, US), on behalf of the Chinese Lubricating Grease Institute, each delivered an update on the activities of their corresponding affiliated Institute. Kaperick gave a report on the Grease Production Survey and shared insights on global lubricating grease statistics per base oil and thickener types and grease market shares per region. The Opening Session ended with the keynote speech by Aris Gorogias (The Hellenic Association of Chemical Industries, GR), who gave facts and figures on the current situation and an auspicious forecast of the Greek Chemical Sector, underscoring energy efficiency challenges. Greece being the birthplace of the Olympic Games, the AGM theme was ‘Olympic Performance’ of lubricating greases. The program of 15 technical papers focused on advances in industrial lubrication, grease performance, additive technology, environmentally advantaged (friendly) greases, and energy efficiency. Topics related to base oil technology, new test methods, and the reduction of grease carbon dioxide footprint via process optimization were also presented. This three-day AGM included 15 technical papers, 5 Working Group Sessions, and a plant tour.

**ELGI Best Paper Award**

The BPA Committee evaluated 15 papers and presentations on the basis of content, quality of the presentation, embodiment of the spirit of originality and technical innovations, and uniqueness (not presented elsewhere before this Meeting).

ELGI’s Committee unanimously selected the paper and presentation, *Grease Production, CO₂ Emission… a New Relationship!*, as the 2019 BPA winner. This paper was presented by Andreas Dodos (Eldon’s S.A., GR) and coauthored with George Dodos (Eldon’s), Mehdi Fathi-Najafi (Nynas AB, SE), and John Kay (STRATCO, Inc., US).

Dodos told his audience that manufacturing conventional lithium grease is a very energy intensive operation and, surprisingly, little work has been done to study the energy consumption and possible environmental impact of grease production. Energy efficiency of grease manufacturing deserves careful study because carbon dioxide emissions from electric power generation and other activities have been shown to be a major contributor to greenhouse gas emissions and global warming.

The goal of this paper was to measure the energy consumption of industrial scale production of conventional NLGI grade 2 lithium grease and compare the use of a pressurized reactor versus a traditional open kettle reactor. This study also compared naphthenic and Group I paraffinic base oils at two viscosity grades (ISO VG 100 and 220) that are used typically in multipurpose lithium greases for industrial applications. All other process parameters were kept constant throughout the study.

The Authors recorded the total energy - electrical for mechanical operations such as pumping, mixing and homogenizing, as well as fuel for heating - consumed for the entire production process, from vessel charging, cooking, cooling, and diluting to homogenizing. They converted the energy consumption to normalized CO₂ emissions per metric ton of lithium grease made with a blend of ISO VG 220 naphthenic and Group I base oil blends in a pressurized reactor versus nominally identical grease made with paraffinic oil in an open kettle.

Dodos reported an overall 21.5% reduction in CO₂ emissions per metric ton of lithium grease made with a blend of ISO VG 220 naphthenic and Group I base oil blends in a pressurized reactor versus nominally identical grease made with paraffinic oil in an open kettle.

He explained that the lithium thickener was more efficient in the naphthenic oil (more product obtained per unit of energy), and the pressurized reactor used approximately one-third less energy than the open kettle (differences in loss of heat and length of time for processing and mixing).

Dodos concluded that this study could be a milestone in assessing grease production in terms of significant reduction of CO₂ emissions and increased awareness.
of the impact of the grease industry on the global environment.

Dodos told The Spokesman, ‘We are delighted to receive this award. It was a great honor and we were very gratified. For this work, it was all about the teamwork. We managed to bring together experts from three different sectors in the industry (equipment supplier, base oil supplier, and manufacturer) and the outcome, judging from the feedback of the industry, was extraordinary.’

The Authors talked with The Spokesman about the motivation for their work. They gave credit to Fathi-Najafi’s concept of reducing carbon emissions through cost-saving production adjustments. Another motivation was to build upon interesting findings from their lab-scale study, conducted by Mehdi Fathi-Najafi and John Kay and presented at the 2018 NLGI Annual Meeting, and move forward to an industrial-scale investigation. Andreas Dodos added, ‘For Eldon’s, this type of work was pretty much in line within the vision of the Company, namely focusing on the total grease-making operation and not only on the environmental impact of the products.’

Andreas Dodos explained. ‘Moving testing from pilot scale to full scale was not easy. This required a significant amount of resources and a six-figure budget for the project. Also, being able to fit the test batches into the production schedule was not always easy.’ Kay and Fathi-Najafi added, ‘However, from a technical point of view, predicting soap content adjustment between cases and isolating/measuring energy for each case were the greatest challenges we faced.’

Andreas and George Dodos agreed, ‘Overall, our greatest challenge is to move away from the ‘if it works don’t fix it’ mentality of the grease industry as a whole. We were very surprised by how much difference we found between the test batches and how inefficient the standard industry practice for grease manufacturing is compared to the alternatives we explored.’

What about the future impact of their work? Andreas Dodos noted, ‘Our Company has been involved in three papers that have won the best paper award in the last 6 years. One has led to the introduction of a new ASTM test method for grease. Now, we are hoping that this work will have an impact on how grease manufacturing is evaluated throughout the industry.’

Railroad Track Grease

Lou A. Honary and Saeed Zaher-Soleimani (Environmental Lubricants Manufacturing, Inc., US) presented a comparative study of high-pressure vs. low-pressure dispensing systems for applying rail curve greases. Honary reported results from a yearlong field test on a shortline railroad in northern Iowa where extreme temperatures challenge the effectiveness of grease dispensers.

Grease dispensing equipment, also called lubricators, are operated by batteries that are charged by solar collectors. A sensor placed ahead of the lubricators detects the arrival of train wheels and signals the motor to pump grease into delivery bars and onto the tracks.

In this study, lubricators from two OEM’s were tested on opposite S-shaped tracks, one for northbound and one for southbound traffic. The high-pressure lubricator had a positive displacement mechanical shovel pump, while the low-pressure lubricator had a gear pump. Engineers used a tribometer to collect friction readings and detect grease on the tracks at different distances from the lubricators. They also measured temperature, grease flow, and other pertinent information.

Honary reported that the high-pressure applicator performed better, especially at extremely cold temperatures, in comparison to the low-pressure applicator in terms of delivering the lubricant more consistently within a wide range of temperatures. Grease was carried farther on the track with the high-pressure applicator.

Ester Base Oils for Grease

George Dodos (Eldon’s), Paul Bonner, and Kevin Duncan (both Croda International, UK) discussed their results for the effects of different bio-based and biodegradable ester base oils on lubricating grease performance. Due to increased awareness and sustainability initiatives within organizations, bio-based lubricants...
are now viewed as a high growth area and have attracted a substantial amount of R&D spending from established suppliers as well as start-ups.

In this study, they investigated the use of four types of renewable (bio-based) esters as base oils for the production of calcium- and lithium-based lubricating greases. They focused on how the esters’ properties changed as they went through the soap grease-making process. The Authors specifically evaluated the oxidative and hydrolytic of the esters to determine their ability to withstand the production processes and to compare the performance of the final formulated greases. Greases were prepared on a basis of a constant soap content.

They reported that all four esters were capable of producing robust base grease formulations that could be further improved with additives. Only one of the eight base greases (combination of lithium thickener and an unsaturated ester) had unusual properties (relatively high consistency and low dropping point).

While a variety of esters can be used to manufacture greases that satisfy requirements for stability, low temperature properties, etc., it can be advantageous to use an ester that is optimized. Lithium- and calcium-thickened greases made with ester D, a special saturated branched ester, had better oxidative stability and higher yields than other greases in this study. Furthermore, results showed the advantage of using a specific ester with the correct viscosity grade (as opposed to blends) to make grease.
Measuring Grease Tackiness
Erik Willett (Functional Products Inc., US), Emmanuel Georgiou (Falex Tribology N.V., BE), and Andreas Dodos (Eldon's) presented data from objective measurements of grease tackiness. According to these Authors, high molecular weight polymers (tackifiers) are added to improve adhesion and cohesion of greases, referred to as ‘tack’ or ‘tackiness’. Adhesion between lubricants and metal surfaces keeps the product in place, and cohesion prevents fling-off from high speed gears. Wire-rope and open gear lubricants are two of the most common applications for tackifiers. Until recently, qualitative, subjective methods such as the ‘two-finger test’ were the only means available to measure grease tackiness.

In this study, an automated Tackiness Adhesion Analyzer (Falex Corp., US) was used to evaluate several tackifier chemistries at various concentrations in calcium sulfonate grease. The TAA operates on the principle of an atomic force microscope, but on a much larger, macroscopic scale. It measures the forces to gradually push a probe into a film of grease on a solid substrate, and then pull the probe back (in the opposite direction) and form ‘threads’ of grease that stretch and eventually break.

Georgiou reported that the TAA demonstrated the ability to discern between a wide array of different polymers and their contribution to thread formation in tacky calcium sulfonate grease. The instrument’s high sensitivity captured many physical measurements while pulling small threads of tacky grease: thread length, pull-off force, compression energy, and separation energy. The study found that thread length and separation energy correlated well with observed tack, but simple pull-off force alone was not adequate to describe the tackiness. Such a method would be useful in formulation and QC of greases where the level of tack integral to different industrial applications.

Wind Turbine Grease
Gareth Fish (The Lubrizol Corp., US) told his audience that with the increasing use of wind turbines for renewable energy generation, there is a need to further improve greases and open gear lubricants for this application. Grease-lubricated WT components include main bearings that support the rotor assembly, electric motors in some pitch and yaw control systems, and shaft bearings on generators.

Fish explained that grease formulations for WT applications must provide protection against micropitting, fretting, and corrosive wear. He discussed issues with developing greases to meet WT specification requirements of friction, low wear, fretting, and corrosion. He also reported on how to formulate bearing greases to pass both standard tests and the Riffel (or Ripple) test, a relatively new test for false brinelling and corrosion.

The Riffel test utilizes a large angular contact bearing, under a high oscillatory thrust loading with no rotation and salt solution pumped through the bearing. At the end of the test, the amount of wear is measured, and the visible corrosion is rated.

First, Fish carried out exploratory work to better understand specifications and test methods for WT bearing greases. He learned that it is necessary to adjust a grease formulation to balance fretting wear, salt water rust resistance, and false Brinelling.

Second, Fish developed fully synthetic lithium complex greases that passed all the basic industry specified requirements for pitch and yaw bearings and, potentially, main bearings. One formulation used low viscosity PAO base oil to solubilize a water-resistant polymer, and the other used an alkylated naphthalene base oil.

A commercial-scale batch of WT grease was manufactured, and it passed all requirements. This grease is now in a field trial to validate its performance under actual service conditions.

Pre-formed Polyurea Grease Thickener
Liwen Wei (Novitas Chem Solutions, US) presented a paper detailing the chemistry and use of a novel thickener for polyurea greases. Wei reminded the audience that polyurea greases are one of the best substitutes for lithium greases, but challenges of handling isocyanate and amine raw materials have discouraged manufacturers. He proposed a new method to make polyurea greases using pre-formed polyurea grease thickener (PUGT) and conventional processing techniques.
Wei disclosed a novel type of PUGT with markedly improved consistency and thickening efficiency over prior pre-formed polyurea chemistries. As little as 6% of this PUGT can be used to make NLGI grade 2 greases. The process is carried out by heating and mixing PUGT powder with a variety of base oils without toxic isocyanates and hazardous amines.

A proprietary, patent pending method was used to make a series of PUGT’s from a variety of primary and secondary amines and alcohols. Each PUGT is ‘tuned’ for manufacturing grease with a specific consistency. Wei claimed that these PUGT’s are odorless, colorless fine powders, and they can be used to form pre-mixes in fluids.

Wei explained a two-step process for using PUGT’s to make grease. First, PUGT is mixed thoroughly with base oil and additives to obtain maximum thickening. Second, additional base oil is added to obtain the desired consistency. Milling is important in both steps.

Choice of base oil in the first stage is particularly important to obtain good gelling and thickening efficiency and yield. Wei recommended AN (alkylated naphthalene), AB (alkyl benzene), and PAG (polyalkylene glycol) base oils for best thickening efficiencies, yields, and milling characteristics. He cautioned that insufficient process conditions and improper PUGT dosage in the first stage would lead to much more milling and lower grease yields in the second stage.

Finally, Wei showed data for mechanical stability (change in cone penetration after working 50 strokes) and high temperature stability (ASTM D1831) for four NLGI grade 2 greases, one grease made with PUGT powder, and three commercial products made ‘from scratch’, i.e., from isocyanates and amines reacted in situ to synthesize polyurea thickener during grease making. Wei concluded that the performance of his PUGT-thickened grease was superior to one of the commercial polyurea greases and comparable to the other two products.

According to Wei, this PUGT technology offers ‘a quantum leap forward’ in the manufacturing of polyurea grease.

**mPAO Advantages for Greases**

Paul A. Bessette (Triboscience & Engineering, Inc., US) and Ken Hope (Chevron Phillips Chemical Company LLC, US) coauthored a paper about the use of mPAO 65 base oil to formulate greases from lithium, preformed polyurea, and aluminum complex thickeners. These various greases have many industrial uses, and mPAO 65 provided many benefits in each of these lubricating greases.

While high viscosity PAO’s have been commercially available since the 1980’s, mPAO’s are relatively new with commercial grades available since 2011. The physical property advantages of the mPAO’s compared to traditional high viscosity PAO’s are a higher viscosity index with lower pour point and better low temperature viscometrics.

The main objective of their lithium grease study was to evaluate the use of mPAO base oils in comparison to traditional high viscosity PAO base oils in lithium grease. They compared test data for lithium greases prepared with PAO 6/PAO 40 blends versus PAO 6/mPAO 65 blends. The low temperature viscometrics, as well as the starting and running torque measured at low temperatures, were highlights of the lithium greases. The PAO 6/mPAO 65 lithium grease had superior low temperature properties due to both a lower amount of the high viscosity base oil as well as the superior low temperature properties of the mPAO.

Finally, the oxidative stability of the lithium polyuria and aluminum complex mPAO-based greases exhibited excellent performance.

**Graphene-based Lubrication**

Florian Pape (Institute of Machine Design and Tribology, DE) presented a paper on graphene-based lubrication for rolling element bearings. Graphene consists of two-dimensional layers of covalently-bonded carbon atoms. It offers advantageous properties such as high strength and electric conductivity. The two-dimensional, layered structure of graphene can be effective against friction and wear under sliding conditions. Graphene coatings have shown promise for reducing friction and wear under rolling conditions.

For this investigation, Pape tested thin films of graphene platelets as dry lubricants on the raceways of angular contact ball bearings. He suspended 0.1 wt% graphene in
DMF (N, N-dimethylformamide), applied this mixture to bearing races and rolling elements, and heated them to form a dry coating of graphene.

In addition, he stirred 0.1 w% graphene into barium complex soap thickened synthetic hydrocarbon based grease and used the grease to lubricate bearings.

Experimental studies were carried out under oscillating conditions with a test rig described in his paper. Laser scanning microscopy was used to investigate wear phenomena. Additionally, frictional properties were measured with a tribometer.

Pape concluded that graphene platelets as dry lubricants offered excellent wear resistance in rolling contacts under reciprocating motion. He noted that laser scanning microscopy results showed that the graphene layer thickness on metal was significantly lower compared to conventional transfer layers. Thus, graphene can also be used for bearings without having to increase the bearing clearance. In the case of the graphene-additized grease under oscillating motion, advantages were also obtained.

Pape proposed that graphene dry lubrication for bearings showed potential for applications in the aerospace industry, under vacuum, at high and extremely low temperatures, and in the event of failure of liquid lubricants. He claimed that his results proved that graphene is suitable for use in rolling bearings that are operated under pivoting motion and in joints. His study confirmed that the excellent properties of graphene, which have so far been proven with nano- and micro-scale test benches, can be transferred to macroscopic applications such as those found in various machine elements.

**Working Group Sessions**

On Sunday morning, various Working Groups assembled for meetings.

First, Grease Particle Evaluation WG Chairman Joe Kaperick gave an update on the Hegman gauge study and recent round robin study. Repeatability was very good, while significant deviations were observed between participating labs for a number of grease samples. It was suggested that it might be helpful to run a round robin with HD photos of the Hegman gauge determinations of problematic samples. A draft method for grease particle evaluation could be discussed in the next ASTM standards meeting on June and prepared for balloting in the ASTM process. Volunteers were requested to help with the drafting of a white paper that will give guidance on the various methods available for particle evaluation.

Second, Food Grade Lubricants Performance WG Chairman George S. Dodos reviewed the final report on the oxidation stability project and underscored the significant contribution of the WG to the new ASTM test method, D8206-18 Rapid Small Scale Oxidation Test (RSSOT). The project on the cold temperature performance of biobased greases was discussed. Lists of candidate test methods and critical points were finalized. Results of a preliminary study were presented by Mikael Kruse (AXEL Christiernsson AB, SE), and certain details on test conditions and test sequence will be examined further. Hydrolytic stability evaluation of biobased greases is a new work item.
Fourth, Test Methods and Rheology
WG Chairman Olav Hoeger (Shell Global Solutions Deutschland GmbH, DE) updated the WG regarding the ISO/TC28 WG on the development of test methods for greases. A new work item on grease sampling is underway. Concerning the ELGI reference grease, a survey with a list of candidate test methods was distributed for members to vote on their choice. Updates were given on rheological measurements vs. consistency, copper corrosion, oxidations stability, dropping point, and EMCOR tests. Issues with new bearing sources for the Fafnir fretting rig were discussed.

Finally, Railway Lubricants
WG Chairman Alder da Costa D’Ambros (Total Lubricants, FR) gave an update on progress toward a European standard for top-of-rail grease. Marc Ingram (Ingram Tribology. UK) has developed a new test method for top-of-rail grease that uses a rig based on the MTM Mini Traction Machine (PCS Instruments, UK). The aim of Ingram’s test is not to replicate the railway but rather to establish a performance baseline for products. The next step will be a round robin study of the test method.

Gala Dinner and Entertainment
The second day of the AGM concluded with the Gala Dinner. Greek hospitality prevailed in a fascinating landscape outside of Athens. The event took place in the vineyards of Oenotria Land, a famous Greek winery. Upon arrival, the guests were welcomed by a Greek folk dancing group performing traditional dances and encouraging everyone to join in. Moreover, a travel in time through the history of the vine and the wine could be experienced, by visiting the Costa Lazaridi Wine Museum. Soon after the actual dinner – with a menu of Greek tastes – the night evolved into a joyful party. Almost everyone kept dancing till the end over the music played by the enthralling band “48 ores” and Greek spirits accompanied the high-spirited mood of this event.

Plant Tour
At the end of the meeting, a group of registered attendees had the chance to tour one of the TITAN Group’s cement plant close to Athens. TITAN Group (GR) is a multinational producer of cement and building materials. Plant Manager Faidon Prokopios gave a warm welcome to everyone, and
then he elucidated technical matters related to cement properties, cement production, the operation procedures of the plant, and its environmental impact. Attendees learned about the lubrication requirements of the several cement production processes. The plant tour included a coach tour of facilities and a visit to the laboratory and the control room.

**Partner Tour**
A partner tour was organized on Monday morning. The day included sightseeing of historic and modern attractions in Athens, a lunch by the sea, and a tour of the Athens Riviera. The tour included the Panathenaic Stadium and the Stavros Niarchos Foundation Cultural Center. The Panathenaic Stadium is an ancient stadium that was refurbished in the 18th century in order to host the first modern Olympics in 1896. It is the only stadium in the world built entirely of marble. The Stavros Niarchos Foundation Cultural Center is a complex that opened in 2017, and includes the new facilities for the National Library of Greece and the Greek National Opera, as well as the 210,000 m² Stavros Niarchos Park.

**Future Events**
The next ELGI AGM is planned for April 25-28, 2020 in Hamburg, Germany.

**Acknowledgements**
Dr. Raj Shah is a Director at Koehler Instrument Company in NY for over 2 decades, a NLGI board member from 2002-2017, and an elected Fellow of STLE, RSC, AIC, EI and NLGI. More information on him can be found at [https://www.gulfcoastconference.com/speakerBio.php?pid=7108&y=2019](https://www.gulfcoastconference.com/speakerBio.php?pid=7108&y=2019)

Dr. Mary Moon is Technical Editor of The NLGI Spokesman, a contributor to Lubes’N’Greases magazine, and a freelance writer and consultant. She has hands-on experience formulating, testing, manufacturing and marketing lubricants and additives. Contact her at MaryMoonPhDMBA@gmail.com or +1-267-567-7234.

Dr. George Dodos is the head Chemical engineer at Eldon’s in Athens, a longtime member of ELGI, and coauthor of the best paper award at ELGI 2019 conference.
FIRST ANNUAL

NLGI Hands-On Education Course

SEPTEMBER 17-19, 2019


The class is taught in a participatory atmosphere, comprised of a Lecture section and a hands-on Laboratory Practical section where participants perform the prescribed test methods using the required instrumentation. Each participant will receive a course workbook upon arrival. Each day following the morning lecture section, participants will perform a selection of test methods discussed during the day using the required instrumentation. This hands-on approach will reinforce the topics and subject matter discussed during the lecture session to enhance learning and retaining knowledge.

TARGET AUDIENCE:

- Scientists
- Plant Supervisors
- Laboratory Personnel
- Engineers
- Senior Technical Staff
- Maintenance Supervisors
- QC Staff
- Senior Plant Operators

REGISTRATION FEES:

$699 for NLGI members
$799 for non-members

*$100 discount may be applied toward membership dues if joining before 12/15/19.

Registration fee includes:
- Course Workbook
- Roundtrip transportation provided by the Courtyard by Marriott
- Lunch & Reception
- Lubricating Grease Guide

This course provides an excellent overview of the types of greases, thickeners, base oils and additives. The methods of manufacturing, testing methodology and their use in bearings and in industrial and automotive applications are also covered.

TOPICS:

- Course Overview & Introduction to Greases
- Application Problem Solving
- Grease Manufacturing Overview
- Grease Testing
- Automotive Applications
- Industrial Applications
- Grease Selection and Recommendations
- Special Tests
- Applications: Grease Tribology
- Grease Composition
  - Base Oil Basics
  - Thickener Basics
  - Additives

QUESTIONS?
Contact NLGI HQ at 816-524-2500 or nlgi@nlgi.org

View SCHEDULE, HOTEL INFO AND REGISTRATION DETAILS online:

https://www.nlgi.org/education/september-education-course/
**Total Attendees:** 473  
**Total Attendees from Abroad:** 92  
**Basic Course Participants:** 42  
**Advanced Course Participants:** 29  
**CLGS Exam Participants:** 13  

**Number of Technical Presentations:** 29  
**Total Number of Exhibitors:** 30  
**Golf Tournament Participants:** 96  
**Fun Run Participants:** 77  

**Industry Co-Speakers:**  
- Piet Lugt & Frank Barens SFK  

**EDUCATION**  
- Food Grade Working Group Meeting  
- Bio-Based Working Group Meeting  
- Grease Particle Working Group Meeting  
- Grease Specifications Working Group Meeting  
- Industry Speaker Presentation  
- Technical Presentations  
- Basic Grease Course  
- Advanced Grease Course  
- CLGS Exam

**NETWORKING OPPORTUNITIES**  
- New Member/First-Timer Reception  
- Saturday Networking Reception  
- Golf Tournament  
- Fun Run  
- Exhibits  
- Breakfast & Lunches  
- Afternoon Coffee/Snack Break  
- Closing Night Celebration

**What value did you find from the technical sessions?**  
“At this meeting I learned quite a bit from the variety of papers being presented. The quality was good and so were the speakers and I especially liked some of the new work presented on tribology of greases.”
What was your favorite thing about the annual meeting?

“NLGI annual meeting was an excellent opportunity for our company to meet a large number of companies in a few days. Every day is organized with opportunities to network existing or new contacts.”
What was your favorite thing about the annual meeting?

“I have been attending NLGI meetings for over two decades. At each meeting I always look forward to catching up with old friends and making a few new ones. The network opportunities that the NLGI annual meeting offers is definitely my favorite part and I can honestly say that networking at NLGI is a lot better than most conferences I attend.”
NETWORKING & EDUCATION
The NLGI Awards recognize those who, through their farsightedness, enterprise and innovation, pioneered significant and lasting improvements within the Industry.

TOM STEIB

This year’s recipient is Tom Steib with The Elco Corporation. Tom started in the grease business with The Southwest Division of Witco in Bakerstown, PA. Tom started in the lab and worked his way up to plant manager. At Southwest, Tom was a co-inventor on a patent for low soap Calcium Sulfonate grease.

Tom was hired by The Elco Corporation, now Italmatch Chemicals, as operations manager. He is now the Vice President Manufacturing where he oversees the daily operations of three manufacturing plants producing and shipping additives for lubricants.

Tom chairs the Finance Committee as a valued member of the NLGI Board, and we have witnessed firsthand his reliability, trustworthiness and dedication. It is our distinct honor to present this award to Tom Steib.

Sponsored by Texas Refinery Corp
**NLGI Founders Award**

In recognition of the three NLGI founding Companies, the Founders Award is presented to a company that has had a positive impact on the NLGI in the tradition established by these founding fathers.

**STRATCO**

This year’s recipient has a long and valued history with NLGI and was one of the earliest joining members. STRATCO was founded as Stratford Engineering Corporation in 1928 before becoming STRATCO, Inc. in 1984. Accepting this award on behalf of STRATCO is Diane Graham, President & CEO. Diane has been the CEO since 1982, was NLGI’s first woman President in 1992 and received the NLGI Fellows Award in 1987. Today, the company is headquartered in Scottsdale, AZ where they continue to serve the grease industry throughout the world through technology innovation, equipment, process design and contributing technical papers at industry conferences in the USA, Europe, India and China. It is our honor to present this year’s Founders Award to STRATCO, Inc.

Sponsored by H.L. Blachford Ltd.

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**NLGI Fellows Award**

Acknowledges valuable work within the Institute, in the technical development of greases, grease tests, or the promotion of grease usage.

**DICK BURKHALTER**

This year’s recipient is Dick Burkhalter with Covenant Engineering Services, LLC. Dick has more than twenty years of plant operations experience. In 1995, he founded Covenant Engineering Services. He has served on the NLGI board of directors for eighteen years, authored and presented six technical papers at the annual meetings, co-chaired two panel discussions, and has been published in The Spokesman, STLE, and Machinery Lubrication.

Award presented by Pat Walsh, Awards Committee Chair.
NLGI Award for Educational Excellence

“For outstanding instruction as exemplified by subject knowledge and presentation skills in NLGI Grease Educational courses.”

This year’s award goes to two deserving recipients - Michael Anderson with Falex Corporation and Chuck Coe with Grease Technology Solutions, LLC

MICHAEL ANDERSON

Michael Anderson received a BS degree in Chemistry and Business Economics. Upon graduation, he joined International Harvester Corporation and was involved in the physical and performance testing of petroleum products and automotive chemicals. In 1982, Mr. Anderson joined Keil Chemical Division of Ferro Corporation and worked in product development and technical support until 1984. He joined Falex in 1984 as Manager Technical Services. Since then, he has held positions including Marketing Manager, Vice President of Marketing, Vice President of Testing Services and is currently Area Manager for Falex products in Asia Pacific and Latin America. He also serves Falex Corporation as the company Tribologist. Additionally, Michael is a STLE Certified Lubrication Specialist.

CHUCK COE

Chuck holds a BS Chemical Engineering, along with the NLGI’s CLGS and STLE CLS professional certifications. He worked for Mobil and ExxonMobil for over 32 years. He retired from ExxonMobil and launched Grease Technology Solutions LLC, a grease training and consulting business in 2009. He is a past president of NLGI, is currently serving on the Board of Directors, and is the Grease Education Course Chair of STLE. He has authored a number of technical papers and articles on grease and received Best Marketing Paper and Best Paper awards from both NLGI (2008) and ELGI (2009), and both the John A. Bellanti Memorial Meritorious Service Award (2012) and the NLGI Fellows Award (2015).

Award presented by Greg Morris, Shell Global Solutions. Sponsored by Shell Global Lubricants
Wayne Mackwood

This year’s recipient is Wayne Mackwood of Lanxess Canada. Wayne is a dedicated individual who is passionate about the Institute and is currently a member of NLGI’s Board of Directors and Executive Committee.

Wayne has been a member of the NLGI Board since 2011 and currently serves as Treasurer. He is a recognized expert in the design, manufacture and use of CSC Grease and has developed over 150 grease formulations. He has authored more than a dozen technical papers, holds two patents, and has given more than 20 presentations at leading conferences and seminars around the world.

Sponsored by Pigging Solutions

Andrew Heimer

This year’s recipient is Andrew Heimer of Chemtool, Inc. Andrew holds a degree in chemistry and began working in the industry as an analytical chemist. Andrew joined Chemtool three years ago where he served in a few different roles including Grease R&D Chemist, Grease R&D Manager and now Process Development Engineer.

Award presented by Bill Mallory, Royal Mfg Co., Inc. and sponsored by Koehler Instrument.

Greg Morris

This year’s recipient is Greg Morris, Grease Product Application Specialist- Americas, with Shell Global Solutions US. Greg has a Bachelor’s degree in Chemistry from West Virginia University specializing in Analytical Methods. He has worked in industrial lubricants since 1998, in multiple roles within Shell, supporting both the commercial and technical community. Prior to his current role, Greg was a plant formulation chemist, local and national sales manager, engineering service manager, as well as the regional sales manager for Grease in North America.

Sponsored by Chevron Lubricants
Clarence E. Earle Memorial Award

For outstanding contribution to the technical literature relating to lubricating greases during the year.

This year’s award goes to two deserving recipients -

**Mehdi Fathi-Najafi** with Nynas AB and **John Kay** of STRATCO, Inc.

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**MEHDI FATHI-NAJafi**

Mehdi holds a Licentiate degree in Chemical Engineering Design as well as a Masters of Science in Chemical Engineering. He has about 25 years of experience within the base oil and lubricating grease industry. Mehdi joined Nynas AB in 2008 as a senior technical coordinator. Today, his main function is in support of the lubes and grease industry.

**JOHN KAY**

John graduated summa cum laude with a degree in mechanical engineering. He was employed by a major design/build mechanical contractor in St. Louis, Missouri from 1980 through 1996 where he became the principal design engineer in 1988. John joined STRATCO in 1997, where he is now the Vice President of Engineering. He has authored several technical papers and articles for NLGI as well as having served on the board of directors for 10 years.

Award presented by Pat Walsh, Awards Committee Chair and sponsored by TrustLube B.V.

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Golden Grease Gun Award (new award this year)

This award acknowledges valuable work within the Grease Industry in the development of grease technology, manufacturing, testing, applications and better understanding of grease behavior or the promotion of grease usage.

**BILL MALLORY**

This year’s recipient is Bill Mallory with Royal Mfg Co, Inc. Bill studied mechanical engineering at Oklahoma State University and served in the US Army until he joined the family owned business. Bill has been active in the development process, procedures, formulation, plant design, equipment, manufacturing and sales of all greases produced by Royal.

Award presented by Pat Walsh, Awards Committee Chair
This year, we'd like to honor two deserving recipients – David Como and Bill Mallory.

DAVID COMO
Retiring in 2009, Dave was a senior member of the Global Development Leadership Team for Dow Corning Corporation's Molykote® lubricants business, representing the Americas area and was responsible for Molykote's Solid Lubricants Technology globally. Dave has served on the NLGI board of directors since 1999 and is NLGI's Immediate Past President.

BILL MALLORY
Bill joined his family owned business in 1960. During his tenure, Bill successfully guided the growth of Royal Manufacturing into one of the leading independent grease and lubricant manufacturers in the industry. Bill is retiring from Royal but plans to remain active in the industry that he's helped to build.

Award presented by Pat Walsh, Awards Committee Chair
The 86th Annual meeting of NLGI kicked off on June 8, 2019 in the Red Rock area of Las Vegas, NV with over 475 delegates from over 10 different countries in attendance; a record for the annual meeting. The program theme was ‘Bearing the Load: Back to the Basics of Grease.” A total of 29 technical papers were presented over the course of four technical sessions. Papers focused on a very wide range of topics including additive technology and selection, new developments in lubricant testing, environmentally friendly greases and new production processes. Two professors addressed attendees during a new Lunch & Learn segment of the program.

**Bio-Based**

The Biobased Greases Working Group is a joint working group of the ELGI and NLGI. Results from the round robin testing (6 members that tested 8 grease samples) on oxidation stability were presented. The test methods performed in the Round Robin were: Oxidation Stability by Oxygen Pressure Vessel Method (ASTM D942), Rapid Small Scale Oxidation Test (RSSOT, similar to ASTM D7545), Modified RPVOT (ASTM D2272) with a test temperature of 150°C and induction time of 25 hours evaluating the greases after liquefying in a silicone oil, and PDSC (ASTM D5483.)

The cold temperature properties of vegetable base oils are not similar to mineral base or synthetic base fluids. Vegetable base oils undergo crystallization at low temperatures. The Round Robin Group is starting preliminary work. This Round Robin Group has gathered a series of methods that are used to measure low temperature performance. Initial screening of low temperature properties of biobased and conventional base oil rheology is also being performed. The Round Robin Group needs to agree on methodology to be used, identify volunteers and decide on the type and number of test samples to be used. Some of the test methodologies that have been discussed as being used are: Flow Properties of Lubricating Greases (DIN 51805), Testing Rheological Properties of Lubricating Greases - Part 2: Determination of Flow Point using an Oscillatory Rheometer with a parallel-plate measuring system (DIN 51810-2), Low Temperature Cone Penetration (DIN 13737), Low Temperature Torque (ASTM D1478) and Lincoln Ventmeter.

The selection of the biobased greases to be evaluated would be made based upon: base oil type and viscosity, type of thickener system and NLGI Consistency. This selection would be made on which one most influences the low temperature performance of biobased greases.
The Grease Particle Evaluation Working Group is a joint working group supported by ELGI and NLGI and continues to make good progress toward defining a system for evaluating the size and number of particles in a grease sample. The group, which is working to evaluate robust methods for measuring these properties, gets together at both the NLGI and ELGI Annual Meetings in addition to other scheduled discussions throughout the year. This group has been assessing the feasibility of combining the results from two test methods as a particle evaluation system. The meeting reviewed the background information, as well as the status of current testing, including an update on an industry round robin that is currently underway with 19 industry/academia participants studying 11 grease samples with changes in formulation.

The results on the rerun round robin with some changes were considered and presented, i.e. uses vertical (85 to 90 degrees) scraper, use 4 particle size ranges for more even distribution and easier rating (15-25 microns, 26-50 microns, 51-80 microns, >80 microns.) The consideration was given changing lower level to 10-25 microns align with SKF and used the photographs as a guide to identify scratches.

The photos (6) were circulated to participants for their review and opinion on the rating. Joe Kaperick, Afton Chemicals investigated correct light and settings to get best pictures of scratches for various 6 tested greases.

Kuldeep Mistry, Timken, Anuj Mistry, Fuchs and Chris Pether, Afton a lead in the white paper write-up to give guidance to users on availability of different methods for grease particle evaluation. This would include a large number of methods which are already in place and standardized by various bodies. It would explain pros/cons of different methods with respect to: what is being measured, cost, availability and ease of use.

Mike Kunselman from the Center for Quality Assurance (CQA) was introduced and mentioned CQA's role in the GC-LB program for management, specification and performance standards of greases.

Next, Dr. Gareth Fish discussed the test methods currently included in the GC-LB standard (ASTM D4950) and highlighted several tests that have been identified as problematic for various reasons. The WG was set up with a 10-year plan to replace the NLGI GC-LB Specification. In the short term, the goal is to define requirements for multi-purpose greases (MPG) with higher performance specifications and to define four sub categories for licensing MPG+ Characteristics (better water resistance, higher load carrying capacity, better salt water resistance, longer life). Several test methods will be added to the specification to better understand performance of the test greases and each sub-category will have additional performance requirements beyond the MPG Specifications. Sample specifications were presented. The issues with replacing dropping point (ASTM D2265) and high temperature grease life (ASTM D3336) tests were discussed.
FEATURED INDUSTRY SPEAKERS

This year’s featured industry speakers were Frank Berens and Piet Lugt, PhD, both with SKF Engineering & Research Center. The topic of their presentation was “A World of Reliable Rotation Grease Lubrication in Rolling Bearings.” Mr. Berens began the presentation by providing the audience with a background of SKF’s business elaborating on the wide variety of products and markets SKF serves. Mr. Berens also discussed some global trends and how these trends will apply to the future direction of the lubricant industry.

Dr. Lugt then began to discuss how to understand grease lubrication in rolling bearings and the many considerations that must be accounted for when selecting a grease for different applications. Grease life is usually the most important performance parameter. Much of SKF’s grease research, in collaboration with academia, is directed towards the development of models, based on the physics and chemistry of grease, that make it possible to predict grease performance.

TECHNICAL PRESENTATIONS

Technical Session 1

The presentations started with George S. Dodos, PhD of Eldon’s S.A., who’s paper was titled “A study on leakage tendencies of rolling bearing lubricating greases.” The paper discussed how grease lubrication of rolling bearings has the primary task of minimizing friction and wear between the rollers and the ring surfaces, providing at the same time protection against corrosion and sealing support. Dr. Dodos mentioned that during operation, separation and overflow of grease or oil from the bulk grease charge may occur, induced by high temperature and bearing rotation resulting in grease leakage. This leakage can cause premature deterioration of the bearing, shortening its service life, as well as contamination of the nearby environment. In his study, the leakage tendencies of a series of rolling bearing lubricating greases were evaluated by a variety of methods.

Next, Kazumi Sakai of JXTG Nippon Oil & Energy Corporation presented a paper titled “Influence of grease component on energy-saving performance.” Mr. Sakai provided an overview of grease lubrication and why the energy-saving performance of greases has become increasingly important for rolling element bearing applications. Underscoring widely-used lithium-type greases, the influence of the grease component was investigated through measurements of the power consumption of a motor employing real bearings and comparing greases made with different base oil viscosity, thickener type and additive incorporation. The results were suggestive of the importance of the thickener entrainment to the contact and the grease movement around the contact.

What value did you find from the technical sessions?

“The technical sessions are the linchpin of the entire conference. No other annual conference in the U.S. focuses entirely on the chemistry and application of lubricating greases. And no other conference in the world presents more such information on an annual basis.”
Gus Flaherty of Nye Lubricants Inc. presented a paper called **“Bearing Simulation Tribometer for Estimating Relative Grease Life in Boundary Film Lubrication.”** In this paper, Mr. Flaherty covered the growing technical demands for lubricating greases in challenging applications in the aviation, semiconductor and aerospace industries and indicated new tools must be implemented to measure lubricant performance since the limitation of bench testing full bearings setups becomes prohibitive due to cost and time factors. This has led to the creation of advanced bearing simulation testing like the Spiral Orbit Tribometer (SOT). In the presented research, a PAO grease was evaluated to determine the significance of various molybdenum additives on the relative lifetime in a bearing compared to performance in a bearing simulation tribometer. During the question and answer section Mr. Flaherty suggested future work will include surface analysis of the wear scars generated by SOT testing.

Michael Holloway of 5th Order Industry then presented **“A Primer on Grease Testing for Performance and Condition Monitoring”** which provided an overview of many conventional and new lab tests that can be used to indicate field performance. As Mr. Holloway presented, he inquired with audience members for feedback on their experiences with the tests and had contributions from David Turner (Citgo), Andy Waynick (NCH Corporation), Rich Wurzbach (MRG Labs) and Piet Lugt (SKF Research and Technology Development).

The first technical session was closed out by NLGI India Chapter Best Paper award winner **Sachin Kumbhar** of Environ Specialty Chemicals Pvt. Ltd who presented the paper **“Alkylated naphthalenes for High Temperature Applications.”** Mr. Kumbhar's paper provided an overview of alkylated naphthalene chemistries and properties and highlighted their use as co-base fluids to impart thermo-oxidative stability to oil and grease formulations when replacing a portion of Group II, III or IV base oil. The paper presented data in various applications and highlighted the improved performance of greases and chain lubricants formulated with alkylated naphthalenes as well as a field study demonstrating the benefits in plywood manufacturing.

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**Would you recommend others to attend?**

“Yes. If you work in the area of lubricating greases in a technical, manufacturing, supplier, or user capacity, then the annual NLGI meeting is the best venue for gaining whatever information or professional contacts you might need.”
The afternoon session of technical presentations opened with Chuck Coe's annual review of the 2018 Grease Production Survey. Mr. Coe, of Grease Technology Solutions, provided an overview of what the NLGI production survey is and the type of information included and moved on to summarize the key results and trends from the most recently conducted survey.

The paper “Fundamentals of Water Soluble Thickeners for Industrial Lubrication” was presented by Erik Willet, PhD of Functional Products Inc. In his paper, Dr. Willet outlines some advantages provided by water-based lubricants including the reduced need for petroleum derivatives and greater fire safety over hydrocarbon alternatives. The first step toward developing new industrial water-based lubricant requires thickening the fluid to typical ISO viscosity grades. This paper evaluated several different polymers using water as a solvent and focused on thickening efficiency and viscosity index improvement and has produced two useful novelties: a clear synthetic water soluble VI improver with no cloud point; and a low cost thickener from biomass.

Next, Brian Casey, PhD of Vanderbilt Chemicals LLC presented a paper titled “Oxothiomolybdate Salts as Novel, Highly Sulfurized Molybdenum Additives.” Dr. Casey began his presentation with a brief overview of molybdenum-based additives before introducing a new class of molybdenum-based additives for use in lubricants which are ionic in nature and contain highly sulfurized binuclear oxothiomolybdate dianion cores. A range of additives possessing distinct physical and performance properties can be produced by varying the chemistry of the counteraction. Lithium-complex grease formulations containing these additives as single components and in combination with other additives were evaluated using SRV, 4-Ball and MTM Bench tests and the performance was compared to traditional solid molybdenum-based additives and liquid organomolybdenum additives. The results Dr. Casey presented indicate that the novel oxothiomolybdate salts are useful, multifunctional additives capable of delivering friction reduction, anti-wear and extreme pressure performance in grease applications.

Liwen Wei, PhD, of Novitas Chem Solutions presented the paper “Lithium Option: A Novel and High Stability Calcium Grease” which focused on a rheologically stable calcium sulfonate grease. This novel class of high stability calcium grease developed was presented by Dr. Wei as a viable and cost-efficient option to supplant lithium grease; the use of which is under threat due to escalating Lithium cost today. This HSC is based on calcium sulfonate thickener in tandem with calcium carboxylates with sulfonate content less than 5%. This offers a lower cost than calcium sulfonate grease, in addition to high stability and better performance than the existing lithium greases.

Following, Vasu Bala, PhD of Tiarco Chemical Corporation presented a paper titled “Performance Considerations in Formulating Multi-Purpose EP Greases.” Dr. Bala gave an overview of the grease market before discussing performance trends for Extreme Pressure (EP) greases and formulation considerations in meeting performance balances for load bearing, wear and yellow metal corrosion. Current sourcing demands for key raw materials used in thickeners were highlighted along with a brief overview on the attributes of the various common greases used. Dr. Bala highlighted the continuous strive for energy efficiency driven by Original Equipment Manufacturers’ (OEM) trends. In order to meet these higher performance trends in multipurpose EP greases, careful consideration is needed regarding the type and functionality of key EP, anti-wear and corrosion additives used. Test results on formulation options with select additives were discussed to attain high load bearings while improving anti-wear and corrosion performances.
NLGI President Joe Kaperick of Afton Chemical Corporation presented next with a paper titled “Back to Basics: The ABC’s of Grease Additive Performance.” Mr. Kaperick’s main focus was on the role of additives in providing the essential performance characteristics typically required by bearing greases and other fully formulated lubricating greases. Research in the area of grease chemistry can reach from the mundane to the esoteric but this paper stresses that sometimes it’s good to step back and examine the basic assumptions and “common wisdom” upon which those studies are often based. During his presentation, Mr. Kaperick covered a variety of additive types evaluated by several different test methods to examine in more depth some of the foundation aspects of grease performance to support or refute the commonly held “facts” of grease additives.

“New Process Methods to Improve the Thickener Yield of Calcium Sulfonate-Based Lubricating Greases” was presented by J. Andrew Waynick from NCH Corporation. Mr. Waynick provided an overview to the history of calcium sulfonate-based grease technology development starting with the first lubricating greases made from highly overbased calcium alkyl benzene sulfonates which were disclosed in the 1960’s. These products would eventually be known as simple calcium sulfonate and required about 50% of the overbased calcium sulfonate to provide an NLGI No. grade grease. About 20 years later, the first calcium sulfonate complex greases were developed and more recently, several new process methods for making calcium sulfonate complex greases have been developed. During this presentation Mr. Waynick focused on three new process methods to improve thickener yield, their impact on relative grease cost and performance, and insight into why they work as they do.

Roland Ardai of AXEL Christiernsson International AB presented a paper titled “Environmentally Acceptable Lithium Complex Grease for Wide Temperature Range.” Mr. Ardai began his presentation giving an overview of EAL and EEL requirements. As those rules and regulations are being revised, new challenges and opportunities are having an impact on environmentally friendly grease business. Previously, aquatic toxicity and biodegradability requirements had been difficult to meet with lithium complex based greases however there is now an opportunity to enter the market with such a thickener. Mr. Ardai gave an overview of the regulation changes before going on to compare the performance of an EU Eco-Label compliant, biodegradable and non-toxic lithium complex grease with that of a non-bio, industrial version based on conventional mineral oils.

The last paper of the day was presented by Lou Honary, PhD of ELM, Inc. and was titled “Transforming Technologies in Grease Industry –Biobased Content - Microwave-Based Reactors - Alternative Cooling.” Dr. Honary started his presentation by reviewing examples through history of technology with examples of accidents that had transformative effects. He then elaborated to give an overview of three transforming technologies that could have a positive impact on the grease manufacturing industry. Products produced using these new technologies were reviewed. Specifically, effects on soap formation, consistency, oxidation and dropping point were studied and reported. Dr. Honary indicated that in addition to the work already conducted, the impact of this technology on fields outside of grease manufacturing will be explored.
The second day of technical talks started with a paper presented by Kuldeep Mistry, PhD of The Timken Company, titled “Grease Evaluation for Continuous Caster Bearings (Development of an Innovative Technique to Accurately Measure Water Content in these Greases).” Dr. Mistry stated that the continuous caster is one of the most challenging environments for bearings from the ladle, down through the bender and segments, to the discharge area. In this application many critical positions are subject to high loads and low rotational speeds, often at elevated temperatures. Additionally, many bearings must perform in an environment heavily contaminated with water, steam and scale making it very important to accurately measure the water within a grease. In this study, the learnings of grease selection for the continuous caster bearings are disseminated and a new procedure for measuring the water content of grease was presented.

Next, Baojie Wu of Sinopec Lubricant Co., Ltd., Tianjin Branch presented a paper titled “Tribological Performances of Novel Molybdenum Dithiocarbamate (HBHS-MoDTC) in Greases studied by Four-Ball, SRV Testers and Mini-Traction Machine (MTM).” This paper evaluated several different greases with and without HBHS-MoDTC to determine the antiwear and friction-reducing properties exhibited in three different tribological contact geometries represented by each tester. Mr. Wu presented data generated under varying conditions and concluded that HBHS-MoDTC is a very potent additive to improve the tribological performance of grease under severe conditions.

Michael Anderson of Falex Tribology NV, presented a paper titled “Adhesion and tackiness: How do they influence the frictional performance of greases?” During this presentation Mr. Anderson introduced tackiness as a key grease property and explained the current limitations for testing this property. Greases are extensively used to decrease friction between industrial and technological components and their performance in the field has been observed to strongly depend on their interaction properties. Mr. Anderson presented a new method that was developed to precisely measure the adhesion and tackiness of greases, based on repeated indentation and retraction measurements. However, until now the link between these intrinsic grease characteristics and their frictional performance has not yet been fully understood. For this reason, this paper focused on investigating the effect of adhesion and tackiness on the friction of greases.

The paper titled “Customizing SRV Tribological Test Techniques to Better Replicate Working Conditions” was presented by Robert Mulkern of Nye Lubricants and Dr. Raj Shah of Koehler Instrument Company. In it Mr. Mulkern discussed how tribology plays a major role in considering the use of a lubricant. Application demands, often, transcend typical ASTM methods. Tried-and-true test methods such as 4-Ball Wear and Timken OK Load are frequently chosen to evaluate a lubricant's performance. To expound on quotidian tribological test methods, the SRV oscillation and wear technique has proven to be a versatile tool. A variety of case studies were conducted. By creating and controlling unique test parameters, the results from the SRV can save development time and money compared to other more typical tests.
In a presentation titled “The Dropping Point Test – Time to Drop it?” Gareth Fish, PhD with The Lubrizol Corporation, covered the history of various methods for evaluating the dropping point of a grease and the limitations to the test as it exists today. It is stated that as originally approved in 1940, the ASTM D566 (ISO 2176) dropping point test was used to give an indication of the higher temperature performance of the grease. Historically, there was a rule suggesting the upper operating temperature of a grease was approximately two-thirds of the dropping point. In this paper, Dr. Fish posits that the dropping point test should be retired from service as it has ceased to have any meaning in the real world and should be replaced with a more robust method. However, as it is expected that the D2265 dropping point test will be around for years to come, ways to get high values through additives and thickener technology were also discussed.

The first recipients of the NLGI Research Grant, Alan Gurt and Lijesh KP, both graduate students at Louisiana State University working with Professor Michael Khonsari, presented their paper “Review of Entropy Considerations in predicting the life of grease.” In this paper, it was discussed that though there exists an estimate for the life of grease in specific applications which have been thoroughly examined, no method has been widely accepted to predict the life of grease for a general case. A promising approach to estimating the life of a grease subjected to mechanical degradation by shearing well below the oxidation temperature has been put forward by applying the principles of irreversible thermodynamics. This paper reviewed recent progress on this subject and provided suggestion for future research.

What value did you find from the technical sessions?
“Excellent opportunity to establish and grow an individuals knowledge of the industry and have exposure to new trends in the industry.”

Technical Session 4
During the new Lunch & Learn part of the program, two professors addressed attendees. First, Professor Robert L. Jackson of Auburn University provided an overview of the Auburn Tribology Education and Research Program, stressing the importance of tribology education. There are immense resources spent annually on issues pertaining to friction, wear and lubrication, together known under the umbrella term: tribology. Industry demand is high for graduates with a background in this multidisciplinary field. Despite this, there are few tribology educational opportunities. In light of this, the Tribology and Lubrication Science Minor was created and officially approved at Auburn University. Prof. Jackson and those under his tutelage have made contributions to this field. This research and how it ties in to the Tribology Minor student experience were discussed.
The second Lunch & Learn presentation was given by **Professor Diana Berman** of the Materials of Science and Engineering Department at University of North Texas. Dr. Berman presented a paper detailing her research titled “Biolubriants based on the unique fatty acid structure of Chinese Violet Seed Oil.” In her presentation Dr. Berman stated that Increasing transportation and other industrial activities since the dawn of the last century has consumed much of our non-renewable fossil-based energy resources (such as petroleum) every day, and a significant portion of the energy produced is spent overcoming friction in moving mechanical systems. A recent discovery was that of a unique structure of the oil extracted from the seeds of Orychophragmus violaceus, a landscape ornamental native to China that is a relative of canola. The oil showed excellent lubricative properties and thermal stability. These findings provide a direct pathway for designing a new class of plant-based lubricants that are more effective and environmentally friendly than widely used synthetic oils.

The paper, “Optimizing Aviation Maintenance Planning with In-service Grease Analysis” was presented by **Rich Wurzback** of MRG Labs. It discusses how Rotary wing aircraft flight controls and drivetrains include multiple components that are grease lubricated, including bearings, swashplates and splines. Periodic relubrication of these components during established maintenance intervals are the primary method for replenishment of grease prior to degradation, to ensure reliable and safe operation of assets. Mr. Wurzback presented the methods developed to obtain representative samples from bearings, splines, data analysis methods that combine maintenance and operating histories with grease analysis results, and initial findings that may lead to more economical operation of critical assets.

Next, the Paper “The Development of Lubricating Greases for Wind Turbines Applications” was presented by **Gareth Fish, PhD**, of The Lubrizol Corporation. With the continued growth of wind turbines (WT) for renewable energy generation, a significant amount of work has been published looking at improved gearbox fluids. However, there has been little focus on the greases and open gear lubricants used in wind turbine systems and components. Dr. Fish discussed issues with developing greases to meet the WT specification requirements of friction, low wear, fretting and corrosion. He also reported on findings to enable lubricating grease to pass the standard bearing grease test requirements and of the ripple test.

The paper, “Can lubrication systems be reliable (in changing conditions)?” was presented by authors **Daphne van der Puijl and Chiel van Daelen** of Trustlube Group B.V. The objective of this paper was to show the different types of greasing systems in the market, the limitations of traditional grease systems and recent innovations. Greasing should take place during operation; however, in many cases it is not possible or safe to stand near the greasing points at this time. Greasing systems are designed to surmount this obstacle and make greasing during operation feasible. But how reliable are these systems? These and more topics were reviewed in this paper.
Kimberly Matthews of Bestolife Corporation presented the paper “Betting on Environmental Thread Compounds.” Ms. Matthews pointed out that Environmental, Health and Safety regulations for the oil and gas industry are very common and noted that even though rules continue to multiply, the implementation of the numerous regulations can move slowly into the industry depending on the risk severity. For several years, the industry has alleged that lead-based thread compounds would be phased out and replaced with nonmetallic options. After a brief overview of EH&S regulations, this paper described why anhydrous calcium and calcium complex greases have fulfilled the need for a biodegradable, non-toxic, and non-bioaccumulating base for environmentally friendly thread compounds by exploring the physical characteristics and ecological toxicity are examined for both greases.

“Grease Compatibility Charts are Dangerous!” presented by Chuck Coe of Grease Technology Solutions, introduced drawbacks to grease compatibility charts which have been around for many, many years. These charts are based solely on thickener type and assess compatibility as “compatible”, “borderline” or “incompatible.” Unfortunately, such charts are unreliable, and in many cases, in violent disagreement with one another. Mr. Coe presented a study of the compatibility of 6 different commercial greases, debunking the usefulness and safety of these dangerous charts.

Would you recommend others to attend?

“I would highly recommend the annual NLGI meeting for its individual technical development, insight into new technical presentations and the many opportunities to network with the industry. It is also well organized to bring your spouse or family and enjoy the many different locations and activities.”
Mehdi Fathi-Najafi of NYNAS AB presented “Grease Production, CO2 emission … a New Relationship!” It delved into the fact that the grease industry is regarded to be very conservative; for example, although conventional lithium grease was invented in 1942, 55 percent of the global grease production is still based on this technology and is close to 90 percent in countries such as China and India. Surprisingly, prior to a recent technical paper no one has studied the energy consumption and possible environmental impact of the grease manufacturing process. In this presentation Mr. Fathi-Najafi aimed to measure the energy consumption in full-scale production when a pressurized reactor is used and compared to a traditional open kettle reactor. The authors believe that the outcome of this study could be a milestone in assessing grease production in terms of significant reduction of carbon dioxide and increase awareness of the impact of our industry in the global arena.

The final technical paper titled “Innovations in Grease Process Control Improve Results” was presented by Arnold Josefson of Emerson Automation Solutions. Mr. Josefson detailed how reproducibility of grease production has been an issue that has vexed the industry since higher performance products became the norm. By applying a proper control philosophy and applying the latest instrumentation to improve the predictability of the reaction, it is possible to improve the repeatability of the product and provide better consistency and reduce costs. Mr. Josefson discussed steps taken to improve the production process and reduce operating costs in a modern continuous grease unit through process design, instruments and control.

What value did you find from the technical sessions?

Absolutely. The NLGI annual meeting has something for everyone. The technical talks help update folks about the latest research and trends in the grease industry. The education course helps newcomers learn, and the various opportunities that new attendees get to interact with folks who have a lot of experience in our industry is also unique to the NLGI conference due to the intimate nature of the annual meeting.”

ABOUT THE AUTHORS:

Dr. Raj Shah is currently a Director at Koehler Instrument company and a retired NLGI board member. He is an elected Fellow of STLE, RSC, NLGI and EI. More information on him can be found at https://www.nlgi.org/dr-raj-shah-honored-by-the-royal-society-of-chemistry-and-the-energy-institute/

Amanda Harris is a Technical Service Chemist in the Lubricant Additives Division at King Industries Inc. with 6 years of industry experience and is active within ASTM, NLGI and STLE.

Kuldeep K. Mistry, Ph.D., is a Product Development Specialist (Greases and Lubrication) with The Timken Company, has more than 10 years of experience in the field of lubrication and is active within professional bodies including NLGI, STLE and ISO.

THANK YOU TO ALL OF THOSE WHO PARTICIPATED IN OUR 2019 ANNUAL MEETING SURVEY.

Congratulations to Michael Tann, Account Manager, Lubrizol as this year’s winner of a Visa gift card.
Industry Calendar of Events 2019

Please contact Denise if there are meetings/conventions you'd like to add to our Industry Calendar, denise@nlgi.org
(Your company does not have to be an NLGI member to post calendar items.)

September 21-24, 2019
ILMA Annual Meeting
The Broadmoor, Colorado Springs, CO

April 25 - 28, 2020
32nd Annual General Meeting
Grand Elysee Hotel
Hamburg, Germany

October 10-14, 2019
CLGI Biannual National Conference
Kunming, Yunnan province, China
Kunming Yun’an Huidu Hotel

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Mr. Enrique Riquelme is Director of Quimica Liposoluble, S.A. de C.V., a producer and supplier of additives to the global lubricants industry. Quimica Liposoluble specializes in sulfur chemistry. The Company is integrated vertically from the sulfonation of hydrocarbons to produce sulfonates, to the toll manufacture of sulfonate greases. Quimica Liposoluble currently employs 65 workers, and annual sales are approximately US$8.5 million. The Company is privately held.

Products include barium, calcium, magnesium, and sodium sulfonates for use in lubricating greases, engine oils, food grade lubricants, metalworking fluids, and a variety of other applications. Quimica Liposoluble sells sulfonates to customers in Mexico, the United States, India, Japan, and throughout Europe.

Company headquarters are located in Guadalajara, a city of over 8 million citizens in the state of Jalisco, Mexico. Guadalajara is the second largest metropolitan area in the country. Manufacturing facilities are in Poncitlan, in the Guadalajara-Barca industrial corridor in Jalisco. The state of Jalisco is situated on the western shore of central Mexico. It is a transportation hub with four airports and extensive networks of bridges, highways, and railroad tracks.

**NLGI: How did you become interested in chemicals and lubricants?**

**ER:** There was always in me an interest in Chemistry. While I was in high school, there was in Mexico a large petrochemical industry development based on the excellent results of the government petroleum company, PEMEX, and the future for chemistry careers looked promising.

PEMEX or Pemex is the trademark for Petroleos Mexicanos, the Mexican state-owned petroleum company. PEMEX was formed in 1938 when the Mexican government nationalized and combined oil companies that were operating in Mexico at that time. The Mexican government continues to hold a majority interest in PEMEX. The Company is vertically integrated, from exploration and refining through product development and marketing. Starting in the mid-1950’s, discovery and development of domestic onshore and offshore oil fields led to the expansion of refining capacity. Daily production grew to 3 million barrels per day in 2004. Major recent developments include the PEMEX gas station franchise, greater reliance on offshore drilling, increased emphasis on environmental priorities, and changes in the Mexican national legal framework to reform managerial decision making and encourage new private investments in PEMEX.

**NLGI: How did you start your career in the lubricants industry?**

**ER:** I started working in the lubricants industry 51 years ago. In 1968, after obtaining my BS Degree in Chemical Engineering from the National University of Mexico, I started to work for one of the two major lube oil additives manufacturers in Mexico at that time. My Employer was starting up their plant for the production of detergents, antioxidants, and dispersants for the lubricants market, which was controlled by the Government petroleum company, PEMEX, at that time.
During 16 years with my Employer, I was involved in all the aspects of production, development, and technical servicing of lubricants for the local market. With a group of colleagues in the petroleum industry, we decided to incorporate a new chemical company in the region.

**Quimica Liposoluble**

**NLGI: What happened next?**

**ER:** So, Quimica Liposoluble, S.A. de C.V. was incorporated in 1984 under the auspices of the prevailing industrialization policies of the Mexican Government.

Quimica Liposoluble was based on the basic sulfonation process of natural and synthetic feedstocks for the manufacture of metallorganic sulfonates with applications in the lubrication industry.

There were great difficulties at the beginning, finding the right raw materials and adjusting the manufacturing processes to these materials, transforming staff from agricultural jobs to work in the chemicals industry, looking for proper markets, making freight and customs arrangements, meeting regulations, etc.

After designing, building, and starting up the manufacturing plant, I was appointed General Manager.

**NLGI: What led to the growth of Quimica Liposoluble?**

**ER:** At first, there was a slow rate of growth due to drastic changes in PEMEX, which reduced the availability of basic petrochemicals and base oils for our operations. So, we decided to look for new suppliers outside of Mexico. At the same time, this gave us a different view on how to market our own products.

This fresh new sense of the export markets and their requirements showed us the need for a better knowledge of the lubricants industry in other countries. We learned about requirements for raw materials, product quality, testing, regulations, specifications, future trends, etc.

We now export our sulfonates to the USA, UK, Japan, Germany, Spain, France, Argentina, and Brasil.

**NLGI: What practices contribute to the success of Quimica Liposoluble?**

**ER:** In addition to a continuous presence in the international professional organizations such as NLGI, we have a Research Department for the development of new products. Our Research Department is also in charge of keeping the high quality of our products and operations and, when required, obtaining the registrations such as REACH (through our OR, Only Representative, for REACH purposes, in Spain), NSF, Kosher, and Halal for the proper commercialization of our sulfonates.

**NLGI: How has Quimica Liposoluble benefitted from NLGI?**

**ER:** We acquired the very specific knowledge of our requirements to cope with export markets through our direct contact with the specialized industry professional organizations like the ACS, STLE, NSF, and, more recently, NLGI and ELGI. Our Supplier Membership to NLGI opened our eyes to new guidelines for the development of our Calcium Sulfonates as grease.
feedstocks for general purpose lubricants, for Food Grade applications, and for applications requiring synthetic base oils and esters.

NLGI: Is there a chapter of NLGI in Mexico?
ER: There is not.

NLGI: What do you think about starting a chapter of NLGI in Mexico?
ER: It could start by promoting NLGI among the lubricant companies in Mexico and trying to get the most important companies to become members of NLGI.

Career

NLGI: In your own words, what is your current role at Quimica Liposoluble?
ER: I am now Director of Quimica Liposoluble, in charge of finance, and act as a senior advisor to the management group.

NLGI: Do you have any words of wisdom for working in Sales? Engineering? Manufacturing?
ER: Imagine it’s possible.

NLGI: Do or did you have a mentor?
ER: I did have one in the first years of my career, from whom I learned discipline related to finances and other matters during the difficult days of Quimica Liposoluble. From my mentor, I learned additives marketing out of Mexico.

NLGI: Does or did someone from history, literature, business, engineering, science, etc. inspire you and your career?
ER: Almost everyone I’ve known has had an influence in me.
Grease Industry

NLGI: What do you think about the position of Mexico in the global grease industry?

ER: As for the general lubricants market, growth has been very low in the last 10 years. There are few manufacturers, and a significant volume is imported for an average annual consumption of 14,000 metric tons.

NLGI: What are your thoughts about the future of the grease industry in Mexico?

ER: Recent changes in the Mexican government that affect the petroleum industry, make us think of greater growth in the economy as a whole that shall result in a better situation for the lubricants market.

NLGI: Do you have any words of wisdom for doing business in Mexico compared to the US?

ER: Doing business in Mexico has some degree of uncertainty compared to the US where rules appear easier to understand.

NLGI: What are your thoughts about the future of the grease industry around the world?

A new batch of calcium sulfonate grease at Quimica Liposoluble

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Food Processing lubricants demand the highest level of purity. The FDA defines Lubricants with incidental food contact in 21CFR 178.3570. In the event of unintentional, incidental contact, the lubricant must not affect the quality or safety of the food.

For a guide to best practices, please see the joint ELGI/NLGI position paper on food processing lubricants. www.lexolube.com/H1guidelines

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synthetic esters
ER: Changes shall be expected due to higher prices of raw materials and new regulations requirements.

NLGI: What are some particular new or future opportunities for the grease industry?

ER: New thickeners and formulations might replace some liquid lubricants applications.

Management and Leadership

NLGI: How would you describe your management or leadership style?

ER: Sometimes I have been forced to take risks but as soon I could afford them, I’ve tried to surround of the best possible advisors to help me make my decisions.

NLGI: What are the most important characteristics or behaviors of good managers and good leaders?

ER: Get the best possible personnel around you and let them grow.

Personal Experiences and Culture

NLGI: Have you worked 'hands-on' in a grease lab or plant? Have you made batches? Performed grease tests? Gone to field trials?

ER: I have, in our grease pilot plant. Never been to a field trial.

NLGI: Do you have a favorite grease?

ER: Yes, calcium sulfonate greases.
NLGI: Do you have a favorite product among those of Quimica Liposoluble?

Overbased calcium sulfonates in different carriers as grease feedstocks.

NLGI: Do you have any favorite stories about your experiences working in the grease industry?

ER: When developing our overbased calcium sulfonates, we went through hundreds of drums of accidentally made grease. A hard way to learn.

NLGI: Where is your favorite place to travel?

ER: Lake Chapala, near Guadalajara.

NLGI: If you could have dinner with any three people, living or deceased, who would they be and why?

ER: My Father, my Mother and my Sister. Miss the time with them.