KELSAN TECHNOLOGIES

RESEARCH & DEVELOPMENT REPORT

Evaluation Of KELTRACK™ Product-Process Trials
March – April 2000

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Date: November 2000
Report Number: 000071
Project: 533

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Summary

During the four-week period of March 12th to April 14th 2000 Kelsan Technologies Corp. and Lubriquip in collaboration with the Western US Freight System (**WUSFS**) evaluated Kelsan Technologies KELTRACK™ top of rail friction modifier technology applied through a prototype on-board locomotive application system developed by Lubriquip. The trial was carried out at the WUSFS FAST test facility.

Key trial objectives included assessment of:

- Equipment performance and reliability, to define the needs for development program for a fully commercial system.
- Product performance related to lateral forces, angle of attack, and energy usage
- Operation of TOR friction management in conjunction with conventional wayside lubrication

Overall, the results of the testing indicated the following benefits of KELTRACK application as well as the strengths and weakness of the prototype system, and the areas for development in commercialization of this technology. This report is intended to complement a separate report by WUSFS covering implementation issues for Top of Rail technology (Ref 2).

Lateral forces

- The trial confirmed the significant reduction in lateral forces previously recorded with KELTRACK. An application rate of approximately 0.15 L/mile provides immediate lateral force reduction in a dry curve on the test loop on the 6° curve. Absolute lateral load reductions relative to dry rail on a 6-degree curve were in the range 25 to 60% depending on application rate.
- KELTRACK also greatly reduced the percentage of lateral forces greater than 10 Kips. The majority of the KELTRACK treated conditions showed 0% > 10 Kips in the 6 degree curve.
- KELTRACK reduced the *variability (standard deviation)* in lateral forces. Typical dry rail results showed one standard deviation of 2-3 Kips about the average compared with < 1 Kip standard deviation about the average for the KELTRACK cases.
- The results indicate a strong correlation between KELTRACK application rate and absolute reduction in lateral forces on the closed loop track.
- The KELTRACK application was effective for at least one full train length, and for some application rates up to 2-3 train lengths (5000 axles).

Background and Objectives

In December 1999, Lubriquip & Kelsan Technologies began a joint effort to develop a prototype process-product system for applying a KELTRACK product to the top of rail using an on-board system. The tentative target of the team was to have a prototype system in time for the Western US Freight System (WUSFS) trials scheduled for the beginning of March.

These trials were to be part of the WUSFS top of rail lubrication evaluation program. This program is guided by an advisory group, which includes representatives from all major North Americal Railroads.

The WUFSF stated objectives for this test sequence were:

"Measure the effects of different types of TOR lubrication policies before implementing into revenue service. Determine methods for implementing top of rail lubrication in conjunction with other lubrication modes, or if mixing TOR and guage face is feasible. This is based on findings that top of rail lubrication alone may not be sufficient to reduce wear and energy consumption as much as other methods".

Other key components of the plan from the WUSFS standpoint were to:

- Evaluate different TOR systems in more extended operation (versus 1998 trials) – looking at longer-term effects and system reliability
- Utilize train operations from existing FAST / HTL program

Among Kelsan and Lubriquip's objectives for the project were to:

- Establish the performance characteristics of the prototype TOR on-board spray equipment
- Confirm the KELTRACK lateral force and energy savings demonstrated in the 1998 WUSFS trial.
- Evaluate a KELTRACK formulation tailored for on-board locomotive application
- Evaluate the effect of application rate on lateral force and angle of attack
- Evaluate retentivity characteristics
- Assess the compatibility of Kelsan and Lubriquip technical teams

In August of 1998, M. Curtis had demonstrated initial positive results of applying KELTRACK to the top of rail using another on-board application system. WUSFS testing on the WORM loop had demonstrated significant lateral force reduction on instrumented track as well as some energy savings brought about by reduced friction on the top of rail (Ref 1). The trial highlighted some deficiencies in the application system used of which the most critical was that the application of the product in the form of a bead caused locomotive wheel slip.

However, since the 1998 WUSFS trial, the preferred method of application has been to apply the product in a fine atomized spray. Advantages include a rapid drying time that would minimize wheel slip as well as assist in the formation of the desired thin film of KELTRACK product. Previous application methods involving the laying of a bead or of a coarser spray pattern are undesirable as these methods would lead to increased drying time which could affect traction properties. They are also believed to reduce overall product effectiveness including retentivity.

The Product

The KELTRACK on board product thus had to be formulated to have the following performance characteristics:

1. *Ability to be atomized.* As the material will be applied on the trailing locomotive, it is imperative that the product dries quickly. Initial studies had revealed a well-defined relationship between product viscosity and air pressure requirements for product atomization.

2. *High Solids Content.* Application rates are also important as the reservoir has to last conceivably for several weeks (or months) prior to refilling. Preliminary objective was to minimize application rate by optimizing solids content in the formulation. This had to be balanced against the need to be able to atomize spray.

After a series of testing several experimental formulations, a high solids KELTRACK formulation was selected. Laboratory work demonstrated the feasibility of reducing product viscosity in a high solids formulation.

The Application Process

For this trial, a prototype spray atomization system was developed. During the week of March 5th, the prototype was installed on a Conrail slug locomotive (figure 1).

Figure 1: Test Slug

The spray atomization system consisted of a primary pump that fed liquid KELTRACK from a 50 (US) gallon reservoir (figure 2) to a set of metering pumps (figure 3). Through the use of a microprocessor, these small volume pumps can meter the KELTRACK on a “shot basis”. Subsequently, the shot rate can be varied to increase/decrease rate. Further changes to the output are possible by changing the needle valve settings on the pumps. The KELTRACK product is metered to an air-liquid nozzle (figure 4) where the liquid stream is atomized with 100 psi air. Primary and metering pumps are also activated by compressed air. The feed line from the reservoir also contains an inline filter.

Figure 2: KELTRACK Reservoir Tank & Primary Pump

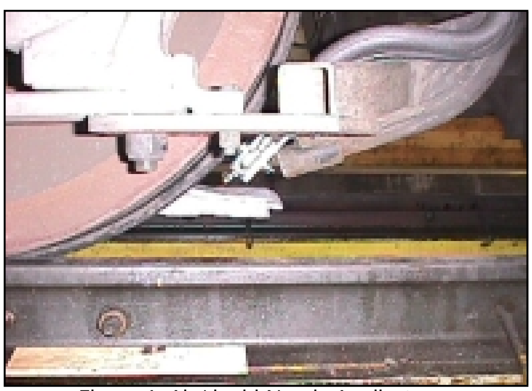

Figure 4: Air-Liquid Nozzle Applicator

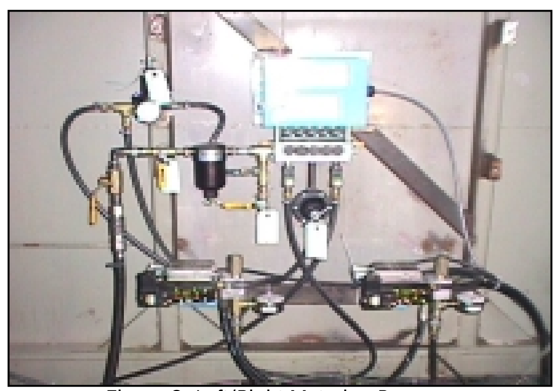

Figure 3: Left/Right Metering Pumps

Application Rates: Review of Historical Data

Table 1 highlights some of the historical application rates for various KELTRACK formulations used for TOR friction management solutions. Generally speaking, the trend has been to lower application rates as developments in the delivery system resulted in less wastage. Initial technology has involved the use of paint sticks that would employ approximately 2.2 liters of KELTRACK product in a mile as compared to *0.2 L/mile* for the KELTRACK on-board transit product. Further analysis of the previous data also indicated some success with an extremely low application rate (0.08 L/mile) with a bead (albeit with locomotive wheel slip).

For this trial, Kelsan decided to use recommended application rates. By estimation, 0.5 L/mile of regular KELTRACK would be optimal in creating the desired thin film for TOR friction management. As mentioned previously, the experimental on-board KELTRACK formulation would have a higher solids content in order to reduce the application rate and extend any reservoir capacity. Based on our analysis of this data, the following range of output rates were proposed for this trial: A: 0.047 L/mile, B: 0.094 L/mile, C: 0.185 L/mile

	Source	Method	Information	Liquid Rate (L/mile)	Liquid Rate (GPM)	Solid Rate (g/ft)
1	Company A	Roller	1.25 ounces per 386 ft	0.514	0.055	0.0168
2	Company A	Roller	2 ounces/ 386 ft	0.825	0.088	0.027
3	Kelsan	Paint-stick	1" per 60 ft	2.198	0.235	0.072
4	Company B	Spray	50ml/100 sec @ 15 kmh	0.191	0.0079	0.003
5	Theoretical	N/A	5 micron	7.307	0.783	0.239
6	Portec	HiRail	Left pump + 0.036" nozzle	1.065	0.117	0.033
7	Portec	HiRail	Right pump + 0.036" nozzle	1.438	0.158	0.044
8	Company C Trial	Bead	0.08L/mile	0.080	0.009	0.0014
9	Company D	HiRail	300ml/mile	0.300	0.033	0.00924
10	Designed 1 Output	On-board	0.185L/mile target	0.185	0.02	0.0114
11	Designed 1 Output	On-board	0.094L/mile (50% target)	0.094	0.01	0.00568

Table 1: Historical KELTRACK Application Data

Notes

- Sources 1,2,3,5 & 9 is based on standard 502 formulation
- Company B Spray formulation solid content
- Application rates based on 25mph speed for 1,2,3 & 5
- Density of Company B: 1.05
- Density of HPF 502: 1.15
- Density of Portec HiRail formulation: 1.12
- HiRail formulation
- Company C Trial – August '98 – KELTRACK used
- Sources 10 & 11 use high solids formulation

WUSFS – HTL Test Track

The High Tonnage Loop (HTL), 2.7 miles long, is used for track component reliability, wear, and fatigue research under heavy axle loads of 39 tons. Operations are restricted to a maximum 40 miles per hour. The HTL is divided into test sections that generally correspond to tangents, spirals, curves (three 5-degree curves and one 6-degree curve), and turnouts. Test train operations are designed to accumulate 1.0 million gross ton (MGT) a day traffic density at a maximum 40 miles per hour operating speed.

During a typical 10-hour shift, 100 to 130 laps can be accumulated; however, due to typical problems with broken welds and/or rails, lap counts range between 65 and 100. This translates to approximately 0.6 to 1.35 MGT per 10-hour shift, depending on train length. Train mileage, for a 65 to 130-lap shift, would range from 175 to 350 miles.

Measured information included the following:

- Lap by lap drawbar data (Energy)
- Periodic special measurements of angle of attack.
- Tribometer data taken throughout the night at pre-selected locations during set-up.
- Wayside L/V at existing load stations. Figures 5, 6 & 7 show the location of the L/V measurement cribs on the instrumented 6^o curve.

Figure 5: Cribs 1 & 2 in Tangent Section (Bungalow 1)

Figure 6: Cribs 4 & 5 in 6° Curve (Bungalow 2)

Figure 7: Cribs 7 & 8 in 6° Curve (Bungalow 8)

Proposed Trial Plan

Prior to commencing the trial, a detailed plan (Appendix A) was put together by Kelsan Technologies. The objective of plan was to run several experiments in an attempt to duplicate real life conditions prior to the 4 week test period. Unfortunately, many components of the trial plan were unable to be put into action as the TOR trial was being "piggybacked" on FAST. As a result, experiments that proposed running on "dry rail" had to be abandoned. Focus of effort was on evaluation of the KELTRACK application rate on reduction of lateral forces and energy consumption. The KELTRACK would be applied to both rails over the entire length of the 2.7 mile loop. A final experiment to be included was the assessment of the on-board system in conjunction with the operation of a wayside unit.

Trial Results & Analysis

The analysis reported below is directed at the process effects of liquid KELTRACK and the prototype delivery system, and the effect of process variables. A separate report has been published addressing implementation issues for Top of Rail friction management (Ref 2)

For convenience, the analysis has been broken down into the following sections. Each section deals with specific characteristics of the KELTRACK on-board system.

1. KELTRACK Effectiveness: Application Rate & Lateral Force Reduction
2. KELTRACK Retentivity ("Wet" & "Dry")
3. Angle of Attack
4. Energy Consumption
5. Noise Reduction
6. Train Handling
7. Process Reliability

KELTRACK Effectiveness: Application Rates & Lateral Force Reduction

Tables 2 & 3 summarize the lateral force behavior in the six cribs in the six degree curve for each 10 hours shift for the low and high rail. Only leading axle data is shown (trailing axle data has been excluded). Furthermore, only train laps that had an average speed above 40 mph were included in the analysis. Data highlighted:

- in red denotes that the TOR system was not in operation;
- in black indicates the system was in operation for all of the shift,
- in green for only part of the shift.
- in blue denotes a combined TOR-wayside operation.

For each shift, the first set of data exhibits the % forces above 10 kips. The later two sections exhibit the average and maximum (peak) lateral force data for each shift.

Dat	KELTRACK	Laps		% Forces > 10 Kips						Average Lateral Forces (kips)						Maximum Lateral Forces (kips)			
	Rate			1	2	4	5	7	8	1	2	4	5	7	8	4	5	7	8
2-1	No	N/A	→	0%	0%	50%	70%	65%	0%	0.95	1.71	10.07	12.51	11.3	7.37	20.9	22.9	20.0	13.7
2-1	No	N/A	→	0%	0%	50%	65%	70%	0%	1.15	1.28	9.97	12.08	11.5	7.22	20.9	23.0	19.2	13.0
2-1	No	N/A	←	0%	0%	50%	0%	0%	15%	0.86	1.48	10.32	6.30	2.89	8.80	21.3	13.6	7.4	15.1
2-1	No	N/A	←	0%	0%	60%	10%	0%	45%	N/A	N/A	11.25	6.87	3.86	10.2	23.5	15.8	9.8	17.4
3-1	.0941	94	→	0%	0%	5%	40%	20%	0%	2.03	2.02	5.99	10.62	7.96	5.31	14.1	23.4	17.1	12.6
3-1	N/A	N/A	→	0%	0%	35%	80%	65%	20%	1.65	1.75	8.93	14.88	11.6	8.22	17.8	27.5	21.3	16.0
3-1	.0941 .0471 .0235	86	←	0%	0%	25%	15%	0%	15%	1.47	1.43	8.71	7.69	2.59	7.54	19.5	18.6	10.6	19.7
3-1	.0471 .0353	73	←	0%	0%	10%	5%	0%	15%	1.75	1.65	7.34	6.79	2.49	7.73	15.9	14.4	8.0	16.3
3-1	.297	119	→	0%	0%	10%	60%	20%	0%	1.56	1.96	6.24	11.22	7.91	4.91	15.4	23.9	17.2	12.1
3-2	.122	N/A	→	0%	0%	10%	70%	15%	0%	1.50	1.72	6.42	11.95	7.80	6.02	16.4	25.7	16.5	12.2
3-2	.149	51	←	0%	0%	10%	10%	0%	5%	N/A	1.25	6.79	6.69	2.53	6.76	17.0	15.8	9.5	14.9
3-2	.152	112	←	0%	0%	50%	40%	0%	40%	1.57	1.44	10.16	9.05	4.08	9.57	19.6	18.5	10.5	17.5
3-2	N/A	112	→	0%	0%	40%	80%	45%	10%	1.39	1.63	9.27	14.74	9.59	7.24	20.2	28.2	18.0	13.5
3-2	N/A	N/A	→	0%	0%	15%	40%	15%	0%	1.40	1.61	6.18	10.66	6.07	4.86	20.0	27.6	16.8	13.4
3-2	.21 .135	108	←	0%	0%	20%	0%	0%	25%	2.39	2.37	9.55	7.98	3.49	8.48	20.7	18.8	9.8	11.4
3-2	.105	97	←	0%	0%	50%	35%	0%	35%	2.25	2.12	10.26	8.84	3.75	9.49	20.8	19.5	10.5	18.5
4-2	.135	99	→	0%	0%	0%	45%	10%	0%	2.25	2.19	5.19	10.19	6.08	4.74	15.2	22.3	14.8	11.3
4-3	.150	97	→	0%	0%	5%	55%	0%	0%	2.23	2.29	5.43	10.53	5.69	4.42	16.5	23.5	14.4	10.4
4-4	.150	124	←	0%	0%	0%	0%	0%	0%	2.27	1.92	6.51	6.57	1.60	5.80	16.2	15.3	8.5	14.0
4-5	.150	109	←	0%	0%	35%	30%	0%	25%	2.03	1.77	9.85	9.06	3.83	8.41	20.5	18.6	15.2	N/A
4-9	.150	111	→	0%	0%	0%	15%	0%	0%	2.18	2.21	3.93	8.06	4.18	1.30	10.2	17.0	14.8	N/A
4-1	.150	119	→	0%	0%	0%	10%	0%	0%	2.16	2.18	4.05	8.10	4.30	1.86	11.2	15.3	10.6	N/A
4-1	.150	26	←	0%	0%	15%	10%	0%	0%	2.29	2.23	2.51	7.55	2.80	N/A	16.9	15.6	9.2	N/A
4-1	.100	115	←	0%	0%	20%	15%	0%	?	2.45	2.63	7.87	7.45	2.91	6.12	25.0	20.8	11.3	N/A

Table 2: Leading Axle – Hi Rail

Date	KELTRACK Rate	Laps		% Forces > 10 Kips 1	2	4	5	7	8	Average Lateral Forces (kips) 1	2	4	5	7	8	Maximum Lateral Forces (kips) 4	5	7	8
2-13	No	N/A	→	0%	0%	15%	20%	45%	10%	1.06	1.72	6.79	7.35	9.48	6.42	15.4	15.1	17.4	12.3
2-14	No	N/A	→	0%	0%	15%	20%	30%	0%	1.15	1.38	6.93	7.68	9.21	6.24	16.8	15.2	17.0	11.7
2-15	No	N/A	←	0%	0%	5%	0%	0%	0%	6.69	6.68	14.08	13.8	10.9	12.9	14.1	13.8	11.0	13.0
2-16	No	N/A	←	0%	0%	5%	0%	0%	10%	N/A	N/A	6.13	4.81	5.07	6.69	16.7	14.8	12.4	14.8
3-12	.0941	94	→	0%	0%	0%	5%	5%	0%	0.97	1.01	3.47	4.72	5.62	4.53	13.2	14.1	13.7	11.2
3-13	N/A	N/A	→	0%	0%	10%	20%	40%	10%	1.14	1.15	6.33	8.25	9.07	7.11	19.9	20.1	16.9	14.0
3-14	.0941 .0471 .0235	86	←	0%	0%	5%	10%	0%	10%	1.63	1.44	4.85	5.40	3.95	4.71	16.5	18.5	12.8	15.4
3-15	.0471 .0353	73	←	0%	0%	0%	0%	0%	0%	1.92	1.78	3.48	4.29	3.89	4.24	11.1	13.1	11.4	13.8
3-19	.303	119	→	0%	0%	0%	5%	0%	0%	1.00	1.17	3.96	6.09	6.38	4.67	11.2	14.0	12.5	10.5
3-20	.125	N/A	→	0%	0%	0%	10%	5%	0%	1.11	1.30	4.63	6.09	6.56	5.53	13.5	15.7	14.2	12.0
3-21	.149	51	←	0%	0%	0%	5%	0%	0%	N/A	1.33	3.31	4.05	3.58	3.98	11.5	14.5	11.9	11.7
3-22	.149	112	←	0%	0%	10%	20%	0%	15%	1.62	1.68	6.13	6.74	5.35	6.92	14.6	15.6	14.3	14.4
3-26	N/A	112	→	0%	0%	10%	35%	20%	0%	1.04	1.17	6.39	8.31	7.94	6.16	15.6	16.7	16.5	12.6
3-27	N/A	N/A	→	0%	0%	5%	10%	5%	0%	1.12	1.31	3.60	4.62	4.19	3.73	17.0	21.1	14.7	10.9
3-28	.21 .135	108	←	0%	0%	20%	0%	0%	10%	2.09	2.64	5.28	6.17	4.73	5.97	16.3	19.0	13.6	15.6
3-29	.105	97	←	0%	0%	10%	20%	0%	10%	2.11	2.44	6.21	7.13	5.03	6.50	17.6	19.4	14.6	15.1
4-2	.125	99	→	0%	0%	0%	5%	0%	0%	1.71	2.15	3.30	4.79	4.91	3.92	12.8	15.2	12.1	9.4
4-3	.150	97	→	0%	0%	0%	5%	0%	0%	1.47	1.96	3.17	4.64	4.58	3.70	15.2	16.7	11.2	9.6
4-4	.150	124	←	0%	0%	0%	0%	0%	0%	1.96	2.07	1.95	2.76	1.94	2.46	9.8	12.3	9.0	10.8
4-5	.150	109	←	0%	0%	0%	20%	0%	10%	1.99	2.13	5.34	6.56	4.56	4.56	14.8	17.6	14.8	19.4
4-9	.150	111	→	0%	0%	0%	0%	0%	0%	1.43	2.00	2.04	2.47	2.43	2.26	8.0	9.5	12.6	10.5
4-10	.150	119	→	0%	0%	0%	0%	0%	0%	1.35	1.87	2.01	2.67	2.45	2.48	5.7	6.9	6.9	5.7
4-11	.150	26	←	0%	0%	0%	5%	0%	0%	1.81	2.02	4.31	5.09	3.64	4.16	12.5	14.3	9.9	12.8
4-12	.100	115	←	0%	0%	0%	5%	0%	0%	1.91	2.43	4.02	4.80	3.67	4.78	21.3	20.3	12.2	15.5

Table 3: Leading Axle – Low Rail

In reviewing the (red) baseline data (waysides only), one can observe that there is a bias in the lateral force data with respect to the train direction. In the clockwise direction, high lateral forces are observed in cribs 5 & 7. For the counter-clockwise direction, high lateral forces can be found in crib 8. Only in crib 4 did one observe consistent lateral force results regardless of train direction. It is thought that the bias is attributed to train handling characteristics such as acceleration (throttling).

In general, one was able to discern a relationship between application rate and reduction in average forces. Figures 8 & 9 demonstrate that relationship using crib 4 as a basis (leading axle) Please note that a zero KELTRACK application rate denotes the baseline wayside application. Typical baseline operation for the wayside would be to occasionally apply some oil to the low rail to help control lateral forces. Typical lateral forces for a dry rail were found to be higher (i.e. 10 – 15 kips for high rail in crib 4).

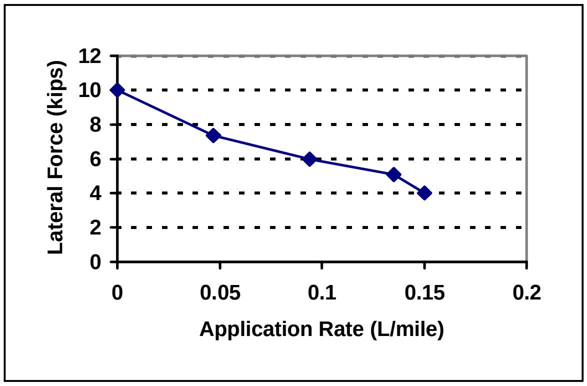

Figure 8: High Rail

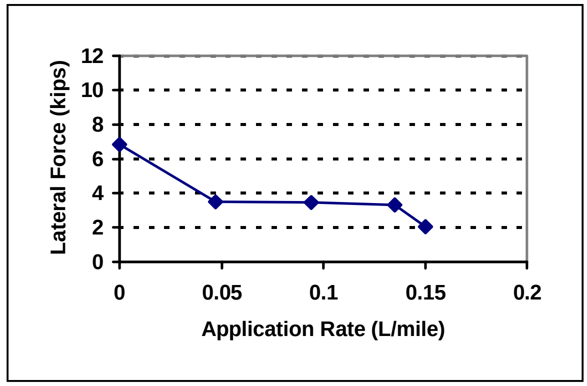

Figure 9: Low Rail

The previous analysis on the effect of KELTRACK effectiveness on lateral force reduction was based on averaging data over the entire 10 hour shift. However, on open track in revenue service, one must be concerned about the *immediate* effect of the application of the KELTRACK on a given curve to reduce lateral forces. The HTL experiments typically would result in a “steady-state” condition where there was sufficient build-up on the entire loop of the KELTRACK product.

To assess a “real life” scenario, the following set of data (figures 10 to 12) evaluated the first several hours of operation on an initially “dry track (Sunday evening shift). The objective would be to determine how quickly it would take for “steady state” conditions to establish themselves as a function of application rate. As before, the data has been filtered from crib 4 (leading axle - high rail) on a lap by lap basis.

“Dry” Baseline (Feb 14th)

Figure 10 represents the “baseline” case where only waysides were used. As one can see, there is an increase in lateral forces in crib 4 as any oils or TOR contamination was removed. The baseline also demonstrates the typical high lateral force behavior (> 10 kips) in the 6 degree curve with respect to the absence of any TOR application. Figure 10b exhibits the typical average lateral forces one would see for a wayside application as well as the large degree of variability associated with those lateral forces.

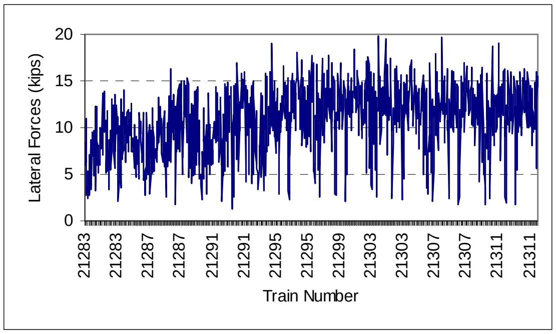

Figure 10a: Crib 4 (Start-up – Waysides)

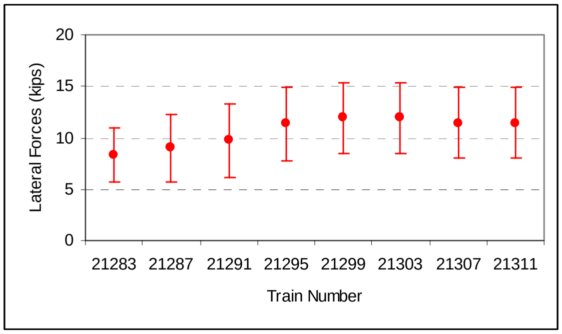

Figure 10b: Crib 4 (Start-up – Waysides)

0.094 L/mile Application Rate (March 12th)

Figures 11a & b highlight the effect of a 0.094 L/mile application rate. Reviewing the data, there does appear to be a slight increase in the initial lateral force data that could be attributed to the requirement for some form of product build-up to achieve steady state conditions. After steady state conditions have been achieved, the lateral force data does appear to be consistent (note small standard deviations) with the average well below the 10 kips limit.

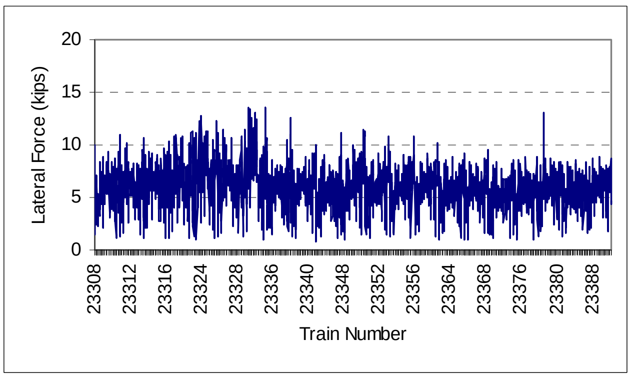

Figure 11a: Crib 4 (Start-up – 0.094L/mile)

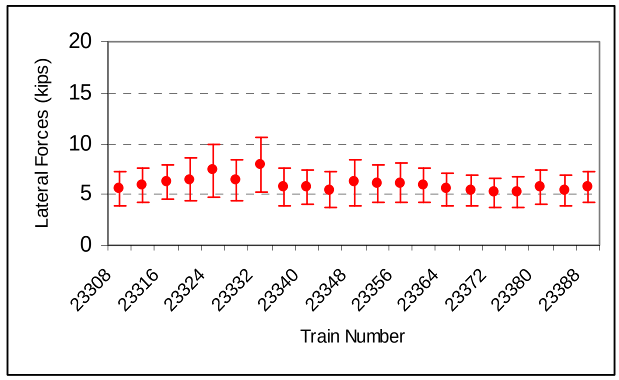

Figure 11b: Crib 4 (Start-up – 0.094L/mile)

Here again one can observe a lower lateral force in the first lap and remains low during the remainder of the start-up period. One can also observe the low variability associated with the lateral forces associated with each consist lap.

On Tuesday March 14th, a series of trials were performed to ascertain the effect of application rates on the reduction in lateral forces. The test plan for this shift was to assess application rates ranging from 0.024 to 0.094 L/mile. The data in figures 13 through 19 highlight the transition ranges for cribs 4 and 7 (Leading axle – high rail). On Tuesdays the consist runs in a counter clockwise direction. In this direction, crib 7 would be close to the entrance of the curve whereas crib 4 would be closer to the exit.

Start-up to 0.094 L/mile Transition

Prior to starting the TOR system, operations involved drying down the rail for approximately 7 laps to establish a baseline. At approximately 12:30 am on the morning of March 15th (train # 25636) the TOR unit was turned on.

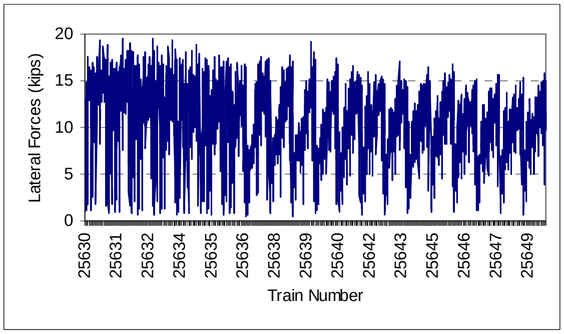

Figure 13a: Crib 4 (0 – 0.094 L/mile)

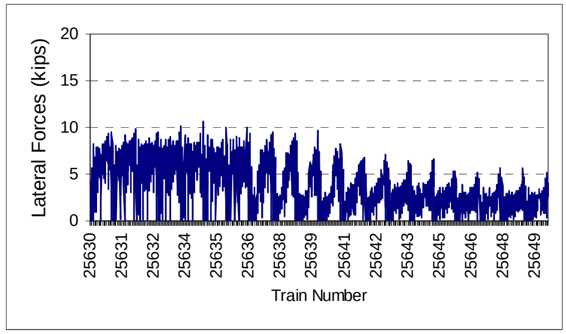

Figure 13b: Crib 7 (0 – 0.094 L/mile)

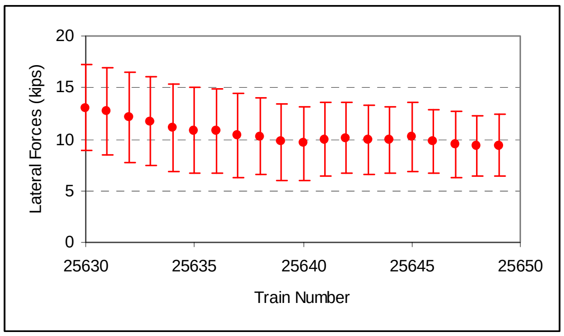

Figure 14a: Crib 4 (0 – 0.094 L/mile)

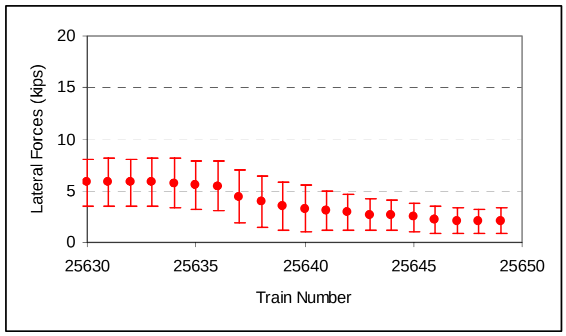

Figure 14b: Crib 7 (0-0.094 L/mile)

Reviewing figures 13 and 14, one can see the effect of the application of 0.094 L/mile of the KELTRACK formulation onto the top of the rail. For both cribs, a pattern emerges (figures 13a & 13b) where the initial lateral forces are low but then gradually increase towards the end of the train. What this suggests is that the rate of KELTRACK consumption is being consumed as the consist passes over the crib(s). The lower forces in crib & are typical when considering its position at the beginning of the curve. Figures 14a & 14b, exhibit the average lateral force for each train pass with the corresponding standard deviation. The product does appear to have more of an impact in the curve entrance, as there is a more dramatic reduction in the average lateral force values. This is not evident in the exit (crib 4) of the curve and is likely due to a high consumption of deposited KELTRACK product. In both cases though, the standard deviation around the average is decreasing indicating some developing consistency in the lateral force data.

One also observes that is has taken longer for lateral forces to reduce for this application of a 0.094 L/mile rate compared to Sunday night's test. A possible explanation is that the deposition rate on Sunday was greater than 0.094 L/mile.

0.094 to 0.047L/mile Transition

The 0.094L/mile application rate was continued until 3:34 am when the rate was halved to approximately 0.047 L/mile; this event occurred at train # 25669. The results of this transition can be seen in figures 15 & 16.

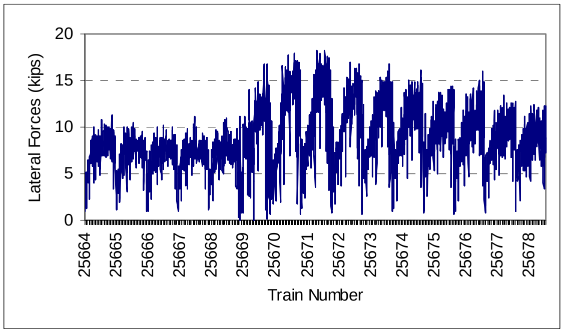

Figure 15a: Crib 4 (0.094 – 0.047 L/mile)

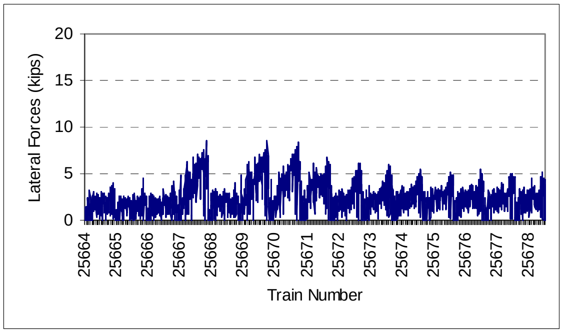

Figure 15b: Crib 7 (0.094 – 0.047 L/mile)

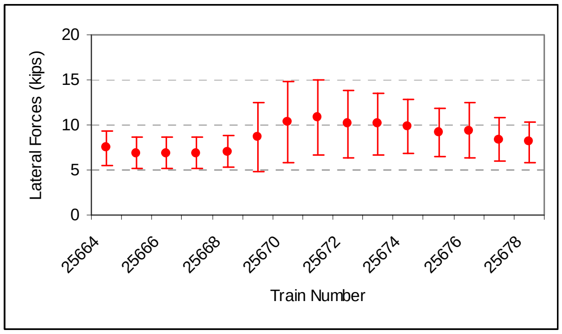

Figure 16a: Crib 4 (0.094 – 0.047 L/mile)

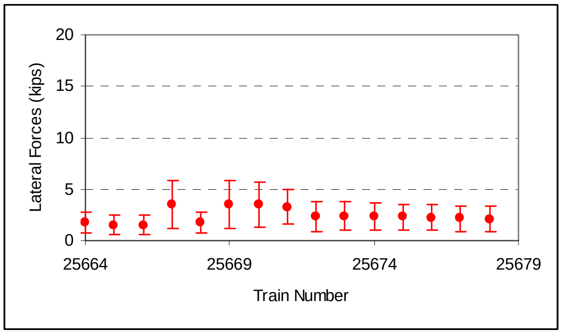

Figure 16b: Crib 7 (0.094 – 0.047 l/mile)

In reviewing the data, one observes that the lateral forces associated with the0.094 L/mile application rate appears to have stabilized at around 7.5 kips in crib 4. This suggests that over the course of the 35 laps where the TOR system was operational, KELTRACK product was eventually brought into the curve resulting in more stable, consistent lateral force data. However, when the application rate was effectively halved, the wheel-rail interface appeared to transition to an “unsteady state” condition as lateral forces and variability increased at both crib sites. Eventually, the entrance of the curve appeared to have reach a new steady state after approximately 6 laps, lateral forces in crib 4 were observed to trend downwards but it is not expected to reach the same levels as with the 0.094 L/mile application rate.

0.047 to 0.0235 L/mile Transition

At approximately 5:30 am (train # 25695), the KELTRACK application was reduced by half again to approximately 0.0235 L/mile. Surprisingly, the effect was minimal in terms of changes to lateral forces in both cribs. Other data though indicated, such as friction readings, indicated that the KELTRACK was being consumed. Testing at the 0.0235 L/mile rate lasted only for nine laps prior to ending the shift. One also does observe a higher degree of variability in the lateral force data on a lap to lap basis.

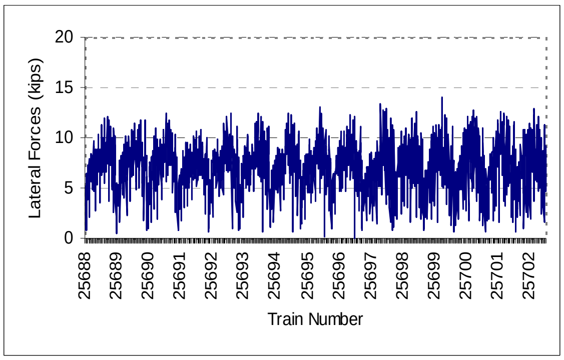

Figure 17a: Crib 4 (0.047 – 0.024 L/mile)

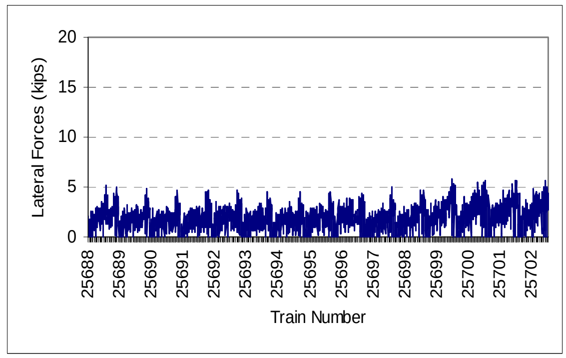

Figure 17b: Crib 7 (0.047 – 0.024 L/mile)

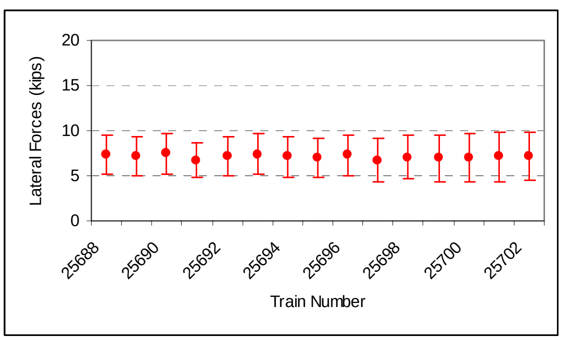

Figure 18a: Crib 4 (0.047 – 0.024 L/mile)

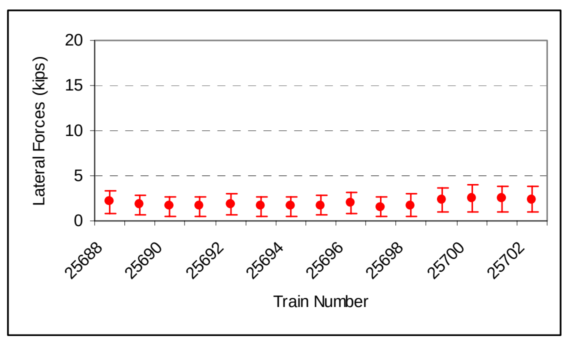

Figure 18b: Crib 7 (0.047 – 0.024 L/mile)