Transportation Safety Board
of Canada

Bureau de la sécurité des transports
du Canada

RAILWAY INVESTIGATION REPORT
R01W0007

DERAILMENT

CANADIAN PACIFIC RAILWAY
TRAIN 308-001
MILE 94.6, NIPIGON SUBDIVISION
NEAR BOWKER, ONTARIO
08 JANUARY 2001

Canada

Railway Investigation Report

Derailment

Canadian Pacific Railway
Train 308-001
Mile 94.6, Nipigon Subdivision
Near Bowker, Ontario
08 January 2001

Report Number R01W0007

Summary

On 08 January 2001, at approximately 1330 eastern standard time, Canadian Pacific Railway train 308-001, proceeding eastward on the Nipigon Subdivision, derailed 59 loaded freight cars of a unit grain train at Mile 94.6 near Bowker, Ontario. The derailment occurred on a left-hand curve, while the train was travelling at 64 mph and was accelerating out of control on a descending grade known as Bowker Hill. There were no injuries, and no dangerous goods were involved in the derailment.

Ce rapport est également disponible en français.

Other Factual Information

The Accident

On 08 January 2001, Canadian Pacific Railway (CPR) train 308-001 (train 308) departed Thunder Bay, Ontario, Mile 132.9 of the Nipigon Subdivision, at 1050 eastern standard time.[1] At about 1330, the eastward train experienced a train-initiated emergency brake application at Mile 94.297 while descending a 0.55 per cent grade, west of Bowker, Ontario. The train was travelling at 64 mph in a maximum allowable speed zone of 50 mph. After emergency procedures were executed, inspection of the train revealed that a total of 59 cars had derailed, the 12th car and the 19th to 76th cars, inclusive. The north and south rails were fractured within a few metres of the initial point of derailment (POD) at Mile 94.65. Initial examination of the POD revealed that the track had spread, the high rail canted over and the wheels dropped between the rails, resulting in a derailment. The head end of the train, with 19 cars, travelled approximately 4500 feet after the derailment occurred. The 12th car and the 19th car were derailed and upright on the roadbed. The 20th to 24th cars were derailed and on their side to the south of the track, approximately 2000 feet behind the head end of the train. The 25th to 76th cars were derailed in an accordion fashion on the right-of-way for a distance of 1085 feet east of the POD (see Photo 1).

Photo 1. Aerial photo of the derailment looking northward

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

Approximately 3500 feet of track was destroyed and 1000 feet of track was disturbed. Train 308 was powered by 4 locomotives and was hauling 86 loaded grain cars. It weighed 11 318 tons and was 5355 feet long.

The operating crew was comprised of a locomotive engineer and a conductor, located in the cab of the lead locomotive. The train conductor was regularly assigned to the Nipigon Subdivision and was familiar with the territory. The locomotive engineer was assigned to the spare board at Schreiber that covers both the Nipigon and the Heron Bay subdivisions. The locomotive engineer was qualified to work on the Nipigon Subdivision, but had not recently operated a grain train over that territory.

Train 308

After departing Thunder Bay, the train proceeded without incident until it was required to stop at Mile 115, at Mackenzie, because of track work. Upon applying the train brakes, an undesired emergency brake application (UDE) of the air brakes (a "kicker"[2]) occurred. The standard procedure for handling a train that has experienced a UDE is prescribed in CPR's General Operating Instructions (GOI) (see Appendix A). At Mile 114, the train received a pull-by inspection from engineering department employees. No anomalies were noted and the train proceeded eastward. CPR's GOI limit the speed at which this type of inspection is to be conducted to 15 mph. During this inspection, the train accelerated to 27 mph, with the locomotive in forward throttle position No. 2.

Recorded Information[3]

The recorded information from the locomotive event recorder indicated that, before the crest of Bowker Hill (Mile 101), dynamic braking (DB)[4] was used to slow the train from 35 mph to 30 mph while travelling in the 50 mph speed zone on a slight ascending grade. Between Mile 101 and Mile 100, the train had accelerated to approximately 35 mph and DB was gradually increased until full DB had been applied by approximately Mile 99.5. The train continued to accelerate at a steady rate. When the train was between Mile 99 and Mile 98, travelling at 48 mph, DB was reduced to position 6, while traversing a level stretch of track. At approximately Mile 97.8, while the train was travelling at 49 mph, full DB was re-applied. The train speed continued to increase to 58 mph, and at Mile 96, the locomotive independent brake was applied at 10 pounds per square inch (psi) and gradually increased to 25 psi. The train speed had increased to 64 mph by the POD. No automatic brake application was made until a train-initiated emergency brake application took place at Mile 94.297. The recorded information indicated that the train had derailed before the emergency application of the air brakes.

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[2] "Kicker" is a slang term commonly used by operating personnel to describe an undesired emergency application of the air brakes.

[3] The Nipigon Subdivision's mileages decline when travelling eastward.

[4] The dynamic brake is a locomotive electrical braking system that converts the locomotive traction motors into generators to provide resistance against the rotation of the locomotive axles. Energy is produced in the form of electricity, and is dissipated as heat through the dynamic brake grids. This brake can be used alone, or in conjunction with the train air brake system.

The Locomotives

The four-unit locomotive consist was made up of a General Motors (GM) SD40-2 unit (CP6009) with DB, a GM SD40 unit (CP6409) with DB, a GM SD40 unit (CP760) without DB, and a GM SD60 unit (CP6013). Locomotive 6013 had a DB capacity of 80 000 pounds (factor[5] of 8) and was cut in for full operation. Locomotive 6009 had a DB capacity of 45 000 pounds (factor of 4.5), but was indicated on the train consist information as having a DB capacity of 60 000 pounds (factor of 6). Locomotive 6409 had a DB capacity of 60 000 pounds (factor of 6). The locomotive engineer cut in locomotives 6013 and 6009, for a total reported DB capacity of 140 000 pounds' braking effort (factor of 14). Section 16, Item 7.1 a), "Dynamic Braking (DB)," of CPR's GOI restricted the maximum amount of DB effort to 180 000 pounds (factor of 18). There was no requirement for DB to be tested by locomotive engineers to ascertain if it was functioning. Subsequent to this derailment, the maximum DB was increased to 200 000 pounds (factor of 20).

At the time of the accident, CPR was in the process of modifying the GM SD40-2 fleet of locomotives to increase the DB capability from 45 000 pounds (factor of 4.5) to 60 000 pounds (factor of 6.0). The SD40-2 locomotive on train 308 had not been modified. CPR's monthly operating bulletins for October 2000 prescribed that, "For the sake of simplicity and safety, effective October the 4th, all CPR SD40-2 locomotives must be considered to be DB factor 6.0." The monthly bulletin stipulated that it would take about six months to complete the modification on the SD40-2 fleet. The locomotive modification is normally completed during shop maintenance and, after completion, the computerized record on the locomotive is changed to reflect the upgrade. There was no formal process for the maintenance department to advise the operating department of the changes to locomotive DB capacity on an individual basis. Modified locomotives were identified as such by a sticker on the control panel attached as part of the modification; however, not all train crews were aware of this practice.

Controlling Train Speed

The primary method for slowing and stopping a train is the train air brake system. To ensure that the locomotive engineer can minimize the in-train forces developed when slowing or stopping a train, the train air brakes must be fully operative in service braking and release, as well as in emergency applications. Locomotive dynamic brakes are a supplementary system, which may be used alone or in conjunction with the train air brakes for controlling speed or stopping trains, within their design limitations. They do not have the retardation capabilities of the train air brakes, degrade in efficiency as train speed increases, and may fail without warning. Trains may be operated without DB, but not without an air brake system.

CPR provided train operating crews with a document entitled *Train Handling Guidelines Nipigon Subdivision*, which used colour-coded instructions to indicate the fuel-conserving method of train handling while travelling over the subdivision. The colour codes indicated green for throttle modulation, red for train air brakes, yellow for DB, or a combination of the colours for using a combination of these controlling methods (see Figure 1).

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[5] The DB factor represents how many multiples of 10 000 pounds' retarding force the locomotive is capable of generating in DB.

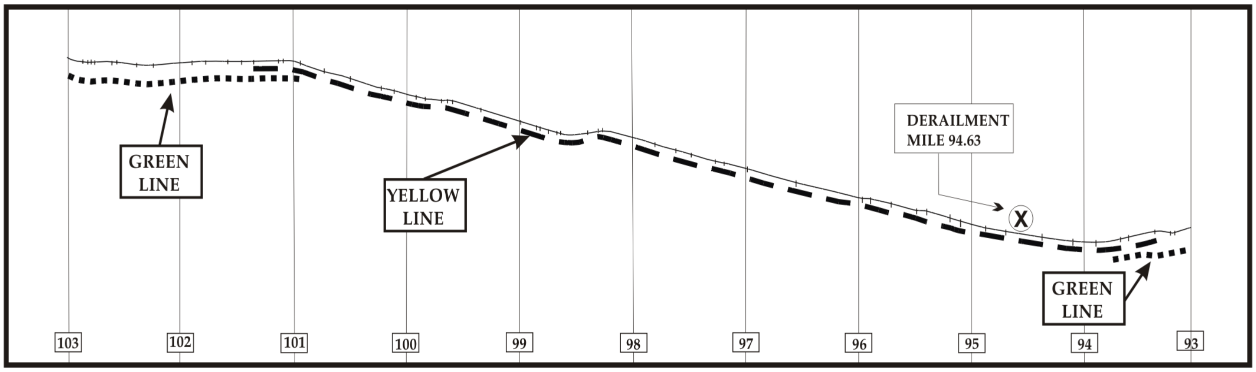

Figure 1. Guidelines for descending Bowker Hill

In addition to the colour-coding explanation, the intent of the *Train Handling Guidelines Nipigon Subdivision* is described as follows:

> The train handling guidelines were established for fuel conservation only. Should any of the information contained in the guideline profiles conflict with any rules or regulations, the CROR [*Canadian Rail Operating Rules*], GOI, Time Table, Monthly Operating Bulletin, Daily Operating Bulletin, Operating Bulletin and/or System Special Instruction will govern.

DB was indicated in the *Train Handling Guidelines Nipigon Subdivision* as the method to handle the train while descending Bowker Hill from approximately Mile 101.3 to approximately Mile 93.3. The guidelines were generic in that they did not apply to a specific type or size of train. Locomotive engineers may use the *Train Handling Guidelines Nipigon Subdivision* as a reference, but need to modify their train handling to account for differences in train make-up. New locomotive engineers were being trained to use DB wherever possible.

While the *Train Handling Guidelines Nipigon Subdivision* provided an indication for ascending or descending the grades, there were no specifics as to the steepness of those grades. The weight and length of trains were given in the train consist information. However, it was not procedure or practice for train crews to calculate the amount of retarding force required to control a train of a specific weight on a specific grade percentage. Although the locomotive engineers' training program included on-the-job training with locomotive engineer instructors and supervisors, and instruction on how to use DB, the knowledge to quantitatively evaluate the effectiveness of DB on a locomotive consist to facilitate planning to descend a heavy grade with any known train was not specifically discussed.

The capability of the locomotive consist to control the speed of a train on any grade is ascertained only by experience, evaluation at crew changes, and getting the feel of how efficiently DB is working. There has been no substantive training on how to evaluate the required DB forces necessary for a given train on a specific descending grade. The extent of the instructions were, "If the dynamic brake alone will provide sufficient retardation to slow or control speed, use of the train air brakes is unnecessary," and "If it is known train air brakes will be needed to supplement dynamic brake, make a minimum brake pipe reduction as the train crests the hill."

DB capacity is expressed in pounds of force (see Figure 2). DB is most effective at retarding a train under 25 mph. The combined DB capacity of the two locomotives declines from 125 000 pounds at 24 mph to approximately 57 000 pounds at 50 mph, and further declines to approximately 46 000 pounds at 64 mph.

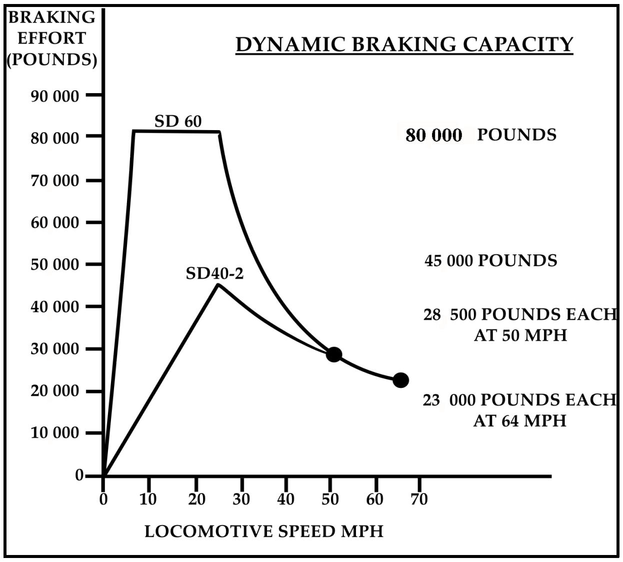

Figure 2. Dynamic braking capacity

The visual indication to a locomotive engineer that DB is operating is presented by a load meter indication. However, the load meter does not provide a complete indication of DB effort generated, nor is there any indication in the cab of the controlling locomotive of the function of DB on trailing locomotives in a consist. The load meter only indicates DB amperage generated on the lead locomotive. Further, the load meter may display the same amperage value when braking effort has decreased with higher speed. It was a common opinion that the DB system functioned better at a lower speed; however, the extent of the decreased effectiveness at higher speeds was not well known among the locomotive engineers who were interviewed.

The locomotive speedometer had an acceleration/deceleration display integrated into the visual display, which displayed the current rate of change of the locomotive speed to the locomotive engineer at all times. This display is an accepted feature in the new United States Federal Railroad Administration’s *Brake System Safety Standards* for U.S. operation.

Train Handling

Some time before reaching Bowker Hill, the method of retarding the train on that section of track had been discussed and agreed upon, on the expectation that cresting the hill at 30 mph, and subsequently using DB, would allow the speed of the train to be maintained under the 50 mph speed limit. The common practice for handling a “kicker” train was to avoid the use of air brake whenever possible, avoiding the probability of another kicker and subsequent in-train forces with the potential for causing a derailment. Interviews with other train crews who operate over the Nipigon Subdivision corroborated the crew members’ understanding of the situation in which they found themselves. They indicated that they would likely have tried to “ride the train out,” since they felt that putting the train into emergency would be more likely to cause a derailment than proceeding around the curve in excess of the speed limit. Crews had expressed that, in the past, other trains had successfully descended Bowker Hill at speeds well in excess of the permissible limit.

The investigation revealed that the operation of “kicker” trains has become commonplace. Although it was not verified through CPR records, operating crews who were interviewed estimated that they operate one train per month in this condition on the Nipigon and Heron Bay subdivisions. As such, crews frequently operated trains with a “kicker” at or near track speed irrespective of the type of train or topography involved, as locomotive engineers are expected to operate their trains as close to the maximum speed as safely possible without exceeding it. There were no special instructions on how to operate a “kicker” train. Common practice was to get a feel for how effective DB was by asking the previous crew, and by trying out the brake at the earliest opportunity, as there was a need to plan in advance when operating “kicker” trains due to increased distances required to slow trains.

Operating crews indicated that they prefer to operate with DB, as opposed to air brakes, whenever possible, to minimize in-train forces. DB may be adjusted as required, and avoiding the use of air brakes reduces the likelihood of a “kicker” recurring. Locomotive engineers reported operating trains over the Nipigon Subdivision at times without ever using the air brakes, except to stop at crew change locations, and indicated that new locomotive engineers are trained to follow similar practices. Regular crews on the Nipigon Subdivision, familiar with the operation of unit grain trains, indicated that, even with a train with “good DB,” a minimum brake pipe reduction was normally required to maintain train speed under the 50 mph speed limit when descending Bowker Hill. The normal practice would be to crest the hill between 42 mph and 45 mph while applying the train air brake, and then balance train speed using DB.

Dynamic Braking Calculations

The TSB Engineering Laboratory[6] calculated that:

- if three locomotives were enabled in DB, and given the sequence of train handling (i.e., attempting to maintain 50 mph), the locomotives could not hold the train speed at 50 mph, and the train would have accelerated to approximately 61 mph;

- if three locomotives were enabled in DB, and DB was applied and fully maintained from 30 mph at the top of the hill, the train speed would not have exceeded 39 mph and would have been approximately 37 mph where the derailment occurred; and

- if three locomotives were enabled in DB, and DB was applied and fully maintained from 25 mph at the top of the hill, the train would have been almost stopped at about Mile 97.3, before reaching the derailment location.

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[6] TSB Engineering Laboratory report LP092/01

DB calculations[7] are illustrated in the Air Brake Association handbook, *Management of Train Operations and Train Handling*,[8] a book that discusses the impact of DB on train handling. In Chapter V, page 169, it states:

> . . . if dynamic braking is lost or becomes overworked and ineffective for any reason on a heavy grade:
>
> 1. Get the train stopped quickly,
> 2. Use emergency application,
> 3. Follow safe practice and local rules before proceeding after such an unplanned stop on the grade.

The Association of American Railroads (AAR) report R-185, *Track Train Dynamics to Improved Freight Train Performance, 2nd Edition*, contains recommended best practices guidelines for train handling. Section 2.2, "Heavy Descending Grades," paragraph 2.2.6.1 b. (3) states:

> (3) Improper judgement in braking may permit the speed to get out of control in a very short time. When there is doubt as to whether or not the train can be properly controlled, the train must be brought to a stop. The engineer should evaluate the possible effects of an emergency application versus the effects of a service application and apply that application which appears to be the safest method of stopping the train. Service applications react more slowly but will retain the dynamic brake whereas emergency applications nullify the dynamic brake on most locomotives.[9] *If the dynamic brake is suddenly lost or becomes ineffective for any reason on a heavy grade, the train should be stopped. Use an emergency application if necessary.* [Emphasis in original]

There were no similar instructions in effect for the operations on the Nipigon Subdivision at the time of the occurrence.

General Operating Instructions

Section 5, Item 15.0, of CPR's GOI prescribes the requirements for train inspection after a UDE (see Appendix A). The conductor would be responsible for undertaking the inspection. There were no instructions on handling a train prone to UDEs and no instructions detailing how to eliminate a UDE condition.

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[7] The retarding capacity of DB in a locomotive consist can be calculated using the DB factor, the gradient percentage, and information from the train consist and subdivision profile.

[8] Air Brake Association, *Management of Train Operations and Train Handling*, Chicago, 1972.

[9] CPR AC locomotives have a DB holding feature that retains DB during an emergency application of the air brakes.

Section 16, Item 6.0, of CPR's GOI contains information on emergency and penalty brake applications indicating in part:

> 6.1 . . . Emergency valves are to be used only in cases of emergency. . . .
>
> 6.2 An EMERGENCY BRAKE APPLICATION must not be made unless it is necessary. . . .
>
> 6.4 In the event of a PENALTY or EMERGENCY BRAKE APPLICATION while moving, the locomotive engineer must, until the movement stops, regulate locomotive brake cylinder pressure to obtain the shortest possible stop required by the situation. Care and good judgment must be exercised to avoid locomotive wheel slide and severe in-train forces.

Controlling a UDE-Problematic Train

The air brake system is the primary fail-safe system, designed to slow or stop a train using applications of the air brakes on the locomotives and cars throughout a train. Proper use of an operative air brake system usually results in the distribution of retarding force throughout the length of a train. Common practice to control the speed of a UDE-problematic train is for a locomotive engineer to avoid using the train air brakes, unless absolutely necessary, as a kicker could occur at each service application. Without a fully operative service braking capability, locomotive engineers will generally use a combination of throttle modulation,[10] locomotive DB and the locomotive independent brake[11] to control train speed. The use of air brakes is avoided to minimize the likelihood of further UDE, which can cause damage to train components, delays due to the requirements to inspect the train following a "kicker," and possibly a derailment.

The locomotive dynamic brakes are a supplementary system for controlling train speed. During DB, retarding force is applied by the locomotives only, and buff (compressive) forces, proportional to the momentum of the rest of the train, increasingly oppose this retarding force as the train slack runs in. The locomotive DB system is intended to be used primarily to control train speed while descending long grades. Under normal operating conditions (i.e., where the train is not prone to UDEs), DB can be supplemented by the air brake system. This course is usually taken when DB force is insufficient to control train speed, or when DB forces diminish at speeds above or below the speed at which optimum DB force is available.

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[10] Throttle modulation is the use of strategic application and reduction of locomotive power in conjunction with the anticipated effects of the subdivision topography on the movement of the train to control the speed of the train.

[11] The independent brake is an air brake that the locomotive engineer can apply on the locomotive consist only. On CPR, application is prohibited during DB at speeds in excess of 10 mph (Section 16, Item 7.7 c) of CPR's GOI).

Particulars of the Track

The portion of the track from Mile 101 to Mile 94, known as Bowker Hill, is single main track, with a ruling grade of 1.4 per cent[12] descending eastward, for a distance of approximately 500 feet between Mile 100.4 and Mile 100.3. The track speed was 50 mph. At Mile 99.75, the grade is ascending for 400 feet and then, except for another 1200 feet of ascending grade at Mile 98.5, the average descending grade is approximately 1 per cent until Mile 94.88, where the descending grade averages approximately 0.5 per cent.

At the POD, the grade was 0.55 per cent, descending on a four-degree, left-hand curve in the direction of travel. The average superelevation[13] of the curve was five inches. The maximum permissible speed for this curvature and superelevation is 50 mph for freight trains, as prescribed within CPR's Standard Practice Circulars (SPC). Transport Canada's *Railway Track Safety Rules* (TSR) would theoretically allow a maximum speed of 53 mph. The theoretical design requirement for a speed of 64 mph would be a superelevation of 8.5 inches.

The track structure was comprised of 115-pound continuous welded rail, manufactured by Sydney Steel, laid on hardwood ties and crushed rock ballast. The low rail in the curve was manufactured in August 1993, and the high rail was manufactured in 1995. The high rail was secured with Pandrol E-clips on 14-inch-by-7-inch modified double-shouldered tie plates and four spikes per plate. The low rail was secured with five spikes on standard 14-inch-by-7-inch double-shouldered tie plates. Both rails were box-anchored every tie.

The track was last inspected on Friday, 05 January 2001, by an assistant track supervisor in a Hi-rail vehicle. No deficiencies were noted at the derailment location.

CPR uses a track evaluation car (TEC) to continuously monitor track condition across the system, to establish maintenance priorities, to prevent derailments, and to provide data for assessments to develop and prioritize track program requirements in the short and long term.

The TEC systems identify urgent defects, which are, by definition, any track condition that can precipitate a derailment due to inadequate or deteriorating track structure, such as wide gauge. The *TEC Guidelines for Track Defects and Reports* contain a section on wide gauge, defining it as a condition where the track is greater than the normal design standard of 56 ½ inches. Reference is made to CPR's SPC 17, Item 2.6, which states that gauge must be corrected when it exceeds ½ inch narrow or wide. Priority wide gauge threshold is ¾ inch wide or 57 ¼ inches. The TEC will also identify near urgent defects that, in the case of wide gauge, is within ⅛ inch from the urgent threshold or 57 ⅜ inches. Urgent wide gauge threshold is 57 ½ inches. The TEC guidelines prescribe that any urgent defect must either be corrected, or protected before the passage of a train, and then corrected. The TEC guidelines further state that wide gauge can become serious once it reaches the urgent threshold. The track gauge can spread or the rail can roll over, causing the wheels to drop between the rails, resulting in a derailment.

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[12] A grade of between 1.0 per cent and 1.8 per cent was considered to be a heavy grade. Safety action taken has redefined heavy grade as between 0.8 to 1.8 per cent.

[13] Superelevation is the banking of the track in a curve. The desired speed and curve radius determine the amount of superelevation.

Post-accident examination of the ties in the derailment area revealed that approximately 35 per cent of the ties had deteriorated to a state where they could no longer effectively maintain proper gauge. Some of the ties were spike-killed[14] from repeated re-gauging. At the POD, there was a cluster of five deteriorated ties. A post-derailment track survey revealed that, approaching the POD, there were urgent wide gauge, near urgent wide gauge, and priority wide gauge conditions. No slow order train protection was afforded.

During a 21 June 2000 test run, the TEC detected 16 priority wide gauge defects in the range of 57 ¼ inches to 57 ½ inches in this curve. The need for tie renewal had been identified and documented; however, the requested replacement of defective ties was deferred to the following summer. Subsequent to this test run, a test run on 10 October 2000 detected 24 wide gauge defects, including six urgent defects, measuring 57 ½ inches to 57 ⅝ inches. The urgent wide gauge locations were adjusted to 57 ¼ inches, ¼ inch below the condition that would require a slow order protection. The loaded gauge measurements, taken throughout the undisturbed area of the curve subsequent to the derailment, indicated that some of the priority wide gauge defects had progressed to an urgent status. The measurements varied from 57 inches to 57 11/16 inches. The maximum allowable wide gauge for Class 4 track, according to Transport Canada's TSR, is 57 ½ inches. Track not meeting this requirement must be reduced in class of track and permissible train speed.

The TEC gauge restraint measurement system (GRMS)[15] measures lateral track strength by using a hydraulically driven split axle to apply a constant lateral load to the rails over which it is operating. Sensors measure the lateral load, applied at 14 000 pounds, the loaded gauge at the point of loading, and the unloaded gauge away from the loading point. These measurements are recorded using a computerized data collection system. The measurements are used to calculate a lateral deflection rate for the track being tested. The gauge measurements and the calculated deflection rate at each location are used to determine the projected loaded gauge at 24 000 pounds (PLG24). PLG24 is used to estimate the risk of a wide gauge derailment at each tested location if a lateral load of 24 000 pounds is applied at that location. This is the force that the track would be subject to if a fully loaded train made an emergency stop. This is consistent with loading data documented through field tests of wheel-rail dynamics during train handling. GRMS testing did not identify any risk of derailment on Bowker Hill.

Subsequent to the derailment, a track-train dynamics report was provided by CPR, indicating that the train applied an outward lateral force on the high rail of the curve of 13 350 pounds at 50 mph and, at 64 mph, the applied lateral force increased to 20 500 pounds. This represented a 54 per cent increase of wheel lateral forces against the high rail of the curve at the POD.

Analysis

Introduction

CPR train 308 derailed on Bowker Hill, travelling at a speed 14 mph in excess of the permissible speed on a section of curved track with wide gauge conditions. These conditions would not

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[14] Spike-killing is the reduction of the holding power of a tie resulting from repetitive spike removal and installation (re-gauging).

[15] CPR's SPC 40, *GRMS System*

have been critical had the train been operating at or below the permissible track speed. The analysis will focus on the factors that led to the excessive speed and on track deficiencies.

Derailment

The derailment occurred when the lateral forces at the wheel-rail interface exceeded the lateral restraining ability of the track structure. This resulted in the outside, or high rail, of the curve canting over, allowing the wheels to fall within the widened gauge. The lateral restraining capability of the track was reduced by excessive gauge and poor tie conditions. However, the train overspeed of 14 mph and the related increase in lateral force were probably the prime factor in influencing the rail rollover. The 20th car behind the locomotives was the first car to derail. The 12th car derailed due to in-train forces after the initial derailment.

Train Handling

The operation of freight trains, and the train handling methods used, are predicated upon the expectation that trains be operated as safely as possible and as close as possible to the maximum allowable train speed. Train air brakes, being recognized as the primary fail-safe[16] and safety-critical system for controlling speed and stopping trains are, by that necessity, required to be fully operative for safe train operations. The occurrence of a UDE on train 308 at Mackenzie, Ontario, had prompted a change in train handling because the operating crew members felt that they could no longer rely on the primary speed control braking system of the train to apply and release as intended. Locomotive DB is a supplementary system that does not have the retarding capabilities of the train air brakes. It degrades in efficiency as train speed increases and may, on rare occasion, fail without warning. DB failures without any warning, on one or all locomotives on a consist, have been known to occur. Irrespective of the nature of the DB failure, a serious train overspeed will be the result despite any immediate corrective action taken by the crew, due to the response time inherent to train air brake systems. The resulting increase in speed may compromise control of the train. This may be the result of either a partial or a complete failure, presenting a risk of loss of control. Unlike the air brakes, DB does not *fail-safe*. It is clear that, under normal operating conditions, train speed for this type of train at this location could not be controlled at or near 50 mph through the use of the available dynamic brake alone. Therefore, in this particular instance, it was not the optimal means of controlling the speed of the train. Despite this train, and reportedly others, essentially being operated without what was perceived as a reliably operative service braking system, no clear procedures were in place to mitigate the increased risk posed by operating a UDE-problematic train. The occurrence of a UDE, when a service application of the train air brakes is required, and the resulting perception of unreliability that this engenders, may result in inappropriate adoption of train control methods that place the safe operation of trains at risk.

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[16] Fail-safe: A term used to designate a design principle, the objective of which is to eliminate the hazardous effects of a failure of a component or system by ensuring that it fails in its most safety-restrictive state.

Contributing to the decision of the crew to operate the train down the hill, allowing acceleration to the maximum track speed of 50 mph, was the expectation that the locomotives' DB would be able to control the train speed. Without a policy or procedure to indicate how to mitigate the increased risk of a "kicker" train on heavy grades, the crew adopted the alternate strategy of avoiding the use of the air brake system, and relied on the DB system, which was not capable of being as effective as the primary system.

In this train handling situation, the crew's plan of operation was modified to accommodate the reduced capability of train retarding systems (i.e., the lack of service braking dependability). The plan chosen was to control the train speed descending the hill by slowing the train to 30 mph instead of the normal 42 to 45 mph, while approaching the crest of Bowker Hill. The steepest portion of the descent is within the first mile (Mile 100.4 to Mile 100.3), and this mile was successfully traversed at less than the permissible speed, controlled by DB.

It would appear that, after meeting the initial expectation of not exceeding the permissible speed when descending the steepest part of Bowker Hill, confidence was placed in the ability of the locomotives to provide a retarding force effectively. DB effort was reduced until the speed of the train approached 50 mph, and afterwards applied fully again. As the impact of speed on the efficiency of DB was not well understood, the crew members did not recognize that they were in an emergency situation, having lost control of the train, until maximum speed was far exceeded. If DB had been supplemented by the train air brakes in time to control the train speed below the maximum authorized speed, the likelihood of a derailment from a UDE would have been less. While the potential of negative consequences following a UDE are great at any speed, the risk of adverse consequence increases with speed.

Upon recognition that the locomotives did not have sufficient retarding capacity to control the train speed, a "point of no return" was perceived and a decision was made to "ride it out" rather than engage the automatic brake and risk a UDE at high speed. At this point, it was realized that the train was not being operated in compliance with railway operating requirements. Despite the risks that this created, the crew decided to maintain their planned course of action, which was not in full compliance with railway requirements, nor with best recommended practices.

In the absence of a clear procedure, decision makers are typically predisposed to opting for the course of action with the lowest probability of an adverse outcome even if the latter outcome is likely more severe. Faced with the perceived high probability of derailing through a UDE versus a lower probability of adverse consequences due to speed, the decision was made not to engage the automatic brake. This fear of the potential consequences of another UDE, along with a history that other trains had successfully descended Bowker Hill at excessive speeds in the past, contributed to this adaptation. In support of this history is the fact that the curve with an equilibrium speed of 53 mph was repeatedly being pushed out to wide gauge, which may have indicated that trains had repeatedly travelled this track in excess of the equilibrium speed. The occurrence of a UDE, without a subsequent derailment, would have delayed the train for a mandatory inspection under CPR's GOI (see Appendix A), as it would have necessitated walking the length of the train.

The *Train Handling Guidelines Nipigon Subdivision* provided information (DB only to descend Bowker Hill) supplementary to the GOI, which created the expectation that the locomotive consist, being enabled per the GOI, would be able to control the train speed when descending Bowker Hill in DB. There was nothing in the guidelines for the Nipigon Subdivision to indicate that DB alone may not have been sufficient to control the speed of the train on Bowker Hill. The guidelines identified other areas that indicated the use of train air brakes with DB, which implies that, if air brakes were recommended on Bowker Hill, the *Train Handling Guidelines Nipigon Subdivision* would have indicated so.

Although they were not directly referenced by the crew on this particular day in planning their method of train handling, the *Train Handling Guidelines Nipigon Subdivision* information assisted in establishing a crew's mental model of train operation. The general emphasis on using DB and inadequate instructions and training increase the risk of over-reliance on the use of DB to control train speed. However, TSB calculations indicated that the braking effort of the available three locomotives in full DB would not have been sufficient to keep the train from accelerating beyond 50 mph, given the sequence of train handling from a speed of 30 mph cresting the grade of the hill.

Dynamic Braking

Two locomotives were enabled for DB before leaving Thunder Bay—one SD40-2 rated at a DB factor of 6 and one SD60 rated at a DB factor of 8—resulting in 125 000 pounds of available braking effort, as the SD40-2 locomotive that was engaged in DB had not been modified and was capable of producing only 45 000 pounds of DB effort. The consist, if all three locomotives capable of DB had been enabled, would have had 185 000 pounds of DB effort available, which was above the allowable maximum DB factor of 18. Operating instructions to use a DB factor of 18, instead of the revised 20, resulted in only two of the three locomotives with DB capability being engaged, resulting in a lower braking effort available to descend Bowker Hill.

The excessive speed of the train on Bowker Hill can be attributed to several operating circumstances. As the consist had been made up that morning in Thunder Bay, there was no information from previous operations regarding the effectiveness of the DB. The only method available to the locomotive engineer to assess the effectiveness of the DB was to use it, and judge effectiveness based on experience. Further, with the exception of slowing for the crest of Bowker Hill (where the train used DB on an uphill grade), there was little opportunity to assess the effectiveness of DB. Even though the DB system was critical to controlling the train, there was no requirement to test it before depending on it.

The training programs for train crews did not provide a complete means of determining the effectiveness of dynamic brakes in a given situation. The effectiveness depends upon DB factors, the speed of the train, the length and weight of the train, and the curvature and steepness of the grade upon which the train is operated. In this occurrence, the insufficient capacity of the locomotive consist to retard the acceleration of the train, as the speed of the train increased while descending the grade, was not recognized. The load meter on the lead locomotive indicated to the locomotive engineer that he had full DB amperage. There was no indication of the DB function in the trailing locomotives. The locomotive engineer did not fully understand that the effectiveness of DB decreased with speed. Therefore, the locomotive engineer was ill-equipped to assess the DB capability of his locomotive consist. Although the accelerator indication was available to the crew, given the excessive speed of the train on the descent, it appears that the indication was irrelevant. Without a substantive means of assessing the ability of DB to control train speed, and a lack of crew understanding of the functions and limitations of DB, the risk of formulating erroneous plans in train operation was increased.

Track Condition

The track condition had been deteriorating for a recognized period, as documented by submissions for tie renewal programs, widening gauge repair, and the defect reports from TEC tests. As GRMS testing did not indicate a weakness in lateral retaining strength, the replacement of deteriorated crossties and re-gauging was deferred. Temporary repairs were made, gauging the track from urgent wide gauge to priority wide gauge. Irrespective of the fact that the track was within the limits prescribed by the SPC and the TSR, the derailment occurred under lateral forces that were less than the PLG24, such as in the case of an emergency brake application. The derailment indicates that the remedial measures taken to provide a sufficient defence barrier and safety margin against unusual in-train forces were inadequate.

Findings as to Causes and Contributing Factors

1. The method of train handling used by the crew when descending Bowker Hill resulted in excessive speed-induced lateral forces at the wheel/rail interface, which exceeded the lateral restraining capacity of the track, resulting in the spreading of the gauge and subsequent derailment.

2. Without a policy or procedure to indicate how to mitigate the increased risk of a "kicker" train on heavy grades, the crew adopted the alternate strategy of avoiding the use of the air brake system, and relied on the DB system, which was not capable of being as effective as the primary system.

3. Operating instructions to use a maximum allowable DB factor of 18 permitted only two of the three locomotives with DB capability to be engaged, resulting in a lower braking effort than what was available to descend Bowker Hill.

4. Without a substantive means of assessing the ability of DB to control train speed, and a lack of crew understanding of the functions and limitations of DB, the erroneous plan for train operation was formulated.

Findings as to Risk

1. The occurrence of UDEs, when service applications of train air brakes are required, and the resulting perception of unreliability that this engenders, may result in inappropriate adoption of train control methods that place the safe operation of trains at risk.

2. The derailment indicates that the remedial measures taken, with respect to wide gauge track repairs, to provide a sufficient defence barrier and safety margin against unusual in-train forces, were inadequate.

3. The general emphasis on using DB and inadequate instructions and training increase the risk of over-reliance on the use of DB to control train speed.

Other Findings

1. CPR train 308 was not operated in full compliance with railway requirements, nor did operation of the train conform with known, recommended best practices.

2. The fact that the curve, with an equilibrium speed of 53 mph, was repeatedly being pushed out to wide gauge may have indicated that trains had repeatedly travelled this track in excess of the equilibrium speed.

3. The lateral forces generated by the train at the POD (20 500 psi) were significantly less than what would be considered a minimum standard (24 000 psi), that is what the track would be subject to if a fully loaded train made an emergency stop.

Safety Action Taken

Subsequent to the occurrence, CPR increased the permissible locomotive DB factor to 20 (200 000 pounds), which would permit the use of two SD40-2 locomotives with a SD60 locomotive in DB, and developed new job aids for train handling procedures on heavy descending grades (0.8 to 1.8 per cent) and on descending mountain grades (greater than 1.8 per cent) for all areas in Canada.

CPR permanently added the “Descending Heavy Grade Job Aid” to Section 18 of the GOI. The GOI include permanent 30 mph speed restrictions on trains that handle more than 6000 gross tons or have an average car weight that exceeds 100 tons when descending Bowker Hill and other heavy descending grades that are more than two miles in length. Such trains are to crest the hill and balance train speed at least 5 mph below permissible speed until braking is seen to be ample.

CPR has added a note to the System Special Instructions to *Canadian Rail Operating Rules* (CROR) Rule 106 to clearly outline the conductor’s responsibilities when a train is not being operated safely (i.e., to initiate an emergency stop if the permissible speed is exceeded by 5 mph).

CPR has completed a tie renewal program on Bowker Hill, bringing the track into proper gauge.

A safety blitz for all CPR service areas has been developed, and a module added for re-qualification standards classes, to highlight the proper operating practices for trains that have experienced a UDE (or “kicker”), and the proper operating practices required when trains exceed certain speeds. This safety blitz also highlighted the importance of brake pipe continuity, and discussed applicable sections of the descending grade job aids.

All CPR road managers have attended a *Road Manager Seminar* at the Crump Engineer Training Centre in Calgary, Alberta, for an expanded version of “Field Hill Refresher Training.” There is a new requirement for on-the-job evaluations—every locomotive engineer working heavy or mountain grades must be evaluated and then re-evaluated at three-year intervals. Locomotive engineers must demonstrate to road managers the ability to safely release the train air brakes following an emergency or full service brake application on a grade and demonstrate the ability to plan operating down a heavy grade with a known “kicker.”

During 2001, the operating officers on the Nipigon Subdivision increased the level of proficiency testing and monitoring for train speed rules compliance from 8 tests in 2000 to 63 tests, and the locomotive event recorder downloading was increased from 51 to 142 downloads.

Safety Action Required

In this occurrence, crew actions were driven by the perception that the train air brake system was unreliable. The experience of the train crews who were interviewed who had experienced UDEs led to consistent adaptation, which allowed them to operate UDE-problematic trains without the railway taking any action. This allowed the railway to operate trains with UDE defects without addressing the root cause of the problem, namely correcting the UDE problem, and reducing the risks that UDE are known to generate. The Board is concerned that the UDE problem has not been adequately addressed by the railway industry.

The Board has noticed the emphasis placed by the railway on the use of DB for slowing and controlling trains. It appears that guidelines, bulletins, time table requirements, system special instructions and training emphasize the DB as the preferred method of train speed control, except where specific local conditions require otherwise. This may have generated an expectation that the train air brake systems were to be used only as required, and has perhaps generated an over-reliance on DB as the principal means of control under conditions where it may be inappropriate or insufficient, increasing the risk of adverse consequences.

The Board is concerned that the training of locomotive engineers may not adequately prepare them and provide the necessary tools to integrate DB performance, track gradient, train weight, and train performance variability when formulating train control strategies.

Aside from the aforementioned concern, the Board acknowledges the significant safety actions taken by the railway subsequent to this occurrence, and believes that those actions will go a long way toward eliminating accidents involving runaway trains on descending grades.

This report concludes the Transportation Safety Board's investigation into this occurrence. Consequently, the Board authorized the release of this report on 12 February 2003.

*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— Canadian Pacific Railway's General Operating Instructions, Section 5

15.0 Inspection Required Following an Emergency Brake Application

Note: This instruction does not relieve crews from the requirements of all CROR Operating Rules, especially Rule 102.

a) Passenger Trains

Stopped by any emergency brake application: before the movement resumes each car must be inspected to ensure all brakes are released. A pull-by inspection of the train must also be made for indications of skidded wheels.

b) For All Other Trains

i) Stopped by an Emergency Brake Application: after the brakes are released, a pull-by inspection must be conducted on at least one side of the train to check for evidence of defective or derailed equipment. The results of the pull-by inspection and the location at which the emergency brake application occurred must be recorded on a **Crew to Crew Form**. This form must remain with the train to its final destination.

ii) At locations where a pull-by inspection cannot be made, the train may proceed at SLOW speed to the first location where a pull-by inspection can be made.

iii) In all cases, whenever a train is moved after any emergency brake application, crew members must pay extraordinary attention to running inspection of the train. If there is evidence of derailed equipment, or if there is unusual train action, the train must be stopped immediately and the cause determined.

iv) The pull-by inspection referred to in clause i) is not required provided ALL of the following conditions are met:

1) The emergency brake application is not the first occurrence for that train consist as indicated by a **Crew to Crew Form**;

2) train tonnage (EGT) is less than 6,000 tons; or train tonnage (EGT) is 6,000 tons or more and each car, except a caboose if provided, exceeds 100 gross tons. If a caboose is provided, it must be marshalled as the last car of the train;

3) speed at the time of the emergency brake application was greater than 25 mph;

4) the emergency brake application occurs within 15 seconds of initiating a service brake application;
5) no unusual slack action is noted during the stop;

6) when the brakes are released, the air flow indicator and rear car brake pipe pressure readings indicate no loss of air pressure; and

7) the train is carrying no SPECIAL dangerous commodities.

v) Trains carrying SPECIAL dangerous commodities: After conditions 1 through 6 in clause iv) have been met, the train must be given a pull-by inspection from the leading locomotive to the last car containing SPECIAL dangerous commodities. Record must be made on a **Crew to Crew Form**.

vi) The pull-by inspection referred to in clause i) may be performed by the following employees, who must be radio equipped and alerted to the situation:

- crew members of the train itself;
- crew members of a stopped train;
- other employees on the right of way.

Appendix B—List of Supporting Reports

The following TSB Engineering Laboratory report was completed:

LP092/2001

The Canadian Pacific Railway Train Accident Prevention and Testing Branch of the Safety & Regulatory Affairs Department completed an investigation report.

The Association of American Railroads (AAR) report R-185, *Track Train Dynamics to Improved Freight Train Performance*, was referred to.

The Air Brake Association handbook, *Management of Train Operations and Train Handling,* Chicago, 1972, was referred to.

Appendix C—Glossary

AAR	Association of American Railroads
CPR	Canadian Pacific Railway
CROR	*Canadian Rail Operating Rules*
DB	dynamic braking
GM	General Motors
GOI	General Operating Instructions
GRMS	gauge restraint measurement system
PLG24	projected loaded gauge at 24 000 pounds
POD	point of derailment
psi	pound per square inch
SPC	Standard Practice Circular
TEC	track evaluation car
TSB	Transportation Safety Board of Canada
TSR	*Railway Track Safety Rules*
UDE	undesired emergency brake application