Port of Vancouver
T-5 Loop Track Assessment

Final Report

Prepared for:

Port of Vancouver WA

Prepared by:

TÜV Rheinland Mobility, Inc.
Rail Sciences Division

May 11, 2016

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Introduction

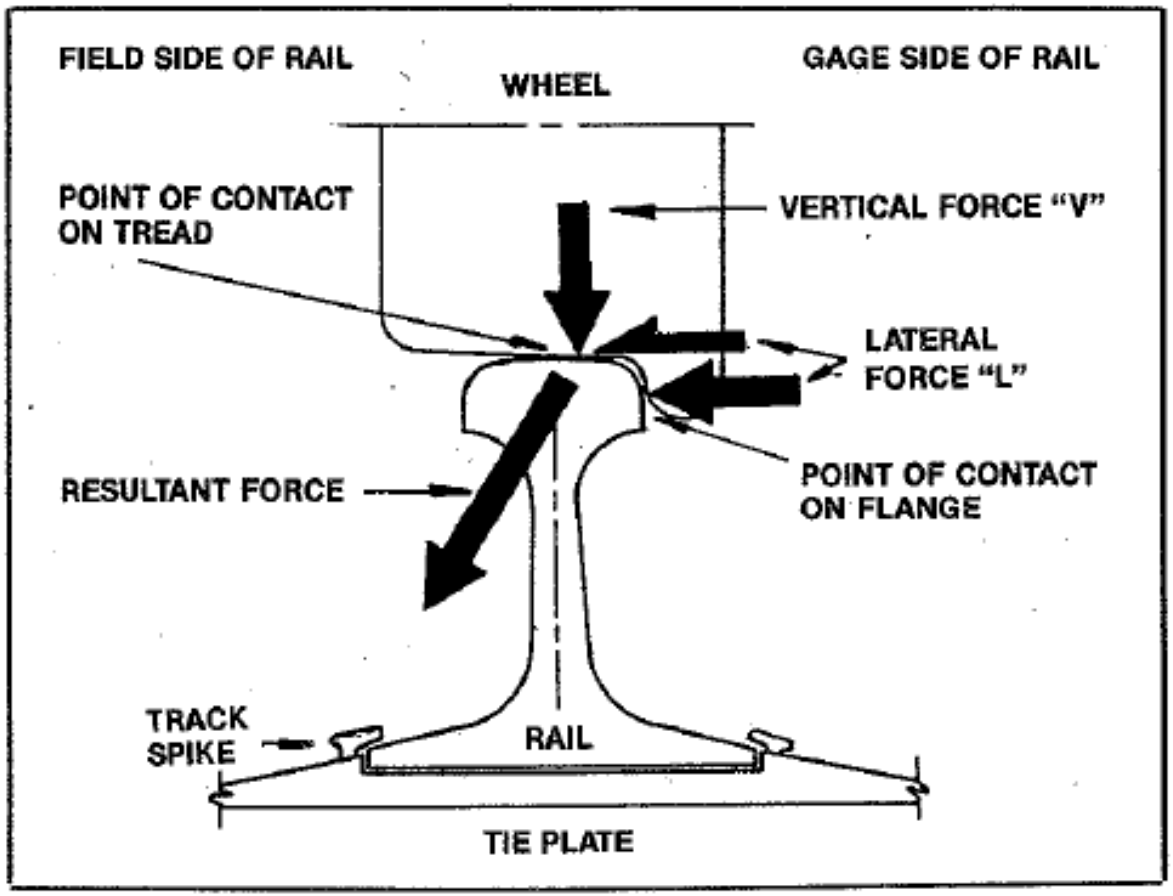
- Port of Vancouver WA (POV) through their consultants at HDR requested that TÜV Rheinland Mobility, Inc. Rail Sciences Division (TÜV Rail Sciences) evaluate the derailment risk for three proposed unloading loops for grain, oil and mineral freight located within the Port.
- Results of the preliminary analysis were forwarded to HDR in August 2014.
- Subsequent to the August 2014 report, Port of Vancouver management removed grain and mineral freight unloading from consideration based on market conditions in 2016.
- Consequently, this report focuses solely on the remaining assessment of potential derailment risk of crude oil unit trains operating on the proposed T-5 unloading loop including the connection track from the BNSF main track.
- POV requested that TÜV Rail Sciences compute the lateral and vertical forces as well as the resulting L/V ratios for the proposed T-5 loop track alignment including the proposed connection track exiting BNSF Fallbridge Subdivision at MP 10.69 into the T-5 loop track.
- The lateral to vertical ratio (L/V) is the lateral force pushing outward against the rail compared to the vertical force pushing downward on the top of the rail.

Introduction

- HDR provided TÜV-Rail Sciences with finalized track geometry data, operating speed limits, and train consist (make-up) information below.
  - Unit train consisting of 120 tank cars, 3 lead locomotives, 2 rear locomotives *
- The AAR Train Operations Simulator (TOS) was used to determine the longitudinal in-train forces and the DeltaRail VAMPIRE® rail vehicle dynamics package was used to determine maximum wheel climb L/V ratios, maximum truckside L/V ratios, maximum axle sum L/V ratios and the minimum wheel unloading percentages.
- The industry accepted L/V ratio and wheel unloading design limit criteria above is established in AAR Manual of Standards and Recommended Practices, M-1001, Chapter 11, Section 11.5.2, Trackworthiness Criteria.
- The following Slide 4 illustrates the lateral to vertical relationship (L/V ratio) between wheel and rail.

* See Slide 10 for discussion of changes to the train make-up after the Draft Environmental Impact Statement (DEIS) was issued.

Lateral to Vertical Force Relationsip Between Rail and Wheel



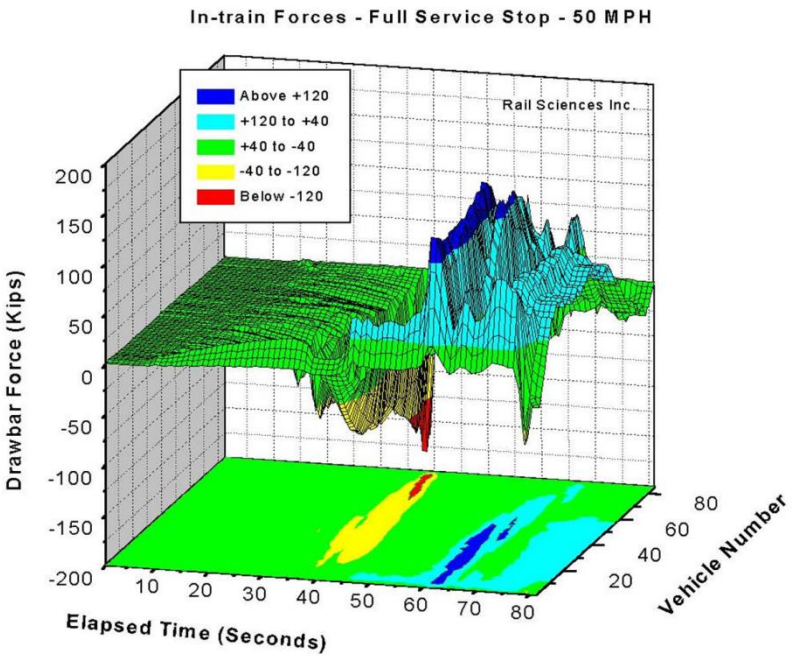
The lateral to vertical ratio (L/V) is the lateral force pushing outward against the rail compared to the vertical force pushing downward on the top of the rail. The tendency for the rail to tip and/or move laterally, or for the wheel to climb the rail increases as the L/V ratio increases.

Introduction

- The results of the analyses are presented in two sections:
  - Longitudinal Force Analysis [TOS]
  - Vehicle Dynamics Simulation [VAMPIRE®]
- Slides 6 and 7 describe analytical applications of the TOS and VAMPIRE® software.

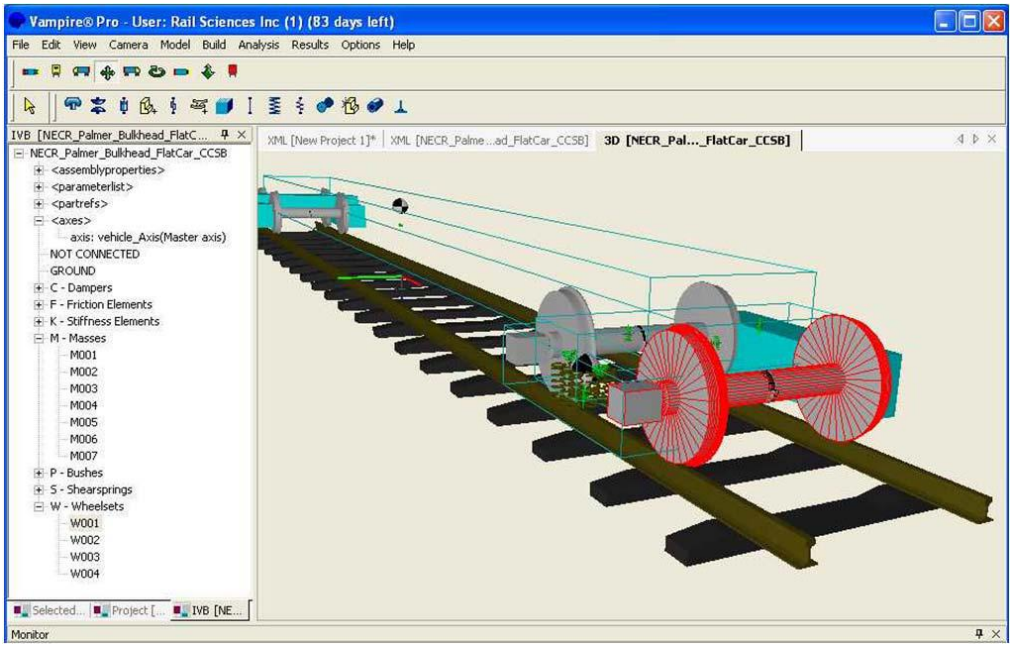
Longitudinal Force Analysis - TOS

- TÜV-Rail Sciences is licensed user of TOS ™
  - Train make up and marshalling
    - » Safe trailing tonnage behind empty, long/short car
    - » Route locomotive tonnage ratings
    - » Operating rules and restrictions; timetable instructions
    - » Locomotive placement for helper locomotives
  - Train slack action
  - Derailments
  - Fuel conservation studies
  - Locomotive utilization studies
  - Over the road running time analysis

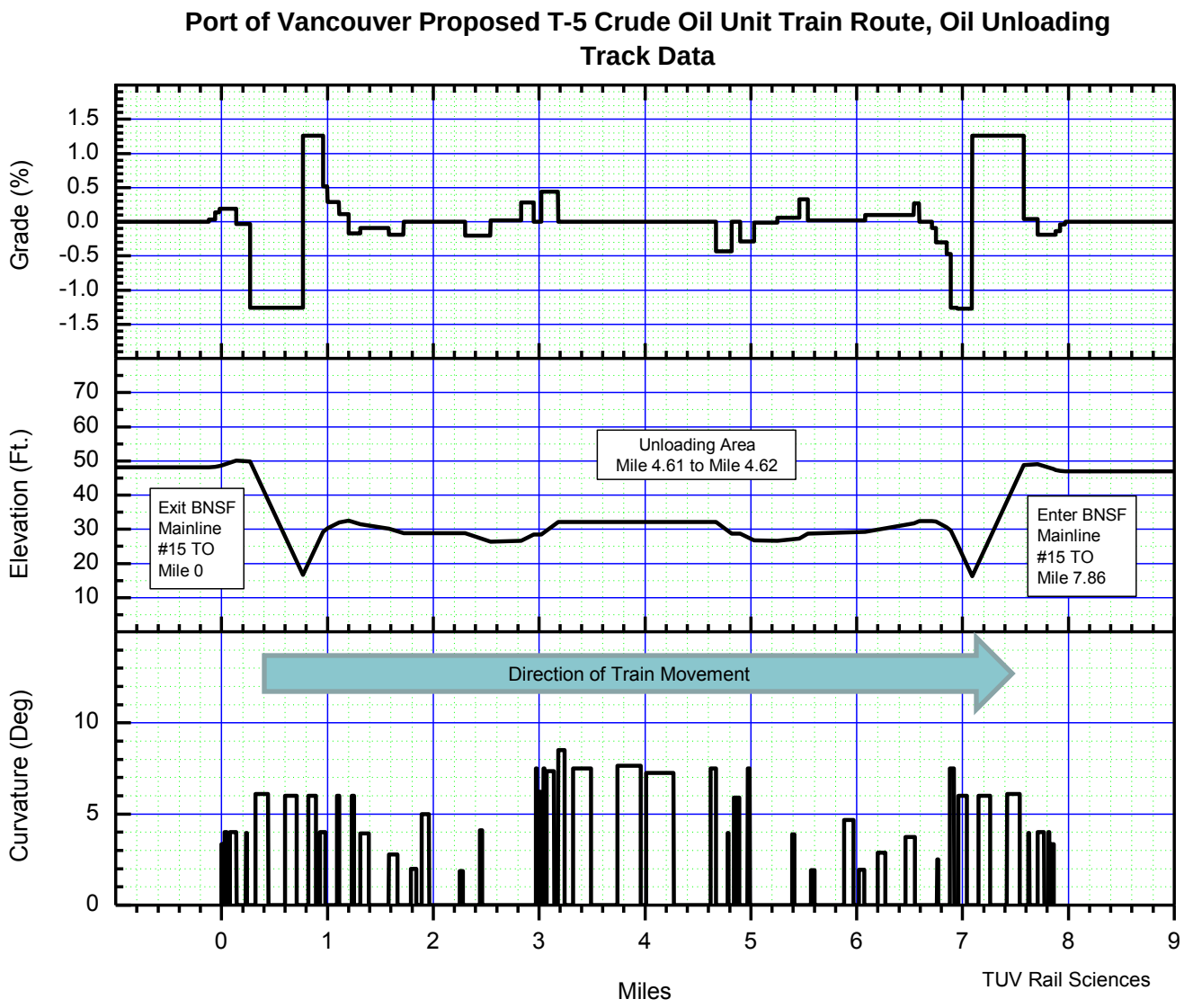


Vehicle Dynamics Simulation - VAMPIRE®

- VAMPIRE® is a vehicle – track interaction computer simulation software.
- It simulates rail vehicles with their suspension characteristics, and their performance travelling over track features.
- It is a tool to predict the following:
  - Derailment Risk (L/V Ratio)
  - Forces into track
  - Ride Quality



- The following steps were followed for the analysis:
  - TOS was used to determine the longitudinal drawbar forces for operations requiring nominal train handling, full service braking, and emergency braking. The maximum draft (in tension) and buff forces (in compression) determined by TOS were evaluated relevant to industry practices.
  - The Vampire® model in conjunction with the results from the TOS simulations were used to determine the maximum L/V ratios and minimum wheel loading percentages for each of the TOS drawbar force inputs. The analysis was performed for various FRA track maintenance levels. Results were compared to industry standards.
- The following Slide 9 shows the geometry data for the proposed track used in the analysis. The survey station data has been converted to mileage to match the simulation output presented later in the report. Mile 0 is the point of switch of the #15 turnout exiting the BNSF mainline [MP 10.69] into the facility.



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- The following trains (1 loaded and 1 empty) were provided to TÜV Rail Sciences by HDR for use in the analysis:

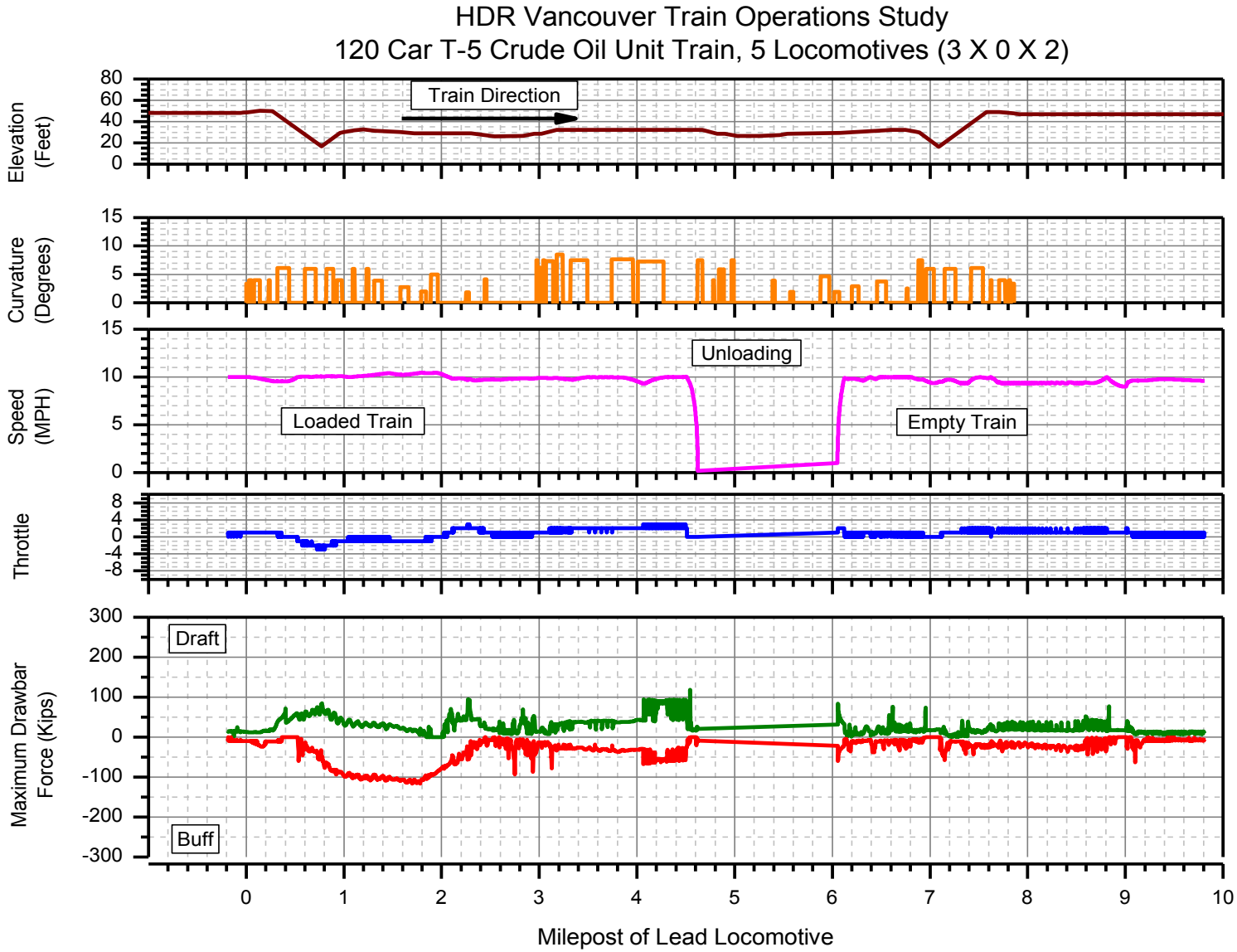
Type of Train	Number of Locomotives	Configuration of Locomotive	Number of Cars	Car Length (Ft.)	Car Weight (Tons)	Trailing Weight (Tons)	Train Length (Ft.)
Loaded T-5 Crude Oil Train	5	3 x 0 x 2	120	63	143	18000	7564
Empty T-5 Crude Oil Train	5	3 x 0 x 2	120	63	29	3500	7564

- TÜV Rail Sciences' analysis is based on the train make-up from the Draft Environmental Impact Statement (DEIS). Subsequent to the issuance of the DEIS, Vancouver Energy submitted comments that slightly altered the train configuration. Under the configuration, crude oil would be delivered to the Port in unit trains composed of up to 100 to 118 tank cars with two buffer cars [120 cars total] and three locomotives instead of five locomotives.
- TÜV Rail Sciences took a conservative approach and performed all longitudinal simulations with five locomotives rather than three to capture the higher in-train forces available with greater motive power. However, our modeling has confirmed that reducing the number of locomotives from five to three had no negative impact on the results of the analysis.

TOS Analysis

- The Train Operations Simulator (TOS) was used to determine the longitudinal in-train drawbar forces for the loaded and empty consists.
- Over-the-road run-through simulations were conducted across the proposed route and through the connection track assuming a 10 MPH speed limit [except while unloading] using nominal train handling.
  - Throttle and dynamic brake modulation was used to handle the trains and maintain the speed limit.
  - Drawbar forces on all cars in each train were extracted for each second of simulation.
  - The maximum draft and buff forces occurring anywhere in the train were compiled and analyzed.
- The following slide shows the run-through simulation results for the loaded and empty trains. Each plot shows the track geometry (elevation and curvature), speed, train handling, and maximum draft and buff forces.
- Empirically, longitudinal dynamic forces within the +/-200 Kip range are acceptable for unit train operations.
- *Forces in the two trains simulated during normal run-through operations [no braking - full service or emergency] did not exceed +/-150 Kips.*

TOS Analysis Results



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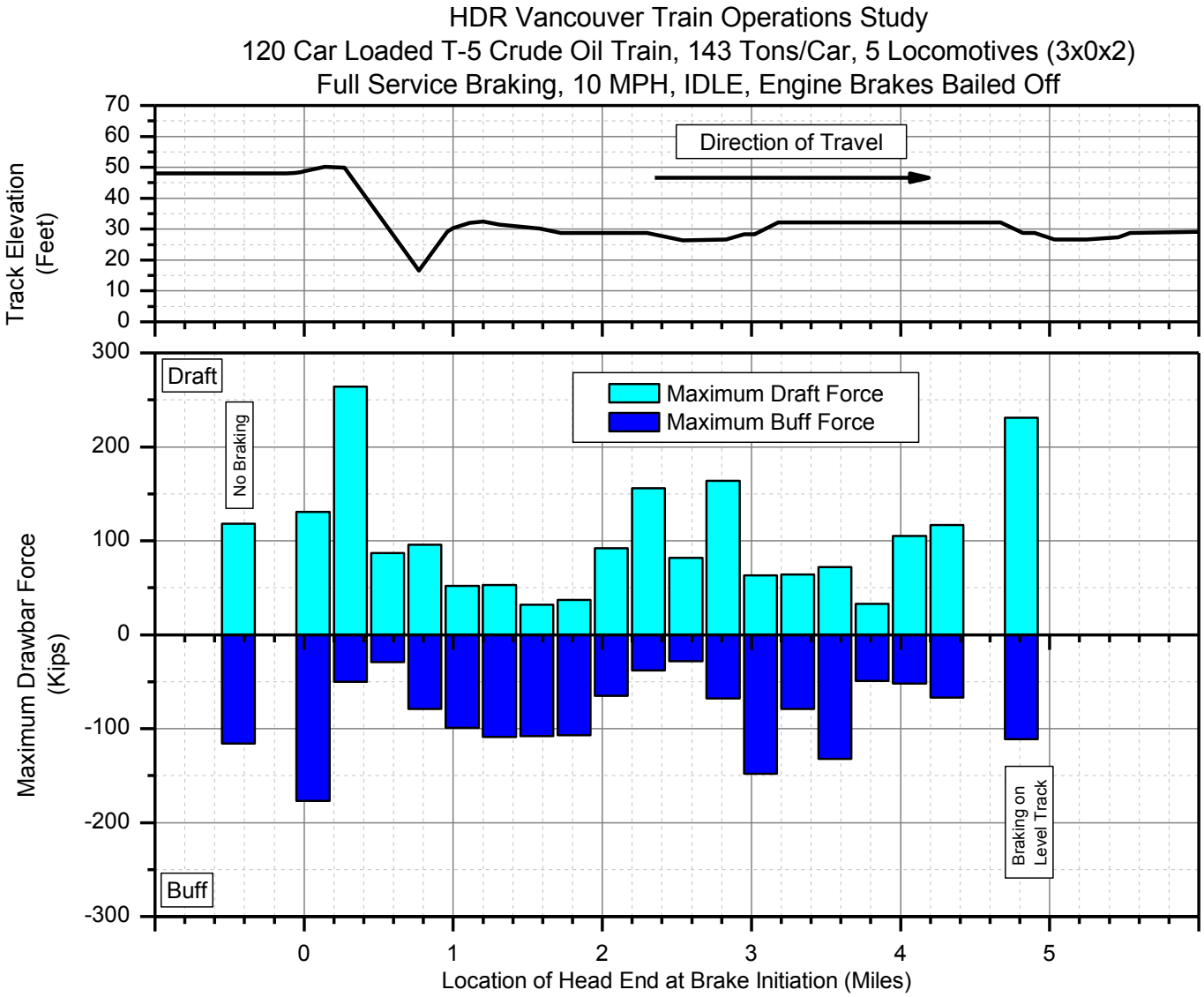
- Next, a series of train stopping simulations was performed using the loaded and empty trains. Train handling leading up to each stop was extracted from the nominal train handling simulations shown in the previous slide.
- Full service and head-end emergency stops are not normally required during operations to control speed but may be initiated if unusual circumstances dictate.
- Two train braking scenarios were simulated:
  1. *Full Service*: Nominal train handling was employed up to the train braking location at which point full service braking was initiated; the throttle was immediately moved to IDLE from its current position; and the engine brakes were bailed off.
  2. *Head-End Emergency*: Nominal train handling was employed up to the train braking location at which point emergency braking was initiated from the lead locomotive; the throttle was immediately moved to IDLE from its current position; and the engine brakes were bailed off.
- Braking from 10 mph was initiated (at 0.25 mile intervals) over the proposed unloading loop.

- The maximum draft and buff forces were extracted from all of the stopping simulations at each track location.
- For comparison, the full service and head-end emergency braking stops were also performed for each train on level track using similar train handling scenarios prior to braking.
- The maximum draft and buff forces are plotted on the following four slides for loaded and empty consists during full service and emergency stops.
- The unloading area in each loop where the train will be at very low speed was not included in the stopping simulations.
- The maximum draft and buff forces from the nominal train handling simulations [no braking] and from the level track stopping simulations are also plotted on the graphs for comparison to the stopping simulations.

TOS Analysis Results



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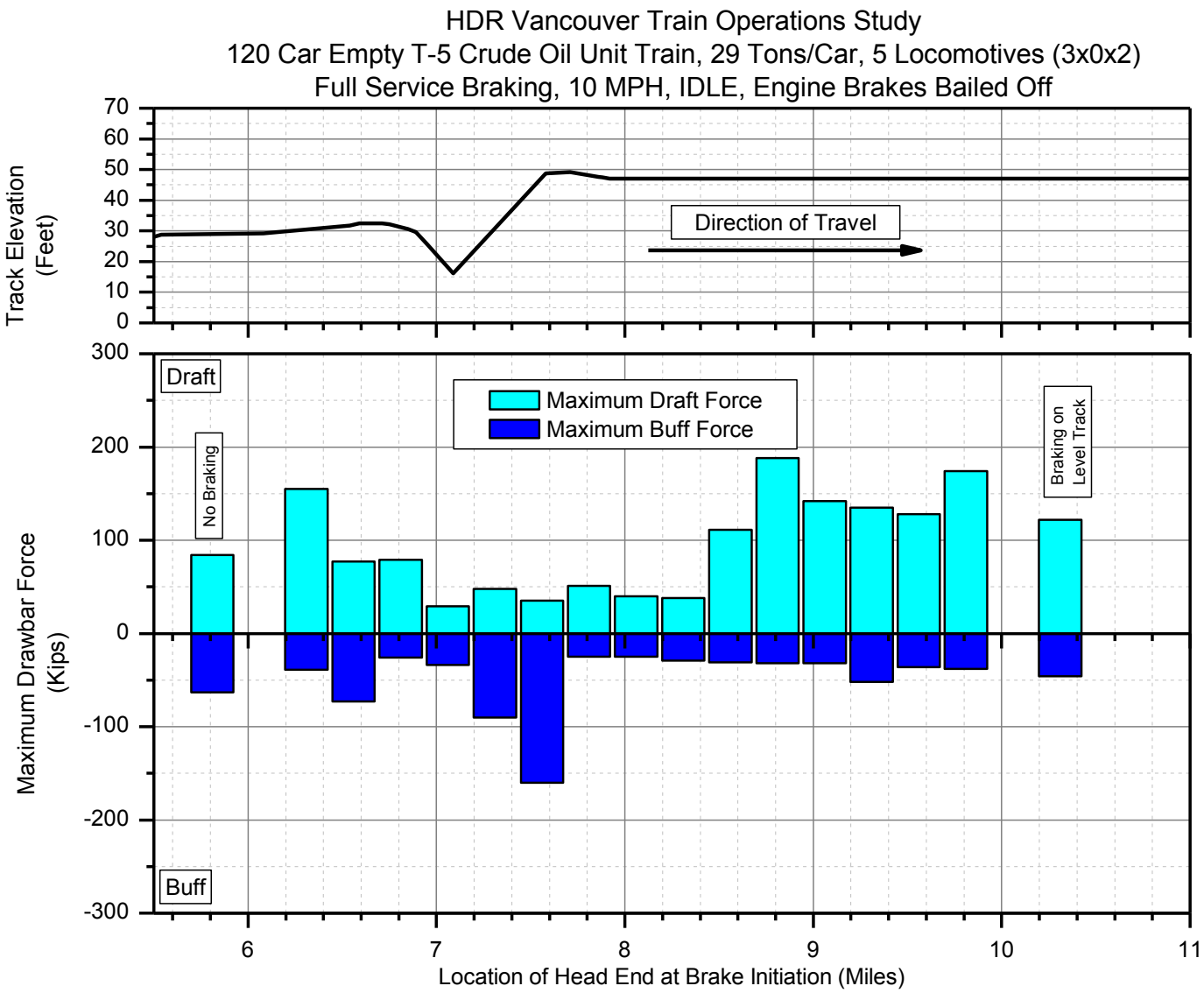
TOS Analysis Results



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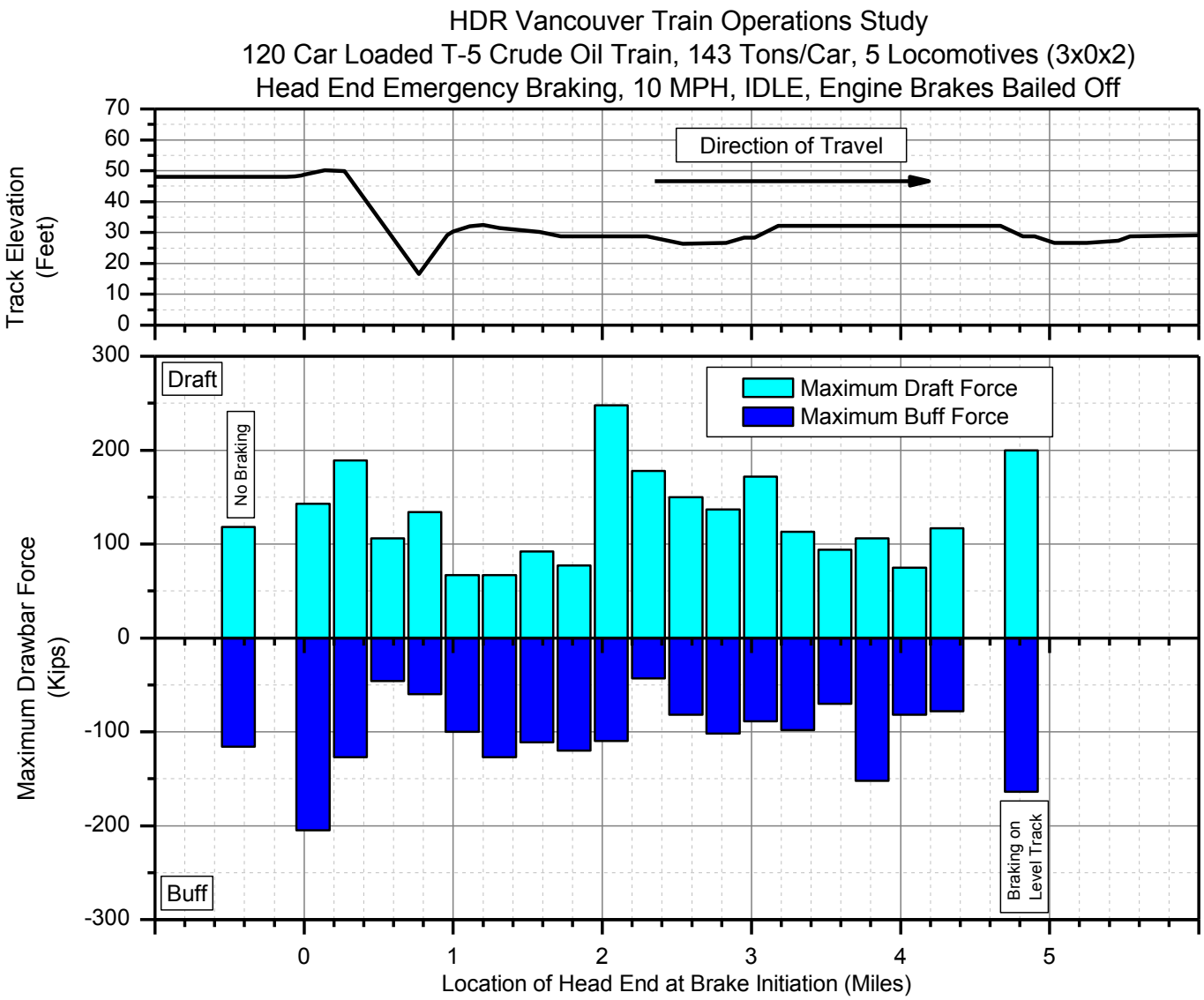
TOS Analysis Results



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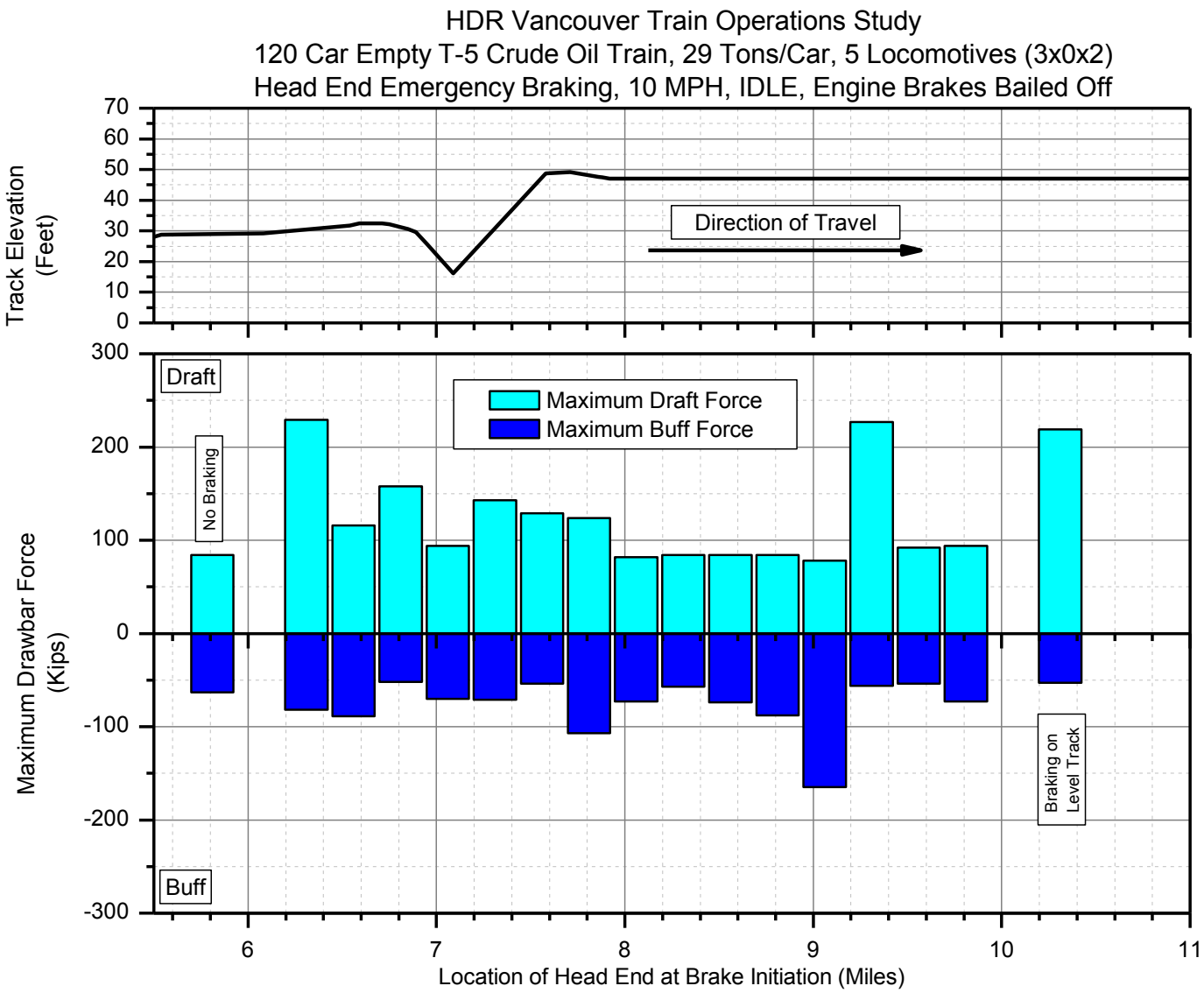
TOS Analysis Results



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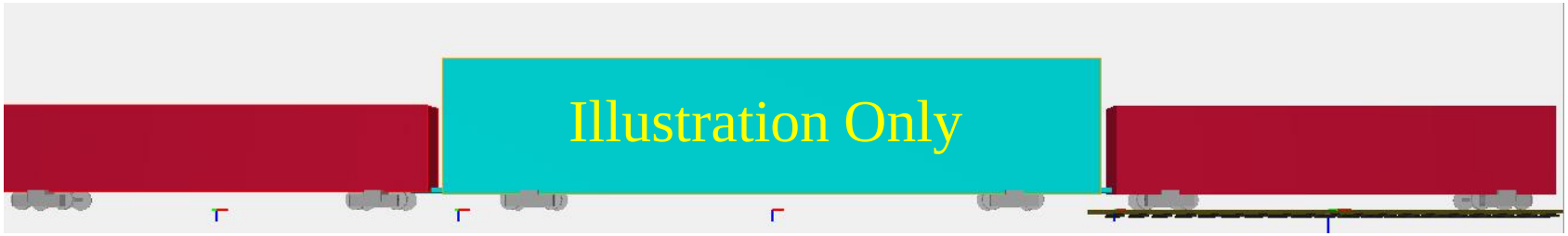
TOS Analysis Summary

- Longitudinal simulations using the TOS model determined moderate throttle and dynamic brake commands (RUN 5 through DYN 5) could be utilized to control train speed at 10 mph and operate through the unloading route.
- Both of the simulated trains (1 loaded and 1 empty), could be moved without stopping using nominal train handling through the loop without any adverse slack or steady-state forces.
  - Maximum forces were predicted to be a maximum of +120 kips draft and -120 kips buff for through-route operations.
  - The predicted forces on the proposed loop tracks are low to moderate and would not present a high risk for derailment.
- *The full service and emergency braking stops resulted in higher draft and buff forces not exceeding +264 Kips and -205 Kips, respectively.* By comparison, drawbar forces for the same trains stopping on level track resulted in maximums of +230 Kips draft and -165 Kips buff.

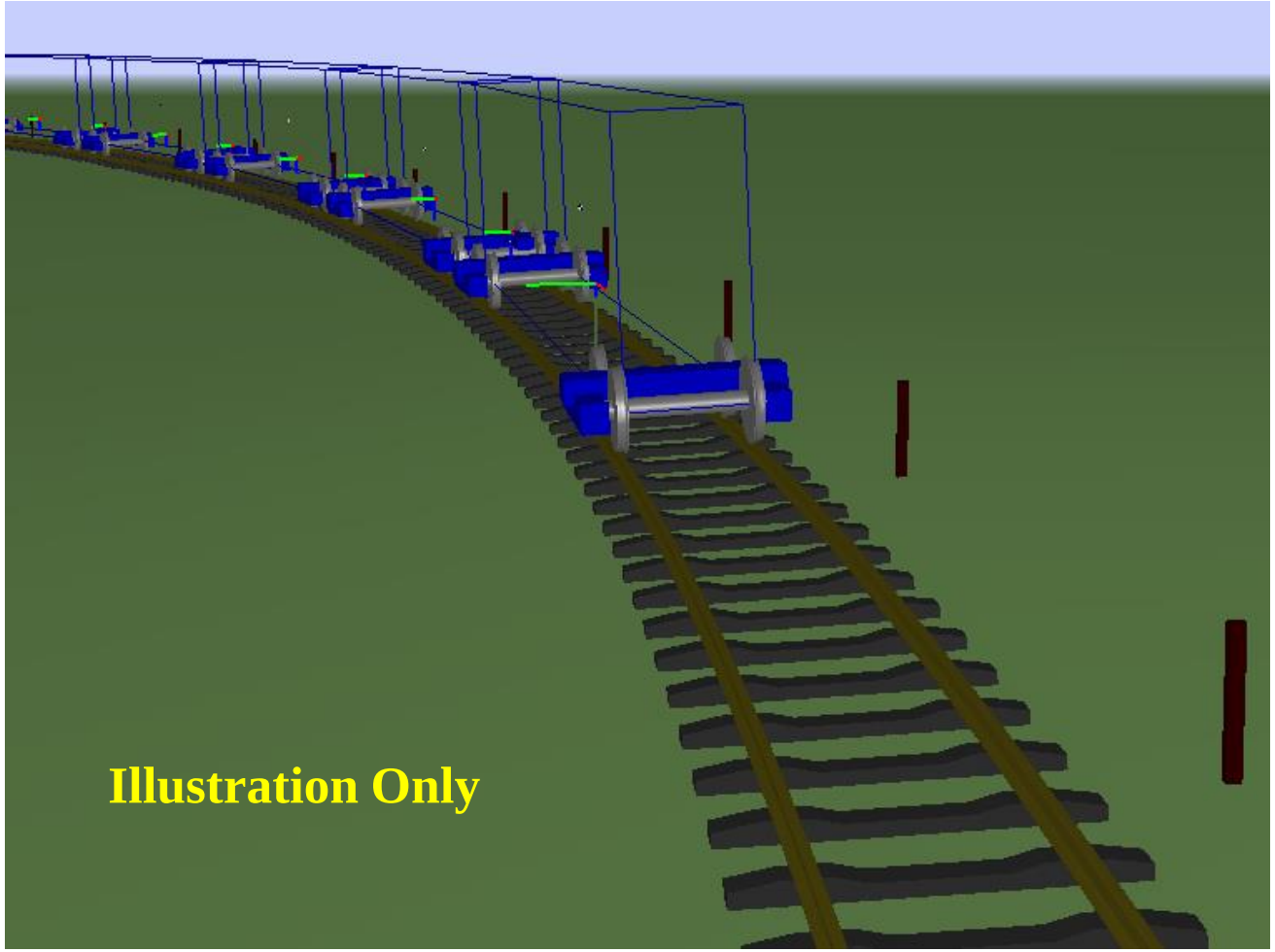
VAMPIRE® Simulation Introduction

- The DeltaRail VAMPIRE® rail vehicle dynamics package was used to determine maximum L/V ratios and minimum wheel unloading percentages.
- The full range of maximum buff and draft forces obtained from the longitudinal simulations were applied individually to the outside vehicles in the three-car models to transmit the coupler forces at the appropriate magnitude and angle to the middle vehicle.
- This method allows the effects of the in-train forces to be included in the calculations of the derailment indicators.

VAMPIRE ® Vehicle Modeling



- Multi-car models of all vehicle [tank car] types in both the loaded and unloaded states were used for the VAMPIRE ® simulations so that in-train forces calculated from the longitudinal simulations and coupler angularity could be included as the vehicles move over the intended route.
- As vehicles move through curves and over track geometry features, the forces being applied through the couplers will change directions along with the couplers.
- The angles that the couplers take, and the subsequent changing directions of action of their forces have a significant effect at the wheel/rail interface. The multi-car model is capable of taking this into account during simulation.
- The maximum forces calculated in the train handling simulations for the various vehicles and loading conditions were applied throughout the corresponding VAMPIRE® simulations to obtain the most conservative results.

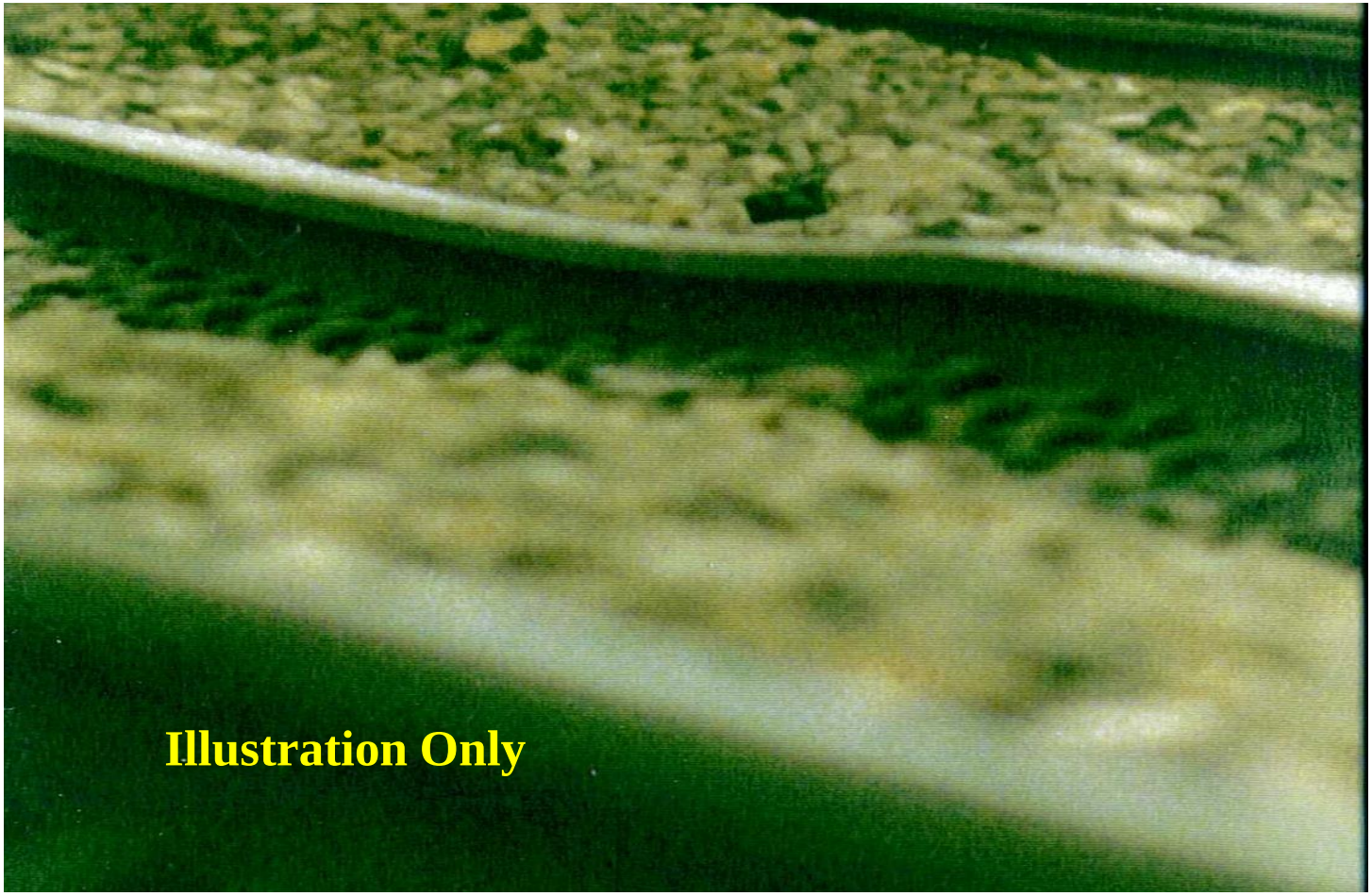


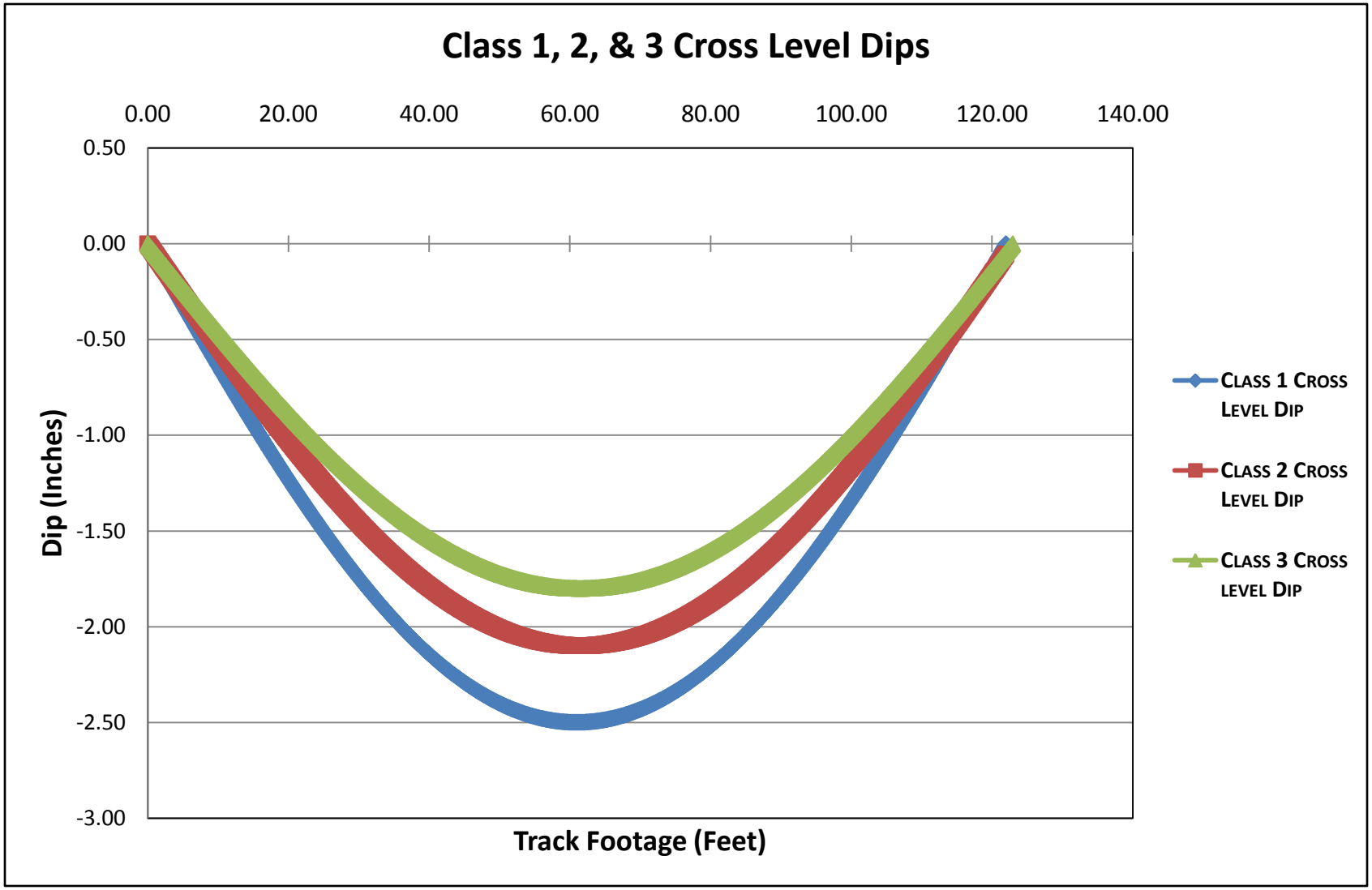
Graphical example of a multi-car model moving through a curve taking into account applied coupler forces and angularity.

- Cross level dips, not exceeding limits specified in 49 CFR §213.63 for Class 1, 2 and 3 track, were introduced at the key locations and the simulations were repeated in order to investigate sensitivity to possible deviation from less than ideal geometry according to the track class.
- This was done to determine if the in-train force levels predicted by TOS simulation are significant with the presence of local track anomalies and indicative of inherent derailment risk.
- Cross level is the measurement of the relative difference in elevation (height) between the top surface of the two rails at any point on the railroad track. Slide 25 shows an example of a cross level dip [illustration purpose only].
- Track models were created of the routes in question using the following conditions:
  - As designed based upon provided data
  - With a Class 1 cross level dip in the center of the 3 highest degree curves
  - With a Class 2 cross level dip in the center of the 3 highest degree curves
  - With a Class 3 cross level dip in the center of the 3 highest degree curves

- Slide 26 shows the Class 1, 2 ,and 3 cross level dips graphically.
- All simulations were performed at 10 mph, i.e., the maximum authorized speed in the Port.

Cross Level Dip




Class 1, 2, & 3 Cross Level Dips
0.00
20.00
40.00
60.00
80.00
100.00
120.00
140.00
0.50
0.00
-0.50
-1.00
-1.50
-2.00
-2.50
-3.00
Dip (Inches)
Track Footage (Feet)
Class 1 Cross Level Dip
Class 2 Cross Level Dip
Class 3 Cross level Dip

VAMPIRE ® Simulation

- The highest degree of curvature on the loop track defined the key locations used for the Vampire ® analysis. As a result, the following curves on the T-5 track loop were singled out for sensitivity to cross level deviations:
  - 8.50 degree curve on the T-5 crude oil unit train unloading track.
  - 7.50 degree curve on the T-5 crude oil unit train unloading track.
- Based on direction of operation on the T-5 loop track:
  - Inbound loaded unit trains negotiate a maximum of 8.50 degree curvature.
  - Outbound empty unit trains negotiate a maximum of 7.50 degree curvature.
- The in-train force (draft and buff) maximums, determined from the TOS nominal handling and stopping simulations were used as input to the Vampire ® model.

- Derailment indicators that were output from the Vampire® simulations for the middle car of the 3-car model are as follows:
  - Individual wheel L/V ratio (wheel climb indicator)
  - Vertical wheel load percentage (wheel lift indicator)
  - Axle sum L/V ratio (wheel climb indicator)
  - Truck side L/V ratio (rail shift/rollover indicator - loaded vehicles only)
- These outputs were compared to AAR Chapter 11 prescribed thresholds indicative of potential derailment conditions.
- The following eight tables contain the Vampire® results at each TOS generated drawbar force maximum.
- The tables are separated into draft and buff and full service and emergency stops for both 8.50 and 7.50 degree curves. TOS force simulation results are shown in yellow in each of the tables.
- Callouts superimposed on the applicable tables identify the four maximum/minimum output values [in red font] compared to AAR Chapter 11 thresholds and the resulting derailment potential.

Draft Forces During Full Service Stop in 8.5º Curve

Simulation Results - Draft Forces During Full Service Stop at 10 MPH					
		8.5 Degree Curve			
Simulation		Crude Oil Car			
Model	Result Description	Loaded	Empty	AAR Threshold	Indicator of:
TOS	Maximum Draft Force During Full Service Stop	264	188		
Vampire	Wheel L/V Design Track	0.35	0.56	Chapter 11 Maximum = 1.0	Wheel Climb
Vampire	Wheel L/V Class 1 Track	0.43	0.58	Chapter 11 Maximum = 1.0	
Vampire	Wheel L/V Class 2 Track	0.43	0.57	Chapter 11 Maximum = 1.0	
Vampire	Wheel L/V Class 3 Track	NC	0.56	Chapter 11 Maximum = 1.0	
Vampire	Vertical Wheel Load (%) Design Track	87.78	55.12	Chapter 11 Minimum = 10%	Wheel Lift
Vampire	Vertical Wheel Load (%) Class 1 Track	69.12	30.44	Chapter 11 Minimum = 10%	
Vampire	Vertical Wheel Load (%) Class 2 Track	72.56	31.27	Chapter 11 Minimum = 10%	
Vampire	Vertical Wheel Load (%) Class 3 Track	NC	31.94	Chapter 11 Minimum = 10%	
Vampire	Axle Sum L/V Design Track	0.69	0.79	Chapter 11 Maximum = 1.5	Wheel Climb
Vampire	Axle Sum L/V Class 1 Track	0.76	0.79	Chapter 11 Maximum = 1.5	
Vampire	Axle Sum L/V Class 2 Track	0.77	0.79	Chapter 11 Maximum = 1.5	
Vampire	Axle Sum L/V Class 3 Track	NC	0.79	Chapter 11 Maximum = 1.5	
Vampire	Truck Side L/V Design Track	0.36	NC	Chapter 11 Maximum = 0.6	Shift/Roll Rail
Vampire	Truck Side L/V Class 1 Track	0.36	NC	Chapter 11 Maximum = 0.6	
Vampire	Truck Side L/V Class 2 Track	0.36	NC	Chapter 11 Maximum = 0.6	

Note: NC = Not Computed.

Empty car values are not relevant since empty unit trains do not traverse 8.50 degree curvature.

Buff Forces During Full Service Stop in 8.5º Curve

Simulation Results - Buff Forces During Full Service Stop at 10 MPH					
		8.5 Degree Curve			
Simulation		Crude Oil Car			
Model	Result Description	Loaded	Empty	AAR Threshold	Indicator of:
TOS	Maximum Buff Force During Full Service Stop	-177	-160		
Vampire	Wheel L/V Design Track	0.47	0.64	Chapter 11 Maximum = 1.0	Wheel Climb
Vampire	Wheel L/V Class 1 Track	0.52	0.79	Chapter 11 Maximum = 1.0	
Vampire	Wheel L/V Class 2 Track	0.50	0.80	Chapter 11 Maximum = 1.0	
Vampire	Wheel L/V Class 3 Track	NC	0.81	Chapter 11 Maximum = 1.0	
Vampire	Vertical Wheel Load (%) Design Track	80.93	53.24	Chapter 11 Minimum = 10%	Wheel Lift
Vampire	Vertical Wheel Load (%) Class 1 Track	54.91	17.42	Chapter 11 Minimum = 10%	
Vampire	Vertical Wheel Load (%) Class 2 Track	57.30	19.27	Chapter 11 Minimum = 10%	
Vampire		NC	21.00	C	
Vampire		0.79	0.93	C	
Vampire		0.85	1.05	C	
Vampire	Axle Sum L/V Class 2 Track	0.83	1.06	Chapter 11 Maximum = 1.5	
Vampire	Axle Sum L/V Class 3 Track	NC	1.06	Chapter 11 Maximum = 1.5	
Vampire	Truck Side L/V Design Track	0.38	NC	Chapter 11 Maximum = 0.6	Shift/Roll Rail
Vampire	Truck Side L/V Class 1 Track	0.40	NC	Chapter 11 Maximum = 0.6	
Vampire	Truck Side L/V Class 2 Track	0.39	NC	Chapter 11 Maximum = 0.6	

81% design vertical wheel load is well above Chapter 11 Minimum of 10%. Indicates low derailment risk due to wheel lift.

0.38 design truck side L/V ratio is well below Chapter 11 Maximum of 0.60. Indicates low derailment risk due to shifted or rolled rail.

Note: NC = Not Computed.

Empty car values are not relevant since empty unit trains do not traverse 8.50 degree curvature.

Draft Forces During Emergency Stop in 8.5º Curve

Simulation Results - Draft Forces During Emergency Stop at 10 MPH					
		8.5 Degree Curve			
Simulation		Crude Oil Car			
Model	Result Description	Loaded	Empty	AAR Threshold	Indicator of:
TOS	Maximum Draft Force During Emergency Stop	248	229		
Vampire	Wheel L/V Design Track	0.35	0.67	Chapter 11 Maximum = 1.0	Wheel Climb
Vampire	Wheel L/V Class 1 Track	0.43	0.82	Chapter 11 Maximum = 1.0	
Vampire	Wheel L/V Class 2 Track	0.43	0.81	Chapter 11 Maximum = 1.0	
Vampire	Wheel L/V Class 3 Track	NC	0.82	Chapter 11 Maximum = 1.0	
Vampire	Vertical Wheel Load (%) Design Track	89.66	44.33	Chapter 11 Minimum = 10%	Wheel Lift
Vampire	Vertical Wheel Load (%) Class 1 Track	68.57	22.59	Chapter 11 Minimum = 10%	
Vampire	Vertical Wheel Load (%) Class 2 Track	72.09	23.01	Chapter 11 Minimum = 10%	
Vampire	Vertical Wheel Load (%) Class 3 Track	NC	23.79	Chapter 11 Minimum = 10%	
Vampire	Axle Sum L/V Design Track	0.69	0.87	Chapter 11 Maximum = 1.5	Wheel Climb
Vampire	Axle Sum L/V Class 1 Track	0.77	0.89	Chapter 11 Maximum = 1.5	
Vampire	Axle Sum L/V Class 2 Track	0.77	0.88	Chapter 11 Maximum = 1.5	
Vampire	Axle Sum L/V Class 3 Track	NC	0.87	Chapter 11 Maximum = 1.5	
Vampire	Truck Side L/V Design Track	0.36	NC	Chapter 11 Maximum = 0.6	Shift/Roll Rail
Vampire	Truck Side L/V Class 1 Track	0.36	NC	Chapter 11 Maximum = 0.6	
Vampire	Truck Side L/V Class 2 Track	0.36	NC	Chapter 11 Maximum = 0.6	

Note: NC = Not Computed.

Empty car values are not relevant since empty unit trains do not traverse 8.50 degree curvature.

Buff Forces During Emergency Stop in 8.5º Curve

Simulation Results - Buff Forces During Emergency Stop at 10 MPH					
		8.5 Degree Curve			
Simulation		Crude Oil Car			
Model	Result Description	Loaded	Empty	AAR Threshold	Indicator of:
TOS	Maximum Buff Force During Emergency Stop	-205	-165		
Vampire	Wheel L/V Design Track	0.47	0.64	Chapter 11 Maximum = 1.0	Wheel Climb
Vampire	Wheel L/V Class 1 Track	0.52	0.79	Chapter 11 Maximum = 1.0	
Vampire	Wheel L/V Class 2 Track	0.50	0.80	Chapter 11 Maximum = 1.0	
Vampire	Wheel L/V Class 3 Track	NC	0.81	Chapter 11 Maximum = 1.0	
Vampire	Vertical Wheel Load (%) Design Track	81.08	53.24	Chapter 11 Minimum = 10%	Wheel Lift
Vampire	Vertical Wheel Load (%) Class 1 Track	54.11	17.42	Chapter 11 Minimum = 10%	
Vampire	Vertical Wheel Load (%) Class 2 Track	56.46	19.27	Chapter 11 Minimum = 10%	
Vampire	Vertical Wheel Load (%) Class 3 Track	NC	21.00	Chapter 11 Minimum = 10%	
Vampire	Axle Sum L/V Design Track	0.80	0.93	Chapter 11 Maximum = 1.5	Wheel Climb
Vampire	Axle Sum L/V Class 1 Track	0.85	1.05	Chapter 11 Maximum = 1.5	
Vampire	Axle Sum L/V Class 2 Track	0.83	1.06	Chapter 11 Maximum = 1.5	
Van		NC	1.06	Chapter 11 Maximum = 1.5	
Van		0.38	NC	Chapter 11 Maximum = 0.6	Shift/Roll Rail
Van		0.40	NC	Chapter 11 Maximum = 0.6	
Van		0.39	NC	Chapter 11 Maximum = 0.6	

0.80 design axle sum L/V ratio is well below Chapter 11 Maximum of 1.5. Indicates low derailment risk due to wheel climb.

Note: NC = Not Computed.

Empty car values are not relevant since empty unit trains do not traverse 8.50 degree curvature.

Draft Forces During Full Service Stop in 7.5º Curve

Simulation Results - Draft Forces During Full Service Stop at 10 MPH					
		7.5 Degree Curve			
Simulation		Crude Oil Car			
Model	Result Description	Loaded	Empty	AAR Threshold	Indicator of:
TOS	Maximum Draft Force During Full Service Stop	264	188		
Vampire	Wheel L/V Design Track	0.35	0.46	Chapter 11 Maximum = 1.0	Wheel Climb
Vampire	Wheel L/V Class 1 Track	0.40	0.44	Chapter 11 Maximum = 1.0	
Vampire	Wheel L/V Class 2 Track	0.40	0.45	Chapter 11 Maximum = 1.0	
Vampire	Wheel L/V Class 3 Track	NC	0.45	Chapter 11 Maximum = 1.0	
Vampire	Vertical Wheel Load (%) Design Track	89.99	59.10	Chapter 11 Minimum = 10%	Wheel Lift
Vampire	Vertical Wheel Load (%) Class 1 Track	68.26	37.91	Chapter 11 Minimum = 10%	
Vampire	Vertical Wheel Load (%) Class 2 Track	72.02	39.49	Chapter 11 Minimum = 10%	
Vampire	Vertical Wheel Load (%) Class 3 Track	NC	39.75	Chapter 11 Minimum = 10%	
Vampire	Axle Sum L/V Design Track	0.68	0.68	Chapter 11 Maximum = 1.5	Wheel Climb
Vampire	Axle Sum L/V Class 1 Track	0.73	0.69	Chapter 11 Maximum = 1.5	
Vampire	Axle Sum L/V Class 2 Track	0.73	0.67	Chapter 11 Maximum = 1.5	
Vampire	Axle Sum L/V Class 3 Track	NC	0.68	Chapter 11 Maximum = 1.5	
Vampire	Truck Side L/V Design Track	0.35	NC	Chapter 11 Maximum = 0.6	Shift/Roll Rail
Vampire	Truck Side L/V Class 1 Track	0.35	NC	Chapter 11 Maximum = 0.6	
Vampire	Truck Side L/V Class 2 Track	0.35	NC	Chapter 11 Maximum = 0.6	

Note: NC = Not Computed.

Buff Forces During Full Service Stop in 7.5º Curve

Simulation Results - Buff Forces During Full Service Stop at 10 MPH					
		7.5 Degree Curve			
Simulation		Crude Oil Car			
Model	Result Description	Loaded	Empty	AAR Threshold	Indicator of:
TOS	Maximum Buff Force During Full Service Stop	-177	-160		
Vampire	Wheel L/V Design Track	0.44	0.57	Chapter 11 Maximum = 1.0	Wheel Climb
Vampire	Wheel L/V Class 1 Track	0.50	0.75	Chapter 11 Maximum = 1.0	
Vampire	Wheel L/V Class 2 Track	0.48	0.74	Chapter 11 Maximum = 1.0	
Vampire	Wheel L/V Class 3 Track	NC	0.74	Chapter 11 Maximum = 1.0	
Vampire	Vertical Wheel Load (%) Design Track	82.86	59.20	Chapter 11 Minimum = 10%	Wheel Lift
Vampire	Vertical Wheel Load (%) Class 1 Track	55.24	22.97	Chapter 11 Minimum = 10%	
Vampire	Vertical Wheel Load (%) Class 2 Track	57.90	25.09	Chapter 11 Minimum = 10%	
Vampire	Vertical Wheel Load (%) Class 3 Track	NC	26.56	Chapter 11 Minimum = 10%	
Vampire	Axle Sum L/V Design Track	0.77	0.87	Chapter 11 Maximum = 1.5	Wheel Climb
Vampire	Axle Sum L/V Class 1 Track	0.80	0.97	Chapter 11 Maximum = 1.5	
Vampire	Axle Sum L/V Class 2 Track	0.79	0.95	Chapter 11 Maximum = 1.5	
Vampire	Axle Sum L/V Class 3 Track	NC	0.96	Chapter 11 Maximum = 1.5	
Vampire	Truck Side L/V Design Track	0.35	NC	Chapter 11 Maximum = 0.6	Shift/Roll Rail
Vampire	Truck Side L/V Class 1 Track	0.35	NC	Chapter 11 Maximum = 0.6	
Vampire	Truck Side L/V Class 2 Track	0.35	NC	Chapter 11 Maximum = 0.6	

Note: NC = Not Computed.

Draft Forces During Emergency Stop in 7.5º Curve

Simulation Results - Draft Forces During Emergency Stop at 10 MPH					
		7.5 Degree Curve			
Simulation		Crude Oil Car			
Model	Result Description	Loaded	Empty	AAR Threshold	Indicator of:
TOS	Maximum Draft Force During Emergancy Stop	248	229		
Vampire	Wheel L/V Design Track	0.35	0.70	Chapter 11 Maximum = 1.0	Wheel Climb
Vampire	Wheel L/V Class 1 Track	0.40	0.70	Chapter 11 Maximum = 1.0	
Vampire	Wheel L/V Class 2 Track	0.40	0.70	Chapter 11 Maximum = 1.0	
Vampire	Wheel L/V Class 3 Track	NC	0.70	Chapter 11 Maximum = 1.0	
Vampire		91.10	50.79	Chapter 11 Minimum = 10%	Wheel Lift
Vampire		67.63	26.83	Chapter 11 Minimum = 10%	
Vampire		71.34	27.42	Chapter 11 Minimum = 10%	
Vampire	Vertical Wheel Load (%) Class 3 Track	NC	28.43	Chapter 11 Minimum = 10%	
Vampire	Axle Sum L/V Design Track	0.69	0.89	Chapter 11 Maximum = 1.5	Wheel Climb
Vampire	Axle Sum L/V Class 1 Track	0.73	0.89	Chapter 11 Maximum = 1.5	
Vampire	Axle Sum L/V Class 2 Track	0.73	0.89	Chapter 11 Maximum = 1.5	
Vampire	Axle Sum L/V Class 3 Track	NC	0.89	Chapter 11 Maximum = 1.5	
Vampire	Truck Side L/V Design Track	0.35	NC	Chapter 11 Maximum = 0.6	Shift/Roll Rail
Vampire	Truck Side L/V Class 1 Track	0.35	NC	Chapter 11 Maximum = 0.6	
Vampire	Truck Side L/V Class 2 Track	0.35	NC	Chapter 11 Maximum = 0.6	

0.70 design L/V ratio is well below Chapter 11 Maximum of 1.0 indicative of low derailment risk due to wheel climb.

Note: NC = Not Computed.

Buff Forces During Emergency Stop in 7.5º Curve

Simulation Results - Buff Forces During Emergency Stop at 10 MPH					
		7.5 Degree Curve			
Simulation		Crude Oil Car			
Model	Result Description	Loaded	Empty	AAR Threshold	Indicator of:
TOS	Maximum Buff Force During Emergancy Stop	-205	-165		
Vampire	Wheel L/V Design Track	0.46	0.57	Chapter 11 Maximum = 1.0	Wheel Climb
Vampire	Wheel L/V Class 1 Track	0.50	0.75	Chapter 11 Maximum = 1.0	
Vampire	Wheel L/V Class 2 Track	0.48	0.74	Chapter 11 Maximum = 1.0	
Vampire	Wheel L/V Class 3 Track	NC	0.74	Chapter 11 Maximum = 1.0	
Vampire	Vertical Wheel Load (%) Design Track	82.51	59.20	Chapter 11 Minimum = 10%	Wheel Lift
Vampire	Vertical Wheel Load (%) Class 1 Track	54.56	22.97	Chapter 11 Minimum = 10%	
Vampire	Vertical Wheel Load (%) Class 2 Track	57.11	25.09	Chapter 11 Minimum = 10%	
Vampire	Vertical Wheel Load (%) Class 3 Track	NC	26.56	Chapter 11 Minimum = 10%	
Vampire	Axle Sum L/V Design Track	0.78	0.87	Chapter 11 Maximum = 1.5	Wheel Climb
Vampire	Axle Sum L/V Class 1 Track	0.81	0.97	Chapter 11 Maximum = 1.5	
Vampire	Axle Sum L/V Class 2 Track	0.79	0.95	Chapter 11 Maximum = 1.5	
Vampire	Axle Sum L/V Class 3 Track	NC	0.96	Chapter 11 Maximum = 1.5	
Vampire	Truck Side L/V Design Track	0.36	NC	Chapter 11 Maximum = 0.6	Shift/Roll Rail
Vampire	Truck Side L/V Class 1 Track	0.36	NC	Chapter 11 Maximum = 0.6	
Vampire	Truck Side L/V Class 2 Track	0.36	NC	Chapter 11 Maximum = 0.6	

Note: NC = Not Computed.

TOS /VAMPIRE ® Summary

- TÜV Rail Sciences concluded from the in-train force and vehicle dynamics analyses that the proposed operation and track configuration as designed presents a low potential for derailment.
- VAMPIRE ® simulations resulted in values that did not exceed the AAR Chapter 11 vehicle dynamics thresholds which are design criteria for prediction of derailment. The following bullets summarize the results.
  - Design Track Conditions:
    - ❑ Maximum L/V Ratio of 0.70 (AAR allowable maximum = 1.0)
    - ❑ Minimum vertical wheel load of 81% (AAR allowable minimum = 10%)
    - ❑ Maximum axle sum L/V ratio of 0.80 (AAR allowable maximum = 1.5)
    - ❑ Maximum truck side L/V ratio of 0.38 (AAR allowable maximum = 0.6)
- All maximums/minimums for the design track condition were within AAR Chapter 11 allowable criteria. The results using the Class 1, 2, and 3 track cross level criteria were also within allowable Chapter 11 thresholds and serve to show the benefit of maintaining the track to higher standards.

TOS Analysis/VAMPIRE ® Simulation Recommendations

- TÜV Rail Sciences recommends the following to further mitigate potential derailment risk of crude oil unit trains operating on the T-5 unloading loop:
  - Construct new track structure with new concrete or wooden ties, premium fasteners, and continuously welded rail [136 – 141 pound] to maintain a robust and less dynamically varying track structure.
  - Perform rail neutral temperature measurements during track construction to properly set track neutral temperature.
  - Maintain track to a *minimum* Class 2 standard to reduce levels of allowable track deviation and the associated risks of local track perturbations over time.
  - Maintain gage face lubrication in 8.50 and 7.50 degree curves to encourage proper railcar steering, lessen curve binding, the potential for rail climb, and rail wear.
  - Periodically measure track geometry to minimize derailment potential as the track changes over time, particularly in the high degree curves, spirals, and switches.
  - Perform vehicle dynamics simulations if track horizontal/vertical geometry, train make-up, or method of operation change significantly.
- The results and recommendations found in this report complement those previously provided to POV in the Train Operations Study Port of Vancouver Connection Track Final Report, dated February 19, 2014, which evaluated the derailment risk of a proposed route exiting BNSF Fallbridge Subdivision at MP 10.69 into the Port of Vancouver.

TÜV Rheinland Mobility Rail Sciences Division

Atlanta Office:

1901 Montreal, Suite 126

Tucker, GA 30084

404-294-5300

Omaha Office:

8428 W. Center Rd.

Suite 214

Omaha, NE 68124