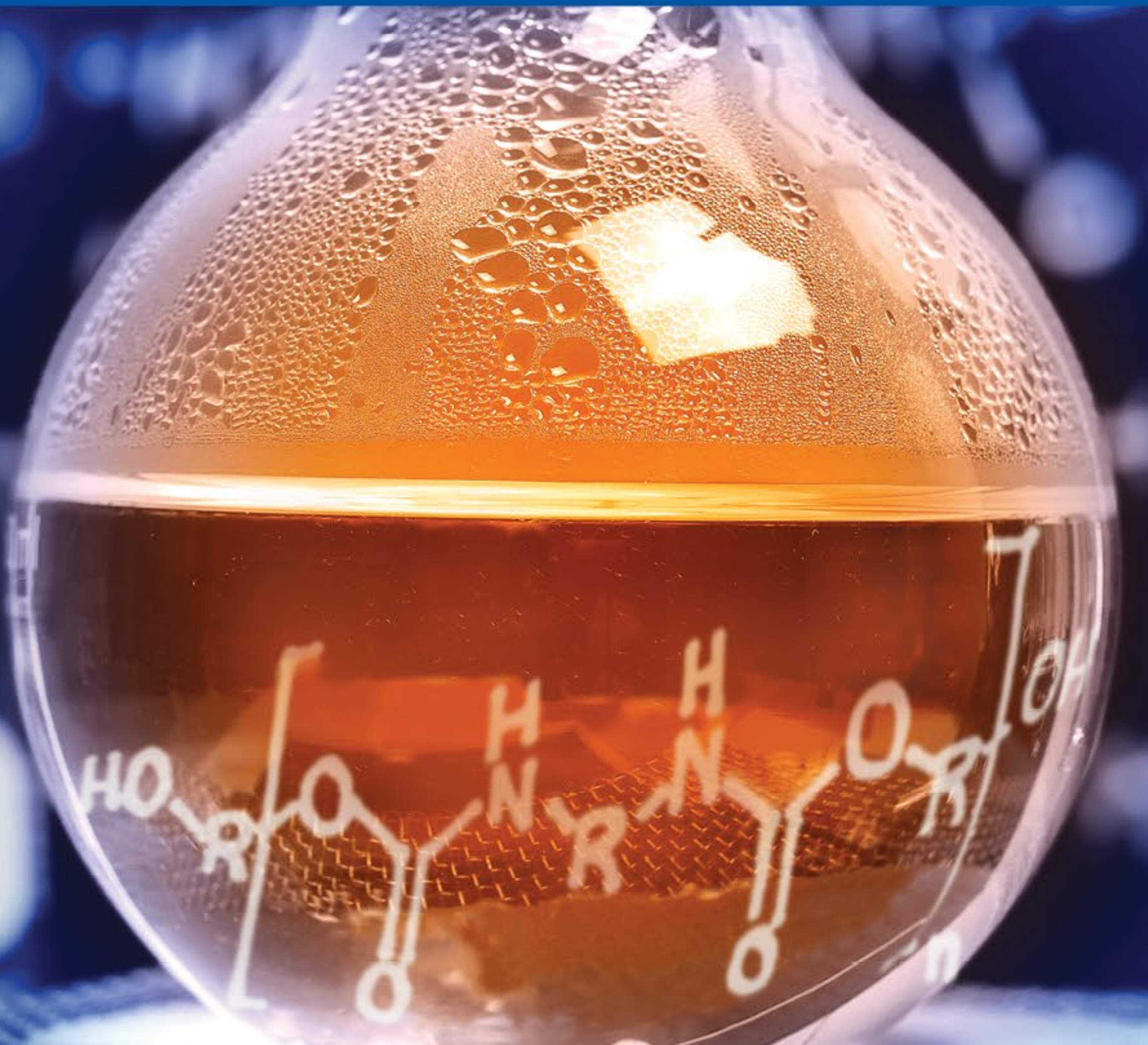
TRCC

DISCOVERING *INNOVATIVE* SOLUTIONS – *TOGETHER*

Performance Considerations in Formulating High Performance Multi-Purpose EP Greases

Dr. Vasu Bala
TRCC
Dalton, GA
USA



5th Grease Market International Conference October 1st, 2025
Millenium Convention Center
São Paulo, Brazil

Outline & Content

- Grease Standards & Trends
- Grease Composition & Additives
- Greases & Additives Used in Study
- Results for Study in Lithium Complex & Calcium Sulfonate Greases
  - Balancing EP Weld, Wear & Copper Corrosion
- Conclusions & Summary
- Acknowledgments

Grease Market Breakdown

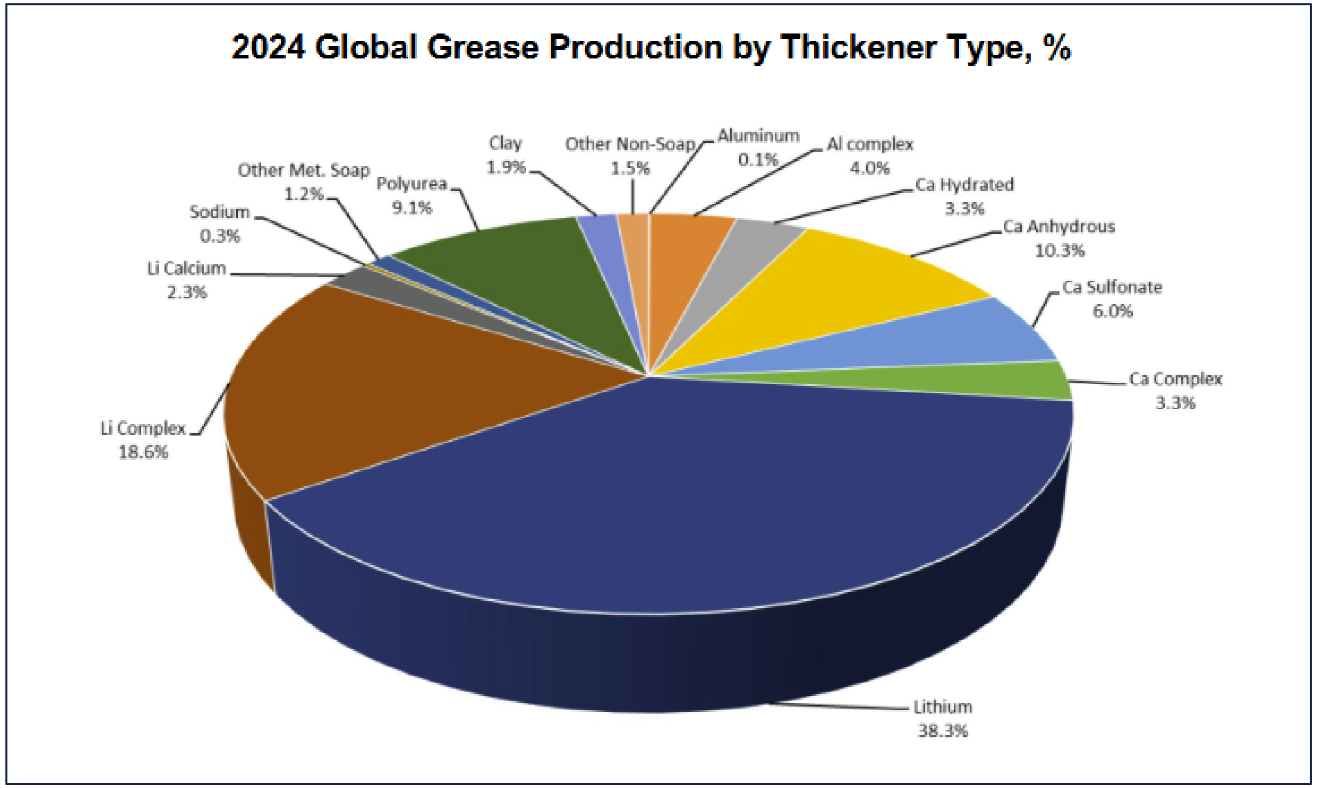
2024 NLGI Production Survey

Thickener Technologies Used in Greases – 2024 Survey

- **Decline Global Grease Production by 3.5% in 2024 primarily in China**
- **Global trend of increasing trend of synthetic (+2.8% 5 yr), declines in semi-synthetic & bio-base fluids.**

Global Production

- **Lithium & Lithium Complex Greases - 56.9%**
- **Calcium based Greases - 22.9%**
- **Polyurea Greases - 9.1%**
- **Aluminum based Greases – 4.1%**



Source: NLGI Grease Production Survey - 2024

TRCC

Grease Standards & Trends

Industrial & Automotive

TRCC

International Standards

- **NLGI Classification System**
- **Industrial**

  ISO 6743-9 Grease Classification for most severe conditions of temperature, water contamination, and loads.

  ISO 12924 Grease Performance Specification for the lubrication of equipment, components of machinery and vehicles.

  Germany, DIN 51802, 51825 & 51826 Classification of Industrial Greases

  Japan, JIS K2220 Standard for Lubricating Greases & Compounds
- **Automotive**

  ASTM D4950 Standard Classification and Specification for Automotive Service Greases

  SAE J310 Recommended Practice

  Both standards assist design of automotive components, and with the selection and marketing of greases for the lubrication of certain of those components on passenger cars, trucks, and buses.
- **New High Performance MultiPurpose (HPM) Grease Categories launched in 2020 by NLGI**

TRCC

Common Grease Tests – Industrial & Automotive

Test Method	Property of Grease	Function Tested
ASTM D1092	Apparent Viscosity	Measures viscosity as function of shear rate
ASTM D217	Consistency	Measures hardness with cone penetration
ASTM D4289	Elastomer Compatibility	Immersion tests for hardness and volume change with Elastomers
ASTM D1743	Corrosion Test	Measures corrosion at specified temperature & humidity
ASTM D566 ADTM D2265	Dropping Point	Temperature at which grease transitions to liquid state
ASTM D972 ASTM D2595	Evaporation	Weight loss after evaporation at specified temperature & duration
ASTM D3232	Flow	Flow properties at high temperature & low shear
ASTM D1263 ASTM D1264	Leakage Water Washout	Measures leakage from unseal wheel assembly Measures resistance to water washout in rotating bearing

ASTM D1741	Grease Life	Measures grease life in steel ball bearings
ASTM D3527	Grease Life	Measures high temperature life of wheel bearing
ASTM D4290	Leakage	Measures leakage of unsealed wheel bearings at high temperatures
ASTM D2509	Load Carrying	Determines load carrying using the Timken Test
ASTM D2596	Load Carrying	Determines load carrying using Four Ball Test
ASTM D1478	Low Temperature Torque	Measures retardation of ball bearings
ASTM D4693	Low Temperature Torque	Measures retardation of wheel bearing assembly
ASTM D1831	Mechanical Stability	Determines consistency change after working
ASTM D942	Oxidative Stability	Static test that measures oxygen consumption
ASTM D1742	Oil Separation	Measures tendency of oil to separate from grease
ASTM D2266	Wear Resistance	Measures wear resistance using Four Ball Test
ASTM D4170	Fretting Wear	Measures fretting wear resistance

Grease Trends & Consequences

End Users → Reduce operational & maintenance cost ,…..increasing profit

OEMs → Increased Performance Demands
Increased Power Densities & Efficiencies
Increased Speeds & Loads
Wider Temperature Range
All Weather & Enviromental Use
Improved Component Life
Extended driveline gearbox warranties
Reduced Consumption & Seal for Life

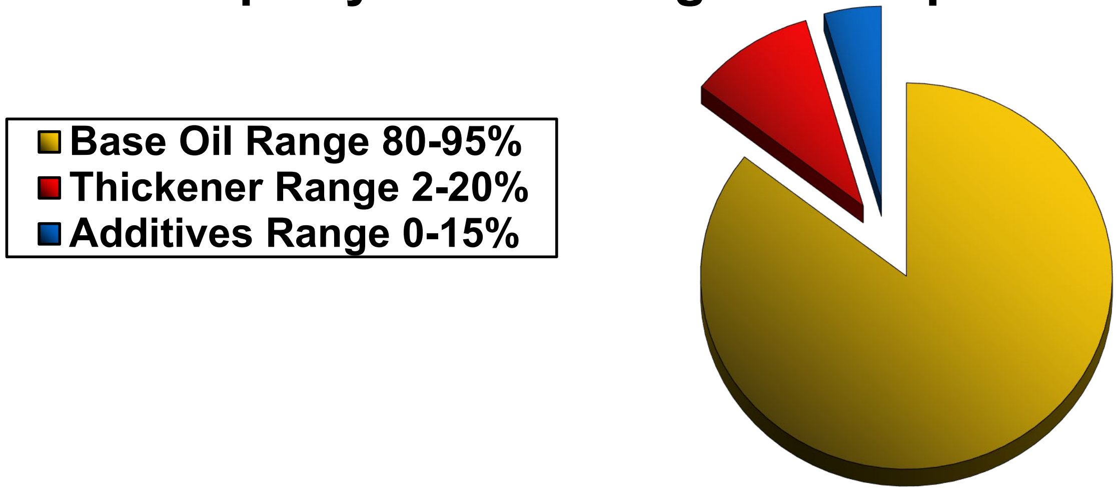
Additive & Grease Suppliers → High Performance Multipurpose Greases
Higher EP & Wear ; Better Washout & Corrosion
Improved shear , thermal & oxidative stability
Use of Synthetic Baseoils
Increased gear & bearing durability
Extending drain intervals
Ecofriendly components
Improved energy efficient greases

Grease Composition & Additives

Grease Types and Additives used in Study

Typical Grease Composition

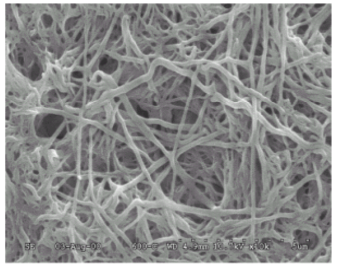
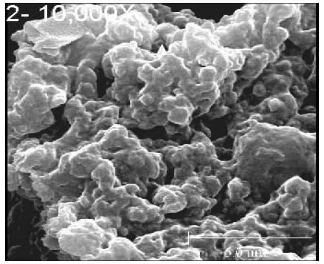
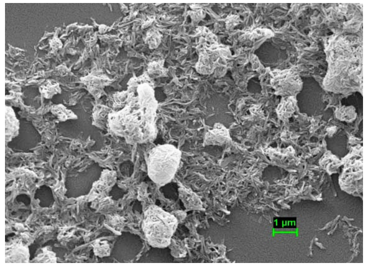
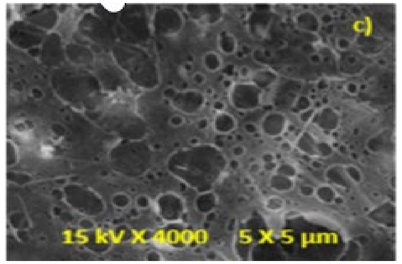
The wide variety of applications for lubricating greases call for an equally diverse range of compositions

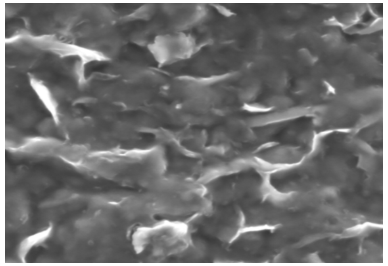


Source: STLE Grease Education Course 2018

Grease Thickener Types Comparisons

Thickener	Lithium Complex	Aluminum Complex	Polyurea	Calcium Sulfonate	Organo Clay
Advantages	Multi-Purpose Good Pumpability	Multi-purpose Water Resistant	Ashless Good Oxidative Stability	Inherent EP/AW Good Corrosion	Good Oxidative Stability
Disadvantages	Rising Cost of Lithium	Oxidation Stability Consistency	Additives for EP/AW & Corrosions Manufacturing Mechanical Stability	Low Temperature Pumpability	Water Resistance Mechanical Stability



Additives & Their Functions

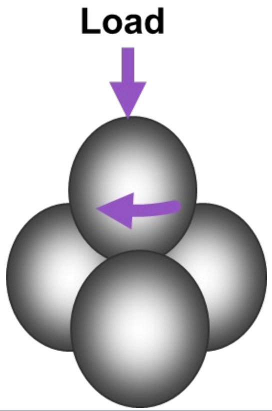
Additive Type	Purpose	Function
Extreme Pressure Metal dithiocarbamates, sulfurised olefins, polysulfides, sulfurised esters ZDDP, Molybdenum disulfide, DMTD, MB	Prevent scuffing, scoring and seizure	Prevents metal to metal adhesion with sacrificial boundary film of low shear strength
Anti-wear ZDDP, Acid Phosphates	Reduce friction and wear	Reduces wear through boundary films
Corrosion Inhibitor Amine phosphate salts, imidazoline derivatives, triazoles, thiadiazoles	Prevent corrosion and rust	Forms protective film on surface to prevent or react with corrosive acids
Metal deactivators imidazoline derivatives, triazoles, thiadiazoles	Prevents catalytic activity of metal surface for oxidation	Forms protective film on metal surface
Anti-oxidants Alkylated Di-phenylamines & Phenolics	Provides oxidative stability	Terminates free radicals and decompose peroxides

Base Greases and Additives Used

BG1 – Lithium Complex Grease NLGI 2
BG2 – Calcium Sulfonate Grease NLGI 2
BG3 – Lithium Complex Grease NLGI 2

EP1, EP2, EP3 - Extreme Pressure; 1-4 wt%
CI1, CI2, CI3 – Corrosion Inhibitor, Metal Passivator; 1-2 wt%
AW1, AW2, AW3, AW4 – Antiwear; < 1wt%

Load Carrying Extreme Pressure & Anti-wear



12.7 mm steel ball is rotated against 3 stationary balls

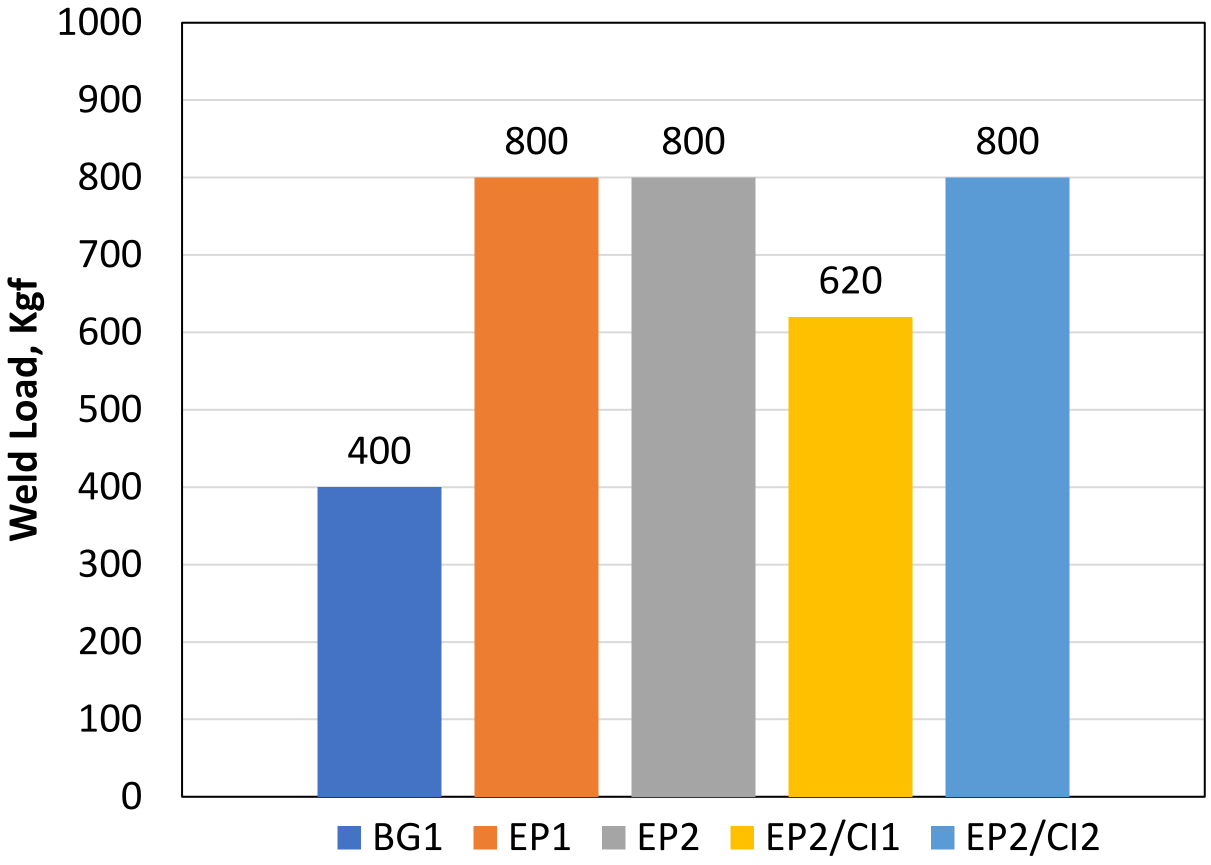
Test Conditions:
ASTM D2596: 1770 rpm, 25°C, 10 sec
Intervals at increasing loads

Test Conditions:
ASTM D2266: 1200 rpm, 75°C, 60 min

Copper Corrosion – ASTM D4048

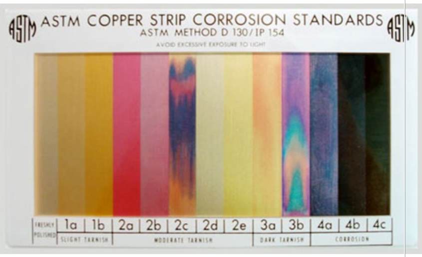
Summary of Test Method: A prepared copper strip is totally immersed in a sample of grease and heated in an oven or liquid bath at **100°C (212°F) for 24 hr**. At the end of this heating period, the strip is removed, washed, and compared with the Copper Strip Corrosion Standard.

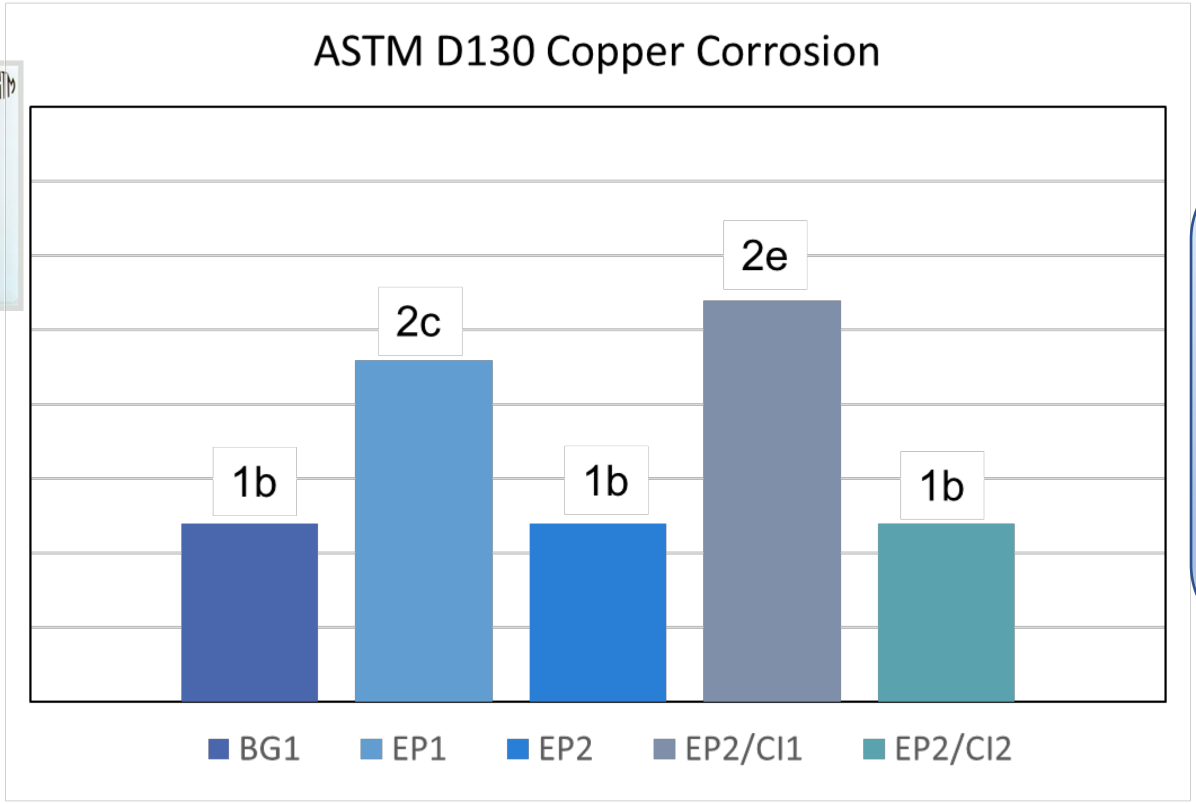
Study 1: Effect of EP & CI Additives on Weld Load in Lithium Complex Grease BG1



- Base grease reported 400 Kgf Weld
- EP1 & EP2 were able to improve weld substantially to 800 Kgf
- C1 derated Weld

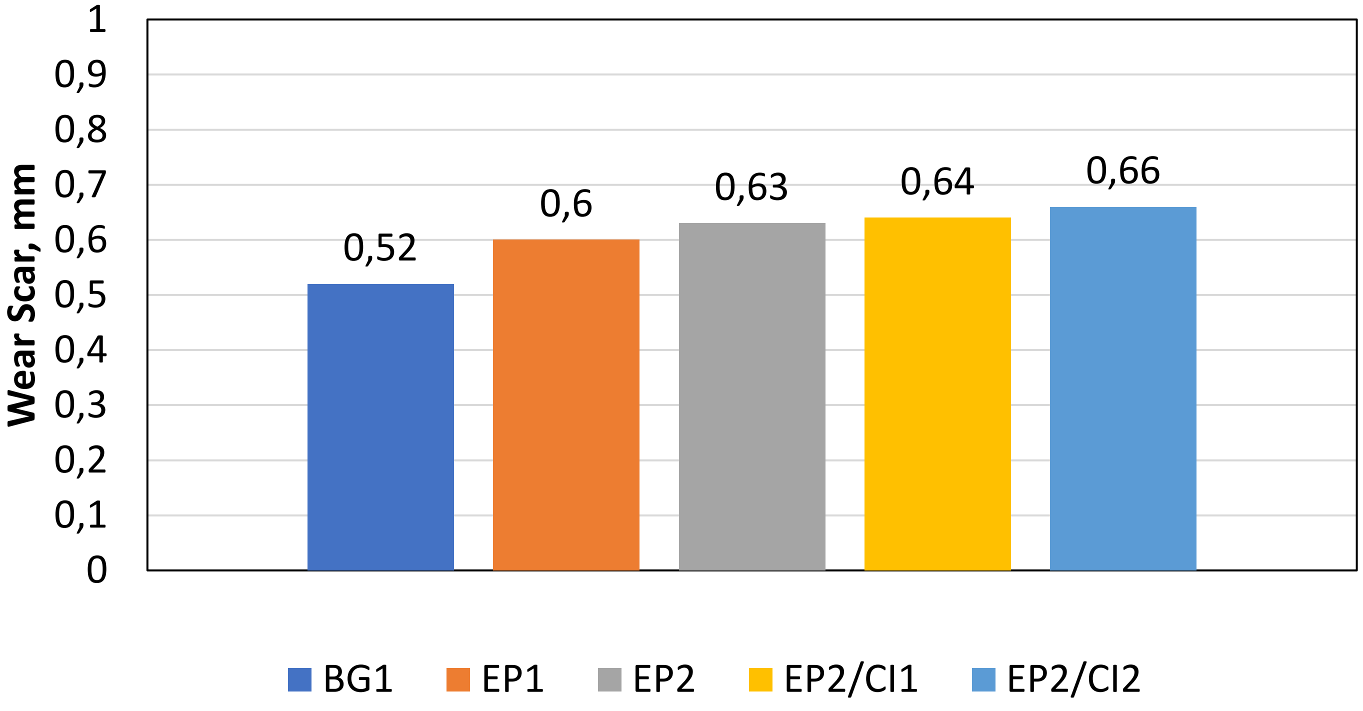
Study 1: Effect of EP & CI Additives on Copper Corrosion in Lithium Complex Grease BG1





- EP1 more severe than EP2
- EP2 affect no change in copper corrosion compared to the base grease. Result is atypical for EP at 800 kgf weld.
- Effect of EP2/CI1 derate weld and copper corrosion.
- Effect of EP2/CI2 did not affect weld or copper corrosion

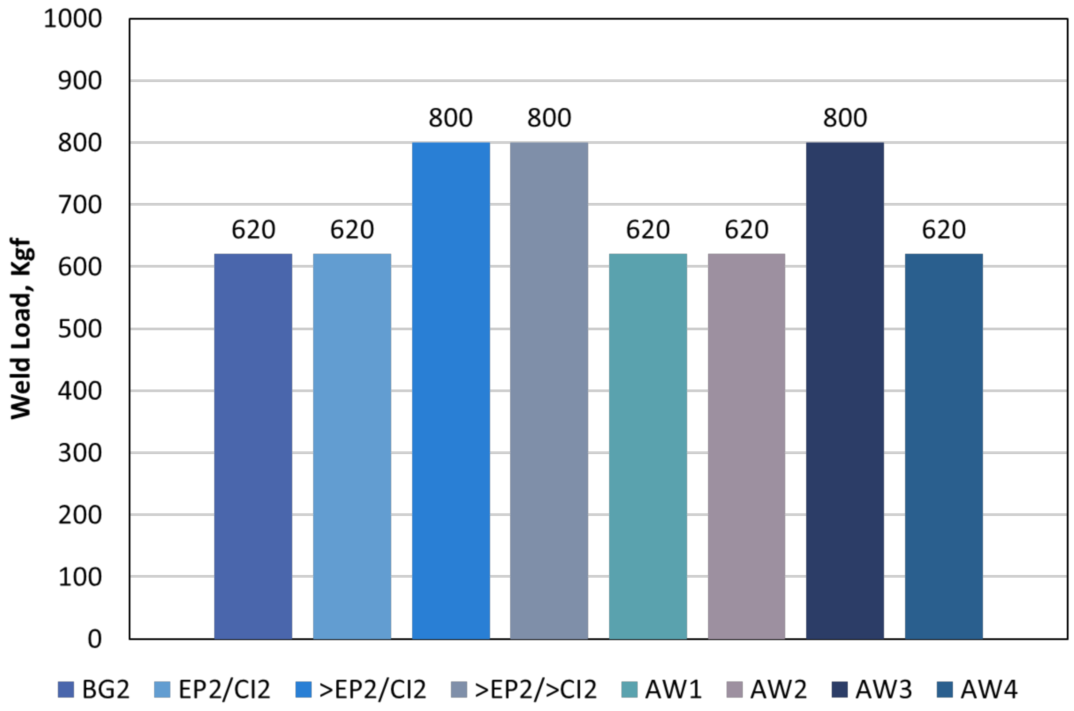
Study 1: Effect of EP & CI Additives on Wear Scars in Lithium Complex Grease BG1



- Combinations of EPs & CIs marginally ↑Wear Scars
- Early optimization for Welds & Corrosion can affect Wear
- Effect of AWs will be discussed next

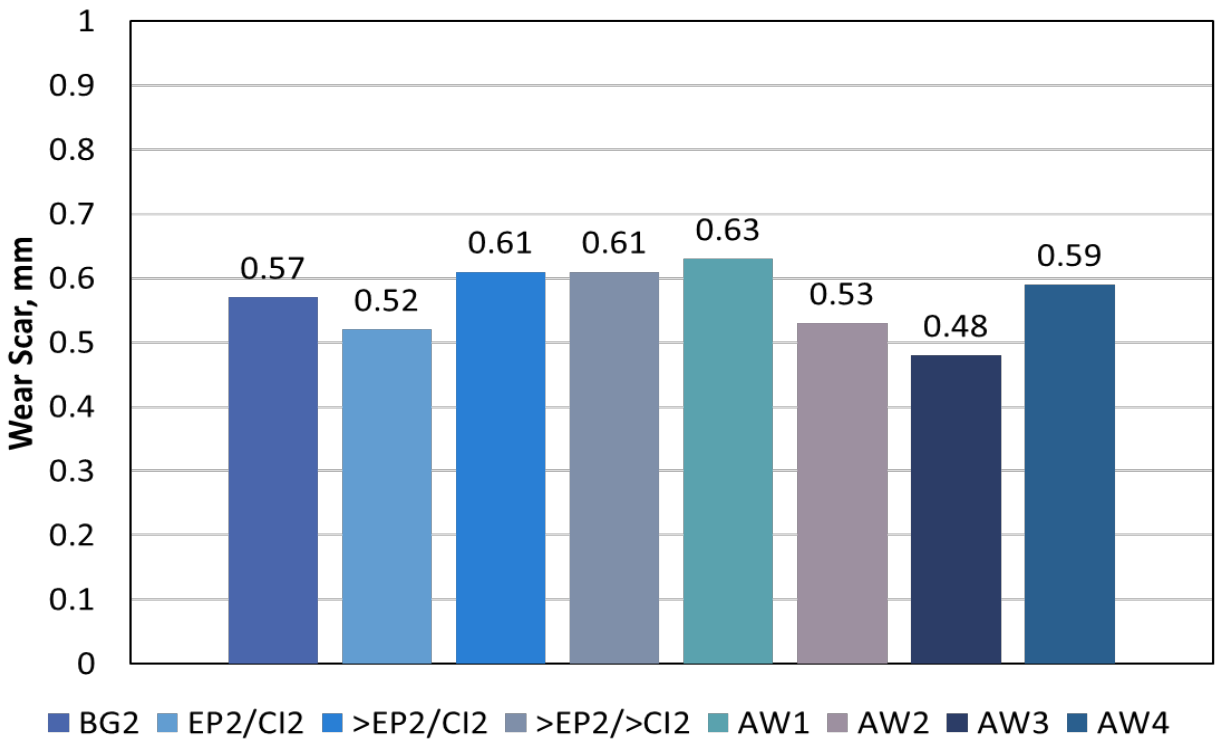
TRCC

Study 2: Effect of EP, AW & CI Additives on Weld in Calcium Sulfonate Grease BG2



- Effect of EP2 & CI2 were initially evaluated.
- Weld loads Increase EP2. No effect with CI2.
- AWs derate Welds.

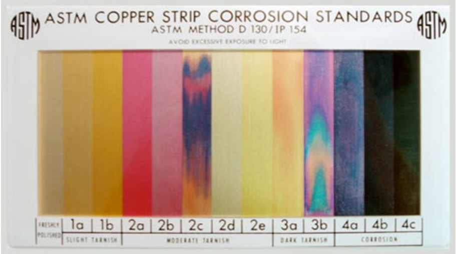
Study 2: Effect of EP, AW & CI Additives on Wear Scar in Calcium Sulfonate Grease BG2

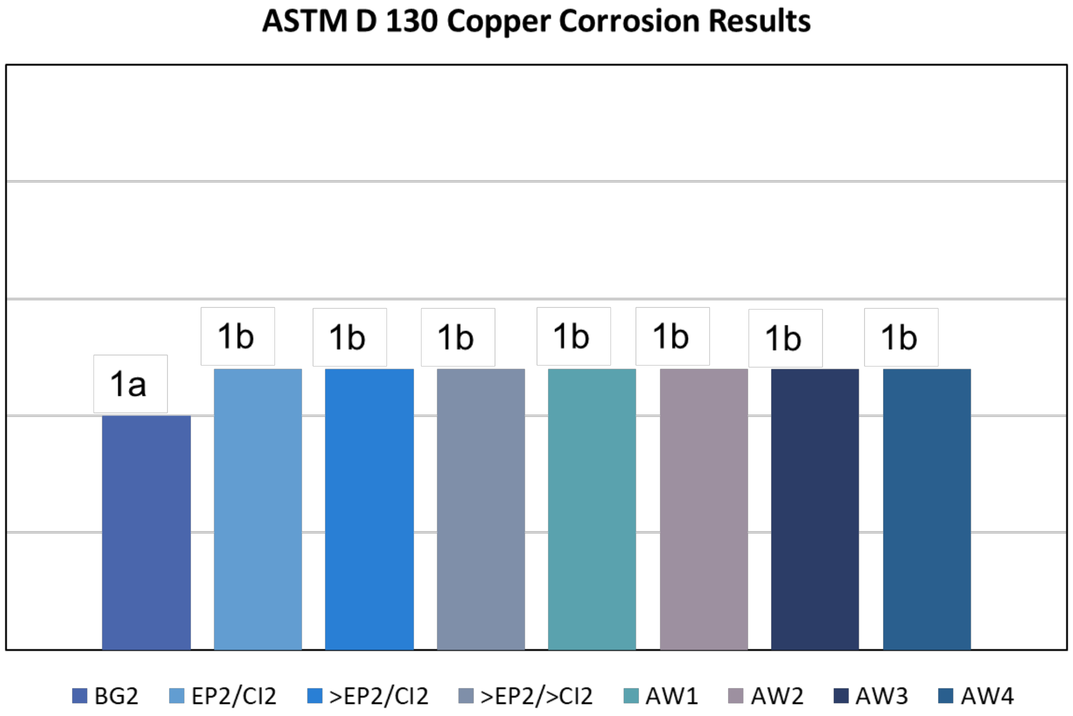


- Wear scars were derated with increasing level of EP2.
- Affect of CI2 on wear was minimal. AWs affect wear scars.
- Choice of EP additive can be critical for initial weld and wear balance.

TRCC

Study 2: Effect of EP, AW & CI Additives on Copper Corrosion in Calcium Sulfonate Grease BG2

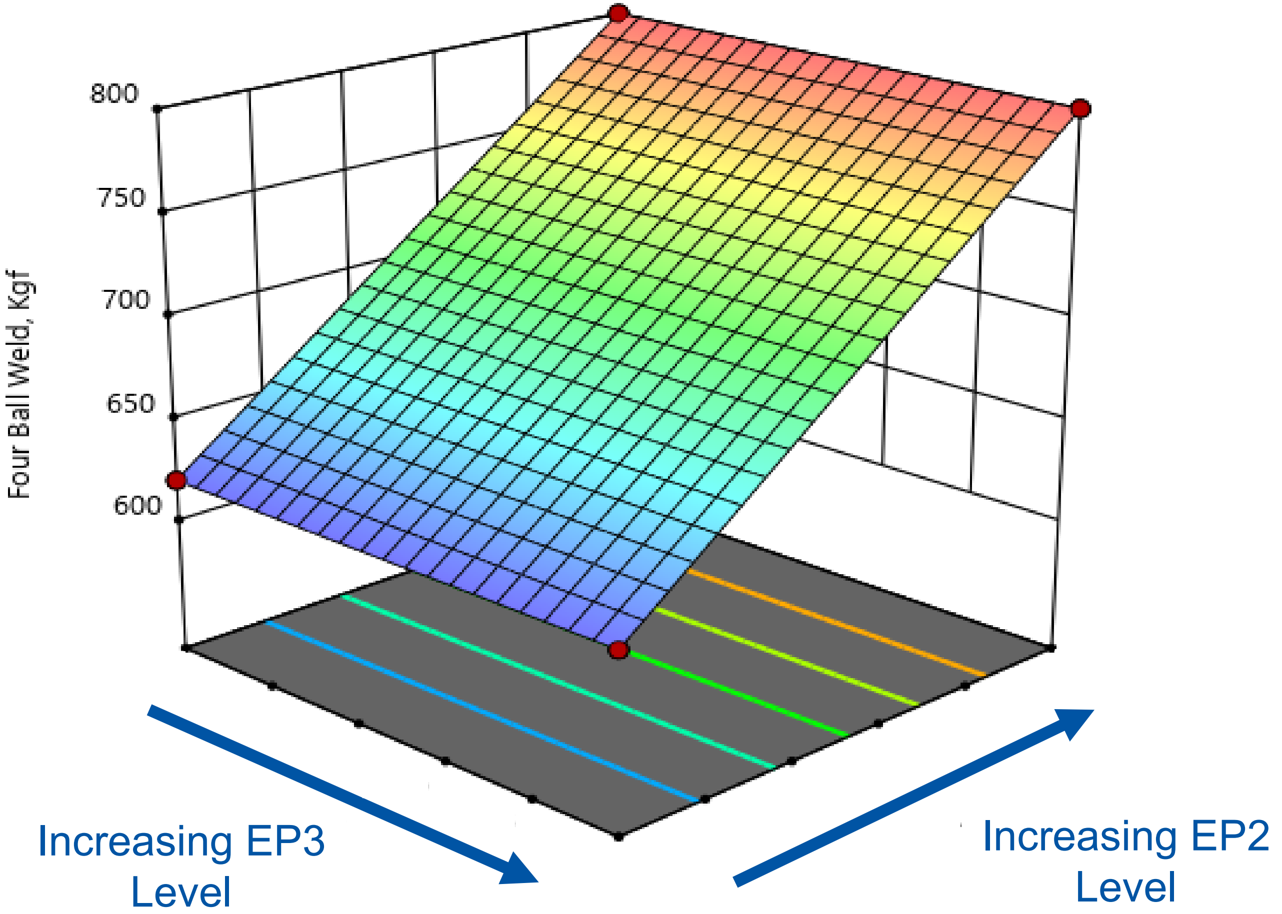




- Corrosion results not affected EP2 - CI2 & AWs
- Results were all favorable with ratings of 1b.
- Possible to optimize performance for weld loads, wear scar and copper corrosion with the proper choice of EP, AW and CI additives.

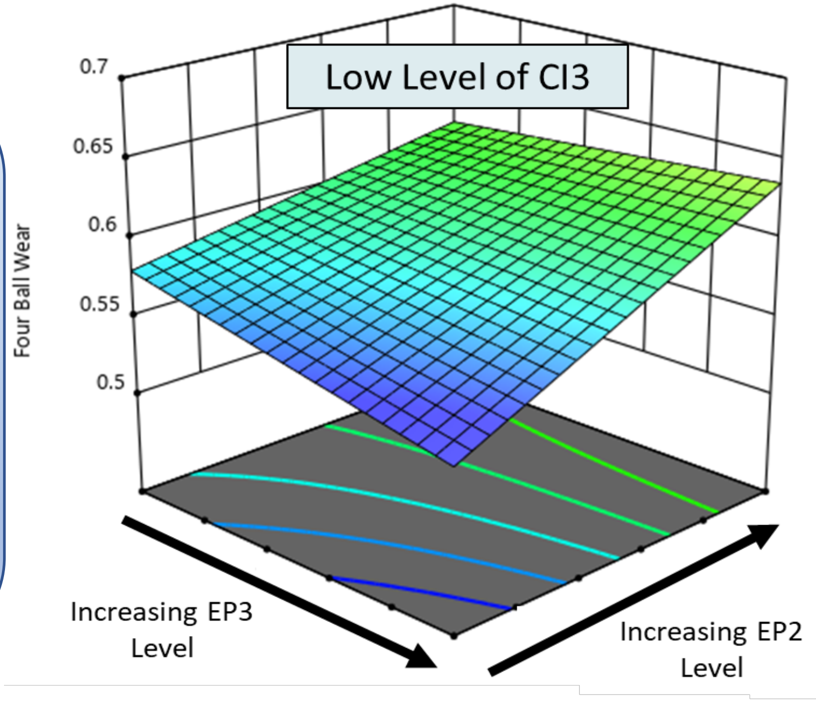
Study 3: Effect of Corrosion Inhibitor on Weld in Lithium Complex Grease BG3

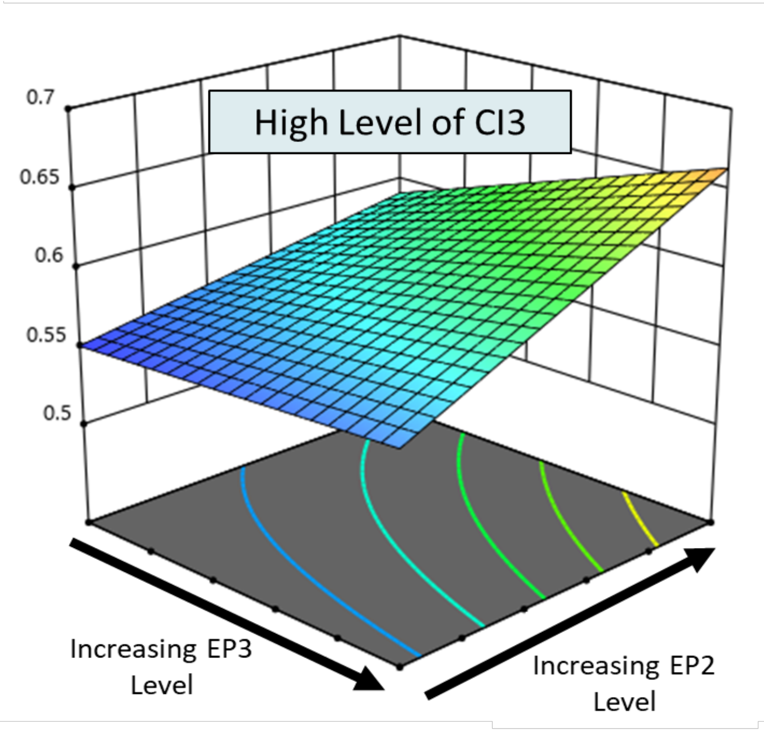
- Studied factorial combinations of EP2, EP3 & CI3
- EP2 > EP3 for Welds Loads
- Minimal Interaction with CI3



Study 3: Effect of Corrosion Inhibitor on Wear Scars in Lithium Complex Grease BG3

- Wear scars are affected by the level of CI3.
- Targeting ↓wear scars are ↑EP3, ↓EP2 & ↓CI3 & ↓EP2, ↓EP3 & ↑CI3.
- Copper Corrosion results similar to base lithium complex grease.
- Results show wide range in Wear performance in choice of EP & CI chemistries.





TRCC

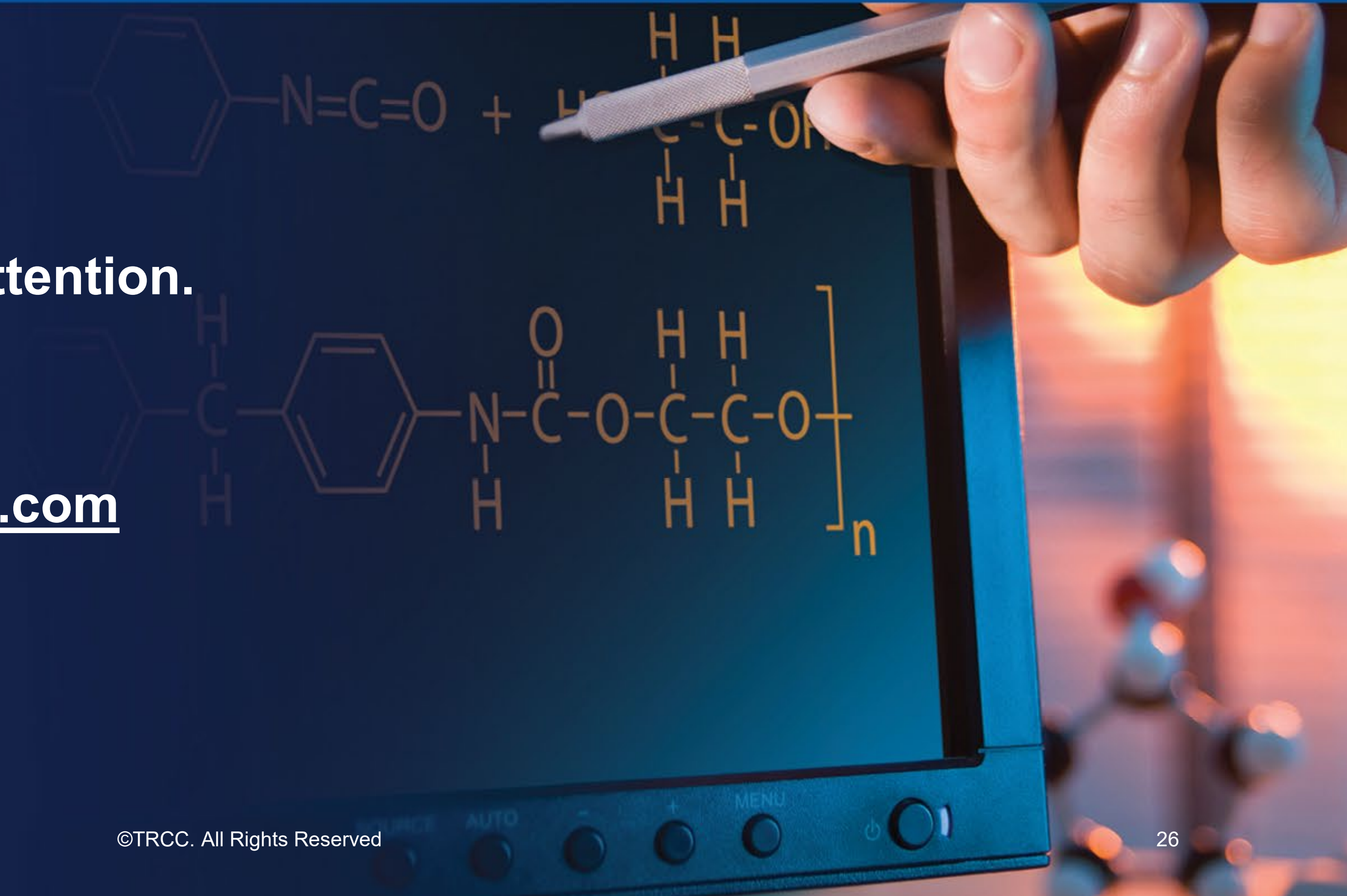
Conclusions & Summary

- Base Greases to be qualified for performance
- Choice of initial EP or AW additive important
- Optimization with EP, AW, CI, & others next steps.
- Grease performance for dropping point, oxidation, bleed, washouts
- Formulary design with performance additives can target to "simultaneously" increase weld and mitigate wear scars & corrosion
- Maximize captured synergies; minimize known antagonisms

TRCC

Acknowledgements

Author wishes to thank Conference Organizers and TRCC for the opportunity to present the results of this study.



Thank you for your attention.

Dr. Vasu Bala
TRCC
Email: vbala@trcc.com