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

RAILWAY INVESTIGATION REPORT R07D0009

MAIN-TRACK TRAIN DERAILMENT

CANADIAN NATIONAL
FREIGHT TRAIN M-31031-10
MILE 99.13, DRUMMONDVILLE SUBDIVISION
DRUMMONDVILLE, QUEBEC
12 FEBRUARY 2007

Canada

The Transportation Safety Board of Canada (TSB) investigated this occurrence for the purpose of advancing transportation safety. It is not the function of the Board to assign fault or determine civil or criminal liability.

Railway Investigation Report

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Canadian National
Freight Train M-31031-10
Mile 99.13, Drummondville Subdivision
Drummondville, Quebec
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Report Number R07D0009

Summary

On 12 February 2007, at 0908 eastern standard time, Canadian National freight train M-31031-10 derailed 8 cars at Mile 99.13 of the Drummondville Subdivision, near Drummondville, Quebec. One of the derailed cars was an empty low-pressure tank car that last contained aviation fuel (UN 1863). There was no release of product and no injuries. Approximately 850 feet of track was damaged.

Ce rapport est également disponible en français.

Other Factual Information

The Accident

On 12 February 2007, eastward Canadian National (CN) freight train M-31031-10 (the train) departed Montréal, Quebec, destined for Joffre, Quebec. The train consisted of 5 locomotives and 105 cars (80 loads and 25 empties). The train was 7006 feet long and weighed 10 815 tons. It was operated by a crew consisting of a locomotive engineer and conductor. They met fitness and rest standards and were qualified for their respective positions.

The trip from Montréal was uneventful until the train was near Drummondville, Quebec (see Figure 1). At 0908:29 eastern standard time, [1] while the train was travelling at 31 mph with the throttle in position 8, an undesired emergency brake application (UDE) occurred at Mile 98.80. At Mile 98.72, with the locomotive brake cylinder pressure at 67 pounds per square inch (psi), the locomotive engineer bailed off the independent brake at 0908:42. Four seconds later, the train accelerated from 8 mph to 10 mph then again began to slow down. The train came to rest at 0909:01 with the lead locomotive at Mile 98.69, just past an automated public crossing at Notre-Dame Street. The train crew followed emergency procedures, inspected the train and found that eight cars had derailed.

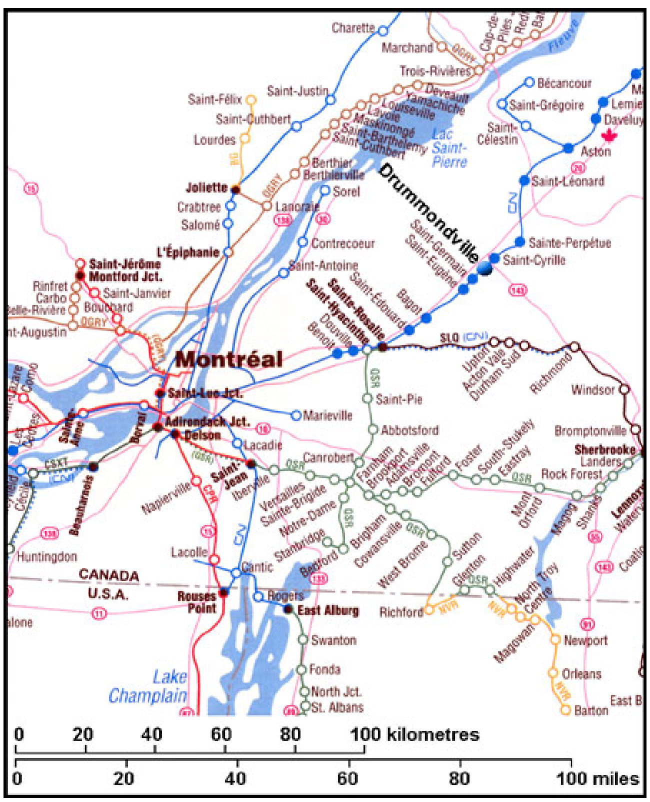

Figure 1. Derailment location, Drummondville, Quebec (Source: Railway Association of Canada, *Canadian Railway Atlas*)

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

The temperature at the time was approximately -12°C and the wind was from the northwest at 22 km/h.

Site Examination

All derailed cars remained upright and sustained minimal damage. The cars jackknifed along the main track and derailed in two groups. The 30th car (CGTX 30583), a 59-foot-long empty tank car, and 31st car (ETTX 701262), a 93-foot-long loaded multi-level automobile car, separated and derailed at Mile 99.13. Wheel flange marks were observed on the head of the south rail between the two cars. The trailing end of the 30th car derailed to the south side of the track while the south-side wheels of the 31st car's lead truck dropped between the rails, near the Drummondville Siding west switch at Mile 99.20 (see Figure 2).

The second group (39th to 44th cars) were all 93-foot-long loaded multi-level automobile cars that derailed at Mile 99.24. Each of these cars came to rest across the track; the rails had rolled out from beneath them. The Drummondville Siding west switch and approximately 850 feet of main track were damaged. The derailed cars were examined and no pre-derailment defects were noted.

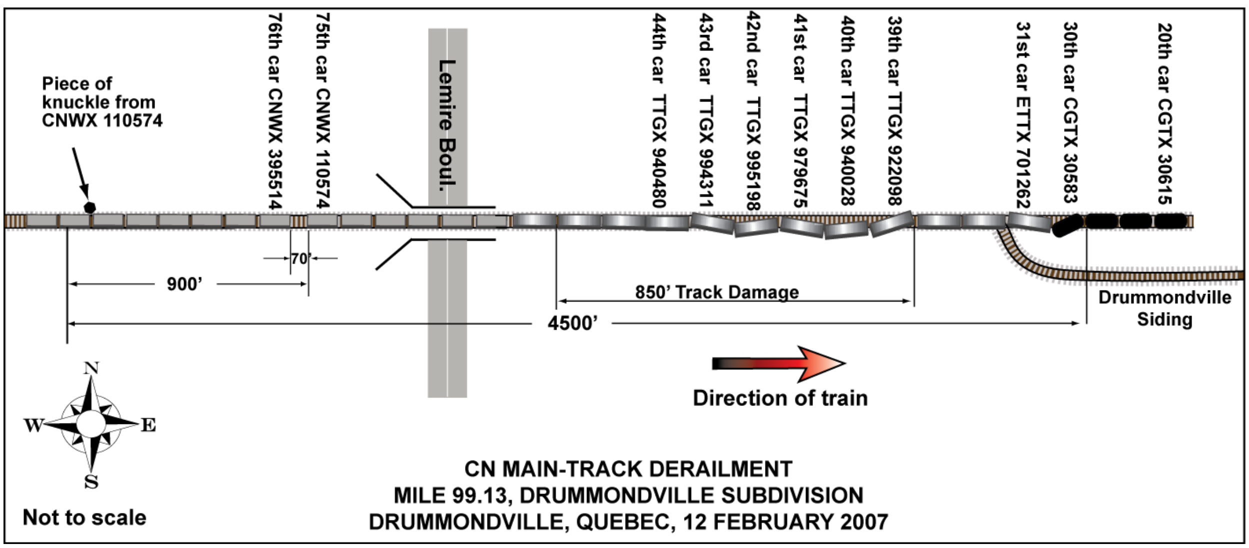

Figure 2. Site diagram

The train separated between the 75th (CNWX 110574) and 76th (CNWX 395514) cars. A broken knuckle was found on the trailing A-end of the 75th car; the mating portion of the knuckle was located on the ground, 900 feet west of the car. The draft gears on most of the head-end cars were fully compressed and the coupler horns were pressed tight against the striker castings.

Following the derailment, the crew tried unsuccessfully to charge the train air brakes on the head-end portion of the train that had not derailed. Subsequent inspection revealed that the air brake cut-out valve assembly (the valve) on the 20th car (CGTX 30615) had broken. The broken knuckle and the valve were sent to the TSB Engineering Laboratory for failure analysis.

Track Information

The Drummondville Subdivision consists of a single main track, with an east-west orientation, extending from Saint-Romuald (Mile 4.4) to Sainte-Rosalie, Quebec (Mile 125.1). In the derailment area, train movements are governed by the Centralized Traffic Control System as authorized by the *Canadian Rail Operating Rules* and supervised by a CN rail traffic controller located in Montréal. It is Class 5 track [2] with a maximum allowable operating speed of 80 mph for freight trains and 100 mph for passenger trains, but with a permanent 30 mph slow order between Mile 97.5 and Mile 99.0, through downtown Drummondville. The traffic consisted of 10 passenger and 14 freight trains daily, with annual tonnage totalling approximately 39 million tons.

In the area of the derailment, the track is tangent. From Mile 99.30, the track ascends eastward at a 0.40 per cent grade to Mile 98.90 then at a 0.80 per cent grade to Mile 98.60. The track was in good condition. The rail was 136-pound continuous welded rail manufactured in 1997, laid on 14-inch double-shouldered tie plates and secured with two spikes per plate on No. 1 treated hardwood ties. There was an average of 59 ties per 100 feet of track with every second tie box-anchored. The ballast was crushed rock, the cribs were full and the shoulders were 12 inches wide. The track was inspected according to regulatory and company requirements; no defects were reported in the derailment area.

Train Marshalling and In-Train Forces

The train was marshalled with a mix of 23 empties and 7 loads in the head-end 30 cars, followed by a block of 25 loaded multi-level automobile cars equipped with long travel (10 inches) hydraulic end-of-car cushioning devices (EOCCD) and a block of 50 heavily loaded grain cars equipped with conventional draft gears on the rear of the train (see Figure 3).

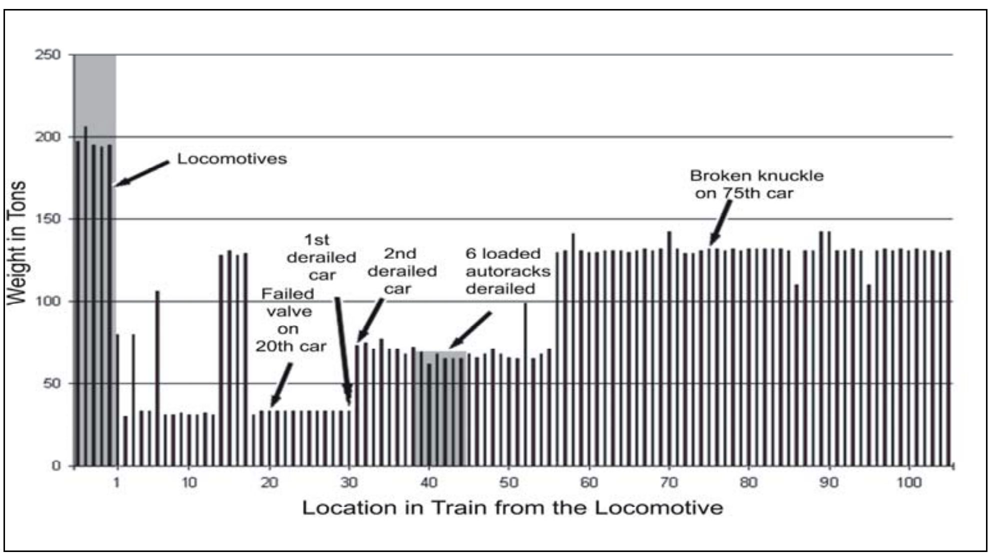

Figure 3. Train tonnage distribution

2 *Railway Track Safety Rules* (TSR), Part II, Section A.

The Association of American Railroads (AAR) *Train Make-Up Manual* [3] indicates that cars equipped with EOCCD add to train slack and can greatly increase in-train forces. Specifically, the manual states that large blocks of EOCCD–equipped cars should not be placed ahead of large blocks of loaded cars with conventional draft gears.

CN freight trains are made up using a destination block marshalling method. Blocks of cars are placed in the train in a manner that expedites their set-out or pick-up along the train's route. To assist in planning the make-up of the train, CN uses a computerized system that identifies any train marshalling that does not comply with either Transport Canada–approved *Transportation of Dangerous Goods Regulations* or CN's General Operation Instructions (GOIs). CN's GOIs have placement and trailing tonnage restrictions for certain types of cars, but there are no operational restrictions for marshalling most empty freight cars in a train.

In contrast, another major Canadian railway has developed and implemented a marshalling system to minimize the effect of in-train forces. It is computer-supported and includes instructions regarding trailing tonnage limits for specific types of car equipment. The limits vary depending on the type of car, length of the car, weight of the car (content plus tare), length of adjacent car as well as the curvature and grade of the track over which the car will operate. The system also considers and assists with the placement of cars with EOCCD and remote locomotive consists. It requires that freight trains be made up, to the maximum extent practicable, with the loads located closest to the locomotives. For mixed conventional trains, the marshalling of heavy blocks of cars at the rear of the train is prohibited unless blocks ahead are equally as heavy. Light cars (empties) or blocks are to be marshalled as close as possible to the rear unless the cars behind are also relatively light.

The Federal Railroad Administration (FRA) has conducted studies [4] to evaluate the operation of freight train air brakes. The studies have shown that, during emergency brake applications, run-in on a train configured with the empties ahead and loads behind can generate significantly higher buff force when compared to trains with a more uniform weight distribution.

To manage in-train forces during emergency braking, CN locomotive engineers are trained to bail off the independent brake when a UDE occurs. However, the decision to bail off is left to the locomotive engineer's discretion because there may be situations, such as descending a grade or approaching crossings, when it may be preferable to keep the independent brake applied. CN has equipped half of its main-line locomotive fleet (including the lead locomotive in this occurrence, CN 5766) with Trainlink-ES, which automatically initiates synchronous braking from both the locomotive and the tail end, to help prevent run-in during braking. For locomotives not equipped with Trainlink-ES, CN directs locomotive engineers to activate the

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3 Association of American Railroads, Research and Test Department, Report No. R-802, *Train Make-Up Manual*, January 1992.

4 DOT/FRA/ORD-84-16, *Freight Train Brake System Safety Study*, November 1984; Association of American Railroads, Report R-185, *Track Train Dynamics to Improve Freight Train Performance*, "TTD Guidelines for Optimum Train Handling, Train Makeup, and Track Considerations," November 1979.

emergency brake from both the locomotive and the tail end by placing the automatic brake valve in the emergency position, and actuating the emergency toggle switch on the locomotive stand.

Buff Force Analysis

Buff force analysis was conducted [5] to determine the amount of in-train buff force generated during the UDE and to replicate other scenarios. Utilizing train consist information and locomotive event recorder timing, and assuming that the train separation between the 75th car and 76th car initiated the UDE, the following observations were made:

- A buff force of 311 000 pounds (311 kips) was recorded just behind the locomotives. A maximum buff force of 444 kips was recorded between the first two derailed cars (30th and 31st) just before the locomotive independent bail off.

- Had the independent brake been bailed off within the average human reaction time of two to four seconds, a maximum buff force of 119 kips would have been recorded between the 30th and 31st cars.

- Had the train been marshalled with the loads at the head end and empties at the rear, a maximum buff force of 311 kips would have occurred in the train.

Failed Knuckle and Valve Examination

A review of maintenance records for car CNWX 110574 determined that the knuckle was installed by a non–CN shop in September 2005. Original casting marks (AAR 553 E50 BE 06 05) indicated that the E-type knuckle was made from Grade E steel manufactured by Siderúrgica Nacional (Sidena) of Mexico in June 2005. CN has never purchased knuckles from this manufacturer and Sidena is no longer supplying these components to the rail industry. The broken knuckle was examined [6] and the following observations were made:

- The fracture surface had an appearance consistent with fresh overstress fracture. There was no rubbing damage, corrosion or unusual features observed. Two small regions of pre-existing fatigue, measuring about 1/4 inch long by 1/8 inch deep and 1/2 inch long by 1/8 inch deep, were observed along the edge of the fracture surface. Chevron markings pointed back to and identified the small fatigue regions as the fracture origin.

- The measured Brinell hardness (BHN) of 170 was well below the AAR requirement of 241 to 291 BHN for Grade E knuckles. The measured BHN corresponds to an estimated tensile strength of 81 000 psi, which is below the 120 000 psi AAR requirement.

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5 TSB Engineering Laboratory Report LP 023/2007

6 TSB Engineering Laboratory Report LP 021/2007

- At the occurrence temperature of -12°C, Charpy impact testing measured 5.5 foot-pounds, which is well below the AAR requirement of 20 foot-pounds at -40°C. In addition, the knuckle was neither quenched nor tempered, which does not conform to AAR specifications.

The valve was manufactured by New York Air Brake and installed when car CGTX 30615 was constructed in 2000. There are no TSB or industry records of similar valve failures. Examination of the valve (LP 021/2007) revealed that there were no manufacturing defects present. The fracture surface exhibited a heavily corroded pre-crack, which progressed through about 20 per cent of the casting wall cross-section. The remainder of the fracture surface exhibited features that were consistent with a fresh overstress fracture. The fracture originated at the casting mold separation seam, which had a rough surface finish and was located in an area of the elbow that was affected by cyclic loads due to flexing of the car structure in normal service. The features and location of the pre-crack were consistent with fatigue failure.

Analysis

The track was in good condition and was not considered to be causal in this occurrence. The train derailed subsequent to a UDE. The damage observed at the site, including the valve failure, was consistent with damage sustained as a result of a high in-train buff force event. Therefore, the analysis will focus on the location and source of the UDE, in-train buff forces, train handling and marshalling practices, as well as the knuckle and valve failures.

The Accident

The train had travelled 580 feet between the time the air brake pressure drop caused by the UDE arrived at the lead locomotive and the time the train stopped. However, the broken knuckle from the 75th car (CNWX 110574) was found about 900 feet behind the stopped location of the car. Therefore, the knuckle failed before the UDE occurred. As a result of the broken knuckle, the train pulled apart between the 75th and 76th cars, which separated the air hoses and caused the UDE.

Cars in the train jackknifed and derailed in two locations. The position of the derailed cars, the wheel flange marks on the south rail head between the 30th and 31st cars, the rails that had rolled out from beneath the 39th to 44th cars and the fully compressed draft gears on the head-end cars all indicate that a high in-train buff force event had occurred as a result of the UDE.

The train was in throttle 8 and fully stretched before the UDE. When the UDE occurred, the emergency brakes applied from the 75th car towards the locomotives and from the 76th car towards the tail end. Initially, this kept the head end stretched. Once the air brake pressure drop arrived at the lead locomotive, the independent brake on the locomotives applied and remained engaged for 13 seconds before being bailed off. The cars behind continued towards the locomotives and generated excessive in-train buff force, which resulted in high lateral forces at the wheel/rail interface and led to the derailment of the eight cars. The 30th and 31st cars derailed due to wheel climb and the 39th to 44th cars derailed as the rail spread beneath them.

Managing In-Train Forces During Emergency Braking

Destination block marshalling is an accepted industry practice. Its primary benefits are increased operational efficiency and simplified service delivery for the carrier. While this type of marshalling is not inherently unsafe, weight distribution within the train is not considered, which can lead to high in-train forces that need to be managed to avoid mishaps. CN has taken positive steps towards managing in-train forces by installing Trainlink-ES on about half of its main-line fleet and training locomotive engineers to activate the end-of-train emergency braking feature as well as bail off the independent brake during emergency braking. However, as demonstrated by this occurrence, shortcomings related to the control of in-train forces are still present.

Train marshalling practices and length affect the magnitude of the in-train forces. When trains are marshalled with light cars at the head end and heavy cars at the tail end, the head end will decelerate sooner and faster than the tail end, particularly if the locomotive independent brake remains on. The heavy cars at the tail end, with their greater momentum, will run into the slowing cars at the head end, generating high run-in buff forces. The amount of slack and the run-in buff forces are further increased on long trains, and on trains containing cars equipped with long travel hydraulic EOCCD. All of these characteristics were present in the train. While it was marshalled in accordance with CN and regulatory requirements, it was not configured in a way that minimized in-train forces.

During the derailment, the independent brake remained engaged on the locomotives for 13 seconds before being bailed off. Under these conditions, a buff force of 311 kips occurred immediately behind the locomotives and a maximum buff force of 444 kips occurred between the first two derailed cars (30th and 31st). Analysis demonstrated that the in-train buff force levels and risk of derailment would have been substantially reduced had the independent brake been bailed off earlier.

However, there were other methods available to minimize these forces. Had the train been marshalled in reverse, with the loads at the head end and empties at the rear, a maximum buff force of 311 kips would have occurred immediately behind the locomotives. Since the same force was not sufficient to derail empty cars at this location during the derailment, it is even less likely that loaded cars would have derailed. Therefore, had the train been marshalled in reverse configuration to minimize in-train forces, the derailment may have been averted even with the independent brake engaged for 13 seconds.

Bailing off the independent brake during emergency braking minimizes in-train buff forces but has limitations. A locomotive engineer must quickly respond and perform a series of time-critical tasks when an emergency brake application occurs. Since each emergency situation is different, a separate decision on how to respond with the independent brake must be made each time. The locomotive engineer must consider the track profile, train speed and train marshalling as well as potential hazards such as crossings and roadway traffic. Because the act of bailing off the locomotive independent brake during emergency braking is dependent upon the particular situation as well as a human decision process and reaction, it is not always performed consistently and therefore cannot be relied upon to manage in-train forces.

Another major Canadian railway recognizes the risk associated with undesirable train configurations and has implemented a marshalling system that minimizes the effect of in-train forces while accommodating destination blocking to a certain extent. Such a system minimizes in-train forces, alleviates the shortcomings associated with bailing off the independent brake and reduces the risk of derailment. In contrast, CN's destination block marshalling system did not consider weight distribution within the train and therefore increased the risk of developing high in-train forces with a commensurate risk of derailment.

Knuckle Failure and Broken Valve

The knuckle material had low fracture toughness at the occurrence temperature (-12°C) and lower-than-specified hardness and tensile strength. It was neither quenched nor tempered during the manufacturing process, which resulted in the substandard material mechanical properties. While the fracture originated from an area containing small fatigue cracks, the absence of surface rubbing or corrosion indicates that the failure occurred suddenly. Since there were no unusual train handling events before the accident and the fracture surface exhibited features consistent with a fresh overstress fracture, the knuckle on the 75th car failed in normal service conditions due to substandard material mechanical properties caused by improper heat treatment during the manufacturing process.

The valve was subject to cyclic loads due to flexing of the car structure in normal service. Such flexing would tend to induce tensile stress in the area of the fracture origin. The appearance and location of the pre-crack as well as the presence of casting surface anomalies at the fracture origin are consistent with the features of fatigue failure. The presence of the pre-crack reduced the casting wall thickness and the load required to cause failure. While the final failure of the valve likely occurred due to overstress as a result of the buff forces generated by the run-in of train slack, it appears that the pre-crack developed in fatigue. However, it was not contributory to the derailment and the lack of cut-out valve failure history suggests that the valve failure was an isolated event with no systemic risk.

Findings as to Causes and Contributing Factors

1. The train separated and an undesired emergency brake application occurred when a knuckle on the 75th car failed.

2. The knuckle on the 75th car failed in normal service conditions due to substandard material mechanical properties caused by improper heat treatment during the manufacturing process.

3. Due to the configuration of the train, the time taken to bail off the locomotive independent brake while the cars behind ran in allowed excessive in-train forces to build up and caused the eight cars to derail.

4. While the train was marshalled in accordance with Canadian National (CN) and regulatory requirements, it was not configured in a way that minimized in-train forces.

Findings as to Risk

1. Because the act of bailing off the locomotive independent brake during emergency braking is dependent upon the particular situation as well as a human decision process and reaction, there is a risk that it cannot be relied upon to consistently manage in-train forces.

2. CN's destination block marshalling system did not consider weight distribution within the train and therefore increased the risk of developing high in-train forces with a commensurate risk of derailment.

Other Findings

1. While the pre-crack likely developed in fatigue, the final failure of the valve occurred due to overstress as a result of the buff forces generated by the run-in of train slack.

2. The lack of cut-out valve failure history suggests that the valve failure was an isolated event with no systemic risk.

Safety Action Taken

On 23 October 2007, the TSB issued Rail Safety Information (RSI) letter 17/07 to Transport Canada (TC). The letter identified that Siderúrgica Nacional (Sidena) Grade E knuckles had substandard material mechanical properties and that there is no requirement to record the knuckle manufacturing information.

TC indicated that neither Canadian National (CN) nor Canadian Pacific Railway purchase Sidena Grade E knuckles and noted that the knuckles are regulated by the Association of American Railroads (AAR). TC will continue to follow up and monitor the issue.

TC is following up with CN to identify other mechanical components that are manufactured offshore to AAR standards.

This report concludes the Transportation Safety Board's investigation into this occurrence. Consequently, the Board authorized the release of this report on 30 July 2008.