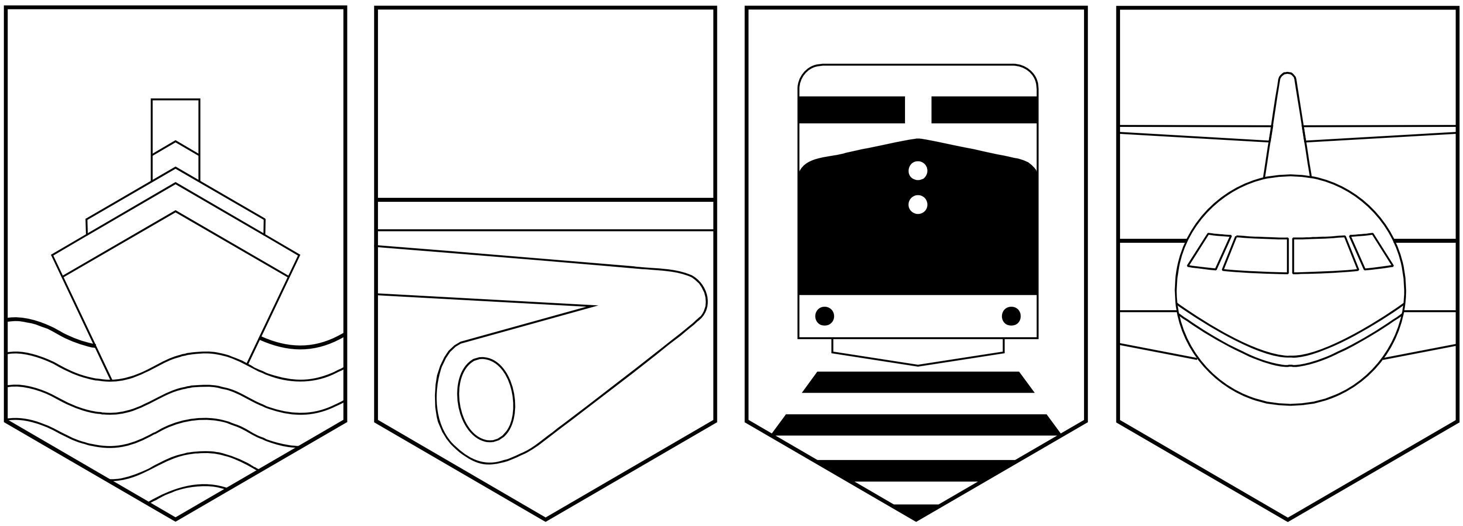
Transportation Safety Board of Canada
Bureau de la sécurité des transports du Canada



RAILWAY OCCURRENCE REPORT

DANGEROUS GOOD LEAK

CANADIAN NATIONAL
YARD ASSIGNMENT NO. 0703
MILE 132.8, SAINT-LAURENT SUBDIVISION
MONTREAL, QUEBEC
27 JANUARY 1994

REPORT NUMBER R94D0033

Canada

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Railway Occurrence Report

Dangerous Good Leak

Canadian National
Yard Assignment No. 0703
Mile 132.8, Saint-Laurent Subdivision
Montreal, Quebec
27 January 1994

Report Number R94D0033

Synopsis

On 27 January 1994, at 1145 eastern standard time (EST), while shoving into the Rivière-des-Prairies Yard, in Montreal, Quebec, a Canadian National (CN) yard crew detected a strong odour of gasoline. The train crew determined that tank car PROX 47917, loaded with gasoline, was leaking from a crack in the tank shell at the "B" end of the car.

The Board determined that the tank shell fractured as a result of being subjected to impact forces which were higher than the anticipated limits of the car design.

Ce rapport est également disponible en français.

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1.0 Factual Information

1.1 Background Information

At approximately 1145[1] on 27 January 1994, at Mile 132.8 of the Saint-Laurent Subdivision, the crew of Canadian National (CN) Yard Assignment No. 0703, while setting out the caboose at the Rivière-des-Prairies Yard, in Montreal, Quebec, detected a strong odour of gasoline and subsequently found that tank car PROX 47917 was leaking gasoline. A CN Special Commodities officer, Petro-Canada (consignor) representatives, and the local fire department were called to the scene. An inspection of the tank car determined that the leak was a result of a fracture in the tank shell on the "B" end of the car, near the stub sill.

The fracture initiated at the weld between the stub sill and the head shoe, propagated along that weld, across the support plate into the tank head, and then into the tank shell at both the left- and right-hand side of the tank car.

Transport Canada (TC) issued an estoppel certificate to allow the gasoline to be transshipped and the damaged car to be forwarded to the Procor shop in Montreal for examination.

The examination revealed:

a) a 12-inch crack along the front weld between the stub sill and the head shoe;

b) an eight-inch crack along both side welds between the stub sill and the head shoe;

c) a crack across the support plate and associated welds on both sides;

d) a diagonal crack into the tank head and shell, 41 3/8 inches on the R-side and 28 1/2 inches on the L-side of the car;

e) four broken safety hand rail supports wired together;

f) a dent in the air brake reservoir;

g) a metal abrasion and surface rust where the coupler horn contacted the end striker casting ("B" end);

h) a broken safety crossover hand rail ("A" end);

i) a chipped and gouged top of centre pin ("B" end);

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

j) two truck springs missing ("A" end, L-side of the car);

k) a broken centre ladder bracket (R-side of the car); and

l) metal distortion in the parent metal around the body bolsters at all four corners.

When tank car PROX 47917 arrived at Taschereau Yard on 25 January 1994, weather conditions were recorded as cloudy with winds between 11 and 15 km/h and a temperature of minus 17 degrees Celsius. When tank car PROX 47917 was released over the hump track at the Montreal Taschereau Yard on 26 January 1994, the weather was cloudy, minus 30 degrees Celsius with 20 to 28 km/h winds. On 27 January 1994, when the leak was detected, the temperature was minus 25 degrees Celsius and sunny with 20 km/h winds.

1.2 Tank Car Information

Tank car PROX 47917 was manufactured in June 1969, in accordance with specification CTC-111A. Tank cars referred to as DOT-111A in the United States and CTC-111A in Canada are low-pressure, general-purpose tank cars used in transporting liquids. Although all tank cars are pressure vessels, the tank cars with test pressures up to and including 100 pounds per square inch (psi) are described as "non-pressure tank cars" for classification purposes. Other tank cars, with test pressures higher than 100 psi, are described as "pressure tank cars." Specification 111A tank cars belong in the non-pressure group. Tank car PROX 47917, a non-pressure tank car used to transport flammable liquids, had a tank constructed of American Society for Testing and Materials (ASTM) specification A-285 grade C steel. The test pressure for the car was 60 psi. The car was equipped with double-shelf couplers, was not jacketed and was fitted with a stub sill at each end of the tank.

1.3 Dangerous Goods

The tank car was laden with 75,207 litres (17,000 gallons) of gasoline, UN 1203, Class 3.1, a flammable liquid. Gasoline emits vapours which are explosive in a mixture with air at concentrations between 1.3 per cent and 6.0 per cent. It is environmentally hazardous; it is also hazardous to health if it is inhaled or ingested, or if it comes into contact with the skin.

1.4 Dangerous Goods Containment

When the leak was discovered, an on-site command centre controlled and contained the leak and the accident site. Traffic into the area was restricted and drip trays were placed under the car to contain the leaking product. A vacuum truck was brought in to remove product from the drip trays. All sources of ignition were eliminated and constant monitoring of the surrounding area for explosive vapours was performed. An estimated 1,125 litres (250 gallons) of product leaked from the car.

1.5 Recorded Information

Records of the hump yard activities show that the car had been released over the Montreal hump track on 26 January 1994, at approximately 0525, travelling at a speed of 2.8 mph with 27 car lengths to couple. Additional records show that tank car PROX 47917 had been scaled for weight on 26 January 1994, at which time it was confirmed as an empty (residue) car. The car was humped into classification track No. 80. Afterwards, a yard assignment picked up cars from classification track No. 80 and marshalled the cars to build train No. 591 which moved them to the Rivière-des-Prairies Yard. From this yard, a yard assignment moved the car to the Petro-Canada loading rack in Montreal east.

1.6 Other Information

1.6.1 Car Manufacturer

Tank car PROX 47917 was constructed by Procor Limited, located in Oakville, Ontario, in June 1969. Repair records indicate that only minor repairs had been performed on the car since construction. A copy of its construction certificate (No. 23263) revealed that 20 cars were built in accordance with this certificate. The other 19 cars have not been reported as having experienced stub sill or tank failure. Tank car PROX 47917 had last received a stub sill inspection in August 1992, with no exceptions noted.

1.6.2 Car Construction Requirements

In Canada, all tank cars transporting dangerous goods must meet the requirements of Canadian General Standards Board (CGSB) standard CAN/CGSB-43.167-94 which also refers to the Association of American Railroads (AAR) Operations and Maintenance Department, Mechanical Division, *Specifications For Tank Cars M-1002*. All cars must meet structural design and test requirements. These specifications relate to materials, welding, repairs, alterations, linings, and markings. The specifications are in the custody of the AAR Mechanical Division's Tank Car Committee. In accordance with the material requirements of these specifications, the shell and the head plate must be a minimum of 7/16 inch thick. ASTM specification A-285 grade C steel was allowed to be used at the time the tank car was built. This grade of steel is no longer permitted to be used for building tank car tanks.

Welding specifications include requirements for size and contour of the weld bead and the weld penetration and fusion of weld with parent metals. Whenever a weld, in excess of three inches in length or width, is welded directly to the tank shell, post-weld heat treatment is required.

1.6.3 Car Movement History

The car had been delivered to the Petro-Canada loading rack at 1600, 26 January 1994. Loading was completed at 0800 the next day and, at 1100, Yard Assignment No. 0703 lifted tank car PROX 47917 from the siding. The shipper had pointed out damage to hand rail supports which CN employees wired up before departing for Rivière-des-Prairies. Upon arriving at the Rivière-des-Prairies Yard, at 1145, it was discovered that the car was leaking.

1.6.4 Car Inspections

Tank car PROX 47917 arrived at the Taschereau Yard on train No. 302 on 25 January 1994. It was subject to a certified car inspection just before noon the same day. An outbound inspection was performed the next day, after the car was humped and placed for movement on train No. 591.

The first inspection, on 25 January 1994, was performed in accordance with TC's Railway Freight Car Minimum Inspection and Safety Standards, the AAR *Field Manual* and the dangerous goods safety inspection standard. The second inspection, on 26 January 1994, involved the testing of the train's air brakes and a departure inspection. No exceptions to the mechanical condition of the car were noted during either of these inspections.

Seven days after the leak of tank car PROX 47917, railway inspectors detected a crack in the stub sill of car PROX 40540 in Senneterre, Quebec. Tracing the car movement history, it was learned that this car had received a certified car inspection at the Taschereau Yard at the same time as car PROX 47917. It was also found that this car was the second car next to car PROX 47917 on train No. 591 on 26 January 1994. Other cars which were coupled on PROX 47917, namely PROX 40611, 40327, 46397 and CGTX 21124, 21235, 21218, were found with different, relatively minor damage between March 1994 and May 1995. Some of the defects found were consistent with high impact damage.

1.7 Tests and Research

1.7.1 Transportation Safety Board Engineering Branch

A part of tank car PROX 47917, containing the fracture surfaces, was cut off and sent to the TSB Engineering Branch for examination.

The examination by the Laboratory (report LP 56/94) concluded that:

1) the fracture originated in two locations in welds between the stub sill and the head shoe on both sides of the head shoe, close to the front corners;

2) the cracks propagated in a symmetrical manner, and progressed into the tank plate following the locations of highest stress concentration;

3) the cracks propagated in a brittle manner and there was no evidence of any pre-cracking;

4) the fracture surface revealed inadequate weld fusion in the transversal weld between the head shoe and the stub sill, resulting in weld pull-out; and

5) Charpy results showed that the head plate energy absorption decreased linearly from 62 foot-pounds at 22 degrees Celsius to 5 foot-pounds at a temperature of minus 30 degrees Celsius.

1.7.2 Inspection Programs

In 1992, a stub sill inspection program was mandated by the AAR, TC, and the U.S. Department of Transportation. The program required the inspection of stub sills on all North American tank cars within a defined schedule, repairing any cracked defects found, and the results to be reported to the AAR.

In 1993, a study of tank car cracking in the stub sill area was undertaken by SIMS Professional Engineers, as commissioned by the AAR. The report included the inspection of 34,403 tank cars. The results were as follows: 16,500 cars (or 48.0 per cent) were found with defects, of which 5,529 (or 16.1 per cent) had parent metal defects, and 5,948 (or 17.3 per cent) had significant weld defects.

The inspection work continued and, as of 28 February 1995, a total of 63,478 tank cars had been inspected. To that date, 46.6 per cent of cars inspected were found with defects, 16.9 per cent had parent metal defects and 17.2 per cent had significant weld defects. A considerable number of cars were found with more than one defect.

1.7.3 CANAC Railroad Technologies

CANAC Railroad Technologies (CANAC), located in Montreal, conducted a stress analysis of tank car PROX 47917 in an attempt to determine the coupling force necessary to cause the crack.

The CANAC report in part contained the following:

> Records from Taschereau Yard showed that PROX 47917 was humped at 0525 hrs on January 26 when the temperature was -30ºC, and that it was travelling at a relatively normal 2.8 mph with 27 car lengths to couple. It is believed that following cars hung up (with possible sticky brakes or bearings), and that the hump loco was later used to push the strings together. PROX 47917 may have therefore received an impact-squeeze.

The information concerning the following cars at the hump and the use of a hump locomotive to push the string together had not been known previously.

CANAC concluded that:

1. Finite element analyses indicated that maximum Von Mises stresses occurred at the front corner connection of the shoe to the stub sill. This is apparently the origination point of the brittle fracture in car PROX 47917.

2. Assuming that the brittle fracture occurred at ultimate stress on account of low steel ductility at low temperature, and there was no prior visible flaw size, it is believed that an impact force in excess of 6,670 kN (1,500 kips) was necessary to cause the observed damage on a properly welded car. In the presence of poor weld fusion along the front of the head shoe, this would be reduced. It is necessary to know much more about the details of the poor weld to estimate this reduction.

3. If the empty tank car was the striking car, it is believed that an impact velocity of roughly 20 mph (33 km/h) would have been necessary to cause the damage. If, however, a string of cars ran into the tank car, they may only have been travelling at 10 mph (16 km/h) to have generated equivalent energy. Such an event (either event) must be considered a rare occurrence.

4. The information would indicate steel yield at 2,240 kN (500 kips) squeeze. This design of car should have passed a 3,580 kN (800 kip) squeeze test. It is believed that local yielding at normal temperature may have relieved the high concentrated stresses, and that stress redistribution would provide load carrying ability with no visible signs of distortion. Had there been an inherent weakness in car design, it would have surfaced long ago during the 25-year history for this car type.

5. The rupture occurred because of an abnormal incident during frigid -30ºC weather. Had the same incident occurred on a warm day (22ºC), the steel could have locally yielded in a ductile manner while absorbing roughly 12 times more energy. There may or may not have been any visible tear, and it certainly would not have progressed beyond the shoe area.

6. The TSB and CANAC materials tests revealed nothing abnormal in the steel itself.

7. Finite element analysis techniques, in the hands of a skilled operator, provide a powerful tool for complex stress analyses. Caution must be exercised, however, in the interpretation of the data to ensure that it is compatible with practical experience.

1.7.4 Other Documented Sill Failures and Damages

Over the last 10 years, numerous problems pertaining to stub sill areas of tank cars have come to light. Some led to dangerous goods releases. Others reduced the structural integrity of tank cars involved.

In some instances, the failure originated at pre-existing cracks. In other cases, there were failures without pre-existing cracks. Some tank cars failed as a result of a brittle fracture; others failed by fatigue.

The following is a summary of cases recorded in TSB files:

- On 04 January 1986, in Campbellton, New Brunswick, tank car NATX 13657 leaked approximately 45,000 litres (10,000 gallons) of sulphuric acid into the Chaleur Bay. An inquiry determined that the fracture origin was located in an inferior weld securing the tank shell to the sill pad, that the welding in the area of the origin of the fracture was not performed in accordance with the original construction certificate, and that the car, sometime during its life, was subjected to an impact great enough to break the main spring of the draft gear.

- On 12 February 1986, in Edmonton, tank car PROX 13499 leaked 30,000 litres (6,600 gallons) of sulphuric acid. The cause of the failure was determined to be an inferior weld at the bottom reinforcing pad.

- On 19 February 1986, when car CEWX 117 required a brake shoe and the correction of an out-of-place spring, a detailed inspection revealed a 10-inch crack in the top cover plate of a stub sill. The crack was determined to have propagated from an inferior weld. An inspection of two other CEWX cars found the same cracking originating from an inferior weld at the same location. This led to further inspections which resulted in 46 tank cars being found defective, requiring considerable repairs.

- On 26 March 1986, car NATX 34165 was observed to have heavy frosting at the "B" end of the car. A further inspection revealed that butane vapours were emitting from a crack in the tank shell. The origin was determined to be an inferior weld in the head shoe area. This led to multi-origin fatigue cracks which formed along this weld. Further, a weld flaw at the corner of the tank stub sill connection provided the origin for a brittle fracture which propagated along the line of fatigue cracks and then continued into the tank head.

- On 01 April 1986, Canadian Pacific Limited (CP) applied to store eight cars of isobutyl alcohol in Welland, Ontario. An inspection of the cars, before granting a special permit, found that four of the cars had cracks developing in the stub sill area. This led to a further inspection of sister cars. Out of the 180 tank cars built to the same design, 50 per cent were found with similar cracks. As a result, the car manufacturer changed its design and all 180 tank cars were modified accordingly.

- On 10 April 1986, during a routine yard inspection, car UTLX 81555 was found to have a fracture on one side of the stub sill. The cause was determined to be a result of high-speed impact at an unknown location by the car itself or by a string of other cars.

- On 12 January 1989, tank car PROX 47921 leaked 51,840 litres (12,000 gallons) of diesel fuel in the Senneterre Yard. The tank shell failed by brittle fracture. A pre-existing crack in the weld between the head shoe and the tank head was the point of origin. The brittle failure was caused by a heavy impact.

- On 16 November 1990, when tank car ECUX 564100 was found with cracks in the stub sill, the cracks were partially covered by a spray-on insulation, impairing visual detection during routine inspections.

1.7.5 Other Related Information

On 01 October 1993, in Alyth Yard, Calgary, Alberta, car BN 875146 was found leaking fuel oil because of cracks in the tank shell. The cracks had developed because of a high impact, as substantiated by physical and metallurgical evidence. As a result of this incident, on 09 November 1993, TC's staff, while inspecting cars in Coutts, Alberta, found three additional BN tank cars with similar cracks (875064, 875023 and 875072).

On 20 August 1993, railway inspectors at Brantford, Ontario, found tank car CITX 35805 with a 37-inch crack originating from a poor weld in the front draft stop and migrating through the stub sill and support plates.

On 28 January 1994, tank car PROX 81631 was found by railway inspectors at Brantford with a 30-inch crack in the stub sill area. Examination of this car revealed previous derailment damage to the stub sill, tank jacket, and roller bearings. The fracture was determined to have originated from the point of previous damage to the stub sill and travelled upwards through the sill.

On 04 February 1994, in Sarnia, Ontario, styrene monomer was found leaking from tank car PROX 24017. An inspection and testing revealed that a 79-inch crack had initiated in the head shoe at a poor weld and had progressed through the stub sill, traversed the support plates and started into the tank shell. Damage to this car appeared to have been caused by a high impact.

On 15 March 1994, in Sarnia, a TC inspection found tank car GATX 13147 with cracks developing in both "A" and "B" stub sills and the body bolster securement (both "A" and "B" ends and R- and L-sides of the car). TC safety officers found five additional cars with varying degrees of stub sill cracks (GATX 97920, 96475, 18569, 13082, and CGTX 64158). Information involving these cars revealed that all cars had been subjected to a stub sill inspection within the previous year in conjunction with the study conducted by SIMS Professional Engineers.

On 26 March 1994, in Edmonton, Alberta, a cut of runaway cars collided with six stationary tank cars on a shipper's private track. Two cars were then found to have cracks in the stub sills (CELX 23050 and 23016). The crack in CELX 23016 was determined to be pre-existing; however, both cars were found to have cracks initiating in poor welds.

On 28 June 1994, in Toronto, Ontario, a hump yard incident occurred involving the impact of two tank cars (PROX 91519 and 91522) with other cars released from the hump track. These cars were equipped with full centre sills, and no cracks were found; however, both cars received an impact great enough to bend the sill, requiring them to be removed from service.

1.8 Miscellaneous Information

All tank cars in North American service are built from metals, predominantly steel. Carbon and alloy steels exhibit ductile-brittle transition at a certain temperature. They typically exhibit a decreased energy absorption capability at low temperatures. In some instances, the relationship is linear, and there is no clear plateau where a nil-ductility temperature can be defined. The relationship is well known and led the AAR Tank Car Committee to change its specifications effective 01 January 1989 to require that only normalized steel plate be used to build cars which carry compressed gases or the most dangerous liquids (which do not include gasoline). The normalization of the steel will provide a uniform structure and properties and will refine the grain size. A finer grain size increases the toughness and ductility.

2.0 Analysis

2.1 Introduction

A crack originating in the weld between the head shoe and the stub sill propagated into the support plate, and then into the tank head and tank shell of tank car PROX 47917. As a result of the fracture, liquid product leaked. It is clear that tank car PROX 47917 failed by the mechanism of brittle fracture. The fracture initiated when a high tensile stress was applied on the weld at a temperature for which this particular steel has very low energy absorption. The weld represented an area of higher stress concentration which located the initiation site of the failure. The analysis will discuss how car PROX 47917 may have been damaged, and focus on the more general issue of tank car integrity.

2.2 Consideration of the Facts

2.2.1 Car Handling

Tank car PROX 47917 may have been subject to an impact squeeze during or after humping at Taschereau Yard. The force needed to cause the damage found on tank car PROX 47917 would have been created if this car had been coupled with other cars in track No. 80 at a speed of 20 mph. If, on the other hand, tank car PROX 47917 was subject to impact squeeze (by being coupled to other cars and struck by a string of other cars), a speed of only 10 mph would have created an identical force. The hump speed of the car on 26 January was recorded at 2.8 mph. Therefore, it is reasonable to say that the humping of car PROX 47917 did not cause the failure. It appears that the damage was inflicted to the car after it came to rest in track No. 80 and that an impact squeeze caused the crack -- likely when the hump locomotive pushed a string of "hung-up" cars into tank car PROX 47917.

2.2.2 Car Construction Requirements

The metal from the tank shell met the requirements of the specifications for tank cars in force at the time that the tank car was built.

The TSB Engineering Branch found the tank shell steel brittle at January temperatures. Based on the result of its stress analysis, CANAC concluded that, had the steel not been brittle, the tank car would have been capable of absorbing about 12 times more energy without failure.

It is also evident, however, that, at a low temperature, a tank car made of a brittle material may perform satisfactorily for its full life. In the case of car PROX 47917, the tank car was in service for 25 years and travelled over 750,000 kilometres without any apparent problem.

The three conditions for a brittle failure to occur on an otherwise ductile material are: a high tensile stress, such as an impact loading, an area of the car inherently subjected to higher stresses, such as a weld, and a temperature low enough to lower significantly the energy absorption capability of the steel.

According to the CANAC report, tank car PROX 47917 theoretically would have had to have been exposed to a force in excess of 6,670 kilonewtons (kN), if properly welded with no prior visible flaw. There was no evidence of any pre-cracking, but there was inadequate weld fusion in the transversal weld between the head shoe and the stub sill, resulting in a weld pull-out. It follows that the car had not previously been subjected to such a force for it would have leaked. In North America, there are tens of thousands of tank cars carrying regulated products which may be brittle at winter temperatures, but which will never be exposed to such a force. Therefore, it would seem that these tank cars, if properly welded with no prior visible flaws, do not present a safety hazard unless they are subject to such extraordinary forces.

2.2.3 Mechanical Inspections and Car Construction

It is reasonable to say that tank car PROX 47917 was not damaged when first inspected on 25 January 1994 and that, based on the facts, the damage was inflicted to the car before it departed the yard on train No. 591 on 26 January 1994. Thus, the damaged condition of tank car PROX 47917 was not detected during the second certified car inspection later on 26 January 1994.

Further, the inspection by Petro-Canada employees did not detect the fracture in the weld between the head shoe and the stub sill and in the head and shell of the tank. Similarly, the train crew which performed temporary repairs to the broken parts on 27 January 1994 did not notice the fracture.

At this point, it should be realized that, despite being fractured, tank car PROX 47917 was not leaking product immediately after loading. Such a fracture is visible, as a hairline mark, over its full length and is clearly visible provided that one looks for it. Employees of the shipper were not specifically instructed to look for fractures in the stub sill area of the tank cars at the time of the accident.

In the case of a brittle failure, there is usually no plastic deformation. However, a hairline crack will be present, and the product will eventually escape.

The defects described in paragraphs a) to d) of subsection 1.1 of this report relate to the fracture and would have been visible on close scrutiny. The defects described in paragraphs f), h), j) and l) of subsection 1.1 were visible on a perfunctory look. To the initiated observer, those defects would have been consistent with a high impact. This fact raises the question of the quality of the inspection of departing train No. 591 on 26 January 1994.

2.2.4 Comparison Between the Failure of Car PROX 47917 and Other Failures

The failure of car PROX 47917 was due to a brittle fracture.

Many of the other failures and occurrences described earlier were also caused by brittle fracture. All of those cars were built from ASTM 285, 515, 516, and TC128 steels. From a theoretical point of view, the TC128 steel should have superior performance as far as a temperature of ductile-brittle transition is concerned. However, in the past, on at least one occasion, the temperature of ductile-brittle transition was found to be minus 37 degrees Celsius for a failed tank car tank made of TC128 steel. The AAR requirement to normalize all plates used to build "pressurised" tank cars should prevent this from happening on cars now built for pressurised service.

2.2.5 Fatigue Cracking

Although normalizing will reduce the incidence of brittle failures, it will not prevent either their recurrence, or the failures due to fatigue. Fatigue is a progressive mode of failure in which a crack initiates and grows according to the applied stress and the size of the existing crack. Again, the crack will initiate in an area of stress concentration, but unlike a brittle failure, may initiate under normal operating loading and at room temperature or above.

As previously mentioned, stress raisers, from which a brittle fracture initiates under given loads, have to be present before a brittle fracture may occur. Each pre-existing crack, defect or imperfection would act as a stress raiser. In the case of a pre-existing crack, the larger it is, the lesser the load needed for brittle fracture propagation. Considering that it is reported that over 45 per cent of North American tank cars inspected between 1993 and early 1995 were found to have pre-existing cracks or defects, some safety concerns may arise.

Some cars developed new stub sill cracks within a year after the AAR-mandated inspection and repairs.

2.2.6 Possible Preventative Measures

In consideration of the facts and analyses, certain possible preventative measures evolve. <u>Careful inspections</u> could lead to both the early detection and repair of the cracks and the removal of unsafe cars from service.

Tank car PROX 47917 failed as a result of a very strong impact. Whenever such an impact occurs, the employees involved are usually aware of it, be it in a hump yard or flat switching. It would stand to reason that the employees who witness, or who believe that they have witnessed, a greater-than-normal impact between a tank car and other rolling stock at coupling either inspect it or cause it to be inspected. Those inspections should concentrate on the structurally sensitive areas of the car.

It would also be reasonable to expect that, if a car sustains damage, such as car PROX 47917, the railway inspections, be they arrival, departure, brake or dangerous goods inspections, should be performed in such a way that visible damage is not missed.

Furthermore, when a tank car is at a shipper's siding, away from the haste of the rail yard, it is the ideal time to look for any signs of inflicted damage or any other distress. Continuous education of the work force at loading racks and a complete inspection of each tank car could prevent most, if not all, of the dangerous situations described in this report.

Finally, if the tank car owners would be made aware that their vehicle was involved in an unusual situation, such as a strong impact, they would be in a position to take necessary corrective action. Most often, they are unaware of such situations or become aware of them only when their cars are involved in an accident or incident.

3.0 Conclusions

3.1 Findings

1. Tank car PROX 47917 leaked gasoline as a result of a fracture in the tank head and shell.

2. Tank car PROX 47917 was subject to an impact severe enough to propagate a brittle fracture.

3. The fracture was present before the tank car was loaded with the product. When the car was transported after loading, the forces of the movement opened the fracture to the degree that the product started leaking.

4. An inspection performed by railway personnel, before loading, failed to detect the fracture and other damage to the tank car.

5. The inspection performed by the shipper detected and recorded some defects on the tank car; however, it did not identify the fractured head and shell of the tank car.

6. Tank cars exhibiting brittle fracture have experienced extraordinary tensile stress from impact loading at low temperatures.

7. Tank integrity is not compromised by normal service forces.

8. Stress raisers (pre-existing cracks, defects or imperfections), from which brittle fractures initiate, existed in more than 45 per cent of North American tank cars inspected between 1993 and early 1995.

9. Fatigue cracking, located in areas of high stress concentration, may initiate under normal operating conditions at moderate temperatures.

10. Some cars developed new stub sill cracks within one year of the Association of American Railroads mandated inspection and repair.

11. The reporting of all apparent greater-than-normal impacts involving tank cars could result in the consequential inspection of the structurally sensitive areas of such cars.

3.2 Causes

The tank shell fractured as a result of being subjected to impact forces which were higher than the anticipated limits of the car design.

4.0 Safety Action

4.1 Action Taken

In December 1994, a TSB Rail Safety Advisory was forwarded to Transport Canada (TC) outlining several examples where tank cars containing serious defects had passed an assortment of CN inspections designed to identify such defects, including serious cracks in tank car stub sills. Following this Advisory, TC conducted a survey and random interviews of CN and CP railway certified car inspectors to evaluate the level of knowledge of safety rules, in particular the rules and inspection practices relating to tank car stub sill inspections. As a result, CN effected a refresher program for its car inspectors. Furthermore, TC advised that the Railway Association of Canada (RAC) was informed to ensure that all its railway members were made aware of the tank car inspection problems.

4.2 Action Required

The Board recognizes that some of the problems experienced with the current design and specification of the stub sill tank cars used in the North American railway industry are being actively addressed. For example, the Board notes that testing is being done at the Transportation Test Center at Pueblo, Colorado, to determine damage tolerance levels for current cars and to ascertain the growth rate of existing cracks. Furthermore, for the newer generation of tank cars, designs must now undergo a computer-based finite element analysis to view a tank car as a complete system to highlight the structural areas prone to stress concentration.

The above-mentioned testing on the existing tank car fleet should enable the railways to better program preventative maintenance for those cracks developed under normal tank car operations. However, the Board believes that, in order to achieve an overall effective control of the stub sill cracking issue, two areas warrant further attention. First, the high impact to which the involved car was subjected caused a brittle failure, creating a crack greatly in excess of the size and growth rate of a crack that would have developed under normal operating conditions. Second, the routine inspection done on this car failed to detect this crack even though it was in an area known to be prone to cracking.

The Board believes that it is not uncommon for stub sill tank cars to be inadvertently subjected to higher-than-normal structural loads or stresses -- even during routine operations. Abnormal impact loads or stresses can occur in high-speed humping, flat switching, "squeezes" while pushing or humping, or when re-railing cars with the use of coupler slings. As noted in this accident, the very cold temperatures which can occur for several months in Canada would increase the likelihood of brittle cracking in the tank car metal. It is recognized that a specialized knowledge of tank car construction and the nature of stub sill cracking is required to detect certain types of cracks, particularly those in the early stages of development. It is also acknowledged that it is difficult to detect some cracks on tank cars fitted with an insulating jacket. In light of the extensive history of problems with cracking in tank car stub sills, the Board is concerned that those stub sill tank cars used in the transportation of dangerous goods, which have been subjected to abnormal impact loads or stresses, are not undergoing a special inspection to confirm their structural integrity for continued use in service. Therefore, to further reduce the risk of a stub sill structural failure or sill cracks propagating into the tank shell on tank cars carrying dangerous goods, the Board recommends that:

> The Department of Transport require that federally regulated Canadian railways:
>
> a) implement an awareness program on the susceptibility of stub sill tank cars to cracking, especially if subjected to abnormal impact loads and stresses in cold temperatures, for all employees engaged in the movement of freight cars;
>
> b) establish a procedure which would allow employees to report stub sill tank cars suspected of having been subjected to abnormal impact loads and stresses; and
>
> c) perform a special inspection on those stub sill tank cars reported as having been subjected to abnormal loads and stresses before the cars are allowed to continue in service.

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Moreover, given that stub sill tank cars are interchanged extensively between the United States and Canadian railways, the Board recommends that:

> The Department of Transport, in consultation with the United States Federal Railroad Administration, encourage the adoption, by American railway companies, of special inspections of stub sill tank cars suspected of being subjected to abnormal impact loads and stresses.

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This report concludes the Transportation Safety Board's investigation into this occurrence. Consequently, the Board, consisting of Chairperson Benoît Bouchard, and members Maurice Harquail, Charles Simpson and W.A. Tadros, authorized the release of this report on 05 May 1997.