RAILWAY INVESTIGATION REPORT
R98C0022

REAR-END TRAIN COLLISION

CANADIAN NATIONAL
FREIGHT TRAINS A-447-51-01 AND C-771-51-28
MILE 165.4, EDSON SUBDIVISION
OBED, ALBERTA
01 MARCH 1998

Transportation Safety Board of Canada

Bureau de la scurit des transports du Canada

Railway Investigation Report

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Synopsis

On 01 March 1998, at approximately 1531 mountain standard time, Canadian National (CN) train No. A-447-51-01 (train 447) collided with the rear end of stationary CN train No. C-771-51-28 (train 771) at Mile 165.4 of the CN Edson Subdivision, near Obed, Alberta. The two crew members in the lead locomotive on train 447 were seriously injured and taken from the scene by ambulance. The last car from train 771 and the lead locomotive from train 447 derailed and both sustained extensive damage. There were no dangerous goods involved.

The Board determined that the rear-end collision occurred when the crew of train 447, which was being operated under the assumption that train 771 was at least 1.5 miles further ahead, did not maintain adequate vigilance, resulting in the rear of train 771 not being noticed in sufficient time to bring the train to a stop. The assumption that train 771 was further ahead was based on the interpretation of an automated voice transmission provided by a Wayside Inspection System (WIS). Contributing to this accident were a lack of accurate information regarding the location of train 771, an inadequate dissemination of information regarding the nature of WIS broadcasts to operating crews, and poor visual conspicuity of the rear of train 771.

Ce rapport est également disponible en français.

1.0 Factual Information

1.1 The Accident

1.1.1 Train No. 771

Canadian National (CN) train 771 departed Bickerdike West, Alberta, Mile 140.1 of the Edson Subdivision, at approximately 1309 mountain standard time (MST)[1], travelling westward destined for Vancouver, British Columbia. Train 771 consisted of 4 locomotives and 100 loaded cars. It was approximately 6,140 feet long and weighed about 13,850 tons. The crew of train 771 was comprised of a locomotive engineer and a conductor both located in the lead locomotive. At approximately 1330, near Mile 150.1, the crew members received a report by radio from a track supervisor that car CN 199168, later established as the 59th car of the consist, was emitting smoke. The crew members immediately initiated a call to the rail traffic controller (RTC) from whom they requested information to determine if there were any heat indications from the train when it passed a Wayside Inspection System (WIS)[2] located at Mile 143.2. The RTC informed the crew of train 771 that there were slightly elevated indications on the 59th car. The crew members and the RTC then speculated that there may have been a lightly applied hand brake that may have caused the slight elevation in the indication and the appearance of smoke. They concluded that this was not serious and the train continued without stopping.

At approximately 1340, the track supervisor, who initially reported the smoke to the crew on train 771, informed the RTC by telephone that the car was smoking profusely and that the train should stop before a burnt-off journal and axle failure could occur. The track supervisor's concern was that the train had already travelled approximately 10 miles and that a burnt-off journal could occur imminently resulting in a derailment. The RTC contacted the crew members of train 771 and requested them to stop and suggested that the crew of train 818, which was travelling in the opposite direction, perform a pull-by inspection of train 771 while it was in the siding at Medicine Lodge, Mile 155.8, to assess the problem. While stopping, a coupler knuckle broke on train 771 between the 10th and 11th cars and the train came to a full stop by a train-initiated emergency brake application.

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[1] All times are MST (Coordinated Universal Time (UTC) minus seven hours) unless otherwise stated.

[2] A Wayside Inspection System (WIS) monitors for potentially unsafe operating conditions for trains and can alert train crews via a radio talker system. A WIS comprises a hot box detector, hot wheel detector, dragging equipment detector and the talker system itself. A detailed explanation of the WIS operation is found in Section 1.10 of this report.

During the time that train 771 was stopped to replace the broken knuckle, train 818 pulled into the Medicine Lodge Siding and performed a visual inspection of train 771 which had now been stopped for approximately 10 minutes. The crew members of train 818 advised the RTC that train 771 had stopped to repair a broken knuckle and that they did not see any smoke as they pulled by. The broken knuckle was replaced by the conductor of train 771 without incident.

Based on the information from the crew of train 818, the conductor of train 771 returned to the locomotive without checking the status of the 59th car. Train 771 continued westward on the single main track beyond Medicine Lodge to Hargwen (a distance of 5.3 miles where double track commences). Near Mile 164.5, the crew from eastward train No. 126 (train 126), upon passing train 771 in the opposite direction while on the double track, advised train 771 of smoke emanating in the vicinity of the 59th car. Still based on the assumption that the problem was likely a sticking brake and in order to expedite traffic and reduce congestion, the crew members of train 771 decided to travel a little farther (approximately one mile) and stop their train beyond the intermediate signal at Mile 164.9. This would allow the block to be cleared and any trains following train 771 would not be required to make an unnecessary stop. The conductor of train 771 then detrained from the locomotive to find the problem car while the train pulled by. The conductor advised the locomotive engineer to stop when he discovered a lightly applied hand brake on the 59th car. The lead locomotive of train 771 stopped approximately 250 feet past the WIS at Mile 166.5. The tail end of train 771 was approximately 5,900 feet east of the WIS at Mile 165.4. Once the WIS timed out, a preset radio transmission was sent, indicating that there were “no alarm.” The location where train 771 was stopped was not communicated by radio to the RTC or to any other train nor was immediate communication required by railway operating rules.

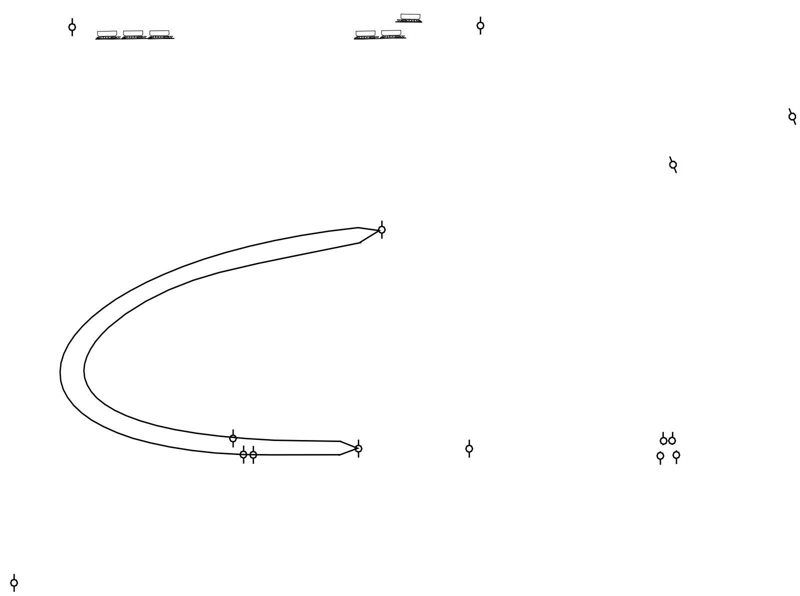
1.1.2 Train No. 447

Train 447 was travelling westward destined for Jasper, Alberta, following train 771. Train 447 was powered by 2 locomotives and was hauling 20 loaded cars and 33 empty cars. The train was approximately 3,140 feet in length and weighed about 3,490 tons. It was operated by a crew of three: a locomotive engineer and a conductor located in the first locomotive and an assistant conductor located in the second locomotive. Since train 771 was stopped with a broken knuckle, the RTC, in order to keep traffic moving, issued an authorization, under Canadian Rail Operating Rules (CROR) Rule 564, to train 447 at Galloway, Mile 150.2, to proceed into the same block occupied by train 771.

At approximately 1527, near Mile 164.6, just past Medicine Lodge, the crew of train 447 observed a restricting signal at Mile 164.9 indicating “proceed at restricted speed.”[3] Upon observing the restricting signal, the locomotive engineer of train 447 reduced the train speed to the maximum permitted speed of 15 mph. As train 447 proceeded past the intermediate signal at Mile 164.9, the crew heard the automated radio transmission from the WIS situated at Mile 166.5 indicate “no alarm.” This message was not intended for train 447 nor was it intended to provide any information related to train operation. The crew did not hear any communication from train 771 indicating that this train had stopped.

3 Restricted Speed and Slow Speed are defined in section 1.8.

The locomotive engineer and conductor of train 447 assumed, based on the information broadcasted from the WIS, that the rear end of train 771 was clear of Mile 166.5. The locomotive engineer decided to have a light snack and the conductor was checking the train manifest while negotiating a two-degree right-hand curve at Mile 165.0. The sight-line from the locomotive of train 447 was obstructed by a grove of trees. The distance from where the last car (CN 197930) of train 771 could be seen by the approaching train 447 was determined to be approximately 1,050 feet. The locomotive engineer of train 447 stated that he saw the last car just before he initiated an emergency brake application. Approximately nine seconds then elapsed before the collision with the rear car. The train proceeded for approximately 190 feet between the time the emergency brake application was made and impact. The estimated distance required to stop train 447 under normal conditions would be approximately 270 feet. The impact occurred at a speed of approximately 8 mph. There was no fuel spillage or fire.



The temperature was six degrees Celsius. The skies were clear and the winds were calm.

1.2 Injuries

Both the locomotive engineer and the conductor from train 447 sustained serious injuries. They recall being seated at their workstations in the lead locomotive at the time of initial impact. The force of the impact caused the two crew members to be thrown about the cab. The assistant conductor located in the second locomotive was not injured.

The crew members from train 406, which was proceeding on the adjacent track in the opposite direction, were the first to arrive on the scene and offer assistance. Ambulance personnel removed the injured crew members in an expeditious manner.

The locomotive from train 447 was manufactured with collision posts and an anti-climb sill, designed to prevent the cab from being crushed. The locomotive was not equipped with personal restraining devices, nor were any required, to hold a crew member in a secure position to protect that individual from secondary impact.

Methods to minimize injury from secondary impact have been addressed by the U.S. Federal Railroad Administration (FRA) in a study published in September 1996. The study was in response to a congressional mandate which dealt in part with the health and safety of cab working conditions. Although the primary focus of the study[4] was on structural design of locomotives and cabs to reduce primary impact crush, it also dealt in

[4] *Locomotive Crashworthiness and Cab Working Conditions*, U.S. Federal Railroad Administration,

detail with issues surrounding secondary impact. Several concepts were examined with regard to secondary impact. Two of the concepts involved protection against secondary impact by rotating the seat of a crew member so that the occupant could ride down a collision with his or her back to the oncoming vehicle or obstruction. Another concept called for the creation of a protective trench located at the rear of the cab in which the crew could seek refuge.

The study suggested that these concepts would protect occupants from even moderate head trauma and would reduce to 20 to 36 per cent the incidence of severe thoracic trauma. Furthermore, the use of refuge sites detailed in the study would eliminate or greatly mitigate uncontrolled momentum resulting in potentially damaging secondary impacts where hard cab surfaces or sharp objects are involved.

1.3 Personnel Information

The crew members on trains 771 and 447 were familiar with the subdivision, met fitness and rest standards and were qualified for their respective positions.

1.4 Method of Train Control

Traffic in the area is governed by the Centralized Traffic Control System (CTC) authorized by the CROR (approved by the Minister of Transport, 16 January 1990) and supervised by an RTC in Edmonton, Alberta.

1.5 Particulars of the Track

The collision occurred on the north main track of a double main track section on a two-degree right-hand curve with a 0.2 per cent descending grade for westward trains. The track structure consisted of 136-pound continuous welded rail (CWR) set on concrete ties and crushed rock ballast. There was minimal damage to the track as a result of the collision: 20 feet of rail on the north track, and approximately 115 feet on the south track. There were 15 concrete ties damaged.

The authorized maximum subdivision speed between Mile 157.5 and Mile 179.3 is 50 mph for freight trains.

1.6 Occurrence Site Information

The occurrence site was approximately 20 miles from Hinton, the nearest urban centre. Initial access to the site was limited to four-wheel-drive vehicles through a snow-covered trail. The track at the occurrence site was located about 500 metres north and parallel to the Yellowhead Highway.

1.7 Damage to Equipment

Washington, D.C., September 1996.

Both the locomotive and empty hopper car derailed and remained upright obstructing the south track. The knuckle of the rear car on train 771, CN 197930, climbed over the knuckle of the lead locomotive of train 447 and severely damaged the nose of the cab. The empty open-top hopper car was also severely damaged.

1.8 Operating Instructions and Rules

Page 4 of Section 5 of CN's General Operating Instructions (GOI) (section 5.3, entitled Talker Systems, item b)) states:

> When an entire train has passed over a hot box and dragging equipment detector and a complete inspection of the train has been conducted and no defects are detected, the following message will be transmitted:
>
> CN detector (subdivision) (mileage) (Designation of track) (in multitrack) No alarm.

Page 8 of Section 5 of CN's GOI, (item 5.3 (m)) states:

> When a train stops before the entire movement has passed over a hot box and dragging equipment detector, the front and rear portions of the train will be considered as two separate trains. Accordingly, messages as though separate trains had passed over the hot box and dragging equipment detector will be received. The crew must contact the RTC Centre to determine which portion of the train (if any) received an inspection.

CN's GOI Section 5, entitled Inspection of MOVING Equipment, item 5.10 c), states:

> If a dangerous condition is reported or noted, the train must be promptly stopped, consistent with good train handling techniques, and the car(s) inspected. If possible the defect must be corrected or other action taken to minimize or eliminate the danger.

CROR Rule 126, entitled Restricted Use of Radio, states:

> In addition to the restrictions in Rules 14 and 602, radio must not be used to;
> (i) give advance information with respect to the indication of a fixed signal; or
> (ii) give information which may influence a crew to consider that speed restrictions are diminished.

CROR Rule 426, entitled Restricting Signal, states: "Proceed at restricted speed."

> RESTRICTED SPEED
>
> A speed that will permit stopping within one-half the range of vision of equipment, also prepared to stop short of a switch not properly lined and in no case exceeding SLOW SPEED. NOTE: When moving at restricted speed, be on the lookout for broken rails.

> SLOW SPEED
>
> A speed not exceeding fifteen miles per hour.

CROR Rule 85, entitled Reporting Delays, states:

> The conductor of each train will ensure that the RTC is promptly advised of any known condition which may delay the train.

1.9 Training and Monitoring for Compliance

CN train crews must demonstrate a knowledge of the CROR through a program titled Qualifications Standard for Operating Crews (QSOC). Upon successful completion of the program and written examination, crews are issued a card which is valid for a period of three years. To requalify after the three-year period, crews are re-examined on the required subjects pertaining to their occupational category. Although the railway's qualification criteria for operating employee certification are specified by Transport Canada (TC), the specific nature of the training required is not prescribed. These are matters considered by TC to be the responsibility of the railway company.

In order to monitor crews for compliance with the many operating rules and instructions, CN has a proficiency verification and testing policy that carries out crew monitoring in three ways:

- In each district, assistant superintendents have monthly crew observation targets. To conduct the crew observations, the assistant superintendent rides along with crew members and observes their operating proficiency as compared to CN's operating practices and the requirements of the CROR.

- An audit team made up of four officers from across CN's system performs crew observation train rides twice yearly in each district. During these audits, the team assesses a broader range of the operation by monitoring not only train operations, but also yard operations, conditions of trackage, signals, and communications.

- Supervisors perform random downloads and analysis of locomotive event recorder data.

In the past, the crews of both train 771 and train 447 had been subject to normal CN proficiency testing. However, they had not had an assistant superintendent or system audit performance observation ride during the year before the occurrence.

A review of the assistant superintendent's crew observation train riding program revealed that, although the monthly target was specified, it did not specify a program that would ensure that each crew operating in the district would be included in the program nor did it contain guidance as to what areas of train operations should be monitored.

TC inspectors also ride trains to monitor employees for rule compliance and operating practices. Proficiency testing is not considered to be a function of these safety audits. TC inspectors conducted audits on 16 September 1997 and 24 November 1997 on the Edson Subdivision.

1.10 *Wayside Inspection Systems*

The WIS has in the past been sometimes referred to as a "hot box detector" because it originally was designed to detect only hot journal bearing boxes. CN uses the term WIS because the system has now expanded to include such things as a hot box detector, hot wheel detector, dragging equipment detector and a synthesized voice transmission system, known as a talker. Should any of the WIS detect an anomaly, the talker transmits a message on a monitored frequency outlining the location and nature of the alarm. The WIS also sends an electronic message of the anomaly to a computerized display system which is monitored by a hot box detector operator and an RTC mechanical supervisor at the rail traffic control centre in Edmonton. Operating crews receive a broadcast message as soon as a defect is detected. If there are no defects or motion after a specified period of time, the WIS automatically transmits a message typically structured as follows:

> CN detector (subdivision) (mileage) (Designation of track) (in multitrack) No alarm.

The message does not distinguish whether a portion or an entire train movement has passed over the detector. Other railways use similar technology but include an axle count in their broadcast message.

The WIS uses transducers which are electromagnetic devices that can detect a moving mass of metal. These transducers are mounted on the web of rail to detect the flange of wheels passing over and to activate the scanner indicating the arrival, direction and speed of a train. A lapse time is calculated relative to the speed of the train. If no transducers are triggered before the lapse time expires, the system will consider that the train has gone past the detector. In the case of train 771, the time lapsed between the passage of the first two locomotives over the WIS. This resulted in the WIS transmitting a "no alarm" message.

1.11 *Situational Awareness of Train Movement and Location*

When making and implementing plans to move and control a train, the success of a train crew's decisions and actions greatly depends upon an accurate assessment and understanding of train movement and an ability to select appropriate courses of action based on situational awareness. Situational awareness is a term used to describe an individual's awareness of operational conditions and contingencies. It is defined as all the knowledge that is accessible and can be integrated into a coherent picture, when required, to assess and cope with a given situation. A person performing a dynamic job, such as operating a train, requires situational awareness to make and implement plans to control the train safely throughout a trip. Under general operating conditions, situational awareness develops on three different levels.[5] Initially, a person perceives situational elements from information displays, communications or other references. Then, this information is integrated into an overall understanding of the situation by the application of past experience and a knowledge of how the system works, often referred to as a mental model. Finally, the person projects the acquired information into the future to make and modify plans as tasks are completed or delayed with new developments.

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5 M.R. Endsley (1994a). Situational awareness in dynamic human decision making measurement. In *Situational Awareness in Complex Systems, Proceedings of a CAHFA Conference, February 1993.* Fl: Embry-Riddle Aeronautical University Press, 79-97.

Cues, or information about the situation, can vary between clear and ambiguous. The clearer the cues, the less mental effort is required to interpret them and the more accurate the diagnosis of the situation is likely to be. Once a mental model, or a certain way of thinking about a problem, is adopted, it is very resistant to change. In order to change one's thinking, the existing mental model must be superseded by another. New information must be sufficiently compelling to cause people to update their mental model.

A train crew's situational awareness may develop from various information sources. These can include radio transmissions, as for example, crew-to-crew conversations or the message received from the WIS. Other information sources can be made up of: signal aspects and RTC information; a crew's view of the track from the cab; landmarks or environmental conditions; sounds from the environment, including noise from other trains and traffic; and written information such as timetables, Daily Operating Bulletins or CROR. Railway rules and guidelines affecting situational awareness, such as those in the CROR and GOI, refer to particular sources of information that operating crews are either permitted or required to use. In this occurrence, examples of permissible information sources included signal indications, radio contact with the RTC, radio contact with other train crews and radio contact with the maintenance supervisor. An example of restricted information is defined in CROR Rule 126, which states, in part, that a radio must not be used to give advance information with respect to the indication of a fixed signal, or to give information which may influence a crew to consider that speed restrictions are diminished.

The Board has previously identified a lack of information available to train crews for developing adequate situational awareness, thus contributing to rear-end collisions (TSB report No. R96Q0050). The TSB expressed concerns that there were no established crew resource management programs in use on railways that would ensure that all persons involved are aware of the most up-to-date, accurate information concerning the movement of trains and engines. The TSB has also expressed concerns that, when specific methods of communications transmission and verification are not in place, there is a greater risk that a piece of information could be misinterpreted.

1.12 Train Conspicuity and Rear-end Reflective Markers

Train 771 was equipped with a red reflectorized marker measuring 6 inches by 10 inches mounted on the Sense and Braking Unit (SBU), positioned on the coupler of the rear car of the train as permitted by TC regulations. The marker on the rear car (CN 197930) was reasonably clean but the car itself was covered with coal dust, dark in colour and blended in with the surroundings.

Historically, trains were equipped with cabooses which were well marked and lighted, making them visible both day and night. However, in 1987, after a series of in-depth public hearings, the Railway Transport Committee of the Canadian Transport Commission granted permission for CN and Canadian Pacific Railway (CPR) to operate trains without cabooses providing these cabooseless trains were operated with certain safety-related conditions. One of these conditions in clause 1.1 of that order (No. R-41300) stated:

> A train may be operated without a caboose and with the rear crew located in the cabs of the lead locomotive consist provided the train is equipped with an end-of-train-information system with a rear train emergency braking feature and a red flashing marker light operated by an automatic light sensitive cell. . . .

This clause was based on the results of a number of field tests which, in part, involved the testing of the reliability of rear marker lights. Both CN and CPR reported, at that time, that the results were excellent.

On 05 November 1990, TC revoked clause 1.1, in response to applications by CN and CPR, which was based on the unreliable operation of the rear marker light particularly under extreme weather conditions and replaced it with a clause that did not require a marker light on the rear car of cabooseless trains. TC concluded that the changes were in the public interest and not likely to threaten safe train operations.

On 11 August 1995, TC revoked order R-41300 and indicated that the stipulations of the Railway Transport Committee order were being addressed effectively by other means and that the revocation of the order was in the public interest and would not likely threaten safe train operations.

Currently, reflectorized markers are being used for domestic traffic. However, in order to meet U.S. regulatory requirements, CN and CPR use flashing rear marker lights on international cross-border traffic. The U.S. regulation requires the use of reflectorized markers by day, and a continuous or flashing rear-end marker light by night and during inclement weather.

The new generation of SBUs are equipped with both light and reflector. Technological advances have allowed extension in battery life and simultaneous reduction in weight.
On 28 October 1994, an eastward freight train struck the rear of a preceding freight train at Mile 5.8 of the Halton Subdivision in Etobicoke, Ontario. In its investigation (TSB report No. R94T0334), the Board made findings as to the causes and contributing factors. However, in keeping with its mandate, the Board delved further and identified a safety deficiency evidenced by the occurrence. Specifically, the TSB found that tank cars carrying loads of explosive or toxic dangerous goods were permitted to be marshalled at and close to the end of non-illuminated cabooseless trains. The Board was concerned that rear-end collisions in these or any other circumstances continued to put Canadians at risk. With a view to reducing or eliminating what is considered an underlying safety deficiency in the rail system, the Board recommended that:

> The Department of Transport re-assess the risk associated with operating cabooseless trains without an illuminated rear marker.

(R96-12, issued July 1996)

On 23 October 1996, TC responded that the accident which had prompted the recommendation would not have occurred had the crew complied with speed requirements. It was further indicated that, since the lack of a marker was not identified as causative, TC did not see the necessity to further review the issue of lighted rear markers. TC also advised that rear markers are intended to define the tail end of a train for the purposes of a number of CROR applications, and not to prevent rear-end collisions.

1.13 Other Previously Reported Rear-end Collisions on Main Track

Between 1993 and 1998, there have been 13 rear-end main track train collisions in Canada where circumstances have involved not stopping within one-half the range of vision of equipment while being required to proceed at restricted speed. The 13 occurrences in this five-year period were at a rate 30 per cent higher than those experienced in the five years previous (between 1988 and 1992). All 13 occurrences involved one train which was stopped and another train which collided with it from the rear. Subsequent to these occurrences, the TSB issued several safety information letters and advisories. These advisories and letters are summarized below:

1. Rail Safety Information 09/95 (TSB Occurrence R95T0023) - *Instruction and Application of CROR Rules Pertaining to Block Signals*
   In this occurrence, an eastward CN freight train collided in the darkness with the rear of a stationary freight train on the Stamford Subdivision. The train crew members inappropriately interpreted a clear signal which indicated that the track was clear for the block ahead to mean that the track was also clear in the block they were occupying. The train proceeded without totally adhering to the speed restriction imposed by the speed-restricting rule and collided with the train ahead.

2. Rail Safety Information 10/95 (TSB Occurrences R94T0334, R95S0021 and R95T0101) - *Correct Application of CROR Rule 34*
The safety information letter, issued through these occurrences, addressed the issue that some crews have adopted unsafe practices and do not communicate signal indications to each other as required by CROR Rule 34.

3. Rail Safety Advisory 10/95 (TSB Occurrence R95T0152) - *Canadian Rail Operating Rules 570 (a) and 575*
A CPR freight train standing on the main track on the North Toronto Subdivision was struck from behind by the 3rd Emery train. The 3rd Emery train entered the block governed by a restricting signal and performed some switching in an adjacent yard. Upon re-entering the main track, the crew members assumed that CROR Rule 575 (Delayed in the Block) would apply allowing them to proceed without any speed restriction except to be prepared to stop at the next signal. This occurrence typified misinterpretation of the requirement of proceeding at restricted speed as governed by signal indication.

4. Rail Safety Information 01/96 - (TSB Occurrence R96Q0050) - *Observations on Quebec North Shore and Labrador Railway (QNS&L) Collision*
A QNS&L freight train collided with the rear of a stationary train on the Wacouna Subdivision. The locomotive engineer in this occurrence operated his train past a restricting signal indication at a speed at which the train could not be stopped within one-half the range of vision of equipment.

1.14 Available Technology to Enhance Situational Awareness

QNS&L presently equips its locomotives and track maintenance vehicles with a Global Positioning System (GPS)-based Proximity Detection Device (PDD) that will warn the operating crew when the proximity limits are exceeded and, in some cases, will ensure that positive train separation is maintained by automatically intervening in the operation of the train. These units operate by providing an audible and visual alarm to the operator when another equipped vehicle is within a prescribed track range. The alarm must be acknowledged by the locomotive engineer within a certain amount of time or the PDD will initiate a penalty brake application on the train.

Other advanced technology such as Positive Train Separation (PTS) provides a safety overlay system that serves as the foundation for reliable communication-based train control. Designed to operate with existing signal systems, this collision-avoidance system maintains PTS by issuing and autonomously enforcing rigid movement authorities. On-board location determination equipment, using GPS, track databases and consist characteristics, enables the PTS system to compute safe braking distances in real time. This ensures that trains will be safely stopped before authority or speed limits are violated, even in the event of locomotive engineer error or impairment, or signal system failure. Position reports are regularly transmitted in real-time, back to control centres for display, new authority generation, and safety checks.

2.0 Analysis

2.1 Introduction

The frequency and circumstances surrounding rear-end collisions and the link to decisions made by crew members regarding the application of a restricted speed rule continue to be problematic. This analysis examines the sequence of events leading up to the collision, causes of crew injuries, responses to warnings of a potential malfunction on train 771, factors that may have influenced the situational awareness leading to the lack of vigilance of the crew on train 447, inadequate rear-of-train conspicuity and the absence of a comprehensive approach to the safe separation of rolling stock.

2.2 Train Operations

The continuous operation of train 771 for approximately 20 miles without confirming the source of smoke emanating from car CN 199168 compromised safe train operation. Once the crew members became aware of the condition on their train, the train should have been brought to an immediate stop without further exposing the train to a potential unsafe operating condition. This requirement is outlined in GOI section 5.10 (c). However, instead of assigning a high level of urgency when the warning of a smoking car was first given, and stopping to verify that condition, train 771 continued and the crew relied on a pull-by inspection by another train. Also, when another opportunity existed at Medicine Lodge to inspect the 59th car, this inspection was not done either. Such an inspection would have discovered the cause of the smoke, prompted release of the hand brake and negated the requirement for further stops.

The crew of train 447 reduced speed to 15 mph upon reaching the signal at Mile 164.9 (the maximum allowable under the provisions of a restricting signal), but did not maintain vigilance being prepared to stop within one-half the range of vision of the preceding train because of an inaccurate mental model of the location of train 771. The "no alarm" broadcast from the WIS prompted the crew to believe that train 771 had completely passed the location of the WIS which was 1.5 miles ahead. The "no alarm" message is ambiguous because it does not distinguish whether an entire train or portion of train has passed over the WIS. This occurrence illustrates that crew members can inappropriately structure a mental model based on outside information such as WIS radio broadcasts, and based on this model, lower their level of vigilance. WIS broadcasts are not intended to be used by train crews for traffic information, but when they are, the "no alarm" message is ambiguous. The mental model is then processed into a work plan which develops into a particular course of action that may not be safe in the circumstances.

2.3 Injuries

Injuries sustained from secondary impact by the two crew members in the lead locomotive of train 447 were consistent with unrestrained occupants striking objects in the cab after the initial low-speed impact.

Without personal restraining devices or a cab designed to provide further protection against secondary impact, it is unlikely that crew injuries would be averted or significantly reduced in severity in low-speed collisions. Notwithstanding the injuries sustained by the crew members, it is recognized that the collision posts manufactured in the locomotive prevented the locomotive cab from being crushed onto the crew during the accident and averted what may have been much more serious injuries.

2.4 Training, Supervision and Monitoring for Compliance

The information prescribed in GOI section 5.3 (b) refers to when the *entire train* has passed a WIS site. The additional information of the WIS site function in GOI 5.3 (m), which refers to the effect on the WIS when a train stops before the entire movement has passed, is presented four pages after item (b). The change in conceptual topics and the physical separation of several pages between these two critically related items reduces the effectiveness of the GOI in conveying the important relationship between section 5.3 (b) and (m).

Adherence to GOI, operating bulletins, CROR, and affirmation of correct procedures and practices were evaluated by CN's set of standards for training and proficiency testing. Without monitoring for compliance to set standards and reinforcement of training, through a systematic program of proficiency testing, it was unlikely that all crews were systematically monitored. Given the nature of CN's supervisory program, it was also unlikely that inappropriate operating practices, such as using the radio broadcast from the WIS stations to orient the location of a preceding train, would have been identified. Had the improper use of this WIS information been identified through the supervisory program, and appropriate steps taken to reduce this practice, the risk of this type of rear-end collision would have been substantially reduced or eliminated.

2.5 Situational Awareness

Communication can often serve a critical role in the creation and maintenance of situational awareness. This allows for the constant updating of the mental model and work plan, thus providing measures that can reduce the potential for error. Communication between the RTC and train crews could provide all crews operating in proximity to each other with more accurate and up-to-date information concerning the location of other trains in the vicinity or in the same block. This can result in crews establishing more effective and error-free work plans. Prompt advising, per CROR Rule 85, does not prescribe immediate radio notification to the RTC or other trains in the vicinity when a train is being delayed. If CROR Rule 85 unambiguously demanded an immediate radio broadcast to take place on recognition of the potential for train delay, the situational awareness of other train crews in the vicinity would be enhanced and their mental models updated according to the radio message, thus reducing the potential for error.

In this case, the crew members of train 447 developed a mental model as to the location of the rear of train 771 based on the radio message from the WIS at Mile 166.5. When they heard this WIS message, they assumed that the entire length of the train had passed over the WIS at Mile 166.5, when in fact only the two locomotives had passed over it. Given their past experience with the WIS as a reliable indicator of the location of other trains, and in the absence of any other information to the contrary, they believed that they were receiving a clear and definite cue as to where the train was located. The information from the WIS was the most compelling and recent information available to them and they therefore built a mental model that oriented the rear of train 771 at the wrong location.

Given that the crew members were very familiar with the territory where they were operating, the locomotive engineer, being confident in his mental model of where the end of train 771 was located, elected to have a snack instead of maintaining the high level of vigilance required when operating at restricted speed. Upon seeing the last car of train 771, the locomotive engineer's mental model had to be quickly updated and an appropriate response initiated. By the time the emergency brake was applied, only nine seconds remained which was insufficient to bring the train to a stop in time to prevent the collision.

2.6 Train Conspicuity

The dirty and dark appearance of the rear of train 771 did not enhance the train's conspicuity nor was the small reflectorized marker clearly visible in these conditions. It is generally recognized that, the more visible the marker of the rear of a train is, the sooner it will be seen, thus providing more time to react and take action when noticed. Visual attention is drawn to items that are large, bright, colourful and changing or blinking.

Since situational awareness relies extensively on vision, it is possible that a more conspicuously marked rear end of train 771 might have allowed the crew of train 447 to recognize the train earlier. Even while this occurrence took place in mid-afternoon local time, the last car on train 771 was neither equipped with a highly visible marker or strobe indicator lights nor was it brightly visible. The visual stimulus, a reflective marker measuring 6 inches by 10 inches, was not enough to attract the crew's attention. Moreover, there is no defined standard either for the size of rear-end reflective markers or for measures to make the rear of trains more conspicuous.

2.7 Safe Separation of Rolling Stock

Although radio communication was available to provide accurate train location information, there was no procedure in place to use radio communications by the train crews for this purpose. The use of advanced technology, which can detect the presence of other trains or equipment and sound an alarm, would have provided up-to-date information to assist the train crew in forming a more accurate mental model of other train and equipment locations. The information on the proximity of preceding train 771 may have provided sufficient information to avert this collision.

3.0 Conclusions

3.1 Findings

1. The crew members of train 447 operated the train under the assumption that train 771 was at least 1.5 miles further ahead, and did not notice the rear of train 771 in sufficient time to bring their train to a controlled stop.

2. The crew's interpretation of the Wayside Inspection System (WIS) broadcast message resulted in train 447 being operated at a reduced level of vigilance.

3. The WIS in use by CN is not designed to distinguish between whether a portion or an entire train movement has passed over the detector, thus the broadcast message does not provide unequivocal information to the train crew on this point.

4. The CN training and proficiency testing standards did not identify inappropriate short cuts and operating practices, such as using the WIS information to establish the location of train 771.

5. An immediate radio broadcast on the designated standby channel and to the RTC by the crew of train 771 upon recognition of a pending train delay would have increased situational awareness for the other train crews in the vicinity and likely averted the collision.

6. Developing an accurate mental model of where train 771 was located would have been enhanced by inter-crew communications or technology used for the safe separation of rolling stock. The use of this technology or enhanced communications would have improved the situational awareness of the crew of train 447 and prompted a higher level of vigilance.

7. Promptly stopping and inspecting train 771 immediately, as required by GOI section 5.10 (c), would have resulted in the smoking condition on the 59th car being corrected, thus eliminating the need for an additional stop and averting this accident.

8. A warning system (such as a highly visible marker or flashing light) making the rear of the train more conspicuous would probably have attracted the crew's attention earlier, providing more time to react.

9. The severity of crew injuries may have been significantly reduced or averted by a cab designed to provide further protection against secondary impact, or use of personal restraining devices on the lead locomotive of train 447. However, the primary impact protection provided by the locomotive collision posts prevented the cab from being crushed onto the crew.

3.2 Cause

The rear-end collision occurred when the crew of train 447, which was being operated under the assumption that train 771 was at least 1.5 miles further ahead, did not maintain adequate vigilance, resulting in the rear of train 771 not being noticed in sufficient time to bring the train to a stop. The assumption that train 771 was further ahead was based on the interpretation of an automated voice transmission provided by a Wayside Inspection System (WIS). Contributing to this accident were a lack of accurate information regarding the location of train 771, an inadequate dissemination of information regarding the nature of WIS broadcasts to operating crews, and poor visual conspicuity of the rear of train 771.

4.0 Safety Action

4.1 Action Taken

4.1.1 Injuries

Transport Canada (TC) advises that the Rail Safety Equipment staff raised the issue of personal restraining devices at the recent semi-annual meetings with the railways and unions. Each of the three major railways has in place a Cab Committee that looks into cab amenities and TC has been invited to participate on the Cab Committees.

4.1.2 Performance Monitoring and Rule Compliance

CN advises that the current version of performance monitoring provides an audit trail that defines what parameters the line officer should monitor, and in addition, includes data on employees who have not been monitored (i.e. riding with) by a line officer.

4.1.3 Available Technology to Enhance Situational Awareness

TC is participating on various working groups examining the implications of technologies to enhance situational awareness as part of the Rail Safety Advisory Council process in the United States. TC states that the result of these efforts will be monitored and considered in terms of the potential for further action in Canada.

4.2 Action Required

4.2.1 Safe Movement of Railway Rolling Stock

The Board has previously addressed the issue of rear-end collisions. The larger issue of reducing the risk of collision on main track is a TSB Key Safety Issue. The National Transportation Safety Board (NTSB) has also stated its concern in this area and has included on its list of "Most Wanted Transportation Safety Improvements" a need for railways to have a collision avoidance system. The railways must be responsible for ensuring the safe operation of trains. Nevertheless, in the public's interest, it is the Board's view that TC's regulatory responsibilities include ensuring that the railways have effective systems in place to prevent train collisions. The Board has observed the growth of rail industry technology and is aware that there are numerous new technologies which are intended to ensure the safe separation of trains. Furthermore, low-cost and interim solutions to reduce the risk of rear-end collisions have not been fully examined. The Board is concerned that the risk of train collisions due to inadequate safe distances between railway rolling stock remains and therefore recommends that:

> The Department of Transport ensure that an assessment is made of the technologies designed for the safe separation of railway rolling stock movements, with the intent of establishing a minimum safety standard.

R00-02

4.2.2 Reporting Delays to Operations

The effective and safe operation of a railway is largely dependent upon accurate and timely communications between the RTC and others whose work may affect or be affected by train operation. The interpretation of "prompt advising," per existing rules, does not always promote timely notification to the RTC, trains and others in the vicinity when a train is being delayed and poses a safety risk. Immediate communication on recognition of the potential for train delays promotes timely adjustment by others affected. Therefore, the Board recommends that:

> The Department of Transport ensure that an assessment is made of the suitability of current Canadian Rail Operating Rules and railway instructions concerning the immediate reporting of operating delays to all concerned when there is a safety risk.

R00-03

4.3 Safety Concern

The Board recognizes that current locomotive cabs are designed with cab crashworthiness and crew injury prevention as a primary concern as it pertains to collisions and derailments. In addition, personal injuries in the locomotive cab can result from train action, such as slack in the train running in or out, unexpected emergency stopping, or sudden lurching of the train. For a person in a locomotive cab, these situations often result in a person losing his or her balance, falling, and in the process, striking any of the sharp metal objects permanently fixed in the cab. For example, abdominal and chest injuries can result when the body torso strikes the edges of the control stand or the conductor's table. Other examples include the water cooler or hot plate bracket which, if fallen upon, could result in a laceration or a blunt trauma injury.

There are a number of approaches that could be employed to reduce secondary impact injuries. A direct approach would be to relocate the hazardous structures, or use personal restraining devices. However, given that there is always a trade-off between safety and operational considerations, it may not be practical to relocate fixed objects. In this case, risk of personal injury may be reduced by applying a number of engineering design techniques, such as smoothing sharp edges, adding padding to distribute the contact force, or using more energy-absorbing materials for construction. Designing the interior of the cab with an ergonomic view of eliminating these situations and introducing the use of personal restraining devices would reduce personal injuries within the locomotive cab. The Board is concerned that, without ergonomically modifying the interior of the locomotive cab to provide protection against secondary impact, the risk of the inherent hazards within the locomotive cab will continue to contribute to injury severity.

This report concludes the Transportation Safety Board's investigation into this occurrence. Consequently, the Board authorized the release of this report on 14 March 2000.

Appendix A - Glossary

CN	Canadian National
CPR	Canadian Pacific Railway
CROR	Canadian Rail Operating Rules
CTC	Centralized Traffic Control System
CWR	continuous welded rail
FRA	Federal Railroad Administration
GOI	General Operating Instructions
GPS	Global Positioning System
mph	mile(s) per hour
MST	mountain standard time
NTSB	National Transportation Safety Board
PDD	Proximity Detection Device
PTS	Positive Train Separation
QNS&L	Quebec North Shore and Labrador Railway
QSOC	Qualifications Standard for Operating Crews
RTC	rail traffic controller
SBU	Sense and Braking Unit
TC	Transport Canada
TSB	Transportation Safety Board of Canada
U.S.	United States
UTC	Coordinated Universal Time
WIS	Wayside Inspection System