National Transportation Safety Board
Washington, D.C. 20594

Safety Recommendation

Date: May 22, 2008

In reply refer to: R-08-9 through -12

Honorable Joseph H. Boardman
Administrator
Federal Railroad Administration
1200 New Jersey Ave, S.E.
Washington, D.C. 20590

About 10:41 p.m. eastern daylight time on Friday, October 20, 2006, Norfolk Southern Railway Company (NS) train 68QB119, en route from the Chicago, Illinois, area to Sewaren, New Jersey, derailed while crossing the Beaver River railroad bridge in New Brighton, Pennsylvania. The train consisted of a three-unit locomotive pulling 3 empty freight cars followed by 83 tank cars loaded with denatured ethanol, a flammable liquid. Twenty-three of the tank cars derailed near the east end of the bridge, with several of the cars falling into the Beaver River. Of the 23 derailed tank cars, about 20 released ethanol, which subsequently ignited and burned for about 48 hours. Some of the unburned ethanol liquid was released into the river and the surrounding soil. Homes and businesses within a seven-block area of New Brighton and in an area adjacent to the accident were evacuated for 2 days. No injuries or fatalities resulted from the accident. The NS estimated total damages to be $5.8 million.[1]

The National Transportation Safety Board determined that the probable cause of the derailment of Norfolk Southern Railway Company train 68QB119 was the Norfolk Southern Railway Company's inadequate rail inspection and maintenance program that resulted in a rail fracture from an undetected internal defect. Contributing to the accident were the Federal Railroad Administration's inadequate oversight of the internal rail inspection process and its insufficient requirements for internal rail inspection.

Rail Defects and Ultrasonic Inspection

During the examination of seven pieces of broken rail recovered from the accident scene, the Safety Board's Materials Laboratory found pre-existing transverse defects[2] (fatigue cracks) at the site of breaks in the north rail of track 1, as well as at other locations within the unbroken rail

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[1] For additional information, see <http://www.ntsb.gov/publictn/2008/RAR0802.pdf>. National Transportation Safety Board, *Derailment of Norfolk Southern Railway Company Train 68QB119 with Release of Hazardous Materials and Fire, New Brighton, Pennsylvania, October 20, 2006,* Railroad Accident Report NTSB RAR-08/02 (Washington, DC: NTSB, 2008).

[2] *Transverse defects* are progressive cracks oriented perpendicular to the length of the rail.

segments. All the transverse defects found in the rail, including the defect at the primary fracture, were identified as detail fractures from shelling.[3]

The largest defect size was at fracture 4; it covered about 70 percent of the existing worn rail head. The next largest defect size was at fracture 5, which covered about 45 percent of the rail head. These two fractures were at the ends of a 14-inch-long piece of rail. Rail-end batter patterns observed at the fractured ends of the recovered pieces indicated that the rail initially broke at fracture 4. Therefore, the primary rail break occurred at the location of the largest defect, with the other fractures secondary to the initial separation. The Safety Board concluded that the failure of the north rail of track 1 was precipitated by a detail fracture (fatigue crack) that originated from shelling on the rail head, reached critical size, and caused a piece of rail to break out under the train.

The rail had been inspected for internal defects about 2 1/2 months before the accident using an instrumented vehicle. At that time, the vehicle operator did not identify any internal rail defects in these sections of rail. The investigation determined that the site of the rail failure was within a 9-foot length of rail where, because of rail surface conditions, the ultrasonic inspection equipment had received only intermittent signal returns from the bottom of the rail.

Based on defect (crack) growth calculations, at the time of the August 1, 2006, rail inspection, the size of the largest defect, which initiated the rail fracture, would likely have been approximately 5 to 11 percent of a new rail head area.[4] Based on Safety Board laboratory evaluations and data from a Transportation Technology Center, Inc., (TTCI) study of rail flaw detection technology,[5] the size of the initiating defect was likely too small[6] at that time to be reliably detected. Also, the shelling that was evident on the rail surface as well as the crack patterns from flaking that were observed on a cross section of the accident rail could have prevented ultrasonic signals sent from the running surface from detecting the defect. A correlation of the data from the August 1, 2006, inspection with the locations of the recovered rail from the area of the derailment showed that the location of the initiating defect was within a 2-inch area that had a loss of bottom signal. The Safety Board concludes that rail surface conditions prevented the effective transmission of the ultrasonic signals, and the defect (fatigue crack) that led to the derailment may not have been large enough at that time to be reliably detected by the inspection vehicle.

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[3] The Sperry Rail Service *Rail Defect Manual* defines a *detail fracture from shelling* as a progressive fracture (fatigue crack) starting from a longitudinal separation close to the running surface of the rail head, then turning downward to form a transverse separation substantially at right angles to the running surface. *Shelling* is surface cracking by metal fatigue near the gage corner caused by repetitive shearing stresses. It is a progressive separation that may crack out at any level on the gage side of the rail but generally at the gage corner.

[4] Defect size is typically given as a percentage of the rail head area of a new rail. The area of the largest defect at the time of the August 1 rail inspection would likely have covered approximately 10 to 22 percent of the existing worn rail head.

[5] B.D. Jeffrey and M.L. Peterson, *Assessment of Rail Flaw Inspection Data,* Colorado State University, disseminated under sponsorship of the U.S. Department of Transportation, University Transportation Centers Program, August 1999.

[6] The TTCI data estimates a 58-percent probability of detection for a defect size of 5 percent of the rail head using an inspection vehicle.

Federal Railroad Administration (FRA) regulations require that all railroads conduct a "continuous search" when inspecting rail for internal defects. In the FRA's interpretation of the regulations, any rail inspection that is interrupted "as a result of rail surface conditions that inhibit the transmission or return of the signal" is not considered to be continuous under the regulation and therefore is not to be considered a valid inspection of the affected rail segment.

About a year and a half before the accident and without consulting the FRA, the NS gave its inspection contractor—Sperry Rail Service (Sperry)—new procedures for inspecting rail for internal defects. In effect, the new procedures permitted the equipment operator to ignore any loss of bottom signal as long as the continuous loss-of-signal distance did not exceed 5 feet of linear rail length. The new procedures were intended to address the detection of vertically oriented longitudinal rail head defects, not transverse defects. Although the new procedures were designed to address a different type of defect, the procedures were applied to the entire inspection process and thereby also affected the detection of transverse defects.

Because the longest loss of bottom signal distance was only about 7 inches of linear rail length (which did not exceed the 5-foot minimum specified by the NS that would have required a repeat inspection), this rail segment was not examined further by the inspection equipment operator during the August 1, 2006, inspection.

The flaking and shelling conditions found on the recovered rail head likely blocked the ultrasonic signals at several locations and caused the intermittent loss of bottom signal at the point of derailment. The point of derailment was within a rail segment about 9 feet long where, during the August 1 ultrasonic inspection, the inspection equipment had encountered an intermittent loss of bottom signal. Because the NS did not require the contractor to repeat the inspection of the rail at these locations (the longest loss of bottom signal distance was only about 7 inches of linear rail length, which did not exceed the 5-foot minimum specified by the NS), the area was not examined further by Sperry, and the internal condition of the rail at these locations was left undetermined. The NS exception to the continuous search requirement eliminated an opportunity to detect the defect that led to the derailment by rerunning the inspection vehicle or by using more effective handheld inspection equipment.

The Safety Board issued recommendations that addressed the effectiveness of internal rail inspections as a result of its investigation of the Burlington Northern freight train accident that occurred in Superior, Wisconsin, in 1992. New provisions were added to the Track Safety Standards through paragraphs (d) and (e) of 49 *Code of Federal Regulations* (CFR) 213.237 that were responsive to the Board's recommendations. These provisions appear to ensure that railroads are required to conduct valid continuous searches for internal defects and that no segments of rail are to remain in service without being inspected.

The FRA reviews the documentation and reports generated from a railroad's internal rail inspections to determine whether the required inspection frequency is met and that any rail defects found are repaired or, if repairs are postponed, protections are put in place as required. These reviews are an important part of the FRA's oversight responsibilities to identify potential safety deficiencies on the railroad. However, the investigation found that the NS procedures allowed as much as 5 continuous feet of signal loss during its ultrasonic inspections, which is not consistent with the requirement in the Track Safety Standards for a continuous search. The NS's preaccident ultrasonic inspection reports for the rail in the derailment area did not identify locations where a valid inspection was not conducted, even though a 9-foot length of track in the area of the derailment showed an intermittent loss of signal. Further, the FRA was not aware that the NS and other railroads had enacted various exceptions to the requirement for a continuous search. The FRA's reviews of railroad rail inspection programs should have identified these inconsistencies. The Safety Board concludes that the FRA's oversight of the NS's and other railroads' internal rail inspection processes was inadequate. Although the Board notes that the FRA is in the process of establishing a rail integrity group that will examine railroads' internal rail inspection programs, the Board understands that the FRA has not required that railroads eliminate potential exceptions to the requirement for a continuous search. Therefore, the Safety Board believes that the FRA should review all railroads' internal rail defect detection procedures and require changes to those procedures as necessary to eliminate exceptions to the requirement for an uninterrupted, continuous search for rail defects.

Rail Defect Management

The rail in the accident area had been in service at this location since 1977. No records were found to indicate the total gross tonnage over the track since that time, but because this track was a main east-west line for the predecessor railroads (Pennsylvania, Penn Central, and Conrail) as well as the NS, it could reasonably be estimated to have carried in excess of 1 billion gross tons before the derailment. Most railroads measure rail wear and consider those wear levels when scheduling rail for replacement. Measurements taken after the accident showed that the rail in some locations in the accident area was near or exceeded the wear level at which the NS would list the rail to be replaced. However, the wear on the rail had not yet reached the level at which the NS would implement a speed restriction.

Over the years, transverse defects have been among the leading causes of train derailments on Class 3, 4, and 5 track.[7] To find defects that can lead to derailments, the FRA Track Safety Standards require that a continuous search for internal rail defects be made for Classes 4 and 5 track (and Class 3 track over which passenger trains operate) after every 40 million gross tons (mgt) of traffic or once a year, whichever interval is shorter. The interval between inspections is intended to provide a safe time frame for detection of internal rail flaws before they can grow to critical size and cause a rail break.

The NS based its ultrasonic rail inspection schedule on a model that takes into account track speed, annual tonnage, hazardous materials transported over the route, whether the territory is signaled or nonsignaled, rail weight and age, curvature, and rail defect/failure history. Rail head wear is not a parameter in the model. Using this model, the NS determined that the track in the accident area should be inspected with ultrasound equipment four times per year.

NS records indicated that track 1 carried about 63.5 mgt per year. Therefore, ultrasonic inspections of this track four times per year resulted in an average interval of about 16 mgt, which was well within the 40-mgt maximum established by the FRA. However, one of a number of factors that can influence growth rates of transverse defects in rail is the amount of rail head wear. When a rail has less material to support the load it carries, the stress levels are higher,

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[7] FRA database: Rail, Joint Bar, and Rail Anchoring Derailments, for all railroads, on main track.

which leads to higher crack growth rates and reduced tolerance for a given crack size. Studies conducted by the Department of Transportation's Volpe Center have confirmed that detail fractures grow faster in worn rail than in new rail, and the critical crack size for failure is smaller.

For worn rail, the time a defect takes to grow from undetectable to critical size is shorter, which increases the risk of failure between inspections. The rail at the point of derailment showed a loss of 40 to 50 percent of the rail head area from wear and grinding. Calculations indicate that in the area of the accident, a defect size of 5 to 11 percent at the time of the August 1 inspection grew to critical size after passage of about 13.8 mgt of traffic, which was less than the average 16 mgt inspection interval developed by the NS. The Safety Board concludes that the NS did not conduct internal rail inspections frequently enough to reliably detect an internal defect before it could grow to critical size in the significantly worn rail.

The New Brighton accident illustrates that as rail wears, it requires more frequent inspections to detect internal defects before they can reach critical size and cause a failure. A defect that was too small to be reliably detected during an internal inspection grew to critical size between inspections even when the interval was more frequent than the 40-mgt or at-least-once-per-year interval required by the FRA. The Safety Board concludes that the FRA's required minimum intervals for internal rail inspections are inadequate because they do not take into account the effect of rail wear, which can allow undetected internal rail defects to grow to critical size between required inspections.

The degree of wear on the accident rail was a factor in the rapid progression of the defect from small to critical size. One of the issues highlighted by the circumstances of this accident is the inadequacy of the internal rail inspection requirement based solely on time and tonnage as set forth in Federal regulations, rather than a damage-tolerance approach.

A damage-tolerance approach would establish an inspection frequency that allows internal rail defects to be identified before they reach critical size. The term *damage tolerance* means the ability of a structure to withstand damage without failure, including damage such as fatigue cracking or wear, which can develop from undetected manufacturing defects or from use in service. For most engineered structural components, including rail, an inspection and maintenance program to detect and repair damage in any component before it reaches critical size is integral to the damage tolerance of the structure. A damage-tolerance approach should (1) identify areas of rail that are prone to failure from high stress and fatigue and (2) determine appropriate inspection intervals based on the defect size detectable by the inspection method being used, the stress level, and the defect (crack) propagation characteristics in the structure. Such an approach would consider all the factors that can affect defect growth rates, including rail head wear, accumulated tonnage, rail surface conditions, track geometry, track support, steel specifications, temperature differentials, and residual stresses in the rail. The capabilities and limitations of the inspection methods used to detect defects are a major factor in determining appropriate inspection intervals in a damage-tolerance approach.

Each railroad should have a rail inspection and maintenance program that addresses its unique operating environment and the effectiveness of its inspection methods. As noted previously, the NS had established rail wear standards, but the amount of wear on the accident rail was sufficient to facilitate rapid progression of a relatively small defect. The Safety Board concludes that, in the absence of a damage-tolerance-based program, rail can remain in use with excessive accumulated wear, which increases the risk of rail failure from rapid growth of undetected internal defects. Therefore, the Safety Board believes that the FRA should require railroads to develop rail inspection and maintenance programs based on damage-tolerance principles, and approve those programs. Include in the requirement that railroads demonstrate how their programs will identify and remove internal defects before they reach critical size and result in catastrophic rail failures. Each program should take into account, at a minimum, accumulated tonnage, track geometry, rail surface conditions, rail head wear, rail steel specifications, track support, residual stresses in the rail, rail defect growth rates, and temperature differentials.

As this accident shows, accurately measuring the level of rail wear is important in order to determine the appropriate frequency for conducting internal rail inspections. When investigators measured the accident rail using a template of the type typically used by railroads to measure rail head wear, they found that the rail head vertical loss appeared to be about 1/8 inch less than was actually measured. Because of downward deformation of the worn rail head under loads, the rail head on both sides of the rail web extended below the profile of new or less worn rail. The rail wear template fits under the rail head, and the downward displacement could have caused the NS to underestimate the amount of wear. The Safety Board concludes that downward deformation of a severely worn rail head can affect the measurement of rail head wear using a rail wear template and may cause a railroad to underestimate the actual amount of wear. Therefore, the Safety Board believes that the FRA should require that railroads use methods that accurately measure rail head wear to ensure that deformation of the head does not affect the accuracy of the measurements.

Placement of Hazardous Materials Cars in Trains for Crew Protection

Twenty-three placarded ethanol tank cars derailed, starting with the 23rd car behind the locomotive units. The 3 locomotives, the first 22 cars (3 empty buffer cars and 19 placarded tank cars), and the last 41 cars (all placarded tank cars) did not derail. Because the first derailed tank car was the 23rd car behind the locomotive units, the train crew was not endangered by the ethanol that was released from the derailed tank cars. Therefore, the placement of the ethanol tank cars in the accident train was not a factor with respect to crew protection in the accident. However, because the accident train was a unit train transporting hazardous materials, questions were raised on scene about the number of buffer cars needed to separate train crews from the hazardous materials on unit trains.

Regulations governing the placement of hazardous material cars in trains for crew protection are contained in 49 CFR 174.85. The regulations specify that, “when the length of the train permits,” a hazardous materials car must be no closer than the sixth car from the locomotive. However, when the length of the train (meaning the number of available buffer cars in the train) does not allow a five-car buffer, trains may move with only a single buffer car. Buffer car regulations were initially developed to address the risks of transporting explosives, which needed to be isolated from ignition sources and from the train crew.

When the basic provisions of 49 CFR 174.85 were developed in the early 1900s, main-line freight trains consisted mostly of a mix of hazardous materials and non-hazardous materials freight cars. As is still the case today, main line trains traveled from one yard to the next (sometimes picking up or dropping off cars along the way), where they were broken down and reassembled into other trains, or where cars were interchanged with other carriers. While the intent of 49 CFR 174.85 was clearly to mandate a minimum five-car buffer on all main-line trains, the regulation made allowances for short trains moving small numbers of cars during switching operations at or between yards. This was the basis for the allowance of a one-car minimum buffer.

Although unit trains transporting nonhazardous commodities such as coal and grain have existed for many years, 49 CFR 174.85 does not address unit trains transporting tank cars or other freight cars containing a single hazardous materials commodity. The FRA, the Pipeline and Hazardous Materials Administration (PHMSA), and the railroads have recognized that buffer cars should be required on unit trains transporting hazardous materials to comply with the intent of 49 CFR 174.85. Because a unit train does not permit the repositioning of cars in the train to provide the five-car buffer (because all the loaded cars contain hazardous materials), the FRA, PHMSA, and the railroads have interpreted the regulation to mean that a one-car buffer is applicable to unit trains transporting hazardous materials. This can result in the contradictory circumstance in which a train of mixed freight cars with a single hazardous materials car must have a five-car buffer and a unit train consisting of all hazardous materials cars may travel across the country with a one-car buffer.

The Safety Board recognizes that the five-car buffer standard was not based upon any rigorous engineering safety analysis, but since the 1920s it has become accepted by regulators and railroads as a proven and effective standard. Although the five-car buffer standard is considered to have been validated over many years, the one-car buffer standard for unit trains does not have as lengthy a historical record and may not be sufficiently validated by historical data.

The Safety Board therefore concludes that without sufficient validation of the one-car buffer standard, the current regulations for the separation of hazardous materials cars from locomotives and their interpretation by the FRA, PHMSA, and the railroads create different levels of safety for crew protection from hazardous materials on unit trains and general freight trains.

The FRA has indicated that the one-car minimum buffer is justified and has concerns regarding regulations that will increase the switching movement for cars of hazardous materials. But unit trains typically involve switching only at the origin and at the final destination. Consequently, adding a specified number of buffer cars to a train at the originating yard generally should not entail additional switching of the hazardous materials cars and therefore would not cause increased risks. Rather, the additional separation could provide greater protection to train crews in the event of an accident.

Unit trains that carry hazardous materials present a special risk because of the high concentration of hazardous materials. Therefore, the Safety Board believes that the FRA should assist PHMSA in its evaluation of the risks posed to train crews by unit trains transporting hazardous materials, determination of the optimum separation requirements between occupied locomotives and hazardous materials cars, and any resulting revision of 49 CFR 174.85.

The Safety Board makes the following recommendations to the Federal Railroad Administration:

> Review all railroads' internal rail defect detection procedures and require changes to those procedures as necessary to eliminate exceptions to the requirement for an uninterrupted, continuous search for rail defects. (R-08-9)
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> Require railroads to develop rail inspection and maintenance programs based on damage-tolerance principles, and approve those programs. Include in the requirement that railroads demonstrate how their programs will identify and remove internal defects before they reach critical size and result in catastrophic rail failures. Each program should take into account, at a minimum, accumulated tonnage, track geometry, rail surface conditions, rail head wear, rail steel specifications, track support, residual stresses in the rail, rail defect growth rates, and temperature differentials. (R-08-10)
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> Require that railroads use methods that accurately measure rail head wear to ensure that deformation of the head does not affect the accuracy of the measurements. (R-08-11)
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> Assist the Pipeline and Hazardous Materials Safety Administration in its evaluation of the risks posed to train crews by unit trains transporting hazardous materials, determination of the optimum separation requirements between occupied locomotives and hazardous materials cars, and any resulting revision of 49 *Code of Federal Regulations* 174.85. (R-08-12)

The Safety Board also issued safety recommendations to the Pipeline and Hazardous Materials Safety Administration and the Norfolk Southern Railway Company.

In response to the recommendations in this letter, please refer to Safety Recommendations R-08-9 through -12. If you would like to submit your response electronically rather than in hard copy, you may send it to the following e-mail address: correspondence@ntsb.gov. If your response includes attachments that exceed 5 megabytes, please e-mail us asking for instructions on how to use our Tumbleweed secure mailbox procedures. To avoid confusion, please use only one method of submission (that is, do not submit both an electronic copy and a hard copy of the same response letter).

Chairman ROSENKER, Vice Chairman SUMWALT, and Members HERSMAN, HIGGINS, and CHEALANDER concurred in these recommendations.

[*Original Signed*]

By: Mark V. Rosenker
Chairman