Transportation Safety Board of Canada

Bureau de la sécurité des transports du Canada

# RAILWAY INVESTIGATION REPORT
# R07V0109

## NON-MAIN-TRACK TRAIN DERAILMENT

## KOOTENAY VALLEY RAILWAY (KVR)
## 0700 TRAIL YARD ASSIGNMENT
## MILE 19.0, ROSSLAND SUBDIVISION
## TRAIL, BRITISH COLUMBIA
## 23 APRIL 2007

Canada

# Railway Investigation Report
# Non-Main-Track Train Derailment
# Kootenay Valley Railway (KVR)
# 0700 Trail Yard Assignment
# Mile 19.0, Rossland Subdivision
# Trail, British Columbia
# 23 April 2007

# Report Number R07V0109

## *Summary*

On 23 April 2007, at about 1436 Pacific daylight time, the 0700 Trail yard assignment ran uncontrolled down the 4.1 per cent grade between Warfield and Trail, British Columbia, derailing two locomotives and eight loaded covered hopper cars of granular ammonium sulphate. A foreman and a helper had detrained prior to the derailment and sustained minor injuries. The locomotive engineer remained on board and suffered fatal injuries. Approximately 20 per cent of the contents (43 836 kilograms) of the covered hopper cars and 500 gallons of diesel fuel were spilled.

*Ce rapport est également disponible en français.*

# *Other Factual Information*

## *The Accident*

On 23 April 2007, at about 0700 Pacific daylight time [1], the crew of the 0700 Trail yard assignment (the assignment), a locomotive engineer, a foreman, and a helper, reported for duty at Trail, British Columbia (B.C.), Mile 18.4 on the Rossland Subdivision (see Figure 1). They were to perform switching operations in Trail and then travel to Warfield, B.C. at Mile 21.2 on the Rossland Subdivision where they were to perform additional switching operations before returning to Trail with eleven cars. After completing their switching in Trail, they departed for Warfield.

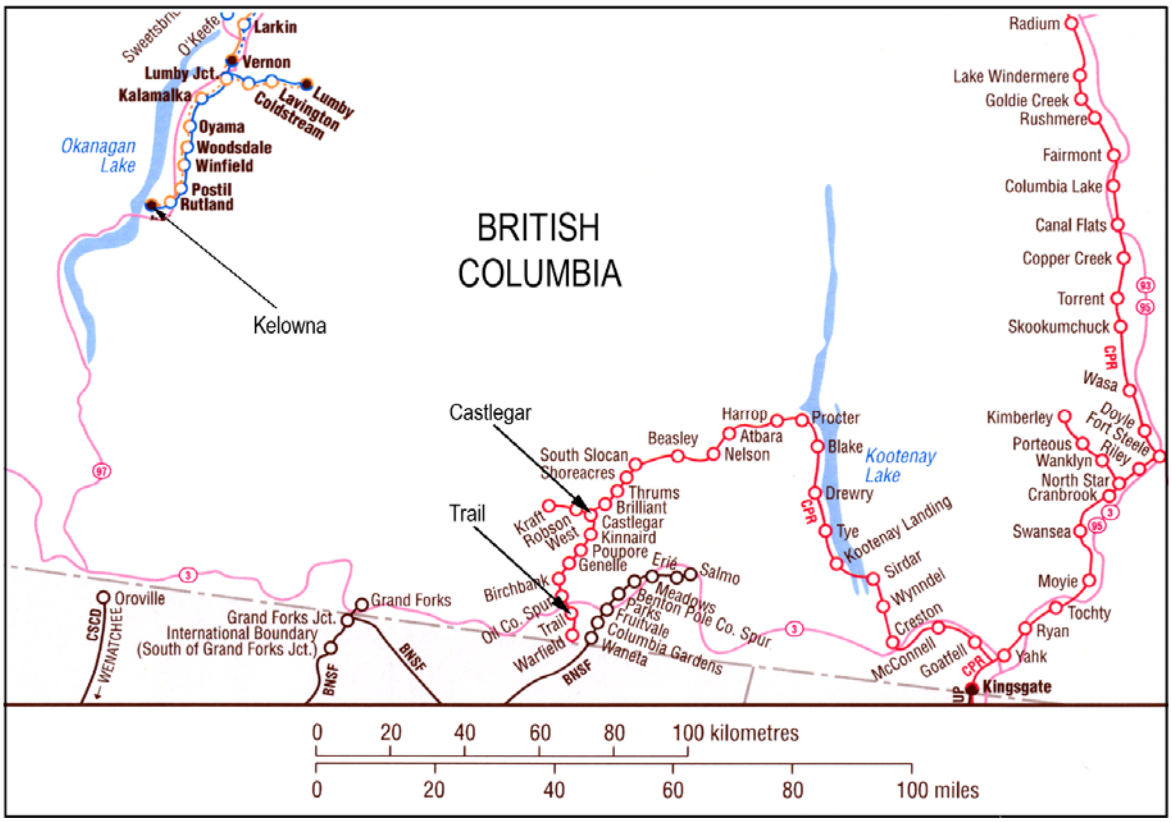


**Figure 1.** Location diagram of accident site (Source: Railway Association of Canada, *Canadian Railway Atlas*)

After completing their switching duties at Warfield, the crew coupled onto the eleven cars to be taken down the steep grade to Trail: eight loaded covered hopper cars of ammonium sulphate and three residue tank cars.

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1 All times are Pacific daylight time (Coordinated Universal Time minus seven hours).

Prior to departing from Warfield, the automatic brake was applied and released to verify that it was in working order and those cars with retainers [2] set to the high-pressure position were inspected.

During the journey to Trail, the helper rode in the lead locomotive and the foreman joined the locomotive engineer in the trailing (controlling) locomotive [3].

To control the movement, the locomotive engineer used the automatic and independent brakes, supplemented with the dynamic brake. Soon after starting down the steepest section of the grade, the locomotive engineer placed the train into emergency. The dynamic brake [4] (DB) cut out and the locomotive engineer increased the locomotive independent brake to the fully-applied position; however, the train speed continued to increase. The foreman radioed to the yardmaster advising him that they had a runaway train and informed the helper and the locomotive engineer that they needed to get off the train. Both the foreman and the helper detrained and sustained minor injuries. The locomotive engineer remained onboard. Heavy smoke emanated throughout the train.

The train speed continued to increase. At a speed of approximately 40 mph, while the train was negotiating the 16-degree right-hand curve at Mile 19.216, the second to the eighth car from the head end derailed to the outside of the curve and separated from the head-end portion of the train. The three residue tank cars, the ninth to the eleventh cars, remained upright on the rails.

The two locomotives and the remaining covered hopper car continued across the Highway 22 overpass and derailed to the outside of the 16-degree right-hand curve at Mile 19.038. The lead locomotive was overturned beside the rail, while the trailing locomotive was overturned down the grade. The locomotive engineer was later found beneath the trailing locomotive having suffered fatal injuries.

An estimated 500 gallons of diesel fuel leaked from the two locomotives and approximately 20 per cent or 43 800 kilograms of the contents of the covered hopper cars (granular ammonium sulphate) was released. Ammonium Sulphate is not a regulated dangerous good.

At the time of the derailment, the sky was clear with good visibility and the temperature was 16ºC.

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2 The function of retainers is to retain air pressure in the brake cylinders after the brakes have been released. This allows cars to be recharged while maintaining braking effort.

3 It was common practice for yard assignments to be operated down Warfield Hill from the trailing locomotive rather than changing controls to the lead locomotive.

4 Dynamic brake systems use 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 resistors (the dynamic brake grids). Dynamic brakes can be used alone or in conjunction with the train air brake system. Unless equipped with a dynamic brake holding feature, the dynamic brake cuts out when the air brake system is in emergency.

## *Site Examination*

The three residue tank cars did not derail. They came to rest at Mile 19.2 (see Figure 2 and Photo 1).

Immediately ahead of the tank cars, a loaded covered hopper car (CP 385119) came to rest with its trailing truck still on the rails and coupled to the residue tank cars. Its leading truck was derailed. The next six covered hopper cars ahead were derailed to the outside of the curve.

The two locomotives and the remaining covered hopper car came to rest derailed to the outside of the curve at Mile 19.038 (see Photo 2).

**Photo 1.** Derailment at Mile 19.2

**Photo 2.** Derailment at Mile 19.038

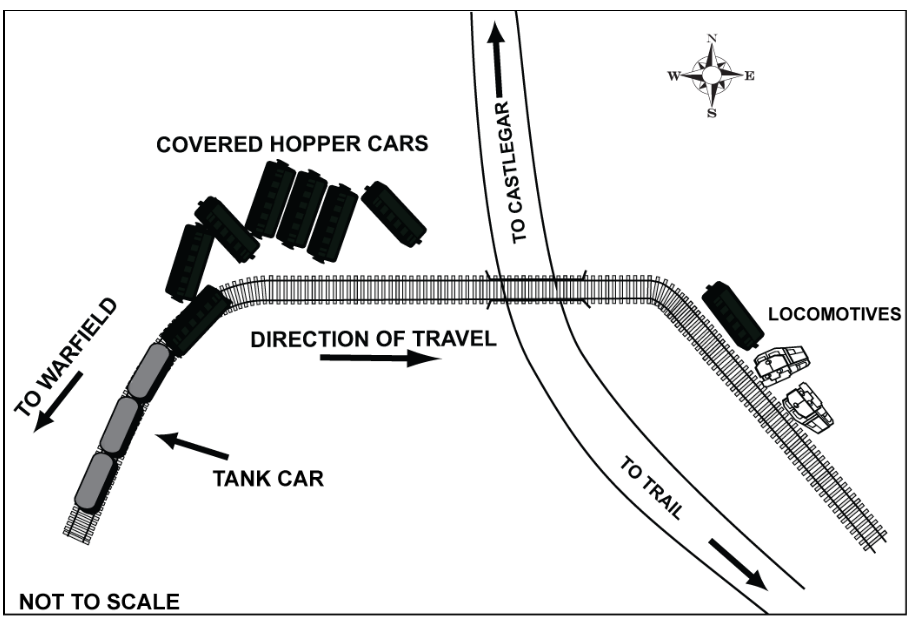



**Figure 2.** Derailment site

An examination of the tank cars revealed that the brake cylinder pistons on the first and third cars were extended and the retainers were in the direct exhaust position. Because these cars were not loaded, they were not required to have the retainers set. The brake cylinder air pressure was measured approximately 24 hours after the derailment had occurred and was 48 pounds per square inch (psi) for car CGTX 65316, 0 psi for car PROX 33301, and 56 psi for car PROX 34166.

An examination of the covered hopper cars revealed that the brake cylinder pressure retainer valve handles were in various positions; four were in the high-pressure position (this includes a sheared-off retainer which was found during the derailment clean-up), two were in the exhaust position, one in the slow direct position, and one was in between the high-pressure and the slow direct positions.

Further examination revealed that the wheels of the two locomotives and the first and third covered hopper cars from the head end showed significant signs of blueing (heavy braking). The second covered hopper did not have blueing of the wheels; however, its brake shoes exhibited signs of thermal deterioration, indicating heavy braking, although not to the same extent as the adjacent cars. The following five covered hopper cars showed only limited, or no, signs of heavy braking. The trailing three residue tank cars did not exhibit any signs of heavy braking. The brake shoes on the cars that exhibited signs of heavy braking also exhibited a glazed surface condition.

Further examination of the derailed equipment did not reveal any pre-derailment mechanical defects that would have affected their safe operation.

At both derailment sites, the first marks on the track were wheel flange markings on the heads of the outside rails, indicating the points of derailment. Several feet beyond each point of derailment, in the direction of travel, wheel flange markings were noted on the ties to the field side of the outside rail.

## *Crew Information*

Two three-man crews worked the assignment. They normally worked a four-day-on, four-day-off cycle with each day consisting of one 12-hour shift.

All crew members of the occurrence train met fitness and rest standards, were qualified for their respective positions, and were familiar with the territory. The locomotive engineer had 25 years of experience working with Canadian Pacific Railway (CPR), 15 years of which had been spent working on the assignment. The helper had worked with CPR for just under 2 years, 10 months of which had been spent working periodically on the assignment. The foreman had four years of experience with CPR, the majority of which was spent working on the assignment.

In response to two incidents involving the locomotive engineer, the runaway of four loads of anhydrous ammonia in 2005 and the derailment of a car that was pushed over the end of a stub track in 2005, the railway had developed a positive action plan for the locomotive engineer focusing on the following two areas:

- train handling
- switching in Trail yard

The positive action began on 03 February 2005 and required the railway to conduct random proficiency tests, which were to include the analysis of the event recorder data. The first test was conducted on 25 February 2005. Of the eight documented tests from this time to the time of the derailment, three were performed by a road manager, one of which was an evaluation of the locomotive engineer's performance with regard to operating down the Warfield Hill as per Timetable 52 instructions. The other five tests were carried out by the area manager, during which he monitored the locomotive engineer for entraining and detraining proficiency, correct whistling at crossings, radio procedures, and testing the effectiveness of hand brakes. During the eight tests, there was no documented indication that locomotive event recorder (LER) data was downloaded and analyzed. The last evaluation of the locomotive engineer took place one week before the accident.

## *Consist/Equipment*

The train departing Warfield consisted of two GP 38-2 locomotives, eight loaded covered hopper cars, and three residue tank cars. It weighed approximately 1255 tonnes and was approximately 795 feet in length.

The locomotives had DB capability but were not equipped with an extended range DB or a DB holding feature. An extended range DB develops its maximum retarding force between 6 and 23 mph, while standard DB develops its maximum retarding force at about 23 mph. The DB holding feature allows the DB to stay engaged when the air brake system is put into emergency. Newer locomotives are manufactured with a DB holding feature. Some railways have also retrofitted their older locomotives to include this capability.

Because a locomotive DB generates a retarding force through the traction motors, it does not contribute to the generation of heat at the interface of the wheel tread and the brake shoe. This form of braking is not subject to friction fade, unlike friction braking systems such as the automatic and independent brakes. For this reason, the DB is a particularly important tool for descending mountain grades.

The eight covered hopper cars were built between 1970 and 1981 and were equipped with either foundation or truck-mounted brakes. The three residue tank cars were built in 1996, 2005, and 2007 and were equipped with truck-mounted braking systems. All cars had been maintained in serviceable condition.

The locomotives were moved to CPR's Ogden shop in Calgary and an inspection revealed that the air brake systems were functioning properly. The locomotives had been maintained in serviceable condition.

## *Track Information*

The Rossland Subdivision extends from Castlegar, B.C. (Mile 0.0) to Warfield (Mile 22.0). Between Mile 0.6 and Mile 16.0, train movements are governed by the Occupancy Control

System as authorized by the *Canadian Rail Operating Rules* (CROR). Mile 16.0 is considered to be the end of the main track. All movements beyond Mile 16.0 to Warfield are governed by Rule 105 of the CROR. Rule 105 requires that all movements operate at reduced speed which is defined as "a speed that will permit stopping within ½ the range of vision of equipment". In addition, railway instructions establish a maximum permissible speed of 10 miles per hour.

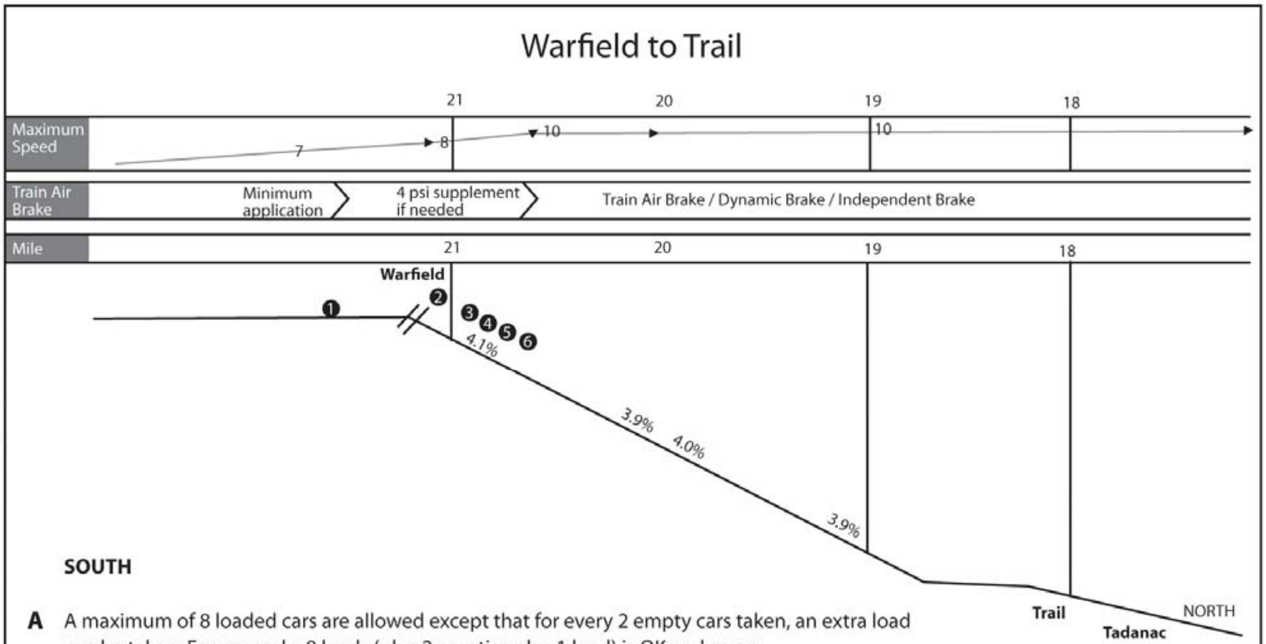
The section of track between Mile 18.4 and Mile 21.2 is known as the Warfield Hill. It descends to the south at grades of up to 4.1 per cent and contains curves of up to 20 degrees. It is common industry practice to consider grades in excess of 1.8 per cent as mountain grade. In the area of the derailment, the track consists of single main track comprised of 130-pound jointed rail manufactured by Algoma Canada in 1961, laid on 14-inch double-shouldered tie plates and secured to softwood ties with four 6-inch spikes per tie plate. The ballast consists of 3-inch crushed rock. The cribs were full and the tie ends were covered with ballast. The track was generally in good condition. It was maintained in accordance with the Transport Canada *Railway Track Safety Rules* and the CPR Standard Practice Circulars. The curve at Mile 19.216 had a design speed of 19 mph.

## *Kootenay Valley Railway*

The Kootenay Valley Railway is an internal short line wholly owned and operated by CPR. It was formed in 1997 when it was decided that the internal short line concept was preferable to selling the railway to an independent operator.

## *Train Handling*

CPR Timetable 52, for the British Columbia Interior Service Area, contains specific operating instructions and train-handling procedures for trains descending Warfield Hill (see Figure 3). These procedures specify the locations and actions that must be taken on the grade and are the most restrictive on any trackage in the CPR system. Compliance using dynamic braking, supplemented by air brakes, to control train speed is intended to avoid brake shoe friction fade and to prevent uncontrolled movements.




Time Table Nº 52 - January 20, 2006

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**A** A maximum of 8 loaded cars are allowed except that for every 2 empty cars taken, an extra load can be taken. For example, 8 loads (plus 2 empties plus 1 load) is OK and so on.

**B** Place retainer valves in the high pressure (HP) position on all loaded cars and then with air brake system fully charged:

- make a 15 psi automatic reduction
- release the automatic brake
- ensure brakes remain applied on at least 85% of cars that have HP retainers applied

**C** Prior to descent, condition car and locomotive brakes by moving back and forth until it is apparent that the brakes are operating sufficient [SIC] to control the movement.

**Train Handling Procedure**

❶ From a fully charged train air brake system, and at a speed not exceeding 7 MPH, make a minimum automatic brake application before the lead locomotive passes the West Kootenay Power Crossing.

❷ Use throttle and dynamic brake as required to not exceed 8 MPH at Mile 21.

❸ Gradually allow speed to increase to 10 MPH.

❹ Attempt to reduce speed to 9 MPH supplementing full dynamic brake with the independent brake.

❺ If unable to reduce speed as desired in step 4, make a supplementary brake applications [SIC] of at least 4 psi.

❻ Repeat steps 4 and 5 until it is evident that speed can be controlled at 10 MPH.

***Reminder - After arriving at Trail, place retainer valves in Direct Exhaust (Ex) position.***

**Figure 3.** CPR's Train-Handling Procedures

## *Recorded Information*

Data from the locomotive event recorders of both locomotives from the 0700 Trail yard assignment were downloaded. These data along with key events are listed in Table 1.

| Time | Location | Event |
|---|---|---|
| 14:29:31-<br>14:29:54 | | While travelling at 8.6 mph with throttle off, an automatic brake application of 20 psi is made. The movement comes to a stop and the brakes are observed to apply at the rear of the train. |
| 14:30:16 | | Throttle is advanced to position 4 with automatic brake set to test the effectiveness of brakes. The brakes are determined to be effective. |
| 14:30:42 | | The brakes are released and the crew confirms that brakes remain applied on the 8 loads with retainers set. |
| 14:32:11 | | The direction changes and movement commences towards the West Kootenay Power Crossing at Mile 21.03 (the crest of the grade). |
| 14:33:45 | Mile 21.15 | The train brakes are applied with a 10 psi brake pipe pressure reduction to 90 psi while travelling at 9 mph. |
| 14:34:22 | Mile 21.04 | The brake pipe pressure has been further reduced by 4 psi to 86 psi and the movement is travelling at 11 mph. |
| 14:34:36 | Mile 21.02 | The movement is travelling at 12 mph (4 mph above the required speed) with the throttle in the off position; the locomotive independent brake is released and the DB has not been applied. |
| 14:34:41-<br>14:34:46 | Mile 20.98 | The movement is travelling at 12 mph, the locomotive independent brake is applied with 16 psi brake cylinder pressure, and the train brake is further applied by reducing brake pipe pressure by 4 psi to 82 psi. |
| 14:34:52 –<br>14:35:03 | Mile 20.94 | The movement is travelling at 11 mph, the DB is applied to position 2, the brake pipe pressure is reduced by 2 psi to 80 psi, and the locomotive independent brake is reduced to 11 psi. |
| 14:35:27 | Mile 20.84 | The movement is travelling at 10 mph, the DB is fully applied to position 8, the locomotive independent brake is at 11 psi, and the brake pipe pressure has been further reduced to 78 psi. |
| 14:36:00 | Mile 20.72 | The speed has increased to 12 mph and the locomotive independent brake is increased to 15 psi. |
| 14:36:20 | Mile 20.65 | The speed has increased to 14 mph, the automatic brake is placed into emergency, and the DB is nullified. |
| 14:36:25 | Mile 20.63 | The speed has increased to 15 mph and the locomotive independent brake is fully applied to 31 psi. |
| 14:36:27 –<br>14:39:37 | Mile 19.05 | The speed has increased to a maximum of 42 mph and the locomotives derail to the outside of a 16-degree curve. |

**Table 1.** An analysis of the locomotive event recorder from both locomotives of the 0700 Trail yard assignment and key events.

## *Handling Comparison*

The TSB compared the handling of the occurrence train to the handling of a similar train that was successfully operated down Warfield Hill subsequent to the accident (see Table 2).

| **Unsuccessful** | | | | **Successful** | | | |
|---|---|---|---|---|---|---|---|
| **Time** | **Mile** | | | **Retainer test is performed. Four minutes, twenty seven seconds elapse before the train begins the descent.** | | | |
| | | **Brake Pipe Pressure (psi)** | 98 to 78 | | | | |
| 14:29:49 | 21.086 | **Dynamic Brake Position** | Out | | | | |
| | | **Independent Brake (psi)** | 26 | | | | |
| | | **Speed (mph)** | 0 | **Time** | **Mile** | | |
| 14:33:45 | 21.152 | **Brake Pipe Press.** | 100 to 90 | 15:21:49 | 21.231 | **Brake Pipe Press.** | 99 |
| | | **DB Position** | Out | | | **DB Position** | Out |
| | | **Ind. Brake Press.** | 0 | | | **Ind. Brake Press.** | 0 |
| | | **Speed** | 9.2 | | | **Speed** | 1 |
| 14:34:16 | 20.919 | **Brake Pipe Press.** | 90 to 80 | 15:24:40 | 20.953 | **Brake Pipe Press.** | 99 to 94 |
| | | **DB Position** | 2 | | | **DB Position** | 1 |
| | | **Ind. Brake Press.** | 16 | | | **Ind. Brake Press.** | 0 |
| | | **Speed** | 11 | | | **Speed** | 5.4 |
| 14:35:19 | 20.867 | **Brake Pipe Press.** | 80 to 78 | 15:25:37 | 20.866 | **Brake Pipe Press.** | 94 |
| | | **DB Position** | 5.3 | | | **DB Position** | 4.3 |
| | | **Ind. Brake Press.** | 11 | | | **Ind. Brake Press.** | 5 |
| | | **Speed** | 10 | | | **Speed** | 6.4 |
| 14:36:00 | 20.718 | **Brake Pipe Press.** | 78 | 15:26:47 | 20.717 | **Brake Pipe Press.** | 94 to 88 |
| | | **DB Position** | 8 | | | **DB Position** | 8 |
| | | **Ind. Brake Press.** | 15 | | | **Ind. Brake Press.** | 5 |
| | | **Speed** | 12 | | | **Speed** | 9.6 |
| 14:36:20 | 20.649 | **Brake Pipe Press.** | Emergency | 15:27:15 | 20.642 | **Brake Pipe Press.** | 88 |
| | | **DB Position** | Nullified | | | **DB Position** | 6.5 |
| | | **Ind. Brake Press.** | 15 | | | **Ind. Brake Press.** | 5 |
| | | **Speed** | 14 | | | **Speed** | 9.6 |
| 14:36:25 | 20.629 | **Brake Pipe Press.** | Emergency | 15:27:26 | 20.616 | **Brake Pipe Press.** | 88 |
| | | **DB Position** | Nullified | | | **DB Position** | 5.1 |
| | | **Ind. Brake Press.** | 20 | | | **Ind. Brake Press.** | 5 |
| | | **Speed** | 15 | | | **Speed** | 8.6 |
| 14:38:16 | 19.866 | **Brake Pipe Press.** | Emergency | 15:33:04 | 19.858 | **Brake Pipe Press.** | 88 |
| | | **DB Position** | Nullified | | | **DB Position** | 3.6 |
| | | **Ind. Brake Press.** | 31 | | | **Ind. Brake Press.** | 5 |
| | | **Speed** | 30 | | | **Speed** | 8.6 |
| 14:39:26 | 19.184 | **Brake Pipe Press.** | Emergency | 15:38:07 | 19.186 | **Brake Pipe Press.** | 88 to 86 |
| | | **DB Position** | Nullified | | | **DB Position** | 4.3 |
| | | **Ind. Brake Press.** | 31 | | | **Ind. Brake Press.** | 9 |
| | | **Speed** | 42 | | | **Speed** | 5.7 |
| 14:39:39 | 19.021 | **Brake Pipe Press.** | Emergency | 15:40:02 | 19.002 | **Brake Pipe Press.** | 86 |
| | | **DB Position** | Nullified | | | **DB Position** | 1.8 |
| | | **Ind. Brake Press.** | 32 | | | **Ind. Brake Press.** | 9 |
| | | **Speed** | 0 | | | **Speed** | 5.7 |

**Table 2.** A comparison of the brake control manipulation between a train which successfully descended Warfield Hill and the accident train.

## *Wabtec Corporation Testing*

Wabtec Corporation of Wilmerding, Pennsylvania, United States, conducted a series of tests on behalf of the TSB using air brake test rack [5] equipment to evaluate the likely state of charge of the train before it began the descent of Warfield Hill. These tests showed that, under ideal circumstances:

- All cars would have been completely charged prior to descending the hill.

- Although the cars with retainers set had somewhat higher brake cylinder pressures throughout the testing, retainer settings had little effect on the brake cylinder pressures obtained when the emergency application of the automatic brake was made.

Wabtec also conducted tests to establish the net shoe forces generated by the air brake systems of sister cars to those that were destroyed in the derailment. The sister cars were of a similar age, braking configuration, and mileage history. The report concluded that the braking ability of the tested sister cars likely met Association of American Railroads (AAR) standards.

## *Friction Fade*

Friction fade is a phenomenon commonly associated with the operation of trains in mountain grade territory. When tread brakes are applied, friction between the shoe and the wheel tread converts the kinetic energy of wheel motion (rotation) into heat energy, heating the wheel. The greater the speed of the wheel and/or the applied force of the shoe on the wheel, the greater the amount of heat generated. As a result of excessive heat build-up, the coefficient of friction between the brake shoe and the wheel tread is lowered, resulting in a significant loss of braking force. At higher speeds, heat builds up faster, resulting in greater loss of braking capacity.

AAR Specification M-926, issued in 1964, is the standard used to manufacture high-friction composition brake shoes for rail cars. At that time, the standard applied to 100-tonne cars with a gross rail load (GRL) of 263 000 pounds. The AAR M-926 grade test requires brake shoes to be exposed to a 1450-pound net shoe force at 20 mph for 45 minutes and produce a minimum retarding force of 400 pounds. Heavy braking, such as occurred during the descent of the occurrence train, can far exceed the limited force requirements of this “light grade” test standard. For braking events of shorter duration than the light grade test requirements and at slower speeds, the temperatures necessary to exceed the thermal threshold of the brake shoes can be exceeded when brake shoe forces are high, such as during an emergency brake application on a train or with a fully-applied locomotive independent brake.

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[5] A test rack comprises a series of air brake control valves and necessary appurtenances to simulate train air brake operation in a laboratory setting.

### *TSB Engineering Laboratory Report LP 133/07* [6]

The TSB Engineering Laboratory was requested to conduct dynamic simulations based on the LER information from the two trains. Assuming that the air brake systems on both the occurrence train and the successful train were fully charged and serviceable, the following can be concluded:

- In the successful descent of the test train, speed was kept lower and the primary means of control was through the use of dynamic braking, supplemented with air brakes. This approach developed lower braking horsepower, and thus lower temperatures at the wheel/brake shoe interface. As a result, friction fade was prevented and a normal coefficient of friction was maintained.

- Brake shoe friction fade occurred just before the locomotive engineer applied full dynamic brake and placed the train brakes in emergency. As a result of friction fade, braking effort was lost by a cumulative margin of 50 to 70 per cent.

- The occurrence train's air brake system was not providing uniform braking throughout. Those pieces of rolling stock with fully functioning air brakes carried more of the braking load than what would be expected had the train been braking uniformly. Consequently, they reached their thermal threshold sooner and suffered the effects of friction fade. Once friction fade occurred, the increased braking force from the emergency brake application further reduced the coefficient of friction, thereby exacerbating the effects of friction fade.

- Had the locomotive been equipped with a DB holding feature, full DB plus the residual emergency brake force would have been able to maintain a survivable speed, even though friction fade would have reduced the coefficient of friction.

### *Transport Canada*

Transport Canada performed an inspection of the function of retainers on sister cars to the ones involved in the derailment. Forty eight per cent of the brake cylinders did not retain the air brake cylinder pressure for 15 minutes, as required to travel down Warfield Hill (see the Safety Action Taken section).

## *Analysis*

Smoke emanating from the train during the descent of the grade, blueing of the wheels on the locomotives and two cars of the consist, and the condition of some brake shoes post-accident indicated that some of the brake shoes had been heavily applied. The testing of sister cars with similar service wear indicated that the braking ability of the occurrence cars likely met AAR standards. Moreover, a review of the maintenance records did not reveal any defect that would

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[6] This report is available from the TSB upon request.

have contributed to the derailment. The mechanical maintenance records for the locomotives, post-accident testing and inspection of the locomotives, and review of the locomotive event recorder data indicated that both locomotives' air brake equipment and DB were serviceable.

Site observations indicated that the locomotive and the first three covered hoppers cars were subject to heavy braking but the following eight cars showed only intermittent signs of heavy braking. A train with a fully-charged and serviceable air brake system, subject to the braking conditions of this event, would be expected to brake uniformly throughout. Post-accident, the TSB engaged the services of Wabtec to help determine if there was sufficient time for the train's air brake system to recharge between the release from a 22 psi brake pipe reduction and the re-application of the brakes 3 minutes and 4 seconds later, when the train began to descend the grade. Wabtec simulated this event and, with all angle cocks properly positioned on a train with a serviceable air brake system, it was concluded that there was sufficient time for the train to fully recharge.

The TSB investigation found all angle cocks properly positioned during the post-accident site examination; however, there was evidence of non-uniform heavy braking in the train, suggesting that the air brake system was not functioning optimally. A train's air brake system charges from the air supply (locomotives) towards the rear. Although Wabtec's testing showed that there was sufficient time to recharge in ideal circumstances, post-accident observations indicate that the train may not have been fully charged prior to commencing the descent. The reasons for this could not be determined.

Given the brake pipe pressure setting on the train at 100 psi, brake cylinder pressures generated by the emergency brake application would have been about 87 psi. Regarding the variations in brake cylinder pressures measured on three of the cars 24 hours post-accident, it would not be considered unusual for brake cylinder pressures to have diminished significantly in that time period.

AAR 1964 Specification M-926, the standard to which high-friction composition brake shoes are currently manufactured, is based on braking a 100-tonne car with a GRL of 263 000 pounds for a period of 45 minutes. The specification requires brake shoes to be exposed to a 1450-pound net shoe force and to produce a retarding force of 400 pounds. However, today's cars can have a GRL of 315 000 pounds [7]. The current performance standards for composition brake shoes may be inadequate to ensure brake shoes can withstand the brake loads of today's heavier cars while descending steep mountain grades, particularly in emergency circumstances.

The remainder of the analysis will focus on railway train handling practices for the safe descent of Warfield Hill and the actual operating decisions made during the operation of the train.

The derailment occurred as the uncontrolled movement reached a speed at which the train was unable to safely negotiate the sharp curves. Locomotive event recorder data indicated that just before derailing, the train was travelling at 42 mph, which is 32 mph in excess of the maximum permissible speed of 10 mph and 23 mph in excess of the maximum design speed of 19 mph for

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7 T. McCabe "Fade Resistant Brake Shoe 2006 Update," 2006 Technical Conference of the Air Brake Association. Chicago: Air Brake Association, 19 September 2006.

the curve. The damage on the end of the ties and the absence of tie damage between the rails and the marks on the head of the rail at the point of derailment were consistent with a wheel lift derailment caused by overspeed.

Warfield Hill has grades of up to 4.1 per cent. It is industry standard to describe any grade that exceeds 1.8 per cent as mountain grade. Subsequent to a number of previous loss of control occurrences (including TSB report numbers R97C0147 and R01W0007), CPR developed train-handling procedures to assist crews in maintaining an adequate margin of safety while operating down mountain grades.

A number of variations from standard operating procedures occurred during the train's descent of Warfield Hill. They are as follows:

- The train attained a speed of 9 mph, 2 mph above the maximum recommended speed prior to the initial automatic brake application before beginning the descent.
- At Mile 21, where the grade is at its steepest decline of 4.1 per cent, train speed reached 12 mph (4 mph above the maximum recommended speed).
- Speed was reduced to 10 mph, rather than the recommended reduction to 9 mph.
- The DB was not engaged to aid in control of the train speed until after it passed Mile 21.
- The train was not placed into emergency until it reached 14 mph, 1 mph in excess of the recommended speed at which an emergency brake application was to be initiated.

The train crested the hill and commenced its descent above the recommended speed. The combination of automatic, independent, and dynamic brake that was used in the attempt to control train speed caused friction fade and resulted in a speed that was too high to permit the train to safely negotiate the sharp curves. The train-handling procedures were known to the locomotive engineer; however, the ramifications of not strictly following these procedures on this extreme mountain grade may not have been fully understood.

In a complex system involving the interplay of humans and machinery there will inevitably be deviations from the rules. That is why many safety experts advocate "defences in depth" and call for multiple and diverse lines of defence to mitigate the risks of normal human errors. One means of adding an additional defence on steep mountain grades that has been explored, and is use on some North American railways, is the dynamic brake holding feature, which allows DB and emergency braking to operate simultaneously.

Examination of the locomotives and the first and third covered hopper cars showed that the brakes had been heavily applied and had become very hot. The second covered hopper had thermally-degraded brake shoes but no blue wheels, indicating heavy braking but to a lesser degree than the two adjacent cars. Because of the resultant high temperature of the brake shoes, it was determined that the effective braking force of the train was diminished by a cumulative margin of 50 to 70 per cent by the effects of friction fade. The high temperature attained at the interface between the wheel tread and the brake shoes was due to the elevated speed and the extent and duration of the brake application.

The DB on the two GP 38-2 locomotives was designed to reach maximum effectiveness at 19 mph. Because the DB's were nullified before reaching their maximum effectiveness, the train's friction braking system had to carry an additional load, increasing the risk of friction fade and derailment. In addition, laboratory analysis determined that full DB plus the residual emergency brake force would have been able to maintain a survivable speed and prevent the derailment, even though friction fade had reduced the coefficient of friction.

A comparison of train-handling procedures between the occurrence train and a similar train that safely descended the hill indicates that the speed could be controlled by strictly following the railway's train-handling guidelines. The railway's recommended procedure was to control the train by using a minimum automatic brake application and a combination of DB and independent brake on the locomotives, supplemented by incremental increases of the automatic brake.

The approach used with the occurrence train was to attempt to control train speed after it was allowed to exceed maximum recommended speeds by using the automatic brake, supplemented with locomotive independent brake and eventually the DB. Consequently, more of the train's overall braking capacity was used in controlling train speed resulting in friction fade and much less braking capacity held in reserve than had the train been handled in accordance with established procedures.

A review of railway records indicates that the locomotive engineer from the occurrence train had been involved in prior occurrences in which train handling was cited as being deficient. While the railway developed a performance action plan to correct these deficiencies, most of the actions taken involved passive observations of activities other than train handling. Although supervisory activities had identified train-handling deficiencies involving the occurrence locomotive engineer, follow-up action did not entirely mitigate the likelihood of recurrence.

After the accident, Transport Canada conducted a review of the procedures and practices utilized by Kootenay Valley Railway crews and discovered a significant failure rate of retainers to maintain brake cylinder pressure. However, testing done for the TSB by Wabtec disclosed that although the retainers did increase brake cylinder pressure, retainer functionality becomes less significant as brake applications are increased. While the effect of properly set and functioning retainers could have been significant in the early stages of the descent, testing showed that the retainers had little effect on the brake cylinder pressures obtained when the emergency application was made.

## *Findings as to Causes and Contributing Factors*

1. The train crested the hill and commenced its descent above the recommended speed. The combination of automatic, independent, and dynamic brake that was used in the attempt to control train speed caused friction fade and resulted in a speed that was too high to permit the train to safely negotiate the sharp curves.
2. The train-handling procedures were known to the locomotive engineer; however, the ramifications of not strictly following these procedures on this extreme mountain grade may not have been fully understood.
3. Most of the train's overall braking capacity was used to control train speed, resulting in friction fade that diminished braking capacity by a cumulative margin of 50 to 70 per cent.
4. Because the dynamic brake was nullified before reaching its maximum effectiveness, the train's friction braking system had to carry an additional load, thus increasing the risk of friction fade and derailment.
5. While there was sufficient time available for the train to have reached a fully-charged state prior to descending the grade, there was evidence of non-uniform braking throughout the train. The reasons for this could not be determined.
6. The current performance standards for composition brake shoes may be inadequate to ensure brake shoes can withstand the brake loads of today's heavier cars while descending steep mountain grades, particularly in emergency circumstances.

## *Other Findings*

1. While the effect of properly set and functioning retainers could have been significant in the early stages of the descent, testing showed that the retainers had little effect on the brake cylinder pressures obtained when the emergency application was made.
2. Full dynamic brake plus the residual emergency brake force would have allowed the train to maintain a survivable speed and prevent the derailment, even with friction fade.
3. Although supervisory activities had identified train-handling deficiencies involving the occurrence locomotive engineer, follow-up action did not entirely mitigate the likelihood of recurrence.

## *Safety Action Taken*

A TSB Rail Safety Advisory was issued on 09 May 2007 regarding the absence of the dynamic brake (DB) holding feature on the two GP 38-2 locomotives, suggesting that Transport Canada review and evaluate the need for Canadian railways to retrofit or modify their older locomotives with the dynamic brake holding feature, particularly to help ensure safe train operation on steep mountain grades. Transport Canada agreed with the advisory and indicated that Canadian Pacific Rail (CPR) was evaluating the feasibility of modifying its older direct current (DC) fleet of locomotives. As of June 2008, CPR had concluded its evaluation but had not submitted its report to Transport Canada.

Transport Canada issued a Notice and Order on 04 May 2007 when an inspection revealed that retainers were observed to be failing to hold brake cylinder pressure as required for safely descending the 4 per cent grade between Warfield and Trail. This order required operating crews to ensure that, prior to descending the grade between Mile 21 and 19 on the Rossland Subdivision:

- All movements receive the equivalent of a number 1A air brake test at Warfield.
- 100 per cent of retainers are operative as noted below.
- Loaded cars with retainers set in the high-pressure position be observed to be holding brake cylinder pressure for a minimum of 15 minutes. This must include observing that the brake cylinders on the required cars are applied and that the brake shoes are seated against the wheels.

Canadian Pacific Railway (CPR) subsequently issued a correction entitled *"Additional Requirements Prior to Descending Warfield Hill"* that stated:

> *In addition to the train-handling procedures for the Rossland subdivision footnotes, on page 51 of Time Table No. 52, the following additional requirements will apply to all movements prior to descending the grade between Mile 21 and 19 on the Rossland Sub.*
>
> - *A No. 1A brake test must be performed at Warfield. Note: An SBU [sense and braking unit] must be used in the application of this provision.*
> - *A retainer test must also be performed on the train as follows:*
>
>   1. *Apply retainers in the HP [high-pressure] position to all loaded cars.*
>   2. *Once the cars are fully charged (air flow at its lowest point for minimum 5 minutes), make a 15-psi automatic brake pipe reduction.*
>   3. *After the service exhaust ceases, release the automatic brake.*
>   4. *After 15 minutes, ensure that the brakes remain applied (on all loaded cars) by observing the brake cylinders and confirming the brake shoes are against the wheels.*
>   5. *Release the retainers on the cars.*
>
>   ***Note:*** *Train must have 100 per cent operative retainers on all loads.*
>
>   ***Note:*** *Once the No. 1A brake test and retainer test are completed, the train-handling procedures as outlined in Time Table 52 must be adhered to prior to descending the grade.*
>
>   *Additionally, all locomotives must be equipped with operative dynamic brakes.*

The Notice and Order was revoked on 23 April 2008 after Transport Canada had reviewed and evaluated the corrective measures taken by CPR in their revision of the operating instructions for Warfield Hill.

Transport Canada is proposing an amendment to the *Railway Locomotive Inspection and Safety Rules* to require that the locomotive safety inspection include verification of the operation of dynamic braking and that the dynamic brake is equipped with the holding feature on locomotives dispatched from a locomotive safety location for trains or for transfers to all territories with a grade of 2 per cent or greater.

*This report concludes the Transportation Safety Board's investigation into this occurrence. Consequently, the Board authorized the release of this report on 22 January 2009.*

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