National Transportation Safety Board

Washington, D.C. 20594

Safety Recommendation

Date: May 10, 2012

In reply refer to: R-12-16 through -22 (New)
R-02-24 through -26 and
R-10-1 and -2 (Reiteration)
R-07-1 (Reclassification)

The Honorable Joseph C. Szabo
Administrator
Federal Railroad Administration
Washington, D.C. 20590

On April 17, 2011, about 6:55 a.m. central daylight time, eastbound BNSF Railway (BNSF) coal train C-BTMCNM0-26, BNSF 9159 East, travelling about 23 mph, collided with the rear end of standing BNSF maintenance-of-way (MOW) equipment train U-BRGCRI-15, BNSF 9470 East, near Red Oak, Iowa. The accident occurred near milepost (MP) 448.3 on main track number two on the Creston Subdivision of the BNSF Nebraska Division. The collision resulted in the derailment of 2 locomotives and 12 cars. As a result of collision forces, the lead locomotive's modular crew cab was detached, partially crushed, and involved in a subsequent diesel fuel fire. Both crewmembers on the striking train were fatally injured. Damage was in excess of $8.7 million.[1]

The National Transportation Safety Board (NTSB) determined that the probable cause of the accident was the failure of the crew of the striking train to comply with the signal indication requiring them to operate in accordance with restricted speed requirements and stop short of the standing train because they had fallen asleep due to fatigue resulting from their irregular work schedules and their medical conditions. Contributing to the accident was the absence of a positive train control system that identifies the rear of a train and stops a following train if a safe braking profile is exceeded. Contributing to the severity of collision damage to the locomotive cab of the striking coal train was the absence of crashworthiness standards for modular locomotive crew cabs.

[1] See *Collision of BNSF Coal Train With the Rear End of Standing BNSF Maintenance-of-Way Equipment Train, Red Oak, Iowa, April 17, 2011*, Railroad Accident Report NTSB/RAR-12/02 (Washington, D.C.: National Transportation Safety Board, 2012) on the NTSB website at <http://www.ntsb.gov>.

Events Leading up to the Collision

The engineer and the conductor of the struck MOW equipment train went on duty in Lincoln, Nebraska, at 1:15 a.m., and their train departed about 3:15 a.m. The engineer and the conductor of the striking coal train went on duty at Lincoln, Nebraska, at 2:31 a.m. After completing the required airbrake test, their train departed about 3:45 a.m.

When the accident occurred, the eastbound MOW equipment train was behind two eastbound coal trains, neither of which was involved in this collision. At MP 450.38 the MOW equipment train encountered a red (restricting) grade signal and continued at restricted speed[2] until stopping about 300 feet behind the second uninvolved coal train. While these two trains were stopped at the east end of the multiple tracks on track two, Amtrak (National Railroad Passenger Corporation) No. 6 (the California Zephyr) passed them eastward on main track number one (track one) about 6:22 a.m. The second uninvolved coal train then received a signal to proceed east and followed Amtrak No. 6. The MOW equipment train then moved up to CP McPherson and stopped at the red stop signal.

While the two uninvolved coal trains and the MOW equipment train were on track two between CP 4580 and CP McPherson, the striking coal train was stopped at Balfour (MP 467.9) on track two. About 6:08 a.m., Amtrak No. 6 passed the striking coal train on the adjacent track, and the Amtrak engineer told NTSB investigators that he was able to see the crewmember on the conductor's side of the striking coal train's lead locomotive. He reported that the crewmember he had observed was in a reclining position.[3]

Data from the signal system and locomotive event recorders indicated that the striking coal train passed a yellow approach signal at CP 4535 while moving about 30 mph in throttle position 1. The train then passed the red "restricting" grade signal, which protected the rear end of the standing MOW equipment train, at MP 450.38, and the train's speed reduced to about 12 mph with its throttle in position 7 as it approached the top of the 0.6-percent grade. The speed reduction was consistent with the signal indication, grade, tonnage, and the amount of power the engineer had applied. Until reaching MP 449.4 the striking coal train engineer maintained the speed at between 11 and 12 mph using throttle adjustments. As the striking coal train crested the grade, train speed increased from 11 mph to 23 mph at the point of collision. There were several throttle adjustments during the last 15 minutes of the trip, but no activity was detected during the last 1 minute 53 seconds. At impact, the throttle was in throttle position 4, and brakes had not been applied.

Data from the striking train's (BNSF 9159) event recorder show that during the 15 minutes prior to the collision, the striking train's lead locomotive alerter alarmed three times after periods of engineer inactivity and was reset using the alerter reset button after a strobe displayed for 5 seconds and an audible alarm sounded for an additional 2 to 3 seconds. The

[2] *Restricted speed* on the BNSF requires operating prepared to stop short of a train ahead within one-half the range of vision not to exceed 20 mph.

[3] BNSF operating rules permit one crewmember to nap while stopped waiting to be met or passed by another train.

collision occurred 1 minute 53 seconds after a throttle movement, and the alerter would have been due to alarm in about 7 seconds had the collision not occurred.

Work-Rest History of Striking Train Crew

During the week leading up to the accident, the BNSF coal train engineer worked both day and night schedules. On the day of the accident, the engineer went on duty at 2:31 a.m. The day before, he was on duty from 4:30 a.m. to 2:30 p.m. Investigators were unable to determine his off-duty activities and rest periods during the 2 previous days on which he had not been called for duty, it is likely that he was awake during the day and slept at night. On the day of the accident, the engineer probably was still adjusting to a nighttime work schedule after spending several days sleeping at night. Consequently, he may have experienced short-term sleep loss resulting in acute fatigue.

The conductor of the BNSF coal train had worked a nighttime work schedule over the 4 days leading up to the accident. Studies have found that the sleep quality of night shift workers, and consequently their alertness levels, is generally inferior to those of people who work a normal (daytime) schedule.[4] Thus the conductor's alertness level also may have been affected by her recent nighttime work schedule.

Both the conductor and the engineer had worked irregular schedules for several weeks leading up to the accident. During this time, work start times often varied significantly from day to day for both crewmembers. Changing work start and end times can make achieving adequate sleep more difficult. That is, irregular work schedules tend to disrupt a person's normal circadian rhythms and sleep patterns, which in turn can lead to chronic fatigue. Moreover, studies of train accidents have shown that very irregular schedules contributed to the accidents by producing sleep loss and fatigue.[5] Therefore, the NTSB concludes that the striking coal train conductor's and the engineer's irregular work schedules contributed to their being fatigued on the morning of the collision.

Medical History of Striking Train Crew

Although the conductor had never undergone a sleep study, she had several risk factors for obstructive sleep apnea (OSA), including a body mass index (BMI)[6] of 37.5, a history of hypertension, and long periods of sitting.[7] OSA is a disorder characterized by repeated episodes of upper airway obstruction that results in recurrent arousals during sleep. The "apnea" in OSA

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[4] G. Richardson and H. Malin, "Circadian Rhythm Sleep Disorders: Pathophysiology and Treatment," *Journal of Clinical Neurophysiology*, vol. 13, no. 1, January (1996), pp. 17–31.

[5] W. Maynard and G. Brogmus, "Shiftwork, work scheduling and safety: How much is too much," 10th Annual Applied Ergonomics Conference (2007).

[6] Obesity is defined as a BMI of 30 and above, according to the National Institutes of Health. People who fall into the BMI range of 25 to 34.9 and have a waist size of over 40 inches for men and 35 inches for women are considered to be at especially high risk for health problems.

[7] A joint task force of the American College of Chest Physicians, American College of Occupational and Environmental Medicine, and the National Sleep Foundation developed screening recommendations for drivers with possible OSA. Five major categories were identified. Additional evaluation was recommended for commercial drivers that had two or more of the following: A BMI $\geq$35; a neck circumference greater than 17 inches for men and 16 inches for women; and hypertension (new, uncontrolled, or unable to control with less than two medications).

refers to a cessation of airflow that lasts at least 10 seconds. The cessation of airflow occurs when the muscles in the back of the throat fail to keep the airway open, despite efforts to breathe. Several studies have shown an association between BMI and the risk of OSA.[8] Significant OSA is present in 40 percent of obese people.[9] The conductor's BMI placed her within this risk group. The conductor was also being treated for high blood pressure with two prescription medications, but she still was hypertensive. OSA is associated with high blood pressure.[10] Since people with sleep apnea tend to be sleep deprived, they often suffer from sleepiness and a wide range of other symptoms such as difficulty concentrating, depression, learning and memory difficulties, and falling asleep while at work, on the phone, or driving. Left untreated, OSA can result in other clinical consequences including disturbed sleep, excessive sleepiness, high blood pressure, heart attack, congestive heart failure, cardiac arrhythmia, stroke, or depression.[11] The conductor was treated for restless legs syndrome (a movement disorder that typically interferes with sleep) with ropinirole. Ropinirole is medication for Parkinson's disease that sometimes results in sleepiness in Parkinson's patients. Additionally, she had been prescribed a medication for insomnia. Thus, it appears that she was not sleeping well, which may have resulted in her being fatigued.

The engineer had never undergone a sleep study, although he, too, had several risk factors associated with OSA: a BMI of 35.7; his gender (men are twice as likely as women to have sleep apnea); and job duties that required prolonged sitting. In addition, he had type 2 diabetes. Recent reports have indicated that the majority of patients with type 2 diabetes also have OSA.[12]

The NTSB concludes that based on their medical histories, both crewmembers on the striking coal train were at high risk for sleep disorders and fatigue.

Striking Train Crew's Actions Leading up to Collision

Based on the indication of the clearly visible red (restricting) signal located almost 2 miles before the point of collision, the crew was required to operate their train at restricted speed—a speed that allowed the train to be stopped within one-half the range of vision short of another train, not to exceed 20 mph. Operating at restricted speed, they should have reduced speed and come to a stop short of the standing train. The crew, however, made no attempt to slow or stop the train during the last 1 minute 53 seconds before impact. As the striking train continued to travel around a curve, the operating crew would have been able to see the clearly visible car at the rear of the MOW train from more than 1/4 mile away (about 46 seconds before impact). This provided adequate time for them to apply emergency brakes that may have stopped, or at least slowed, their train before impact. However, despite having enough time to

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[8] T. Young, P.E. Peppard, and S. Taheri, "Excess weight and sleep-disordered breathing," *Journal of Applied Physiology,* 99(4), Oct. (2005), pp. 1592–9 contains a list of studies that show the association between BMI and OSA risk.

[9] A.N. Vgontzas and others, "Sleep apnea and sleep disruption in obese patients," *Archives of Internal Medicine,* vol. 154, no. 15, Aug 8 (1994), pp. 1705–11.

[10] F.J. Nieto and others, "Association of Sleep-Disordered Breathing, Sleep Apnea, and Hypertension in a Large Community-Based Study," *Journal of the American Medical Association*, vol. 283, no. 14 (2000), pp. 1829–1836.

[11] Information from the National Sleep Foundation.

[12] E. Tasali, B. Mokhlesi, and E. Van Cauter, "Obstructive sleep apnea and type 2 diabetes: interacting epidemics," *Ches,* vol. 133, no. 2, Feb. (2008), pp. 496–506.

take action, the crew made no attempt to apply the brakes or stop their train to avoid the collision.

During the last 15 minutes of the trip and while the striking train was approaching the standing MOW equipment train, the engineer reset the alerter by using the reset button three times after prompting by a lengthy strobe and audible alarm sequence.[13] These resets were initiated only after 5 seconds of flashing strobe and an additional 2 to 3 seconds of an increasingly louder audible alarm. The reset button requires less attentiveness than actually manipulating the controls of the engine.

Investigators considered the possibility that both the engineer and the conductor were impaired by fatigue at the time of the accident. In general, fatigue results in a reduction in alertness, longer reaction times, memory problems, poorer psychometric coordination, and less efficient information processing.[14] Fatigue also could lead to the onset of an episode of microsleep, in which a person enters a sleeping period that lasts from a few seconds to as long as half a minute, becomes unresponsive, and fails to respond to outside information.[15] However, given the crew's failure to attempt to slow or stop the train for nearly 2 minutes despite explicit warnings, it is likely that the crew was impaired by more than temporary fatigue-related loss of focus or an episode of microsleep. The NTSB concludes that based on the conductor's and the engineer's irregular work schedules, their medical histories, and their lack of action before the collision, both crewmembers on the striking coal train had fallen asleep due to fatigue.

Identification, Diagnosis, and Treatment of Medical Conditions Affecting Fatigue

Based in large part on the NTSB recommendations made after the 2001 train collision in Clarkston, Michigan,[16] the Federal Railroad Administration (FRA) formed a Rail Safety Advisory Committee working group on medical standards for safety-critical personnel. The NTSB safety recommendations from the Clarkston accident investigation are the following:
To Canadian National Railway:

> Require all your employees in safety-sensitive positions to take fatigue awareness training and document when employees have received this training. (R-02-23)

[13] When the alerter system does not detect engineer activity, it will alarm (strobe light followed by horn). The alarm can be silenced by moving a control lever or by pressing the reset button.

[14] I.D. Brown, "*Driver fatigue," Ergonomics*, vol. 36 (1994), pp. 298–314.

[15] M.R. Rosekind and others, "Alertness Management in Long-Haul Flight Operations," in *Proceedings of the 39th Annual Corporate Aviation Safety Seminar* (St. Louis, Missouri: Flight Safety Foundation, 1994), pp. 167–178.

[16] See *Collision of Two Canadian National/Illinois Central Railway Trains Near Clarkston, Michigan, November 15, 2001*, Railroad Accident Report NTSB/RAR-02/04 (Washington, D.C.: National Transportation Safety Board, 2002) at <http://www.ntsb.gov>.

To the FRA:

> Develop a standard medical examination form that includes questions regarding sleep problems and require that the form be used, pursuant to Title 49 *Code of Federal Regulations* Part 240, to determine the medical fitness of locomotive engineers; the form should also be available for use to determine the medical fitness of other employees in safety-sensitive positions. (R-02-24)
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> Require that any medical condition that could incapacitate, or seriously impair the performance of, an employee in a safety-sensitive position be reported to the railroad in a timely manner. (R-02-25)
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> Require that, when a railroad becomes aware that an employee in a safety-sensitive position has a potentially incapacitating or performance-impairing medical condition, the railroad prohibit that employee from performing any safety-sensitive duties until the railroad's designated physician determines that the employee can continue to work safely in a safety-sensitive position. (R-02-26)

The first working group meeting was held 5 1/2 years ago on December 12–13, 2006. The purpose of the working group was to enhance the safety of railroad employees and the public by establishing standards and procedures for determining the medical fitness for duty of personnel engaged in safety-critical functions. A physicians' task force, established by the working group, has been working since May 2007 on developing medical guidelines that will be used to provide consistent criteria for determining the medical fitness for duty of those in safety-critical positions. The task force has been compiling a list of medical conditions that can cause sudden incapacitation and serious impairments of hearing and vision, determining the elements to be included in a health history form that covered employees will complete, and determining the medical criteria (standards) that a covered employee must meet to be certified. A draft Notice of Proposed Rulemaking (NPRM) was developed by the FRA and presented to the working group. The original target date for publishing the NPRM was December 2009. This NPRM was never published. It is disturbing that such an important railroad safety issue is taking this long to address.

The FRA recently has advised the NTSB that a regulation to address medical fitness for duty of railroad safety critical personnel is no longer being considered because of the high cost to railroads. Instead, the FRA indicated that it will produce nonmandatory recommendations for the industry. The Rail Safety Advisory Committee working group will be reconvened at some future date to finalize these recommendations. Obstructive sleep apnea will be addressed separately as part of the fatigue management regulation currently in development. The NTSB is disappointed that the FRA will not promulgate a requirement to ensure that operating employees in safety-sensitive positions are medically fit for duty. The NTSB concludes that had the requirements described in Safety Recommendations R-02-24, -25, and -26 been in place, this crew would likely have been identified as at high risk for sleep disorders, which may have led to appropriate medical intervention. Therefore, the NTSB recommends that the FRA require railroads to medically screen employees in safety-sensitive positions for sleep apnea and other sleep disorders. The NTSB reiterates Safety Recommendations R-02-24, -25, and -26 to the FRA and hopes that the FRA will take prompt action.

Fatigue Management and Rail Safety Improvement Act of 2008

Congress enacted the Rail Safety Improvement Act of 2008 (RSIA) following the September 12, 2008, head-on collision between a passenger train and a freight train in Chatsworth, California.[17] The RSIA requires the Secretary of Transportation to require that most passenger and freight railroads develop fatigue management plans. The RSIA gives railroads 4 years after enactment of the law in which to develop these plans, which must include methods to manage and reduce fatigue experienced by railroad employees in safety-related positions and to reduce the likelihood of accidents, incidents, injuries, and fatalities caused by fatigue. There are several elements to the RSIA's fatigue management plan requirements, many of which are relevant to this accident.[18] Three of these elements are listed below:

> Employee education and training on the physiological and human factors that affect fatigue, as well as strategies to reduce or mitigate the effects of fatigue, based on the most current scientific and medical research and literature.
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> Opportunities for identification, diagnosis, and treatment of any medical condition that may affect alertness or fatigue, including sleep disorders.
>
> Scheduling practices for employees, including innovative scheduling practices, on-duty call practices, work and rest cycles, increased consecutive days off for employees, changes in shift patterns, appropriate scheduling practices for varying types of work, and other aspects of employee scheduling that would reduce employee fatigue and cumulative sleep loss.

Scheduling Practices for Employees

The NTSB previously has recommended incorporating scientifically based principles when creating work schedules. The NTSB is cognizant of several biomathematical models of fatigue and performance either currently used or proposed for use in various modes of transportation, including aviation and railroads, to help predict the risk of incidents caused by crewmember fatigue based on work schedules and opportunities to sleep. Biomathematical models of fatigue attempt to predict the effects of various work patterns on job performance. They also consider scientific input about the relationship among working hours, sleep, and employee performance. The FRA is advocating the use by commuter and passenger railroads of models that the FRA indicated have been validated and calibrated, such as the Fatigue Avoidance Scheduling Tool and the Fatigue Audit InterDyne Model.[19] The RSIA does not specify the role of the FRA in evaluating the railroad industry's use of biomathematical models of fatigue and performance.

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[17] See *Collision of Metrolink Train 111 With Union Pacific Train LOF65–12, Chatsworth, California, September 12, 2008,* Railroad Accident Report NTSB/RAR-10/01 (Washington, D.C.: National Transportation Safety Board, 2010) at <http://www.ntsb.gov>.

[18] Title 49 *United States Code* (U.S.C.), chapter 201, subchapter II, section 20156. "Railroad safety risk reduction program."

[19] The FRA has conducted an evaluation of six of the most recognized alertness models and is currently funding a project to develop a method of correlating the results among models.

The NTSB is aware, however, of some general limitations regarding the use of these models. For instance, in general, biomathematical models have been calibrated to represent a population average rather than real-time fatigue levels of a specific individual.[20] It is unclear how individual differences (such as age, sex, and operating experience) may affect the output of these models. Additionally, biomathematical fatigue models predict risk factors for an average healthy person; thus, the output may not accurately predict the risks to a crewmember who may have medical conditions or otherwise not be fully fit for duty. The NTSB further recognizes that biomathematical models may not consider all factors affecting fatigue such as workload (mental or physical, high or low cognitive demand), the operating environment (including lighting, temperature, and noise level), and pharmacological agents, for example, caffeine and changes in adrenaline levels due to stressors. Other factors that may not be represented in biomathematical models include stressors in the workplace (that is, time pressure, social friction) and aspects of the work (such as monotony and repetitive motion).[21] Studies have pointed out the need for additional research to determine whether one or more of these work-related factors are important alone or in interaction with sleep/wake cycles and circadian dynamics, especially for risk-focused models.[22] The NTSB notes that several studies have concluded that fatigue model predictions cannot be the sole means upon which fatigue risk management operational decisions are made.[23] The NTSB concludes that because biomathematical models of fatigue are relatively new to the railroad industry, the use of this technology should be evaluated for its effectiveness within the context of railroads' fatigue management plans through independent scientific peer review. Therefore, the NTSB recommends that the FRA establish an ongoing program to monitor, evaluate, report on, and continuously improve fatigue management systems implemented by operating railroads to identify, mitigate, and continuously reduce fatigue-related risks for personnel performing safety-critical tasks, with particular emphasis on biomathematical models of fatigue.

Limitations of Alerters

The FRA Collision Analysis Working Group[24] found that nearly 30 percent of collisions over a 5-year period involved lack of alertness as a probable contributing factor. In those collisions, about 70 percent of the locomotives involved were equipped with alerters. Oman and Liu[25] cite a study by an unidentified major freight railroad indicating that its trains experienced four alerter-induced penalty braking events[26] during the first 6 months of 2006. They extrapolate this number to the U.S. railroad network and estimate that there would have been several dozen

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[20] *Biomathematical Fatigue Modeling in Civil Aviation Fatigue Risk Management,* (Australian Government Civil Aviation Safety Authority Human Factors Section, March 2010.

[21] D. Dinges, "*Critical Research Issues in Development of Biomathematical Models of Fatigue and Performance,*" *Aviation, Space, and Environmental Medicine,* vol. 75, no. 3, section II, March (2004).

[22] D. Dinges references relevant studies.

[23] D. Dinges references relevant studies.

[24] Federal Railroad Administration *Collision Analysis Working Group Final Report*, August 2006.

[25] C.M. Oman and A.M. Liu, Locomotive In-Cab Alerter Technology Assessment, Man Vehicle Laboratory Report #07.30, excerpted from Development of Alternative Locomotive In-Cab Alerter Technology: Final Technical Report (Cambridge, MA: DOT Volpe National Transportation Systems Center, 2006).

[26] An *alerter-induced penalty brake event,* or *brake application*, occurs when an engineer fails to respond to visual and audible warnings for up to 25 seconds, causing the alerter system to stop the train.

such alerter-induced penalty brake applications in a 12-month period. They conclude, "clearly, conventional alerters are not preventing all fatigue and alertness related accidents."

Most important, current alerter technology does not address the underlying cause of fatigue-related inattention: fatigue. A sleeping engineer who is roused by the alerter remains fatigued and is still at higher risk of having an accident. There are a number of initiatives aimed at addressing fatigue before a crew goes on duty. Fatigue training, medical monitoring, and schedule analysis are all proactive approaches that are mandated by the RSIA.

Although addressing fatigue before a fatigued crew is called on duty is a preferred approach, the Red Oak collision and the other fatigue-related accidents investigated by the NTSB suggest that a broader technological approach is needed to help identify fatigued train crews once they go on duty. The optimum strategy is to address fatigue, but alerter devices will remain one element of a risk-mitigation strategy, and other technological methods for detecting and addressing fatigued crews on duty need to be explored.

Larger railroads now use technology to monitor engineer train handling performance, in some cases on a near real-time basis. Typically, this is achieved by computer-driven analysis of event recorder data. Exception reports are produced and communicated to managers where certain criteria are met such as emergency braking or fuel-inefficient throttle use. These systems allow timely communication with crews to investigate certain events and to identify the need to provide training and coaching to improve performance where warranted. FRA researchers have previously suggested[27] using event recorder data as an evaluation tool to assess the effectiveness of fatigue management interventions.

The NTSB believes that this same approach may have value for identifying fatigued engineers proactively. Event recorder and alerter data inputs could be used to develop a "fatigue signature" that could result in management intervention. An alerter-induced penalty brake application is one element of such a signature. As geographic databases are created to support positive train control (PTC), it will be possible, for example, to coordinate locations of grade crossings with whistle use; when a locomotive whistle is not sounded at a crossing, it is often an indicator of crew inattentiveness. In the future, if railroads implement the NTSB's recommendations on inward-facing video cameras,[28] image analysis technology could be used to activate an in-cab alerter device when an engineer appears to have fallen asleep on a moving train, and also to provide an alert to a dispatch center to trigger a timely intervention.

The NTSB concludes that locomotive alerters only detect engineer inactivity and should not be used as a substitute for an effective fatigue mitigation strategy. Therefore, the NTSB recommends that the FRA conduct research on new and existing methods that can identify fatigue and mitigate performance decrements associated with fatigue in on-duty train crews. The NTSB further recommends that the FRA require the implementation of methods that can identify

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[27] M. Coplen and D. Sussman, "*Fatigue and alertness in the United states (sic) railroad industry part II: Fatigue research in the Office of Research and Development at the Federal Railroad Administration," Transportation Research Part F,* January 15, 2001.

[28] See *Collision of Metrolink Train 111 With Union Pacific Train LOF65–12, Chatsworth, California, September 12, 2008,* Railroad Accident Report NTSB/RAR-10/01 (Washington, D.C.: National Transportation Safety Board, 2010) at <http://www.ntsb.gov>.

fatigue and mitigate performance decrements associated with fatigue in on-duty train crews that are identified or developed in response to the previous safety recommendation.

Restricted Speed and Positive Train Control

In this accident, had a positive train control (PTC) or Electronic Train Management System[29] (ETMS) been installed on the Creston Subdivision, it would have established the red restricting grade signal as a target and the system would have enforced the upper limit of restricted speed (20 mph on the BNSF). An ETMS onboard locomotive display unit would have shown a "restricted speed fence" (that is, diagonal lines on the display) and would have required restricted speed. Upon reaching 3 mph over the 20-mph restriction (23 mph),[30] a visual alarm would have been displayed and an audible alarm would have sounded. If the engineer did not take action to reduce speed, a full service penalty brake application would have been applied automatically, bringing the train to a stop. If the ETMS had been installed on the Creston Subdivision, as currently designed it would have conveyed a visual and audible warning to the crew when a speed of 23 mph was detected.

In this accident, after passing the red restricting grade signal, had the ETMS been installed, it would have identified the next target as the stop signal at CP McPherson. The ETMS system would have sounded a warning based on the braking profile of the train and initiated automatic braking to stop the train before it reached the CP McPherson stop signal (not the rear of the standing MOW train). The stopped train that stood between the grade signal and the CP McPherson stop signal would not have shown up on the display of the approaching coal train. As the ETMS is currently designed, the rear end of the standing train would not have been a target.

The NTSB, therefore, concludes that had the PTC/ETMS currently in development been installed on the Creston Subdivision, it most likely would not have prevented this accident because it does not identify the rear end of a standing train as a target and because it allows following movements at up to 23 mph. The NTSB emphasized the importance of preventing accidents when trains are operated at restricted speed in its response to the FRA's notice of proposed rulemaking, "Positive Train Control Systems," that was published in the *Federal Register* on July 21, 2009. The FRA had mentioned that PTC technology does not protect following trains proceeding at restricted speed into an occupied block (the circumstances in this accident at Red Oak). The NTSB's comments on the proposed rulemaking included the following:[31]

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[29] ETMS is the system the BNSF is installing to comply with the regulatory requirement for PTC.

[30] Event recorder data indicate that the striking train's speed increased from 22 mph to 23 mph about 5 seconds before impact.

[31] NTSB, Office of the Chairman, To U.S. Department of Transportation, Docket Management Facility, Attention: Docket No. FRA-200800132, Notice No. 1, August 18, 2009.

Train-to-Train Collisions at Restricted Speed

> Although the NTSB recognizes that proposed PTC requirements will prevent high-speed collisions, the NTSB also recognizes that railroads may need to move trains at restricted speeds and, as noted in Subpart I, train-to-train collisions at restricted speeds could still occur. Current PTC systems do not track the location of the rear end of each train and do not use the rear location as a target to determine where following trains must stop. The NTSB urges the FRA and the railroads to work on developing technology that will improve the prevention of rear-end collisions at restricted speeds and to incorporate that technology into existing PTS systems as it becomes available.

After receiving the NTSB's concerns, the FRA continued to focus on the absolute speed limit when addressing restricted speed and collision avoidance. The following is an excerpt from the FRA's final rule addressing train-to-train collisions that was published in the *Federal Register* on January 15, 2010:

> To avoid rear end collisions, available PTC technology does not always locate the rear-end of each train, but instead relies on the signal system to indicate the appropriate actions. In this example the PTC system would display "restricted speed" to the locomotive engineer as the action required and would enforce the upper limit of restricted speed (i.e., 15 or 20 miles per hour, depending on the railroad). This means that more serious rear end collisions will be prevented, because the upper limit of restricted speed is enforced.[32]

Because the PTC designs that are being deployed are not required to detect the rear of a train as a target, restricted speed collisions can continue to occur. Therefore, the NTSB concludes that the PTC designs that are being deployed and the FRA's final rule on the application of PTC are unlikely to prevent future restricted speed rear-end collisions similar to the 58 rear-end collisions reported to the FRA over the last 10 years or the collision at Red Oak because train speeds at the upper limit of restricted speed are allowed. The NTSB recommends that the FRA require the use of PTC technologies that will detect the rear of trains and prevent rear-end collisions.

Locomotive Crashworthiness Standards

The lead locomotive of the striking train, BNSF 9159, was an Electro-Motive Diesel SD70ACe manufactured in March 2008. The design incorporates a modular operator's cab at the front end of the unit and has a fabricated steel underframe that extends the length of the unit, upon which the diesel engine and alternator components are mounted (aft of the operator's cab).

During the collision sequence, the clip car at the rear end of the struck train immediately folded, derailed, and was displaced north of the track. A powered axle and truck from that car along with other train equipment became lodged in front of the snow plow of BNSF 9159, forming a ramp in front of the locomotive. The next car in the struck train, an 89-foot flatcar outfitted with a specialized loading ramp (scorpion car), rode up and over the trapped equipment in front of BNSF 9159 overriding the locomotive anti-climber and collided with the modular

[32] *Federal Register* vol. 75, no. 10, (January 15, 2010), p. 2610.

operating cab. The collision forces lifted and rotated the modular operating cab toward the rear, shearing and separating it from its attachment points. When the modular operating cab separated and rolled rearward, the short hood and collision posts no longer provided the protection intended by the crashworthiness design standards. The cab was then crushed at the rooftop as it rolled into the electrical locker, and the forward-facing window frame was folded forward over the top of the cab. The side walls remained relatively intact below the window line. Diesel fuel from the scorpion car leaked onto the front end of BNSF 9159 and caught fire. Several other flatcars overrode the scorpion car before the striking train came to a stop. The detachment and upending of the cab module and subsequent crushing action exerted forces on the cab occupants that would not have been present had the cab remained fixed to the deck. Because the operating cab rotated into the electrical locker, the rear door was crushed. The NTSB concludes that because the isolated locomotive cab module detached from the deck of the locomotive and was subsequently rotated and crushed, the crew could not have survived.

BNSF 9159 was constructed to meet the crashworthiness standards in AAR Standard S-580, "Locomotive Crashworthiness Requirements." This standard is incorporated by reference in Title 49 *Code of Federal Regulations* (CFR) 229.205 and is applicable to all locomotives built after January 2009. Documentation from the manufacturer on the structural design and analysis of this model locomotive confirmed BNSF 9159 was in compliance with these regulatory requirements. However, AAR Standard S-580 does not specifically address modular (isolated) wide-nose locomotive operating cabs like the cab on BNSF 9159.

Current crashworthiness requirements are design standards. Design standards fix requirements under prescribed conditions, which are not necessarily related to the variety of conditions that could occur in a collision. They were based on specific accident scenarios and on locomotive designs in use at the time of their development. In comparison, performance standards attempt to define equipment performance requirements. For example, maintaining survivable space in a control compartment following a collision is a performance standard; prescribing the strength of a collision post in front of the control compartment is a design standard.

Modular cabs are very effective at reducing crew noise and vibration exposure, which can have a safety benefit. There are about 562 isolated cab locomotives operating in North America. Cab integrity is vital to crew safety in a variety of accident scenarios including train-train collisions, train-motor vehicle collisions, and train derailments in which a locomotive overturns. There are no crashworthiness criteria for modular cabs in the existing standards. The NTSB concludes that although the current locomotive crashworthiness standards include a procedure to validate alternative locomotive crashworthiness designs that are not consistent with any FRA-approved locomotive crashworthiness design standard, this requirement was not effective in identifying the modular operating cab as an alternate design. Consequently, the NTSB recommends that the FRA revise 49 CFR Part 229 to ensure the protection of the occupants of isolated locomotive operating cabs in the event of a collision. Make the revision applicable to all locomotives, including the existing fleet and those newly constructed, rebuilt, refurbished, and overhauled, unless the cab will never be occupied. To address future locomotive designs, the NTSB recommends that the FRA revise 49 CFR Part 229 to require crashworthiness performance validation for all new locomotive designs under conditions expected in a collision.

The NTSB issues the following safety recommendations to the FRA:

Require railroads to medically screen employees in safety-sensitive positions for sleep apnea and other sleep disorders. (R-12-16)

Establish an ongoing program to monitor, evaluate, report on, and continuously improve fatigue management systems implemented by operating railroads to identify, mitigate, and continuously reduce fatigue-related risks for personnel performing safety-critical tasks, with particular emphasis on biomathematical models of fatigue. (R-12-17)

Conduct research on new and existing methods that can identify fatigue and mitigate performance decrements associated with fatigue in on-duty train crews. (R-12-18)

Require the implementation of methods that can identify fatigue and mitigate performance decrements associated with fatigue in on-duty train crews that are identified or developed in response to Safety Recommendation R-12-18.
(R-12-19)

Require the use of positive train control technologies that will detect the rear of trains and prevent rear-end collisions. (R-12-20)

Revise Title 49 *Code of Federal Regulations* Part 229 to ensure the protection of the occupants of isolated locomotive operating cabs in the event of a collision. Make the revision applicable to all locomotives, including the existing fleet and those newly constructed, rebuilt, refurbished, and overhauled, unless the cab will never be occupied. (R-12-21)

Revise Title 49 *Code of Federal Regulations* Part 229 to require crashworthiness performance validation for all new locomotive designs under conditions expected in a collision. (R-12-22)

The NTSB also reiterates the following safety recommendations previously issued to the FRA:

Develop a standard medical examination form that includes questions regarding sleep problems and require that the form be used, pursuant to Title 49 *Code of Federal Regulations* Part 240, to determine the medical fitness of locomotive engineers; the form should also be available for use to determine the medical fitness of other employees in safety-sensitive positions. (R-02-24)

Require that any medical condition that could incapacitate, or seriously impair the performance of, an employee in a safety-sensitive position be reported to the railroad in a timely manner. (R-02-25)

> Require that, when a railroad becomes aware that an employee in a safety-sensitive position has a potentially incapacitating or performance-impairing medical condition, the railroad prohibit that employee from performing any safety-sensitive duties until the railroad's designated physician determines that the employee can continue to work safely in a safety-sensitive position. (R-02-26)

> Require the installation, in all controlling locomotive cabs and cab car operating compartments, of crash- and fire-protected inward- and outward-facing audio and image recorders capable of providing recordings to verify that train crew actions are in accordance with rules and procedures that are essential to safety as well as train operating conditions. The devices should have a minimum 12-hour continuous recording capability with recordings that are easily accessible for review, with appropriate limitations on public release, for the investigation of accidents or for use by management in carrying out efficiency testing and systemwide performance monitoring programs. (R-10-1)

> Require that railroads regularly review and use in-cab audio and image recordings (with appropriate limitations on public release), in conjunction with other performance data, to verify that train crew actions are in accordance with rules and procedures that are essential to safety. (R-10-2)

As discussed in the Red Oak accident report, the NTSB reclassifies the following previously issued recommendation to the FRA:

> Require railroads to ensure that the lead locomotives used to operate trains on tracks not equipped with a positive train control system are equipped with an alerter. (R-07-1)

Safety Recommendation R-07-01, previously classified "Open—Acceptable Action," is reclassified "Closed—Acceptable Action."

The NTSB also issued safety recommendations to the Association of American Railroads and the BNSF Railway.

In response to the recommendations in this letter, please refer to Safety Recommendations R-12-16 through -22. We encourage you to submit updates electronically at the following e-mail address: correspondence@ntsb.gov. If your response includes attachments that exceed 5 megabytes, please e-mail us at the same address for instructions. To avoid confusion, please do not submit both an electronic copy and a hard copy of the same response.

Chairman HERSMAN, Vice Chairman HART, and Members SUMWALT, ROSEKIND, and WEENER concurred in these recommendations.

[Original Signed]

By: Deborah A.P. Hersman
Chairman

Safety Recommendation Reiteration List

SR Number	Reiteration Number	Report Number	Report Date	Accident Description	Accident City	Accident State	Accident Date
R-12-016	1	NTSB/SIR-14/04	11/19/2014	Organizational Factors In Metro-North Railroad Accidents	Bridgeport	CT	5/17/2013
					West Haven	CT	5/28/2013
					Bronx	NY	7/18/2013
					Bronx	NY	12/1/2013
					Manthattan	NY	3/10/214
R-12-016	2	RAR-14-02	11/17/2014	Collision Of Union Pacific Railroad Freight Train W/BNSF Railway Freight Train	Chaffee	MO	5/25/2013
R-12-016	3	RAR-16-03	1/24/2017	Collision of Two Union Pacific Railroad Freight Trains, Hoxie, Arkansas August 17, 2014	Hoxie	AR	8/17/2014
R-12-016	4	SIR-18-01	2/14/2018	End-of-Track Collisions at Terminal Stations Hoboken, New Jersey, September 29, 2016 and Atlantic	Hoboken Brooklyn	NJ NY	9/29/2016 1/4/2017

SR Number	Reiteration Number	Report Number	Report Date	Accident Description	Accident City	Accident State	Accident Date
				Terminal, Brooklyn, New York, January 4, 2017			

Safety Recommendation Reiteration List

SR Number	Reiteration Number	Report Number	Report Date	Accident Description	Accident City	Accident State	Accident Date
R-12-017	1	RAR-13-01	2/12/2013	Collsion Of Two Candian National Railway Freight Trains	Two Harbors	MN	9/30/2010