Abstract
Increases in traffic density, track utilization, and limited maintenance windows, are current challenges faced by the North American (NA) railroads. The demands for heavy haul traffic on available track-time will necessitate the use of rail steels with optimized performance and track maintenance practices that will extend rail life. A proven methodology to reduce rail wear and increase rail life in curves is the utilization of gage face lubrication. Canadian National (CN) Railway worked with EVRAZ Product Technology to develop and implement a laboratory disc-on-disc test methodology to evaluate the relative performance of gage face lubrication products. The test methodology employed was able to define the laboratory lubrication carry distance, dose interval to maintain or limit a maximum specified friction level, sample wear rate, deformation and rolling contact fatigue damage, etc. The laboratory results led to the selection of a refined subset of gage face lubricants for revenue service testing. The results also provided the lubrication manufacturers with quantifiable test data performed in a controlled and repeatable manner that allows accelerated feedback on product development.

Introduction
Rail life extension programs in heavy haul service include the utilization of high strength premium rail, which provides the highest resistance to wear loss and rolling contact fatigue, as well as utilization of gage face (GF) lubrication products, which manage high friction forces in curves to further reduce gage face wear. Increased traffic densities across North America (NA) have highlighted the necessity of prolonging rail life in curves, as maintenance opportunities consume valuable operational time. Revenue service tests have inherent challenges with regard to equivalencies from one test location to another, as curvature, traffic density, car loading and arrangement, etc. make selection of identical conditions improbable for multiple locations. EVRAZ Product Technology and CN Railway developed a laboratory twin-disc test method to evaluate the relative performance of seven (7) different gage face lubrication
products. The results of the evaluation were used to select products for revenue service testing, which reduced the number of test locations needed for the study and improved the data collection efforts at the test locations.

**MATERIAL**

Seven gage face lubrication products were submitted for twin disc testing. The identifications of the evaluated products are confidential to the CN Railway, and each GF lubrication product was assigned an alphabetical identifier for reporting purposes (A-G). Each supplier was provided the test results and informed of their alphabetical identifier.

Specimens for twin disc testing were prepared from the head portion of a head hardened rail as shown in the schematic of Figure 1. The twin disc test utilizes two disc samples that are in contact with each other and rotate such that the velocities of the two surfaces in contact are in the same direction, but may have different magnitudes to establish a relative slip condition. The first disc, as shown in Figure 1(a) represents the rail material, and for these experiments a 136RE section, high strength rail with a nominal surface hardness of 400 HB was selected. The specimen geometry of the rail sample is a right circular cylinder with a contact length of 0.14 in (3.5 mm) and a diameter of 1.77 in (45 mm). The surrogate wheel sample, as shown in Figure 1(b), is selected from a 136RE section, head hardened, intermediate strength rail which has similar strength, microstructure, and chemical composition characteristics of class C wheels used in NA heavy haul service. A rail material was selected to act as a surrogate to railway wheel steels in an effort to limit test-to-test variation. The specimen geometry of the wheel sample is a right circular cylinder with a 1.82 in (46.2 mm) diameter and a cylindrical height of 0.79 in (20 mm). Samples were machined from the rail head in a milling machine and finished by grinding to maintain consistent surface finish. Specimen geometries were designed based upon considerations of machine force and torque capacities, expected contact pressures and slip ratios, and the geometry of the rail section.

![Figure 1](image)

Figure 1 Schematic showing twin disc testing specimen design and location in the rail head for (a) the rail sample and (b) the surrogate wheel sample machined from High Strength and Intermediate Strength rail, respectively.

**TEST METHOD**

Disc on disc testing of the GF products was performed on a Wazau UTM 5000 tribometer. The test method consisted of application of a constant volume of GF lubrication product to the running surface of the rail sample during initialization. Then, as the applied force was increased, the rotating discs distributed the lubricant about the contacting surfaces of the two samples. GF lubrication product was applied to the specimen running surface using a micro-pipette with a dose volume of 0.0012 cubic inch.
(20 µL). The application method was evaluated by measuring accumulated mass and accumulated dose count by dosing onto a collection plate in a micro-balance. The micro-pipette GF application method showed excellent consistency with linear regression $R^2$ values approaching unity, and isolated deviations from linearity were due to air bubbles in the high viscosity grease.

An eddy current system was used to monitor for rolling contact fatigue cracks on the surface of the rail sample. The pencil probe eddy current system was calibrated to a disc sample with a reference flaw of 0.040 in (1.0 mm) length at an angle to the surface of 45° with a 0.079 in (2 mm) standoff height at a rotational speed of 400 RPM. An accelerometer sensor was used to monitor system vibration and a limit level of 4.8 ft/s² (0.15 g) was set to prevent equipment damage. A laser displacement gage was used to monitor in-situ displacement between the drives of the two discs and is a measure of combined wear and deformation between the two discs under constant applied force of the test. A force level corresponding to an initial contact pressure of 217 ksi (1500 MPa) was maintained constant for this test procedure, with a constant slip ratio of -3%. Equation 1 lists the calculation for maximum Herztian contact pressure, where the pressure distribution in the solid bodies will be a semi-elliptical prism of half-width $a$, which is determined through Equations 2-4 (1). Equation 5 lists the calculation for slip ratio where a negative value for slip ratio indicates that the surface velocity of the wheel exceeds that of the rail sample (2, 3).

$$P_{\text{max}} = \frac{2F}{\pi a L}$$

where $a$ is the half contact patch width, $F$ is the applied force, and $L$ is the contact length

$$a = \sqrt{\frac{F \cdot \frac{2(m_1+m_2)}{\pi B}}{L}}$$

where $B$ is a geometry constant and $m_i$ is the elastic constant of the material

$$B = \left( \frac{1}{R_1} + \frac{1}{R_2} \right)$$

where $R_1$ and $R_2$ are the radii of curvature of the respective bodies

$$m_i = \frac{1-v_i^2}{E_i}$$

where $v_i$ and $E_i$ are the Poisson’s ratio and Young’s modulus values of the respective body

$$\text{Slip Ratio} \times 100\% = \frac{2(V_{\text{Rail}}-V_{\text{Wheel}})}{V_{\text{Rail}}+V_{\text{Wheel}}}$$

where $V_i$ are the wheel and rail surface velocities

The test was designed to evaluate the ability of the GF lubrication product to maintain low friction under severe contact and slip conditions, and was termed the "carry distance" test in reference to the idea that the rail wheels carry GF product along a curve, and the longer the wheels can distribute product or the more dilute a product can be while maintaining the lubrication effect, the more effective the GF product. With a twin disc test, the lubricant deposited on the running surface is returned to the point of contact each revolution, unless it is diluted through expulsion out of the contact patch. The carry distance test evaluates the material’s ability to maintain lubrication under extreme dilution until the point when a friction threshold is exceeded. When the coefficient of friction (CoF) exceeded 0.3, additional lubrication was applied to the rail sample running surface, resulting in an immediate decrease in friction. The interval between doses typically decreased with cycle count because the surface material of the wheel and rail sample becomes damaged at the elevated friction state and begins to foul the GF product. The tests ran continuously until 50,000 cycles (rail sample revolutions) were achieved unless either a vibration limit or rolling contact fatigue crack extension limit were exceeded.

Evaluation of the performance of the GF products included the cycles to 1st dose application (termed the carry distance), the cycles and distance interval between required doses to maintain CoF<0.3 after the 1st dose, the wear performance, the total required doses of GF for the experiment duration (the number of high friction states achieved), the lateral expansion of the rail sample running surface from plastic deformation, and the surface rolling contact fatigue (RCF) damage evaluated by eddy current monitoring.

TEST DATA

Figure 2 shows examples of the full array of data collected during the test for (a) E-1 (lubricant E, test no. 1), (b) B-2, (c) G-3, and (d) D-3 which are presented in order of decreasing carry distance of initial
dose of lubricant. For each case, Figure 2 shows the maximum RCF flaw size as indicated by eddy
current signal; coefficient of friction determined from torque, normal force transducers and specimen radii;
normal force; specimen displacement; and vibration magnitude versus cycle data. The zero cycle
position is based upon the time at which the constant force level is achieved during test initiation, at which
point the displacement offset value for the elastic deflection of the load train is determined.

Samples E-1, B-2, and G-3 ran to the test completion of 50,000 cycles, whereas sample D-3 was arrested
at 49,955 cycles because the vibration limit was exceeded. The data in Figure 2 clearly show the
differences in the effectiveness of the initial dose of lubricant, where the E-1 sample sustained
approximately 24,000 cycles before requiring an additional dose, the B-2 sample was approximately
12,000 cycles, and the G-3 and D-3 samples required additional lubrication applications at less than
4,000 cycles. The displacement data shown in Figure 2 demonstrates the relative effectiveness of the
lubricants. In Figure 2(a) for the E-1 test, the displacement data shows negligible change up to the point
of the first additional application of lubricant, which shows that negligible wear occurs in the test while the
friction is maintained at the low level. However, when friction increases, the damage to the rail and wheel
materials results in the onset of material loss as shown by an increase in the slope of the displacement
vs. cycles data. Comparison of the displacement data between Figure 2(a), Figure 2(b), Figure 2(c) and
Figure 2(d) shows that the onset of the high wear rates coincides with the start of the high friction regime
where constant dose applications are required and is influenced by the intervals between doses. Another
difference evident in Figure 2 is the effect of the lubricant on the development of RCF cracks as shown by
the maximum crack size data. The data in Figure 2(a) and 2(b) exhibit no sustained RCF crack
propagation, indicating that any RCF growth was removed through wear losses. In contrast, the data in
Figure 2(c) and 2(d) show steady propagation of RCF cracks even with sustained wear losses throughout
the tests.
Figure 2 Disc on disc test data of maximum RCF crack size from eddy current signal, coefficient of friction, applied force, displacement (black line, negative value indicates wear losses), and vibration (red line) versus cycles for samples (a) E-1, (b) B-2, (c) G-3, and (d) D-3.
Figure 3 shows representative photographs of the rail running surface after testing for the evaluated GF lubrication products. The photographs in Figure 3 show that the running surface of the rail samples all exhibit surface damage. The apparent severity of the surface damage from the surface examination showed reasonable correlation with the magnitude of the estimated flaw size from the \textit{in situ} eddy current signal.

![Representative photographs of the rail sample running surface after testing for each evaluated GF lubrication product, 0.079 inch = 2 mm.](image)

**RESULTS**

Figure 4 shows CoF and displacement versus cycles data from sample C-1, with annotations indicating the definitions for additional measurement terms. Figure 5 shows an individual value plot of cycles to the 1\textsuperscript{st} dose for each test; the individual tests are shown as the grey circles and the mean value for each GF material is shown as a black triangle. The data in Figure 5 show that the consistency between replicates was good and that there are discernable performance differences between different GF materials. Materials D, F, and G exhibited the shortest durations to first dose at less than 10,000 cycles. Materials A, B, and C exhibited the next longest durations to first dose at between 10,000 and 25,000 cycles. Material E exhibited the longest overall duration to first dose at greater than 25,000 cycles.
Figure 4  CoF and displacement versus cycles for sample C-1, showing definitions of additional measurement terms used to compare GF lubrication products.

Figure 5  Individual value plot of cycles to first dose for the evaluated GF lubrication products. The grey circles are individual test results and the black triangles are mean values for each GF product.

Figure 6(a) shows an individual value plot of the mean dose interval (not including the initial dose at startup) converted to linear distance for the evaluated GF lubrication products. The dose interval was evaluated as the number of cycles between the \( i^{th} \) dose and the \( i+1^{th} \) dose as demonstrated in Figure 4. The value of the mean dose interval was converted to linear distance based upon the initial circumference of the rail sample. The interval distance data in Figure 6(a) indicates the relative ability of the different GF lubrication products to maintain low friction conditions under non-ideal conditions, i.e. when high friction has already been achieved and wear debris is present on damaged surface layers. These data should not be construed as guidelines for positioning of lubrication applicators. While in individual tests, the interval period can exhibit variability throughout the test as shown in Figure 2(a) and Figure 2(d), as well as highly repeatable behavior as shown in Figure 2(c) and Figure 2(d), the average behavior from test to test shows excellent agreement as exhibited in Figure 6(a). Figure 6(b) shows a plot of the total number of GF lubrication doses (not including the initial dose at startup), which is the also the number of times the twin disc test achieved a high friction state, versus the mean interval distance. It is apparent that as the mean interval distance between required GF applications decreases, more overall GF product is required.
in order to maintain CoF<0.3 and the disc samples are exposed to more occurrences of high friction contact stresses.

Figure 6  (a) Individual value plot of mean interval distance (converted from cycles) between doses required to maintain CoF<0.3 for the evaluated GF lubrication products. The grey circles are individual test results and the black triangles are mean values for each GF product. (b) Effect of mean interval distance on the number of high friction states and doses required to maintain CoF<0.3.

Wear was evaluated using two separate measurements: the mass loss of the rail and wheel samples and the change in displacement during the test under constant load. As shown in Figure 2 and Figure 4, the change in displacement during the low friction cycles where CoF<0.15 was negligible. Therefore, the number of cycles in the high friction state were determined as demonstrated in Figure 4, and the wear rates for a test were calculated by dividing the mass loss and change in displacement by the number of high friction cycles in the test. Figure 7 shows individual value plots of the (a) wear rate by mass loss of the rail and wheel sample and (b) wear rate by total displacement change during the test versus material code for the evaluated GF products. Figure 7(c) shows a comparison of wear rate by mass loss to wear rate by displacement change, which exhibits excellent linear agreement between the two methods. Wear rate was also evaluated at the highest sustained slope in the displacement versus cycles data for each test, as shown in Figure 7(d). Of the various methods to evaluate the wear performance in disc-on-disc testing, the mass loss method shows excellent agreement with the total displacement method, and is approximately equivalent to the instantaneous slope method shown in Figure 7(d).

The lateral expansion of the rail sample running surface was measured at the end of the test and is compared against the number of high friction cycles in Figure 8(a) and against the number of high friction states (GF lubrication doses) in Figure 8(b). The data in Figure 8(a) seem to exhibit two bands of data, where GF lubricants A, B, C, E, G all exhibit lower lateral expansion intercept behavior in comparison to the behavior of the D and F lubricants. However, when compared against number of high friction states, or doses of the GF lubrication required to maintain CoF<0.3, the lateral expansion shows a linear increase with number of high friction states. The lateral expansion measurement is an indication of degree of plastic deformation induced in the rail sample during the disc-on-disc test, and should increase with plastic ratcheting occurring during high friction cycles. A revenue service corollary of this behavior could be shear lip development in the fish corner under flanging contact conditions.
Figure 7  Wear rates for the evaluated GF lubrication products through (a) total mass loss measurements and (b) total displacement change measurements, normalized by the number of high friction cycles. (c) Wear rate by mass loss versus wear rate by total displacement change for the evaluated GF lubrication products. (d) Individual value plot of wear rate measured in the high friction regime. The grey circles in (a), (b), and (d) are individual test results and the black triangles are mean values for each GF product.

Figure 8  Rail sample running surface lateral expansion versus (a) number of high friction cycles and (b) number of high friction states or required doses of lubrication required to maintain CoF<0.3 for the evaluated GF lubrication products.
DISCUSSION

The effectiveness of the GF lubrication product on managing friction, wear, and RCF damage can be evaluated through sub sized twin disc testing. Figure 9 shows the influence of the carry distance on the sample wear loss and RCF damage development, where carry distance is defined as the number of cycles to the first additional application of lubrication. Figure 9(a) shows that the wear losses are greatly reduced with increased carry distance of the GF lubrication product. Figure 9(b) shows the average flaw size determined by eddy current in the rail sample during the final 1,000 cycles of the test are reduced with increased carry distance performance of the GF lubrication products.

Considering all of the tests, in the high friction regime where nearly continuous GF applications were required to maintain CoF<0.3, the shorter the intervals between doses, the steeper the slope of the displacement vs. cycles data. Figure 10 shows the high friction wear rate (from the slope of the displacement sensor data) versus the mean interval distance (as determined by converting the timing of the required lubrication applications to maintain CoF<0.3). The data show a general trend indicating that wear rates are reduced through increased effectiveness of lubrication in the high friction state. In other words improvement to the friction control in regimes with wear debris and surface damage appear to improve wear performance.

The data in Figure 6(b) shows that the quantity of GF lubrication product required to maintain friction control increased as the mean interval distance decreased. Figure 8(b) shows that the plastic
deformation in the rail sample increased with the number of doses of GF lubrication required to maintain low friction. With a shorter interval distance between doses, the contact surfaces experience more occurrences with damaging high friction contact conditions. Figure 11(a) shows that the wear losses from the rail sample are influenced by number of high friction states, i.e. doses of GF lubrication during the twin disc test. Figure 11(b) shows a plot of the correlation between the RCF damage on the rail sample at the end of the test and the amount of wear loss from the rail sample. The interpretation of these results is that with low carry distance levels and short interval distances the number of high friction contact stress states and GF doses increase, the resulting damage results in deformation and RCF damage accumulation and increased wear loss. It is apparent from this data that higher wear rates do not necessarily mitigate RCF damage propagation in the presence of friction management products.

![Figure 11](image)

Figure 11 Relationship between rail wear mass loss and (a) number of high friction states (GF lubrication doses) and (b) average final flaw size in the rail sample.

CONCLUSION

The effectiveness of GF lubrication products on managing friction, wear, and RCF damage was evaluated using sub-sized twin disc testing. The twin disc results showed that the carry distance (the longevity of the initial application of GF lubrication) was an important metric for lubrication efficacy that influenced wear and RCF damage accumulation. Continued application of lubricant beyond the first instance of high friction allowed the wear, deformation, and RCF damage development to be evaluated. These factors were also correlated with measurable lubrication effectiveness parameters such as interval distance, dose count and number of high friction contact stress states, and initial carry distance. The carry distance, dosing interval, and wear performance characteristics were included in the selection process of GF lubrication products for continued evaluation leading to revenue service testing.

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Canadian National Railway & EVRAZ Laboratory Evaluation of Gage Face Lubricants Using Disc-on-Disc Testing

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Outline

• Introduction
• Experiment design
• Disc on disc machine and samples
• GF lubrication application
• Example data
• Analysis of data
• Conclusions
Introduction

- Heavy haul strategies for rail life extension include
  - Use of premium rail steels
  - Grinding
  - Gage face and top of rail lubrication

- CN Railway wanted a method to evaluate the performance of various gage face lubrication products
  - Inherent difficulties with test curves
  - Limit number of required revenue service test curves

- EVRAZ and CN Railway developed disc-on-disc test to screen GF lubrication products
  - 7 different GF lubrication products, identified A-G
  - Results were used to select products to proceed with for revenue service testing
Experiment Design: Carry Distance and Friction Management

Test design is to evaluate:
- Ability of Gage Face (GF) product to lubricate in severe conditions
- Response on the wheel / rail contact and GF lubrication response after deterioration

### Disc on Disc Test

**Stress and Slip Conditions**
- 217 ksi (1500 MPa)
- -3% Slip
  - Sufficient to result in damage
  - Not so much damage to trigger machine alarms

**Carry Distance**
- Initial Dose
  - 0.0012 in³ (20 µL) / Dose
  - Applied on Force Ramp
  - How long does the initial application last?

**Friction Management**
- Total of 50,000 Cycles
- Additional Doses @ CoF > 0.30
  - How effective is lubricant once damage has occurred?
  - How much damage occurs to wheel + rail samples?
Machine Capacity
- 5000 N Force Capacity
- 50 N-m Torque Capacity
- 3000 RPM, independent drive spindles

Auxiliary Sensing
- *in-situ* eddy current & vibration

GF Application
- Micro-Pipette Dispenser
  ~10-50 µL / dose
  - 1 mL Pipette tip, set to 50 doses \(\rightarrow\) 20 µL / dose
Disc on Disc Samples, Steel and GF Materials

**Rail Sample**
- Head Hardened
- Rail: ~400 HB
- Ø = 1.77 in (45 mm)
- 0.14 in (3.5 mm) length

**Wheel Surrogate**
- Head Hardened IH
- Rail ~360 HB
- Ø = 1.82 in (46.2 mm)
- 0.79 in (20 mm) length

**Gage Face Lubricants**
- 7 GF Lubricants were evaluated
- Alphabetical identifier: A-G
- Identities were maintained confidential to the CN
- Coded results were transmitted to the GF lubrication suppliers and each supplier was notified of their identifier
- Triplicate tests (min) performed for each GF lubricant
Initial Dose – Distribution of Initial GF Application

Drive #1 “Wheel”

Drive #2 “Rail”

Picture #1

Picture #2

Picture #3

Pictures show excess material is uniformly distributed about Wheel sample.

Excess pushed to edge of contact area.

∴ Contact Band Saturated
GF Lubrication Application Method

- GF application method shows superb linearity
- Deviations were due to air bubbles in high viscosity liquid
- Linear regression statistics

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Normalized Accumulated Mass, 0-1

Scatterplot of A-Norm, B-Norm vs Application

- Linear regression statistics
- Air Bubble
- Dose Count
- 0.0012 in³/dose (20 µL/dose)
Disc on Disc Test Data

- Applied force is constant
- Cycles (rail sample revolutions) based upon start of constant force segment
- Coefficient of friction (CoF) calculated from Torque, Force, Geo
- Eddy current estimate of max crack size
- Displacement measures *in situ* wear
- Vibration measures surface running quality (safety)

Lubricant E
Test No. 1
50,000 Cycles

1 initial dose additional doses at COF>0.30

- $\sigma_0 = 217.5$ ksi
- -3% Slip Ratio
- 400 RPM

Displacement (inch)

Force (lbf)

Coefficient of Friction

Vibration (ft/s²)

Cycles
Key Characteristics

- Initial dose provides lubrication effectiveness for initial time period
- Negligible wear occurs during this period of high lubrication

- When the *initial* lubrication fails the friction increases until CoF>0.3
  - Onset of damage + wear
  - Start applying *additional* doses
- After the initial onset of wear, addition of lubrication is less effective
What we evaluate from the data...

- Cycles to 1\textsuperscript{st} additional dose
  - “Carry Distance” – longevity of initial GF lubrication
- The interval between lubrication doses
  - Total number of high friction states (required doses)
- Cycles in Low / High friction
- Wear: Mass loss & displacement
- RCF Flaw Size
  - Average of the last 1,000 cycles
Comparison of two tests / lubricants

Lubricant E
Test No. 1
50,000 Cycles

Max Crack Size (inch)

Coefficient of Friction

Force (lbf)

Displacement (inch)

Vibration (ft/s²)

σ₀ = 217.5 ksi
-3% Slip Ratio
400 RPM

1 initial dose
additional doses at COF > 0.30

Lubricant D
Test No. 3
49,955 Cycles

Max Crack Size (inch)

Coefficient of Friction

Force (lbf)

Displacement (inch)

Vibration (ft/s²)

σ₀ = 217.5 ksi
-3% Slip Ratio
400 RPM

1 initial dose
additional doses at COF > 0.30
Cycles to 1st additional lubrication dose
CoF > 0.3

Cycles (avg.) between lubrication doses to maintain CoF < 0.3
Measures of Damage – Wear, Deformation, RCF

Wear (mass loss) of rail + wheel sample per cycle in high friction

Expansion of running surface, measure of plastic deformation

RCF damage at end of test, ave. of last 1,000 cycles
Influence of Initial Carry Distance (Cycles to 1st Dose)

- GF products that have good carry distance show less wear losses
- GF products that have good carry distance show less RCF damage

1 lb = 7000 grains
15.4 grains = 1 gram
0.04 in = 1 mm
As the interval between doses increases

The total number of doses (high friction states) decreases

Decreases the exposure to damaging high friction conditions
Friction Management
Number of High Friction States (Doses)

Short dose intervals result in more accumulated exposures to high friction...

Increased plastic deformation damage

Increased wear loss

Increased RCF damage and crack extension

0.04 in = 1 mm

1 lb = 7000 grains
15.4 grains = 1 gram
Wear and RCF

From the disc-on-disc tests
- Correlation between GF application and increase in wear and RCF
- Correlation between Wear and RCF

Material Code
- A
- B
- C
- D
- E
- F
- G

Wear (Rail Sample), grains
- 0.2
- 0.4
- 0.6
- 0.8
- 1
- 1.2
- 1.4

Ave. Final Flaw Size, inch
- 0
- 0.01
- 0.02
- 0.03
- 0.04

0.04 in = 1 mm
1 lb = 7000 grains
15.4 grains = 1 gram

Lubricant G
Test No. 3
50,000 Cycles

0.03
0.02
0.01
0.00
0.0

Max Crack Size (inch)

1 initial dose additional doses at COF>0.30

-3% Slip Ratio
400 RPM

Coefficient of Friction

570
565
560

Force (lb)

Displacement (inch)

Vibration (ft/s²)

0
10
0
2
4
6
8
10

0
1000
2000
3000
4000
5000

Cycles

G=217.5 ksl
Conclusions

Experiment Design
- Designed to evaluate effectiveness of lubrication to manage friction
  - Stress states representative of railway wheel / rail contact
- Disc on disc test shows ability to differentiate between key measures for friction management
  - Carry distance – Cycles to 1st Dose
  - Dose Interval & Number of high friction states

Experiment Results
- Increased carry distance and extension of dose to dose intervals
  - Decreases wear
  - Decreases deformation
  - Decreases RCF flaw extension
- Results used to select GF products for continued evaluation leading to revenue service testing