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

RAILWAY INVESTIGATION REPORT
R05C0082

MAIN-TRACK DERAILMENT

CANADIAN PACIFIC RAILWAY
TRAIN 277-26
MILE 69.2, RED DEER SUBDIVISION
NEAR BOWDEN, ALBERTA
27 MAY 2005

Canada

Railway Investigation Report

Main-Track Derailment

Canadian Pacific Railway
Train 277-26
Mile 69.2, Red Deer Subdivision
Near Bowden, Alberta
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Summary

On 27 May 2005, at about 0125 mountain daylight time, Canadian Pacific Railway northbound freight train 277-26 derailed 2 locomotives and 24 cars, including 3 pressure tank cars last containing anhydrous ammonia (UN 1005), at Mile 69.2 of the Red Deer Subdivision, near Bowden, Alberta. There were no injuries. No dangerous goods were released.

Ce rapport est également disponible en français.

Other Factual Information

On 26 May 2005, at 1934 mountain daylight time,[1] Canadian Pacific Railway (CPR) freight train 277-26 (the train) departed Calgary, Alberta, destined for Red Deer, Alberta. The train consisted of 2 General Electric (GE) AC4400 operating locomotives followed by 2 isolated rear-facing General Motors (GM) GP 9 locomotives, 22 loaded cars and 55 empty cars. It weighed 4512 tons and was 5050 feet long. The train crew consisted of a conductor and locomotive engineer who were qualified for their respective positions and met fitness and rest standards.

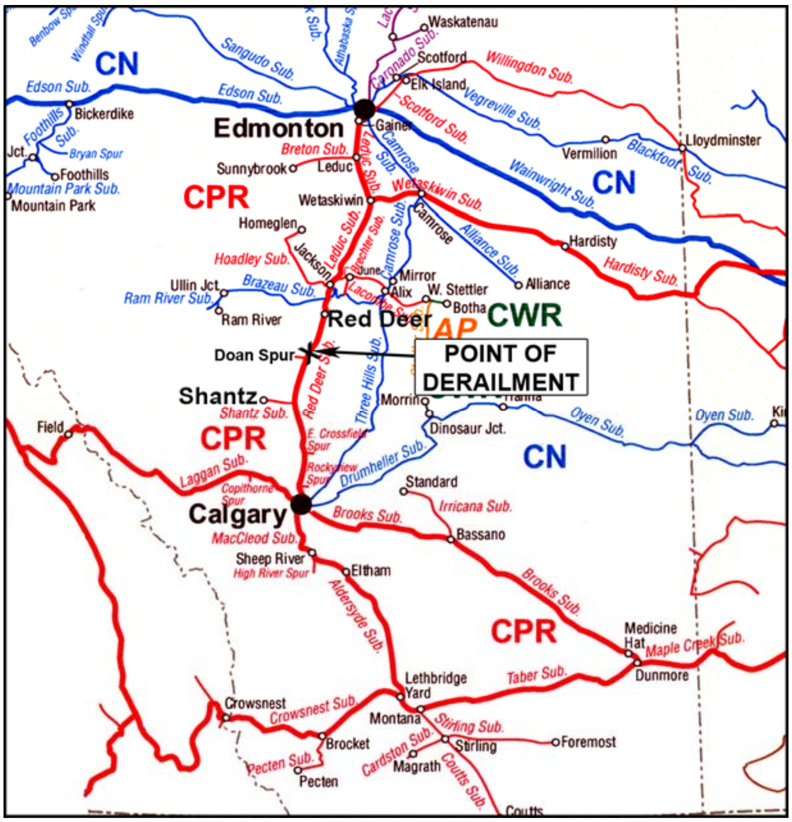

Figure 1. Map of the derailment location (Source: Railway Association of Canada, *Canadian Railway Atlas*)

En route, the rail traffic controller (RTC) issued a General Bulletin Order (GBO) to the train to manually protect its movement over the crossing at Mile 69.8 because the automatic crossing protection was defective. A signal maintainer had been dispatched and was repairing the crossing protection.

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[1] All times are mountain daylight time (Coordinated Universal Time minus six hours).

The train was cleared through to Mile 68.0 and stopped there at 0054. At 0103, the RTC issued a clearance to the train crew that included a restriction to protect the work limits of the signal maintainer between Mile 68.0 and Mile 70.0.

At 0116, the signal maintainer gave the train permission to proceed through his work limits at 10 mph. The train crew confirmed with him that the mileage of the crossing in need of protection was Mile 69.8 and then proceeded.

Approaching Mile 69.08, the crew spotted the signal maintainer and determined that the crossing to be protected was at Mile 69.08 rather than Mile 69.8. The locomotive engineer applied the train brake and the dynamic brake[2] (DB) and slowed the train over the crossing. The conductor detrained and protected the movement.

The following events were noted from the locomotive event recorder:

- A minimum brake pipe reduction and full DB application were used to reduce train speed to 1.1 mph at the crossing at Mile 69.08 at a recorded time of 0123:21.
- Five seconds later, at 0123:26, the train brake was released.
- The DB was shut off and within 24 seconds the throttle was advanced to the No. 8 position or full throttle.
- The train accelerated to 13.7 mph in 1 minute 11 seconds. The throttle was then closed. The DB was initiated and moved to position 6.5 in less than 20 seconds, pausing at idle for 1.3 seconds.
- At 0124:55, a change from deceleration to acceleration occurred and the train speed briefly increased from 11 mph to 13 mph.
- At 0126:24, the DB was shut off, and at 0126:28, the throttle was moved to motoring, increasing to position 6 in 1 minute 5 seconds. The train then began to decelerate, reducing speed from 5.8 mph to 3.5 mph at 127:53.
- At 0127:58, while traveling at 3.5 mph in throttle position 5, there was a train-initiated emergency brake application. The train stopped at 0128:06 at Mile 69.58. It had been pulled, in a derailed state, for at least 1 minute 34 seconds before the train-initiated emergency brake application.

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2 The dynamic brake system uses the locomotive traction motors to provide resistance against the rotation of the locomotive axles. Energy is produced in the form of electricity and is dissipated as heat through resisters (that is, the dynamic brake grids). Dynamic brake can be used alone or in conjunction with the train air brake system. Extended range dynamic brake develops its maximum retarding force between 6 and 23 mph while standard dynamic brake develops its maximum retarding force at about 23 mph.

After conducting the necessary emergency procedures, the train crew determined that the two isolated locomotives and the following 24 cars had derailed. Of the 24 derailed cars, 18 were empty centre beam bulkhead flat cars with cushion draft gear, one was a loaded gondola car, two were empty covered hopper cars, and three were pressure tank cars last containing anhydrous ammonia. The derailed locomotives and cars remained upright. There was no product lost. The 24 derailed cars sustained minor damage and were repaired and returned to service.

Site Examination

The first marks on the rail were found at Mile 69.2. At that point, the west rail was rolled to the field side with flange marks visible on its web and the east rail had raised spikes on the gauge side. Northward, the track was damaged for a distance of about 1960 feet to Mile 69.58. At that point, the west rail had rolled outward under the leading (front) truck of the third locomotive, CP 1632, between wheels R1 (derailed between the rails) and R2 (derailed to the field side). The fourth locomotive, CP 1514, was derailed between the rails.

The two derailed locomotives were inspected. Each had sustained damage, including cracks, to the east side of the coupler housing. The lead truck of locomotive CP 1514 was found to have no side bearing clearance and the left-side bolster stops on the trailing truck had been broken off. (Because the two isolated GM GP 9 locomotives were facing backwards (south), the missing bolster stop affected the coupling between the third and fourth locomotives.)

The broken bolster stop and the bolster bowl liner and lubricant from the lead truck on locomotive CP 1514 were sent to the TSB Engineering Laboratory for analysis (TSB Engineering Laboratory report LP 062/2005). See Appendix B for more detail.

At the time of the derailment, the weather was clear, the winds were calm, and the temperature was 8°C.

Red Deer Subdivision

The Red Deer Subdivision is a single main track that extends from Mile 0.0 in Calgary to Mile 95.6 in Red Deer. Train movements are governed by the Occupancy Control System (OCS) of the *Canadian Rail Operating Rules* (CROR) and supervised by an RTC located in Calgary. Authorized track speed for freight trains was 45 mph; however, at the time of the derailment, the following temporary slow orders were in effect (see Figure 2):

- 40 mph between Mile 66.1 and Mile 71.2 – due to excessive cross-level variation
- 25 mph between Mile 68 and Mile 69 – due to tie conditions
- 25 mph between Mile 70.5 and Mile 71.3 – due to tie conditions

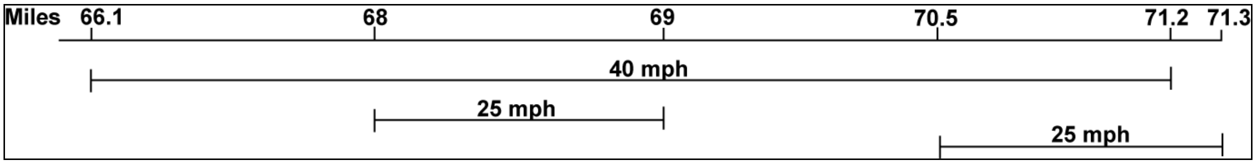

Figure 2. Slow orders

In the vicinity of the derailment, the track was tangent and descended northward at one per cent. It comprised 115-pound continuous welded rail laid on double-shouldered tie plates, secured to softwood ties with two spikes per plate and a hold-down spike every other tie plate. The rail was installed in 1985. It had a vertical wear of about 0.125 inch and no lateral wear. Both rails were anchored every other tie. The tie condition was fair to poor. The ballast consisted of gravel and was fouled with subgrade material. The shoulders and cribs were full.

The track in the derailment area was inspected as required by CPR Standard Practice Circulars (SPCs). A rail flaw detector car inspected the rail on 03 May 2005 and found no internal defects. The Gauge Restraint Measuring System (GRMS) tested the track on 22 November 2004 and discovered no defects. The track evaluation car (TEC) tested the track on 18 April 2005; no defects were noted. On 26 May 2005, the track maintenance foreman inspected the track at the derailment location and no irregularities were noted.

GP 9 Locomotives (Bolster Stops and Couplers)

The two isolated[3] GP 9 locomotives had been inspected and serviced at the Alyth diesel shop in Calgary and were being transferred on train 277 to Edmonton, Alberta. Both locomotives were equipped with couplers without alignment control features (see Figures 3 and 4).

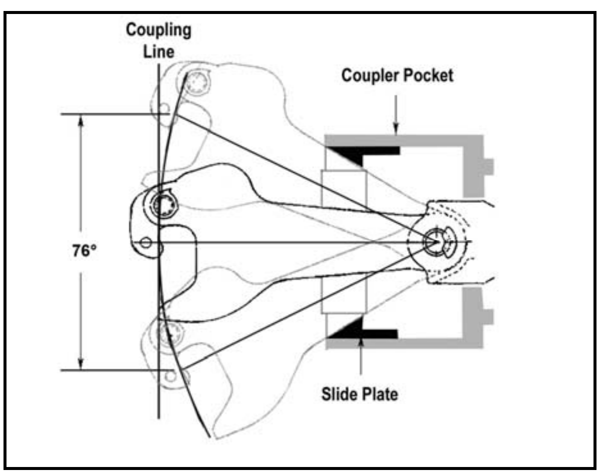

Figure 3. Coupler without alignment control

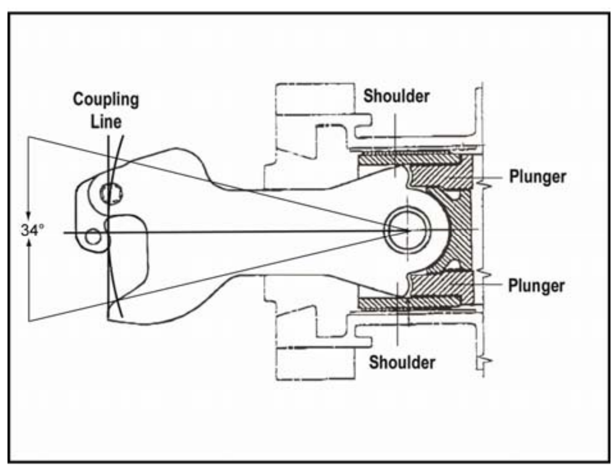

Figure 4. Coupler with alignment control

The alignment control feature on the coupler restricts the lateral movement of the drawbar when longitudinal in-train forces are in compression, or buff. A lower drawbar angle reduces the lateral forces placed on the track at the wheel-rail interface and consequently lowers the possibility of derailment from rail rollover. Couplers without the alignment control feature

3 The locomotive cannot be used for either power or dynamic braking operation.

provide a greater range of coupler movement while negotiating tight curves in yards and industrial spurs. Alignment control couplers, under buff conditions, can limit the drawbar angle to +/- 17 degrees, while couplers without alignment control permit a drawbar angle as large as +/- 34 degrees.[4] The locomotive manufacturer recommends that bolster stops[5] be installed when locomotives without alignment control features operate in consists with units capable of generating high dynamic effort.

The last annual inspection report of locomotive CP 1514, conducted in July 2004, indicated that the bolster stops were in place. The last datal (periodic) inspection was conducted on 29 March 2005. Neither the datal (periodic) nor the pre-trip mechanical inspections, conducted just before departure on 26 May 2005, discovered a broken bolster stop bracket. Because the bolster stop is affixed to the inside of the truck side frame, it is not visible during most inspections.

Railway General Operating Instructions for Dynamic Brake

The two lead operating locomotives were GE AC4400s equipped with extended range DB, each capable of producing 98 000 pounds (DB factor of 9.8) of retarding force; 196 000 pounds in total. Because of the longitudinal force placed in the rail during braking, and because of the risks associated with a run-in of train slack during braking, CPR General Operating Instructions (GOIs) provide guidance on the use of the DB and the throttle. Section 16, entitled Train Handling, states

- When changing from motoring to DB when the train is in motion, pause for ten seconds with the throttle in IDLE.

- When moving into the braking zone, pause at the minimum braking position long enough to adjust train slack, then move the handle slowly within the braking zone to obtain the desired braking effect.

- After releasing the DB in preparation for applying power, the throttle must be advanced with care to ensure gradual adjustment of train slack.

- When governed by temporary speed restriction, when DB factor of the lead locomotive consist is 14 or greater, the DB handle MUST NOT be placed in a position higher than No. 5 for approximately one half Mile prior to the beginning of, or when the locomotive is moving over any temporary speed restriction. Note: The train air brakes and DB may be used to comply with the speed restriction.

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4 The drawbars on the GP 9 locomotives equipped with couplers without alignment control can achieve an angle of +/- 34 degrees.

5 Bolster stops are used to reduce the potential of jackknifing of locomotives not equipped with alignment control couplers. The bolster stop limits the lateral movement of the locomotive car body thus reducing the lateral force at the wheel-rail interface generated from transformed longitudinal forces, such as experienced during episodes of heavy dynamic braking and/or slack run-ins.

TSB Engineering Laboratory Reports LP 057/2005 and LP 062/2005[6]

The TSB Engineering Laboratory performed an analysis of the in-train forces generated during the braking event that led up to the derailment (LP 057/2005, see Appendix A). The following information is from that report:

- A combination of the significantly high buff force caused by improper operation and abrupt DB application, and the large drawbar angle due to couplers without alignment control produced an excessive transformed lateral force that rolled over the rail and led to the derailment.

- Improper operational activities and abrupt DB applications produced a significantly high buff force in the range of 200 to 300 kips (1000 pounds) at the isolated yard locomotives (CP 1632 and CP 1514) behind the operating locomotives.

- The couplers without alignment control between CP 1632 and CP 1514 permitted a large drawbar angle and jackknifing of the isolated locomotives.

- The cushioned draft gears of the 18 cars immediately behind the head-end locomotives and the couplers without alignment control of the two isolated locomotives contributed to and increased the high impact force.

- Under the actual track condition with 1 gauge side spike on each plate and the installation age of 20 years, the slightly worn RE 115 rail could resist rollover up to L/V[7] of 1.12. This is a typical level of resistance against rail rollover for similar common conditions.

- The estimated buff force of 250 kips in this derailment would have produced a truck side L/V of 0.54 for a drawbar angle of 8.5 degrees, 1.12 for 17 degrees, 1.25 for 19 degrees and 2.16 for 34 degrees.

This dynamic analysis also determined that there was sufficient force generated to have rendered functioning bolster stops on the two GP 9 locomotives ineffective in preventing this derailment.

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6 These reports are available upon request from the Transportation Safety Board of Canada.

7 L/V (lateral over vertical) is a ratio of the forces that act upon the rail at the interface between the wheel flange and the rail. This ratio can also be used to express rail resistance against rollover.

The TSB Engineering Laboratory also examined the fracture surface of the bolster stop bracket and the lubricant and bolster liner from the No. 1 (leading) truck (report LP 062/2005, see Appendix B). The examination determined that

- the bolster stop had broken off prior to the accident, and
- the lubricant had migrated to the centre of the truck bolster bowl and the remainder of the liner was inadequately lubricated resulting in excessive wear. The excessive wear resulted in zero side bearing clearance.

Canadian Pacific Railway Accident Report

Using its Train Operations and Energy Simulator (TOES), CPR concluded that the primary cause of this derailment was poor train handling that resulted in a slack run-in impact of 255 kips on CP 1632 at the point of derailment.

An important contributing factor was the marshalling of the locomotives and cars so that the slack run-in was increased by having 18 cars with cushion draft gear placed immediately behind the locomotive consist. The effect of the run-in was increased by marshalling two locomotives without alignment control couplers, one of which had a broken bolster stop, between the two lead AC4400 locomotives and the remainder of the train.

Train Marshalling

CPR's GOIs[8] specify train marshalling requirements to reduce undesirable track-train dynamics in mixed trains. Train 277 was marshalled in accordance with the GOIs.

Crew

The locomotive engineer's and the conductor's work/rest schedule met the requirements of Transport Canada (TC)–approved *Work/Rest Rules for Operating Employees*.

On 26 May 2005, the locomotive engineer had taken a nap in the afternoon to ensure that he was rested for his tour of duty. He was called at 1630 to report for work at 1830. However, before May 26, the locomotive engineer had worked a combination of day, evening, and night shifts as summarized in Table 1.

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8 CPR's GOIs, Section 7, item 5, Cushion Drawbar Rules, and item 6.1, Marshalling Heavy and Light Cars or Blocks.

Table 1. Locomotive Engineer's Work/Rest History for 96 Hours Before the Accident

Day	Time Ordered	Off Duty	Type of Shift
May 22	1930	0340	Night shift
May 23	0950	1815	Day shift
May 24	2340	0745/May 25	Day off followed by night shift
May 25	1201	1446	Day shift
May 26	1830	Accident at 0125 on May 27	Day off followed by night shift

Ten months before this accident, the locomotive engineer qualified on the Laggan and Red Deer subdivisions. Before the accident, he had worked only once as the assigned locomotive engineer over the Red Deer Subdivision. However, he had gained experience at the controls of the locomotive while working as a conductor and trainman.

On May 26, the conductor worked a yard assignment, and was off duty at 0405. He rested before going to work at 1830. However, before this shift, the conductor worked mostly nights. Table 2 is a summary of the previous 72 hours work history.

Table 2. Conductor's Work/Rest History for 72 Hours Before the Accident

Day	Time Ordered	Tied Up	Type of Shift
May 23	0330	1105	Night shift
May 23	1616	1801	Day shift
May 24	2000	0400/May 25	Night shift
May 25	2000	0400/May 26	Night shift
May 26	1830	Accident at 0125 on May 27	Night shift

Since qualifying in May 2003, the conductor worked a variety of positions (yardman, trainman, yard foreman and conductor) intermittently with 29 per cent of his time on the Red Deer Subdivision. He was not qualified as a locomotive engineer.

Hours of Work Regulations

The *Work/Rest Rules for Railway Operating Employees,*[9] developed by the Railway Association of Canada and approved by the Minister of Transport, became effective 01 April 2003 and were revised 29 June 2005. The rules were developed pursuant to the *Railway Safety Act*[10] and are

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9 *Work/Rest Rules for Railway Operating Employees*, TC-O 0-33, conditionally approved June 18, 2002, revised October 18, 2002, and effective April 1, 2003.

10 *Railway Safety Act*, Section 20(1), R.S. 1985, c.32 (4th Supplement)

accompanied by Railway Association of Canada's Circular[11] on the "Recommended Procedures and Practices for Application of Work/Rest Rules." CPR's system for scheduling hours of work for train crews was developed based on these rules and in accordance with collective agreements. A review of the provisions of the rules, the circular and aspects of railway culture by a TSB Human Performance Specialist identified a number of elements that increase the risk of fatigue-related errors and accidents.

- The lack of work schedule predictability increases the difficulty for employees to obtain adequate adjustment periods between shift types.

- The *Work/Rest Rules for Railway Operating Employees* make no distinction between night and day shifts.

- There is no regulation specifying the training required to help operators determine if they are fit and well rested for duty.

- The scheduling system and organizational culture predispose a crew to report that they are fit and well rested.

Supervision

The CPR recertification policy required that all locomotive engineers and conductors have an on-the-job evaluation performed by a road manager every three years. In addition, the locomotive engineer and the conductor must be recertified in a number of areas (that is, CROR, *Transportation of Dangerous Goods Regulations*), as per TC's *Minimum Qualification Standards Regulations*. Neither the locomotive engineer nor the conductor were required to be re-evaluated on the job by a road manager because they were both still within the three-year requirement for on-the-job re-evaluation.

Analysis

Elevated buff forces that resulted from the rapid application of dynamic braking concentrated behind the locomotives and caused the locomotive to briefly accelerate. These forces were transformed to lateral force at the wheel-rail interface, rolling over the rail and leading to the derailment. The magnitude of the buff force was augmented by the slack run-in of the 18 cars with cushion drawbars located immediately behind the locomotive consist. Moreover, the transformed lateral force was increased due to the large drawbar angles of the couplers without alignment control of the trailing two locomotives.

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11 Railway Association of Canada, Circular 14, "Recommended Procedures and Practices for Application of Work/Rest Rules." This document was replaced by the "RAC Work/Rest Rules Interpretation Document," effective 29 June 2005.

The analysis will focus on train handling, train crew experience, supervision, fatigue, *Work/Rest Rules for Railway Operating Employees*, locomotive and train marshalling practices and overlapping slow orders. Rolling stock defects did not contribute to this accident; however, locomotive inspection and maintenance shortcomings will be discussed. The ties were in fair to poor condition; however, they were not defective and are not considered a contributing factor.

Although the crew was twice given incorrect crossing location information, it is unlikely that any resulting confusion played a role in this derailment. Both crew members were familiar with the subdivision and would have localized the GBO restriction to the only possible place it could have applied—the crossing at Mile 69.08—since there was no crossing at Mile 69.8. In addition, the critical control manipulation that led to the derailment took place after the train had been slowed to manually protect the crossing at Mile 69.08.

There were a number of instances where the locomotive engineer applied power and dynamic braking in a manner inconsistent with safe railway operating practices. Departing the crossing, the throttle was moved immediately to maximum position and the train was allowed to accelerate to 13.7 mph, a speed in excess of the speed specified by the signal maintainer (that is, 10 mph). The throttle was then closed and the DB heavily applied, leading to the rapid buildup of buff forces and ultimately the derailment. Given the rapid response to the realization that the speed of the train had significantly exceeded the signal maintainer's instruction (for example, maximum 10 mph), it is likely that the crew had momentarily forgotten the restriction.

Furthermore, while the train continued to descend the one per cent grade, the locomotive engineer continued to apply power, dragging the train in a derailed state for approximately 1960 feet, until it came apart and an emergency brake application resulted. It is likely that the locomotive engineer did not recognize that the train had derailed with the slack run-in that resulted from the heavy DB application. However, it remains unclear why he did not suspect that there was a problem as he was decelerating downhill while applying power with the brakes fully released for about 1 minute 30 seconds. Overlapping slow orders and the 10 mph speed restriction imposed by the foreman may have created some confusion for the crew. However, this does not explain the rapid changes from heavy motoring to heavy DB application that initiated this derailment.

Since qualifying, the locomotive engineer had returned to work as a conductor, operating trains when possible under the supervision of qualified locomotive engineers. While he had not gained a great deal of experience as a working locomotive engineer after qualification, his training program and subsequent work on the Red Deer Subdivision had afforded him the opportunity to maintain familiarity with the territory.

Railway records indicate that the accumulated service of both crew members did not dictate that they receive on-the-job evaluation by a supervisor in their respective positions. Although there is not always a direct relationship between supervision and performance, it is likely that a more robust regimen of supervisory contact would have resulted in train handling practices more consistent with railway requirements.

The train crew's work/rest cycle was within company and government requirements. The crew members had taken lifestyle training on recommended sleep patterns so both of them had prepared for the trip by getting some rest beforehand; the locomotive engineer took a nap in the afternoon, the conductor had rested during that day.

Operational requirements frequently dictated that crews alternate their work between day and night shifts (tables 1 and 2). In the days before the derailment, the train crew had changing work schedules. The repeated changes from night to day shift and vice versa could not allow fully restorative sleep, and their circadian rhythm was disrupted by every change, potentially leading to fatigue.[12] In this instance, the likelihood of fatigue from the difficult schedules was compounded by an extended period of wakefulness[13] immediately before the trip on train 277. It is possible that fatigue played a role in the train handling errors, that is, the rapid changes in throttle and DB operation that were made in this instance.

The TSB review of the provisions of the regulatory and industry framework for the management of risks related to fatigue revealed a number of shortcomings. This framework did not adequately protect against the cumulative effects of fatigue that resulted from the crew's work/rest cycle, even though they were working within its parameters.

The marshalling of the isolated GP 9 locomotives immediately behind the two high-horsepower locomotives was consistent with railway or locomotive manufacturer recommended practices because the locomotives had been modified with the addition of bolster stops. However, the inspection process does not ensure that the bolster stops remain in place as they are not easily viewed during the periodic and pre-trip inspections.

The purpose of bolster stops is to limit lateral sway of the car body and thereby limit the lateral force applied to the rail. However, under the circumstances of high buff force created by the abrupt application of DB, the derailment would have taken place even if the bolster stops had been in place. Given the calculated resistance against rail rollover and the angles taken by the drawbars of the non-alignment control couplers between the two GP 9 locomotives, the lateral force would have at least met the calculated rail resistance against rollover.

The presence of rolling stock with cushion draft gear next to the locomotives without alignment control couplers contributed to this accident, but only because of high buff forces that resulted directly from throttle and DB manipulations that were inconsistent with safe railway operating practices. There were no restrictions against the manner in which this train was marshalled. Although it was not an ideal situation, it would not be reasonable to expect industry to endorse marshalling restrictions predicated upon the eventuality of inappropriate control decisions.

Locomotive CP 1514 had several mechanical conditions that could have affected its safe operation.

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12 D.I. Tepas and T.H. Monk, "Work Schedules," in G. Salvendy (Ed.), *Handbook of Human Factors*, New York: John Wiley & Sons, 1987, pp. 819-843.

13 D. Dawson and K. Reid, "Fatigue, Alcohol and Performance Impairment," *Nature*, 388, 1997, p. 235.

- inadequate truck bolster bowl lubrication had led to wear in the liners to create zero side bearing clearance; and
- the missing bolster stop on the left side of No. 2 truck.

When a locomotive with these defects is subject to high buff and draft forces, there are likely to be adverse consequences. However, the forces that were generated in this occurrence were so severe that the train would have derailed irrespective of the mechanical condition of locomotive CP 1514.

Findings as to Causes and Contributing Factors

1. A combination of the significantly high buff force caused by the abrupt dynamic brake application, and the large drawbar angle due to couplers without alignment control produced an excessive transformed lateral force that rolled over the rail and led to the derailment.
2. The magnitude of the slack run-in (buff force) that resulted from the abrupt dynamic brake application was exacerbated by the positioning of 18 cars with cushion drawbars immediately behind the locomotive consist.
3. It is possible that fatigue played a role in the train handling errors, that is, the rapid changes in throttle and dynamic brake that were made in this instance.

Findings as to Risk

1. The regulatory and industry framework for the management of risks related to fatigue may not adequately protect against the effects of fatigue that result from the work/rest cycle of train crews.
2. A more robust regimen of supervisory contact may have resulted in the application of train handling practices more consistent with railway requirements.
3. Although the defects identified on locomotive CP 1514 were not considered causal to this accident, subjecting defective locomotives to high buff and draft forces increases the likelihood of adverse consequences.

Other Finding

1. The rapid increase in dynamic brake that led to the derailment took place after the train had been slowed to manually protect the crossing at Mile 69.08; therefore, confusion about the actual location of the crossing was not causal to this accident.

Safety Action Taken

Additional Canadian Pacific Railway Training

Following the derailment, a four-hour training session called "Professionals in Motion" was developed by local management and provided to all terminal locomotive engineers (optional for conductors and train persons). The training session focused on the causes and contributing factors of the derailment. Subsequent sessions have been held in 2006 and 2007 with content specific to the duties of the locomotive engineer.

In addition, Canadian Pacific Railway (CPR) is developing an air brake refresher course to be offered to all running trade employees.

TSB Rail Safety Information Letters

Overlapping Slow Orders

On 14 March 2006, the TSB issued Rail Safety Information (RSI) letter 01/06 to Transport Canada (TC) regarding the dangers associated with overlapping slow orders. In that letter, the TSB noted that, while track speed in the vicinity of the derailment was 45 mph, overlapping slow orders restricted trains between Mile 66.1 and Mile 71.2 to 40 mph, between Mile 68 and Mile 69 to 25 mph, and between Mile 70.5 and Mile 71.3 to 25 mph. Even though Canadian Transport Commission Board Order R-18953 of 03 July 1974 requires that the reasons for placing a slow order be indicated within the body of an order, the TSB was concerned that the Board Order does not address the confusion associated with overlapping slow orders such as was identified in a prior TSB investigation report (R03Q0036).

In its response, TC indicated that overlapping slow orders are unavoidable and do not represent a bona fide safety concern. TC replied that the train crew complying with the overlapped slow orders would likely have proceeded at 25 mph from Mile 69 to Mile 70.5 or from Mile 68 to Mile 71.3. TC did not see a problem with overlapping slow orders.

Locomotive Truck Bolster Stops

On 30 March 2006, the TSB issued RSI letter 04/06 to TC. The TSB was concerned that the locomotive inspection process did not find defective bolster stops.

In the letter, the TSB explained that the locomotive manufacturer specifies that locomotives without alignment control features (such as the two GP 9 switching locomotives—CP 1514 and CP 1632) must have bolster stops applied to allow them to operate trailing in consists with locomotives capable of high dynamic brake effort (but not over 200 000 pounds). Both of these locomotives were modified with the addition of bolster stops. However, post-accident examination revealed that locomotive CP 1514 had a broken/missing truck bolster stop on the left side of the No. 2 truck that had broken away before the derailment.

The 2004 annual locomotive inspection report for locomotive CP 1514 indicated that the bolster stop was in place. There were no other scheduled inspections during the nine months between the annual inspection and the derailment where the bolster stop had to be checked. A missing/broken bolster stop increases the risk of a jackknifing derailment.

TC replied that it would place more emphasis on the inspection of bolster stops during monitoring and safety audits.

Locomotive Side Bearing Clearance

The TSB issued RSI letter 03/06 to TC concerning the zero side bearing clearance. The TSB was concerned that there was no place on the annual inspection form to record information pertaining to the side bearing clearance. In addition, the 2004 annual inspection form for locomotive CP 1514 indicated that the bolster bowl had been lubricated with oil even though lubrication piping used to oil the bowl had been removed.
TC replied that the CPR inspection form requires mechanics to check locomotive side bearing clearance; however, it does not require that the actual measurements be recorded. TC stated that this actual measurement would not have any safety value. TC added that locomotive side bearing clearances are checked during regular trip inspections and on periodic inspections. Although TC feels that there is a low rate of defects related to locomotive side bearing clearance, it will be placing more emphasis on this inspection during its regular monitoring activities.

Marshalling of Locomotives without Alignment Control Couplers

CPR revised General Operating Instructions (GOIs) Section 15, items 5.0, 7.4 and 7.5, so that only one GP 9 unit may be moved in a consist if placed between two alignment control coupler–equipped locomotives. A GP 9 locomotive may be moved in a train if two cars (minimum 45 tons and 65 feet long) are placed on either side of the locomotive. Finally, a GP 9 locomotive can be moved in a train if two cars (minimum 45 tons and 65 feet) are placed ahead of the locomotive with no loaded cars marshalled behind that locomotive.

This report concludes the Transportation Safety Board's investigation into this occurrence. Consequently, the Board authorized the release of this report on 13 July 2007.

*Visit the Transportation Safety Board's Web site (**www.tsb.gc.ca**) for information about the Transportation Safety Board and its products and services. There you will also find links to other safety organizations and related sites.*

Appendix A – Transformed Lateral Forces and Resistance against Rail Rollover

Table 3. Calculated Transformed Lateral Forces

In-train Force F (kips)	8 degrees		17 degrees		19 degrees		34 degrees	
	L (kips)	L/V	L (kips)	L/V	L (kips)	L/V	L (kips)	L/V
0	0	0	0	0	0	0	0	0
50	6.96	0.11	14.62	0.22	16.28	0.25	27.96	0.43
100	13.92	0.21	29.24	0.45	32.56	0.50	55.92	0.86
150	20.88	0.32	43.86	0.67	48.84	0.75	83.88	1.29
200	27.83	0.43	58.47	0.90	65.11	1.0	111.84	1.72
250	34.79	0.54	73.09	1.12	81.39	1.25	139.80	2.15
300	41.75	0.64	87.71	1.35	97.67	1.50	167.76	2.58
Net truck side vertical load: 65 kips Association of American Railroads Chapter XI Truck Side L/V Ratio Requirement: 0.6 Estimated Resistance against Rail Rollover on the Derailment Site (L/V): 1.12 Estimated Resistance against Rail Rollover for New Rail with Full Spikes (L/V): 2.23								

Table 4. Calculated Resistance against Rail Rollover

	Worn RE 115 Rail with 1 Gauge Spike at Age 20	Worn RE 115 Rail with 2 Gauge Spikes at Age 20	New RE 115 Rail with 1 Gauge Spike	New RE 115 Rail with 2 Gauge Spikes	New RE 115 Rail without Fastening
Rollover L (kips)	72.887	104.681	92.594	144.869	40.318
Rollover L/V	1.12	1.61	1.42	2.23	0.62
Comparison per cent	100	144	127	199	55
Rail head width W: 2.71875 inches Rail base width B: 5.5 inches New rail height H: 6.625 inches Worn rail height H: 6.5 inches					

Appendix B – Locomotive Information

Locomotive Bolster Bowl

Following the derailment, the TSB Engineering Laboratory examined the bolster bowl liners and lubricant from both trucks (report LP 062/2005). The examination determined that the lubricant from the No. 1 (leading) truck had migrated to the centre of the truck bolster bowl and the remainder of the liner was inadequately lubricated, resulting in excessive wear. The excessive wear resulted in zero side bearing clearance. In addition, the lubricant was found to be greased instead of car oiled as specified in the Canadian Pacific Railway (CPR) maintenance procedures. The No. 2 truck (trailing) had car oil as its lubricant and its liners were in good condition.

Annually, the bolster bowl was to be lubricated by adding one quart of car oil through the oil passage piping. The examinations reveal that locomotive CP 1514 no longer had an oil passage pipe. The annual inspection form (2004) indicated that the bolster bowl had been lubricated even though there was no way of doing so. In addition to the annual inspection, CPR required that the bolster bowl be inspected and lubricated during every major repair or every six years. Locomotive CP 1514 had not been inspected for eight years.

Locomotive Side Bearing

Each locomotive truck has a side bearing mounted on either side of the truck bolster matching a car body side bearing on the locomotive underframe (see Figure 5). General Motors (GM) prescribed a minimum side bearing clearance of 5/32 inch; however, CPR allowed that, before the clearance decreased to 1/32 inch, the truck bolster bowl wear plate liners must be checked for wear and replaced, if necessary. No measurement of side bearing clearance was recorded on inspection reports to indicate if the locomotive side bearing clearance met the manufacturer's specifications and was in compliance with Transport Canada (TC) rules.

TC–approved *Railway Locomotive Inspection and Safety Rules* state in part that "The bolster side bearing and pedestal clearances shall be maintained within manufacturer's specifications."

GM's GP 9 locomotives have swing hanger design trucks. The truck bolster swings laterally, minimizing impacts between the bolster and the car body so that lower lateral forces are transmitted to the track structure. At the bottom of the bolster bowl, liners assist truck bolster and car body movement by maintaining side bearing clearance. Inadequate truck bolster bowl lubrication can wear the liners to create zero side bearing clearance, which adversely affects truck swivel and can contribute to increased lateral forces being placed on the rail at the wheel-rail interface.

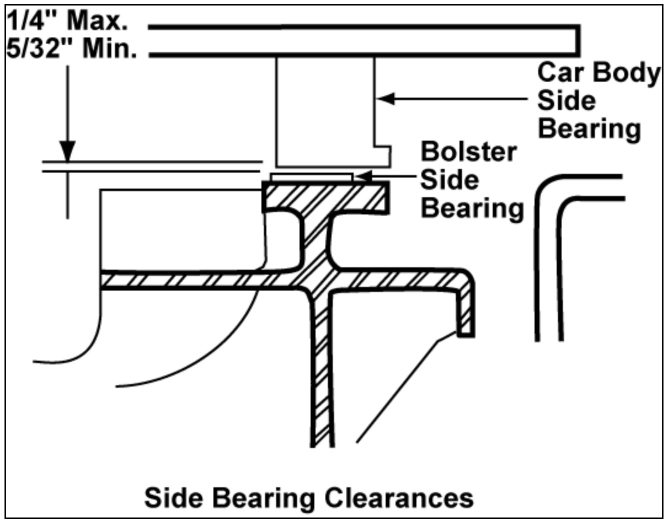

Figure 5. Diagram of side bearing clearances

Bolster Stop on Locomotive CP 1514

The bolster stop on the left side (east side) of the No. 2 (trailing) truck of locomotive CP 1514 was broken off. The remaining portion of the bolster stop bracket was obtained for analysis by the TSB Engineering Laboratory (report LP 062/2005). The bracket was not fastened with bolts as per the manufacturer's specifications; it was welded to the top of the truck frame. The analysis determined that the bolster stop fractured along the bent portion of the bracket. The fracture surface revealed beach marks indicating a high cycle fatigue failure mode. Each cycle would be associated with an impact between the truck's side frame and the swing bolster assembly. No metallurgical anomalies or manufacturing defects were observed that would have contributed to its failure. It did not appear to have been a recent break.

Bolster stops are used to reduce the potential of jackknifing of locomotives not equipped with alignment control couplers. The bolster stop limits the lateral movement of the locomotive car body, thus reducing the lateral force at the wheel-rail interface generated from transformed longitudinal forces, such as experienced during episodes of heavy dynamic braking and/or slack run-ins.

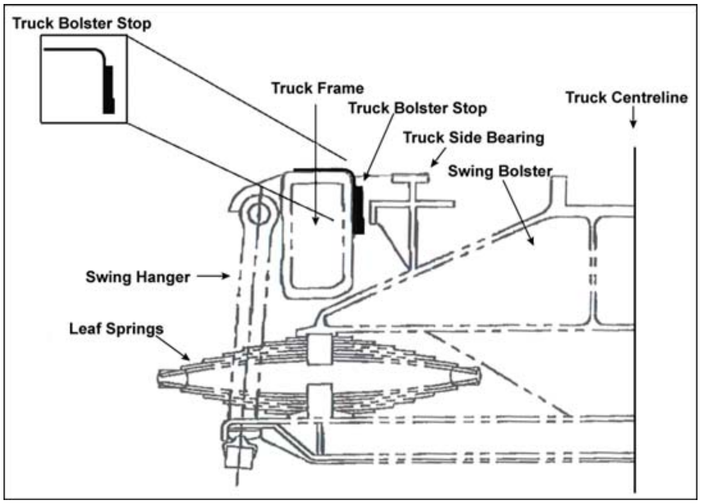

Figure 6. Diagram of truck bolster stop and side bearing

Inspection of the Two GP 9 Locomotives

On 26 May 2005, the locomotive consist pre-trip inspection report was signed off indicating that the locomotive consist met the requirements of the TC–approved *Railway Locomotive Inspection and Safety Rules*.

The locomotive engineer's inspection verified that the locomotive consist was marshalled in accordance with CPR's General Operating Instructions (GOIs), Section 15, item 4.4, that required dead or idling locomotives to be handled immediately behind the operating locomotives. He determined from the side sill stencil that the two isolated locomotives had bolster stops because these locomotives were not equipped with alignment control couplers (see figures 3 and 4).

The manufacturer, General Motors, recommended that GP 9 locomotives with pin-type couplers without alignment control features have bolster stops applied to allow them to operate trailing in consists with locomotives capable of high dynamic braking effort (but not in excess of 200 000 pounds).

Annual and Periodic Inspections

CPR records indicated that the annual inspections had been completed on locomotive CP 1632 on 16 November 2004 and on locomotive CP 1514 on 08 July 2004. Both locomotives passed periodic inspections on 16 February and 29 March 2005 respectively. Side bearing clearance was not recorded.

Overhaul of Locomotive Trucks

Overhaul of each locomotive truck was performed in March 1998 for locomotive CP 1514 and March 2002 for locomotive CP 1632, both at the Ogden shop in Calgary. CPR's locomotive maintenance regulation for GP 9 trucks prescribed that trucks be overhauled during major repair or every six years, whichever came first.

Appendix C – Glossary

CPR	Canadian Pacific Railway
CROR	*Canadian Rail Operating Rules*
DB	dynamic brake
GBO	General Bulletin Order
GE	General Electric
GM	General Motors
GOIs	General Operating Instructions
GRMS	Gauge Restraint Measuring System
L	lateral
L/V	lateral over vertical
mph	miles per hour
OCS	Occupancy Control System
RSI	Rail Safety Information
RTC	rail traffic controller
SPCs	Standard Practice Circulars
TC	Transport Canada
TEC	track evaluation car
TOES	Train Operations and Energy Simulator
TSB	Transportation Safety Board of Canada
°C	degrees Celsius