Evaluation of Two TOR Products on River Grade Track

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ABSTRACT
A collaborative series of field studies involving Indiana Rail Road and LB Foster Rail Technologies were undertaken to evaluate the comparative effectiveness of water-based, drying friction modifiers and petroleum-based top of rail (TOR) lubricants applied through industry standard trackside application units. The testing was conducted on a 32-mile rolling grade section of Indiana Rail Road’s Indianapolis Subdivision; traffic on this section consisted of loaded and empty unit coal trains with distributed power configuration and mixed freight, on the bi-directional track. The study focused on establishing the comparative trackside unit spacing and product application rate settings required to achieve significant lateral force reduction on an instrumented 5.57° curve. The field studies also included assessing the impact of the two TOR products on train handling and braking.

Results from the nine month trial have demonstrated:

- An average of 23% lateral force reduction was achieved on the low rail with the water-based, drying friction modifier product with a spacing distance of 4 miles between trackside units in comparison to baseline (no TOR) conditions.
- An average of 23% lateral force reduction was achieved on the low rail with the petroleum-based TOR lubricant with a spacing distance of 8 miles between trackside units in comparison to baseline (no TOR) conditions.
- Comprehensive braking tests performed during both the water-based, drying friction modifier and the petroleum-based TOR lubricant phases demonstrated no negative impact of the TOR products on train handling and train braking when compared to baseline (no TOR) conditions.

INTRODUCTION
Track structure degradation, rail wear, and rolling contact fatigue in curves can be accelerated by high lateral forces. In addition to train handling, track geometry and wheel/rail profiling, lateral forces also depend on the coefficient of friction (COF) at the wheel-rail interface (1). It is understood that application of friction modifiers to the top of rail (TOR) can lower the COF thereby mitigating the lateral forces and reducing the stress state of the railroad and associated track structure degradation.

In recent years, oil-based TOR products have started to enter the heavy haul market. It has been informally reported that oil-based TOR lubricants have extended coverage distance at reduced application rates relative to water-based, drying friction modifiers. Despite the potential risks associated with applying lubricants (e.g. low coefficient of friction values of < 0.20-µ at the top of rail / wheel tread interface and
accelerated crack growth in wheels and rails) freight railroads are closely examining oil-based products as a means to control and manage TOR friction, based on the potential for lower “Cost Per Treated Mile” for these materials. Again, it has been informally reported that the controlled application of a TOR lubricant in this manner does not impact train handling, most notably traction and braking. Due to the extended spacing and reduced application rates associated with TOR lubricant technology, lower capital expenditure, as well as lower annual operating costs, can be expected.

This paper reports results of top of rail friction control and lateral force reduction at Indiana Rail Road using LB Foster’s premium petroleum-based TOR lubricant, KELSAN InfiniTrack™, as well as the water-based, drying friction modifier, KELTRACK® ER. Indiana Rail Road is a Class II railroad hauling mixed freight and unit coal trains over mainly rolling grade terrain (Figure 1). This trial was initiated as a collaborative test venture involving Indiana Rail Road (INRD) and LB Foster Rail Technologies. In addition to evaluating the performance of the petroleum-based versus water-based TOR products using different application rates, their impact on train handling and braking is also reported.

TRIAL CONDITIONS

Trial Zone Characteristics
The test site was located between MPs 100 and 132 of the INRD Indianapolis Subdivision. This area represents a typical low to medium curve density operating environment, with multiple low to medium radius curves over the selected area. There are 33 curves within the test zone, with a maximum curvature of 5.57°. The route is single track, oriented in an east-west direction, on “river grade” territory (<1% gradient). The track is standard gage and construction (wooden ties, plates, spikes and anchors). Rail type is 115-lb rail along the majority of the trial zone. Traffic is bi-directional (Southbound/Westbound – increasing mileage) with trains entering and leaving at several locations within the test site. Traffic type varies from mixed freight to unit coal trains and the total daily train count is approximately 8 trains. The main train type used for the analysis was the Dynegy unit coal train, with loaded trains heading Southbound (Westbound) and empty trains heading Northbound (Eastbound). Unit coal train traffic averaged to approximately one train a day.

Trackside Application Equipment and Products
LB Foster electric PROTECTOR®-IV (PIV) Top of Rail applicator units with silicon foam bars were used for the trial (Figure 2) (2). Remote Performance Monitoring™ (RPM) was used to record the temperature data for the area, in addition to providing product tank level and axle count data to allow calculation of product consumption. Product consumption rates were further cross-checked by manual on-site volumetric pump output tests during field visits. This trial incorporated the use of two wayside TOR products manufactured by LB Foster Rail Technologies for top of rail friction control: the water-based, drying friction modifier KELTRACK® ER Winter and the petroleum-based TOR lubricant KELSAN InfiniTrack™.

Six wayside TOR application units were installed in the test site at MPs 101.9, 108, 112, 120, 124, and 132. The two outer units (MPs 101.9 and 132) were used for the TOR lubricant only, while the two inner units (MPs 112 and 120) were used for the friction modifier only. The two units at MPs 108 and 124 were used for both the TOR lubricant and the friction modifier. The tanks were cleaned in between TOR products and new bars and hoses were used for the latter units to ensure that there was no contamination between the two products. The product consumption rate was averaged among the units used during each product phase.

DATA COLLECTION AND ANALYSIS METHODOLOGY

Lateral Force
Strain gages were installed on both the high rail and low rail at the body of the 0.25 mile long 5.57° right-hand curve located at MP 116.1 (Figure 3). This curve had adequate gage face lubrication upon visual inspection.
The instrumented cribs provided lateral and vertical force data of each axle and the “per axle” data were processed and used to assess the effect of friction control strategies (or other operating changes) on the lateral force values. For the analysis, only the forces corresponding to the leading axles of cars (i.e. no locomotives) were used. Furthermore, the lateral force data were filtered based on the following criteria:

- Direction (Southbound and Northbound)
- Axle count filter of ≥550 axles (to isolate the unit coal trains) unless otherwise specified
- Leading axles of cars having a wheel load of greater than 25 kips for Southbound trains (“loaded” axles)
- Leading axles of cars having a wheel load less than 12 kips for Northbound trains (“empty” axles)

Two sets of analyses were performed for this trial. One analysis consisted of comparing only the unit coal trains, which are high tonnage trains. Typically, when the analysis is done on a certain train type, a speed filter is also applied to the data. This ensures that the changes in the lateral forces are only due to the application of TOR products and not the train speed (provided all other variables are kept constant), thus making the comparison more valid. However, due to the low coal train traffic, thereby resulting in low data number, the data from all the coal trains, regardless of the train speed, were used in this analysis. In order to account for the differences in lateral forces as a result of the differences in train speed, a plot using lateral force against the train speed was created. Parallel trend lines of different sets of data indicate that the lateral force is mainly affected by the speed and not by other factors. This implies that the plot can be used to determine the lateral force reduction by data interpolation. Figure 4 shows a representative plot of the lateral force as a function of speed. In this report, the average of the statistical modes of train speed in each phase was used to determine the lateral force reduction.

The lateral force for each of the TOR product was compared against the lateral force of the “dry” rail/baseline phase to obtain the percent reduction. Since the lateral force distribution plots have a relatively normal distribution, the Student T-test was used to test if average lateral force differences between the baseline and TOR test phases were statistically significant. Results are reported graphically for easier representation of the data. The time series scatter plots show the effects of the TOR product on the lateral forces of each train, if any, as a function of time. Bar graphs, on the other hand, display the relative differences in the average lateral forces between each phase.

The second analysis performed used lateral force data from all Southbound trains to provide information on the absolute lateral forces as observed by the rails, regardless of train speed, train type, train length, etc. The lateral force at the 90th percentile and the percent of trains exceeding a threshold lateral force value are reported. The threshold lateral force values used are listed in Table 1, which were chosen based on the lateral force distribution curves of the baseline (no TOR product) phase.

### Table 1. Threshold Lateral Force Values.

<table>
<thead>
<tr>
<th>Trains</th>
<th>Low Rail</th>
<th>High Rail</th>
</tr>
</thead>
<tbody>
<tr>
<td>Empty</td>
<td>2.6 kips</td>
<td>2.6 kips</td>
</tr>
<tr>
<td>Loaded</td>
<td>10 kips</td>
<td>14 kips</td>
</tr>
</tbody>
</table>

**Brake Test**

Braking tests were conducted using loaded and empty coal trains running with distributive power (2 locomotives at the front of the train and 1 locomotive at the rear of the train) of similar make ups (number of cars, tonnage, etc.) and speeds entering the brake test area. Event recorder data (capturing gps coordinates, train speed, brake pipe pressure, braking information, braking distance and time) from the coal trains used for the braking trial were used to determine stopping distances. The event recorder data for the lead locomotive only was collected from the test trains since the coal trains were running in synchronous mode throughout the entire round trip.

Designated brake point markers were located one mile downstream a wayside TOR unit such that most, if not all, of the wheels of the coal train had passed over the TOR applicator bars prior to braking. The test methodology consisted of applying a fixed reduction in the brake tube pipe pressure (BTP) with no other
braking source being applied (e.g. dynamic braking). A 20-lb reduction was applied for the loaded trains and a 10-lb reduction was applied for the empty trains. All conditions, including the weather and speed prior to the brake application, were attempted to be kept the same. Baseline (dry) rail braking tests were performed at all locations to be used as references against the TOR product braking tests.

RESULTS
Lateral Force
Lateral forces of both the low rail and the high rail were monitored during this three-phase trial. The first phase consisted of a “dry” rail/baseline phase where no TOR product was applied on the rails. The second phase consisted of the water-based, drying friction modifier, while the third phase consisted of the petroleum-based TOR lubricant. A “dry” rail/baseline was re-established between the two TOR product phases to ensure that there was no residual product on the top-of-rail prior to the start of the next TOR product. Furthermore, for phases 2 and 3, various application rates were tested to determine the optimal application rate for that product in order to achieve a goal of 25% lateral force reduction. Only the top of rail conditions were varied in this trial, while gage face grease application practices within the test site were left unchanged.

Friction Modifier – Unit Coal Trains
The initial conditions for the trial (i.e. wayside TOR units located 4 miles from each other and an application rate of 0.06 gallons/1000 axles) were selected appropriate as a starting point for the friction modifier based on past trials on Class I Railroads.

Figure 5 shows the time series graph of the loaded coal trains where the high rail and low rail lateral forces as experienced by the rails are plotted as a function of time. It can be seen that while there is a reduction in the lateral force, the low application rate did not result in the targeted 25% lateral force reduction. Thus, the application rate was increased to 0.12 gallons/1000 axles. This resulted in a minimal further reduction in the lateral forces for the low rail at the higher application rate. However, when the wayside units were turned off to re-establish the baseline, the lateral forces for both the high rail and the low rail increased significantly. The differences in the lateral force values between the first and second set of baseline measurements show a seasonal effect and thus emphasizes the importance of re-establishing the baseline.

Typically, a speed filter is applied to eliminate atypical forces resulting from trains operating significantly outside the normal speed range observed through the lateral force site. In this trial, the trains travelled at different speeds during the different phases. Hence, in order to be able to do a true comparison between the baseline and the different friction modifier application rate phases, the lateral forces were plotted as a function of train speed. The parallel trend lines in both the low rail (Figure 6) and the high rail (Figure 7) indicated that the lateral forces of the different phases could be directly compared despite the differences in train speed. Furthermore, Figure 6 and Figure 7 show that regardless of train speed, the lateral forces exhibited by the train during the dry/baseline phase are higher than with TOR application. By interpolating the lateral force associated with a particular train speed, the lateral force reduction for the low rail and high rail were determined and are presented in Table 2. Figure 8 shows the bar graph of the interpolated lateral forces.

| TABLE 2. Lateral Force Reduction of Loaded Coal Trains using Friction Modifier. |
|-----------------------------------------------|---|-----------------|-----------------|-----------------|
| Product | Application Rate | # of Trains | Avg. Low Rail (kips) vs. Baseline | Avg. High Rail (kips) vs. Baseline |
| Baseline | 0 | 7 | 9.77 | % Difference | 12.32 | % Difference |
| Friction Modifier | 0.06 gals/1000 axles | 12 | 8.40 | -14.0% | 11.64 | -5.5% |
| Friction Modifier | 0.12 gals/1000 axles | 13 | 7.96 | -18.5% | 11.55 | -6.3% |
TOR Lubricant – Unit Coal Trains

After re-establishing the baseline, the next product phase used the petroleum-based TOR lubricant. For this phase, the wayside units closest to the lateral force site were turned off; the spacing between the wayside units and the lateral force site was now 8 miles. A similar application strategy was used where a low application rate of 0.06 gallons/1000 axles was firstly used, followed by a higher application rate of 0.12 gallons/1000 axles. An additional application rate of 0.09 gallons/1000 axles was tested to identify the optimal application rate. The time series plot of the lateral forces of the loaded coal trains shows more obvious changes in lateral force as the application rates are varied (Figure 9), albeit a few outliers. The interpolated lateral force reduction on the low rail and the high rail using the TOR lubricant is listed in Table 3. Figure 10 shows the bar graph of the interpolated lateral forces.

<table>
<thead>
<tr>
<th>Product</th>
<th>Application Rate</th>
<th># of Trains</th>
<th>Avg. Low Rail (kips)</th>
<th>vs. Baseline2</th>
<th>Avg. High Rail (kips)</th>
<th>vs. Baseline2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baseline2</td>
<td>0</td>
<td>22</td>
<td>10.53</td>
<td>% Difference</td>
<td>14.75</td>
<td>% Difference</td>
</tr>
<tr>
<td>TOR Lubricant</td>
<td>0.06 gals/1000 axles</td>
<td>11</td>
<td>9.02</td>
<td>-14.4%</td>
<td>13.28</td>
<td>-10.0%</td>
</tr>
<tr>
<td>TOR Lubricant</td>
<td>0.12 gals/1000 axles</td>
<td>9</td>
<td>7.25</td>
<td>-31.2%</td>
<td>10.95</td>
<td>-25.8%</td>
</tr>
<tr>
<td>TOR Lubricant</td>
<td>0.09 gals/1000 axles</td>
<td>10</td>
<td>8.08</td>
<td>-23.3%</td>
<td>11.99</td>
<td>-18.7%</td>
</tr>
</tbody>
</table>

Note that due to space considerations, only the detailed results for the loaded coal trains are reported since higher lateral forces are attributable to loaded trains. Lateral force reductions of 13-27% were achieved on the high and low rails for the empty coal trains using varied application rates of the friction modifier. Lateral force reductions were observed for the empty coal trains with the TOR lubricant, however, the amount of lateral force reduction was undeterminable.

Friction Modifier and TOR Lubricant – All Southbound Trains

Since INRD has trains of various different commodities and lengths, the absolute lateral forces the rails experience from all the trains were also examined. Keeping with the same type of wheel load analysis above, only train cars with leading axle wheel loads greater than 25 kips were analyzed for the Southbound trains. Table 4 and Table 5 list the lateral force of the 90th percentile of trains, as well as the percent of trains exceeding a lateral force considered to be “high”. Figure 11 and Figure 12 show a visual representation of the results.

<table>
<thead>
<tr>
<th>Product</th>
<th>Low Rail</th>
<th>High Rail</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baseline</td>
<td>10.6 kips</td>
<td>12.0 kips</td>
</tr>
<tr>
<td>Friction Modifier 0.06 gals/1000 axles</td>
<td>8.4 kips</td>
<td>12.2 kips</td>
</tr>
<tr>
<td>Friction Modifier 0.12 gals/1000 axles</td>
<td>8.6 kips</td>
<td>12.2 kips</td>
</tr>
<tr>
<td>Baseline2</td>
<td>11.6 kips</td>
<td>16.2 kips</td>
</tr>
<tr>
<td>TOR Lubricant 0.06 gals/1000 axles</td>
<td>10.8 kips</td>
<td>14.2 kips</td>
</tr>
<tr>
<td>TOR Lubricant 0.12 gals/1000 axles</td>
<td>8.4 kips</td>
<td>12.0 kips</td>
</tr>
<tr>
<td>TOR Lubricant 0.09 gals/1000 axles</td>
<td>9.8 kips</td>
<td>12.8 kips</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Product</th>
<th>Low Rail (&gt;10 kips)</th>
<th>High Rail (&gt;14 kips)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baseline</td>
<td>20.0%</td>
<td>2.4%</td>
</tr>
<tr>
<td>Friction Modifier 0.06 gals/1000 axles</td>
<td>0.0%</td>
<td>0.0%</td>
</tr>
<tr>
<td>Friction Modifier 0.12 gals/1000 axles</td>
<td>0.0%</td>
<td>0.0%</td>
</tr>
<tr>
<td>Baseline2</td>
<td>29.2%</td>
<td>22.9%</td>
</tr>
<tr>
<td>TOR Lubricant 0.06 gals/1000 axles</td>
<td>15.4%</td>
<td>15.4%</td>
</tr>
<tr>
<td>TOR Lubricant 0.12 gals/1000 axles</td>
<td>0.0%</td>
<td>5.9%</td>
</tr>
<tr>
<td>TOR Lubricant 0.09 gals/1000 axles</td>
<td>4.3%</td>
<td>4.2%</td>
</tr>
</tbody>
</table>

In all the cases above, the application of a TOR product reduced the overall lateral force, as noted by the shift in the cumulative curves to a lower lateral force in Figure 11 and Figure 12. Furthermore, the peak forces for the TOR phases are lower than those for the baseline phase.

Brake Test
Brake tests were performed to determine whether the TOR products had any negative impact on the braking and traction of the loaded and empty coal trains. Brake tests were performed for each of the three test phases using two application rates for each TOR product: the optimal application rate and a high application rate to simulate a worst case scenario. However, for the friction modifier phase, due to time constraints and the less than ideal weather conditions for the Winter-grade product, brake tests were only done using the application rate of 0.12 gallons/1000 axles. For the TOR lubricant phase, brake tests were conducted using the 0.09 gallons/1000 axles (optimal) and 0.18 gallons/1000 axles (high) application rates.

The event recorder data provided for each run were analyzed to determine train conditions and stopping distances. The average stopping distances for the empty coal trains and the loaded coal trains are listed in Table 6 and Table 7, respectively. Due to the different trackside TOR equipment spacing depending on the TOR product used, two braking point locations had to be used for the loaded coal trains, as denoted by A and B in Table 7.

TABLE 6. Braking Test Results for the Empty Coal Trains.

<table>
<thead>
<tr>
<th>Product</th>
<th>Application Rate</th>
<th>Avg. Speed at Brake Point (MPH)</th>
<th>Avg. Stopping Distance – Event Recorder Data (ft)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baseline</td>
<td>0</td>
<td>29.7 (0.6)*</td>
<td>1105 (73)</td>
</tr>
<tr>
<td>Friction Modifier</td>
<td>0.12 gals/1000 axles</td>
<td>29.3 (1.2)</td>
<td>1091 (152)</td>
</tr>
<tr>
<td>TOR Lubricant</td>
<td>0.09 gals/1000 axles</td>
<td>24.0 (n/a)</td>
<td>845 (n/a)</td>
</tr>
<tr>
<td>TOR Lubricant</td>
<td>0.18 gals/1000 axles</td>
<td>29.0 (0)</td>
<td>1217 (3)</td>
</tr>
</tbody>
</table>

* Values listed in the parenthesis are the standard deviations. n/a = not available as there was only data from one train.
TABLE 7. Braking Test Results for the Loaded Coal Trains.

<table>
<thead>
<tr>
<th>Product</th>
<th>Application Rate</th>
<th>Avg. Speed at Brake Point (MPH)</th>
<th>Avg. Stopping Distance – Event Recorder Data (ft)</th>
</tr>
</thead>
<tbody>
<tr>
<td>[A] Baseline</td>
<td>0</td>
<td>18.0 (1.0)*</td>
<td>845 (115)</td>
</tr>
<tr>
<td>[A] Friction Modifier</td>
<td>0.12 gals/1000 axles</td>
<td>17.8 (1.5)</td>
<td>806 (150)</td>
</tr>
<tr>
<td>[B] Baseline</td>
<td>0</td>
<td>20.0 (0)*</td>
<td>1072 (61)</td>
</tr>
<tr>
<td>[B] TOR Lubricant</td>
<td>0.09 gals/1000 axles</td>
<td>20.0 (n/a)</td>
<td>1162 (n/a)</td>
</tr>
<tr>
<td>[B] TOR Lubricant</td>
<td>0.18 gals/1000 axles</td>
<td>20.0 (0)</td>
<td>1188 (49)</td>
</tr>
</tbody>
</table>

* Values listed in the parenthesis are the standard deviations. n/a = not available as there was only data from one train.

For each of the TOR product phases, an LB Foster representative was present on the test train to observe whether any train handling difficulties were experienced by the train engineer. During all the rides, the engineers did not notice any notable differences in train handling. Furthermore, no wheel burns or scuff marks were noted at the brake point area during a visual inspection of the rails (Figure 13).

Although the petroleum-based TOR lubricant provided greater lateral force reduction compared to the water-based, drying friction modifier, it should be noted that there are some risks associated with a petroleum-based product. For example, while the relationship between the water-based, drying friction modifier and rolling contact fatigue (RCF) has been extensively studied (3-5), more study is recommended for the petroleum-based TOR lubricant to monitor the presence or lack of RCF when it is used over an extended period of time. This is particularly true for areas with high degrees of curvature that are especially prone to RCF development. For the duration of the trial, no visible RCF was noted.

CONCLUSION
Two TOR products were tested and evaluated in their performance to reduce lateral forces. Both products provided downward trends in the low rail and high rail lateral force results, with the petroleum-based TOR lubricant providing the targeted 25% lateral force reduction. Furthermore, the petroleum-based TOR lubricant demonstrated carry down of at least 8 miles on river grade terrain with low to medium degree of curvature. This was achieved in concert with conventional gauge face lubrication practices. The results from this paper suggests that using either product offer significant stress state reduction potential compared to no TOR product conditions without causing any negative impact on train braking under heavy haul conditions.

REFERENCES
Figure 1. Typical Indiana Rail Road train operating over the test site.

Figure 2. Wayside TOR-PIV setup at MP 112.0 in the Indianapolis Subdivision.
Figure 3. Lateral force measurement site located at the body of the curve at MP 116.1 in the Indianapolis Subdivision.

Figure 4. Lateral force as a function on train speed using high rail as an example. If speed is the main factor affecting the lateral forces, then parallel trend lines are observed between data A (red) and data B (blue). Data A represents higher coefficient of friction conditions (for example, dry rail) while data B represents lower coefficient of friction conditions (for example, with friction modifier and lubrication).
Figure 5. Time series graph of the loaded coal trains. High rail (red) and low rail (blue) lateral forces of leading axles of cars where the wheel load is greater than 25 kips, are plotted as a function of time.

Figure 6. Low rail lateral force of the loaded coal trains as a function of train speed. Red = baseline, light blue = Friction Modifier 0.06 gals/1000 axles, dark blue = Friction Modifier 0.12 gals/1000 axles.
Figure 7. High rail lateral force of the loaded coal trains as a function of train speed. Red = baseline, light blue = Friction Modifier 0.06 gals/1000 axles, dark blue = Friction Modifier 0.12 gals/1000 axles.

Figure 8. Low rail and high rail lateral forces of loaded coal trains. Red = baseline, light blue = Friction Modifier 0.06 gals/1000 axles, dark blue = Friction Modifier 0.12 gals/1000 axles.
Figure 9. Time series graph of the loaded coal trains. High rail (red) and low rail (blue) lateral forces of leading axles of cars where the wheel load is greater than 25 kips, are plotted as a function of time.

Figure 10. Low rail and high rail lateral forces of loaded coal trains. Orange = baseline, light purple = TOR Lubricant 0.06 gals/1000 axles, dark purple = TOR Lubricant 0.12 gals/1000 axles, pink = TOR Lubricant 0.09 gals/1000 axles.
Figure 11. Low rail lateral force distribution graph showing the frequency (solid) and cumulative (dotted) curves of the Southbound trains using the friction modifier. Red = baseline, light blue = Friction Modifier 0.06 gals/1000 axles, dark blue = Friction Modifier 0.12 gals/1000 axles.

Figure 12. Low rail lateral force distribution graph showing the frequency (solid) and cumulative (dotted) curves of the Southbound trains using the TOR lubricant. Orange = baseline, light purple = TOR Lubricant 0.06 gals/1000 axles, dark purple = TOR Lubricant 0.12 gals/1000 axles, pink = TOR Lubricant 0.09 gals/1000 axles.
Figure 13. Photos of the (a) south rail and (b) north rail at MP 113.15 where the brake test was performed for loaded coal trains.

FIGURE CAPTIONS

Figure 1. Typical Indiana Rail Road train operating over the test site.

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Figure 11. Low rail lateral force distribution graph showing the frequency (solid) and cumulative (dotted) curves of the Southbound trains using the friction modifier. Red = baseline, light blue = Friction Modifier 0.06 gals/1000 axles, dark blue = Friction Modifier 0.12 gals/1000 axles.
Figure 12. Low rail lateral force distribution graph showing the frequency (solid) and cumulative (dotted) curves of the Southbound trains using the TOR lubricant. Orange = baseline, light purple = TOR Lubricant 0.06 gals/1000 axles, dark purple = TOR Lubricant 0.12 gals/1000 axles, pink = TOR Lubricant 0.09 gals/1000 axles.

Figure 13. Photos of the (a) south rail and (b) north rail at MP 113.15 where the brake test was performed for loaded coal trains.

TABLE TITLES
Table 1. Threshold Lateral Force Values.
Table 2. Lateral Force Reduction of Loaded Coal Trains using Friction Modifier.
Table 3. Lateral Force Reduction of Loaded Coal Trains using TOR Lubricant.
Table 4. 90th Percentile Lateral Force of All Southbound Trains with Leading Axles of Cars Having Vertical Wheel Loads Greater than 25 kips.
Table 5. Percent of Southbound Trains with Leading Axles of Cars with Vertical Wheel Loads Greater than 25 kips Exceeding Lateral Forces of 10 and 14 kips on the Low Rail and High Rail, Respectively.
Table 6. Braking Test Results for the Empty Coal Trains.
Table 7. Braking Test Results for the Loaded Coal Trains.
Evaluation of Two TOR Products on River Grade Track

Marcia Yu, PhD (LB Foster Rail Technologies)
Pete Ray, P.E. (Indiana Rail Road)

October 06, 2015
Overview

- Introduction
- Purpose and Objectives
- Field Test
  - Test zone
  - Equipment and Product
- Data Analysis Methodology
- Results
  - Lateral Force
  - Brake Test
- Summary

Introduction

Chicago

Terre Haute

Indianapolis

Louisville

Purpose

High Rail

Low Rail

Rolling Contact Fatigue

Before

After

INRD Inspection Truck

Gage Face and TOR Inspection

Objectives

- Compare effective lateral force reduction of water-based, drying friction modifier and petroleum-based TOR lubricants
- Determine optimal application rate
- Assess the impact of the two TOR products on train handling and braking
Field Test – Test Zone

- Linton, IN to Newton, IL (32 mile track)
- Rolling grade
- Single Track
- Medium to low curvature curves
  - 33 curves
  - Maximum curvature = 5.57°

Field Test (Con’t)

- Instrumented Curve - 0.25 mile; 5.57° RHC
  - Friction Modifier units – 4 mile spacing
  - TOR Lubricant units – 8 mile spacing

- Brake Test – 1 mile past TOR unit
  - Loaded, unit coal train
  - Empty, unit coal train

Field Test – Equipment

- LB Foster PROTECTOR®-IV

Field Test – Products

- KELTRACK® ER Winter (water-based, drying friction modifier)
- KELSAN InfiniTrack™ (petroleum-based TOR lubricant)

Field Test – Trains

Data Analysis – Lateral Force

- Filters for Unit Coal Trains
  - Southbound
  - Axle Count > 550 axles
  - Leading axles with wheel load > 25 kips

- Filters for All Trains
  - Southbound
  - Leading axles with wheel load > 25 kips (90th Percentile)
  - Threshold Values of 10 kips (LR) and 14 kips (HR)
Results – Friction Modifier

- Spacing: 4 miles between TOR units
- Application rates:
  - 0.06 gallons/1000 axles (A)
  - 0.12 gallons/1000 axles (B)

Results – Friction Modifier (Con’t)

Results – TOR Lubricant

- Spacing: 8 miles between TOR units
- Application rates:
  - 0.06 gallons/1000 axles (A)
  - 0.12 gallons/1000 axles (B)
  - 0.09 gallons/1000 axles (C)
Results – TOR Lubricant (Con’t)

- Lateral Force vs. Date
- Results for TOR Lubricant (A, B, C)

Results – All Trains

- Product vs. Rail Condition
- Baseline, Friction Modifier – A, B
- Baseline 2, TOR Lubricant – A, B, C

Results – All Trains (Con’t)

- Product vs. Rail Condition
- Baseline, Friction Modifier – A, B
- Baseline 2, TOR Lubricant – A, B, C

Results – Brake Test

- South Rail vs. North Rail
### Results – Brake Test (Loaded)

<table>
<thead>
<tr>
<th>Product</th>
<th>Applic. Rate</th>
<th>Avg. Speed (MPH)</th>
<th>Avg. Stopping Distance (ft)</th>
</tr>
</thead>
<tbody>
<tr>
<td>[A] Baseline</td>
<td>0</td>
<td>18.0 (1.0)</td>
<td>845 (115)</td>
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<tr>
<td>[A] Friction Modifier</td>
<td>0.12 gals/kaxles</td>
<td>17.8 (1.5)</td>
<td>806 (150)</td>
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<tr>
<td>[B] Baseline</td>
<td>0</td>
<td>20.0 (0)</td>
<td>1072 (61)</td>
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<tr>
<td>[B] TOR Lubricant</td>
<td>0.09 gals/kaxles</td>
<td>20.0 (n/a)</td>
<td>1162 (n/a)</td>
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<tr>
<td>[B] TOR Lubricant</td>
<td>0.18 gals/kaxles</td>
<td>20.0 (0)</td>
<td>1188 (49)</td>
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</table>

### Results – Brake Test (Empty)

<table>
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<tr>
<th>Product</th>
<th>Applic. Rate</th>
<th>Avg. Speed (MPH)</th>
<th>Avg. Stopping Distance (ft)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baseline</td>
<td>0</td>
<td>29.7 (0.6)</td>
<td>1105 (73)</td>
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<tr>
<td>Friction Modifier</td>
<td>0.12 gals/kaxles</td>
<td>29.3 (1.2)</td>
<td>1091 (152)</td>
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<tr>
<td>TOR Lubricant</td>
<td>0.09 gals/kaxles</td>
<td>24.0 (n/a)</td>
<td>845 (n/a)</td>
</tr>
<tr>
<td>TOR Lubricant</td>
<td>0.18 gals/kaxles</td>
<td>29.0 (0)</td>
<td>1217 (3)</td>
</tr>
</tbody>
</table>

### Summary

- For loaded unit coal trains:
  - Water-based, drying friction modifier, 4 miles spacing = 18% lateral force on low rail
  - Petroleum-based TOR lubricant, 8 miles spacing = 23% lateral force on low rail
- No negative impact of the TOR products on train handling and train braking

### Questions?