RAILWAY INVESTIGATION REPORT
R00E0126

DERAILMENT

CANADIAN PACIFIC RAILWAY
TRAIN LDRS-12
MILE 85.94, LLOYDMINSTER SUBDIVISION
LONE ROCK, SASKATCHEWAN
12 DECEMBER 2000

Railway Investigation Report

Derailment

Canadian Pacific Railway
Train LDRS-12
Mile 85.94, Lloydminster Subdivision
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Summary

On 12 December 2000 at about 2225 Central standard time, Canadian Pacific Railway southward freight train LDRS-12 derailed 13 cars at Mile 85.94 on the Lloydminster Subdivision near the hamlet of Lone Rock, Saskatchewan. The 13 cars were all dangerous goods cars, seven loaded with kerosene and six loaded with liquid asphalt. Five cars lost approximately 84 000 litres of kerosene and three cars lost approximately 150 000 litres of liquid asphalt. Environmental damage occurred as a result of the spill. There were no injuries.

Ce rapport est également disponible en français.

Other Factual Information

On 12 December 2000, Canadian Pacific Railway (CPR) freight train LDRS-12 left Lloydminster, Saskatchewan, at about 2150 Central standard time,[1] proceeding southward on the Lloydminster Subdivision, destined for Wilkie, Saskatchewan. At about 2225, while travelling at approximately 27 mph, a train-initiated emergency brake application occurred. After emergency procedures were executed, inspection of the train revealed that 13 cars, the 26th to the 38th car behind the locomotives, had derailed. Twelve tank cars and approximately 600 feet of track were destroyed. There were no reported injuries. The closest habitation was the hamlet of Lone Rock, Saskatchewan, approximately one mile south of the accident site.

The weather at the time of this occurrence was -30°C, clear and calm with unlimited visibility.

Seven of the derailed cars were loaded with kerosene (UN 1223)[2] and six cars were loaded with liquid asphalt (UN 3257).[3] Approximately 84 000 litres of kerosene and 150 000 litres of liquid asphalt were released to the environment as a result of the derailment.

The train was powered by 4 locomotives and was hauling 55 loaded cars. It weighed approximately 7150 tons and was 3540 feet long. The operating crew consisted of a locomotive engineer, conductor and trainman. They were qualified for their respective positions and met the required fitness and rest standards.

The Lloydminster Subdivision is controlled by a rail traffic controller located in Calgary, Alberta. The method of train control is Occupancy Control System[4] authorized by the Canadian Rail Operating Rules.

Particulars of the Track

The Lloydminster Subdivision is designated as Class 2[5] track with a maximum allowable operating speed of 25 mph. The track in the vicinity of the derailment is tangent and consisted of 80 pounds per yard rail manufactured by Algoma in 1909 in various lengths. The rails were joined with 24-inch joint bars and four bolts. The rail was laid on single-shouldered tie plates

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1 All times are Central standard time (Coordinated Universal Time minus six hours) unless otherwise stated.

2 United Nations dangerous goods identification number

3 Transport Canada's *Transportation of Dangerous Goods Regulations* do not apply to rail shipments of liquid asphalt, UN 3257, in Canada; however, there are restrictions on shipments entering the United States.

4 Occupancy Control System—A system where the movement of trains is supervised by the rail traffic controller, who will issue clearances, Track Occupancy Permits, General Bulletin Orders and instructions as required.

5 Transport Canada, *Track Safety Rules*, Part II, Subpart A, Classes of Track: Operating Speed Limits

measuring 6.5 inches by 8.5 inches and was secured to eight-foot treated track ties with two 5.5-inch spikes. The rail was box-anchored every fourth tie. The track ties and fasteners were in fair condition for Class 2 track. The ballast consisted of crushed stone with good drainage.

A broken rail, with the rail head separated from the web, was found in a rail joint at Mile 85.94. The broken rail pieces were sent to the CPR laboratory for analysis. The rail head separation produced a 12-inch gap on the south end of the joint that could not be bridged by the oncoming wheels.

The analysis indicated the presence of oblong bolt holes and pre-existing cracks extending from a bolt hole. One pre-existing brittle fracture propagated into the rail base. The three fractures that caused the rail head separation also displayed brittle fracture characteristics. The rail head separation was precipitated by a loose joint condition. The presence of bolt hole cracks could not be detected by track personnel performing regular inspections without removing the joint bars.

The track was normally inspected once a week by the track maintenance supervisor (TMS) and twice a week by other track forces. It was inspected before the derailment on the morning of 11 December 2000 by the TMS and again by other track forces on the afternoon of 12 December 2000. Both inspections were performed using a Hi-rail vehicle and no anomalies were noted at the location of the derailment.

A track evaluation car[6] (TEC) tested this portion of track on 07 September 2000 and no deficiencies were found in the immediate area of the derailment. However, 37 urgent defects for tight gauge conditions of more than 0.5 inches and one priority defect for excessive change in elevation on the tangent track were found between Mile 84 and Mile 90. As a result of these defects, the maximum allowable speed was temporarily reduced to 10 mph, the recommended speed for Class 1 track, until the defects were repaired, and normal subdivision speed resumed.

A rail flaw detection car[7] tested the rail on 25 October 2000, and no defects were found in the immediate vicinity of the derailment. However, from Mile 76 to 89 (16.9 miles), 34 defective rails were found consisting of 18 bolt hole cracks, 1 head and web separation within the joint, 9 vertical split heads, 4 transverse defects, 1 head and web separation outside the joints and 1 miscellaneous defect.

Tank Cars

The 30th car (NCTX 20736) was loaded with kerosene and lost approximately 48 000 litres through four holes torn open in the bottom of the tank. The 34th car (CP400335), which did not have a head shield, received a head shell puncture and lost approximately 34 000 litres of kerosene. The 29th (CP400281), 32nd (CP400295), and 33rd (CP400305) cars, which did not have manway housings, lost approximately 2000 litres of kerosene from leaks through damaged safety vents. The safety vent on car CP400281 broke off at the nipple connection to the manway cover, allowing the valve and stem to drop into the tank, leaving a 1½-inch hole. As the car was leaning at a 45-degree angle, kerosene leaked through this opening. Tank cars CP400295 and CP400305 had minor leaks through the safety vent due to deteriorated o-rings. The 27th, 35th, and 36th cars, loaded of liquid

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6 A track evaluation car electronically locates and identifies irregularities in track geometry, providing a real time report of overall track condition relative to track roughness standards for the class of track.

7 A rail flaw detection car uses induction or ultrasonic technology to detect internal rail defects, which normally cannot be detected visually during routine track inspections.

asphalt, leaked approximately 150 000 litres of asphalt as a result of damage to the tank shells. The 27th car received punctures to the head shell at both ends of the tank car. The 35th car (GATX 89182), not having a head shield, received an impact resulting in a one-foot hole in the "A" end head shell. The 36th car (GATX 72480) had a small leak at a tank shell puncture. Five of the thirteen cars sustained damage to the bottom unloading valves. There was no protection for the bottom outlets or top fittings on these cars.

Tank car NCTX 20736 was a general purpose, non-insulated, non-pressurized tank car built in 1975 to specification DOT 111A100W1. The tank material specified was 7/16-inch thick ASTM A516 grade 70 steel. During the derailment, four brake support brackets located on the underside of NCTX 20736 were torn away from the tank shell, leaving four holes approximately six inches in diameter. Each support bracket was a 4.5-inch-diameter steel pipe welded to a round steel pad six inches in diameter, leaving an edge distance of 0.75 inches. The six-inch pad, which was 0.5 inches thick, was welded to the tank shell. The purpose for welding the brake support brackets to the pads, and then welding the pads to the tank shell, is to provide engineered failure points in the event of an abnormal impact. This design allows the support brackets to break away from the pads rather than breaching the integrity of the tank shell.

The Association of American Railroads (AAR) specification for tank cars M1002 (January 1996), Section E15.02 (a)(4), requires the edge distance between the pad and the bracket to be "three times the thickness of the pad." The AAR "edge distance" rule was not in effect in 1974 when the design of NCTX 20736 was approved.

The AAR specification for tank cars M1002 (January 1996), Section E15.02(a)(2), for attaching pads to a tank shell specifies that "Pads shall be attached by continuous fillet welds except for venting provisions. The ultimate shear strength of the pad-to-bracket weld shall not exceed 85 per cent of the ultimate shear strength of the pad-to-tank weld. Fillet leg size shall not exceed tank shell thickness."

Portions of the tank shell on car NCTX 20736 were cut out of the tank car and forwarded to the TSB Engineering Laboratory for analysis (TSB Engineering Laboratory report LP 005/2001).

Some of the report's salient points are:

- For a pad six inches in diameter, the location of highest stress is at the pad-to-tank joint, making this joint the weakest link. This is contrary to the intention of the design, as the weakest link should actually be at the pad-to-bracket interface.

- As the pad becomes smaller and approaches the size of the tube structurally, the pad simply acts like a continuation of the tube. With the pad now acting like a part of the tube, the pad no longer acts as an intermediate structural component transferring loads from the tube to the tank. Effectively, the loads transmit directly from the tube to the tank, so all the stresses are concentrated at that interface, making that the weak link. In this case, the tube diameter of 4.5 inches and the pad diameter of 6 inches left an edge distance of 0.75 inches, much of which was taken up by the weld. Therefore, the pad acted as an extension of the tube rather than as an intermediate structural member.
- Assuming that the shear strength is directly proportional to the length of the weld bead, the pad-to-bracket weld was only 57 per cent as long as the pad-to-tank weld. Therefore, the 85 per cent requirement was met and the weak link should have been the pad and not the tank. It is considered that the reason the failure occurred in the tank rather than the pad was that the geometry phenomenon caused by the small pad size was so significant that it overwhelmed the strength effect.

Environmental Issues

Kerosene (UN 1223) is classified as a dangerous good. It is a highly flammable liquid that can be easily ignited by heat, sparks or flames. In this occurrence, there was no fire. Approximately 7100 cubic metres of soil was contaminated by the spilled kerosene. The contaminated soil was excavated and transported to a land farm for treatment. The liquid asphalt, a non-regulated product in Canada, solidified and approximately 480 tonnes of asphalt and asphalt-contaminated soil was removed and transported to a recovery centre. There was no observed infiltration of liquid asphalt into the subsurface soil.

Previous TSB Reports

In TSB investigation report R94C0137, the Board determined that "the derailment was caused by a rail fracture which was initiated by the propagation of undetected fatigue cracks in rail that had worn beyond condemnable limits." The report also mentioned that the United States National Transportation Safety Board *Safety Study into the Transport of Hazardous Materials by Rail* (NTSB/SS-91/01) questioned the safety of 111A specification tank cars. The report determined that this series of tank cars has a high incidence of tank integrity failure when involved in accidents and that certain hazardous materials are transported in these tank cars even though better protected cars are available.

In TSB investigation report R95D0016, the Board recommended that the Department of Transport take immediate action to further reduce the potential for the accidental release of the most toxic and volatile dangerous goods transported in Class 111A tank cars. Recommendation R96-13, issued November 1996, required design changes to improve tank car integrity in crashes or further restrict the products that can be carried in them. In response to this recommendation, Transport Canada issued Amendment Schedule 21 to the *Transportation of Dangerous Goods Regulations*, which makes mandatory the use of revised tank car standard CAN/CGSB 43.147-94. This standard restricts the use of 111A tank cars, and removed over 80 dangerous goods previously authorized for transportation in Class 111 cars.

TSB investigation report R94T0029 indicated that the derailment and breach of Class 111A tank cars resulted from a vertical split head (VSH) rail defect. The Board determined that:

> The well-developed nature of the VSH, however, suggests that the defect existed at the time of the last visual inspection of the track two days before the derailment. Such inspections, carried out on Hi-rail vehicles, have limited potential for detection of this type of defect.

TSB investigation report R99D0159 indicated where six cars ran away and struck a stop block, resulting in a breach of containment of a Class 111A tank car. The Board determined that:

> In general, data collected by the TSB on accidents suggest that over 60 per cent of releases of products from Class 111A tank cars were through damaged top fittings; over 25 per cent were due to car structural failure, mainly from punctures in the head or shell; and about 10 per cent of releases were through damaged bottom fittings. Class 111A tank cars do not have sufficient protection against punctures, even in a low-speed impact due to the thinness of the tank shell and the absence of a head shield.

In TSB investigation report R96M0011, referring to the issue of damaged tank cars that presented a potential hazard prompting an evacuation, the Board expressed a safety concern as follows:

> In view of the vulnerability of Class 111A tank cars to product releases in accidents, the Board is concerned that the carriage of certain dangerous goods in such cars may be putting persons and the immediate environment at risk. These risks could be mitigated by reducing the probability of product releases through design improvements for protecting the cars, especially the protuberances that are prone to being sheared off in an accident.

In TSB investigation report R92D0065, the Board found that:

> Experience has revealed that, due to their construction, series 111A tank cars have a reduced ability to maintain tank integrity, and reduced ability to provide a degree of protection against loss of product, when compared to the preferable series 112 and 114 cars.

The following is a list of developments that have taken place to address the issues brought forth in the above occurrences:

- Work was initiated and is now completed, at the request of Transport Canada (TC), prescribing design improvements to top fitting protection for tank cars in sulphuric acid service (Section 2.2.3 of AAR M1002 as referenced in CAN/CGSB 43-147-97).

- Work is in progress, with representation by TC under Tank Car Committee Docket T94.27 (January 2001), to investigate top fitting protection for all tank cars.

- Work jointly initiated by TC and the Federal Railroad Administration prescribes enhanced requirements for tank cars to be authorized for increased gross weight by exemption, and TC permits for equivalent level of safety. Such tank cars must have an increased puncture resistance, an optimal cushioning system, and must be designed to fatigue requirements over and above those prescribed by the AAR. Additionally, these tank cars must be equipped with re-closing pressure relief devices and the owner is required to implement a life cycle inspection program. Many of these car types are already in service.

- Aluminum and nickel material cars must have a full shield when in dangerous goods service [CAN/CGSB 43-147-97, Section 73.31 (b)(3)(ii)].

Analysis

Train operation was not considered a causal factor in this derailment. Therefore, the analysis will focus on the failure of the rail, track inspection and the cause of the breach in the tank cars that resulted in the release of kerosene and asphalt.

Track

The failure of the rail was due to a combination of factors. The joint bar assembly at Mile 85.94 was loose for an extended period of time, as evidenced by the oblong bolt holes and the polishing of the rail and the joint bars. The initial brittle fracture initiated from a pre-existing minute crack (stress raisers) located in a mechanically induced and plastically deformed metal structure around the bolt hole. The combination of pre-cracks and low ambient temperature caused the rail failure and subsequent derailment. Because the pre-existing crack was not visible during regular track inspections and was not detected by the rail flaw detection equipment during the 25 October 2000 run, there were no corrective measures taken. Had the rail joint been tightened to the specified torque level to prevent the joint assembly from moving, the rail failure may have been prevented by eliminating the plastic deformation of the bolt hole that caused the stress raisers to form.

Although the track inspection program included electronic testing and regular inspection by track forces using a Hi-rail vehicle, the inspections were not adequate to detect damaged bolt holes or the loose joint assembly. As a result, the assembly, that should have been torqued to maintain tightness, remained loose in service for an extended period of time. The number of bolt hole defects detected by the rail flaw detection car, and the number of urgent narrow gauge defects detected by the TEC should have warranted a more detailed, visual inspection.

Tank Cars

The tank shell steel of NCTX 20736 met AAR design specifications for 111A tank cars. The pad material had a lower ultimate tensile strength of approximately 93 per cent of the strength of the tank shell steel and, therefore, it would be expected that the weak link would have been the pad and not the tank. The use of undersized pads to secure the brackets to the tank shell of tank car NCTX 20736 resulted in the pads acting as extensions to the brackets rather than as engineered failure points. This placed the weak point at the tank shell rather than at the bracket-to-pad interface as required by AAR specifications. In this case, since the pad was 0.5 inch thick, the required edge distance would be 1.5 inches. Therefore, the pad should have been at least 7.5 inches in diameter to meet the AAR specifications. During the derailment, the brackets were struck and the inadequate diameter of the brake bracket support pad resulted in the stress loads being transferred through the pad to the tank shell rather than the bracket breaking away from the pad. This resulted in the breach of containment and release of approximately 48 000 litres of kerosene into the soil.

The loss of an additional 34 000 litres of kerosene, resulting from derailment damage, may have been prevented had head shield protection been installed on tank car CP400335. Because there was no manway housing to offer protection for the top fittings on the 29th, 32nd, 33rd cars, the safety vents were damaged and approximately 2000 litres of kerosene was lost. The risk of a breach of containment during derailments is increased when dangerous goods are shipped in tank cars without head shields and top fitting protection.

Environmental Issues

The accidental release of kerosene and liquid asphalt required extensive remedial action to protect the environment. Although the ground was frozen, there were surface cracks in the soil that allowed the spilled kerosene to penetrate the surface and infiltrate the subsurface soils. The liquid asphalt solidified and was removed with little environmental damage. CPR contracted an engineering firm to reclaim the contaminated soil, in accordance with provincial and federal regulatory requirements, until it has been returned to its natural state. The process should be completed in 2003.

Findings as to Causes and Contributing Factors

1. The derailment occurred in cold weather due to a brittle fracture of the rail at a joint where there were existing pre-cracks at an elongated bolt hole.

2. Although the track inspection program included electronic testing and regular inspection by track forces using a Hi-rail vehicle, the inspections were not adequate to detect damaged bolt holes or the loose joint assembly.

3. The inadequate diameter of the brake support bracket pad resulted in the stress loads being transferred through the pad to the tank shell, rather than the bracket breaking away from the pad, resulting in the breach of containment.

Finding as to Risk

1. The risk of a breach of containment during derailments is increased when dangerous goods are shipped in tank cars without head shields and top fitting protection.

Safety Action

Track Particulars

TC advises that the issue of the existence of loose rail joints and bolts at the location of the derailment will be examined by TC's regional office.

Tank Cars

Tank car NCTX 20736 is one of a fleet of cars owned by PLM International Inc. (PLM) and identified by the AAR as having a potential problem with the dimension and welding of the pad to the tank shell. The AAR and the car owner are working together to ensure that all cars in the fleet that have been identified with similar brake support pad size be inspected at the next shopping of the car. At the beginning of 2003, there are 14 out of a total of 1208 identified cars left to be inspected. Of these, 7 cars are in active service. It is planned to have them inspected by the end of March 2003. Another 4 cars are in storage and will have the necessary changes completed before they are returned to service. The remaining 3 cars have been assigned "to be scrapped" status. Car owners other than PLM have been notified of the problem and requested to initiate a modification program similar to PLM's to conclude by 10 October 2003.

Environmental Clean-up

CPR contracted an engineering firm to reclaim the soil contaminated from the tank car containment breach. The accidental release of kerosene and liquid asphalt required extensive remedial action to protect the environment. Approximately 7125 cubic metres of kerosene-contaminated soil was excavated from the derailment site and transported to a land farm treatment area. The soil is to be reclaimed in accordance with provincial and federal regulatory requirements until it has been returned to its natural state. The top nine inches of soil is tilled, allowing hydrocarbons to vent to the atmosphere. The soils are sampled two to three times a year. When the soil meets the provincial criteria, it is returned to the excavation site. To date, three lifts have been returned to the excavation site. This leaves two lifts for 2003, which should complete the mediation of the contaminated soils.

Earth dykes were constructed to contain the liquid asphalt, which solidified and did not infiltrate the soil. Approximately 481 tonnes of solidified asphalt was excavated and disposed of at a resource recovery facility.

This report concludes the Transportation Safety Board's investigation into this occurrence. Consequently, the Board authorized the release of this report on 06 December 2002.

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