Palo Verde Generating Station

Use of High Temperature Oven Aging to Determine COF of Candidate Greases as Oil loss within the Grease Occurred

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Presentation Overview

- Lubrication requirements for high temperature application
  - To use grease or a solid lubricant?
- Forecasting Grease Performance through Aging Strategies
  - Flat Panels
  - Mesh Cone
  - Pin and Vee
  - Full scale testing
- Discussion of test data
- Observations
- Questions?

Image from https://www.lelubricants.com/industrial-greases.html

The Technical Challenge

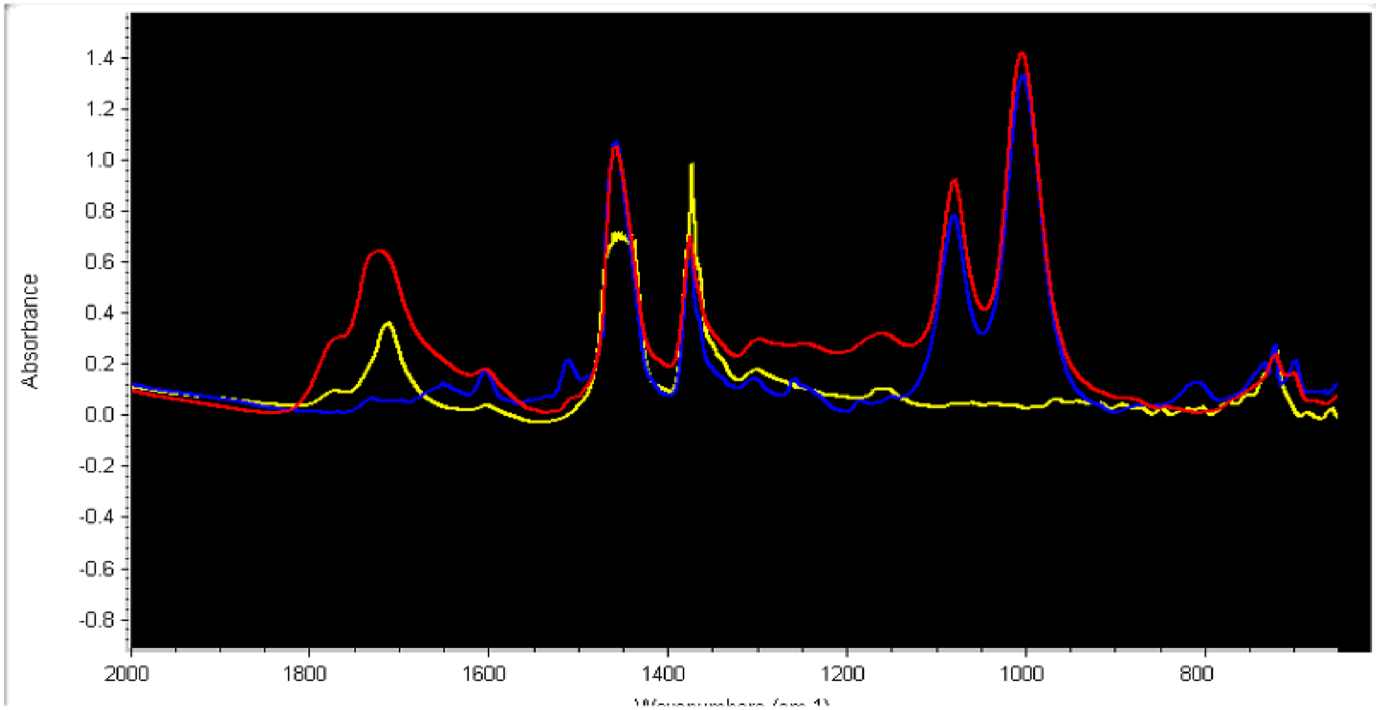
Difficult lubrication requirements included

- High temperature environment (285-185 F across ends of stem)
- Slow surface speeds at lubrication interface
- High expected loads
- Poor industry consensus on how to age grease and determine best product
- 18 Months needed

Additional Info

- Stem: Typ, ASTM A564 Grade 630
- Nut: Typ, ASTMB584 C86300
- Stem speeds from 0.006 ft/s to 0.1 ft/s

Field Example -Oxidized Grease



Key: Red is used Grease from a station stem / stem nut
Yellow is heavily oxidized oil
Blue is new fresh grease

In-service grease sample (Clay-Group I oil) extracted from valve stem / stem nut near a steam pipe. Grease felt pliable but was oxidized.

- Oil is a group I but not from the grease vendor
- Plant experience suggests that grease fails by drying out before it oxidizes
  - Plant experience suggests that <u>finding oxidized grease is extremely rare</u>

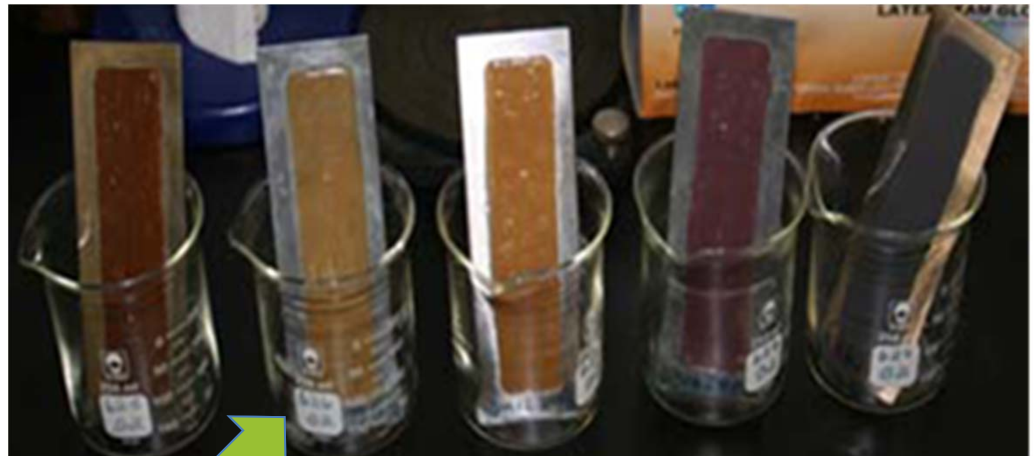
Lubricants Considered
(all marketed for high temperature applications)

Five Lubricants were considered for the application

- Clay thickened NLGI 2 grease with Group I Mineral oil
    - Used elsewhere in facility
- Clay thickened NLGI 2 grease with Ester base oil
- Lithium Soap NLGI 2 grease with Silicon base oil
- Calcium Sulfonate NLGI 2 with Group II Mineral base oil
    - Used elsewhere in facility
- Paste type solid lubricants
    - Eliminated as they “gummed up” with significantly increased friction
- Solid lubricant (Moly), applied by aerosol
    - Surprisingly this product dried out and lost significant mass in the oven temperature aging experiment. It was later learned that the aerosol carrier contained chlorides which could be detrimental to the lubricated surfaces. – This lubricant was eliminated from consideration

Flat Panel Oven Aging

(design of experiment)



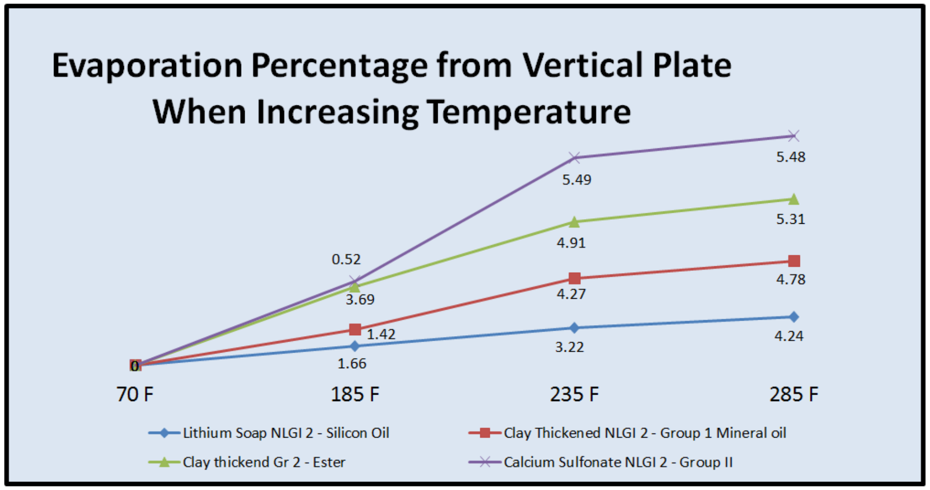
Vertical

Horizontal

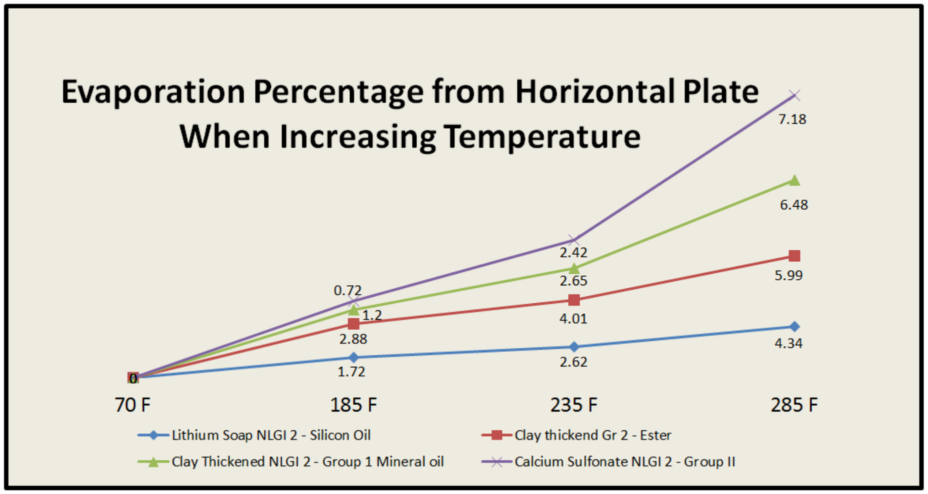
- Flat plate cut out / inset results in a controlled deposit layer of 1/32 inch
- Temperature controlled ovens are used to maintain desired test condition for "X" days
- All grease sample from new packaging

Images provided by SGS North America Inc. - Oil Condition Monitoring

Comparison of Grease Aging at Various Oven Temperatures



All test data after 168 hours of oven aging

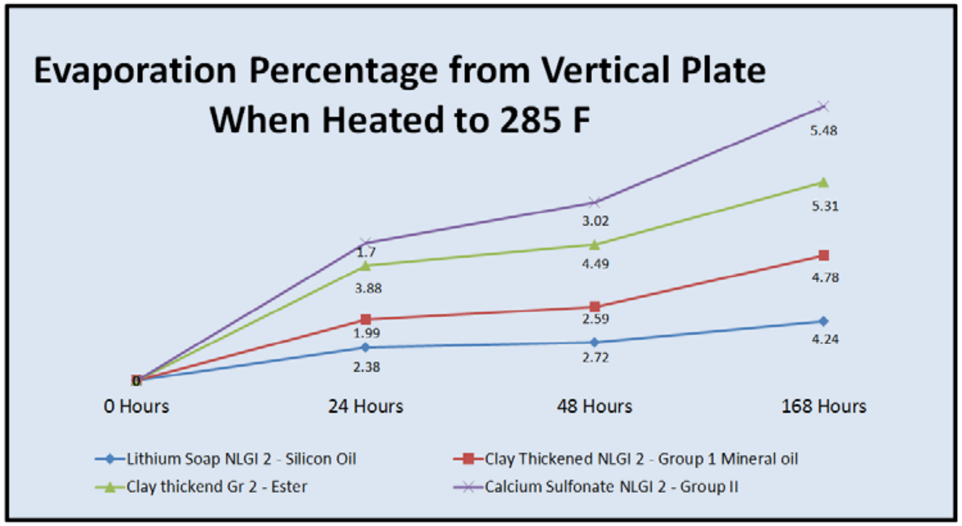


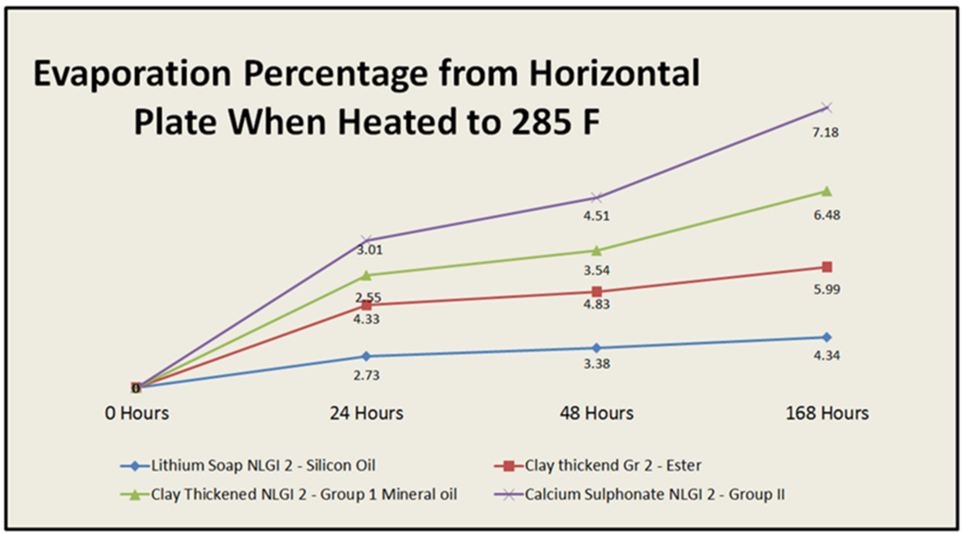
Other observations:

- Evaporation caused the most significant volume changes
  - Oil Loss occurred through evaporation and oil bleed
  - Calcium Sulfonate worst performer
- Bleeding wasn't evident for the horizontal plates
- Some bleeding observed in vertical orientation test variant
  - Calcium Sulfonate did exhibit bleeding @ 235 F (1.52 @ 24 hour, 1.70 @ 48 and 1.89 @ 168 hours)
  - No bleeding for the Clay thickened Group I base oil
  - Trace levels for the Lithium/Silicon grease and the Clay/Ester

Flat Plate Tests Progression of Oil Loss

(Hold 285 F temperature while measuring time progression)





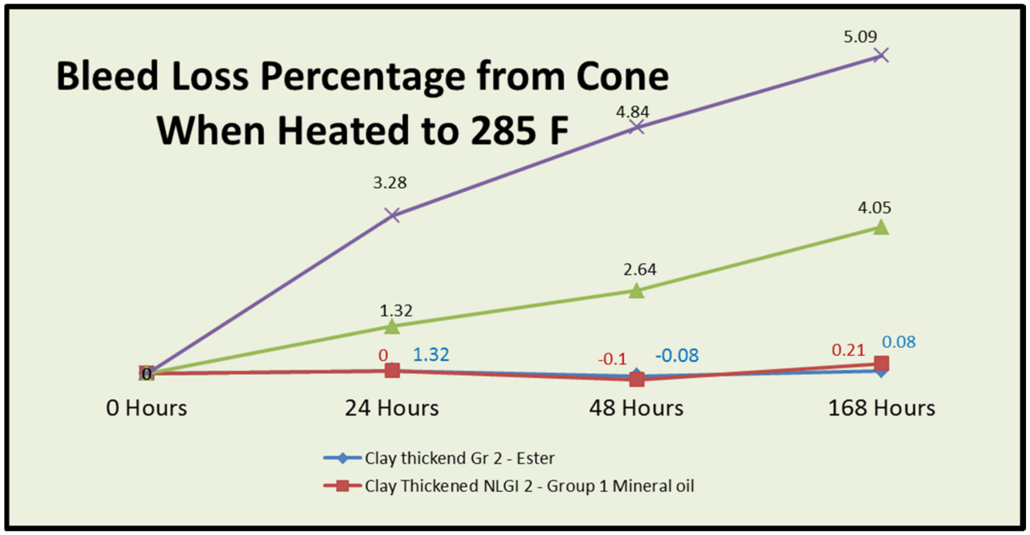
Oil Loss occurred through evaporation and oil bleed

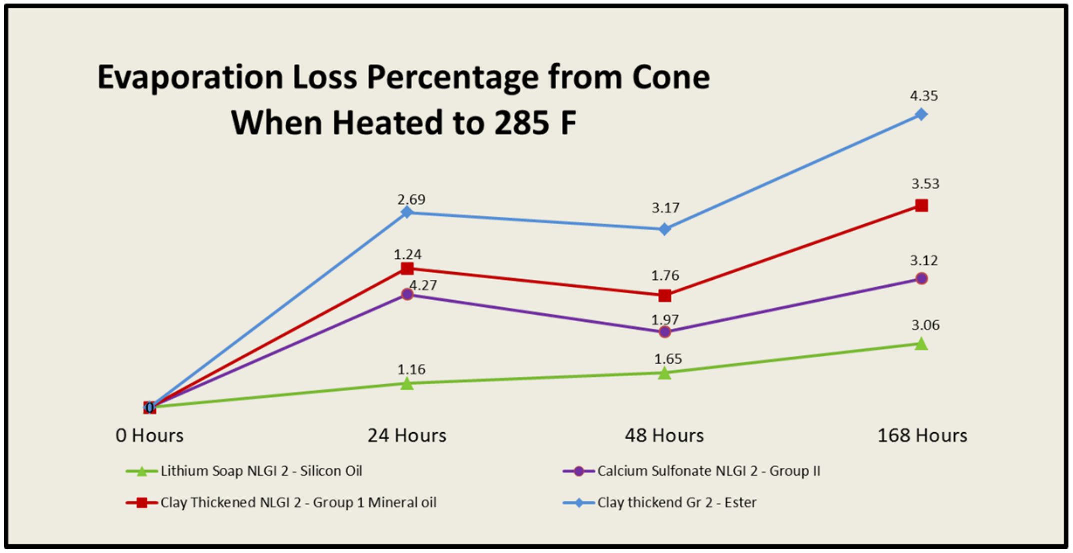
- Minimal oil loss occurred through bleed
  - Clay Gr 1 – 0
  - Clay Ester - 0
  - Lithium – 0
  - Calcium Sulfonate – 0.19 %
- Most volume loss was by evaporation (see to left)
  - Calcium Sulfonate worst performer

The Perforated Cone / Mesh Test

Bulk grease aging

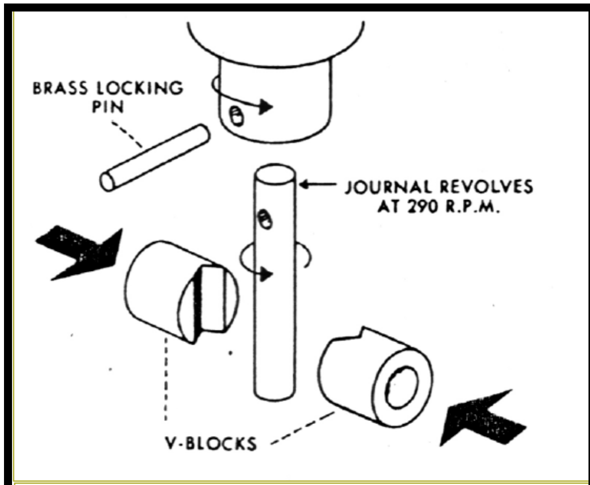
- Measures oil loss
- Accounts for both bleed and evaporation
- Evaporation most significant mechanism although more bleed occurred
    - Calcium Sulfonate worst performer



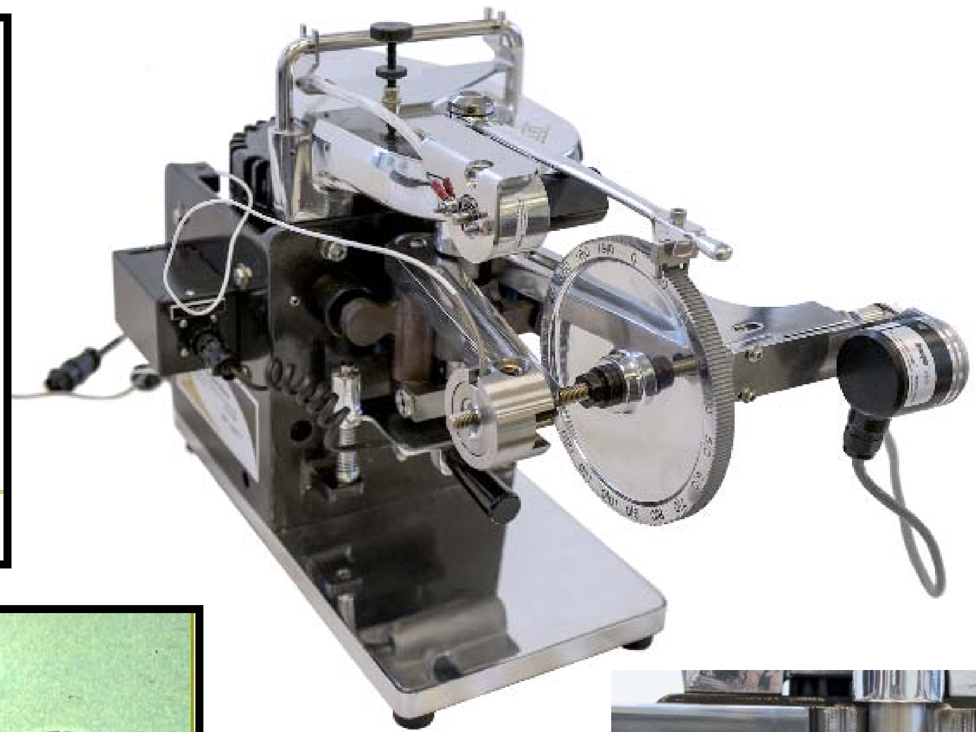


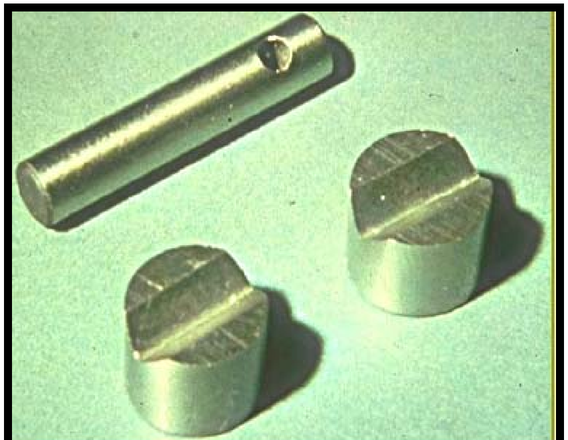
Cup images provided by SGS North America Inc. - Oil Condition Monitoring

Pin and Vee Instrument – Measures COF

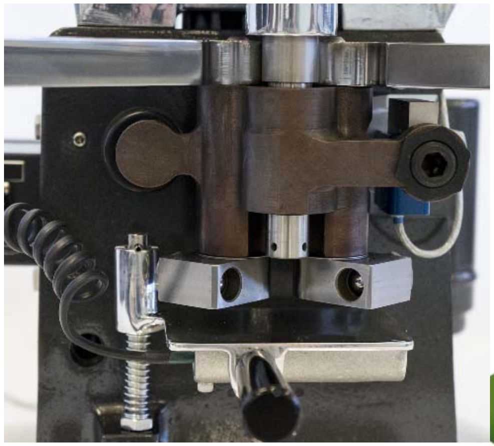


Pin & Vee Block Configuration



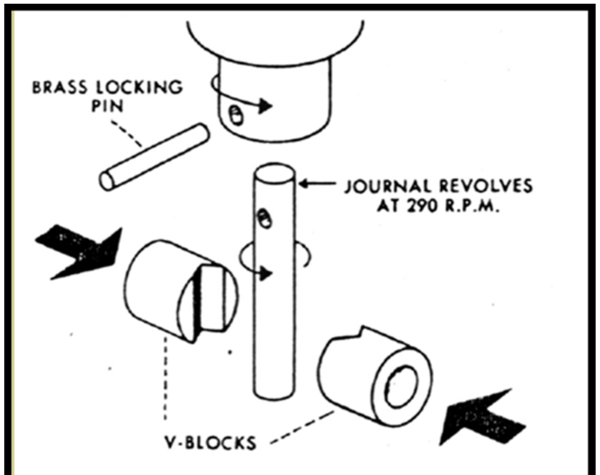


New Test Specimens

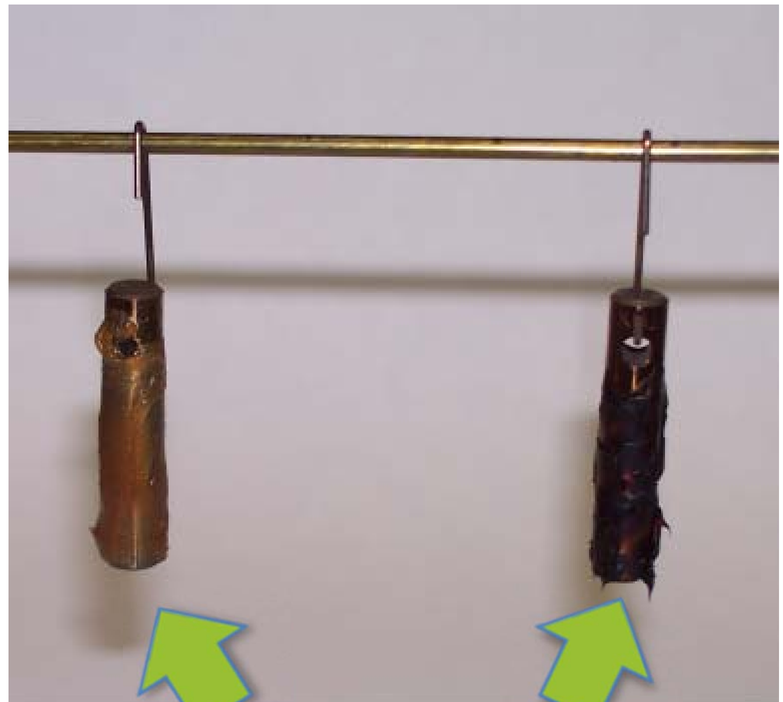


Images from https://www.falex.com/testing-instruments/

The Pins Shape Lend Itself to Oven Aging



Pin & Vee Block Configuration



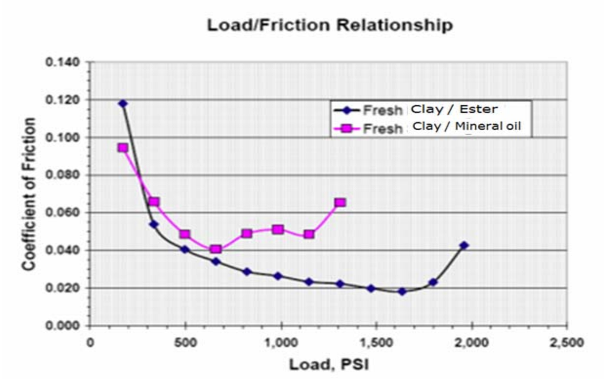
New pins - Left (Ester), Right Clay/Mineral

- 5 days oven aging at 340 F -

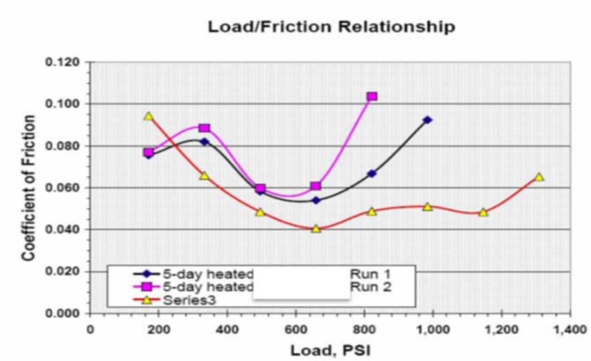
Failed pins following testing

- note: Vee blocks should be Vee' d, not rounded -

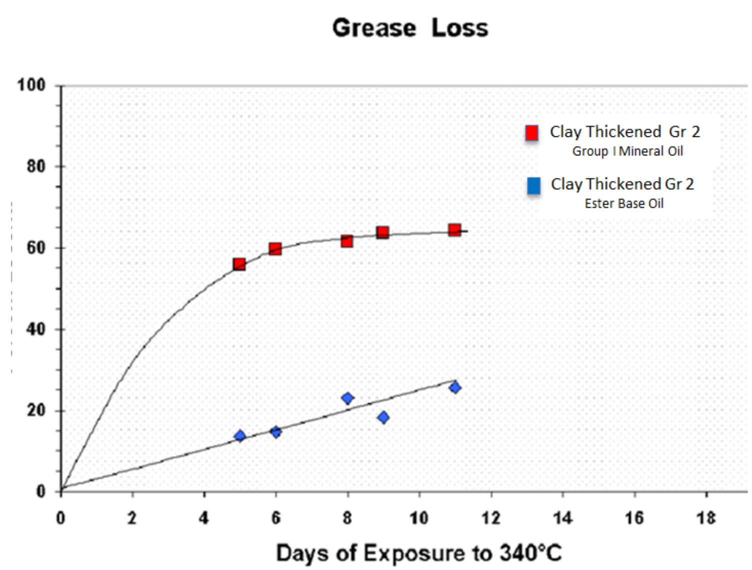
Pin and Vee Oven Aging @ 340 F

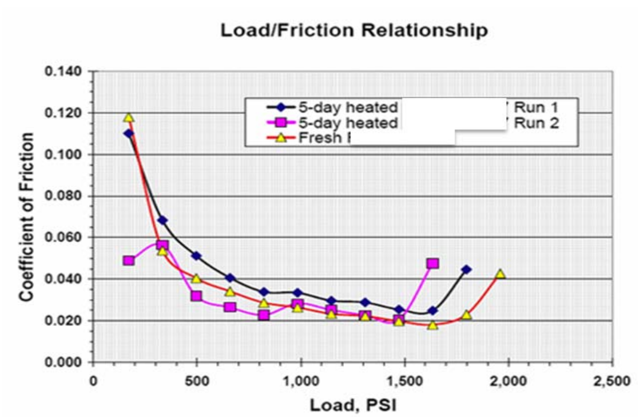


New Grease Baseline Performance



Clay Thickened / Mineral Oil
(Series 3 is new grease baseline)

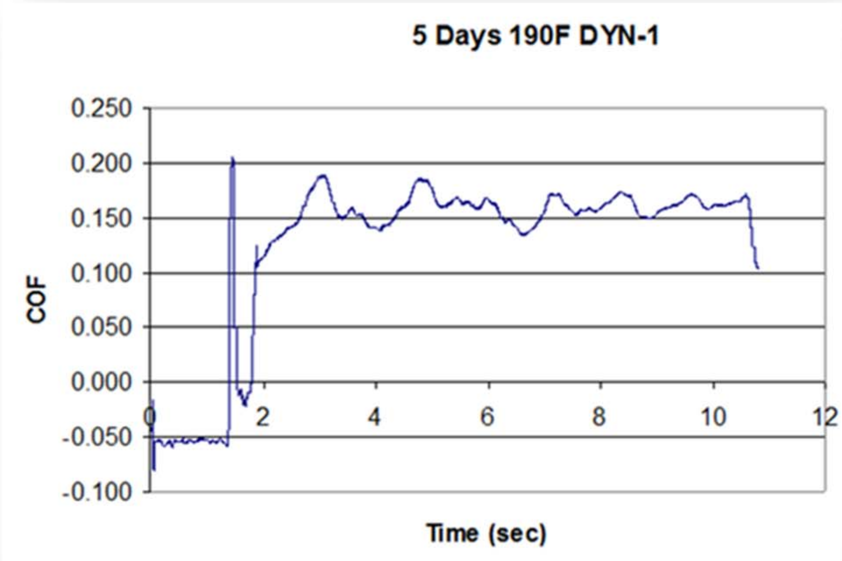




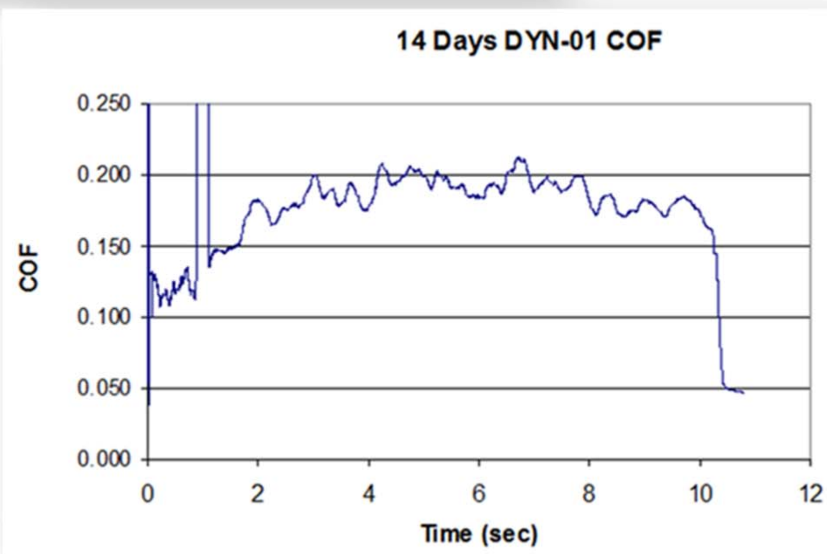
Clay Thickened with Ester Base oil

Each grease was started in the same oven with several like lubricant covered pins with pins removed by “X” day

Example of Full Scale Aged testing (@185 F)

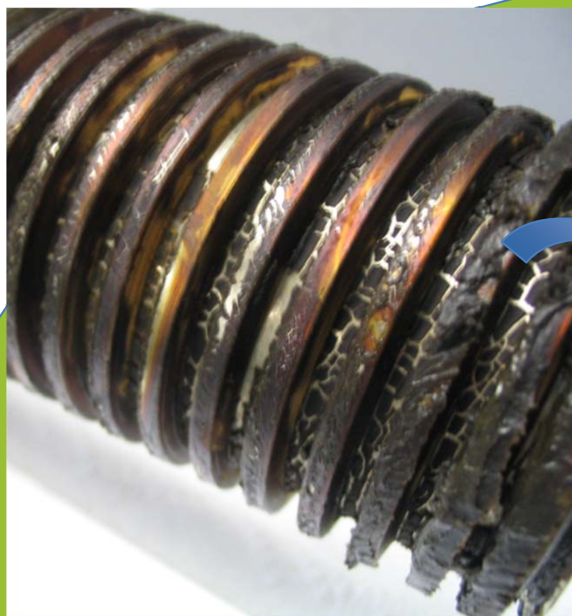


- Stem Nut moves relative to the stem for the time duration shown. Coefficient of friction is measured during the duration



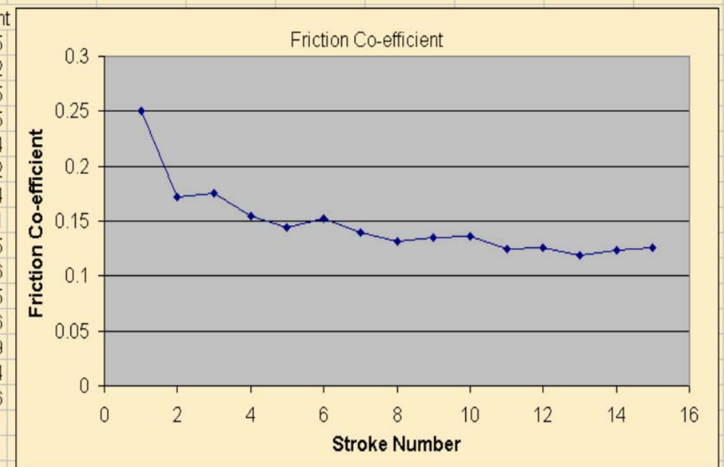
- Oven aged stem cover in grease
- Clay thickened Ester base oil grease shown

Clay Thickened / Group I Mineral Oil



Close-up of stem after removal from the oven

Stroke Number	Friction Co-efficient
1	0.25
2	0.172
3	0.175
4	0.155
5	0.144
6	0.152
7	0.14
8	0.131
9	0.135
10	0.136
11	0.125
12	0.126
13	0.119
14	0.124
15	0.126



Change in friction Co-efficient

112 Hours @ 340 F

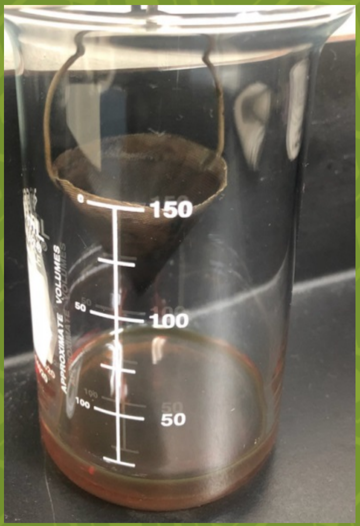
Close up of stem after 15 strokes of the valve

Observations

- Oil loss is more significant than chemical degradation (oxidation)
    - Plant experience based upon thousands of test samples using FTIR and grease consistency testing indicates that chemical degradation is extremely rare when the grease has failed by becoming hard.
- Oil loss through evaporation appears to be more significant than oil bleed
- Even with significant drying, some reconstitution of the grease is possible
- Oil loss may lead to a machine failure due to loss of transportation or an increased Coefficient of Friction/reduced load capacity
    - <u>Both of these factors</u> should be considered in any oven aging experiment used to forecast expected grease performance
    - The Pin and Vee option allow both a characterization of oil loss as well as an indication of friction performance

Plant experience based upon testing of in-service machine samples and this work suggests that the primary focus of grease aging testing should be on oil loss mechanisms rather than chemical degradation

Questions?



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