National Transportation Safety Board

Washington, D.C. 20594

Safety Recommendation

R-647

Date: April 1, 1994

In reply refer to: R-94-1 and -2

Honorable Jolene M. Molitoris
Administrator
Federal Railroad Administration
Washington, D.C. 20590

About 2:50 a.m. local time on June 30, 1992, Burlington Northern Railroad (BN) freight train No. 01-142-30 derailed as it approached a bridge over the Nemadji River in the Town of Superior, Wisconsin. The derailment resulted when a preexisting crack (detail fracture) inside the rail caused the rail to break under the train load. Fourteen freight cars derailed, including three tank cars that contained hazardous materials: one contained a flammable liquid mixture of aromatic hydrocarbons (aromatic concentrates) that included benzene; one contained liquefied petroleum gas; and one contained crude butadiene. The three tank cars were pulled off the bridge by derailing freight cars behind them and fell about 71 feet, one landing in the river and two landing in a flood plain adjacent to the river. About 21,850 gallons of aromatic concentrates spilled into the river and were carried downriver. The more volatile constituents of the aromatic concentrates evaporated from the surface of the river and formed a vapor cloud, about 20 miles long and 5 miles wide, that resulted in the evacuation of more than 40,000 people from the Town of Superior, the city of Duluth, Minnesota, and the surrounding areas.[1]

The 7/8-inch superelevation in curve 12A (the right curve entering the accident area just north of the Nemadji River bridge) shown in the BN maintenance records for May 1992 indicates that the superelevation was within Federal Railroad Administration (FRA) track safety specifications. Postaccident measurements of the gage, alignment, and superelevation of the undamaged track north of the accident

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[1] For more detailed information, read: National Transportation Safety Board. 1994. Derailment of a Burlington Northern freight train and the release of hazardous materials in the Town of Superior, Wisconsin, on June 30, 1992. Hazardous Materials Accident Report NTSB/HZM-94/01. Washington, DC.

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location revealed that the measurements were within allowed tolerances given in the FRA track safety standards. Postaccident inspection of the track in the accident area revealed no evidence of track subgrade stability problems.

However, Safety Board metallurgical testing and examination of 13 pieces of broken high rail from curve 12A, which contained the first rail breaks, revealed a substantial amount of shelling on all 13 pieces.[2] Shelling spots were along the upper gage corner of the head of the rail and were generally bowl-shaped depressions from which material had been lost. The depth of the most severe spots ranged from 0.12 to 0.202 inches.

Six fractures in the broken rail initiated from darkly discolored transverse fracture regions with crack arrest positions, typical of long-term exposure of a fatigue crack to the environment. Each of the six fatigue cracks initiated at the upper gage corner of the rail head (the corner between the top of the head and the gage surface). Metallurgical examination revealed that the six fatigue cracks were detail fractures from shelling.

According to BN officials, 14 to 18 freight trains per day operate over this track, resulting in about 28 million gross tons (MGT) of annual traffic. The maximum speed authorized by the BN timetable between MP 11.8 and MP 15.5, which included the track in the area of the accident, was 35 mph. The FRA track safety standards define this track as class 3 track based on the speed limit set by the BN. The BN maintenance officers stated that they inspect and maintain the main line, which includes curve 12A in the accident area, to FRA standards for class 4 track.

The FRA track safety standards for class 4 track require only one internal inspection of the rail per year. The FRA track safety standards for class 3 track do not require an internal inspection of the rail unless it carries passenger trains. However, the BN inspection program requires a minimum of two ultrasonic rail inspections a year on main tracks. The roadmaster stated that line segment 2108, the segment of track on which the accident occurred, was ultrasonically inspected three times in 1992.

The most recent internal rail inspection of curve 12A in line segment 2108 was conducted on May 13, 1992, about 6 weeks before the accident. As noted above, postaccident metallurgical examination of the rail disclosed the presence of several

[2] Shelling is technically defined as a progressive horizontal separation of the upper gage corner of the rail head, initiated below the surface and propagating largely parallel to the gage corner surface, commonly found in the high rail of curves. Some areas of damaged rail appeared to meet this definition. However, some of the cracking in other areas on the rail had initiated on the surface of the head of the rail. Surface-initiated cracking on the head of the rail would more properly be referred to as flaking or gage corner spalling. As used here, shelling generally refers to all of the head and gage face damage.

extant detail fractures. Although the Safety Board recognizes that a crack often does not grow at a linear rate, the Board was interested in determining an approximate average rate of propagation for a crack in the rail at the accident site. Accordingly, the Board applied information on propagation rates of detail fractures in rails, reported in a 1988 Department of Transportation study,[3] to conditions of the rail in curve 12A. Results indicate that a crack in that rail could propagate at an average rate of about 2.5 percent of the rail head per MGT of train traffic. Based on annual train traffic provided by the BN, about 3.5 MGT of train traffic had passed over this rail since the rail was inspected with ultrasonic equipment 6 weeks before the accident. The Safety Board's calculations indicate that the detail fractures at the first and second rail breaks were present within the rail during the BN's ultrasonic inspection 6 weeks before the accident. Further, the Safety Board concludes that the internal defects in the rail at the time of this inspection were of substantial size.

During the May 13, 1992, inspection, the ultrasonic inspection car operator recognized that the rail contained shelling but did not consider the conditions severe enough to warrant an exception report. However, because of the surface condition, he conducted additional ultrasonic inspections using handheld equipment. The operator considered the rail to be free from internal defects based on his evaluation of the tests and his experience.

A thorough inspection with handheld ultrasonic equipment performed at the Safety Board's laboratory in conjunction with a Sperry Rail Service official failed to produce any conclusive evidence of internal defects. Further, visual examination at the Board's laboratory of a cross section of the rail near the first break revealed that the propagation of the shelling cracks from the surface into the rail head had formed a series of overlapping cracks extending from the gage side of the head onto the top of the head. The Board believes that this series of overlapping cracks in the rail head prevented the penetration of the ultrasonic sound waves through the head of the rail. For these reasons, it would have been extremely difficult or impossible for the BN's ultrasonic equipment operator to detect these detail fractures, because the surface condition of the rail head caused partial or total reflection of the ultrasonic sound waves before they reached the internal defect.

In addition to ultrasonic inspection methods, the railroad industry also uses induction inspection methods to detect internal defects. According to a representative of Sperry, however, induction inspections are more sensitive to interference from surface conditions than are ultrasonic inspections. Consequently, induction inspections of rail at the accident site, which had severe shelling conditions, may have been less likely to detect the detail fractures within the rail than would the ultrasonic inspection.

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[3] U.S. Department of Transportation, Transportation Systems Center. 1988. Crack propagation life of detail fractures in rails. Cambridge, Massachusetts. October. Available from U.S. Department of Commerce, National Technical Information Service, Springfield, Virginia, No. PB90-113044.

The Safety Board concludes that current ultrasonic and induction inspection methods used to detect internal defects are inadequate when rail has severe shelling or other surface conditions. Therefore, the Safety Board believes that the FRA, should research and develop, with the assistance of the AAR, inspection methods that will identify internal defects in rail that has significant shelling and other surface conditions.

Over the past 20 years, the Safety Board has made several recommendations to the FRA seeking various actions to address rail defects: to study factors affecting rail failures and to develop criteria that will improve the effectiveness of rail inspection procedures and regulations; to revise the track safety standards to ensure the discovery of internal defects in rail before those defects develop into failures; and to amend the track safety standards to require railroad inspectors to list on their inspection records the location of rails that exhibit external conditions, such as shelling, and remedial actions taken.

The 1975 FRA track safety standards identified shelling as a rail condition that could require remedial action, including replacing the rail when a designated railroad track inspector determined that the rail conditions were severe. However, the Board noted to the FRA that the track safety standards failed to define limits of allowable surface conditions, leaving track inspectors to rely on subjective judgment.

Instead of strengthening the 1975 track safety standards, the FRA (in 1982) weakened the standards by deleting several sections that related to rail inspection and remedial action. The Safety Board opposed the proposed changes and commented that the proposed amendments to the track safety standards would adversely affect rail safety.

The Safety Board considered the effect that the 1975 track safety standards might have had on the accident in Superior, Wisconsin, had those standards not been weakened in 1982. The BN's decision to replace the rail would still have been based on the subjective judgment of the BN personnel involved. However, because the track roadmaster and manager of rail quality determined (less than a month before the accident) that the surface condition of the rail in curve 12A warranted rail replacement (which they recommended to BN management for inclusion in the 1993 rail replacement program), the 1975 track safety standards would have required that a 20-mph speed limit be placed on the track until the rail was replaced. (The timetable speed of the track at the time of the accident was 35 mph.) The Safety Board could not determine if, or to what extent, the 15-mph lower speed limit would have mitigated the circumstances of the accident.

The accident in Superior, Wisconsin, is similar to an accident that occurred at Thermal, California, in 1982. Both accidents resulted from detail fractures that initiated from shelling conditions visually apparent to rail inspectors. Prior to both accidents, track inspectors had to rely on their own judgment to evaluate the condition of the rail and to determine what they believed to be appropriate remedial action based on the rail condition. However, had the FRA taken the actions requested in the safety recommendations resulting from the Safety Board's investigation of the Thermal accident, track safety standards could have been in place prior to the Superior accident that provided track inspectors with defined limits of allowable rail surface conditions, including shelling, and that addressed problems associated with shelly rail obstructing the detection of detail fractures during ultrasonic inspections. Such standards could have required the removal of the rail in curve 12A from service prior to its failure or, perhaps, placement of a slow order on the track, which may have reduced the severity of the derailment. Thus, the Safety Board determines that causal to the Superior derailment were (a) the FRA track safety standards, which failed to adequately address rail-head surface conditions (such as shelling) that are known to be associated with rail failure modes and failed to require remedial action; and (b) the lack of objective criteria to assess the risk posed by shelled rail, which has not been adequately addressed by the railroad industry and the FRA.

Therefore, as a result of this accident investigation, the National Transportation Safety Board recommends that the Federal Railroad Administration, U.S. Department of Transportation:

> Research and develop, with the assistance of the Association of American Railroads, inspection methods that will identify internal defects in rail that has significant shelling and other surface conditions. (Class II, Priority Action) (R-94-1)
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> Perform the necessary research and develop standards that (1) provide defined limits of allowable rail surface conditions (such as shelling) that can hinder the identification of internal defects, and (2) require remedial action for rail with surface conditions that exceed defined limits. (Class II, Priority Action) (R-94-2)

Also as a result of this accident investigation, the Safety Board issued safety recommendations to the Association of American Railroads, the American Short Line Railroad Association, the U.S. Department of Transportation, and the U.S. Environmental Protection Agency.

Chairman VOGT, Vice Chairman COUGHLIN, and Members LAUBER and HAMMERSCHMIDT concurred in these recommendations. Member HALL did not participate.

By: Carl W. Vogt
Chairman