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

RAILWAY INVESTIGATION REPORT
R03W0169

DERAILMENT

CANADIAN PACIFIC RAILWAY
FREIGHT TRAIN NO. 202-16
MILE 86.5, KAMINISTIQUIA SUBDIVISION
CARLSTADT, ONTARIO
19 OCTOBER 2003

Canada

Railway Investigation Report

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Canadian Pacific Railway
Freight Train No. 202-16
Mile 86.5, Kaministiquia Subdivision
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Summary

On 19 October 2003 at 2318 central daylight time, Canadian Pacific Railway freight train 202-16, eastbound for Toronto, Ontario, came to a stop with two double stack container cars derailed at Mile 86.5 of the Kaministiquia Subdivision, near Carlstadt, Ontario. There were no injuries and no dangerous goods involved in the occurrence.

Ce rapport est également disponible en français.

Other Factual Information

Train, Crew and Weather Information

On 19 October 2003, Canadian Pacific Railway (CPR) freight train 202-16 (the train) was en route from Coquitlam, British Columbia, to Toronto, Ontario, on the main track of the Kaministiquia Subdivision. The train, comprised of one locomotive and 45 loaded cars, was 6061 feet long, weighed 4658 tons and contained no "special dangerous commodities." Movements on CPR's Kaministiquia Subdivision are governed by the centralized traffic control system as authorized by the *Canadian Rail Operating Rules* (CROR), and are supervised by a rail traffic controller (RTC) located in Calgary, Alberta. An average of 21 freight trains per day traverse this area at authorized track speeds between 45 mph and 60 mph. There were no General Bulletin Orders in effect.

The crew, consisting of a locomotive engineer and a conductor, had taken control of the train at their away terminal of Ignace, Ontario. The train was destined for the crew's home terminal of Thunder Bay, Ontario. The crew met fitness and regulatory rest requirements. They were familiar with the territory. Each crew member had at least 28 years of experience, primarily operating trains on the Kaministiquia Subdivision. At the time of the accident, the sky was overcast and the temperature was 6°C.

The Accident

After working a train from Thunder Bay to Ignace earlier that day, the crew was called for duty at 2035 central daylight time.[1] They took control of the train and commenced duty at 2110. After entraining, the crew conducted a crew-to-crew radio check as required under CROR Rule 117.[2] Following the check, the conductor's portable radio was turned off and the crew continued with only the locomotive radio in use. CROR Rule 119 requires portable and locomotive radios to remain on and set to the appropriate standby channel for continuous monitoring. In interpreting CROR Rule 119, CPR's General Operating Instructions (GOI)[3] state that, on main line subdivisions, all trains and engines must have at least one radio set to monitor the standby channel as indicated in the subdivision timetable.

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1 All times are central daylight time (Coordinated Universal Time minus five hours).

2 CROR Rule 117 states that the crew of a train or engine when equipped with radios must carry out an intra-crew test of such radios before leaving their initial terminal, change-off or starting point.

3 CPR's GOI, Section 4, item 9.0, effective 01 March 2002

After waiting for eastbound train 104 to depart ahead of them, the train departed Ignace at 2145. When leaving Ignace, the train passed a crossing at Mile 147.16 without sounding the locomotive whistle or bell.[4] Shortly thereafter, the crew heard a "no alarm" transmission on the radio standby channel (CP 01). This radio message had been generated by the hot box detector (HBD) at Mile 140.7 and was directed at the train ahead of them. After departing Ignace, the train crew heard very little additional radio traffic. The train continued en route past HBDs at miles 140.7 and 123.0. "No alarm" messages were received after passing these locations.

As the train approached Sheba, Ontario (Mile 105), the crew decided to call the RTC to discuss a possible meet with a westbound train. After the locomotive engineer selected the RTC call-in channel (CP 03), the crew decided that the call was not necessary. The locomotive engineer attempted to return the radio to the standby channel (CP 01). In performing this action, he pressed "Home 0 4" rather than "Home 0 1," inadvertently setting the radio channel to CP 04. The train continued en route and passed the HBD at Mile 98.5. The crew did not notice that they had passed the HBD and had not received an audible message or alarm. The train continued on until approximately Mile 88.0, where the locomotive engineer noticed a slight pull and a change in the train handling.

The locomotive event recorder (LER) revealed that the train had been in full throttle (position 8) from the time it departed Ignace. The train had averaged speeds between 35 mph and 45 mph for most of its journey. At 2314:15, near Mile 87.4, the train began to steadily decelerate while still in full throttle. The locomotive engineer then throttled down to idle and eased the train to a stop without the use of any train braking systems. At 2318:30, the locomotive came to a stop at Mile 86.0, just east of Carlstadt, Ontario.

The conductor took his portable radio, detrained and proceeded to inspect the train. While walking the train, the conductor received a call on the standby channel from the RTC. The RTC, who was not aware that the train had stopped, inquired whether they had cleared the east end of the Carlstadt Siding, as that switch was showing out of correspondence. The conductor informed the RTC that they had passed the siding and were presently stopped to inspect the train. During this time, the locomotive engineer had been trying unsuccessfully to contact the RTC. After realizing that the radio was not set to the correct channel, the locomotive engineer changed the radio channel to CP 01 and heard the RTC and conductor talking.

The conductor continued his inspection and found the 23rd and 24th cars behind the locomotive (DTTX 656207 and DTTX 54636) derailed and leaning to the north. Both were single platform double stack container cars loaded with mixed lading. Both had sustained mechanical damage and the roller bearing and axle journal in the R-2 position of the 24th car had burnt off. Inspection of the cars did not reveal any pre-existing mechanical defects that may have contributed to the derailment.

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[4] CROR Rule 14 states that an engine whistle must be sounded at least 1/4 mile from every public crossing at grade until the crossing is fully occupied by the engine or cars.

Site Inspection

Extending westward from the derailed cars, surface marks were observed along the track structure. These marks were traced back to Mile 96.41, identifying this location as the initial point of derailment (POD). Pieces of the R-2 roller bearing were recovered at Mile 97.4. In the 10 miles between the POD and where the derailed cars came to rest, the track structure exhibited intermittent damage to the ballast, ties, anchors, spikes and crossing planks. The power turnout at the east end of Carlstadt Siding (Mile 87.9) was damaged, and the main-track signal mast at this location was knocked over. The turnouts at Mile 95.5 and Mile 91.0 were also damaged.

Roller Bearing Teardown Examination

The wheels, the axle and recovered components from the burnt-off R-2 roller bearing from car DTTX 54636 were sent to CPR's Test Department for analysis. The examination determined that the R-2 journal had burnt off the axle approximately 6 1/4 inches outboard of the wheel hub. The remaining axle journal was conical in shape tapering down to a diameter of one inch at the point of separation. The cause of the roller bearing failure could not be determined due to the severity of the damage.

Track Information and Inspection

The Kaministiquia Subdivision consists of Class 4, single main line track. The rail was 136-pound continuous welded rail laid on 14-inch double-shouldered tie plates. The ties consisted of a 60/40 mix of treated hardwood and softwood ties, with an average of 60 ties per 100 feet of track. The rail and tie plates were fastened to the ties with three spikes per plate and anchored as required. The track structure was laid on rock ballast, the cribs were full and the shoulders extended 24 inches beyond the end of the ties. From Mile 98.5 to Mile 88.0, track grade is relatively level with minor ascending and descending variations. From Mile 88.0 to Mile 84.0, there is a continuous ascending grade in the direction of travel.

In addition to regular weekly and monthly track inspections, the Kaministiquia Subdivision is ultrasonically tested five times per year by a rail flaw detection car. Track geometry is tested four times a year by CPR's track evaluation car. Track in the area of the derailment was last tested by a rail flaw detection car on 04 September 2003, by CPR's track evaluation car on 17 September 2003, and it was visually inspected on 17 October 2003. In all cases, there were no significant defects in the derailment area that could be considered causal.

Hot Box Detector Information and Roller Bearing Burn-Off Statistics

Based on reportable occurrences in Canada since 1996, roller bearing failures that lead to burnt-off journals result in an average of 11 derailments each year on federally regulated rail lines. HBDs on CPR's rail network in Canada are spaced approximately 20 to 30 miles apart. There are seven SERVO 9000 HBD sites on the Kaministiquia Subdivision, located at miles 140.7, 123.0, 98.5, 78.5, 59.2, 31.5 and 16.1. HBDs monitor trains to detect overheated roller bearings, overheated wheels and dragging equipment, and to alert train crews to these problems. HBDs will scan each roller bearing for heat as the train passes over an infrared sensor. HBDs measure and record bearing temperature in millimetres (mm) with each mm of heat equating to 10°F. When the difference between heat measurements from opposite bearings of the same axle is greater than 10 mm (100°F) or the bearing exceeds an absolute measurement of 18 mm (180°F) above ambient temperature, an overheated roller bearing alarm is triggered. In 2003, CPR connected the HBDs on its British Columbia coal loop to a central monitoring system. Through this central system, CPR can perform trending analysis, which allows it to proactively set out cars with suspect bearings. However, on the remainder of CPR's rail network, each HBD is used as a stand-alone unit that operates independently with no network connections to each other or to the RTC. CPR is currently considering extending the British Columbia coal loop process to other subdivisions and car types.

In comparison, Canadian National (CN) links its HBDs to a network that allows it to access roller bearing temperature data through a centralized control centre that is staffed 24 hours a day by RTC mechanical technicians (Mech Techs). In addition to monitoring HBD field alarms, Mech Techs also monitor the system to identify warmer-than-average bearings. Based on the trends or alarms they observe, Mech Techs have the authority to stop a train. For example, when monitoring temperature trends, a Mech Tech can trigger an alarm after a roller bearing records three "warm" readings. A "warm" bearing is identified as having a temperature that is at least one-half of the HBD alarm threshold. In 2003, approximately 40 per cent of CN's overheated roller bearings were identified through this process. CN removed these bearings from service before they reached the alarm threshold.

CPR's HBD Alarm "Talker" System

Section 5, Part II of CPR's GOI provides specific instructions for the train crew to ensure that appropriate action is taken when the train passes through an HBD or generates an alarm at an HBD. CPR's HBD installations use a "talker" system of automated voice messages. When an alarm occurs, a one-second alert tone is immediately transmitted by the HBD on the radio standby channel designated for the subdivision. After the entire train has passed over the detector, an automated voice message identifying the defect type and location is transmitted in the same manner. This message will sequentially list all defects from the head end of the train. This message is repeated after a two-second pause, and then it is followed by "message complete, detector out." When no alarms occur, a "no alarm" voice message is broadcast in the same manner. If the HBD is not operative but can still broadcast messages, a "not working" voice message will be transmitted.

HBD Recorded Readings

Alarm messages and roller bearing temperature data are recorded from each train and stored in computer memory located in each HBD track-side bungalow. The length of time that data are retained depends on the volume of train activity over a given HBD. CPR Signals & Communications (S & C) personnel reported that, based on the volume of traffic over the Kaministiquia Subdivision, HBD data are stored for approximately two days before they are overwritten.

After the accident, train data from the HBDs at miles 140.7, 123.0 and 98.5 were downloaded. These HBDs had functioned as designed with no exceptions. An examination of the download from the HBD at Mile 98.5 confirmed that a talker alarm had been broadcast on the standby channel (CP 01). The alarm message indicated that the train had a “one alarm, first alarm, hotbox North rail, axle number 168.” This axle position corresponded to the R-2 location on car DTTX 54636. The R-2 bearing temperature readings and average roller bearing temperatures for the train from each HBD are listed in Table 1.

Table 1. HBD recorded temperatures for R-2 roller bearing on car DTTX 54636

Hot Box Detector	Roller Bearing Temperature (F)	Train Average Roller Bearing Temperature (F)
Mile 140.7	83°	38°
Mile 123.0	12°	43°
Mile 98.5	24°	46°

A review of the HBD data from two other ongoing TSB investigations (R03T0080 and R03T0158) that involved burnt-off roller bearings revealed that the roller bearings were heating up prior to the HBD, which generated the alarm. Because these elevated temperatures did not reach CPR’s HBD alarm threshold, this information was not conveyed to anyone.

Reporting of HBD Alarms and Inoperative HBDs

CROR Rule 85 states that “the conductor of each train will ensure that the RTC is promptly advised of any known condition which may delay the train.” In addition, Section 5, Part 1, Item 16 of CPR’s GOI deals with the reporting of train delays due to en route car repair, car set out and HBD alarms. Regarding HBD alarms and inoperative HBDs, the GOI indicate that the conductor must verbally transmit the information to the RTC at the first opportunity. Section 5, Part II, Item 1.5 of the GOI indicates that, when the train crew notifies the RTC of a suspected inoperative HBD, the RTC must advise S & C personnel, who will follow up on the report. The GOI further indicate that, when an inoperative HBD is reported and there are no “special dangerous commodities” on the train, a train inspection is not required and the RTC may allow the train to proceed to the next HBD location.

For a “no alarm” message, there is no action required of the crew. However, it was reported during the investigation that some train crews will employ *ad hoc* methods to keep track of scanner locations as they pass.

In this occurrence, each crew member reported having heard only two HBD alarms in the previous year.

Locomotive Radios

The single locomotive (CP 9639) powering the train was a GE AC4400CW built in 1997. Due to the move towards desktop style controls, the locomotive cab for this type of GE unit was re-designed, resulting in the placement of the radio above the front windows of the cab and to the left of the locomotive engineer's chair. This radio location has become the present standard for GE locomotives, and this layout is in use on thousands of locomotives across North America. GE locomotives currently make up approximately 30 per cent of CPR's road fleet.

The most common radio type on CPR locomotives, including the one used on CP 9639, is the Motorola Spectra (see Figure 1).

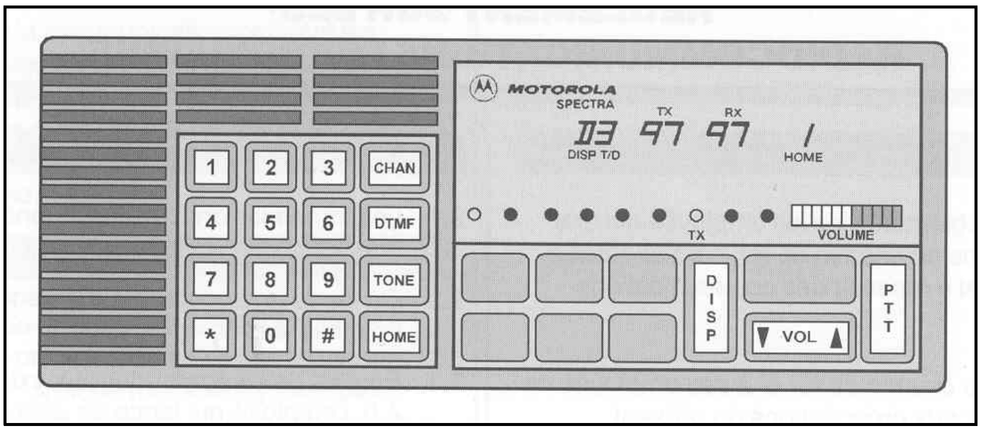

Figure 1. Motorola Spectra radio

The keypad on the Motorola Spectra radio is operated in the same fashion as a telephone push button keypad. During the course of the investigation, several CPR employees indicated that it is not uncommon to occasionally select the incorrect channel when operating this type of radio.

CPR's GOI provide instructions for radio operation. Two primary radio channels are used by CPR trains, the "standby" (or "road") channel and the "RTC call-in" channel. Train crews monitor the standby channel designated in the timetable for the territory in which they operate. The standby channel is used for most train communication and is the only channel on which HBDs broadcast messages. The standby channel is not normally monitored by the RTC. A train crew initiates a call to the RTC using the RTC call-in channel specified in the timetable, then returns to the standby channel to await the RTC call back.

As outlined in CPR Timetable No. 10 for the Northern Ontario Service Area, the standby channel on the Kaministiquia Subdivision is CP 01 and the RTC call-in channel is CP 03. As specified in the GOI and CPR Timetable No. 10, keystrokes of "* 3 1 #" are used to initiate the call to the RTC on channel CP 03. After entering the keystrokes, an "OK" message is received, which is followed by a ring back within eight seconds. The radio operator must then enter keystrokes of "HOME 0 1" to return to the standby channel (CP 01) and wait for the RTC response.

TSB Field Test Comparison of Locomotive Radios

TSB investigators examined three different locomotive cab layouts to determine radio location and to evaluate the ease of radio operation while seated in the locomotive engineer's chair. The cab layouts examined were for the GE AC4400CW, GM SD-90 MAC and GM SD-40-2 locomotives.

Within the GE AC4400CW cab, a seated individual of average height would have to stretch approximately 6 inches with his left hand or 12 inches with his right hand to reach the locomotive radio. In comparison, because the radio in the GM SD-90 MAC is located to the right of the locomotive engineer's chair (above the window) and the radio in the GM SD-40-2 is incorporated into the standard control stand (to the left of the locomotive engineer's chair), these radios can be reached more easily than those in the GE cab. Photographs illustrating the location of each radio and the ease of reaching the radio with the right hand are shown below.

Photo 1. GE AC4400CW

Photo 2. GM SD-90 MAC

Photo 3. GM SD-40-2

Hours of Work Regulations

The *Work/Rest Rules for Rail Operating Employees*, which were conditionally approved by Transport Canada on 18 June 2002, became effective 01 April 2003. The rules were developed pursuant to the *Railway Safety Act* and are accompanied by Railway Association of Canada's Circular 14 on the "Recommended Procedures and Practices for Application of Work/Rest Rules." CPR's system for scheduling operating crew work hours was developed based on these rules and in accordance with collective agreements.

The work/rest rules specify that operating employees have the responsibility to be rested and fit for duty when they report to work. The rules define "on-duty" time as the total elapsed time from when the employee is required to report for duty until the time when the employee goes off duty. The rules further indicate that a single tour of duty cannot exceed a maximum of 12 hours. However, if a crew member completes a single tour of duty and arrives at the away terminal in under 10 hours, he/she will be afforded a reasonable break before returning to work for the return trip. In this situation, the total hours of work can exceed 18 hours in a 24-hour period. Booked rest, a reasonable break time and the time awake between trips (if no rest is booked) do not count as on-duty time.

In contrast, the Canadian airline industry permits 14 hours of flight duty, while truck drivers are allowed up to 15 hours on duty with a maximum of 13 hours driving. In these industries, on-duty time includes the time preparing for the trip and the awake time between trips, if no rest is booked.

Train Crew Hours of Work

In the rail industry, it is standard operating procedure to call an operating crew two hours prior to their required on-duty time to enable them to prepare for work. In addition, it is common practice for train crews to avoid booking a rest period at an away terminal since that may cause them to miss the first opportunity to return home.

In this occurrence, both crew members reported that they felt rested and fit for duty when they took control of the train. Their work history for the seven days prior to the occurrence was reviewed. The locomotive engineer's shift work pattern changed six times in the seven days before the accident. The conductor had worked a similar work schedule for the seven days preceding the occurrence.

The locomotive engineer's work history for the two days prior to the accident is summarized as follows:

- On 17 October 2003, the locomotive engineer had an advance call at 1011 before reporting for duty at 1200.
- He departed Thunder Bay and arrived in Ignace at 1830 the same day.
- The locomotive engineer did not book rest in Ignace while waiting for a return train. He eventually departed at 2203 and arrived back in Thunder Bay at 0915 on 18 October 2003.
- After booking 24 hours of rest, the locomotive engineer was called for a train at 1039 on 19 October 2003. He departed Thunder Bay at 1145 and arrived in Ignace at 1730.
- The locomotive engineer did not book rest and was assigned to the train involved in the occurrence, departing Ignace at 2110.
- The accident occurred approximately two hours later.

Circadian Rhythms, Prolonged Wakefulness and Fatigue

Virtually every function in the body (e.g., body temperature, digestion, hormone levels) follows daily cycles known as circadian rhythms. Disruptions in circadian rhythms can affect performance and cognitive functioning.[5] Shift workers in particular demonstrate impairments in

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5 T. H. Monk, "Shift Work: Determinants of Coping Ability and Areas of Application," *Advances in the Biosciences* 73 (1988), pp. 195–207.

these functions.[6,7] Performance and cognitive functioning are at their worst during periods when other circadian rhythms dictate sleep. Specific performance measurements, such as reaction time[8] and train safety alarm alerts,[9] demonstrate the worst performance during the night shift. In addition, researchers have found that adjustment of the human circadian system occurs at a rate of 1.5 hours per day if the shift rotation is clockwise, or one hour per day with a counter-clockwise adjustment.[10]

Performance decrements associated with periods of prolonged wakefulness have been addressed in research literature and in a previous TSB report (R97C0147). One laboratory study of fatigue[11] demonstrated that 17 hours of sustained wakefulness produces impairments in psychomotor functioning (hand-eye coordination) equivalent to a blood alcohol concentration (BAC) of 0.05 per cent, and 24 hours of sustained wakefulness produces impairments equivalent to a BAC of 0.10 per cent. Fatigue due to both prolonged wakefulness and disruptions to the circadian rhythm are known to produce similar detriments in performance and cognitive functioning.

Analysis

There were no track infrastructure defects present. Except for the overheated R-2 roller bearing on car DTTX 54636, there were no other pre-existing car defects considered causal in the accident. The analysis will focus on the crew actions and on the circumstances preceding the derailment. It will also focus on CPR's GOI and on CPR's use of HBD technology. The effect of fatigue on train crew performance, train crew scheduling, and Transport Canada-approved *Work/Rest Rules for Rail Operating Employees* will also be discussed.

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6 A. D. Baddeley and G. Hitch, "Working Memory," *The Psychology of Learning and Motivation: Advances in Research and Theory* 8 (New York: Academic Press, 1974), pp. 47–89.

7 S. Folkard, P. Knauth, T.H. Monk and J. Rutenfranz, "The Effect of Memory Load on the Circadian Variation in Performance Efficiency Under a Rapidly Rotating Shift System," *Ergonomics* 19 (1976), pp. 479–488.

8 A. J. Tilley, R.T. Wilkinson, P.S.G. Warren, B. Watson and M. Drud, "An Analysis of the Work Schedules of Great Barrier Reef Pilots," *Human Factors* 24 (1982), pp. 629–641.

9 G. Hildebrandt, W. Rohmert and J. Rutenfranz, "Twelve and 24-Hour Rhythms in Error Frequency of Locomotive Drivers and the Influence of Tiredness," *International Journal of Chronobiology* 2 (1974), pp. 97–110.

10 K. E. Klein and H.M. Wegmann, *Significance of Circadian Rhythms in Aerospace Operations*, NATO AGARDograph (Neuilly sur Seine, France: NATAO AGARD, 1980), p. 247.

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

The Accident

The train passed an HBD at Mile 98.5, where an overheated roller bearing was detected. The HBD broadcast a talker alarm on the standby channel (CP 01). Since the train crew were monitoring the wrong channel, they did not receive the alarm. The crew also failed to recognize that they had passed the HBD without having received a message. As the train continued, the roller bearing heated up and seized, resulting in the axle journal failure. As the axle journal overheated, it began to extrude, reducing its cross-sectional thickness. The final burn off occurred when the reduced cross-sectional area of the axle journal could no longer support the weight of the loaded car.

Pieces of the R-2 bearing recovered at Mile 97.4 indicated that the burn off likely occurred at that point. Ground marks identified the initial point of derailment at Mile 96.41. Near Mile 88.0, the locomotive engineer noticed a change in train handling and eased the train to a stop at Mile 86.0, without the use of any train braking systems. By not using the train brakes, the locomotive engineer minimized the in-train forces and in doing so likely lessened the severity of the derailment.

Locomotive Radios

The location of the cab radio in the occurrence locomotive, a GE AC4400CW, likely contributed to the error of selecting the incorrect radio channel. The radio is located above the front window to the left of the locomotive engineer's seat, which is the present standard for GE locomotives. TSB tests demonstrated that, in GE locomotives with this type of cab layout, a seated individual of average height would have to stretch beyond their normal range of motion to reach the radio. This extra distance is approximately 6 inches with the left hand or 12 inches with the right hand. In comparison, radios in the GM SD-40-2 and SD-90 MAC locomotives, which are also used at CPR, are easily reached by an individual of average height seated in the locomotive engineer's chair. Although locomotive engineers are not restrained in their seats, having to reach beyond one's normal range of motion to access the radio buttons increases the probability of an error when entering the radio channel.

CROR and CPR's GOI

CROR Rule 119 and CPR's GOI require that the train crew continuously monitor the appropriate standby channel. In this occurrence, the selection of the incorrect radio channel was a keypunch error. This occurrence illustrates that a rule that is unsupported by secondary procedures or defences may be inadequate. In this occurrence, the keypunch error was compounded by the design of CPR's HBD system, as it is dependent on a talker message broadcast over a single radio channel that is only monitored by the train crew.

The train crew was not aware that they had passed an HBD without receiving a talker message. A person's ability to remain vigilant during repetitive tasks depends upon a number of factors, including the amount of time on the task and the rate of events in monitoring the task. Train crews regularly operate over the same territory, for hours at a time, sometimes for the duration of their career. Train operation is to a large extent repetitive. This crew had each worked the same territory for more than 25 years and reported receiving only two HBD alarms in the past year. Based on past experience, their expectation when passing an HBD was to receive a "no alarm" message. Given such expectations and since there is no action required at HBDs when a "no alarm" message is received, train crews are less likely to be attentive for such "non-events." While train crews are generally familiar with HBD locations, the frequency with which they pass them, combined with the high probability of a "no alarm" message and the lack of any action required on their part from such a message, increases the risk of train crews being inattentive to HBDs as they pass them.

CPR's GOI require the conductor to notify the RTC if an HBD is inoperative or if the crew does not receive a talker message. In this occurrence, the HBD system was ineffective in that the overheated roller bearing alarm broadcast on the single standby channel was not received by the crew. However, even if the crew had recognized that they did not receive a talker message from the HBD at Mile 98.5 and notified the RTC, the train would still have been allowed to continue to the next HBD at Mile 78.5, because there were no "special dangerous commodities" on the train. CPR's GOI contain no secondary defence to attract attention to an HBD warning if that warning is missed by the crew. In addition, CPR's GOI do not require a train inspection in all circumstances when an HBD message is not received. Without secondary defences implemented for HBD operations, there is an increased risk of roller bearing burn offs occurring under similar circumstances.

HBD Technology

Roller bearing failures leading to burnt-off journals cause an average of 11 derailments each year on federally regulated rail lines. The railway's primary defence against such occurrences is the use of HBDs. CPR has made a significant investment in its HBD network. The purpose of HBD warning systems is to detect overheated roller bearings and to alert the crew to potential danger. In this occurrence, the HBD alarm was not heard by the crew, nor was it communicated to anyone else for action. Therefore, once the crew missed the alarm message, the defence provided by the HBD was no longer of any value.

Examination of the data downloaded from the HBDs at miles 140.7, 123.0 and 98.5 determined that the roller bearing was warmer than the train average and had continued to heat up en route. While each HBD recorded the bearing temperature, this information was not shared with any other person nor linked to other HBDs. Unlike CN, most of CPR's HBD system does not centrally record information to allow en route monitoring or trend analysis of HBD data. Consequently, information available from CPR's HBD system is not used to its full potential. This decreases the effectiveness of the HBD as a safety defence and increases the risk that overheated bearings will be allowed to continue in service and result in a burn-off derailment.

Regulatory Overview with Regard to Wakefulness and Fatigue

The *Work/Rest Rules for Rail Operating Employees* is the primary defence against worker fatigue. These rules define duty time as the time spent operating a train. The work/rest rules allow up to 18 hours, in total, as the maximum on-duty time for employees working more than one tour of duty in road service for any 24-hour period. The rules permit an excess of 18 consecutive hours of wakefulness, if no rest is booked. Based on these rules, the train crew met the regulatory requirements for rest governing the rail industry. When compared to the airline and trucking industries, however, the standards set forth in the work/rest rules are less restrictive. The regulations for the airline and trucking industries are set at lower limits for maximum on-duty time. In addition, on-duty time for these industries includes the time spent preparing for a trip and the time spent awake while waiting between trips, if no rest is booked.

In this occurrence, the locomotive engineer recorded 16 hours of on-duty time during his two tours of duty on his 17–18 October 2003 trip, which was one day prior to the accident. If call time is considered along with his wake time at the away terminal and his time to return to his residence upon arrival back in Thunder Bay, the locomotive engineer may have been awake for up to 24 hours. In addition, he was operating a train near the end of that 24-hour period. Though not working on the same trains, the conductor had a similar work pattern. Such work scheduling meets current regulatory requirements and is not uncommon in the rail industry. This situation exists in spite of research that has determined that 17 hours of sustained wakefulness can produce fatigue-related decrements in hand-eye coordination equivalent to the impairment associated with a blood alcohol concentration of 0.05 per cent. The *Work/Rest Rules for Rail Operating Employees* permit consecutive hours of wakefulness in excess of 18 hours with no scheduled rest, which increases the risk of fatigue-related errors and accidents.

Regulatory Overview with Regard to Shift Work and Fatigue

Decreased vigilance and disregarding warning signs are typical of the types of attentional deficits associated with fatigue. In this occurrence, the crew failed to whistle at a crossing when departing Ignace. In addition, the locomotive engineer's keypunch error resulted in the incorrect radio channel being monitored. Also, the train crew members were not aware that they had passed an HBD at Mile 98.5 without receiving an audible "talker" message. These three crew errors are consistent with fatigue-related performance impairment.

The *Work/Rest Rules for Rail Operating Employees* permit highly unpredictable work patterns. In addition, the rules make no distinction between day shifts and night shifts. Research has determined that disruptions in circadian rhythms affect performance and cognitive functioning. Shift workers in particular demonstrate impairments in these functions. Studies of locomotive engineers have demonstrated degradation in reaction time and response to train safety alarm alerts during the night shift. This derailment occurred during a night shift. The locomotive engineer's work pattern had changed six times in the seven days before the accident. The most notable lack of adjustment time was on the day of the occurrence, when the train crew worked both a day and night shift. Such a transition would have required at least six days for full circadian adjustment to occur. The combination of less-than-adequate adjustment periods and complex schedules that reduce the predictability of work increases the risk of fatigue.[12] The nature of railway operations requires crew members to work variable, unpredictable schedules often for their entire working lives. Such unpredictable schedules increase the probability that train crews will be working in a chronically fatigued state, which can lead to errors associated with fatigue.

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

Findings as to Causes and Contributing Factors

1. The train initially derailed at Mile 96.41 of the Kaministiquia Subdivision as a result of a burnt-off roller bearing and axle journal in the R-2 position of car DTTX 54636. Although the hot box detector (HBD) at Mile 98.5 had broadcast an alarm on the standby channel (CP 01), the train crew was monitoring the incorrect channel (CP 04) and the message was not received.

2. The locomotive radio was inadvertently tuned to the incorrect channel (CP 04) as a result of a keypunch error by the locomotive engineer. The location of the radio in the locomotive likely contributed to the selection of the incorrect channel. Having to reach beyond one's normal range of motion to change channels increases the probability of an error in radio operation.

Findings as to Risk

1. The frequency with which train crews pass HBDs, coupled with the high probability of a "no alarm" message and the lack of any action required on their part from such a message, increases the risk of train crews being inattentive to HBDs.

2. Canadian Pacific Railway's (CPR) General Operating Instructions (GOI) contain no secondary defence to attract attention to an HBD warning if that warning is missed by the crew, nor is a train inspection required in all circumstances in the event that an HBD message is not received. Without system-wide secondary defences to support HBD operation, there is an increased risk of roller bearing burn offs occurring under similar circumstances.

3. Information recorded by CPR's HBD system is not used to its full potential. This decreases the effectiveness of the HBD as a safety defence and increases the risk that overheated roller bearings will be allowed to continue in service and result in a burn-off derailment.

4. The *Work/Rest Rules for Rail Operating Employees* permit consecutive hours of wakefulness in excess of 18 hours with no scheduled rest, which increases the risk of fatigue-related errors and accidents.

5. The nature of rail operations requires crew members to work variable, unpredictable schedules, often for their entire working lives. Unpredictable schedules increase the probability that train crews will be working in a chronically fatigued state, which can lead to errors associated with fatigue.

Safety Action

In May 2004, Canadian Pacific Railway (CPR) modified its General Operating Instructions (GOI) in an effort to improve situational awareness for locomotive engineers regarding hot box detectors (HBDs). Section 5, Item 21.2 requires the locomotive engineer to set the locomotive distance measuring device as soon as the train reaches the HBD location, and for the crew to verbally confirm any HBD announcements received with each other.

CPR, jointly with Canadian National (CN), has installed a track-side acoustic detector system on CN's Yale Subdivision (directional running zone). This device, the only one of its kind in Canada, is being tested to determine whether this technology can identify defective bearings on a predictive basis before they fail or overheat.

In 2003, CPR initiated a pilot project that involved connecting the HBDs on its British Columbia coal loop to a central monitoring system. Using this system, CPR can perform trending analysis to identify suspect bearings and can proactively set out the cars. CPR is reviewing the possibility of extending this bearing trending process to other subdivisions and car types.

This report concludes the Transportation Safety Board's investigation into this occurrence. Consequently, the Board authorized the release of this report on 07 July 2004.