Transportation Safety Board of Canada

Bureau de la sécurité des transports du Canada

RAILWAY INVESTIGATION REPORT
R04W0148

NON–MAIN-TRACK TRAIN DERAILMENT

CANADIAN PACIFIC RAILWAY
FREIGHT TRAIN 494-05
MILE 0.01, BROMHEAD SUBDIVISION
ESTEVAN, SASKATCHEWAN
08 AUGUST 2004

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

Non–Main-Track Train Derailment

Canadian Pacific Railway
Freight Train 494-05
Mile 0.01, Bromhead Subdivision
Estevan, Saskatchewan
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Report Number R04W0148

Summary

On 08 August 2004 at 1341 central standard time, Canadian Pacific Railway freight train 494-05 was reversing onto the Bromhead Subdivision when it derailed six cars at Mile 0.01 within the city of Estevan, Saskatchewan. Five of the six derailed cars were pressurized tank cars containing anhydrous ammonia. One tank car sustained a fracture in the tank head, releasing a small amount of product to atmosphere. As a precaution, about 150 people within a three-block radius of the derailment site were evacuated for two days. There were no injuries.

Ce rapport est également disponible en français.

Other Factual Information

The Accident

On 08 August 2004, Canadian Pacific Railway (CPR) freight train 494-05 (the train) was proceeding southbound on the Weyburn Subdivision en route from Swift Current, Saskatchewan, to St. Paul, Minnesota, United States. Train movements on CPR's Weyburn and Bromhead subdivisions are governed by the Occupancy Control System as authorized by the *Canadian Rail Operating Rules* and supervised by a rail traffic controller located in Calgary, Alberta. No General Bulletin Orders were in effect.

The train, comprised of 2 locomotives and 84 cars (56 loads and 28 empties), weighed 8088 tons and was 5323 feet long. In all, 30 of the 56 loaded cars were pressurized tank cars carrying anhydrous ammonia (UN 1005). The operating crew (a locomotive engineer and a conductor) took control of the train in Moose Jaw, Saskatchewan. The crew met established fitness and rest standards, were qualified for their respective positions, and familiar with the territory.

The train stopped in Estevan, with the rear of the train just past the No. 11 left-hand mainline switch at Mile 137.2. That switch leads onto the Bromhead Subdivision. While the crew was reversing the train westward onto the Bromhead Subdivision, there was a train-initiated emergency brake application. After conducting the necessary emergency procedures, the crew determined that six cars (the 17th to the 22nd cars from the tail end) had derailed at Mile 0.01 of the Bromhead Subdivision. The crew disconnected the head end of the train and pulled clear of the derailment area.

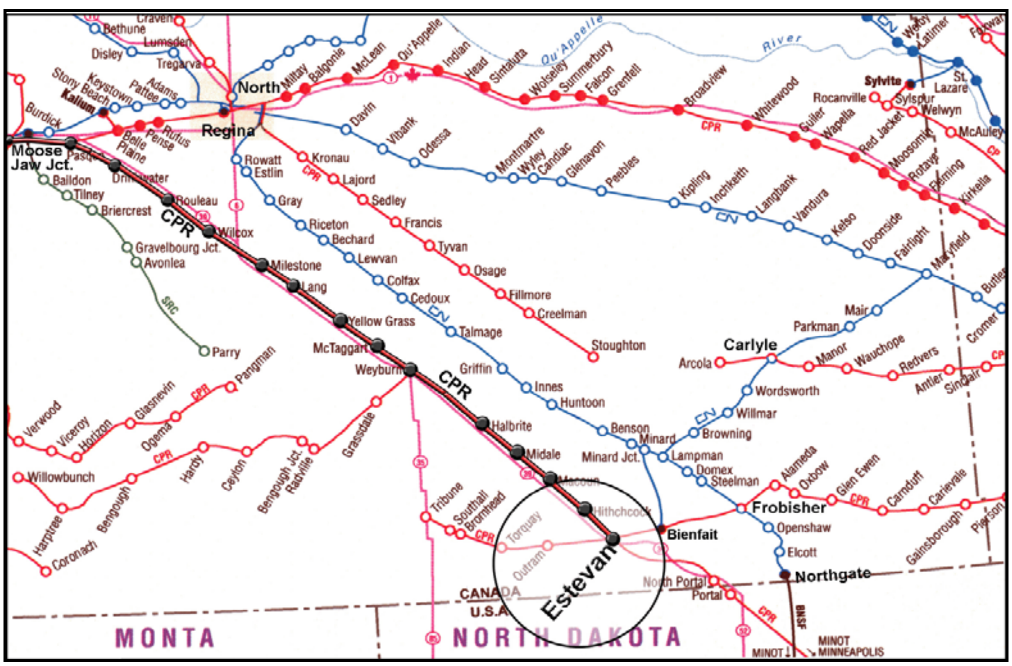

Figure 1. Location of derailment (Source: *Canadian Railway Atlas*, Railway Association of Canada)

The Estevan Police arrived first, followed by the Fire Rescue Service. After meeting the conductor and reviewing the train documentation, the Fire Chief determined that anhydrous ammonia was involved in the derailment and ordered the evacuation of a three-block radius as a precautionary measure. Approximately 150 people, including 45 people from a nearby senior citizens residence, were evacuated. The evacuation was lifted two days later.

The *2004 Emergency Response Guidebook* identifies anhydrous ammonia as a corrosive gas. It is toxic and may be fatal if inhaled, ingested, or absorbed through skin. Its vapours are extremely irritating and corrosive. Although the vapours are lighter than air, during an accidental release, they may combine with air moisture and stay near the ground. The product has a high affinity to moisture and may react with body moisture causing chemical burns.

A review of the locomotive event recorder indicated that, from a stop, the train reversed slowly and smoothly. It accelerated to 9.9 mph, then experienced a train-initiated undesired emergency brake application and came to a stop at 1341 central standard time.[1]

At the time of the accident, the temperature was 17°C with light rain. Relative humidity was 89 per cent, the wind was from the northwest at 22 km/h and the visibility was 24 km.

Site Examination

Five of the six derailed cars were pressurized tank cars loaded with anhydrous ammonia; the other car was a covered hopper car loaded with urea. At the west end of the derailment, the first two derailed cars were tank car ACFX 220149 and covered hopper car FURX 818699, respectively. Both cars derailed all wheels, but remained upright. They were sent to Moose Jaw for further examination. The following three derailed tank cars remained coupled together and came to rest on their sides lying to the north side of the track. At the east end of the derailment, the last derailed tank car, GATX 48058, with the B-end leading, came to rest leaning to the south. The car had sustained impact damage to the B-end tank head, and a small amount of product was released to the atmosphere. The remaining product was safely transferred from the car at the site, and the damaged car was sent to Moose Jaw for inspection.

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

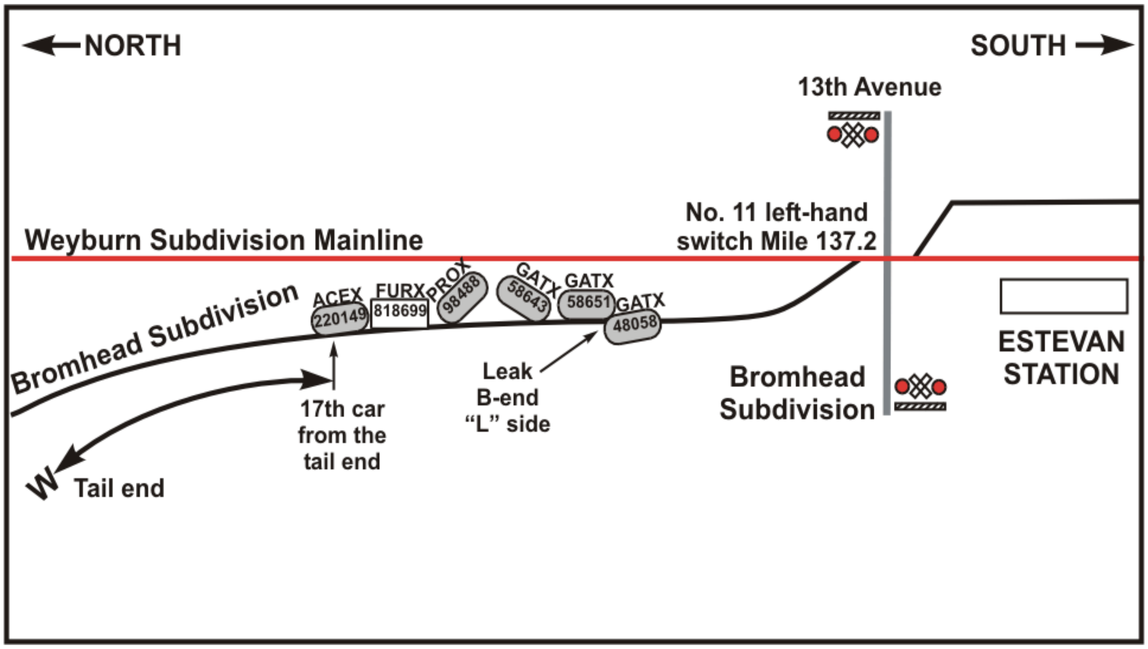

Figure 2. Derailment site diagram

The turnout curve consisted of 115-, 100-, and 85-pound rail. In the 85-pound track structure within the limits of the turnout curve, spike lift was observed on the gauge side of the south rail over a distance of 66 feet, between the 100/85-pound compromise joint[2] and the insulated joint (see Figure 3). Over the same area, the field-side track spike heads were bent back and the south rail had begun to roll to the field side. Wheel marks were visible on the tie ends approximately 6 feet west of the insulated joint, 275 feet from the point of switch. Approximately 450 feet of track was destroyed. Most of the rail was recovered and re-constructed near the derailment site. All fracture surfaces exhibited brittle characteristics consistent with catastrophic failure; no significant pre-existing defects were observed in any of the rail or joints.

Photo 1. The B-end of car GATX 48058 remained on the canted south rail. A close-up of the shaded area shows the spike lift observed beneath the B-end truck.

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[2] A compromise joint is a specialized joint that is slightly vertically offset to permit abutting ends of different rail weights to be joined together.

Track Information

The Bromhead Subdivision extends westward from a mainline turnout switch located at Mile 137.2 of the Weyburn Subdivision. Prior to 2000, traffic on the Bromhead Subdivision consisted of one train every three weeks. In 2000, the Bromhead Subdivision was designated as a spur with a maximum authorized speed of 10 mph. Since then, the traffic on the Weyburn Subdivision has increased significantly, with the first two miles of the Bromhead Subdivision being used to stage up to five trains a week.

The mainline turnout was upgraded from 100-pound rail to 115-pound rail in May 2000. However, with the low traffic volume at the time of the upgrade, it was not deemed necessary to renew the entire turnout curve. The upgrade included 164 feet of 115-pound rail that extended onto the Bromhead Subdivision. The rail then changed to the existing 100-pound rail that had been in place for 10 to 20 years. A second change, from 100-pound rail to 85-pound rail, was located 203 feet from the point of the switch. The 115-pound and 100-pound jointed rail within the turnout curve was laid on 14-inch double-shouldered tie plates and secured with three spikes per plate, two on the gauge side and one on the field side, to hardwood ties. The 85-pound rail portion of the turnout curve was laid on 8 ½-inch single-shouldered tie plates, secured to No. 2 softwood ties with two spikes per tie plate, one on the gauge side and one on the field side, mostly installed 20 to 30 years ago. There were an average of 62 ties per 100 feet of track. The ties were in fair condition, with no evidence of loose spikes, tie plate cutting, or gauge widening. The ballast was crushed stone, the cribs were full, and the shoulders extended 24 inches beyond the end of the ties. The turnout and track were relatively level.

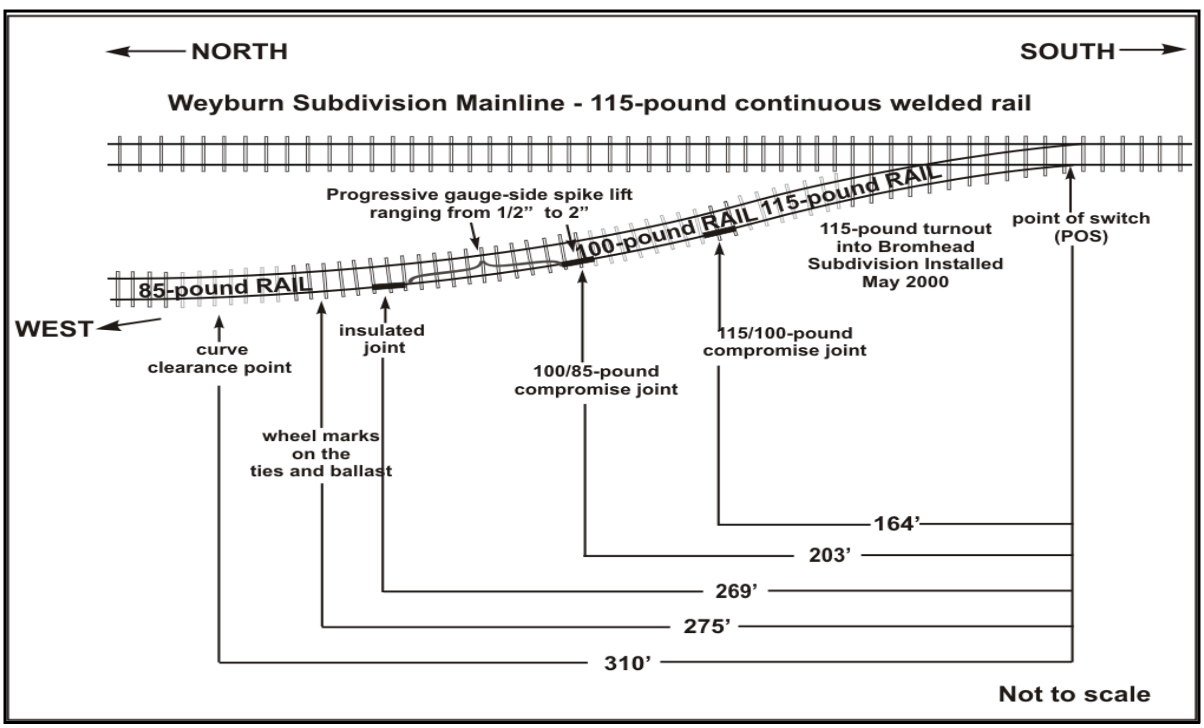

Figure 3. Observations and general track layout in the area of the derailment

CPR Standard Practice Circular (SPC) 18 requires that turnouts be fully spiked with three spikes, two on the gauge side and one on the field side, through each tie plate and tie in curves or spirals where elevation is ½ inch or less. SPC 20 stipulates that, within the limits of a turnout, which includes the siding curve, rail of the same weight and section as the switch and frog should be used in both tracks and should extend to the clearance points of both mainline and turnout sides of the turnout. It also states that compromise joints should not be used in turnouts.

For the Bromhead Subdivision spur, the Transport Canada-approved *Railway Track Safety Rules* and CPR's SPCs require monthly track and turnout inspections and a record of those inspections. Inspection records indicated that the mainline turnout was inspected monthly. There were no records pertaining to track inspection; however, CPR indicated that track inspection was carried out monthly, with the last inspection occurring on 13 July 2004, three weeks prior to the occurrence.

Engineering Laboratory Evaluation of Rail Roll-Over Resistance

Chapter XI of the Association of American Railroads (AAR) *Manual of Standards and Recommended Practices*[3] sets forth guidelines for testing and analysis to determine the trackworthiness of new freight cars. The testing requires that the truck-side lateral/vertical (L/V) ratio not exceed 0.60 to be safe from a rail roll-over derailment[4] irrespective of track structure. Truck side L/V ratio is defined as "the sum of the lateral forces (L) on all the wheels on one side of a truck divided by the sum of all vertical loads (V) on the same wheels."

The TSB Engineering Laboratory assessed the differences in lateral restraint against rail roll-over for the 115-, 100- and 85-pound rail portions of the turnout curve under the weight of car FURX 818699 (report LP 149/04). The following observations were made:

- Without any spikes, new 115-pound rail can resist a truck side L/V ratio of 0.62 under the involved car weight. Similarly, 100-pound rail and 85-pound rail can resist truck-side L/V ratios of 0.66 and 0.73, respectively.

- With two newly installed gauge-side spikes securing new rail to each tie plate, the resistance of 115-, 100- and 85-pound rail against roll-over was strengthened, resisting truck-side L/V ratios of 2.24, 2.39, and 2.63, respectively. The 85-pound rail with only one gauge-side spike holding it on each plate resisted a truck-side L/V ratio of 1.68. When 85-pound rail secured with one gauge-side spike was compared to 85-pound rail secured with two gauge-side spikes, the single-spike model demonstrated a 42 per cent reduction in rail roll-over resistance.

- When site conditions were considered and the pullout resistance of spikes was simulated to reflect the age and deterioration of the spikes and ties, the 115-pound rail

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3 *Manual of Standards and Recommended Practices*, Section C, Part II, Specifications for Design, Fabrication and Construction of Freight Cars, M-1001, Vol. 1, p. C-II-397

4 *The Acceptance Criteria for Trackworthiness*, John A. Elkins, Director, Research and Technology Development, AAR Transportation Test Center, Pueblo, Colorado

installed four years ago with two gauge-side spikes had the best resistance to rail roll-over. In comparison, the resistance of the 100-pound rail, with two gauge-side spikes installed 20 years ago, was 20 per cent lower while the resistance of the 85-pound rail, with one gauge-side spike installed 30 years ago, was 47 per cent lower.

Freight Car Information

CPR and the TSB conducted a mechanical tear-down inspection of the first two derailed cars, ACFX 220149 and FURX 818699. While no defects were identified in car ACFX 220149, the inspection of car FURX 818699 revealed a number of defective and worn truck components. In particular, the B-end car body centre plate was dry, oxidized, and binding on the truck bolster rim. The contacting surfaces of the body centre plate were smeared and gouged. In addition, both side bearings were tight, and three of four bolster gibs, as well as the L-1 and R-1 bolster friction pockets, were worn to condemning limits (see Appendix A). The TSB identified five train accidents in the previous 18 years in which binding car body centre plates were contributory factors.

The *Railway Freight Car Inspection and Safety Rules*, approved by Transport Canada (TC), and CPR's General Operating Instructions specify that, at locations where a certified car inspector is not on duty, pre-departure inspections of the train or the cars added shall be performed by a qualified person (or train crew) as a minimum requirement. Thereafter, a safety inspection will be performed by a certified car inspector at the first safety inspection location designated for that train by the railway company in the direction of travel. Moose Jaw was designated as the safety inspection point for the train.

During a safety inspection, a train is inspected for defects outlined in both the AAR *Field Manual of the Interchange Rules* and the TC-approved *Railway Freight Car Inspection and Safety Rules*. A number of visual inspections are performed to determine the mechanical condition of each car inspected. These visual inspections include, but are not limited to, air and car couplings, car undercarriage, truck and bolster components, doors, gates, car superstructure, shifted loads, dangerous good leaks, and general car appearance. Under both the TC and AAR rules, a binding centre plate is a defect requiring that the car be removed from service.

Photo 2. The truck bolster rim on car FURX 818699 was worn at four locations. The wear on the corners of the matching car body centre plate corresponded to the bolster rim wear. The sketch indicates the clearance between the two.

A CPR switching assignment lifted car FURX 818699 in Medicine Hat, Alberta, on 04 August 2004. The car arrived on 06 August 2004 in Swift Current and was put onto the train. On 07 August 2004, the train travelled from Swift Current to Moose Jaw and received an inbound pull-by inspection upon arrival by a CPR car inspector who was certified in accordance with TC regulatory requirements. While in Moose Jaw, the train also received a full safety inspection including a No. 1 air brake test. The inspection was performed by a certified car inspector who inspected one side of the train while operating a four-wheel drive all-terrain vehicle and the other side of the train while on foot. The inspection was performed near the end of the car inspector's shift between 2215, 07 August 2004 and 0015, 08 August 2004. The train departed Moose Jaw at 0927 on 08 August 2004 and received an outbound pull-by inspection by a CPR certified car inspector. At no time were any exceptions noted on car FURX 818699.

Tank Car GATX 48058

Tank car GATX 48058 was one of 34 cars built in 1976 to specification DOT 105A300W, by the General American Transportation Corporation (GATX) of Chicago, Illinois, United States, under AAR Certificate of Construction F-763020. The car was insulated with a ceramic blanket covered by an outer steel jacket. The construction material for the tank shell prescribed by the certificate was AAR TC 128, Grade B steel. At the time the car was constructed, regulations required that TC 128 Grade B non-normalized steel of fine grain quality be used. There were no requirements to meet Charpy V-notch energy absorption criteria.

Pressure tank cars built after 01 January 1989 were required to be constructed of American Society for Testing and Materials (ASTM) 516 or TC 128 Grade B normalized steel. The standard recently changed to require that new cars ordered after 01 July 2005 be constructed with material that meets Charpy V-notch energy absorption criteria of 10 to 15 foot-pounds at -30°F. These requirements provide for greater ductility and toughness of tank car steel.

On 15 September 2004, car GATX 48058 was examined at the GATX facility in Moose Jaw. A two-foot diameter dent was observed in the B-end tank head. The lower portion of the dent contained a wheel flange burn that extended into the weld securing the tank head to the body of the tank. The burn measured about five inches long, two inches wide and one inch deep. At the root of the flange burn, a two-inch-long crack extended into the tank head weld area. On the inside of the tank, a one-inch longitudinal crack was visible extending up to the tank head weld. A second crack, perpendicular to the longitudinal crack, had propagated 2 ½ inches along the toe of the weld. The damaged area of the tank car was removed and sent to the TSB Engineering Laboratory for further analysis.

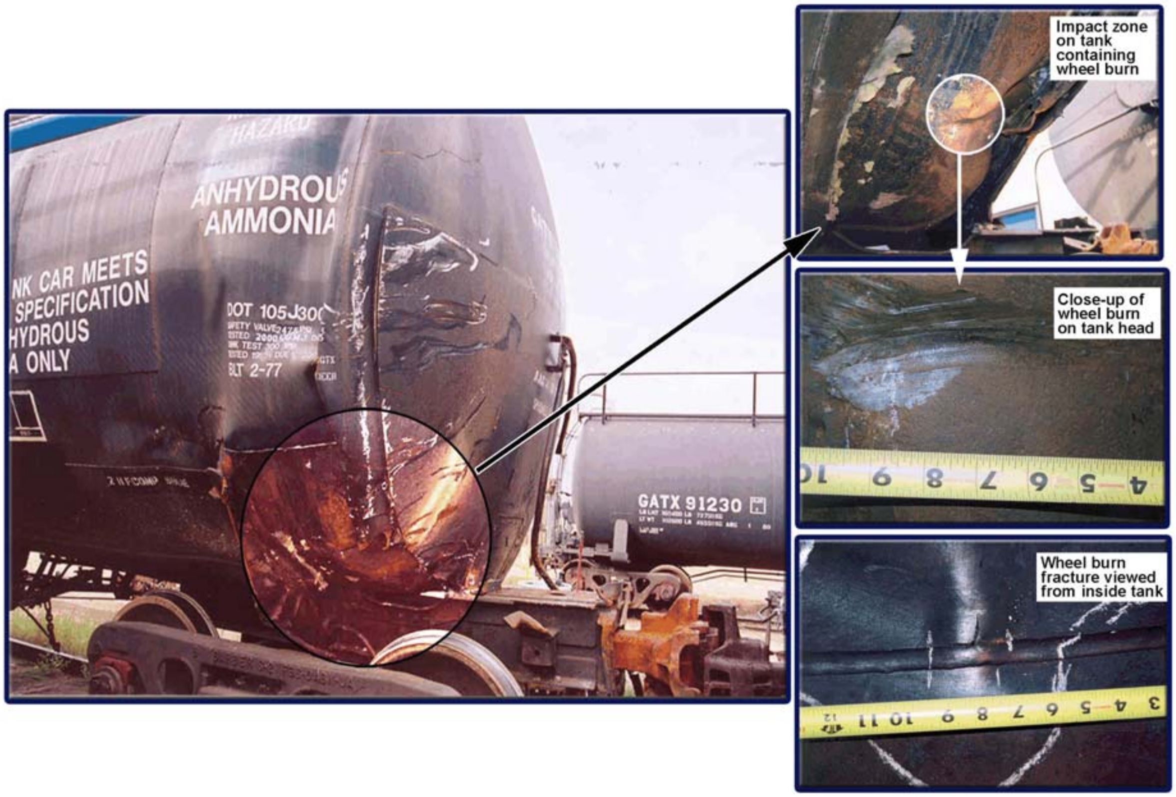

Photo 3. Zone affected by impact on B-end of tank car GATX 48058. Note wheel flange burn on tank exterior and a through crack on tank interior.

TSB Engineering Laboratory Analysis of Tank Car GATX 48058

The TSB Engineering Laboratory analysis of tank car GATX 48058 (report LP 134/04) revealed the following:

- The B-end of the tank car sustained a small through fracture as a result of an impact with the flange of a wheel during the derailment. No pre-existing primary or secondary fractures were observed.

- No metallurgical anomalies were observed in the tank head, weld, or shell material. The chemical and tensile properties of the tank car met or exceeded the minimum AAR specifications for TC 128 Grade B steel.

- The tank car head and shell were constructed with a very fine-grained steel (ASTM 10), which provides superior toughness and resists crack propagation.

- The Charpy impact value of the tank car head material was measured at 66.8 foot-pounds at -45.6°C. Testing in previous TSB investigations (R94D0033 and R96M0011) revealed Charpy impact values of 3 to 5 foot-pounds at temperatures between -30°C and -45.6°C, for tank cars constructed prior to 1989.

Analysis

A review of the locomotive event recorder determined that train handling was not a factor in this occurrence. Site inspection did not reveal any track geometry problems in the area of the derailment. The analysis will focus on the mechanical condition of freight car FURX 818699, the lateral resistance of the 85-pound track structure, freight car inspection, tank car crashworthiness, and the emergency response.

The Derailment

The gauge-side spike lift (which originated immediately west of the 100/85-pound compromise joint on the south rail), the bent field-side track spike heads, and the canted south rail were all observed prior to the first wheel marks, indicating that rail roll-over was the derailment mechanism. The lack of obvious track defects, such as tie plate cutting or loose spikes, suggested that a higher-than-usual lateral load was exerted on the track structure and caused the south rail to roll over.

While negotiating a curve, lateral forces generated by a properly performing truck will not exceed the lateral restraint capacity of adequately secured rail. However, when freight car and truck defects that restrict truck rotation and facilitate truck warp are present, the wheel flange angle of attack is increased, and higher-than-usual truck-side lateral forces are generated in curves. Binding centre plates, tight side bearings, and truck components worn to condemning limits are defects that increase truck rotational resistance and warp. Since these defects were present on car FURX 818699, it can be concluded that the B-end truck induced higher-than-usual lateral forces on the south rail as the car negotiated the turnout curve.

The extent of the wear exhibited by the defects on the B-end of car FURX 818699 indicated that they had existed for some time prior to the derailment. Therefore, the car had negotiated other similar turnouts and curves without derailing. The car had also successfully negotiated the 115- and 100-pound sections of the turnout curve while exiting from the Weyburn Subdivision and did not derail until it reached the section built with 85-pound rail. This suggests that certain conditions had to exist both in the B-end of car FURX 818699 and in the 85-pound track structure within the turnout curve for the derailment to occur.

The TSB Engineering Laboratory assessed the differences in lateral restraint against rail roll-over between 115-, 100- and 85-pound rail under conditions similar to those at the derailment site. Analysis confirmed that the 85-pound rail portion of the turnout curve had lower resistance to rail roll-over when compared with the 115-pound and 100-pound rail portions of the curve. Therefore, the higher-than-usual lateral forces exceeded the restraint capacity of the 85-pound rail portion of the curve, causing the roll-over of the south rail and the subsequent derailment.

At the time the turnout was upgraded, there was only one train every three weeks on the Bromhead Subdivision. Therefore, it was not deemed necessary to renew the entire turnout curve to bring it into conformity with the SPCs. Consequently, the two compromise joints and the existing 85-pound track structure were left in place. Since then, the traffic and tonnage on the subdivision has increased, and the portion of the curve constructed with 85-pound rail has sustained that increase without incident, even though the existing turnout curve had not been upgraded. However, due to its reduced resistance to lateral forces, the portion of the curve constructed with 85-pound rail, secured with one gauge-side and one field-side spike, could not sustain higher-than-usual loads.

Freight Car Inspection

The binding centre plate on the B-end of car FURX 818699 was a defect that had existed for some time. Although this condition required immediate attention, it remained undetected despite a number of inspections that had been performed on the car prior to the derailment. Such defects are supposed to be captured during safety inspections; however, as demonstrated by this occurrence, they are not always identified. The quality and thoroughness of the inspections may be hindered by a number of factors such as car configuration, work environment, and awareness of the inspector.

Freight car inspection is essentially a visual signal-detection task that requires the inspector to remain vigilant for a variety of potential defects. In this occurrence, the inspector performed a large number of separate but concurrent visual inspection tasks on each car. An inspector's ability to remain vigilant to stimuli during inspection tasks has been shown to be adversely affected by increases in the number of signals to be attended to and the level of complexity and uncertainty of these signals.[5] If a number of tasks use only one sense, such as vision in the case of car inspectors, the ability to monitor the tasks is reduced. When the tasks are performed in darkness, the inspector's ability is further impeded. Each of these factors on their own may reduce the effectiveness of inspections. The situation is aggravated when these factors are combined. Under such conditions, the current method of performing safety inspections presents a risk that binding centre plates may not be consistently detected.

Tank Car GATX 48058 Crashworthiness

Tank car GATX 48058 sustained a relatively small fracture and released a minimal amount of product. However, analysis determined that the car was constructed from material that had properties superior to current AAR specifications. The high Charpy impact values and fine-grained microstructure of the tank car steel were characteristic of a material with high impact resistance and toughness. These properties likely played a role in the survival of tank car GATX 48058 and reduced the risk of a more serious tank breach.

Emergency Response

Since anhydrous ammonia is highly attracted to moisture, the high humidity and light rain helped to minimize the effect of the released product. Furthermore, Estevan police and fire services arrived on scene shortly after the derailment and quickly secured and evacuated the surrounding area. Their timely response and the evacuation of nearby inhabitants minimized the risk of exposure to dangerous goods.

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5 C.D. Wickens and J.G. Hollands, *Engineering Psychology and Human Performance*, 3rd edition, New Jersey: Prentice Hall, 2000

Findings as to Causes and Contributing Factors

1. The train derailed when the 85-pound south rail in the turnout curve rolled over beneath the train.

2. The restricted rotation and warp of the B-end truck of car FURX 818699 induced higher-than-usual truck-side lateral forces into the south rail while the car was negotiating the turnout curve.

3. The 85-pound rail portion of the turnout curve had a lower resistance to rail roll-over when compared with the 115-pound and 100-pound rail portions of the curve.

4. Due to its lower resistance to lateral forces, the portion of the turnout curve constructed with 85-pound rail, secured with one gauge-side and one field-side spike, could not sustain the higher-than-usual forces exerted by car FURX 818699.

Findings as to Risk

1. At the time the turnout was upgraded, traffic was low on the Bromhead Subdivision. Consequently, it was not deemed necessary to bring the entire turnout curve into conformity with Canadian Pacific Railway's Standard Practice Circulars; had that been done, the risk of derailment would have been reduced.

2. The current method of performing safety inspections presents a risk that defects, such as binding centre plates, may not be consistently detected.

Other Findings

1. The Charpy impact values and fine-grained microstructure of the tank head material of tank car GATX 48058 exceeded current Association of American Railroads specifications, and likely reduced the risk of a more serious tank breach.

2. The timely response and evacuation of the inhabitants in the surrounding area minimized the risk of exposure to dangerous goods.

Safety Action Taken

Acknowledging the human limitations on performing visual inspections, the rail industry is implementing automated inspection technologies. Canadian Pacific Railway (CPR) is currently reviewing options for installing up to two truck performance detectors on its network in the next few years. These detectors are designed to identify defects in freight car trucks similar to those that were present in car FURX 818699.

CPR developed and distributed a "Tech Tip" poster across its system to illustrate what to look for when inspecting freight car centre plates and side bearings. CPR instructed all certified car inspectors to review the poster.

On 16 August 2004, all 85-pound rail was replaced beyond the clearance point of the Bromhead turnout curve with 100-pound rail sections, set on double-shouldered tie plates secured with three spikes per plate.

CPR developed and implemented a system-wide risk assessment process that requires Engineering and Field Operations departments to jointly perform a risk assessment on track condition prior to any significant operational changes or when traffic is expected to increase substantially.

This report concludes the Transportation Safety Board's investigation into this occurrence. Consequently, the Board authorized the release of this report on 28 July 2005.

Appendix A – Car FURX 818699 B-End Mechanical Inspection Results

Item	Observed	Association of American Railroads Specification
Coupler height	32 1/4"	32 1/2" minimum
Side bearing clearance (L&R)	1/8"	3/16" minimum
Clearance between car body centre plate and truck bolster	None	1/16" clearance must be maintained
Car body centre plate height	2" – corners smeared and gouged	1/16" clearance must be maintained
Truck bolster bowl depth	2 1/8" – bolster rim smeared and gouged	1/16" clearance must be maintained
Bolster bowl lubrication	dry and rusted	
Bolster gibs	3 of 4 measure 9 3/4"	condemning limit – 9 3/4"
Bolster friction pocket (L-1&R-1)	3/16" wear	condemning limit – 3/16"
Friction wedge (L-1&R-1)	3/4" wedge rise	
Clearance between side frame thrust lug and adapter (R-2) position	9/16"	7/16" maximum
Main spring free height	1 outer spring – 9 7/16" 2 inner springs – 9 5/8"	Free height condemning limit – 9 5/8"