# When Wheels and Rails don't

# Interact in a Good Way


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Canada

# The TSB

Our Mission

To advance transportation safety in the air, marine, rail, and pipeline modes of transportation that are under federal jurisdiction by:

- conducting independent investigations
- identifying safety deficiencies
- identifying causes and contributing factors
- making recommendations
- reporting publicly

# Who We Are

- An independent agency that currently has four Board members, including a chairperson, and approximately 220 employees (16 rail investigators and specialists).
- It is not the function of the TSB to assign fault or determine civil or criminal liability.

- Head Office Gatineau, Quebec
- The Engineering Laboratory in Ottawa, Ontario
- Regional offices located across the country in Ydqfrxyhu/#Fdojdu|/#Hgprqwrq/#Zlqqlshj/#Wrurqwr/#Prqwuhdo/#Txhehf#dqg##Kdolid{#

# Investigations and Reports

- Approximately 1500 rail transportation occurrences are reported to the TSB annually
- Approximately 1% formally investigated
- The primary criterion for determining if an occurrence in any mode will be investigated is whether or not such analysis is likely to lead to a reduction of risks to persons, property, and the environment.

# MAIN-TRACK DERAILMENT
# CANADIAN NATIONAL
# FREIGHT TRAIN G84042-09
# MILE 73.6, FORT FRANCES SUBDIVISION
# NICKEL LAKE, ONTARIO
# 10 NOVEMBER 2013

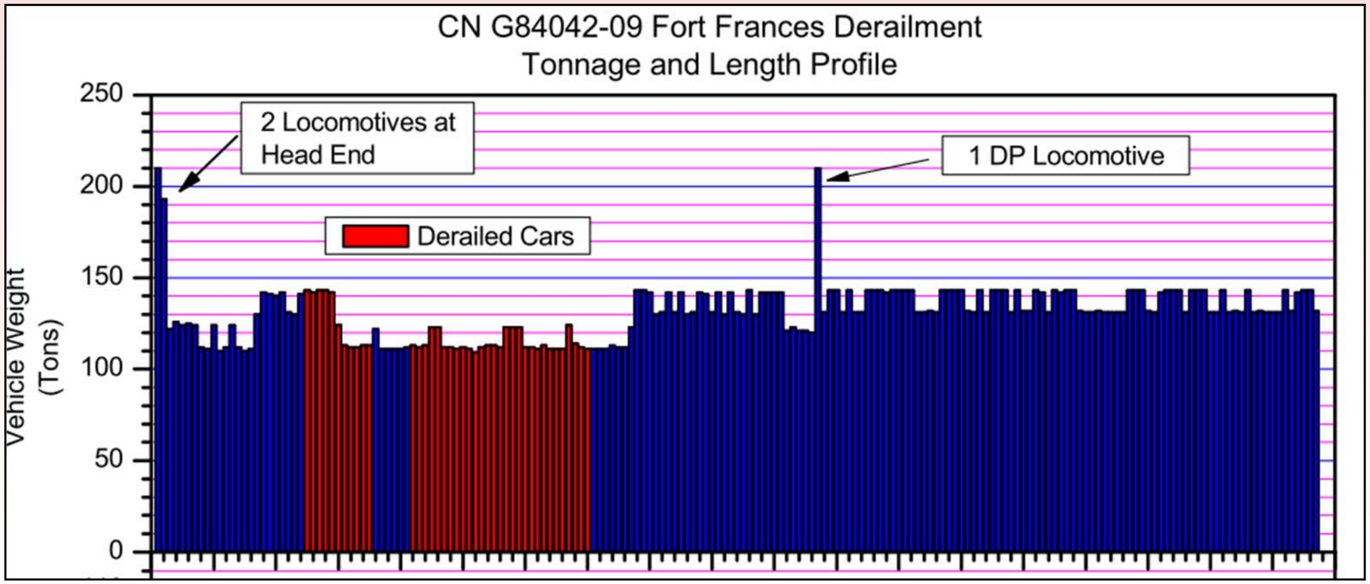
# The Train

- DP train pulled by 2 head-end locomotives and 1 remote locomotive positioned between the 104th and the 105th car
- 184 loaded covered hopper cars, 24,432 tons and 11,058 feet long

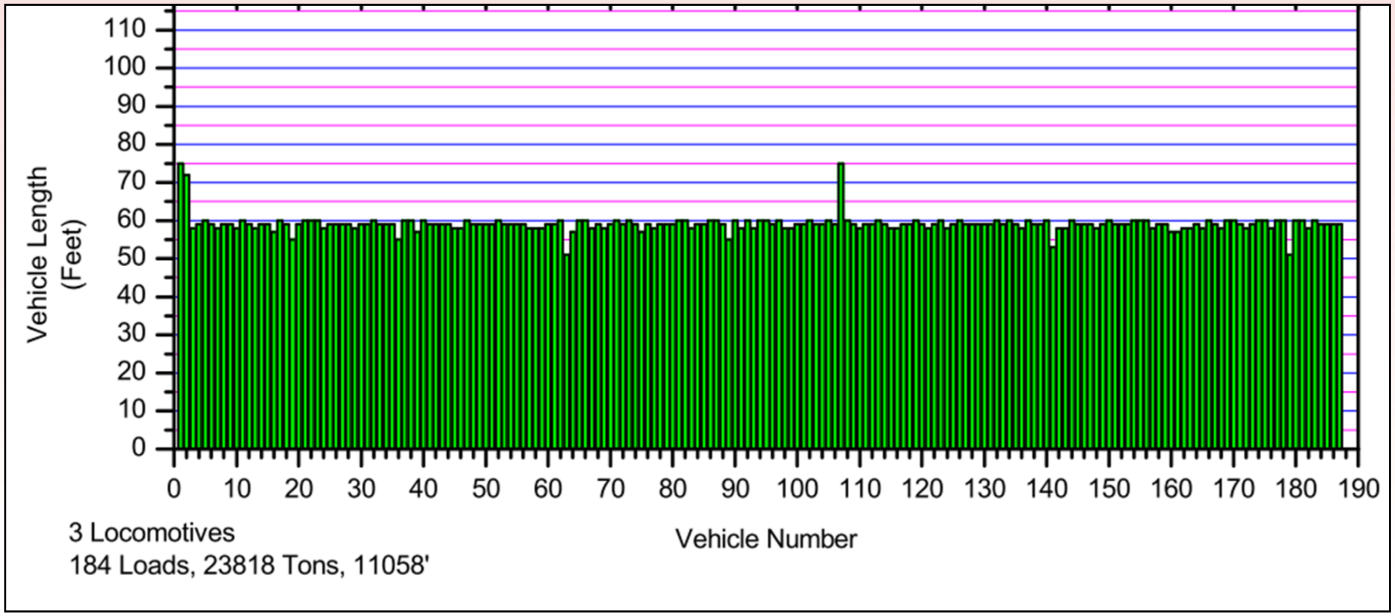
# The Train

- train was being operated in DP synchronous mode over relatively flat terrain in throttle 8 in a steady-state and stretched condition
- grades and curves in the area were not known to be problematic for train handling

# Train Tonnage & Length Profile



# Vehicle Length Profile



# Distributed Power

- Train marshalled with 12 828 tons ahead of and 10 990 tons behind the remote locomotive
- train had been configured with 4108 tons more behind the remote locomotive than the guideline stipulated

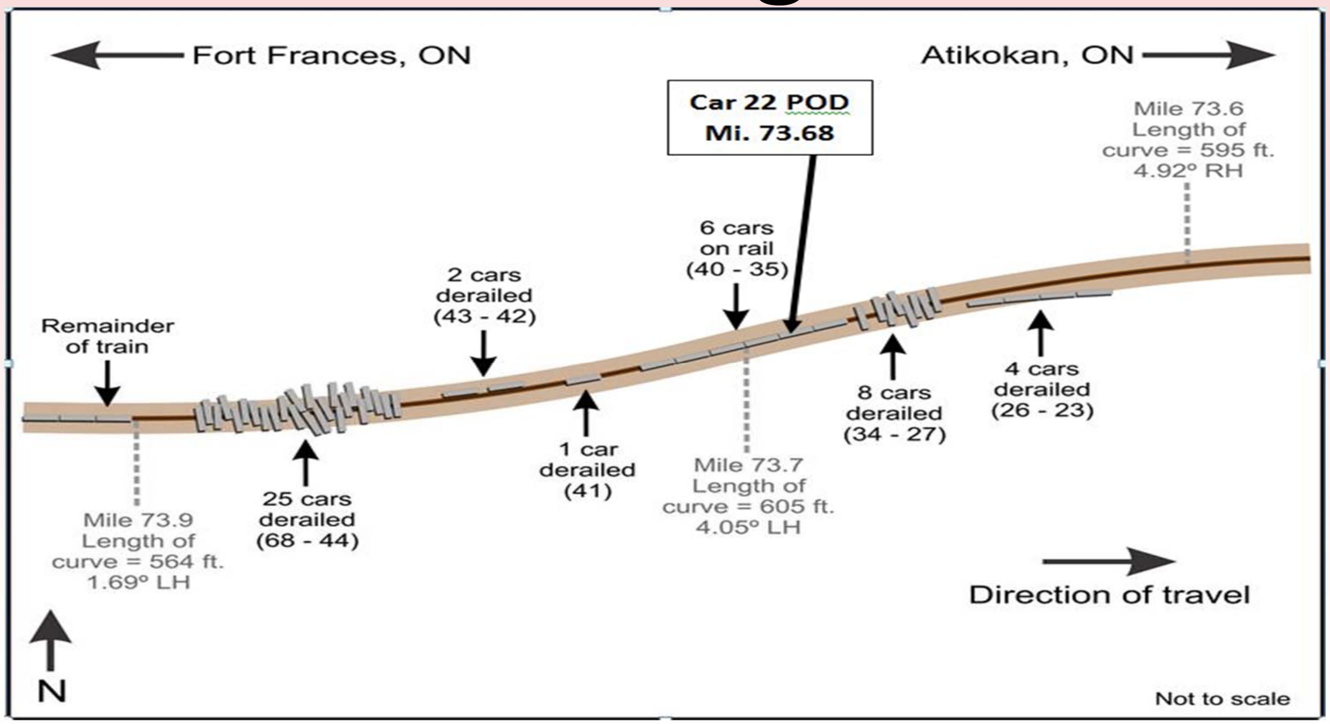
# Emergency

- UDE initiated in the vicinity of the 22nd and 23rd cars
- Train travelling 37 mph in throttle 8
- the train brakes and the independent locomotive brake both activated
- locomotive brakes were not bailed off

# Point of Derailment

- Mile 73.68, between reversing 4.05° LH and a 4.92° RH curves 182' apart
- Cars 22 and 23 separated
- 40 cars derailed in two main groups

# Site Diagram



# The Track

- 115lb CWR, wood ties 15% defective, 14” plates, 6 spikes/plate low rail, 5 spikes/plate high rail, box anchored every tie
- Crushed rock ballast
- Nearest flange and TOR lubricators at miles 76.2 and 68.65

# Rail in 4.05° LH Curve

- high rail was 1989/1991 115-pound CWR with 14 mm of head wear and 6 mm of flange wear
- low rail was 1994 115-pound CWR with 13 mm of head wear and no flange wear
- wheel flange marks on the web of the high rail
- wheel marks on the head of the low rail

# High Rail

# Low Rail

# High Rail

# Track at POD

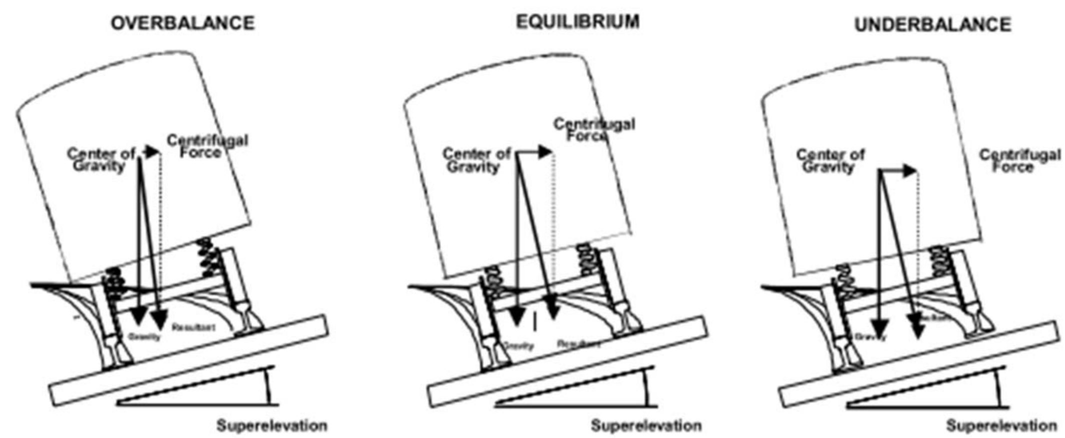
- ascending at a 0.3% grade, 4.05° curve was 605 feet long with average superelevation of 0.35 inch
- Class 3 track - maximum freight train speed of 40 mph
- 30 mph PSO

# 4.05° LH Curve Superelevation

- minimum SE on a 4.05° curve for 30 mph is balanced SE of 2.5 inches less 2 inches or 0.5 inch
- for 0.35 inches actual SE equilibrium speed is 11 mph → actual speed of 37 mph was 26 mph above equilibrium speed

# 4.05° LH Curve Superelevation

- With 0.35-inch actual SE and 2 inches imbalance, the design speed was 28.8 mph
- For actual speed of 37 mph, the balanced SE for a 4.05° curve is 3.9 inches → curve was 3.55 inches under elevated
- With 2” imbalance, minimum SE is 1.9 inches




$$V_{\max} = \sqrt{\frac{E_a + 3}{0.0007D}}$$

Amount of Underbalance (the $+3$ term)

$V_{\max}$ = Maximum allowable operating speed (mph).

$E_a$ = Average elevation of the outside rail (inches).

$D$ = Degree of curvature (degrees).

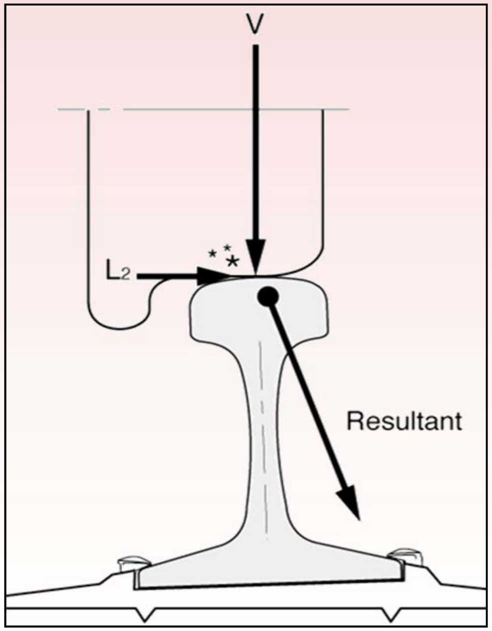
# Wheel/Rail Interface Forces

The lateral and vertical forces at the wheel/rail interface are a result of interaction between:

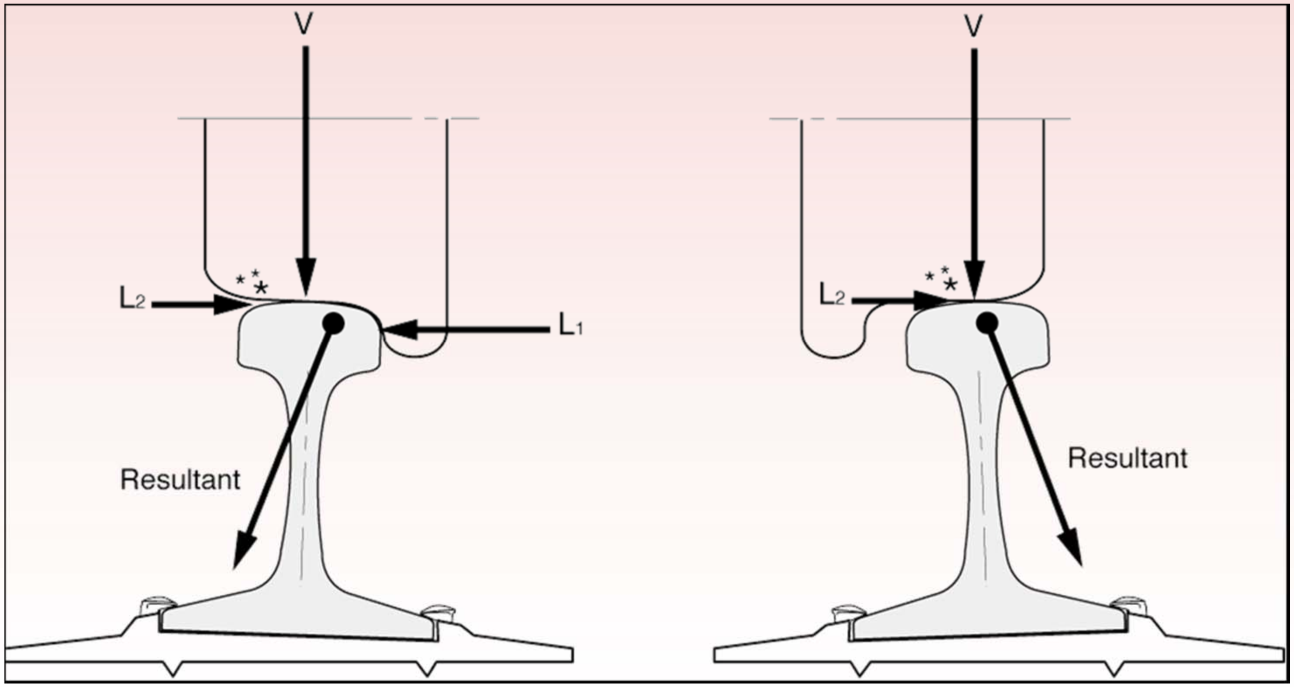
- track geometry
- vehicle dynamics
- wheel/rail profile

# Wheel/Rail Interface

- Combined, lateral & vertical forces form the **L/V ratio**
- The **L/V ratio** determines whether or not a vehicle will stay on the rail.



# Lateral, vertical and resultant forces



# Worn vs New Rail Contact

# Track Gauge in 4.05° LH Curve

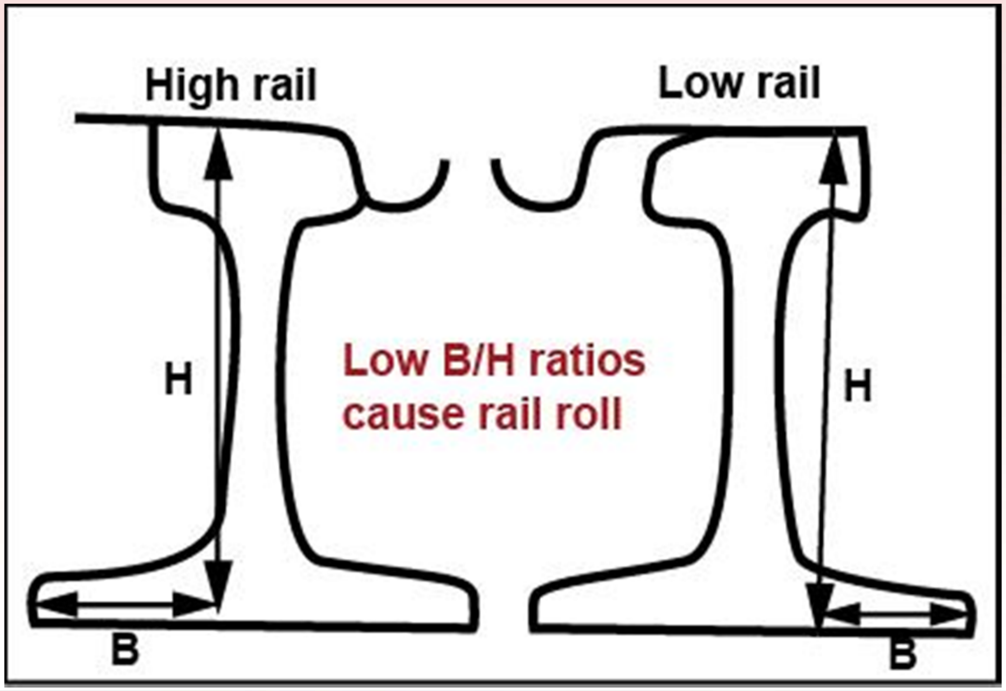
- 175 feet of wide gauge over ½ inch,
- 41 feet of wide gauge over ¾ inch, and
- 10 feet of wide gauge over 1 inch
- minor, non-actionable high-rail cant anomalies

# Track Maintenance

- 260 feet of track re-gauged on 06 September 2013.
- high-rail gauge spikes removed, high rail pulled down into gauge
- hand-adzing new seats for the tie plates
- spike holes filled with glue
- fully spiking all 6 holes in the tie plates

Transportation Technology Center, Inc./Norfolk Southern report (TD-11-052, *Root Cause of Rail Roll/Reverse Rail Cant*) December 2011

# Rail base/rail height ratio



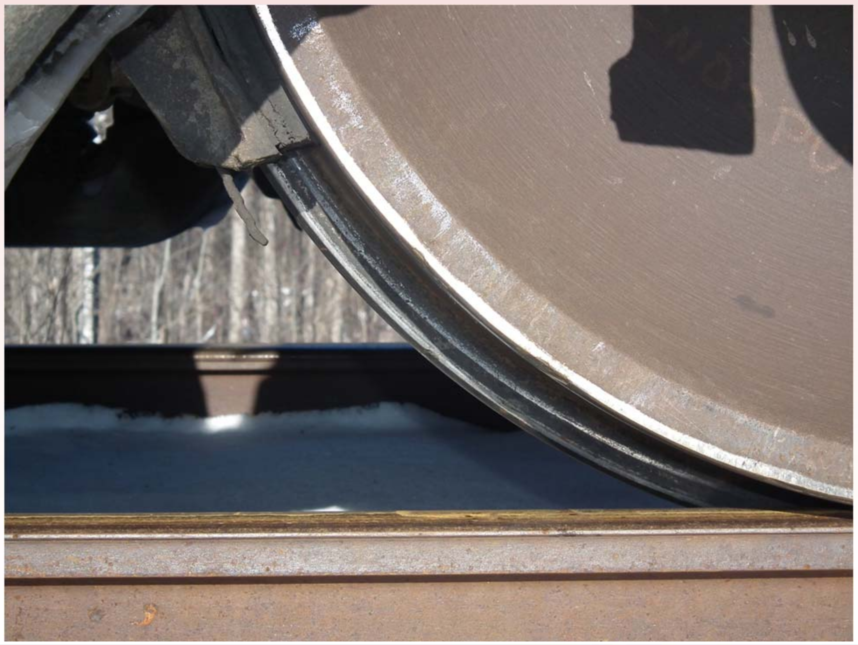
# Effect of Rail Cant Restoration and Gauging

- Rail cant restoration and gauging tend to move the contact position towards the field side of high and low rails
- 2-point contact at the wheel/rail interface can occur, especially in worn rails
- Rail grinding required to restore profiles

# The 22nd Car

- L4 wheel on trailing truck on 22nd car derailed first but then re-railed itself
- abrasion marks throughout the L4 wheel rim face circumference and flange

# L-4 Wheel



# The 22nd Car

- A-end truck was in like-new condition with little to no wear in the constant contact side bearings, side wedges, bolster gibs and bolster bowl
- There was no indication that the truck had been binding or skewing
- five (5) years of repair history was reviewed for lines 22-24 with no excessive wheel usage noted

# Track Train Dynamics Simulation

Analysis based on the 09 July track geometry information along with a severely worn-curve high-rail profile and the wheel profiles of the trailing wheels of the 22nd car

# Longitudinal Force Simulation

- Longitudinal forces on the first derailed car was 50,000 lbs draft at the time of the derailment
- Considered low and not causal
- No slack or buff forces occurred

# Vampire Simulation

- L/V ratio of 0.43, maximum truck-side L/V was 0.21, indicating a low potential for rail rollover or wheel climb
- maximum lateral wheel force was calculated to be 16,400 pounds - considered moderate and sustainable by well-maintained track

# Investigation Findings

- The longitudinal forces and lateral forces were considered low to moderate
- Inspection of the trailing truck of the 22nd car revealed no abnormal conditions that may have led to the derailment

The reason for the undesired emergency brake application was not determined - so What Happened??

# Derailment Mechanism

The derailment likely initiated when the high rail of the 4.05° left-hand curve rolled out, allowing the trailing L-4 wheel of the 22nd car to drop down and ride on the web and base of the high rail, spreading the high rail behind it as it proceeded

# The Curve

The curve was under-elevated for 37 MPH, resulting in increased lateral forces being exerted on the high rail, promoting dynamic wide gauge

# Rail

- With the high rail close to its wear limits, wheel/rail contact was closer to the field side of the high rail, resulting in a lower lateral-to-vertical derailment threshold
- High rail likely rolled or canted out sufficiently to allow low rail wheels to drop in

# Rail

The absence of lubrication on the gauge face of the high rail resulted in increased flange/gauge friction and higher lateral forces

# Cause

High lateral-force rail rollover likely occurred from a combination of train speed on the under-elevated curve, lowered lateral-to-vertical (L/V) threshold on the worn high rail, and degraded rail fastener resistance to dynamic wide gauge

# Other Findings

The delay in braking from the tail end of the train and the fact that the locomotive brakes were not bailed off allowed the braking cars to bunch up, creating a jackknifing situation that increased the severity of the derailment

# Other Findings

The placement of the distributed power remote locomotive, while not in accordance with railway guidelines, did not contribute to the derailment

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