Transportation Safety Board of Canada
Bureau de la sécurité des transports du Canada

RAILWAY INVESTIGATION REPORT
R04T0013

MAIN-TRACK DERAILMENT

CANADIAN PACIFIC RAILWAY
FREIGHT TRAIN NO. 104-18
MILE 24.83, MACTIER SUBDIVISION
BOLTON, ONTARIO
22 JANUARY 2004

Canada

Railway Investigation Report

Main-Track Derailment

Canadian Pacific Railway
Freight Train 104-18
Mile 24.83, MacTier Subdivision
Bolton, Ontario
22 January 2004

Report Number R04T0013

Summary

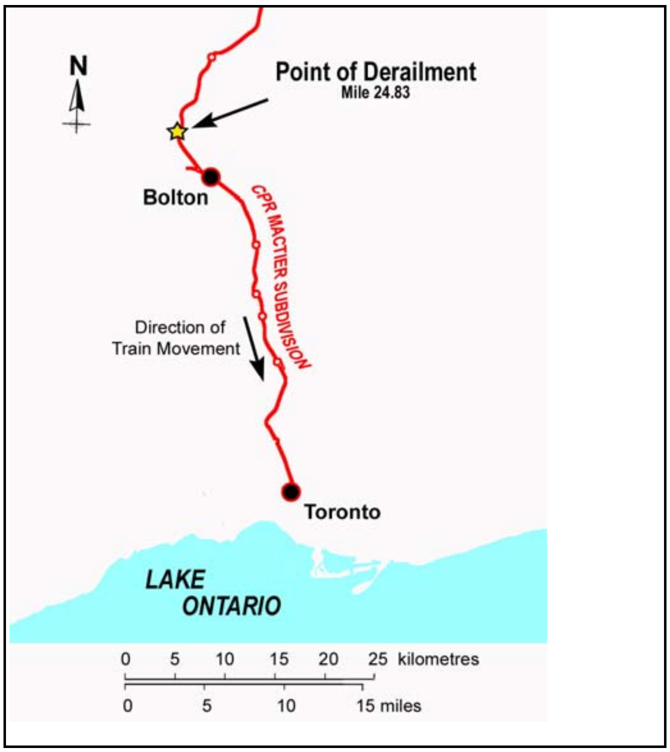
At approximately 0315 eastern daylight time on 22 January 2004, southward Canadian Pacific Railway freight train 104-18, travelling at 56 mph, derailed 2 locomotives and 26 cars at Mile 24.83 of the MacTier Subdivision. The derailed cars included 14 loads of general freight and 12 intermodal flat cars loaded with containers. One container was carrying a regulated product. The derailment occurred immediately south of a rural level crossing, approximately five miles west of Bolton, Ontario. There were no injuries and no release of product.

Ce rapport est également disponible en français.

Other Factual Information

Train Information

Canadian Pacific Railway (CP Rail) freight train 104-18 (the train), comprised of 3 locomotives and 43 loaded freight cars, was en route from Edmonton, Alberta, to Toronto, Ontario,[1] and was proceeding southward on the MacTier Subdivision (see Figure 1). It was 4284 feet long and weighed 5077 tons. The crew, a locomotive engineer and a conductor, had taken control of the train at MacTier. They were familiar with the territory, qualified for their positions, and met fitness and rest requirements.



Train movements are governed by the Occupancy Control System/Automatic Block System, authorized by the *Canadian Rail Operating Rules* (CROR), and supervised by a rail traffic controller located in Montréal, Quebec. An average of 16 freight trains per day traverse this area at a maximum permitted speed of 55 mph. No temporary slow orders were in place in this area on the day of the occurrence.

Weather

The temperature was c22°C, with scattered clouds and good visibility. The wind was from the west at 16 km/h.

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1 All locations are in Ontario unless otherwise stated.

Locomotive Event Recorder

Locomotive event recorder data indicated that an emergency brake application was initiated within the train line at approximately 0315 eastern standard time[2] on 22 January 2004 as the train was travelling at 56.1 mph between Mile 24.698 and Mile 24.686 in close proximity to the Castlederg Sideroad crossing at Mile 24.84. Approximately two minutes before the accident, the throttle setting on the locomotive was reduced from notch 7 to notch 3, and a minimum brake application was made approximately 600 feet north of the crossing to condition the brakes[3] for a meet in Bolton.

The Accident

As the lead locomotive passed over the Castlederg Sideroad crossing, the crew felt a sharp sideways lurch. This was immediately followed by a train-initiated emergency brake application. After emergency procedures were performed, it was determined that the two trailing locomotives and the following 17 cars consisting of 26 intermodal platforms had derailed. The trailing set of wheels on the second locomotive and all wheels on the third locomotive had derailed between the rails. The west rail was displaced and had rolled over. The locomotives were separated from the derailed cars by approximately 1800 feet. Over this distance, the west rail had turned on its side.

The first derailed car, a 79-foot centre-beam bulkhead flat car loaded with lumber, came to rest on its side in the west ditch. This flat car was followed by 13 box cars loaded with wood pulp and 12 intermodal flat cars loaded with containers. The derailed cars came to rest at various angles. The last derailed car, with only the front wheels derailed, had stopped on the public crossing. This car, DTTX 657174, was loaded with a container carrying a flammable, paint-related product (UN 1993). There was no release of regulated product and no injuries.

Track Information

The MacTier Subdivision is a single, Class 4 main track. The track in the vicinity of the derailment consisted of 115-pound Algoma continuous welded rail manufactured in 1986. The rail was laid on 14-inch tie plates and was fixed to hardwood ties with 6 spikes per tie. The ties were box anchored on every tie for 195 feet on each side of the joints. Beyond this distance, the ties were box anchored on every second tie. The ballast consisted of crushed rock and slag. The cribs were full, and the shoulders extended from 12 inches to 24 inches beyond the end of the ties. In the derailment area, the track was in a four-foot cut with drainage to the south.

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[2] All times are eastern standard time (Coordinated Universal Time minus five hours).

[3] CP Rail General Operating Instructions, Section 16, Item 1.5: "Under winter conditions, the locomotive engineer shall make use of the air brake at sufficient interval to keep the brake surfaces free of ice and snow and the brake equipment conditioned for service."

Approaching the derailment site from the north, the track grade descends to the south, in a grade that ranges from 0.28 per cent to 1.07 per cent. South of the derailment location, the track grade transitions through a vertical curve and then rises to a 1.1 per cent grade.

Between Mile 25.3 and Mile 24.2, there is a compound horizontal curve oriented as a left-hand curve for southward trains. Track curvature is 1.5 degrees north of Mile 24.7 and 1.0 degree south of this location. The Castlederg Sideroad crossing is located within the 1.5-degree portion of the curve. In July 2000, the track through this crossing was rehabilitated with 78-foot Nippon rails manufactured in 1999.

Site Examination

The derailed cars and damaged track were south of the crossing. There were wheel rim marks on the rail head on the east (low) rail approximately 45 to 50 feet south of the crossing. Similar marks were present on the west (high) rail approximately 80 feet south of the crossing.

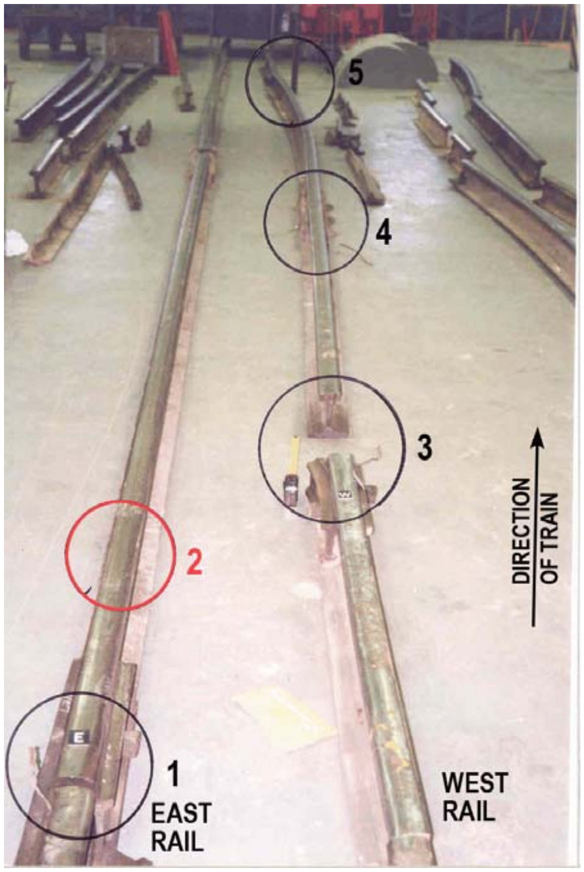
Both rails had multiple catastrophic breaks. Rail pieces were recovered and sent to CP Rail's Test Department for analysis.

Approximately five feet south of the crossing, the crossing rails had been connected to continuous welded rail using thermite welds. There were a number of other welds located south of the crossing to accommodate plug rails and track circuits. Approximately 25 feet south of the thermite weld on the west rail, there was a standard rail joint. There was a polyethylene-insulated joint 20 feet still further south and a standard joint another 20 feet beyond that point. These joints were secured using 36-inch standard joint bars that were fully bolted. On the east rail, there was a standard joint 20 feet south of the thermite weld, and a polyethylene-insulated joint 22 feet further south. There was a thermite weld approximately five feet south of the polyethylene-insulated joint.

The trailing coupler of the last locomotive (SOO 6615) was broken. The fracture was catastrophic and displayed failure characteristics consistent with torsional loading.

Detailed Rail Examination

The recovered rail sections and associated track components (including broken joint bars) were arranged into their approximate field position at CP Rail's Test Department (see Photo 1). As observed by TSB investigators, the examination revealed marks on the gauge side of both rails, on the gauge side of the joint bars, and on the head of the rail. These marks indicated that the wheels had dropped between the rails (see Photo 2). Wheel flange marks were present on the web of the west rail (gauge side), indicating that this rail had turned over to the high side of the curve. Impact damage was present on the fasteners.


5
4
3
DIRECTION
OF TRAIN
2
1
EAST
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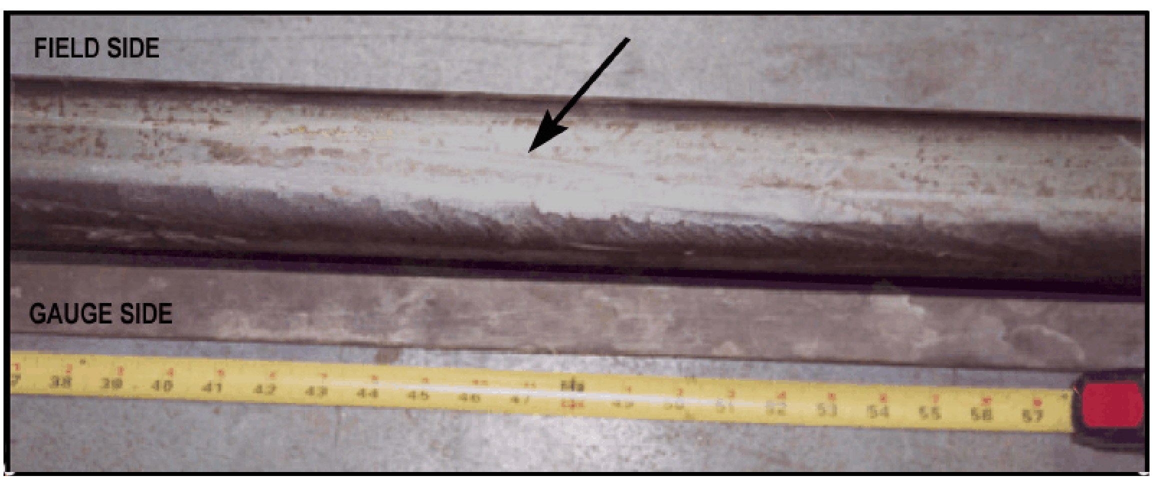
FIELD SIDE
GAUGE SIDE

There was no evidence of polishing or of batter marks on the rail fracture surfaces, or on the fracture surfaces of the broken joint bars. However, one joint bar on the west rail and a second joint bar on the east rail exhibited some pre-existing fatigue cracks.

Computer Simulation of Train Derailment

CP Rail conducted a computer simulation of the derailment using the NUCARS software. This software program predicts the response of a rail vehicle (a locomotive or a freight car) as it travels over a section of track. The simulation analysed the potential for:

- wheel climb on the high rail,
- dynamic gauge spreading, and
- wheel unloading on the low rail (combined with car body/high rail roll).

Specifically, the simulation focused on the lead locomotive (CP 9539) and on the loaded centre-beam bulkhead flat car (CP 318338). Although the lead locomotive did not derail, it likely caused the rail to roll over because it exerted sufficient lateral force on the rail. The loaded lumber car was simulated because this vehicle was likely the first car to derail. In the simulation, the track was modelled based on measurements recorded by CP Rail's track evaluation car (TEC) on 06 October 2003. The simulation was performed with the rail vehicle travelling at 56 mph.

For both the lead locomotive and the bulkhead flat car, the simulation results indicated that there were no significant unstable operating conditions in the vicinity of the point of derailment (POD).

Track Inspection at Derailment Location

On 15 December 2003, an ultrasonic rail test had been conducted through the derailment area. During this test, no internal rail defects were detected.

Before the derailment, CP Rail's track maintenance supervisor had last inspected this track on 20 January 2004. During this inspection, no surface or track irregularities were noted in the derailment area.

Track Geometry Testing at CP Rail

CP Rail's Standard Practice Circular (SPC) 34 describes each type of geometry defect that is measured by the TEC, and how each defect type is classified. The TEC can identify 23 types of geometry defects. Depending on the extent of a defect, it is classified as urgent, near urgent, or priority. CP Rail's standards for geometry defects are generally more stringent than the specifications in the federally approved *Railway Track Safety Rules* (TSR).

An urgent defect requires immediate protection of the track (a temporary slow order) or immediate correction of the defect. Track defects that are within ⅛ inch of being urgent are classified as near urgent. Near urgent defects must be inspected and corrected as soon as practicable. Priority defects must also be inspected and corrected as soon as practicable.

The last TEC test through this area was conducted on 06 October 2003. In the vicinity of the derailment, there were seven priority defects within 89 feet south of the Castlederg Sideroad crossing. These are detailed in the following chart.

Defect Type	Length of Defect (feet)	Measured Value (inches)	Urgent Defect Limit (inches)	Priority Defect Limit (inches)
AL/31[4]	7	5/8	1	1/2
AL/62[5]	7	5/8	1c	5/8
AL/31	4	5/8	1	1/2
D ELV C[6]	3	1/4	1c	1
AL/31	3	5/8	1	1/2
AL/62	26	7/8	1c	5/8
AL/62	19	3/4	1c	5/8

Curve Information

The following list summarizes curve information from the derailment area, as recorded by the TEC on 06 October 2003:

Posted Speed: 55 mph (Class 4)
Design Speed: 65 mph

Maximum degree of curve: 2° 1' at Mile 24.8 + 83 feet
Average degree of curve: 1° 30'
Average superelevation: 1c inches
Maximum superelevation: 2 inches at Mile 25.1 + 371 feet (north of crossing)

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4 If the alignment of either or both rails in a curve or spiral over a 31-foot chord deviates more than the specified value from the design alignment for that curve or spiral, an urgent or priority defect is recorded.

5 If the alignment of either or both rails in a curve or spiral over a 62-foot chord deviates more than the specified value from the design alignment for that curve or spiral, an urgent or priority defect is recorded.

6 If the measured curve elevation deviates by more than the specified value, an urgent or priority defect is recorded. The measured minimum superelevation was c inch. The required superelevation was 1c inches. With a 1c-inch difference in elevation between the required elevation and the actual elevation, this defect was categorized as a priority defect.

> Minimum design speed: 47 mph at Mile 24.8 + 82 feet at an elevation of C inch and 2° 1' curvature

CP Rail's Standard Practice Circular (SPC) 02, which relates to curve easement and elevation, describes how curve elevation is calculated and how curve elevation tables are used. Railway curve elevations are normally set to accommodate both passenger and freight trains. Although passenger trains no longer operate over the MacTier Subdivision, many of the curves on this subdivision were designed for 3-inch unbalanced speed.

This minimum design speed is that speed at which a passenger train would require a 3-inch higher elevation for equilibrium.[7] However, due to their higher lateral and vertical loads, freight trains are normally limited to the speed that corresponds to 2 inches of unbalanced elevation.

SPC 02 contains curve elevation tables for equilibrium speed, 2-inch unbalanced speed, and 3-inch unbalanced speed. Based on SPC Table 3, a 1.5-degree curve with a superelevation of 1.5 inches would have a 3-inch unbalanced design speed of 66 mph. Based on SPC Table 2, a 1.5-degree curve with a superelevation of 1.5 inches would have a 2-inch unbalanced design speed of 58 mph.

Previous TSB Investigations

In 1999, the TSB conducted an investigation into a main-track derailment at Mile 202.98 of the Canadian National (CN) Bala Subdivision near Mowat (R99T0256). In this occurrence, cross-level and alignment deviations were present in the track near the POD. Based on the specifications in effect at that time, taken individually, these track anomalies did not require corrective action. However, collectively, these track anomalies contributed to the derailment. Following this investigation, CN established limits, as part of its track maintenance practice, to address track deviations involving combinations of sub-urgent track defects.

In 2001, the TSB conducted an investigation into a main-track derailment at Mile 8.15 of CP Rail's Broadview Subdivision near Kemnay, Manitoba (R01W0182). This investigation identified multiple, priority-level track deviations as a contributing factor to the derailment. Following this investigation, CP Rail, CN, and Transport Canada (TC) initiated a joint research study targeted at characterizing this type of track geometry defect.

Railway Track Safety Rules

As indicated in Section 3.1 of the TSR:

> "A combination of track conditions, none of which individually amounts to a deviation from the requirements in this part, may require remedial action to provide for safe operation over that track. Nothing in the TSR prevents a railway company

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7 Equilibrium for a curve is achieved when the vehicle's resultant force is perpendicular to the plane of the track. The resultant force is determined by the vehicle's weight and the centrifugal force generated as the vehicle travels through the curve.

from prescribing a higher level of maintenance."[8]

Despite recognizing the adverse effect of a combination of track conditions that may require remedial action, neither TC nor CP Rail have developed specifications establishing limits for a combination of such conditions.

Analysis

In this occurrence, there were neither equipment nor car loading irregularities that were causal to the derailment. The analysis will focus on track geometry problems in the vicinity of the Castlederg Sideroad crossing and on the management of the combination of adverse track geometry conditions that were present.

The Accident

Based on marks on the rail, the POD was approximately 45 to 50 feet south of the Castlederg Sideroad crossing. The derailment likely occurred when the west (high) rail started to roll over under the lead locomotive. The wheel rim marks on the head of the east (low) rail, approximately 50 feet south of the crossing, likely occurred when the trailing truck of the second locomotive (CP 6010) dropped between the rails. Similar marks on the west rail, approximately 80 feet south of the crossing, likely occurred when the wheels of the third locomotive dropped in as that rail rolled over. The joint bars, weakened by pre-existing fatigue cracks, broke as the rail twisted and rolled.

The train was travelling at 56 mph at the time of the derailment. The permissible track speed for this curve was 55 mph. From CP Rail's SPC 02 Table 2, the maximum speed for a 1.5-degree curve and 2-inch unbalance is 58 mph. Had the track curvature remained 1.5 degrees (or less) throughout the curve, the permissible maximum speed would have been within the standard. However, the maximum curvature within the curve was greater than 1.5 degrees (approximately 2 degrees at Mile 24.8 + 83 feet).

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8 Transport Canada, *Railway Track Safety Rules*, Part 1—General, Clause 3—Scope.

From SPC 02 Table 3, the maximum speed for a freight train travelling through a 2-degree curve with zero superelevation (i.e., minimum design) is 47 mph. As a train travels through a curve, it will exert increased lateral forces on the track structure as its speed increases. If the curve is properly superelevated, and the ties and fasteners are in good condition, the track structure will be able to support these increased forces. However, even with proper superelevation and good track structure, for this curve, with continued train operation at speeds greater than 47 mph, the track structure's ability to support these forces through the 2-degree section gradually decreased over time. In addition, increased train speeds result in increased lateral forces on the high rail, creating a high L/V ratio.[9] An increased L/V ratio creates greater potential for high rail roll over and low rail unloading.

At Mile 24.8 + 83 feet (the location of maximum curvature), a curve elevation defect of C inch over a length of three feet was present in the track. There were also alignment defects near this location. Poor alignment within a curve causes wheels on a moving rail vehicle to kick

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[9] The L/V ratio is the ratio of the lateral load over the vertical load.

outwards, resulting in additional lateral forces on the track structure. While the curve elevation defect and the alignment defects were not critical individually, these multiple geometry defects in close proximity would have amplified the lateral forces on the track structure.

Despite the results of the NUCARS simulation, which indicated that train operating conditions near the POD were stable, it is likely that the presence of multiple sub-urgent defects contributed to the derailment. The derailment likely occurred when the train travelled over the combination of sub-urgent defects at 56 mph (9 mph above the minimum design speed), resulting in unloading of the low rail and increased lateral forces on the high rail. With increased lateral forces on the track structure, the high rail rolled over as the train passed through the curve.

Managing a Combination of Adverse Track Conditions

The TSR indicate that a combination of track conditions, none of which individually amounts to a deviation from TSR requirements, may require remedial action to provide for safe operation over that track. Nothing in the TSR prevents a railway company from prescribing a higher level of maintenance.

Although the TSR and the CP Rail specifications recognize the adverse effects of a combination of track geometry conditions, they do not establish limits for a combination of conditions defined as sub-urgent or priority track defects by CP Rail's Standard Practice Circular 34. Without measures in place to identify and remedy combinations of sub-urgent track defects, there is an increased risk of track geometry-related derailments.

Findings as to Causes and Contributing Factors

1. The presence of sub-urgent track geometry defects (specifically, curve elevation and alignment deviations) affected the train as it travelled through the curve. These track geometry defects, acting in combination, likely resulted in unloading of the low rail and in increased lateral forces on the high rail.

2. The high lateral forces on the track structure resulted in the high rail rolling over to initiate the derailment.

Finding as to Risk

1. Although the *Railway Track Safety Rules* and the Canadian Pacific Railway specifications recognize the adverse effects of combination track geometry conditions, they do not establish limits for a combination of these conditions that are defined as sub-urgent or priority track defects by Canadian Pacific Railway's Standard Practice Circular 34. Without measures in place to identify and remedy combinations of sub-urgent track defects, there is an increased risk of track geometry-related derailments.

Safety Action

Canadian Pacific Railway identified two additional track geometry defect types that will be measured by its track evaluation car. These new defect types take into consideration the effect of a combination of defects:

1. Urgent Combined Cross-level/Alignment Defect – This classification will be used when a Priority Alignment Defect is found within 11 feet of a Priority Design Elevation Defect.

2. Urgent Curve Design Speed Defect – This classification will be used when the posted freight speed in a curve is 10 mph greater than the design speed of the curve based on a 1-inch unbalanced superelevation.

The two new defect types will be fully implemented on the Canadian Pacific Railway track evaluation car by Spring 2005.

This report concludes the Transportation Safety Board's investigation into this occurrence. Consequently, the Board authorized the release of this report on 21 April 2005.

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