

Collision of Two Union Pacific Railroad Freight Trains
Hoxie, Arkansas
August 17, 2014



Accident Report

NTSB/RAR-16/03
PB2017-100970



**National
Transportation
Safety Board**

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490 L'Enfant Plaza, S.W.
Washington, D.C. 20594

National Transportation Safety Board. 2016. *Collision of Two Union Pacific Railroad Freight Trains, Hoxie, Arkansas, August 17, 2014*. Publication Type NTSB/RAR-16/03. Washington, DC.

Abstract: On August 17, 2014, at 2:28 a.m. central daylight time, southbound Union Pacific Railroad (UP) freight train IMASNL-16 (southbound train) collided with northbound UP freight train IQNLPI-17 (northbound train) at milepost 228.6, while traversing the turnout at control point Y-229 on the UP Hoxie subdivision in Hoxie, Arkansas. Going north, the track in the area transitions from a single main track into two main tracks. As a result of the collision, the engineer and the conductor from the southbound train died, and the engineer and the conductor from the northbound train were seriously injured. The southbound train consisted of 2 locomotives and 86 cars; the northbound train consisted of 2 locomotives and 92 cars. The locomotives from both trains derailed and the second locomotive from the northbound train released diesel fuel, resulting in a fire. A total of 55 cars derailed, 41 cars from the southbound train and 14 cars from the northbound train. About 500 people within a 1.5-mile radius of the derailment were evacuated as a precaution. One tank car loaded with alcohol for human consumption breached and burned. The product posed no environmental hazard and emergency responders allowed the product to burn out. Damage was estimated by UP to be \$10.7 million.

The safety issues covered in this report include: fatigue and employee work schedules, medical issues, UP medical rules, automated systems that reset alertness devices, and positive train control.

As a result of the investigation of this accident, the National Transportation Safety Board makes new safety recommendations to the Federal Railroad Administration; BNSF Railway, Canadian National Railway, Canadian Pacific Railway, CSX Transportation, Kansas City Southern Railway, Intercity Railroads, and Commuter Railroads; Class I Railroads; and Union Pacific Railroad. Further, the National Transportation Safety Board reiterates two recommendations to the Federal Railroad Administration.

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For more detailed background information on this report, visit <http://www.nts.gov/investigations/dms.html> and search for NTSB accident ID DCA14FR011. Recent publications are available in their entirety on the Internet at <http://www.nts.gov>. Other information about available publications also may be obtained from the website or by contacting: **National Transportation Safety Board, Records Management Division, CIO-40, 490 L’Enfant Plaza, SW, Washington, DC 20594, (800) 877-6799 or (202) 314-6551.**

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Abbreviations and Acronyms

| | |
|----------------------------|---|
| AAR | Association of American Railroads |
| AHI | apnea-hypopnea index |
| Amtrak | National Railroad Passenger Corporation |
| APTA | American Public Transportation Association |
| ASLRRA | American Short Line and Regional Railroad Association |
| CFR | <i>Code of Federal Regulations</i> |
| CP | control point |
| CPAP | continuous positive airway pressure |
| DOT | US Department of Transportation |
| EQMS | Employee Quality Management System |
| FAID | Fatigue Audit InterDyne Model |
| FAST | Fatigue Avoidance Scheduling Tool |
| FR | <i>Federal Register</i> |
| FRA | Federal Railroad Administration |
| FTA | Federal Transit Administration |
| MP | milepost |
| mph | miles per hour |
| ng/ml | nanogram/milliliter |
| northbound engineer | northbound train locomotive engineer |
| NPRM | notice of proposed rulemaking |
| NTSB | National Transportation Safety Board |
| PTC | positive train control |

| | |
|-----------------------------|--------------------------------------|
| RRP | risk-reduction program |
| RSAC | Railroad Safety Advisory Committee |
| RSIA | Rail Safety Improvement Act of 2008 |
| SB | southbound |
| southbound conductor | southbound train conductor |
| southbound engineer | southbound train locomotive engineer |
| UP | Union Pacific Railroad |
| <i>USC</i> | <i>United States Code</i> |

Executive Summary

On August 17, 2014, at 2:28 a.m. central daylight time, southbound Union Pacific Railroad freight train IMASNL-16 collided with northbound Union Pacific freight train IQNLPI-17 at milepost 228.6, while traversing the turnout at control point Y-229 on the Union Pacific Hoxie subdivision in Hoxie, Arkansas. As a result of the collision, the engineer and the conductor from the southbound train died, and the engineer and the conductor from the northbound train were seriously injured.

The following safety issues are covered in this report:

- Fatigue and Employee Work Schedules: Regulatory requirements to use science-based tools, such as biomathematical models, are needed to reduce start time variability that results in irregular work-rest cycles and train crew fatigue
- Medical Issues: Regulatory requirements for screening, evaluating, and ensuring adequate treatment standards for sleep apnea and other sleep disorders for railroad employees in safety-sensitive positions
- Union Pacific Railroad Medical Rules: Union Pacific Railroad needs: (1) medical rules that would require railroad employees in safety-sensitive positions to report all diagnosed sleep disorders; and (2) to perform periodic evaluations to ensure the condition is appropriately treated
- Automated Systems that Reset Alertness Devices: An automatic horn sequencer prevented the operation of an electronic alertness device that was designed to help the southbound train crewmembers maintain vigilance in the locomotive cab by monitoring engineer activity and applying the train brakes should the device fail to detect activity for a predetermined period of time
- Positive Train Control: A functioning positive train control system would have prevented this accident

The National Transportation Safety Board determines that the probable cause of the accident was the failure of the southbound train crewmembers to respond to the signal indications requiring them to slow and stop their train prior to control point Y-229 because they were fatigued and had fallen asleep due to (1) the locomotive engineer's inadequately treated obstructive sleep apnea, (2) the conductor's irregular work schedule, and (3) the train crew operating in the early morning hours when they were predisposed to sleep. Contributing to the accident was (1) the lack of a functioning positive train control system; (2) the use of an automatic horn sequencer that, when activated, negated the operation of an electronic alertness device; (3) the Federal Railroad Administration's failure to promulgate rules regarding sleep disorders; and (4) the absence of federal regulations requiring freight railroads to use fatigue modeling tools for train crew work schedules.

1 Investigation and Analysis

1.1 Accident Narrative

On August 17, 2014, at 2:28 a.m. central daylight time, southbound Union Pacific Railroad (UP) freight train IMASNL-16 (southbound train) collided with northbound UP freight train IQNLPI-17 (northbound train) at milepost (MP) 228.6, while traversing the turnout at control point (CP) Y-229 on the UP Hoxie subdivision in Hoxie, Arkansas.¹ Going north, the track in the area transitions from a single main track into two main tracks. As a result of the collision, the engineer and the conductor from the southbound train died, and the engineer and the conductor from the northbound train were seriously injured. (See figure 1.)



Figure 1. Collision at CP Y-229. (Photo courtesy of UP.)

The southbound train consisted of 2 locomotives and 86 cars; the northbound train consisted of 2 locomotives and 92 cars. The locomotives from both trains derailed and the second locomotive from the northbound train released diesel fuel, resulting in a fire. A total of 55 cars derailed, 41 cars from the southbound train and 14 cars from the northbound train. About 500 people within a 1.5-mile radius of the derailment were evacuated as a precaution. One tank car loaded with alcohol for human consumption breached and burned. The product posed no environmental hazard and emergency responders allowed the product to burn out. Damage was estimated by UP to be \$10.7 million.

¹ All times in this report are central daylight time; A *turnout* is a track arrangement that enables trains to be guided from one track to another and includes a switch and rails.

The maximum authorized speed in the area was 70 miles per hour (mph) for freight trains and 75 mph for passenger trains. National Railroad Passenger Corporation (Amtrak) passenger trains operate over this segment of the UP Hoxie subdivision. The maximum authorized speed through the turnout from main track 1 to main track 2 was 40 mph for both freight and passenger trains. There were no temporary speed restrictions in the area at the time of the accident. The weather at the time of the accident was reported to be 79°F and clear with no precipitation.

Figure 2 shows a map of the routes taken by the accident trains.



Figure 2. Map of the routes of the accident trains.

The crewmembers (locomotive engineer and conductor) of the southbound train went on duty in Dexter, Missouri, on August 16, 2014, at 5:40 p.m. and departed Dexter at 6:31 p.m. National Transportation Safety Board (NTSB) investigators questioned the crewmembers who brought the accident train into Dexter about the train performance during their trip prior to handing it off to the accident train crew. The earlier crewmembers reported no issues with the train and confirmed that the alerter on the lead locomotive (UP 9707) was in working order.² They said they did not know the accident train crewmembers, but they did not notice anything unusual about them or their behavior during the brief turnover period. Qualified UP employees completed mechanical

² An *alerter* is a safety device or system installed in the locomotive cab to promote continuous and active locomotive engineer attentiveness by monitoring select locomotive engineer-induced control activities. If fluctuation of a monitored locomotive engineer-induced control activity is not detected within a predetermined time, a sequence of audible and visual alarms is activated so as to progressively prompt a response by the locomotive engineer. Failure by the locomotive engineer to institute a change of state in a monitored control, or acknowledge the alerter alarm activity through a manual reset provision, results in a penalty brake application that brings the locomotive or train to a stop.

inspections on the southbound train on August 16, 2014, at 7:40 a.m. at Gatyard, Illinois.³ The record indicated the train passed the Federal Railroad Administration (FRA) Class I air brake test with no exceptions noted.⁴

The southbound train crew was scheduled to pick up 2 locomotives and 10 cars at Poplar Bluff, Missouri (MP 167.6). The crew arrived at Poplar Bluff on August 16, 2014, at 8:50 p.m. and experienced difficulty adding the locomotives and cars to the train. The southbound train locomotive engineer (southbound engineer) spoke with the UP Harriman Dispatch Center in Omaha, Nebraska, at 10:45 p.m. and was told to “highball” (skip) the scheduled pick up. The crew made contact with the UP dispatcher and departed on August 17, 2014, at 12:27 a.m.

The crewmembers (locomotive engineer and conductor) of the northbound train went on duty on August 16, 2014, at 9:45 p.m. in North Little Rock, Arkansas, and departed North Little Rock at 10:57 p.m. An FRA Class I air brake test was conducted in North Little Rock by UP personnel with no exceptions noted. The crew had no scheduled stops to add or remove cars between North Little Rock and Dexter, Missouri.

The northbound train locomotive engineer (northbound engineer) told NTSB investigators there were no unusual events during the trip prior to the accident. At 2:14 a.m., the UP train dispatcher contacted the northbound train crewmembers via radio and advised them that they would meet one, or most likely, two trains at Hoxie. The crew acknowledged the plan for the meets at Hoxie.

The northbound engineer told NTSB investigators that he knew he would be meeting one or more trains at Hoxie, and that receiving this kind of information from train dispatchers was common, although not required. He said that he saw the headlight of the southbound train as it approached the end of the multiple main tracks and noticed the oncoming locomotive headlight being dimmed.⁵ He said this made him think that the train he was meeting was under control. As his train entered the turnout, he estimated that he had only 1 second of warning before the collision.

1.2 Method of Operation

On the Hoxie subdivision, train movements are governed by operating rules, timetable instructions, general orders, and the signal indications of a traffic control system. The UP Hoxie subdivision train dispatcher, located at the Harriman Dispatch Center, coordinated train movements using the traffic control system. The train dispatcher told NTSB investigators that train operations on his shift prior to the accident were normal. He said that he had not experienced any signal problems, nor did he receive reports of any during his shift.

The train dispatcher said he had advised the northbound train crew of meeting a southbound train at Hoxie. Earlier in the shift, the train dispatcher said that he also advised the southbound

³ *Gatyard* is short for Gateway Yard, which is located in Illinois, near St. Louis.

⁴ Refer to Title 49 *Code of Federal Regulations (CFR)* 232.205 for information on a Class I air brake test.

⁵ *Multiple main tracks* are two or more adjacent tracks that are signaled for movement in either direction and are designated in the railroad timetable; Rule 5.9.1 of the *General Code of Operating Rules*, Sixth Edition, effective April 7, 2010, requires that locomotive headlights be dimmed when approaching and passing the head end of a train at night.

train crewmembers that they would meet a train at Peach Orchard (MP 202.2) and meet an Amtrak train at O’Kean (MP 212.7). He said he did not advise the southbound train of the plan to meet the northbound train at Hoxie. His last communication with the southbound train crewmembers, about 49 minutes before the accident, was advising them that they would be relieved at Tuckerman, about 21 miles south of the accident site.

1.3 Site Description

The southbound train was operating on main track 1, and the train dispatcher planned to stop and hold it on main track 1 at CP Y-229 and allow the northbound train to diverge onto unoccupied main track 2. (See figure 3.)

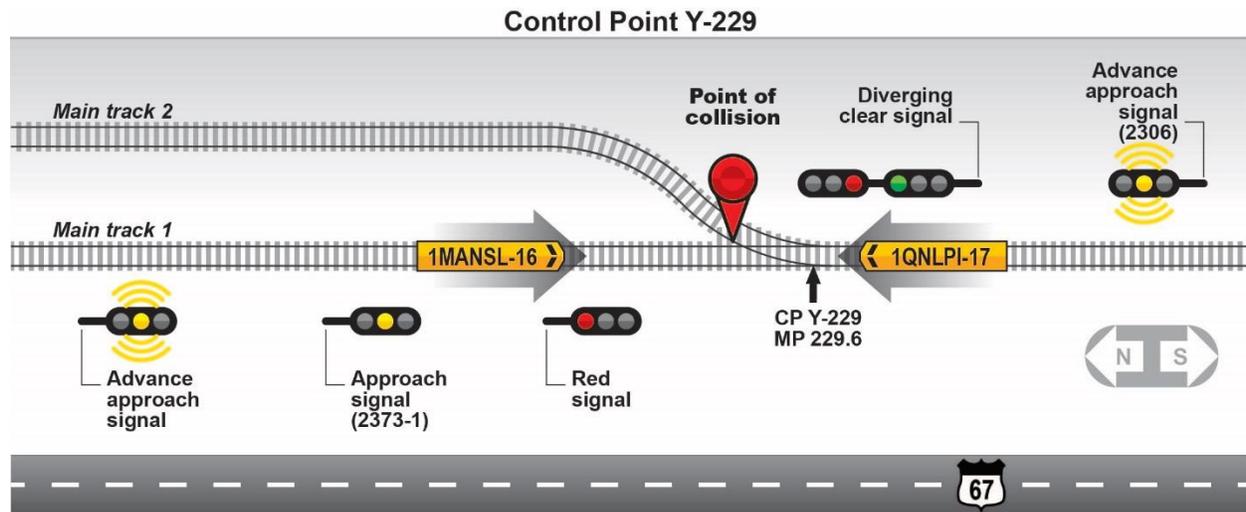


Figure 3. CP Y-229 and the signal indications prior to the collision.

1.4 Signal System and Locomotive Event Recorder Data

As seen in figure 3, the southbound train would have encountered the following three signal indications before Hoxie CP Y-229: an Advanced Approach, an Approach, and a Stop. UP rule requirements on selected signal aspects and indications are noted in the *UP System Special Instructions*, Item 19, “Block and Interlocking Signals”. (UP 2014) The rules relevant to this accident are as follows:

- Rule 9.2.4: Advanced Approach – requires that a train proceed prepared to stop at the second signal. Freight trains exceeding 40 mph must reduce speed to 40 mph. When the signal governs the approach to a control point with a 40 mph turnout speed, be prepared to advance on normal or diverging route [flashing yellow aspect]
- Rule 9.2.6: Approach – requires that a train proceed prepared to stop before any part of the train or engine passes the next signal. Freight trains exceeding 30 mph must immediately reduce to 30 mph [solid yellow aspect]
- Rule 9.2.9: Diverging Clear – requires that a train proceed on a diverging route not exceeding the prescribed speed through the turnout [solid red over green aspect]

- Rule 9.2.15: Stop – requires a train to stop before any part of the train or engine passes the signal [solid red aspect]

Information derived from the signal system data and the southbound train's locomotive event recorder indicate that the train was traveling at about 42 mph at signal 2373-1, which was displaying an approach signal (solid yellow aspect). When the southbound train passed the approach signal, locomotive event recorder data showed the throttle was in position 7 of 8 possible tractive power positions. At the stop signal (red aspect) at CP Y-229, event recorder data showed the throttle position remained unchanged and the train speed had increased to 45 mph at the time of the collision. Event recorder data further indicated that the air brakes were not applied by the southbound train crew before the collision. The southbound engineer should have slowed the train to 40 mph in response to the flashing yellow aspect, slowed to 30 mph in response to the yellow aspect, and stopped the train in response to the solid red aspect before any part of the train reached CP Y-229. The NTSB concludes the southbound train crew did not respond to the three restrictive signals immediately prior to the collision and took no action to slow or stop the train prior to arriving at CP Y-229, resulting in the collision with the northbound train.

Signal system data and data from the Harriman Dispatch Center indicate that the northbound train encountered an advanced approach (flashing yellow aspect) signal at MP 230.6 (signal 2306) and a diverging clear signal (solid red over green aspect) at CP Y-229, which meant the northbound train would be diverging onto main track 2. Event recorder data from the northbound train also indicated that just before impact the throttle was in the dynamic brake position, the air brakes were not applied, and the train speed was 35 mph, in compliance with signals and maximum authorized speed. The data further showed that the subsequent emergency brake application was not locomotive engineer induced. The NTSB concludes that the northbound train crew operated their train in accordance with traffic control signals, had no indication of the impending collision with the southbound train, and did not have time to apply the emergency air brakes prior to the collision.

2 Safety Issues

2.1 Introduction

The NTSB examined and analyzed the following factors in its investigation of this accident: (1) the southbound train conductor's (southbound conductor) work schedule; (2) the southbound engineer's work schedule; (3) the southbound conductor's medical issues; (4) the southbound engineer's medical issues; (5) UP fatigue educational training; (6) UP medical rules; (7) automated systems that reset alertness devices; (8) the lack of a positive train control (PTC) system; (9) the traffic control system; (10) the mechanical condition of the southbound train; and (11) train crew experience, use of alcohol, other drugs, or impairing substances, or distraction by cell phones of the southbound train crewmembers.

2.2 Southbound Train Conductor's Work Schedule

The southbound conductor worked the extra board, meaning his work schedule varied; he was subject to being called on duty at any time that he was in compliance with the Hours of Service Act.⁶ The accident occurred at 2:28 a.m., a time when he likely would have been asleep on the days preceding the accident. As a result of this information, the NTSB examined the southbound conductor's fluctuating start times and circadian factors to determine if he was fatigued and had possibly fallen asleep at the time of the accident. As shown in figure 4, the hashmarks on the graph between 8:00 p.m. and 4:00 a.m. indicate the time where commuter and passenger train service schedules are required to be analyzed using validated biomathematical models of fatigue, according to FRA regulations.⁷ However, freight trains are currently exempt from these regulations.

⁶ An *extra board employee* does not have a regular job assignment. These employees are used to fill an assignment that has been left open when the regularly assigned employee is not available. The FRA noted that train and engine employees who work in yards, local freight service, and passenger and commuter operations have jobs with regular start times and high work-start predictability. (FRA 2014) Title 49 *CFR* Part 228 - "Hours of Service of Railroad Employees; Recordkeeping and Reporting; Sleeping Quarters".

⁷ Title 49 *CFR* Part 228, Subpart F - "Substantive Hours of Service Requirements for Train Employees Engaged in Commuter or Intercity Rail Passenger Transportation".

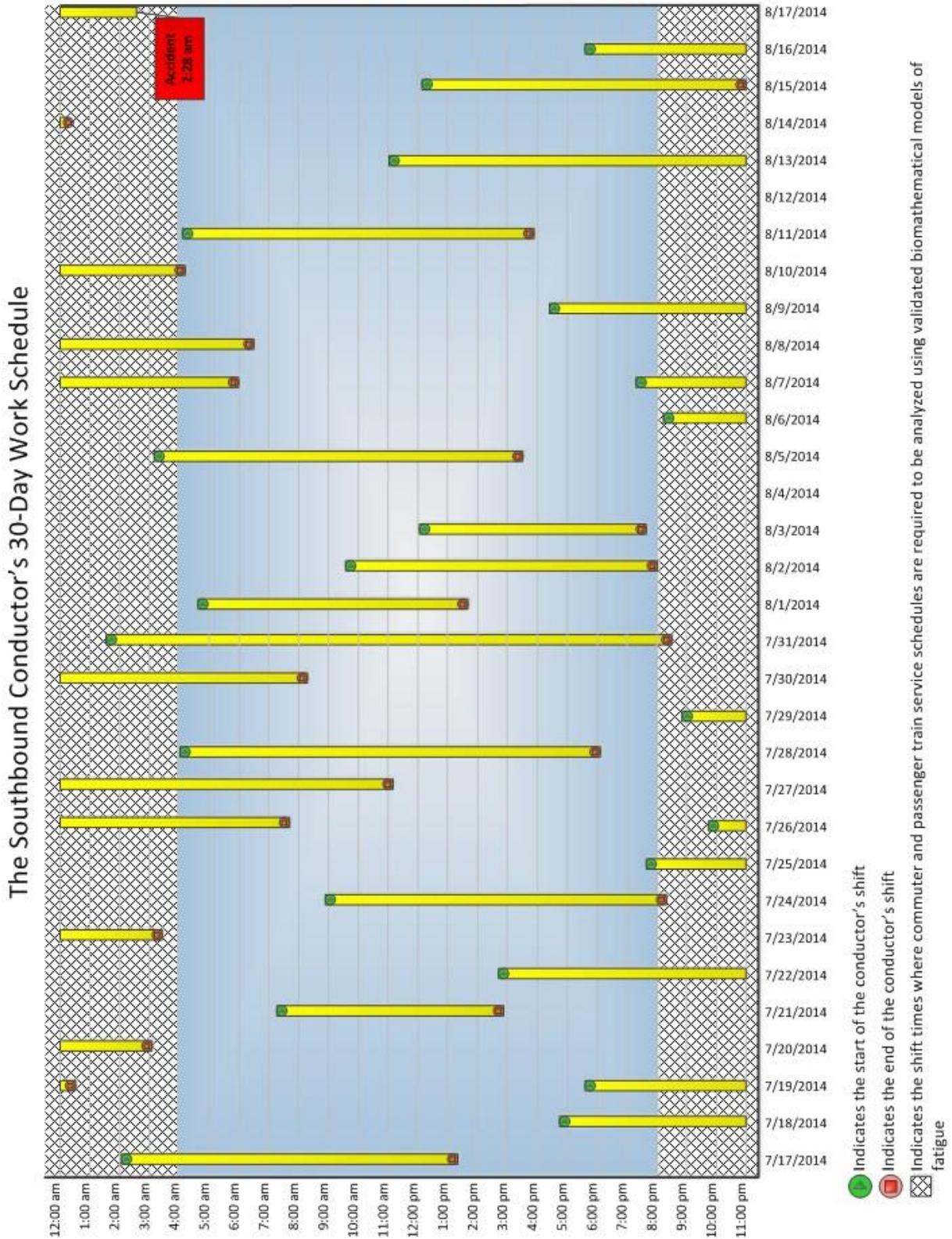


Figure 4. Southbound conductor's 30-day work schedule.

In the 30 days leading up to the accident, the southbound conductor's reporting times were irregular. His reporting times were not identical on consecutive days, and they often varied by more than 2 hours, and as much as 16 hours, 50 minutes. On 10 occasions, he reported to work at least 8 hours either earlier or later than he had on his previous shift. In effect, he experienced a shift change about 33 percent of the time. This pattern continued during the week leading up to the accident. Starting with the day before the accident and working backward, the southbound conductor's reporting times were: 5:40 p.m., 12:10 p.m., 11:00 a.m., day off, 4:05 a.m., and 4:20 p.m.

NTSB investigators were unable to reconstruct the southbound conductor's sleep routine because sources of information about his off-duty activities were not available. However, given the irregularity of his work schedule, it is likely that both the quality and quantity of his sleep would have been affected. Studies have shown that people who work irregular shifts sleep less and report more frequent sleep problems than do people who work regular daylight shifts. (National Sleep Foundation 2015)

Irregular schedules have been shown to have a negative impact on employees and safety in the railroad industry. Extra board employees, as well as train and engine employees who work in freight service, typically work schedules with low start-time predictability because their schedules vary from day to day. A recent FRA study examined the effects of start-time variability and the predictability of fatigue. The study found that:

The probability of a human factors accident is a function of the start time variability.
... High variability in shift start times is found to contribute to human fatigue, which, from previous accidents, is known to increase the probability of accidents.

The FRA noted that a potential way of increasing safety is to reduce shift start-time variability. (FRA 2014)

As previously stated, during the 30 days leading up to the accident, 10 of the southbound conductor's shifts (more than 33 percent) started in the evening and continued past midnight. Research on shift work and fatigue has found that the night shift will have pronounced negative effects on sleep, sleepiness, performance, and accident risk. (Akerstedt and Wright 2009) The southbound conductor, however, had worked only one shift past midnight (12:16 a.m.) during the 7 days before the night of the accident. Thus, the accident trip required him to quickly adapt to a nighttime schedule, a change for which he was likely unprepared. Studies have shown that it typically takes several days or weeks to adequately adjust to working a nighttime schedule after routinely working during the day and sleeping at night. Circadian desynchronization, which is being awake when one typically is asleep or being awake during the early morning hours when the body is inclined to sleep, can lead to sleepiness and fatigue.⁸

The accident occurred at 2:28 a.m., a time that coincides with a circadian low, making train crews more prone to fatigue and decrements in attention and performance. At this time of night, the human body is predisposed to sleep.⁹ (National Sleep Foundation 2015) Thus, at the time of

⁸ Early morning hours are considered to be those between 4:00 a.m. and 7:00 a.m.

⁹ The circadian rhythm dips and rises at different times of the day, so adults' strongest sleep drive generally occurs between 2:00 a.m. and 4:00 a.m.

the accident, the crewmembers, particularly the southbound conductor, were most vulnerable to the effects of fatigue and had a higher risk of experiencing performance decrements.

NTSB investigators examined the southbound conductor's likely activities leading up to the accident. When the accident occurred, the southbound conductor's activity level would have been low. He did not need to communicate with the train dispatcher.¹⁰ At this point of the trip, his primary duties were not physical and he was likely sitting adjacent to the locomotive engineer. The low operating demands and lack of physical activity would have produced an environment conducive to sleep.

The southbound conductor was responsible for the overall operation of the train. His duties included working with the engineer. "Engineer" is defined in FRA regulations as any person who moves a locomotive or group of locomotives, regardless of whether they are coupled to other equipment.¹¹ The conductor was also required to be alert for signal indications, communicate them to the engineer to ensure compliance with the signal aspect, document the results in his report, and be prepared to activate the emergency brakes from his side of the train if necessary.¹² Train crews are required to verbally communicate signal aspects with one another as they are encountered and both the conductor and engineer were responsible for responding appropriately. UP rules required that conductors maintain an up-to-date report documenting a number of operational events, including meeting restrictive signals like those in this accident. The southbound conductor's report was recovered and examined by NTSB investigators.¹³ The southbound conductor began documenting operational events at 6:31 p.m., when the train departed Dexter, Missouri. The report was current up to the last three restrictive signals.

Minutes before the accident, the southbound train passed two signals indicating a requirement to slow down before reaching the next (red) signal. However, the train had not slowed or stopped. Moreover, neither the southbound conductor nor the southbound engineer activated the emergency brake to stop the train to avoid the collision. The failure of both southbound crewmembers to take action to stop the train suggests that they were unaware of the signal aspects and the oncoming northbound train. The southbound conductor's toxicology testing was negative for alcohol and other drugs. Although he had reported a history of asthma to UP, no other personal medical information was identified. There were no reduced visibility issues attributable to environmental conditions. The terrain was flat, and NTSB investigators were able to observe unobstructed views of the red stop signal from about 3,000 feet. Therefore, the NTSB concludes the southbound conductor was likely asleep at the time of the accident because of the variability of his shift start times which caused fatigue and the circadian desynchronization he experienced due to his operating the train in the early morning hours when he was predisposed to sleep.

In this accident, as with the vast majority of railroad fatigue-related accidents investigated by the NTSB, the southbound train's crewmembers did not violate FRA's hours of service

¹⁰ The southbound train crew's last communication with the train dispatcher occurred at 1:39 a.m., about 49 minutes prior to the accident. It could not be determined if the communication was with the engineer or the conductor.

¹¹ Title 49 *CFR* 240.7 – "Definitions".

¹² This locomotive was equipped with a conductor valve or an emergency brake valve. Thus, the conductor could activate the emergency brake for any reason.

¹³ The southbound conductor's report can be found in NTSB docket DCA14FR011.

regulations for freight train operations.¹⁴ The NTSB first recommended that railroads incorporate scientifically based regulations that set limits on hours of service, provide predictable work and rest schedules, and consider circadian rhythms, and human sleep and rest requirements in 1999.¹⁵

The FRA hours of service regulations for freight train operations differ from those for commuter and passenger train operations. The FRA hours of service regulations regarding employees in commuter and passenger train operations became effective on October 15, 2011, and provided new limitations for passenger train crews engaged in commuter or intercity rail passenger transportation.¹⁶ The regulations added a requirement to analyze employee work schedules with fatigue modeling tools, and consecutive-days limitations that recognize the difference between work during daylight hours and work during nighttime hours. Some of the key provisions of the regulations that appear relevant to the circumstances of this accident include:

- Use of fatigue science: Passenger train employees' work schedules are to be analyzed under an FRA-approved validated biomathematical fatigue model, such as the Fatigue Audit InterDyne Model (FAID) and the Fatigue Avoidance Scheduling Tool (FAST) with the exception of certain schedules (completely within the hours of 4:00 a.m. and 8:00 p.m., and otherwise in compliance with the limitations in the regulations) deemed as categorically presenting an acceptable level of risk for fatigue that does not exceed the defined fatigue threshold.¹⁷
- Specific rules for nighttime operations: Schedules that include any time on duty between 8:00 p.m. and 4:00 a.m. must be analyzed using a validated biomathematical model of human performance and fatigue approved by the FRA. Schedules with excessive risk of fatigue must be mitigated or supported by a determination that mitigation is not possible and the schedule is operationally necessary and approved by the FRA.
- Specific rules for unscheduled assignments: The potential for fatigue presented by unscheduled work assignments must be mitigated as part of a railroad's FRA-approved mitigation plan.

In the NTSB's investigation of the April 17, 2011, collision between a BNSF Railway freight train and a BNSF maintenance-of-way train near Red Oak, Iowa, the NTSB concluded that the conductor and engineer had fallen asleep, in part, due to their irregular work schedules. The NTSB also concluded 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

¹⁴ Title 49 *CFR* 228.7 – "Hours of Duty".

¹⁵ NTSB Safety Recommendation R-99-2, June 1, 1999. The recommendation letter can be found through the Safety Recommendations Search feature at <http://www.nts.gov/safety/safety-recs>.

¹⁶ Title 49 *CFR* Part 228, Subpart F – "Substantive Hours of Service Requirements for Train Employees Engaged in Commuter or Intercity Rail Passenger Transportation". In the Rail Safety Improvement Act of 2008 (RSIA), FRA received regulatory authority to establish hours of service limitations for train employees providing commuter and intercity rail passenger transportation service (passenger train employees). Title 49 *United States Code (USC)* Section 20156. Public Law 110-432, Division A, October 16, 2008, 122 Stat. 4848, 4853-56.

¹⁷ 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 has identified two fatigue models as being scientifically validated: FAST and FAID. For additional information see 49 *CFR* 228.407 – "Analysis of work schedules; submissions; FRA review and approval of submissions; fatigue mitigation plans".

context of railroad's fatigue management plans through independent scientific peer review.” (NTSB 2012) Consequently, the NTSB made the following safety recommendation to the FRA:

R-12-17

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.

In a December 1, 2015, letter to the FRA, the NTSB stated, in part:

We are pleased that you have developed a protocol for validating and calibrating any models that might be developed in the future and that you intend to continue learning from the practical application of biomathematical models to railroads' fatigue management plans. Accordingly, pending the timely issuance of a final rule that satisfies Safety Recommendation R-12-17, it is classified *Open—Acceptable Response*.

In addition to commuter and intercity passenger railroads, the use of biomathematical models of fatigue can be used to analyze employee work schedules in the transit industry. Currently, at least one major transit system is using these models to analyze the work schedules of subway train operators. Furthermore, the NTSB recommended the use of biomathematical models in the transit industry following the investigation of the March 14, 2014, Chicago Transit Authority train collision with a bumping post at O'Hare Station. The NTSB determined that the probable cause of the accident was “the failure of the train operator to stop the train at the appropriate signal due to falling asleep as a result of fatigue, which was the result of the challenges of working shiftwork, circadian factors, and acute sleep loss resulting from her ineffective off-duty time management.” (NTSB 2015)

As a result, the NTSB made the following safety recommendation to the Federal Transit Administration (FTA):

R-15-18

Develop a work scheduling program for rail transit agencies that incorporates fatigue science—such as validated biomathematical models of fatigue—and provides for the management of personnel fatigue risks, and implement the program through the state safety oversight program.

In October 2014, the FTA tasked the Transit Advisory Committee for Safety with developing recommendations for establishing a fatigue management program for the bus and rail transit industry, based on the principles of safety management systems.¹⁸ On March 29, 2016, the NTSB classified this recommendation as *Open—Acceptable Response*.

During the 30 days leading up to the accident, the southbound conductor had worked an on-duty period for 6 or more consecutive calendar days and worked a nighttime assignment on at least one of those days. Had he been working in passenger service, the FRA regulations would have required that his risk for fatigue be mitigated and his work schedule would require him to be off duty for 24 consecutive hours at his home terminal before reporting back for duty. Therefore, the NTSB concludes that had the provisions specified in the hours of service requirements for commuter and passenger trains been applied to freight operations, the southbound conductor would not have been allowed to work such a highly variable schedule because of its high risk for causing fatigue. The NTSB, therefore, recommends the FRA require freight railroads to use validated biomathematical fatigue models, similar to the models used by passenger railroads, to develop work schedules that do not pose an excessive risk of fatigue. Further, the NTSB recommends that all Class I railroads revise their scheduling practices for train crews and implement science-based tools, such as validated biomathematical models, to reduce start time variability that results in irregular work-rest cycles and fatigue.

2.3 Southbound Train Locomotive Engineer's Work Schedule

NTSB investigators examined the southbound engineer's on-duty and off-duty schedule on the days leading up to the accident. The southbound engineer had several days off in the 3 weeks leading up to the accident. In fact, he was only on duty for 4 days in the week before the accident. On the days that the southbound engineer worked, his start times varied. However, he did not go on duty before 5:30 a.m., and worked past midnight once—the day of the accident. Although the southbound engineer had varied start times, he would have been able to maintain a daytime schedule. Therefore, it does not appear that the southbound engineer's work schedule resulted in his being fatigued. Moreover, he had several days off in the time leading up to the accident trip, giving him the opportunity to get restorative sleep. However, the investigation could not determine the southbound engineer's specific off-duty activities on the days leading up to the accident, including the amount or quality of sleep he had received. As stated in section 2.2, the accident occurred at 2:28 a.m., a time coinciding with a circadian low; making the southbound engineer vulnerable to the effects of fatigue.

2.4 Southbound Train Conductor's Medical Issues

According to his (limited) UP medical records, the southbound conductor had asthma, but had not reported using any medications that would have affected his awareness of train operations

¹⁸ *Safety management systems* combine established system safety engineering principles with advanced organizational management techniques, and support continuous improvement in safety performance through a positive safety culture founded on four key priorities: safety policy, safety risk management, safety assurance, and safety promotion.

or his ability to act upon signals. In addition, no alcohol, other drugs, or impairing substances were identified on extensive postaccident toxicology testing.

2.5 Southbound Train Locomotive Engineer's Medical Issues

The southbound engineer's postaccident urine toxicology testing identified 94 ng/ml diphenhydramine and citalopram/escitalopram in his urine, but no blood was available for testing. Although diphenhydramine is considered sedating, there is no accepted method for relating postmortem urine drug results for diphenhydramine to cognitive function impairment at the time of the fatal injury.¹⁹ Therefore, it cannot be determined if the engineer was impaired by this sedating antihistamine or its hangover effects at the time of the accident. Urine testing did not differentiate between citalopram and escitalopram, antidepressants commonly marketed with the names Celexa and Lexapro. Both are psychoactive medications and carry warnings about the risk of cognitive impairment in the mental and/or physical ability required for the performance of potentially hazardous tasks (such as, driving, operating heavy machinery). However, personal medical records revealed the southbound engineer had been using escitalopram for many years without reported performance problems.

According to his personal medical records, between 2006 and 2014, the southbound engineer repeatedly reported feeling tired to his primary care physician. In 2010, the primary care physician considered the diagnosis of obstructive sleep apnea and obtained a polysomnography, also known as a sleep study, which was performed in a sleep laboratory. The results included an apnea-hypopnea index (AHI) of 19.3 episodes/hour, oxygen saturation ranging from 93-87 percent, and 29 periodic limb movements recorded with an index of 5.3 per hour.²⁰ All of these measurements are considered abnormal. The sleep specialist diagnosed moderate sleep apnea and the possibility of restless leg syndrome.²¹ The southbound engineer returned to the sleep center for a trial of treatment with continuous positive airway pressure (CPAP). Following that trial, the sleep specialist recommended the "CPAP be placed at 7 cm/H₂O. (No apneas, no snoring, no periodic limb movements)."

The NTSB medical officer reviewed records from the sleep laboratory and sleep specialist, as well as the primary care physician, and interviewed the primary care physician. However, no follow-up visits or evidence of treatment initiation, maintenance, or review with the sleep specialist or the primary care physician were discovered. No evidence was found that the southbound engineer ever obtained or used a CPAP machine to treat his sleep disorder. The night before the

¹⁹ *Diphenhydramine* is an antihistamine, commonly found in medications such as Benadryl and Unisom.

²⁰ An *apneic episode* is the complete absence of airflow through the mouth and nose for at least 10 seconds. A *hypopnea episode* is when airflow decreases by 50 percent for at least 10 seconds or decreases by 30 percent if there is an associated decrease in the oxygen saturation or an arousal from sleep. The *AHI* sums the frequency of both types of episodes. An AHI of less than 5 is considered normal. An AHI of 5–15 is mild sleep apnea; 15–30 is moderate sleep apnea; and more than 30 events per hour is considered severe sleep apnea. *Periodic limb movements* are involuntary, jerking movements of the limbs—usually the legs—during sleep. They may awaken or arouse the person from sleep, contributing to fatigue.

²¹ According to the National Institute of Neurological Disorders and Stroke, *restless leg syndrome* is a neurological disorder characterized by throbbing, pulling, creeping, or other unpleasant sensations in the legs and an uncontrollable, and sometimes overwhelming, urge to move them. For additional information, see http://www.ninds.nih.gov/disorders/restless_legs/detail_restless_legs.htm, accessed November 10, 2016.

accident, the southbound engineer's work schedule required him to sleep away from home. He had checked out of his accommodation and did not have a CPAP device in his possession at the time of the accident. There is also no evidence that he obtained any other treatment for his sleep apnea, such as surgery or a customized mouthpiece. The NTSB concludes the southbound engineer was fatigued and likely asleep due to his diagnosed but inadequately treated moderate sleep apnea and operating the train in the early morning hours when he was predisposed to sleep.

In September 2013, the southbound engineer was noted to be 6 feet, 3 inches tall and weigh 250 pounds. According to the body mass calculator from the National Institutes of Health, National Heart, Lung, and Blood Institute, his body mass index was 31.2 kg/mg², which is considered obese.²² Although his body mass index was in the obese category, which increased the risk for sleep apnea, the southbound engineer's weight was not known to directly cause it.

The NTSB has investigated a number of previous railroad accidents where undiagnosed or inadequately treated sleep apnea or other sleep disorders in safety-sensitive employees caused or contributed to the accident. A head-on collision of two Canadian National/Illinois Central Railway trains occurred in Clarkston, Michigan, in 2001 that the NTSB determined was due to "...crewmembers' fatigue, which was primarily due to the engineer's untreated and the conductor's insufficiently treated obstructive sleep apnea." (NTSB 2002) As a result, the NTSB issued the following safety recommendation to the FRA:

R-02-24

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.

In 2006, partly in response to this recommendation, the FRA created a Medical Standards Working Group as part of the Railroad Safety Advisory Committee (RSAC). Although the FRA has mentioned the RSAC and its Medical Standards Working Group in responses to NTSB recommendations on a number of occasions, it was disbanded after 5 years for being unable to reach consensus.²³ On March 10, 2016, the FRA and the Federal Motor Carrier Safety Administration jointly published an advance notice of proposed rulemaking in the *Federal Register (FR)* regarding obstructive sleep apnea. (*FR* 2016, 12642) However, the notice primarily poses questions and asks for public comments on the topic. It does not provide information regarding any proposed rules. Currently, no public action has been taken by the FRA to develop guidelines or require screening, diagnosis, or treatment of sleep disorders among railroad employees.

Following the investigation of a head-on collision between two UP freight trains in Goodwell, Oklahoma, in June 2012, the NTSB determined the probable cause of the accident was,

²² This calculator can be found at http://www.nhlbi.nih.gov/health/educational/lose_wt/BMI/bmicalc.htm; accessed November 15, 2016.

²³ Multiple letters from former FRA administrators to the NTSB, March 17, 2003; January 13, 2004; November 23, 2004; August 18, 2006; July 24, 2009; and July 31, 2012.

in part, due to the conductor's lack of engagement and the engineer's inability to see and interpret signals due to a chronic illness and deteriorating eyesight. (NTSB 2013) As a result of this, the NTSB reclassified Safety Recommendation R-02-24 to the FRA as *Closed—Unacceptable Action* and superseded it with the following safety recommendation:

R-13-21

Develop medical certification regulations for employees in safety-sensitive positions that include, at a minimum, (1) a complete medical history that includes specific screening for sleep disorders, a review of current medications, and a thorough physical examination, (2) standardization of testing protocols across the industry, and (3) centralized oversight of certification decisions for employees who fail initial testing; and consider requiring that medical examinations be performed by those with specific training and certification in evaluating medication use and health issues related to occupational safety on railroads.

The FRA reported it had already created a new RSAC working group, the Fatigue Management Working Group, to develop standards for a railroad's fatigue management plan.²⁴ The NTSB did not view this reply as responsive to this recommendation and has, therefore, classified Safety Recommendation R-13-21 *Open—Unacceptable Response*. Like the previous medical working group, the fatigue working group has been operating for years without any publicly available output regarding medical conditions and fatigue.

In the investigation of the April 27, 2011, rear-end collision in Red Oak, Iowa, discussed earlier in this report, the NTSB determined the collision occurred due to “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.” Among other ailments, the medical conditions included probable sleep apnea, restless leg syndrome, and chronic insomnia. (NTSB 2012) As a result of that investigation, the NTSB made the following safety recommendation to the FRA.

R-12-16

Require railroads to medically screen employees in safety-sensitive positions for sleep apnea and other sleep disorders.

In response to Safety Recommendation R-12-16, the FRA cited the Rail Safety Improvement Act of 2008 (RSIA) which requires, under section 103, that certain railroads develop a risk-reduction program (RRP).²⁵ Section 103(d)(2) of the RSIA requires a railroad to include a fatigue management plan in its RRP. As part of the development of fatigue management plans, railroads will be required to provide opportunities for the identification, diagnosis, and treatment of any medical condition that may affect alertness or fatigue, including sleep disorders. The FRA, in response to Safety Recommendation R-12-16, stated, “Currently, FRA, in conjunction with a working group of members from the Railroad Safety Advisory Committee (RSAC), is developing

²⁴ Former FRA administrator letter to the NTSB, January 2, 2014.

²⁵ Title 49 USC Section 20156. Public Law 110-432, Division A, October 16, 2008, 122 Stat. 4848, 4853-56.

a fatigue management regulation that will be responsive to the requirements set forth in the RSIA.”²⁶ The recommendation was classified *Open—Acceptable Response* by the NTSB in October 2012. However, RSIA specified that this be carried out within 4 years of its implementation, which would have been October 16, 2012. However, as of October 2016, such a regulation has not been promulgated.

On May 25, 2013, a UP railroad freight train collided with a BNSF freight train in Chaffee, Missouri, resulting in a total derailment of 24 cars and 2 locomotives, as well as a postimpact diesel fire and severe damage to a highway overpass. The two UP train crewmembers were injured and five occupants of motor vehicles on the bridge were transported to local hospitals.

The NTSB determined that the probable cause of the accident was:

...the failure of the UP train crewmembers to comply with wayside signals leading into the Rockview Interlocking as a result of their disengagement from their task likely because of fatigue-induced performance degradation. Contributing to the accident was the lack of: (1) a positive train control system, (2) medical screening requirements for employees in safety-sensitive positions for sleep apnea and other sleep disorders, and (3) action by the FRA to fully implement the fatigue management components required by the RSIA. Likely contributing to the engineer’s fatigue was undiagnosed obstructive sleep apnea. Also contributing to the accident was inadequate crew resource management.

As a result of this accident investigation, the NTSB changed the classification of Safety Recommendation R-12-16 that was issued to the FRA to *Open—Unacceptable Response*. (NTSB 2014)

The NTSB concludes that the continued occurrence of railroad accidents attributed to fatigue caused by sleep apnea are due in part to the failure of the FRA since 2002 to respond to the hazards posed by undiagnosed or inadequately treated sleep apnea. Therefore, the NTSB reiterates Safety Recommendations R-12-16 and R-13-21.

On February 27, 2015, the FRA published a notice of proposed rulemaking (NPRM) regarding RRP that noted it had tasked a Fatigue Management Plan Working Group in 2011 to “review the mandates and objectives of the [RSIA] related to the development of Fatigue Management Plans,” including to “determine how medical conditions that affect alertness and fatigue will be incorporated into Fatigue Management Plans.” In addition, the NPRM contained the following:

FRA notes that the RRP Working Group recommended including a placeholder in the proposed RRP rule text that would require a railroad, as part of its RRP, to develop a fatigue management plan no later than three years after the effective date of the final rule, or three years after commencing operations, whichever [was] later. (FR 2015, 10949)

²⁶ Former FRA administrator letter to the NTSB, July 31, 2012.

However, instead the FRA chose to address “substantive requirements of the fatigue management plan mandate in [a] separate rulemaking.” The NTSB notes there has been no public evidence of such rulemaking or any evidence of output from a RSAC working group addressing medical conditions affecting alertness and fatigue.

Commercial operators in the marine, highway, and aviation modes of transportation require periodic comprehensive medical evaluations including a medical history, symptom checklist, review of current medications, and a physical examination. In addition, each mode has medical standards that identify certain medical conditions as disqualifying for employment in safety-sensitive roles and a set of criteria, specific to the medical condition, which must be met for an operator with the condition to obtain medical certification and be considered fit for duty. Specifically, each of the other commercial modes has standards requiring operators with sleep apnea to periodically demonstrate adequate, ongoing treatment before they can obtain medical certification and be considered fit for duty. The NTSB concludes that if the FRA had similar standards as those in other modes of transportation, the southbound engineer would have been required to periodically demonstrate adequate, ongoing treatment before he could obtain medical certification and be considered fit for duty. Therefore, the NTSB recommends the FRA develop and enforce medical standards that railroad employees in safety-sensitive positions diagnosed with sleep disorders must meet to be considered fit for duty.

2.6 UP Fatigue Educational Training

UP has developed educational materials on fatigue for its employees. These include safety meeting packages titled, “Sleep Disorders/Sleep Apnea Assessment” and “Alertness Management Education Packet.”²⁷ Additional educational materials include “Good Sleep Habits” and “The Science of Fatigue and Alertness.” The latter material is comprehensive and discusses several areas related to sleep including: fatigue and alertness, circadian rhythms, sleep requirements, sleep disruption, sleep disorders, and the demands of railroad operations.

The fatigue training listed above is required for operating employees (in departments such as transportation, engineering, mechanical, Harriman Dispatch Center, safety, intermodal, and telecom) and available on a voluntary basis for the balance of the workforce. New employees receive fatigue training as part of their orientation. Refresher training is required for transportation department employees during biennial rules classes. The training is either computer based or provided in a classroom. UP training records show the southbound train crew received this training in 2013.

All UP employees are made aware of educational materials and training on fatigue through a number of different sources, including: articles, posters, messaging, videos/brochures, field site meetings, training classes, having occupational health nurses in the field, and other employee events. Materials are posted on the employee website and distributed at various locations throughout the system.

²⁷ The UP fatigue education materials were developed between 2003 and 2013 and were used prior to this accident. The materials can be found in NTSB docket DCA14FR011.

2.7 UP Medical Rules

The NTSB investigation found that UP has developed a set of medical rules that is more extensive than the current medical standards required by the FRA and includes “severe sleep apnea” in the list of medical conditions that employees in safety-sensitive positions are required to report. In this instance, the southbound engineer was diagnosed with moderate sleep apnea. He was not required to report his condition to UP and his UP medical records indicate that he did not. The NTSB concludes that UP’s medical rules did not require the southbound engineer, diagnosed with symptomatic, moderate sleep apnea to report his condition or ensure he followed the treatment recommendations from his sleep physician. The NTSB recommends that UP revise its medical rules to add any diagnosed sleep disorder to the list of medical conditions that employees in safety-sensitive positions must report and, when an employee makes such a report, perform periodic evaluations to ensure the condition is appropriately treated and the employee is fit for duty.

Furthermore, the NTSB recognizes that other railroads have a variety of internal medical standards, rules, and protocols, many of which go beyond the minimal vision and hearing standards set by the FRA. However, until such time as the FRA provides appropriate minimum standards regarding sleep apnea and other medical disorders, the railroads themselves must determine whether their rules are comprehensive enough to ensure employees in safety-sensitive positions with diagnosed sleep disorders are adequately treated and fit for duty. The NTSB concludes that the lack of minimum standards for medical rules among Class I, intercity, and commuter railroads poses an unnecessary risk for employees in safety-sensitive positions who are diagnosed with sleep disorders. The NTSB therefore recommends that BNSF Railway, Canadian National Railway, Canadian Pacific Railway, CSX Transportation, Kansas City Southern Railway, Norfolk Southern Railway, intercity railroads, and commuter railroads review and revise as necessary their medical rules, standards, or protocols to ensure they are informed of any diagnosed sleep disorders that employees in safety-sensitive positions must report and, when an employee makes such a report, perform periodic evaluations to ensure the condition is appropriately treated and the employee is fit for duty.

2.8 Southbound Train Horn Sequencer and Alerter

The lead locomotive in the southbound train, UP 9707, was equipped with a horn sequencer. Design documentation provided by the UP showed the system was designed to sound the highway-rail grade-crossing cadence from the horn when activated.²⁸ The system was activated from inside the cab of the locomotive by pressing a pedal on the floor under the control console on the engineer’s side of the locomotive cab (right side). (See figure 5.)

²⁸ The highway-rail grade-crossing cadence consists of two long blasts from a locomotive horn, followed by one short blast and one long blast. The cadence is commonly stated as “long, long, short, long.”



Figure 5. Locomotive horn sequencer pedal from exemplar UP locomotive.

The second locomotive from the southbound train, which was configured with the front facing the rear of the train, was equipped with an outward-facing camera (track image recorder) that recorded video and audio data to external storage. Data extracted from the camera covered a 10-minute period that included the accident. The extracted recording captured video images of the rear of the train off to the left and right sides and the trailing car behind the second locomotive. Repeated train horn sounds were heard from the lead locomotive on the recording. At 2:23:47 a.m. (about 5 minutes before the collision), the horn on the southbound train was activated and shortly thereafter, the train began to pass multiple highway-rail grade crossings. The horn remained active sounding uninterrupted grade-crossing cadences for a total duration of 4 minutes, 6 seconds.

NTSB investigators asked the UP about the operating characteristics of the horn sequencer system to understand its functionality. The UP stated the sequencer pedal is pressed only once and released to activate the system, and pressed and released again to deactivate the system. On December 9, 2014, NTSB investigators examined a similar UP locomotive to further evaluate operating characteristics of UP horn sequencers. They found that at locomotive speeds ranging from 20 mph to 75 mph, the horn sequencer, when activated, would sound the highway-rail grade-crossing horn cadence repeatedly at all speeds until the sequencer was deactivated.

The lead locomotive of the southbound train was equipped with an electronic alertness device commonly called an alerter. The alerter is designed to help crews maintain vigilance in the locomotive cab by monitoring engineer activity and applying the train brakes should the device fail to detect activity for a predetermined period of time. The alerter timeout period is variable, based on locomotive speed and an initial reset-timing cycle. The alerter reset-timing cycle is designed to start over when it detects an engineer-induced control activity.

Title 49 *CFR* 229.140 contains the locomotive alerter requirements. All controlling locomotives manufactured after June 10, 2013, are required to be equipped with a functioning alerter when operating at speeds in excess of 25 mph. Beginning January 1, 2017, all controlling

locomotives that will operate at speeds in excess of 25 mph will be required to have (be retrofitted with) a functioning alerter.

An alerter receives inputs from various locomotive systems that determine engineer activity and, after a predetermined period of time without activity, provides visual and audible alarms and a brake initiation, also referred to as a penalty brake application. Any of the following locomotive control inputs (engineer activity) will reset the alerter:

- Change in throttle position
- Change in generator field switch position
- Change in dynamic brake handle position
- Change in reverser handle position
- Alerter reset switch activation (manual reset)
- Horn activation
- Locomotive independent brake bail off activation²⁹
- Manual sand activation

The alerter timeout period is variable and based on locomotive speed and the initial reset time cycle. A mathematical formula determines the length of the timeout period. The value of the timeout period is calculated as follows:

- Threshold speed is configured to 20 mph
- When locomotive speed is less than threshold speed, timeout = 120 seconds
- When locomotive speed is greater than threshold speed,
timeout = $(60 \times 40) \div \text{locomotive speed}$

If a reset action is not made before the end of the alerter timeout period, the alerter alarm cycle will activate. The alerter alarm cycle begins with 10 seconds of visual alarms of increasing intensity followed by 10 seconds of visual and audible alarms of increasing intensity. (See figure 6.) After this sequence, if the locomotive engineer does not perform an input or action to reset the alerter (one of the control inputs and actions listed above), the alerter relay is de-energized, the alarm is silenced, and the brakes are applied.

²⁹ “*Bailing off*” is a feature that allows the engineer to release the locomotive’s independent brake to better control train operations when using the train brakes.



Figure 6. Exemplar locomotive alerter indication.

During the December 9, 2014, examination of a similar UP locomotive, NTSB investigators found that the alerter did not alarm when the locomotive was in forward motion at speeds over 25 mph, the horn sequencer was activated, and the locomotive controls were not manipulated for more than 2 minutes.

As mentioned above, image data from the southbound train showed that the horn sounded repeatedly for 4 minutes, 6 seconds starting at 2:23:47 a.m. During the first 1 minute 49 seconds (109 seconds) while the horn was sounding, event recorder data showed the throttle remained in position 8. The data revealed no other actions that would have reset the alerter. The average speed of the southbound train at this time was 32.5 mph. Using the formula for calculating the timeout period, at this speed if the horn sequencer had not been configured to reset the alerter, the alerter would have alarmed about 74 seconds after the horn sequencer was activated.

The configuration of the horn sequencer on the UP's locomotives prevented the alerter from activating and initiating a penalty brake application at least three times before the collision. The NTSB determined this automatic horn sequencer prevented and negated the operation of the alerter. NTSB investigators determined that if the alerter had not been repeatedly reset, it would have alarmed in the minutes before the collision with visual and audible alarms and a penalty brake initiation had the engineer not responded. Although the investigation could not determine whether an alerter activation would have prevented the Hoxie collision, the NTSB concludes that the horn sequencer negated the alerter from alarming and providing an opportunity for the southbound train crew to prevent this accident.

Event recorder data further showed that at 2:25:37 a.m., with the horn sequencer still activated, the throttle was moved from position 8 to position 7, which reset the alerter timing cycle. For the next 2 minutes, 16 seconds, the horn continued sounding the grade-crossing cadence. The data showed no other actions that would have reset the alerter. The average speed of the southbound train at this time was 41 mph. Again, using the formula for calculating the timeout period, if the horn sequencer had not been configured to reset the alerter, the alerter would have

alarmed about 59 seconds after the throttle moved from position 8 to position 7, requiring the engineer to reset the alerter twice during the 2 minutes, 16 seconds before the horn sounds ended.

Data from the signal system and the southbound train's image recorder indicated that the southbound train crossed the grade crossing at MP 227.84 at 2:27:44 a.m. It was the final grade crossing before the point of collision, which was 0.72 miles away. The horn sounds ended about 10 seconds later, at 2:27:54 a.m. No further horn input was audible for the duration of the recording. The collision occurred at 2:28:38 a.m.

Table 1 summarizes the events of the southbound train in the 5 minutes leading up to the accident.

Table 1. Sequence of Events of the Southbound Train Leading to the Accident.

| Event | Time | Throttle | Speed |
|-------------------------------------|---------|----------|--------|
| Horn begins | 2:23:47 | 8 | 27 mph |
| Throttle change | 2:25:37 | 7 | 43 mph |
| Crosses grade crossing at MP 227.84 | 2:27:44 | 7 | 44 mph |
| Horn stops | 2:27:54 | 7 | 44 mph |
| Collision | 2:28:38 | N/A | N/A |

On February 4, 2015, the NTSB issued two urgent safety recommendations to the FRA. In the accompanying letter to the FRA administrator, the NTSB stated the following:

The NTSB has investigated dozens of railroad accidents over the decades in which crew inattentiveness was a causal factor. We have examined the role of locomotive alerter technology many times and have recognized the potential value of alerters along with their limitations. Despite those limitations and the fact that some investigations have found that alerters were likely reset by reflex action with no increase in crew alertness, alerters can still prevent some train accidents.

The safety issue we have identified during this investigation involves an onboard system (in this case the horn sequencer) that, once activated, repeatedly resets the alerter cycle without any intervention by a crewmember. This vulnerability needed to be immediately addressed by the FRA and the industry. Therefore, the NTSB made the following urgent safety recommendations to the FRA:³⁰

R-15-4 (Urgent)

Review your existing regulations and your motive power and equipment compliance manual, and revise them as needed to prohibit automatic systems from resetting the locomotive alerter.

R-15-5 (Urgent)

Immediately notify railroads of the circumstances of this accident and the risks posed by automated inputs that reset alerter cycles. Urge railroads to assess all

³⁰ NTSB Safety Recommendations R-15-4 and -5, February 4, 2015. The recommendation letters can be found through the Safety Recommendations Search feature at <http://www.ntsb.gov/safety/safety-recs>.

controlling locomotive alerter systems to (1) identify and document any system inputs that reset the alerter cycle without manual intervention by crewmembers and (2) determine ways to eliminate such resets.

The FRA responded to the NTSB's urgent recommendations by publishing Safety Advisory 2015-06 on December 1, 2015, which recommended that all freight railroads check the operation of their locomotives equipped with alerters to ensure that no system resets the alerter warning timing cycle without direct locomotive engineer action. (FRA 2015) Therefore, Safety Recommendation R-15-4 is classified *Open—Acceptable Response* and Safety Recommendation R-15-5 is classified *Closed—Acceptable Action*.

The NTSB also issued one urgent safety recommendation to the Association of American Railroads (AAR), the American Short Line and Regional Railroad Association (ASLRRA), and the American Public Transportation Association (APTA):

R-15-6 (Urgent)

Inform your members of the circumstances of this accident and the risks posed by automated inputs that reset alerter cycles. Urge your members to assess their locomotive alerter systems to (1) identify any inputs that reset the alerter cycle without intervention by crew members and (2) determine ways to eliminate such resets.

On June 12, 2015, the NTSB reclassified Safety Recommendation R-15-6 to the AAR as *Closed—Acceptable Action*. On April 7, 2016, the NTSB reclassified Safety Recommendation R-15-6 to APTA as *Closed—Acceptable Action*. On August 22, 2016, the NTSB reclassified Safety Recommendation R-15-6 to ASLRRA as *Closed—Acceptable Alternate Action*.

As discussed above, the horn sequencer is activated by pressing and releasing the foot pedal only once and is deactivated by pressing and releasing the foot pedal for a second time. Based on the operating characteristics of the horn sequencer and event and image recorder data from the southbound train, there were two events that showed engineer activity in the moments before the collision.

The first activity was the movement of the locomotive throttle from position 8 to position 7. This action occurred at 2:25:37 a.m., 3 minutes, 1 second before the collision. The second activity was the deactivation of the horn sequencer at 2:27:54 a.m., about 44 seconds before the collision.

Despite these two activities during the minutes leading up to the accident, the southbound engineer appeared to have become disengaged from critical train operations during this period. While moving the throttle from position 8 to position 7 may have marginally slowed the train, it would not have slowed the train enough to comply with the restrictive signal indications. The NTSB suggests that the southbound engineer may have either lost awareness of the train's speed, or he failed to observe and properly respond to the three wayside signal indications, because he had fallen asleep.

Moreover, the NTSB believes that 2 minutes, 17 seconds later, the southbound engineer deactivated the sequencer, despite being asleep at the time. In the head-end collision of freight trains UBT-506 and TV-61 near Thompsettown, Pennsylvania, on January 14, 1988, the NTSB

cited the testimony of sleep researcher, Dr. Donald I. Tepas, who stated that individuals in all stages of sleep can make a well-developed, simple motor response to external stimuli. (NTSB 1989) More recently, sleep research has identified automatic behaviors, as well as more complex behaviors that occur when a person is partially asleep.³¹ (Morandin and Bruck 2013) (Kryger, Roth, and Dement 2011) He also stated that the act of pressing and releasing the floor-mounted acknowledgement pedal by a locomotive engineer who is conditioned to hearing and responding to this device would fit the parameters of such a response, particularly if the locomotive engineer was in the habit of resting his foot against the pedal. After the train horn sequencer was deactivated, there would not have been any audio cues available to the crew in the operating compartment until the collision 44 seconds later. Even if the engineer had momentarily awakened, there may have been sufficient time for him to again have fallen asleep.³² (Dement and Vaughan 1999)

2.9 Positive Train Control

At the time of the accident, UP had installed the field equipment for PTC on the Hoxie subdivision in response to the requirements of 49 *CFR* Part 236, Subpart I, “Positive Train Control Systems,” that required PTC be implemented on certain railroad corridors across the United States no later than December 31, 2015.³³ UP was installing an overlay PTC system that would use the existing traffic control system and monitor train operations to enforce compliance. At the time of the accident, the UP was still equipping its locomotive fleet with the necessary on-board equipment and was modifying dispatch office software to make PTC fully functional. A PTC system would have interceded by first providing the train crew with both visual and audible warnings that they were approaching the red signal. If the crew failed to take any action to slow or stop their train, the PTC system would have initiated a penalty brake application and stopped the southbound train prior to it reaching the red signal at CP Y-229. The NTSB concludes that had the territory been equipped with a properly functioning PTC system, the collision would have been prevented.

2.10 Factors Not Contributing to This Accident

The NTSB determined that the factors described in this section did not contribute to the accident. The NTSB postaccident examination of the signal system determined it displayed the proper signal sequence for train movements on both tracks of the Hoxie subdivision. Examination of the data logs from the computer-aided dispatch system at the Harriman Dispatch Center and field testing of the signal system determined the displayed signal aspects were not in conflict with each other.

NTSB investigators questioned the crewmembers who had operated the southbound train on the prior trip about the train’s performance. The earlier crewmembers reported no issues with the train and confirmed that the alerter on the lead locomotive (UP 9707) was in working order

³¹ *Automatic behaviors* are stereotyped, repetitive behaviors performed without awareness. Tasks associated with automatic behavior are often monotonous and unskilled.

³² Sleep research has shown that sleep-deprived subjects could fall asleep in less than a minute.

³³ RSIA required that each Class I railroad and each railroad providing regularly scheduled intercity or commuter rail passenger transportation implement a PTC system by December 31, 2015. The Positive Train Control Enforcement and Implementation Act of 2015, section 1302 of Public Law 114-73, 129 Stat. 568, 576-82 extended the PTC implementation date to December 31, 2018.

during that trip. Qualified UP employees completed mechanical inspections on the southbound train the day before the accident and recorded no issues. UP provided personnel information on the two southbound train crewmembers. In addition to being qualified as a conductor, the southbound conductor was certified as a locomotive engineer. Select personnel background information is summarized in table 2.

Table 2. Dates of selected train crew personnel events.

| Select Events | SB Engineer | SB Conductor |
|--|----------------|-------------------|
| Hire date | March 30, 1998 | June 12, 2012 |
| Engineer date | May 29, 2002 | August 27, 2013 |
| Conductor date | June 17, 1998 | November 20, 2012 |
| Last check ride (Engineer) | May 9, 2014 | March 6, 2014 |
| Last check ride (Conductor) | N/A | June 3, 2013 |
| Last event recorder check ^a | July 28, 2014 | February 16, 2014 |
| Last rules exam | July 3, 2013 | March 12, 2014 |

^a Assessment to review crew compliance with operational rules.

NTSB investigators reviewed the personnel information for the southbound train crewmembers and determined that their training was appropriate and that they were qualified for the route. A UP manager told investigators that there was “nothing out of the ordinary” in terms of the locomotive engineer’s attendance and performance and both crewmembers had acceptable scores in the UP Employee Quality Management System.³⁴

Investigators obtained the cell phones from the two southbound train crewmembers.³⁵ The last text message made by the southbound engineer occurred at 5:40 p.m., before the start of the accident trip. His last call on his cell phone was made at 12:10 a.m., more than 2 hours before the accident.³⁶ Although this call was made on his personal cell phone, records indicate this call was made to the UP dispatcher and was work related. Investigators noted that the southbound engineer’s cell phone internet browsing history on the day before the accident included WebMD, where he had searched for natural health tips for insomnia. The last text message made by the southbound conductor (which was an outgoing message) occurred at 1:14 a.m., more than 1 hour before the accident.

The NTSB concludes that none of the following were factors in the accident: (1) the traffic control system; (2) the braking system of the southbound train; (3) train crew experience, or distraction by cell phones by the southbound train crewmembers; (4) medical conditions or use of alcohol, other drugs, or impairing substances by the southbound conductor; or (5) the work schedule of the southbound engineer.

³⁴ *UP Employee Quality Management System* includes employee scores based on various employee actions, including written examinations, efficiency testing, and any disciplinary actions. Each employee begins with a score of 1000 and has points deducted for various actions.

³⁵ The RSIA authorized the FRA to prohibit the use of personal electronic devices that may distract employees from safely performing their duties.

³⁶ NTSB investigators could not determine the exact location of the train when these calls were made.

3 Conclusions

3.1 Findings

1. The southbound train crew did not respond to the three restrictive signals immediately prior to the collision and took no action to slow or stop the train prior to arriving at control point Y-229, resulting in the collision with the northbound train.
2. The northbound train crew operated their train in accordance with traffic control signals, had no indication of the impending collision with the southbound train, and did not have time to apply the emergency air brakes prior to the collision.
3. The southbound train conductor was likely asleep at the time of the accident due to the variability of his shift start times which caused fatigue and the circadian desynchronization he experienced due to his operating the train in the early morning hours when he was predisposed to sleep.
4. Had the provisions specified in the hours of service requirements for commuter and passenger trains been applied to freight operations, the southbound train conductor would not have been allowed to work such a highly variable schedule because of its high risk for causing fatigue.
5. The southbound train locomotive engineer was fatigued and likely asleep due to his diagnosed but inadequately treated moderate sleep apnea and operating the train in the early morning hours when he was predisposed to sleep.
6. The continued occurrence of railroad accidents attributed to fatigue caused by sleep apnea are due in part to the failure of the Federal Railroad Administration since 2002 to respond to the hazards posed by undiagnosed or inadequately treated sleep apnea.
7. If the Federal Railroad Administration had similar standards as those in other modes of transportation, the southbound train locomotive engineer would have been required to periodically demonstrate adequate, ongoing treatment before he could obtain medical certification and be considered fit for duty.
8. Union Pacific Railroad's medical rules did not require the southbound train locomotive engineer, diagnosed with symptomatic, moderate sleep apnea to report his condition or ensure he followed the treatment recommendations from his sleep physician.
9. The lack of minimum standards for medical rules among Class I, intercity, and commuter railroads poses an unnecessary risk for employees in safety-sensitive positions who are diagnosed with sleep disorders.
10. The horn sequencer negated the alerter from alarming and providing an opportunity for the southbound train crew to prevent this accident.
11. Had the territory been equipped with a properly functioning positive train control system, the collision would have been prevented.

12. None of the following were factors in the accident: (1) the traffic control system; (2) the braking system of the southbound train; (3) train crew experience, or distraction by cell phones by the southbound train crewmembers; (4) medical conditions or use of alcohol, other drugs, or impairing substances by the southbound train conductor; or (5) the work schedule of the southbound train locomotive engineer.

3.2 Probable Cause

The National Transportation Safety Board determines that the probable cause of the accident was the failure of the southbound train crewmembers to respond to the signal indications requiring them to slow and stop their train prior to control point Y-229 because they were fatigued and had fallen asleep due to (1) the locomotive engineer's inadequately treated obstructive sleep apnea, (2) the conductor's irregular work schedule, and (3) the train crew operating in the early morning hours when they were predisposed to sleep. Contributing to the accident was (1) the lack of a functioning positive train control system; (2) the use of an automatic horn sequencer that, when activated, negated the operation of an electronic alertness device; (3) the Federal Railroad Administration's failure to promulgate rules regarding sleep disorders; and (4) the absence of federal regulations requiring freight railroads to use fatigue modeling tools for train crew work schedules.

4 Recommendations

4.1 New Recommendations

As a result of this investigation, the National Transportation Safety Board makes the following new safety recommendations:

To the Federal Railroad Administration:

- 1 Require freight railroads to use validated biomathematical fatigue models, similar to the models used by passenger railroads, to develop work schedules that do not pose an excessive risk of fatigue. (R-16-043)
- 2 Develop and enforce medical standards that railroad employees in safety-sensitive positions diagnosed with sleep disorders must meet to be considered fit for duty. (R-16-044)

To BNSF Railway, Canadian National Railway, Canadian Pacific Railway, CSX Transportation, Kansas City Southern Railway, Norfolk Southern Railway, Intercity Railroads, and Commuter Railroads:

- 3 Review and revise as necessary your medical rules, standards, or protocols to ensure you are informed of any diagnosed sleep disorders that employees in safety-sensitive positions must report and, when an employee makes such a report, perform periodic evaluations to ensure the condition is appropriately treated and the employee is fit for duty. (R-16-045)

To Class I Railroads:

4. Revise your scheduling practices for train crews and implement science-based tools, such as validated biomathematical models, to reduce start time variability that results in irregular work-rest cycles and fatigue. (R-16-046)

To the Union Pacific Railroad:

5. Revise your medical rules to add any diagnosed sleep disorder to the list of medical conditions that employees in safety-sensitive positions must report and, when an employee makes such a report, perform periodic evaluations to ensure the condition is appropriately treated and the employee is fit for duty. (R-16-047)

4.2 Previously Issued Recommendations Reiterated in This Report

As a result of this investigation, the National Transportation Safety Board reiterates following two safety recommendations:

To the Federal Railroad Administration:

- 1 Develop medical certification regulations for employees in safety-sensitive positions that include, at a minimum, (1) a complete medical history that includes specific screening for sleep disorders, a review of current medications, and a thorough physical examination, (2) standardization of testing protocols across the industry, and (3) centralized oversight of certification decisions for employees who fail initial testing; and consider requiring that medical examinations be performed by those with specific training and certification in evaluating medication use and health issues related to occupational safety on railroads. (R-13-21)
- 2 Require railroads to medically screen employees in safety-sensitive positions for sleep apnea and other sleep disorders. (R-12-16)

4.3 Earlier Recommendations

On February 4, 2015, the National Transportation Safety Board proposed the following urgent recommendations to the Federal Railroad Administration, the Association of American Railroads, the American Short Line and Regional Railroad Association, and the American Public Transportation Association regarding automated inputs on locomotives through the use of alerter:

To the Federal Railroad Administration:

1. Review your existing regulations and your motive power and equipment compliance manual, and revise them as needed to prohibit automatic systems from resetting the locomotive alerter. (R-15-4) (Urgent)
2. Immediately notify railroads of the circumstances of this accident and the risks posed by automated inputs that reset alerter cycles. Urge railroads to assess all controlling locomotive alerter systems to (1) identify and document any system inputs that reset the alerter cycle without manual intervention by crewmembers and (2) determine ways to eliminate such resets. (R-15-5) (Urgent)

To the Association of American Railroads, the American Short Line and Regional Railroad Association, and the American Public Transportation Association:

3. Inform your members of the circumstances of this accident and the risks posed by automated inputs that reset alerter cycles. Urge your members to assess their locomotive alerter systems to (1) identify any inputs that reset the alerter cycle without intervention by crew members and (2) determine ways to eliminate such resets. (R-15-6) (Urgent)

BY THE NATIONAL TRANSPORTATION SAFETY BOARD

CHRISTOPHER A. HART
Chairman

ROBERT L. SUMWALT
Member

T. BELLA DINH-ZARR
Vice Chairman

EARL F. WEENER
Member

Adopted: December 19, 2016

Vice Chairman Dinh-Zarr and Member Weener filed the following statements.

Board Member Statements

Vice Chairman T. Bella Dinh-Zarr filed the following statement on December 13, 2016.

While I concur with the findings, recommendations, and overall report, I, once again (as in the Philadelphia Amtrak 188 report), disagree with the probable cause. I do so not because I disagree with the staff's analysis, but rather, because I agree with the findings and hope that my dissent will help advance the way we, as a Board, think about probable cause and about prevention. I agree that the primary probable cause was the failure of the southbound crewmembers to act because they had fallen asleep. I also appreciate that positive train control (PTC) is listed first in the contributing factors and I agree with Member Sumwalt's change in the probable cause language at the Board meeting to clarify the role of the automatic horn sequencer.

But, like in the Amtrak 188 accident in Philadelphia, I strongly believe that PTC should be in the main probable cause and not simply a contributing factor. Why? For three reasons. First, because we have all agreed with the conclusion that, had the territory been equipped with a properly functioning PTC system, the collision would have been prevented. Second, because PTC is a mature and accepted solution that we have recommended in some form since 1970. This preventive system could and should have been in place and would have prevented not only this accident but the more than 30 accidents that we have investigated since 2004 alone, saving more than 70 lives and preventing 1,200 injuries. Third, we know and can predict that humans will make errors. With PTC we have redundancy so that there are not catastrophic results because of a single human mistake—or, in this case, a series of human mistakes. In this accident, we had a two-man crew but it was not enough to overcome human mistakes. The crew had three opportunities to stop the train as they passed signals and missed each of the three opportunities. Both crewmembers failed to perform their duties appropriately—one fell asleep due to unreported sleep apnea and the other fell asleep due to his variable shift schedule. In this accident, properly functioning PTC could have compensated for these compounding mistakes.

PTC is part of a safe systems approach that is based on prevention and we have analogies in other modes of transportation. Just as traffic collision avoidance system (TCAS) prevents most mid-air collisions in aviation, PTC would prevent most train-to-train as well as other collisions. It only took three mid-air collisions for the Federal Aviation Administration to require every aircraft to be equipped with TCAS and for it to be universally installed. Today, we rarely hear of a mid-air collision of two aircraft because of the pervasiveness of TCAS. With PTC, one day we will rarely hear of catastrophic train collisions such as this one in Hoxie.

Perhaps this accident in Hoxie is not the ideal accident for implementing a change in thinking because it occurred before the Congress's deadline that this territory be equipped with PTC, but I feel compelled to speak out now, especially in light of Congress's extension of the PTC deadline to 2018. This accident occurred in August 2014. At that time, the railroads had until December 31, 2015, to complete installation of PTC. Union Pacific had started installing the components of PTC on the Hoxie subdivision, intending to have installation complete by the end of 2015. Now that Congress has delayed the deadline until December 31, 2018, over 2 years later,

Union Pacific is still in the process of installing PTC components on the Hoxie subdivision and intends to have PTC fully functioning by the end of 2018.

How many times can we afford to delay this much needed safety prevention? The design is there—we could choose to significantly mitigate or eliminate these accidents through design. That is why today I respectfully ask that my fellow Board Members, the NTSB staff, and truly, everyone concerned with rail safety, including the industry and Congress, to begin thinking of the lack of PTC as a primary probable cause in these accidents.

The NTSB staff have done their job in conducting a rigorous investigation and a careful analysis. My fellow Board Members have done their job in thoughtfully reviewing the report and making sound and informed decisions. But, as the first public health-trained Board Member, I would not be doing my job if I did not continue to urge that PTC be considered a primary probable cause. It is commonly accepted that the lack of a smallpox vaccine caused deadly outbreaks of smallpox in children. Exposure to this virus was predictable and the vaccine would have prevented the deadly disease. Likewise, we can also say that that the lack of PTC has caused accidents because human error is predictable and PTC would have prevented deadly accidents. The smallpox vaccine became required because we, as a society, felt that children's deaths from a preventable disease were unacceptable and we knew the lack of a vaccine was the cause. I know that one day we will all feel the same about PTC. Vaccines cannot prevent every death, just as PTC cannot prevent every rail accident, but smallpox has been eradicated because of society's belief in prevention. I know it is only a question of time until the epidemic of catastrophic PTC-preventable rail accidents is also eradicated.

Member Earl F. Weener joined this statement, in part.

Board Member Earl F. Weener filed the following statement on December 13, 2016.

I commend the Vice Chairman on her determined support of the swift implementation of positive train control (PTC). I voted to adopt the overall report, findings, recommendations and, specifically, the probable cause determination because I agree with staff that the first cause of this accident was the failure of the crew to stop the train. That failure was the first intervening event, without which there would have been no collision with the oncoming train. That said, I am persuaded by the Vice Chairman's comments to the extent that, while the first part of the causal statement should be the crew's failure, there is no question that a properly functioning PTC would have substantially mitigated, if not completely prevented, this accident. To that end, I agree that a lack of PTC could be included as the second half of the causal statement, following the crew's failure to stop the train appropriately.

5 Appendix

The National Transportation Safety Board was notified on August 17, 2014, that two Union Pacific Railroad freight trains had collided on the Union Pacific Hoxie subdivision in Hoxie, Arkansas. The National Transportation Safety Board launched an investigator-in-charge and three team members to investigate the accident.

The parties to the investigation were the Federal Railroad Administration, Union Pacific Railroad, the Brotherhood of Railroad Signalmen, the International Association of Sheet Metal, Air, Rail and Transportation Workers, and the Brotherhood of Locomotive Engineers and Trainmen.

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