Port of Vancouver
Schedule 1
Rail Engineering, Operations, and Safety Review
Final Report

Prepared for:

HDR

Prepared by:

TÜV Rheinland Mobility
Rail Sciences Division

March 25, 2014

TÜVRheinland®
RSI Rail Sciences

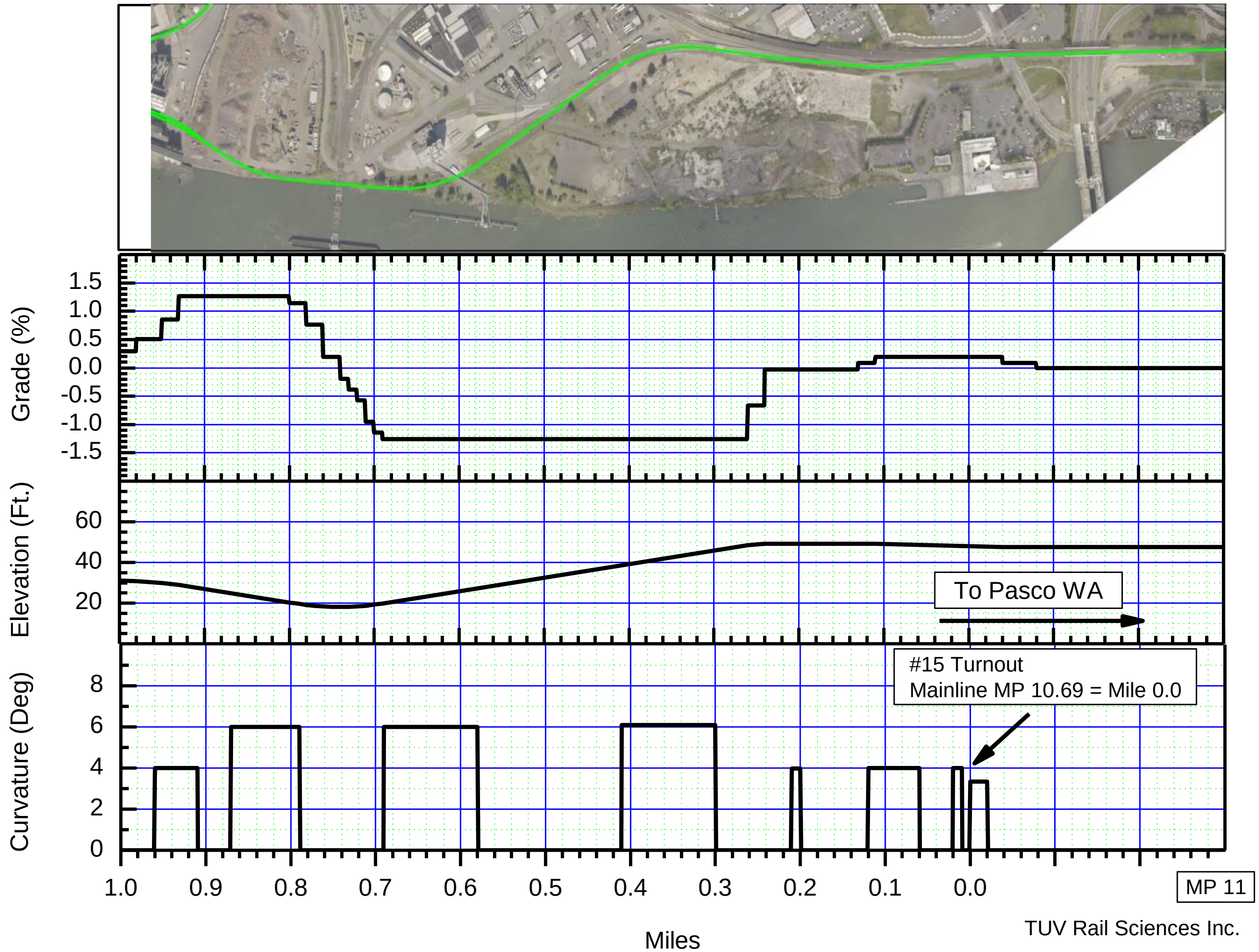
Who We are

- TUV Rheinland was founded 1872, ~18.000 Employees in 65 countries
- RSI was founded 1987, ~30 Employees
- Offices in Atlanta, Rochester, Detroit and Omaha
- Specialize in rail safety assessments and simulation technology
- TOS, VAMPIRE®, TOES™ ,NUCARS™
- Conducted investigations in 5000+ Derailments/Accidents
- Specialize in Railroad component failures
- Wheel/Rail Interaction Studies
- Testing and Instrumentation
- General Engineering and design
- Vehicle and Train Dynamics
- Network Capacity Modeling
- Technical Training
- Testing/Inspection/Certification Services for Rail & Transit
- International Approvals
- Vital system assurance

Project Introduction

- POV through their partners at HDR requested that TÜV Rheinland Mobility Rail Sciences Division (TÜV Rail Sciences) evaluate the derailment risk of a proposed route exiting BNSF Fallbridge Subdivision at MP 10.69 into the Port of Vancouver.
- POV provided TUV RSI with track profile information, typical train configurations and operational criteria such as speed with expected train consists, track data and operating speed limits.
  - Grain, 110 covered hopper cars, 2 locomotives at head end and 1 at rear end
  - Oil, 120 tank cars, 3 locomotives at head end and 2 at the rear end
  - Potash, 170 covered hopper cars, 2 locomotives at head end and 2 at the rear end.
- HDR also requested that TUV RSI compute the lateral and vertical forces using VAMPIRE as well as the resulting L/V ratios for the proposed track alignment between the BNSF main line track and Lafarge.
- The AAR’s Train Operations Simulator (TOS) was used to determine the longitudinal in-train forces

HDR Vancouver Connection Track
Track Profile



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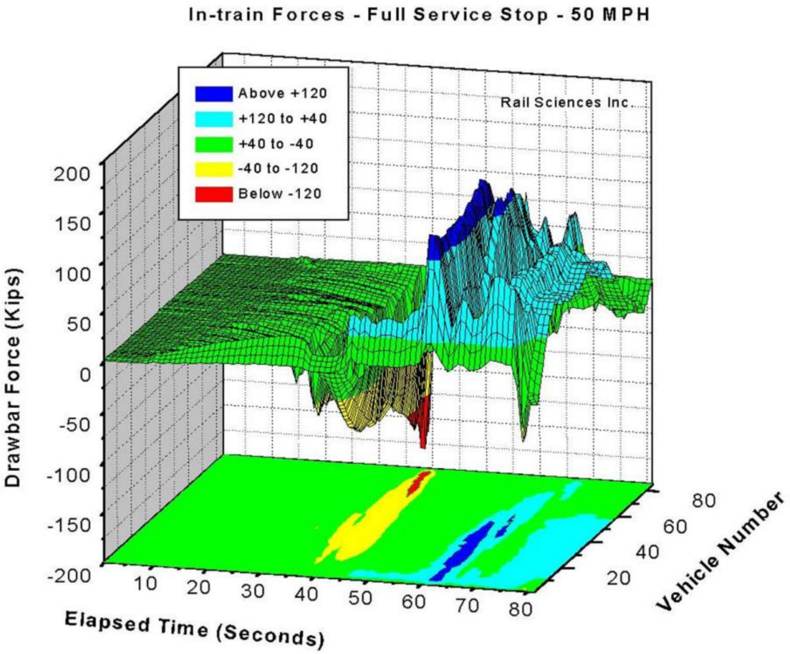
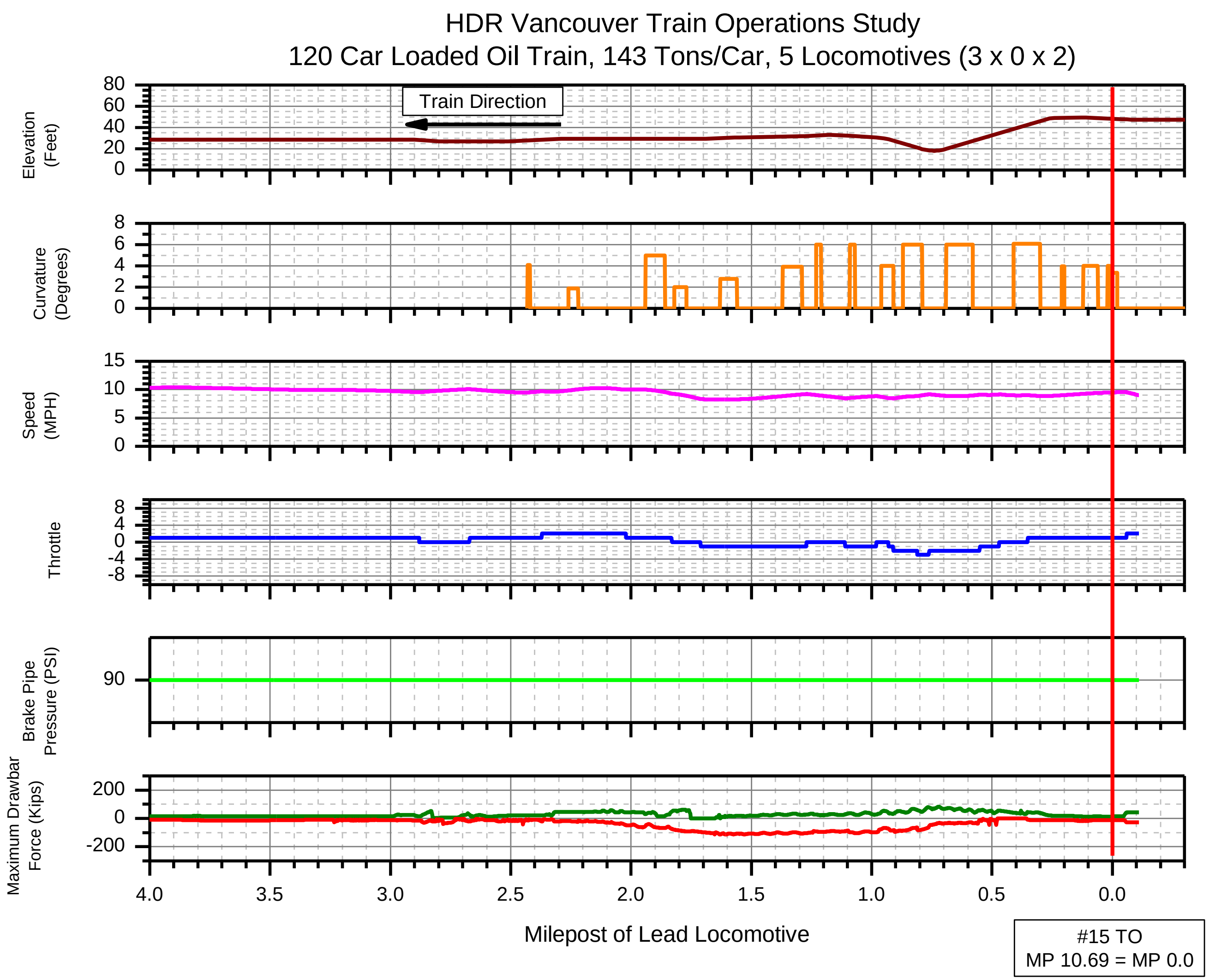
Analysis – Longitudinal In-Train Forces

- TUV-RSI 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 and locotrol
  - Train Slack action
  - Derailments
  - Fuel conservation studies
  - Locomotive utilization and performance
  - Over the road running time analysis





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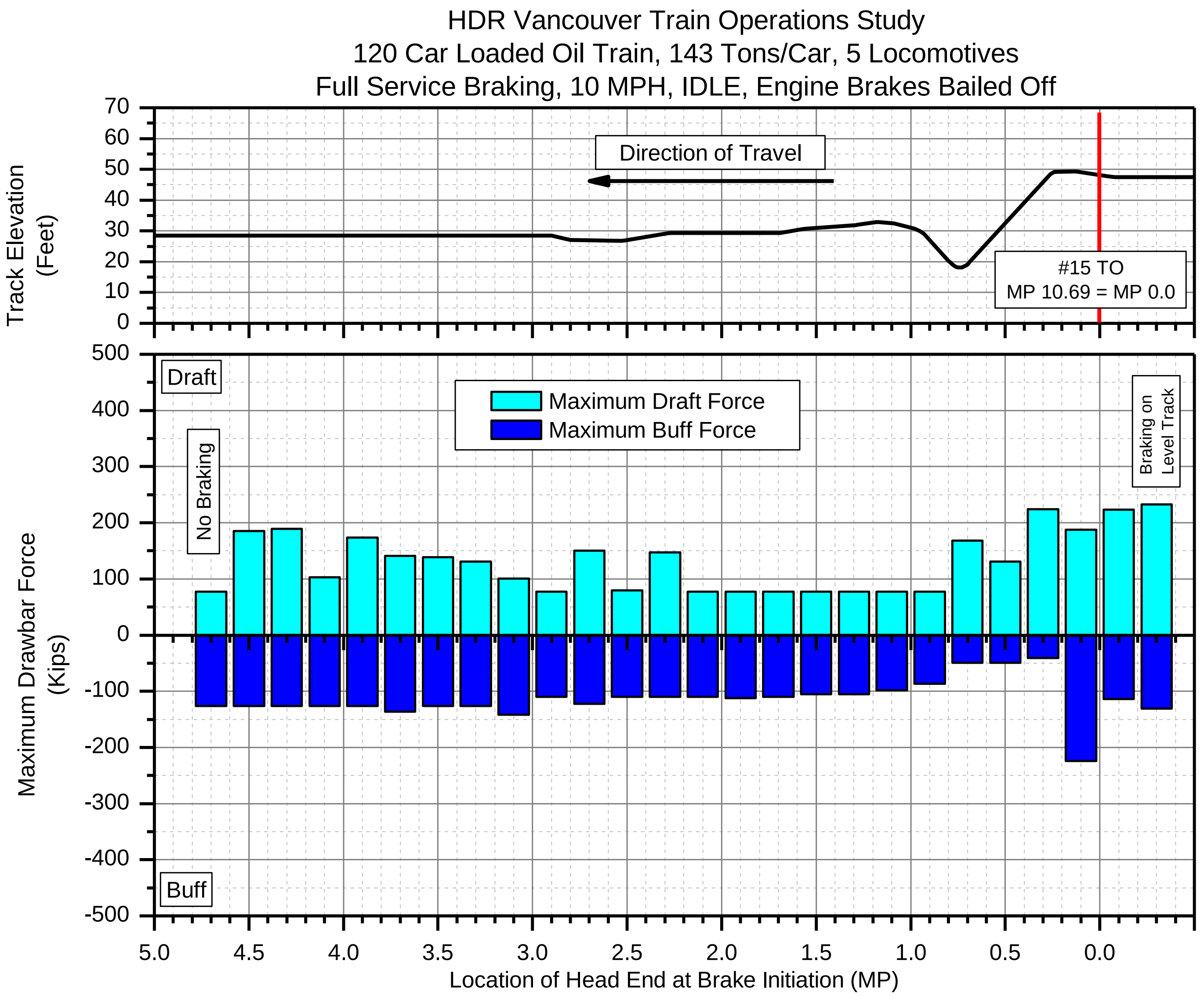
- Next, a series of train stopping simulations were performed using loaded trains with nominal train handling approaching the track location where braking was initiated during:
  - Full service braking stops
  - Emergency braking stops
- Utilizing nominal train handling prior to the onset of braking normalized the train slack in a representative state to determine if train slack is a significant factor relevant to predicted in-train forces.
- Braking from 10 mph was initiated (at 0.2 mile intervals) encompassing the 3 miles of proposed connection track. Track was assumed to be level on each end of the provided track data.
- 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 form the lead locomotive, the throttle was immediately moved to IDLE from its current position, and the engine brakes were bailed off.



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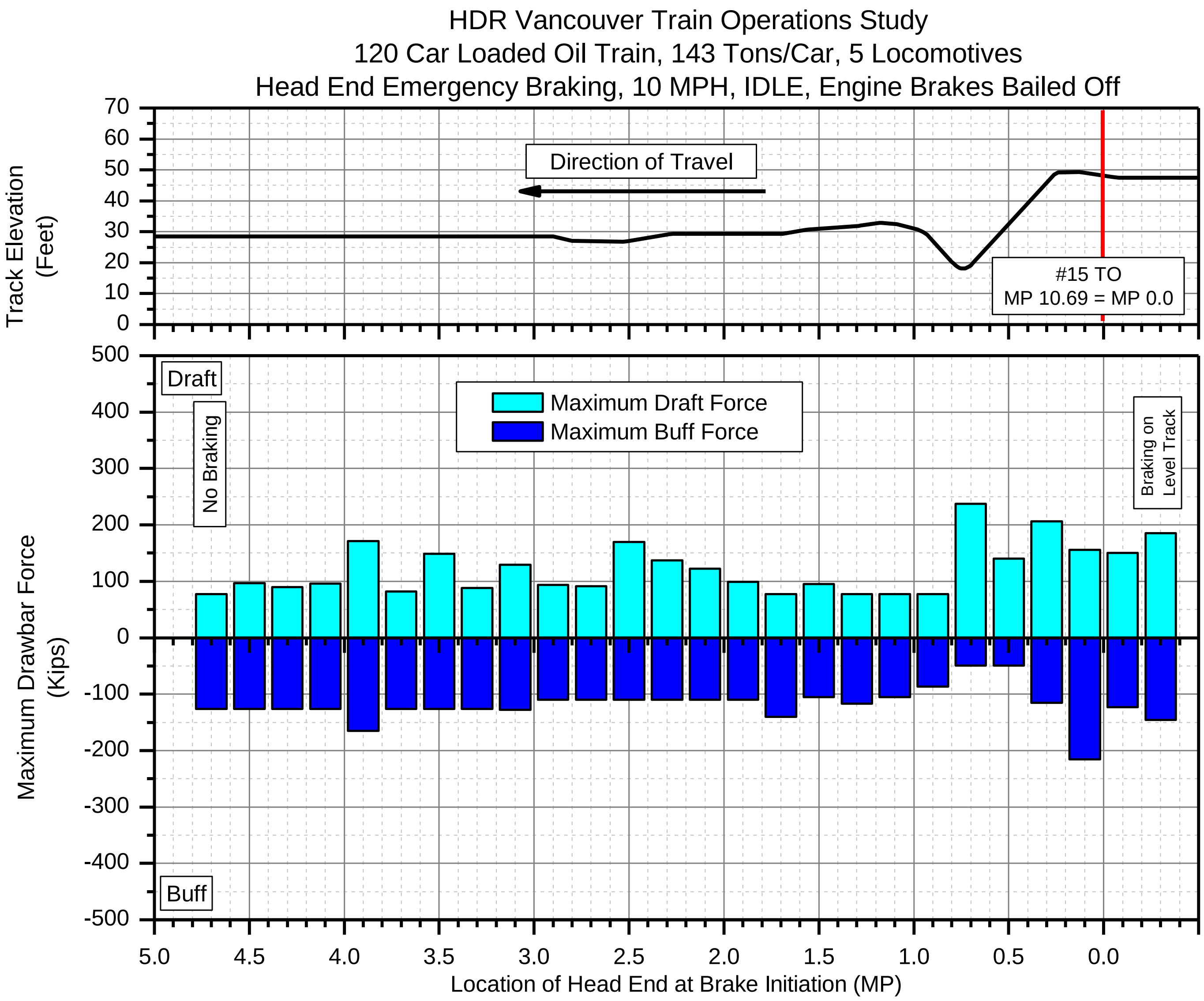

HDR Vancouver Train Operations Study
120 Car Loaded Oil Train, 143 Tons/Car, 5 Locomotives
Head End Emergency Braking, 10 MPH, IDLE, Engine Brakes Bailed Off
Track Elevation (Feet)
Direction of Travel
#15 TO
MP 10.69 = MP 0.0
Maximum Drawbar Force (Kips)
Draft
Buff
No Braking
Maximum Draft Force
Maximum Buff Force
Braking on Level Track
Location of Head End at Brake Initiation (MP)
70
60
50
40
30
20
10
0
500
400
300
200
100
0
-100
-200
-300
-400
-500
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0

- The following table quantifies the maximum in-train longitudinal forces observed in all nominal and braking simulation scenarios

Table 1.0 Maximum Longitudinal Forces

Scenario			Maximum In-Train Longitudinal Forces (Kips)*									
Train	Consist		Nominal 10 MPH		Full Service Braking				Emergency Braking			
Type	Locomotives	Cars	Connection Track		Connection Track		Level Track		Connection Track		Level Track	
			Draft	Buff	Draft	Buff	Draft	Buff	Draft	Buff	Draft	Buff
Grain	C44-9 2x0x1	110 Covered Hoppers	115	-110	225	-185	225	-125	165	-140	150	-90
Fuel	C44-9 3x0x2	120 Tank Cars	75	-125	225	-225	235	-130	235	-215	185	-145
Potash	AC4400 2x0x2	170 Covered Hoppers	110	-140	320	-210	135	-120	265	-235	170	-150

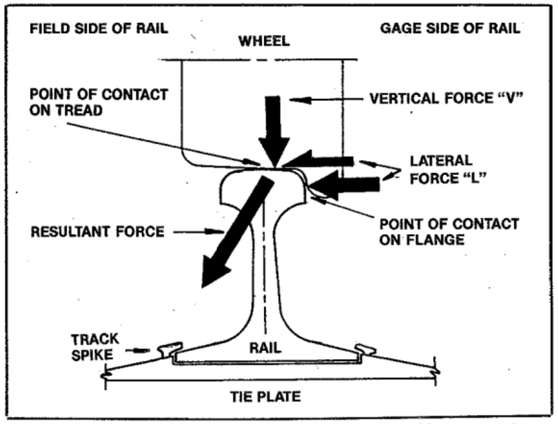
* Note: Forces rounded to nearest multiple of 5.

- The maximum simulated Draft and Buff forces are well within industry and AAR recommended limits

Analysis – Lateral/Vertical

- Computed L/V ratios and lateral bolster forces for both the empty and loaded car configurations. The L/V ratios for the empty cars are wheel climb (single wheel) ratios. The L/V ratios for the loaded cars are rail rollover ratios. The AAR L/V established industry accepted design limits

Figure VI-1
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.

L/V = 1.29 wheel may climb new rail
L/V = .82 wheel lift impending
L/V = .75 wheel may climb worn rail
L/V = .64 rail overturn force starts
(unrestrained rail may overturn)

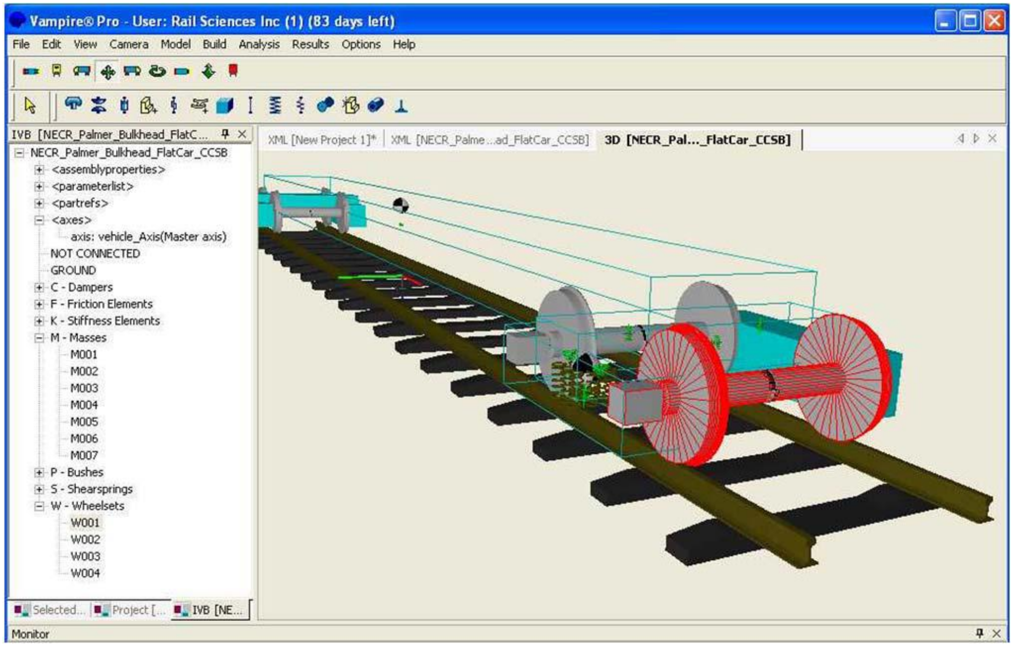
Lateral Forces
Lateral forces are influenced by the following factors:

- Centrifugal force
- Coupler forces
- Wheel creep forces
- Track geometry input.

1. Centrifugal force is only associated with negotiating curves and is a direct result of speed and curvature. This force is normally nullified by the amount of superelevation for a given "balance" speed around the curve. However, it will produce a significant lateral force at the wheels if the train is moving much faster than the balance speed. The force will occur at the outside rail and will

VAMPIRE Analysis

- **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



Vehicle Dynamics Results – Loaded Vehicles

Maximum Individual Wheel L/V Ratio				
Vehicle	**In-Train Force**	**As Designed Track**	**Class 1 Cross Level Dip**	**Class 2 Cross Level Dip**
Grain Car Loaded	300 Kips Buff	0.44	0.58	0.56
	300 Kips Draft	0.34	0.50	0.48
	None	0.39	0.56	0.54
Potash Car Loaded	300 Kips Buff	0.43	0.59	0.57
	300 Kips Draft	0.34	0.52	0.50
	None	0.39	0.56	0.54
Tanker Car Loaded	300 Kips Buff	0.43	0.57	0.55
	300 Kips Draft	0.34	0.50	0.48
	None	0.39	0.54	0.53

- *Indicator of Wheel Climb Potential:*
  - Industry Recommended Maximum Allowable L/V Ratio = 0.82
  - AAR Chapter XI Standard Maximum Allowable L/V Ratio = 1.00

Vehicle Dynamics Results – Loaded Vehicles

Minimum % Wheel Unloading				
Vehicle	**In-Train Force**	**As Designed Track**	**Class 1 Cross Level Dip**	**Class 2 Cross Level Dip**
Grain Car Loaded	300 Kips Buff	82.58	55.75	58.35
	300 Kips Draft	90.30	66.23	69.22
	None	90.78	60.95	63.31
Potash Car Loaded	300 Kips Buff	86.29	58.83	61.01
	300 Kips Draft	91.89	67.13	69.83
	None	91.05	62.36	65.32
Tanker Car Loaded	300 Kips Buff	83.86	56.96	59.42
	300 Kips Draft	90.60	68.37	70.75
	None	90.87	62.09	64.75

- *Indicator of Wheel Lift Potential:*
  - AAR Chapter XI Standard Minimum Allowable Percent Wheel Unloading = 10.0%

Vehicle Dynamics Results – Loaded Vehicles

Maximum Axle Sum L/V Ratio				
Vehicle	**In-Train Force**	**As Designed Track**	**Class 1 Cross Level Dip**	**Class 2 Cross Level Dip**
Grain Car Loaded	300 Kips Buff	0.77	0.92	0.90
	300 Kips Draft	0.65	0.84	0.82
	None	0.73	0.89	0.87
Potash Car Loaded	300 Kips Buff	0.76	0.93	0.91
	300 Kips Draft	0.66	0.86	0.84
	None	0.72	0.90	0.88
Tanker Car Loaded	300 Kips Buff	0.76	0.91	0.89
	300 Kips Draft	0.67	0.84	0.82
	None	0.73	0.88	0.86

- *Indicator of Wheel Climb Potential:*
  - AAR Chapter XI Standard Maximum Allowable Axle Sum L/V Ratio = 1.50

Vehicle Dynamics Results – Loaded Vehicles

Maximum Truck Side L/V Ratio				
Vehicle	**In-Train Force**	**As Designed Track**	**Class 1 Cross Level Dip**	**Class 2 Cross Level Dip**
Grain Car Loaded	300 Kips Buff	0.31	0.37	0.36
	300 Kips Draft	0.30	0.28	0.27
	None	0.28	0.33	0.32
Potash Car Loaded	300 Kips Buff	0.31	0.37	0.37
	300 Kips Draft	0.31	0.31	0.30
	None	0.29	0.35	0.34
Tanker Car Loaded	300 Kips Buff	0.32	0.39	0.38
	300 Kips Draft	0.33	0.32	0.31
	None	0.30	0.36	0.35

- *Indicator of Potential to Shift the Rail Laterally or Roll the Rail:*
  - AAR Chapter XI Standard Maximum Allowable Truck Side L/V Ratio = 0.60

- TÜV-RSI concluded, based on in-train force and vehicle dynamics analyses that the proposed operation and track configuration is well within industry safety standards, a low risk of derailment

- To further improve safety POV requested TUV RSI to propose further enhancements:

  - 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.

  - Install a high guard rail frog on #15 turnout and double guard rail on the connection track between #15 turnout and the BNSF overhead bridge and through the “Trench”, to further lessen the potential for damage.

- Construct the track structure with new concrete or wooden ties, premium fasteners, and continuously welded 141 pound rail to maintain a robust and less dynamically varying track structure.
- Perform rail neutral temperature measurements during track construction to properly set track neutral temperature.
- Periodically measure track geometry to ensure safety against derailment as the track changes over time.

- Based on these recommendations, POV will further improve the safety performance characteristics, which will result in a very low likelihood of derailment.

TÜV Rheinland Mobility Rail Sciences Division