Collision of Union Pacific Railroad Freight Train with BNSF Railway Freight Train Near Chaffee, Missouri May 25, 2013

Accident Report

NTSB/RAR-14/02
PB2015-102084

National Transportation Safety Board

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Railroad Accident Report

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

National Transportation Safety Board. 2014. ***Collision of Union Pacific Railroad Freight Train with BNSF Railway Freight Train Near Chaffee, Missouri, May 25, 2013*. Railroad Accident Report NTSB/RAR-14/02. Washington, DC.**

Abstract: On May 25, 2013, at 2:30 a.m. central daylight time, near Chaffee, Missouri, a Union Pacific Railroad (UP) freight train collided with a BNSF Railway (BNSF) freight train at Rockview Interlocking, where tracks of the two railroads cross. The BNSF train was moving through the interlocking when the UP train struck the 12th car behind the locomotives of the BNSF train. As a result of the collision, 13 cars of the BNSF train derailed and two locomotives and 11 cars on the UP train also derailed. Diesel fuel spilled from the derailed locomotives and caught fire. The engineer and the conductor on the UP train were injured and transported to a local hospital. The Missouri State Highway M bridge crossed over the Rockview Interlocking, and derailed train cars struck bridge supports and collapsed portions of the bridge. After the bridge collapsed, two motor vehicles struck damaged highway elements. Five occupants of the motor vehicles were transported to a local hospital. Damage was estimated to be more than $11 million.

For more detailed background information on this report, visit http://www.ntsb.gov/investigations/dms.html and search for NTSB accident ID DCA13MR004. Recent publications are available in their entirety on the Internet at http://www.ntsb.gov. Other information about available publications also may be obtained from the website or by contacting:

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Acronyms and Abbreviations

AASHTO	American Association of State Highway and Transportation Officials
AHI	apnea-hypopnea index
AREA	American Railway Engineering Association
AREMA	American Railway Engineering and Maintenance-of-Way Association
BMI	body mass index
BNSF	BNSF Railway
bpm	beats per minute
CFR	*Code of Federal Regulations*
CRM	crew resource management
CT	computed tomography
EEG	electroencephalogram
FHWA	Federal Highway Administration
FRA	Federal Railroad Administration
LRFD Manual	*Load Resistance Factor Design Manual*
mg/dL	milligrams per deciliter
MODOT	Missouri Department of Transportation
MP	milepost
MRI	magnetic resonance imaging
NHBLI	National Heart, Blood and Lung Institute
NTSB	National Transportation Safety Board
OSA	obstructive sleep apnea
RSIA	Rail Safety Improvement Act of 2008
UP	Union Pacific Railroad

Executive Summary

On May 25, 2013, at 2:30 a.m. central daylight time, near Chaffee, Missouri, Union Pacific Railroad (UP) freight train 2-ASMAR-25 UP 5668 South collided with BNSF Railway (BNSF) freight train U-KCKHKM0-05T at Rockview Interlocking, where tracks of the two railroads cross. (See figure 1.) The BNSF train was moving through the interlocking when the UP train struck the 12th car behind the locomotives of the BNSF train. As a result of the collision, 13 cars of the BNSF train derailed. Two locomotives and 11 cars on the UP train also derailed. Diesel fuel spilled from the derailed UP locomotives and caught fire. The engineer and the conductor on the UP train were injured and transported to a local hospital.

The Missouri State Highway M bridge crossed over the Rockview Interlocking, and derailed train cars struck bridge supports and collapsed portions of the bridge. After the bridge collapsed, two motor vehicles struck damaged highway elements. Five occupants of the motor vehicles were transported to a local hospital.

As a result of their variable work schedules both UP crewmembers experienced disruptions to their normal circadian rhythms for several days before the accident, and at the time of the accident experienced fatigue caused by circadian disruption and the requirement to operate the train during the window of circadian low. Prior to the collision, both UP crewmembers failed to comply with four wayside signals because of likely fatigue-induced performance degradation. Obstructive sleep apnea likely contributed to the engineer's fatigue. Damage was estimated to be more than $11 million.

The National Transportation Safety Board determines that the probable cause of the accident was the failure of the Union Pacific Railroad 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 Federal Railroad Administration to fully implement the fatigue management components required by the Rail Safety Improvement Act of 2008. Likely contributing to the engineer's fatigue was undiagnosed obstructive sleep apnea. Also contributing to the accident was inadequate crew resource management.

1 Accident Information and Investigation

1.1 Accident Overview

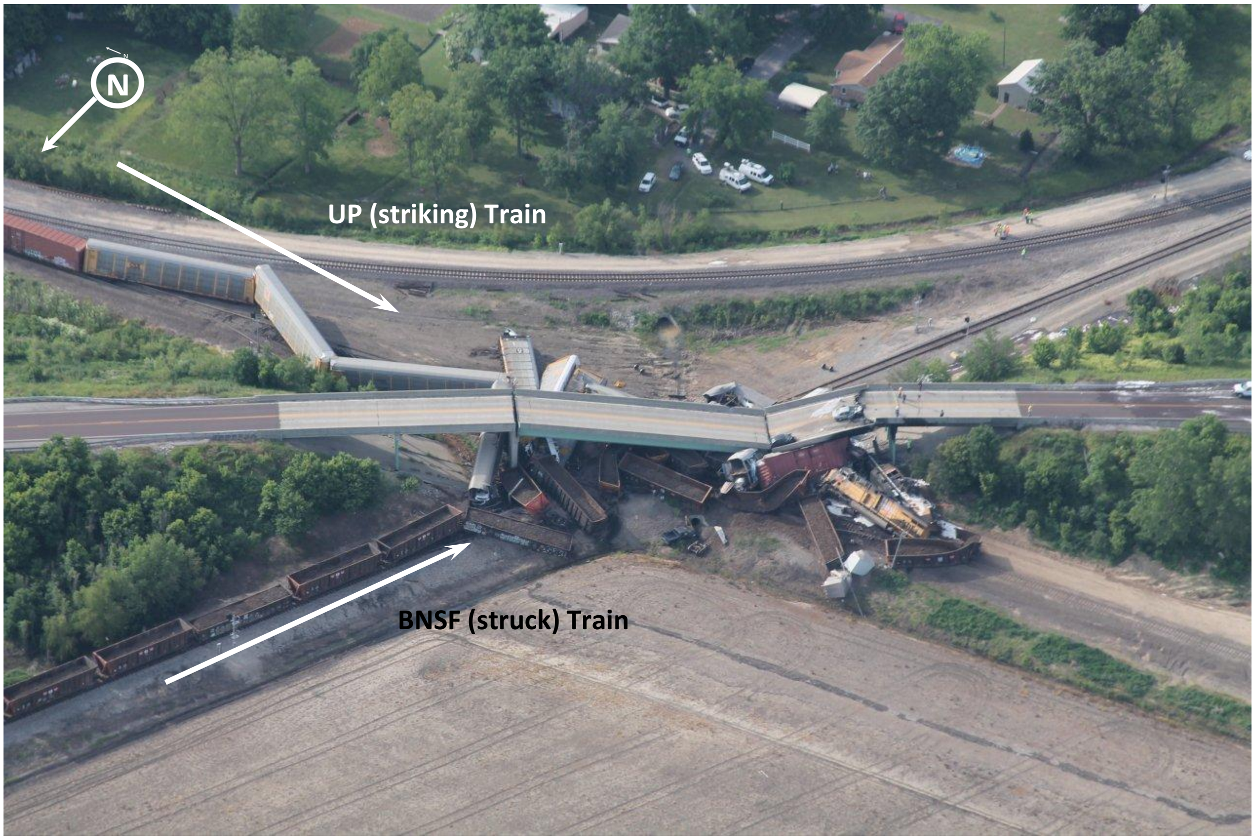

Figure 1. Aerial view of accident scene and wreckage.

1.2 Accident Narrative

The crew of the UP train, consisting of an engineer and a conductor, went on duty at 9:45 p.m. on May 24, 2013, at Salem, Illinois, and departed at 10:10 p.m. The train had 2 locomotives on the head end and 60 loaded cars. The train was scheduled to travel south to Dexter, Missouri, on the Chester Subdivision. A qualified UP mechanical employee performed a predeparture mechanical inspection and a brake test had been performed on the train at 9:15 p.m., and no exceptions were noted on the brake test report. The conductor did not take any exception to the mechanical condition of the train other than the speedometer on the conductor's side of the locomotive cab was not working. However, the FRA only requires a working speedometer on the engineer's side of the cab. The conductor could have viewed the speedometer on the other side of the cab with minimal effort.

According to the crew, they met one opposing train at Mt. Vernon, Illinois, and then continued south. The conductor told investigators that on the day of the accident, the engineer appeared to be alert. The conductor said that they called the wayside signals aloud (as UP operating rules require), although he could not remember which of them called each of the signals after they departed Salem. He also said that the trip was uneventful until they approached Rockview Interlocking and the crossing with the BNSF tracks. He described nearing the interlocking:

> I was writing in my logbook. I saw that … the absolute signal at the north end was [indicating] Approach. I called it out. [The] engineer repeated it back to me. I was writing in my logbook, doing what I have to do as a conductor, [doing] my duties, talking on the radio …. Nothing was out of the [ordinary].

The conductor described passing the Approach signal (yellow aspect), noting that the signal required them to reduce speed to 30 mph and be prepared to stop at the next signal. The conductor said he had no reason to believe that the train was not doing that:

> When we passed the Approach [signal], I asked [the engineer] what our speed was, and he responded, "30-something." So I assume[d] that … he [was] doing what he ha[d] to do.

The conductor also told investigators that he did not notice anything out of the ordinary until the train got closer to the interlocking. He said that he was familiar with the Rockview Interlocking area, which has "a sweeping curve to the right, when you're heading south, and … the signal is at the south end." He said that after the train went around the corner he saw the Restricting signal (flashing red aspect). At that point, he did not think the train was slowing down like it should have been, so he used the emergency brake valve to place the train into emergency braking. The UP train struck the passing BNSF train shortly thereafter. Event recorder data indicated that the speed at impact was 43 mph. (See figure 2 for accident location.)

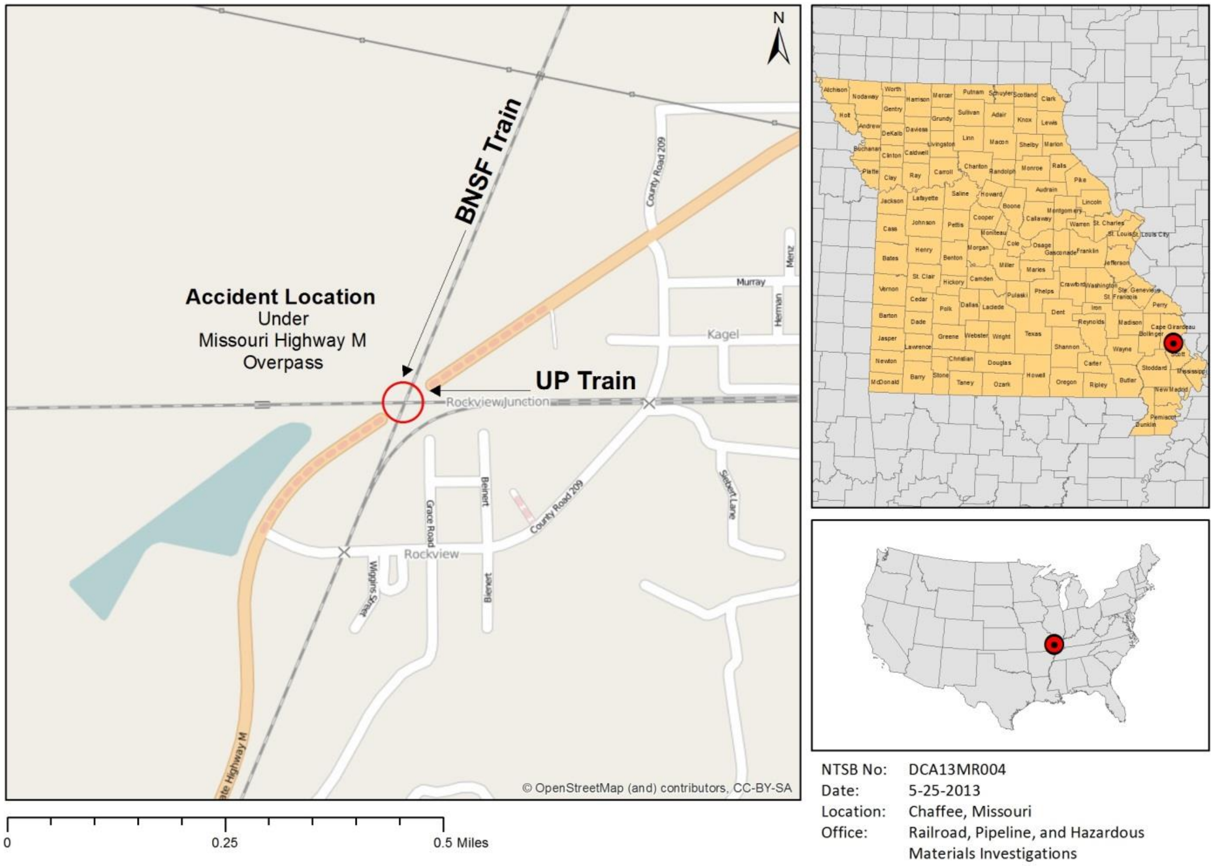

Figure 2. Accident location.

The conductor told investigators that he was writing entries in his log between the Approach signal and the point where he pulled the valve to apply the emergency brakes:

> I think the only time I looked at him was when I asked the speed at the Approach [signal]. I don't recall looking at him; I had my head down … writing in my book. When I looked up [was] when I realized we were going faster … than we had been.

In the followup interview in August, investigators asked the conductor about his observations of the engineer. When the conductor was asked whether he believed the engineer was asleep, the conductor said, "No."

The conductor's log, at appendix B, indicates the names of the "less than Clear" signal indications the train crew encountered along with the time and speed. The distance between the Approach signal and the Restricting signal was 10,291 feet. The Rockview Interlocking signal was 1,215 feet from the Restricting signal. (See section 1.5 for further information about the signal system.)

The UP engineer told investigators that he remembered riding on the train and calling out signals but that his memory faded after that. The next thing he remembered was the conductor's leaning over him and asking whether he was all right. The engineer remembered looking up at the conductor and answering him, saying yes, that he was all right. He also recalled wondering why he was lying down and hearing the conductor say they had been in an accident.

Investigators showed the engineer event recorder data that had been downloaded from the UP train after the accident. The data indicated that at 2:25 a.m., about 5 minutes before the collision, the train was operating at 54 mph for several minutes, beyond the Approach signal where the train should have been travelling no more than 30 mph and the crew should have been prepared to stop at the next signal. The engineer told investigators that he should not have been "going that fast." The event recorder data also indicated several horn activations in an area where blowing the horn was not required. The engineer was unable to explain why the locomotive horn had been activated in that area. The event recorder data also indicated that the horn was not activated at the last highway-railroad grade crossing and that it had been activated several times immediately before the UP train struck the BNSF train. The engineer was unable to explain the failure to activate the horn or the multiple activations just before the collision. When investigators asked the engineer whether he fell asleep before the accident he said, "I don't know."

During the followup interview in August, the engineer told investigators that he still could not remember the final part of the accident trip. He indicated that he had discussed his memory lapse with several medical practitioners, and he had come to believe that he had a "diabetic blackout" on the day of the accident.

1.2.2 BNSF Crew

The crew of the BNSF train, consisting of an engineer and a conductor, took charge of their train in Lindenwood Yard in St. Louis, Missouri, on May 24 at 7:00 p.m. and departed about 8:32 p.m. The train had 3 locomotives on the head end and 75 loaded cars. The BNSF train was scheduled to travel to Chaffee, Missouri, on the River Subdivision. A predeparture mechanical inspection and a brake test were performed on the BNSF train at Kansas City, Kansas, on May 23, 2013. No exceptions were noted on the brake test report.

According to the crew, the trip was routine until the collision. The crew told investigators that at Rockview Interlocking (BNSF MP 141.7) the train entered the interlocking on a Clear (green aspect) signal. The crew said that they saw the headlight of the UP train and that it was not unusual to see a train on the UP track at this location. The southbound BNSF train was struck by the westbound UP train after the locomotives and the first 12 cars of the BNSF train had passed the crossing with the UP tracks, causing an emergency application of the BNSF train brakes.

1.2.3 Automobiles on Highway Bridge

Two automobiles westbound on Route M crashed when they drove into the void created by the collapse of highway bridge supports. (See section 1.10 for further information about the bridge collapse.) The first crash, which occurred 3 minutes 52 seconds after the derailment, involved a 2010 Nissan Versa occupied by a 30-year-old male driver and a 38-year-old female passenger. The second automobile crash, which occurred 1 minute after the first, involved a 2000 Chevrolet Malibu occupied by a 22-year-old male driver and two passengers: a 19-year-old female seated in the right front seat and an unrestrained 19-year-old female seated in the rear.

1.3 Injuries

After the collision, both the engineer and the conductor of the UP train were transported to the hospital by ambulance. The conductor was awake, alert, and ambulatory. He had a scalp laceration and skinned knuckles on both hands, and he was complaining of pain in his left elbow and right knee. The UP engineer did not remember the accident, remembering only lying on the floor of the locomotive and the conductor's rousing him. However, he was ambulatory by the time the ambulance arrived. He had a laceration of the left arm, pain with some swelling on the left chest, and pain on the right leg below the knee. The notes from ambulance personnel indicate that he was "neuro intact" and oriented to events, person, place, and time. A Missouri State Highway Patrol sergeant told investigators both UP crewmembers showed no symptoms of impairment and appeared alert when he saw them at the hospital.

The five passengers in the two automobiles that struck damaged portions of the highway bridge were transported to the hospital. The driver and passenger of the automobile in the first crash were wearing seat belts and received minor injuries. In the automobile involved in the second crash, the driver and the passenger in the rear received minor injuries. The passenger in the right front seat received serious injuries that consisted of lower leg fractures.

1.4 Operations Information

1.4.1 General

UP crews were governed by the *General Code of Operating Rules*, 6th Edition, effective April 7, 2010, and updated April 23, 2013 (UP 2013). The territory was designated the UP Northern Region, St. Louis Service Unit, Chester Subdivision. At the time of the accident, the current timetable was St. Louis Timetable No. 4, effective December 14, 2009. Four supplemental operating rules documents were System Special Instructions, April 20, 2012, updated April 23, 2013; Air Brake and Train Handling Rules, April 20, 2012, updated April 23, 2013; Safety Rules, July 30, 2007, revised April 23, 2013; and System General Orders, April 23, 2013.

BNSF crews were governed by the *General Code of Operating Rules*, 6th Edition, effective April 7, 2010, and updated February 1, 2013 (BNSF 2013). The territory was designated the BNSF Springfield Division, River Subdivision. At the time of the accident, the current timetable was Springfield Division Timetable No. 8, August 15, 2012. Three supplemental operating rules documents were System Special Instructions No. 3, July 18, 2012, revised May 1, 2013; Air Brake and Train Handling Rules, April 7, 2010, revised May 1, 2013;

and TY & E (Train, Yard, and Engine) Safety Rules, October 30, 2005, revised November 1, 2012.

Further, each train was issued track bulletins (BNSF) or track warrants (UP) for their respective subdivisions that covered unique speed restrictions or other requirements specific to the date of the accident. Neither railroad's bulletins or warrants had special restrictions at Rockview Interlocking.

The Rockview Interlocking operated on a first-come, first-served basis: the first train to arrive received a Clear signal (green aspect) to enter the interlocking and cross the track, and a train arriving second, on the other track, received a Stop signal (red aspect). In this case, the southbound BNSF train arrived first and received a Clear signal to enter the interlocking, and a Stop signal was displayed to the westbound UP train.

1.4.2 Operating Rules Relevant to Accident

The UP *General Code of Operating Rules* (2013), rule 1.47 C: Duties of All Crew Members, contains the following provisions that are relevant to this accident:

> 1. Crew Members in Control Compartment
>
> Crew members in the control compartment must communicate to each other any restrictions or other known conditions and required actions that affect the safe operation of their train sufficiently in advance of such condition to allow the engineer to take proper action. If proper action is not being taken, crew members must remind engineer of such condition and required action.
>
> Crew members in the control compartment must be alert for signals. Crew members must:
>
> - Communicate clearly to each other the name of signals affecting their train as soon as signals become visible or audible.
> - Continue to observe signals and announce any change of aspect until the train passes the signal.
> - Communicate clearly to each other the speed of the train as it passes a signal with an indication other than Clear.
> - Immediately remind the engineer of the rule requirement if the signal is not complied with.
>
> 3. Proper Action
>
> If engineer and/or conductor fail to comply with a signal indication or take proper action to comply with a restriction or rule, crew members must immediately take

action to ensure safety, using the emergency brake valve to stop the train, if necessary.

Additionally, the UP *General Code of Operating Rules* (2013) 1.47.1 establishes a *cab red zone* for certain circumstances, which include when a train is operating at restricted speed and when a train is operating on a signal that requires the train to be prepared to stop at the next signal:

> During a cab red zone, an environment must be created in the control compartment that focuses exclusively on controlling the train and complying with the rules. The conductor must be in the control compartment unless required by other duties to leave (i.e., to operate switches, be at a road crossing, passenger train duties, etc.).
>
> The following restrictions or conditions must be met:
>
> - Cab communication is restricted to immediate responsibilities for train operation.
>
> - A crew member other than the employee operating the controls will be required to handle radio communications when another crew member is in the control compartment …. Radio communication must be limited to the train's immediate movement and complying with the rules ….
>
> - If proper action is not being taken, crew members must remind each other of the cab red zone condition.

Investigators asked the conductor about cab red zone. He responded that it comes into effect anytime safety is involved, and added that in-cab communications under cab red zone conditions applies to movement of and stopping a train. Specifically, he said cab red zone goes into effect once a train has passed an Approach signal.

1.5 Signals Information

The Chester Subdivision in the UP St. Louis Service Unit extends from East St Louis, Illinois, to Dexter, Missouri, in a timetable north-south direction. The maximum authorized timetable speed on the subdivision is 70 mph for freight trains with a 40 mph restriction through the Rockview Interlocking. In the vicinity of the accident area, the UP operates over a single main track using a traffic control system controlled by a dispatcher at the Harriman Dispatch Center in Omaha, Nebraska.

The Rockview Interlocking is located on the BNSF River Subdivision of the Springfield Division. The BNSF operates through this area over a single main track using a traffic control system controlled by a dispatcher at the Network Operations Center in Fort Worth, Texas.

Both UP and BNSF dispatchers send signal requests to Rockview Interlocking. A railroad that wants to move a train over the interlocking sends a request to the field equipment to line a signal to operate over Rockview Interlocking. The other railroad dispatcher then receives an onscreen indication that the first railroad has requested a signal, and the dispatcher acknowledges the request. If both railroads make this request at the same time, the first train that occupies the Approach track circuit to the interlocking receives a signal to operate over the railroad crossing. The signal aspect for the other train will remain red.

1.5.1 Signal Requirements Before Collision

As the BNSF train approached Rockview Interlocking, it passed signal aspects indicating the route was aligned and maximum speed (25 mph) was authorized. A green aspect (Clear) displayed on the Rockview Interlocking signal allowed the BNSF train to operate through the Rockview Interlocking; event recorder data indicate that the BNSF train was traveling at 22 mph when it was struck by the UP train.

As the UP train approached Rockview Interlocking, it passed four signals that governed its movement and provided information to the crewmembers before the train reached the interlocking. (See table 1.)

Table 1. Signals encountered by striking UP train.

Location	Aspect Displayed	Aspect Name	Indication
MP 127.7	Flashing Yellow	Advance Approach	Reduce speed to 40 mph prepared to stop at second signal
MP 129.1	Solid Yellow	Approach	Reduce speed to 30 mph prepared to stop at next signal
MP 131.2	Flashing Red	Restricting	Reduce speed to restricted speed
Rockview Interlocking	Solid Red	Stop	Stop

The first of the four signals was a flashing yellow aspect (Advance Approach) on the intermediate signal at MP 127.7, which required the train crew to reduce speed to 40 mph and be prepared to stop at the second signal. A solid yellow aspect (Approach) on the next signal, at MP 129.1, required the train crew not to exceed 30 mph and to be prepared to stop at the next signal. The third signal at MP 131.2 was a flashing red aspect (Restricting) that required the train to operate at restricted speed. Restricted speed on the UP is defined in the *General Code of Operating Rules* (UP 2013) 6.27 as “a speed that allows stopping within half the range of vision short of” the Stop signal and “the crew must keep a lookout for broken rail and not exceed 20 mph.” The fourth signal displayed a solid red aspect (Stop), which required the train to stop short of the signal. Event recorder data indicate that the actual speed of the UP train was between 48 mph and 54 mph as it passed the final four signals.

Along with responding appropriately to the signal aspect requirements, the UP crew was required to activate the locomotive horn at the last highway-railroad grade crossing before the collision. The horn was not activated at that grade crossing according to locomotive event recorder data. However, the horn was activated many times about 10 minutes before the collision. It is unclear why the horn was activated; review of the track profile chart indicated no crossings in that area, and the recording from the inboard video recorder showed no equipment or personnel in the vicinity of the tracks.

1.5.2 Postaccident Signal System Inspection and Testing

A postaccident inspection of the signal system found all signal bungalows and signal equipment locked and secured with no indications of tampering. Data from each signal location were downloaded. The Federal Railroad Administration (FRA) recreated the associated track circuit codes both in and out and verified each signal aspect displayed as intended. Ground tests did not indicate any exceptions. The signal lenses were inspected, and no defects were noted. Circuit plans were reviewed and all associated junction boxes inspected. No defects of the signal system or associated appurtenances were noted during these inspection activities. Maintenance, inspections, and tests were in accordance with FRA requirements.

The FRA measured distances from signal mast to signal mast in the direction of the UP train approaching the accident area. The first signal encountered was at MP 127.7. No obstructions were identified that could have interfered with the signal preview. The next signal, at MP 129.1, was 7,164 feet from the previous signal. No obstructions were identified that could have interfered with the signal preview. The signal at MP 131.2 was 10,291 feet from the signal at MP 129.1. The Rockview Interlocking signal was 1,215 feet beyond the signal at MP 131.2. No obstructions were identified that could have interfered with the signal preview.

As a result of the collision, damages to signals and signal bungalows were estimated to be $500,000.

1.6 Personnel Information

1.6.1 Employment History and Qualification

The UP engineer was hired as a brakeman on the Chicago Eastern and Illinois Railroad in April 1974. He began working as a freight locomotive engineer out of Salem, Illinois, in 1980 and had operated out of Salem for most of his career. Records indicate that he was qualified on the territory at the time of the accident. His last check ride was in November 2012. He successfully passed a Stop signal test on May 22, 2013.

The UP conductor was hired in October 2008. He has been based in Salem, Illinois, since May 2011. His last check ride was in August 2012. He successfully passed a Stop signal test on December 30, 2012.

The BNSF engineer was hired into train service in January 1997. Records indicate that he worked as a conductor, brakeman, and switchman at various locations on the BNSF system until 2003. In 2004 he began working as a locomotive engineer in Gainesville, Texas. He had worked out of Chaffee, Missouri, since June 2008. Records indicate that he was qualified on the territory at the time of the accident. His last check ride was in March 2013 with a performance score of 98 out of 100.

The BNSF conductor was hired in September 2003. Since that time, he worked mostly out of Springfield, Missouri, until he transferred to Chaffee in June 2012. He had operated over the accident territory since January 2012. Records indicate that he was qualified on the territory at the time of the accident. His last recertification as a conductor was on June 21, 2011.

1.6.2 UP Crew Performance History

Specific requirements for the testing and observation of operating employees while they perform their duties are contained in Title 49 *Code of Federal Regulations* (CFR) 240.303 (engineers) and 242.123 (conductors). The UP maintained an operational testing program in accordance with 49 CFR 217.9 to monitor the performance of employees operating trains and assess their compliance with rules. Additional testing requirements that railroads must follow for certification of locomotive engineers are at 49 CFR 240.303(d)(1)(i) and include a requirement that locomotive engineers operating on signaled track be tested once per year on a "less than Clear" signal.

The UP provided data covering the 12 months preceding the accident for the engineer and the conductor of the striking train. Supervisors had observed both employees while they performed a variety of operations. (See table 2.)

Table 2. Operations tests performed on UP crew.

Category	Engineer	Conductor
Total test events[a]	22	18
Total individual tests	56	63
Total individual rules checked	128	169
Test events on Chester Subdivision	5	6
Test events at Rockview Interlocking	1	0

[a] A test event may involve more than one individual test and more than one individual rule.

Several of the tests outlined in the UP *Field Training Exercise Program, Manager's Guide* (UP 2012) relate to procedures relevant to this accident. (See table 3.)

Table 3. Number of operations tests performed on UP crew.

Test Number	Test	Engineer	Conductor
1A	Stop test	4	3
3A	Stop signal	7	8
3B	Restricted proceed	0	1
4	Restricting	0	0
5A	Approach/Approach Diverge	0	0
5B	Signal less than Clear	0	0
8	Speed limit	1	1
11A	On-board assessment	10	10

On these tests, the UP conductor did not score below standard on any, whereas the UP engineer scored below standard on three items. These were minor deficiencies regarding general rules compliance, and the engineer was coached following each of these events.

1.6.3 UP Crew Schedules

UP Engineer. The UP engineer told investigators that he was unable to recall the times he awoke and retired on May 22, and the time he awoke on May 23. (See UP engineer's sleep/work/rest history at table 4.) He did remember that, on May 23, he went off duty at 9:35 p.m. and retired for the evening between 11:00 p.m. and 11:30 p.m. He awoke the following day, May 24, at 7:30 a.m., had coffee, checked train line-ups via his computer, had breakfast, and remained home. He recalled that he napped from about 1:00 p.m. until 4:00 p.m., had dinner at 7:30 p.m. and went on duty at 9:45 p.m. At the time of the accident the UP engineer had been on duty for 4 hours and 45 minutes, and he had been awake for about 10 hours 30 minutes.

Table 4. UP engineer's recent work/rest/sleep history.

Date	BeginSleep	Wake Up	Time Asleep	Shift Start	Shift End	Time On Duty
May 19	does not recall	does not recall	does not recall	1:15 a.m.	1:08 p.m.	11 hr. 53 min.
May 22	does not recall	does not recall	does not recall	2:00 a.m.	2:08 p.m.	11 hr. 52 min.
May 23	11:30 p.m.	7:30 a.m. (May 24)	8:00 hr.	1:05 p.m.	9:35 p.m.	8 hrs 30 min.
May 24	1:00 p.m.	4:00 p.m.	3 hr. (nap)	9:45 p.m.	2:30 a.m. (May 25)	4 hr. 45 min.

In the 6 days preceding the accident, the UP engineer had worked two very long—nearly 12-hour—shifts that began early in the morning, about 1:00 a.m. and 2:00 a.m., respectively, and lasted until early afternoon. Then, on the day after the second long shift, May 23, he worked an 8-hour shift that began in the early afternoon about 1:00 p.m. and ended at 9:35 at night. On May 24–25, he worked a night shift, reporting for duty at 9:45 p.m.

UP Conductor. The UP conductor told investigators that he was unable to recall when he awoke and retired on May 22 and the following day, May 23. (See UP conductor's sleep/work/rest history at table 5.) He recalled that he went off duty at 3:00 a.m. on May 24 and retired between 3:30 a.m. and 4:00 a.m. He slept until noon, showered, had dinner, was called for duty at 6:45 p.m., and went on duty at 9:45 p.m. At the time of the accident the UP conductor had been on duty for 4 hours 45 minutes and, based on his recollections, awake for about 14 hours 30 minutes.

In the 6 days preceding the accident, the UP conductor had worked a number of shifts that began at varying times, including one day when he worked two shifts. On May 19 he worked a night shift beginning about midnight. Two days later, he worked a day shift beginning at 7:30 a.m. Two days after that, he worked two shifts; the first shift began about midnight and ended nearly 10 hours later at 9:52 a.m., and the second shift began at 11:00 p.m. and ended at 3:21 a.m. On the day of the accident, he worked a night shift, reporting for duty at 9:45 p.m.

Table 5. UP conductor's recent work/rest/sleep history.

Date	BeginSleep	Wake Up	Time Asleep	Shift Start	Shift End	Time On Duty
May 19	does not recall	does not recall	does not recall	11:55 p.m.	7:55 a.m. (May 20)	8 hr.
May 21	does not recall	does not recall	does not recall	7:30 a.m.	3:00 p.m.	7 hr. 30 min.
May 23	does not recall	does not recall	does not recall	12:15 a.m.	9:52 a.m.	9 hr. 37 min.
May 23	--	--	8:00 hr.	11:00 p.m.	3:21 a.m. (May 24)	4 hrs 21 min.
May 24	4:30 a.m.	noon	7:30 hr.	9:45 p.m.	2:30 a.m. (May 25)	4 hr. 45 min.

1.7 UP Crew Medical Information

The FRA does not require a complete medical history, list of medications, or physical exam for railroad employees in safety-sensitive positions. The UP performs a complete medical history and physical only as part of preemployment or return-to-work examinations but limits the triennial medical evaluation to the minimum required by the FRA: vision testing and hearing screening.

Investigators reviewed a series of medical records for both the engineer and the conductor. These included UP medical records and postaccident ambulance and emergency department medical records for both crewmembers and, for the engineer, personal medical records from before and after the accident.

1.7.1 UP Conductor

On the conductor's initial physical on September 4, 2008, he reported only a previous knee surgery, denied any medical problems, and answered "No" to a host of specific health problems. At that time, he was recorded as 5 feet 10 inches tall and 200 pounds. His binocular visual acuity was 20/15, and he passed the Ishihara color vision plate test with 13 out of 14 plates correct.[1]

At the time of the accident, the UP conductor was 33 years old, and his most recent UP physical examination was performed on May 14, 2010, when he was returning to work after a period of furlough. At that time he was 5 feet 10 inches tall and weighed 202 pounds. During that examination he completed an "interval medical history" form. Among the questions on the form, he answered "No" to the following:

- Was he returning to work after an illness or injury?
- Did he require work restrictions or accommodations?

[1] The Ishihara test is the standard protocol mentioned in 49 CFR Part 240, Appendix F (Medical Standards Guidelines), to test for color vision deficiencies.

- Did he have limitations to his ability to wear safety protective equipment?
- Did he have a health condition, take any medications or treatment, or depend on any medical devices that do (or might) adversely affect his judgment, alertness, balance, coordination, or that might in any way interfere with his ability to safely and efficiently perform his job functions?

On this visit the conductor passed the visual acuity testing without glasses or contact lenses (20/15) and color vision testing (14/14 Ishihara plates correct). The conductor's hearing was tested on February 25, 2010, and he had no deficits above 10 decibels.

Postaccident Medical Information. After the collision, the conductor was ambulatory at the crash scene but was transported to the hospital by ambulance. The ambulance run sheet notes "no significant [past medical history]" and "None" under medications. The conductor was awake and alert with a Glasgow Coma Scale score of 15/15.[2] He was noted to have a scalp laceration and skinned knuckles on both hands, and he was complaining of pain in his left elbow and right knee. The narrative note from the emergency medical services provider says, "The [patient] stated they attempted to stop but could not stop in time." As noted previously, a Highway Patrol sergeant told investigators the UP conductor showed no symptoms of impairment and appeared alert when he saw him at the hospital.

In the emergency department, the conductor reported no medical history and said that he was not taking any medications to both the triage nurse and the physician. According to the emergency department, he weighed 210.1 pounds and was 5 feet 10 inches tall, with a calculated body mass index (BMI) of 30.42 (NHBLI 2013).[3] The conductor was diagnosed with a scalp laceration, and the laceration was repaired. A second diagnosis was "multiple contusions." Tests performed in the emergency department included CT (computed tomography) scans of his head, entire spine, chest, abdomen, and pelvis, but no significant traumatic findings were uncovered. Laboratory testing revealed normal blood counts, electrolytes, and liver and kidney function. His random glucose was mildly elevated at 133 milligrams per deciliter (mg/dL); normal range in the lab was 72–113 mg/dL. The conductor was discharged from the emergency department to his home.

1.7.2 UP Engineer

The UP engineer was 58 years old at the time of the accident. He had passed his most recent routine medical certification exam on July 20, 2012. At that visit only vision and hearing were tested; no questions were asked about medical problems or medications, and no other physical examination was performed. At that time, his corrected binocular visual acuity was 20/30, and he passed the Ishihara color vision plate test with 13 correct out of 14 plates. He had chronic partial hearing loss with a 40–55-decibel loss in the higher frequencies (>3,000 hertz) in

[2] The *Glasgow Coma Scale,* composed of three tests—of eye, verbal, and motor responses—is used to assess the neurological state of a patient. The number of points resulting from the assessment give a patient a score between 3 (indicating deep unconsciousness or coma) and 15 (fully awake).

[3] BMI is a measure of body fat that applies to adults. Normal BMI is between 18.5 and 24.9, overweight is considered 25.0 to 29.9, and a BMI of more than 30.0 is considered obese.

the right and a 60–70-decibel loss at 4,000 hertz and above on the left.[4] This approximate degree of high-frequency hearing loss had been present for many years. (In 1994, he was able to pass at 40 decibels in every frequency from 4,000 hertz and below.) There are no measurements of height and weight nor any mention of medication use or chronic medical problems in the last 15 years in the UP medical record.

The engineer told investigators that he had been a diabetic and using insulin to treat it since 1997 and that he believed the railroad was aware of that diagnosis. His UP medical record included personal medical records from 2001 and 2002. Recorded within the 2001–2002 information is the fact that the engineer had been diagnosed as diabetic and treated with insulin beginning in 1997, when his Hemoglobin A1C was measured as high as 16 percent.[5]

The most complete medical history form in the UP medical record is a 1974 entry from the Missouri Pacific and Texas Pacific Railroad. At that time, the engineer, who was then 19 years old, was asked a series of history questions that included, “Do you now or have you ever had …” followed by a list of medical conditions, including diabetes. He responded “No” to each question. In addition, he replied “No” to the question, “Are you taking drugs of any kind?” At that time, the engineer was recorded at 6 feet 3 inches and 190 pounds. His examination was otherwise unremarkable.

Investigators obtained preaccident personal medical records from the engineer’s primary care physician. The engineer had begun to visit this physician on December 2, 2010, after his previous physician closed his office. The engineer visited his physician about every 6 months for routine followup of his Type II diabetes. His blood pressure was normal throughout his outpatient care, but his heart rate (pulse) was generally measured above 100 beats per minute (bpm), ranging from 90 bpm to 120 bpm on routine visits. Over the period that he saw the physician, the engineer’s weight increased from 275 pounds at his initial visit to 291 pounds in January 2013. Just after the accident, on May 28, 2013, the engineer’s weight was noted to be 287 pounds.

The engineer initially was treated for his Type II diabetes with a NovoLog FlexPen using 70/30 insulin.[6] He continued to use the FlexPen as a delivery device, but his daily dosing increased over the years from 46 units twice a day to 60 units twice a day. He did not routinely perform blood glucose monitoring tests at home. Over the 2 1/2 years that the engineer saw his primary physician before the accident, the engineer’s Hemoglobin A1C test result varied from a high of 9.1 percent in July 2011 to a low of 7.2 percent in December 2012. The engineer underwent postaccident Hemoglobin A1C testing the last week of August 2013, and at that time his level was 7.6 percent.

Postaccident Medical Information. After the collision, the UP engineer was transported to the hospital by ambulance. The ambulance run sheet noted Insulin under “Medications” and

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[4] *Hertz* is a unit of frequency equal to 1 cycle per second.

[5] The Hemoglobin A1C test indicates average blood sugar level for the past 2–3 months. The higher the blood sugar level, the more hemoglobin with sugar attached. For someone diagnosed with diabetes, a level of 7 percent or less is a common treatment target, but higher targets may be chosen in some people.

[6] *NovoLog* (brand name of insulin) *FlexPen* is a prefilled insulin syringe.

Diabetes under "Past Medical History." The ambulance assessment identified a laceration of the left arm, pain with some swelling on the left chest. His Glasgow Coma score was 15/15 points. His blood pressure was measured twice, at 162/104 and 174/107, and his pulse was 113 bpm and 114 bpm. The ambulance personnel noted that "he was the conductor (*sic*) of the train … and was pulled out of the train when the fire broke out by his partner." He was ambulatory at the scene by the time the ambulance arrived. As noted previously, a Highway Patrol sergeant told investigators the UP engineer showed no symptoms of impairment and appeared alert when he saw him at the hospital.

The record from the receiving emergency department includes information from the triage nurse that states, "[Passenger], train accident – [patient] does not remember events prior to conductor rousing him – pain left ribs/upper left [abdomen], pain [right] leg below knee with movement." The triage note recorded the engineer's weight as 287.9 pounds and his height at 6 feet 4 inches, with a BMI of 35.06. NovoLog FlexPen was recorded as the engineer's only medication, and the medical history section noted, "History of diabetes, that is currently treated with insulin." In the physician's notes on the chief complaint is the following: "Uncertain as to whether or not loss of consciousness occurred." In the notes from the physician's initial physical exam, the engineer was noted to be tachycardic and to have pain in the left chest and left upper abdomen.[7] As discussed later in this report, all of the evidence suggests his blood sugar had been in good control for years and was normal at the time of the accident. This should not have degraded his performance.

The engineer underwent CT scans of his head, spine, chest, abdomen, and pelvis. No acute traumatic injuries were identified. Laboratory tests including a complete blood count, electrolytes, and kidney and liver function tests were performed and were generally normal or negative. His glucose was 90 mg/dL. Throughout the engineer's emergency department stay, the Glasgow Coma score remained 15/15; his systolic blood pressure ranged from 164 to 189 and his diastolic from 80 to 150. He remained tachycardic with a heart rate between 109 bpm and 112 bpm. The final diagnoses were multiple contusions and multiple abrasions, and the engineer was discharged to his home.

About 2 months after the accident, on July 18 and 29, 2013, the engineer visited a neurologist for further evaluation. The note from the first visit includes the following as part of the history of the present illness:

> The last thing he remembers was talking to the conductor. After that, he remembers waking up with glass at his side and [having] the conductor over him calling his name. He states that he felt disoriented. He remembers [Emergency Medical Services] coming and putting his neck in a brace. He denies any headaches, vision changes, or nausea at that time. He feels that he did black out. He has not talked to the conductor, who was the only witness, due to investigational purposes. He states that after the accident he had bruises in the back of his head on the right side behind his ear and on the shoulder and lower back … he states that the total time of his memory lapse was less than 2 hours.

[7] *Tachycardic* means affected with a faster-than-normal heart rate.

> Prior to this incident, he states that he was having trouble with names and word finding and would lose track of what he [was] saying during sentences ….

The neurologist recorded that the past medical history was significant for "arthritis, back problems, diabetes, head injury, and neuropathy." The engineer's medications were listed as NovoLog, tapentadol, and baby aspirin. The tapentadol had been prescribed for his postaccident pain and is a Schedule II controlled substance that is an opioid analgesic (narcotic pain medicine) (Drugs.com 2014).

At this exam, the engineer was noted to be 6 feet 3 inches tall and weigh 280 pounds (BMI=35).

On the mental status exam, the engineer was oriented to person, place, and time. His speech was described as "fluent, clear, and coherent." To the neurologist, "the memory, judgment, and insight seem[ed] intact." The remainder of the physical exam was unremarkable.

Following the initial evaluation, the engineer underwent MRI (magnetic resonance imaging) of the brain with and without contrast, which was interpreted as demonstrating "no acute intracranial process."[8] Under findings, the MRI report states the following:

> There is no restricted diffusion to suggestion hyperacute/acute ischemia or cytotoxic edema. There was no evidence of mass, mass effect, midline shift, hemorrhage or acute/subacute focal infarct. The ventricles and cisterns are normal in size and configuration. There is no epidural or subdural hematoma. Significant white matter signal abnormalities are not identified. The sella turcica and pituitary are unremarkable. Postcontrast imaging demonstrates no abnormal enhancement."
> In addition, an EEG (electroencephalogram) performed in both awake and drowsy states was interpreted as normal.

The engineer followed up with the neurologist after this testing was performed. The neurologist's notes from the second visit include the engineer's reporting being "amnestic to the event and 30 to 40 minutes prior to the event."[9] The final diagnosis was "Neurogenic Spell—questionable syncope; transient global amnesia."[10]

Requested Sleep Evaluation. The engineer in this accident was obese, had diabetes, and was unable to recall events or his behavior before the accident. Other information suggested the engineer was not operating the train as required for several minutes prior to the collision, including failing to obey wayside signals, failing to activate the horn when required, and activating the horn when not required. As a result, the NTSB requested that the engineer voluntarily undergo a diagnostic evaluation by a sleep specialist including a polysomnogram (a sleep study) for the NTSB's investigative review in assessing the possibility that the engineer had obstructive sleep apnea (OSA). Although the engineer initially agreed to undergo this

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[8] An MRI *with contrast*—an intravenous dye—enables certain areas to be seen more clearly.

[9] *Amnestic* means affected with amnesia.

[10] *Syncope* means fainting. *Transient global amnesia* is "a sudden, temporary episode of memory loss that cannot be attributed to a more common neurological condition, such as epilepsy or stroke" (Mayo Clinic 2014).

evaluation, he did not comply with repeated requests or sign the required paperwork. No sleep study was performed.

1.8 Toxicological Information

After the accident, toxicological specimens were obtained from the engineers and the conductors of the BNSF and UP trains in accordance with 49 CFR Section 219, Subpart C, "Post-Accident Toxicological Testing." These tests screened for cannabinoids, cocaine, opiates, amphetamines, methamphetamines, phencyclidine, barbiturates, benzodiazepines, and ethyl alcohol. The results were negative for these drugs. Also, the four crewmembers were administered breath analyzer tests to determine the presence or absence of alcohol. No alcohol was detected.

1.9 Highway Bridge Information

1.9.1 Construction

Missouri State Route M travels through western Scott County, Missouri, from Interstate Highway 55 west to the western county line near the communities of Rockview and Chaffee. The Route M highway bridge, designed and constructed in 1988, spans the at-grade crossing of the BNSF and UP tracks where the accident occurred. It had five spans supported by two abutments and four intermediate column bent assemblies.[11] The approach spans were prestressed concrete, precast four-beam girders, each of which was 62 feet long on the west side of the bridge and 58 feet long on the east side of the bridge. The main bridge span had 66-inch-deep rolled steel four-beam girders that were 125 feet long. The bent caps had concrete diaphragms the girders were connected to. Both bents next to each abutment were steel pipes filled with concrete. These bents were 60 feet long and embedded to a depth of 30 feet. Both were composed of six steel columns: three concrete columns were at bents 3 and 4. Each column was 36 inches in diameter and embedded to a depth of 41 feet below the footings.

1.9.2 Damage

As a result of the train impact after the derailment, bent 3 was sheared off at the base of the footing. This loss of structure allowed spans 2 and 3 to collapse. (See figures 3 and 4.) The downward vertical movement of these spans was stopped by the wreckage of the derailed train cars underneath the structure. Several UP auto-rack cars came to rest against the fractured columns of bent 3. Also, oval-shaped impact damage 42 inches wide and 39 inches deep, consistent with an impact with one of the bent columns, was found on one BNSF car. This car was the 22nd car in the BNSF train, 10 cars behind the point where the UP train struck the BNSF train. The vertical clearance between the track elevation and the bottom of the girders was about 24.5 feet. The horizontal clearance from the center of the rails to bent 3 was 21 feet 9.75 inches. There was no crash-protection wall shielding the bents from impact with railroad equipment.

[11] A *bent*, part of a bridge substructure, is a rigid frame that supports a vertical load and is placed transverse to the length of a structure. Bents support beams and girders; an *end bent* is a supporting part of an abutment. A *column* is a vertical member of a bent; the horizontal member resting on top of the columns is a *bent cap*.

Figure 3. Derailed train cars and damaged bridge supports.

Figure 4. Collapsed bridge deck.

1.9.3 Design and Construction Regulations

Federal. The Federal Highway Administration (FHWA) has no pier protection requirements for highway bridges over railroads. Because these public structures are constructed on private railroad property under the authority of easements granted by a railroad, the governing documents for design and construction are those of the railroad or the American Railway Engineering and Maintenance-of-Way Association (AREMA).

State. Investigators reviewed Missouri Department of Transportation (MODOT) documents related to pier protection. MODOT materials contain specifications for the design and construction of bridges that addressed pier protection walls but no warrants on when the specifications were to be used. The American Association of State Highway and Transportation Officials (AASHTO) 2012 *Load Resistance Factor Design Manual* (LRFD Manual) (AASHTO 2012) advises engineers to contact AREMA for specifications and warrants for pier crash protection near railroads.

Industry. When the Route M highway bridge was built in 1988, the 1986 edition of the design guidelines of the American Railway Engineering Association (AREA)[12] applied to its

[12] AREA merged with other industry groups to form AREMA in 1997.

construction. This guidance recommended “heavy construction” for concrete piers if the horizontal clearance from the centerline of the rails to the piers was less than 25 feet, but it did not define “heavy construction.” (As noted previously, the horizontal clearance from the center of the rails to bent 3 was 21 feet 9.75 inches.) Thus the Route M highway bridge was built to the guidelines in effect at the time of its construction.

1.9.4 Inspection

The Route M highway bridge was subject to the bridge inspection standards required by FHWA. The bridge was last inspected on February 25, 2013, and the deck and substructure were rated as satisfactory and the superstructure as good. A special inspection was performed on January 30, 2013, after a BNSF derailment that occurred on the evening of January 29, 2013. The inspector noted that bent No. 3 had been struck in that derailment and that the impact caused only light scraping and paint marks on the concrete bent with no structural damage.

1.10 Tests and Research

1.10.1 Mechanical Condition of Trains

Postaccident mechanical inspections were performed on both trains, and their brake test records were reviewed. The investigation determined that the mechanical condition of both trains was in compliance with FRA regulations. The crashworthiness inspection of the UP train determined the interior of the lead locomotive cab was intact and no occupant space was lost.

1.10.2 Portable Electronic Devices

NTSB investigators obtained usage records for the cell phone numbers of the four crewmembers of the two trains involved in the accident. The records revealed no portable electronic device activity for any of the crewmembers just before or at the time of the collision.

1.10.3 Sight-Distance Observations

On the night of May 28, 2013, investigators conducted sight-distance observations to determine the distances from the UP train at which an operating crewmember on the train could first see and visually identify the aspects of the four signals that the train passed as it approached the accident site. Weather and lighting conditions during the sight-distance observations were similar to those at the time of the accident.

At the UP Illmo Yard in Scott City, Missouri, investigators boarded a locomotive that was similar to the lead locomotive on the striking train. The locomotive was operated by an engineer and a conductor who were qualified on and familiar with the territory. The signals were set to display the same aspects as on the morning of the accident. The operating crew was instructed to note when they could first determine the aspect displayed on each of the four signals leading up to the accident location. The locomotive distance counter was used to measure the sight distance to the four signals. Observation results are summarized in table 6.

Table 6. Sight-distance measurements for both UP crewmembers.

Observable Aspect	Engineer [a]	Conductor
Advance Approach signal - MP 127.7	3,749 feet	3,749 feet
Approach signal - MP 129.1	3,690 feet	3,690 feet
Restricting signal - MP 131.2	4,403 feet	4,315 feet
Rockview Interlocking Stop signal	4,702 feet	4,702 feet
[a] Because of track curvature, signals may become visible from one side of the cab before they are visible from the other side.		

1.11 Postaccident Actions

1.11.1 Union Pacific Railroad

The UP issued an Incident Alert to all train and engine service employees on the UP system after the accident that referenced operating rules on which crews should focus and provided a general description of the accident so that crews and managers would be aware of what happened. The rules referenced were: Rules 1.1.2 (Alert and Attentive), 1.47 (Duties of Crew Members), 1.47.1 (Cab Red Zone), 6.27 (Movement at Restricted Speed), 9.12.2 (Manual Interlockings), 70.3 (Job Briefing). The Incident Alert was also posted on the Operating Practices Incident Alert page of the UP employee website.

1.11.2 BNSF Railway

The BNSF included discussion of the accident in safety briefings with all crews on the Springfield Division.

1.11.3 Missouri Department of Transportation

As a result of this accident and the January 29, 2013, BNSF derailment, MODOT incorporated crash walls in the design for the rebuilt Highway M bridge that provided about 600 kips[13] of resistance to impact forces. The equivalent 600-kip static load is based on information obtained from crash testing an 80,000-pound truck into a concrete structure at 50 mph. The redesigned and reconstructed bridge is shown in figure 5.

[13] One *kip* (kilo-pound) equals 1,000 pounds of force.

Figure 5. New Highway M bridge.

2 Safety Issues Analysis

This issues analysis begins with a summary of the accident sequence and includes discussion of the following safety issues identified in this report:

- Fatigue awareness
- The need to implement crew resource management
- The need for inward- and outward-facing audio and video recorders in locomotive cabs
- Positive train control

The remainder of this introductory section discusses those elements of the investigation that the NTSB determined were not factors in the accident. The balance of the safety issues analysis addresses the factors that were found to have caused or contributed to the accident, or to have contributed to its severity.

Both trains' crewmembers were qualified and trained to perform their duties, and they had consistently passed applicable skills and knowledge tests. Both trains were inspected before the trips began on May 24, and no exceptions were taken to their mechanical condition. Postaccident inspection of the trains also revealed no significant mechanical defects. The investigation revealed that the routes and the signals had been set correctly for both trains, and postaccident tests demonstrated that the signal systems functioned as intended. Based on the negative results of the toxicology testing performed after the accident, alcohol and drug use were not factors in the accident. Also, the use of personal electronic devices just before or at the time of the accident was not a factor in the accident, because the investigation found that the cell phones of the crewmembers on both trains had not been used while the trains were operating. The NTSB therefore concludes that the following were not factors in the accident: the qualification of the crewmembers on both trains; the mechanical condition of the trains; the dispatching activities; the signal systems; and alcohol use, drug use, and the use of portable electronic devices by the crewmembers on both trains.

2.1 Performance of UP Train Crew

The investigation examined the handling of the UP train by its crew. In particular, investigators focused on event recorder data, wayside signal logs, and on-scene tests to understand the crew's performance once they encountered and passed four signals as the train neared the Rockview Interlocking, over a distance of about 3.7 miles. The lead UP locomotive was equipped with an alerter, although alerter acknowledgement was not a parameter that was recorded. The locomotive was built in 2004 and had not been rebuilt. Locomotives built before 2009 are not required to have event recorders that capture alerter acknowledgement activity.

The UP crew first encountered an Advance Approach (flashing yellow aspect), which authorized the crew to proceed at not more than 40 mph once they arrived at the signal.

Sight-distance tests indicate that the signal was observable at a distance of 3,749 feet (0.71 mile). The train was operated at about 52 mph (76.4 feet per second) throughout its approach to and upon its arrival at the Advance Approach signal. At that speed, the crew had about 49 seconds to detect and react to the Advance Approach signal, but they did not slow the train.

The second signal was an Approach signal (solid yellow over red aspect), which authorized the UP crew to proceed at not more than 30 mph once they arrived at and passed the signal. Sight-distance tests indicate that the signal was observable at a distance of 3,690 feet (0.70 mile). Data from the train's event recorder indicate that the train was traveling 53.5 mph (78.5 feet per second) when it passed the Approach signal. At that speed, the crew had about 86.5 seconds to detect and react to the signal, but again they did not reduce train speed.

The track was tangent (straight), the terrain was level and without obstructions, and sight distance tests show that the next two signals could be seen from the location of the second (Approach) signal stand.

The third signal displayed a flashing red aspect, which required the crew to reduce train speed in preparation to stop at the next signal. Sight-distance tests indicate that the signal was observable from the engineer's seat at a distance of 4,403 feet (0.83 mile) and from the conductor's seat at 4,315 feet (0.82 mile). Locomotive event recorder data indicate the train passed the flashing red signal aspect at 50 mph.

The fourth signal was a solid red aspect, which required the train to stop. The signal was observable at a distance of 4,702 feet (0.89 mile). Although the UP crew was expected to gradually slow and stop the train at the absolute signal, they operated past the signal at 48 mph and collided with the BNSF train at about 43 mph.

Based on the UP crew's actions from the Advance Approach signal location to the Stop signal at Rockview Interlocking, the NTSB concludes that the UP crew failed to comply with four wayside signals immediately preceding the collision.

2.2 Fatigue of UP Crew

The NTSB investigation examined the possibility of fatigue as a factor in the performance of the UP engineer and the conductor, which involved a review of their work records for the 96 hours preceding the accident, as well as a consideration of the time at which the accident occurred.

For the UP engineer, work records indicated that he had worked two day shifts, which began in the early morning and lasted until the early afternoon. The day before the accident, he worked an afternoon shift, which began in the early afternoon and ended on the evening of May 23. On the day of the accident, he worked a night shift, reporting for duty at 9:45 p.m.

For the UP conductor, work records indicated that he had worked both very early and mid-morning hours 2 days before the accident. Then, on the day before the accident (May 23), he was called and worked twice in the same day.

During the 4 days leading up to the accident, both UP crewmembers had been called to work at different times of the day and night. These variable work schedules meant the pattern of awake and asleep time for both UP crewmembers was unpredictable, inconsistent, and disruptive to normal circadian rhythms. In a normal circadian rhythm, the human body naturally sleeps to refresh its capabilities for normal physical and cognitive performance during the time between about midnight and 6:00 a.m.; the window of circadian low generally occurs between 3:00 a.m. and 5:00 a.m. People who are awake during the window of circadian low are less alert, have degraded performance, and are susceptible to the effects of fatigue. Further, fatigue is known to be triggered by circadian disruption, and it can be exacerbated by ongoing circadian disruptions, which the UP crewmembers were experiencing before the accident. Fatigue can degrade task performance, leading to longer reaction times, memory problems, poor decision-making, workload shedding, and inefficient information processing. (Brown 1994) The Chaffee accident occurred at 2:30 a.m., during the window of circadian low. Therefore, the NTSB concludes that as a result of their variable work schedules, both UP crewmembers experienced disruptions to their normal circadian rhythms for several days before the accident, and at the time of the accident both were experiencing fatigue caused by circadian disruption and the requirement to operate the train during the window of circadian low.

The UP crew's failure to take action to slow and stop their train is consistent with fatigue-induced performance degradation. The conductor's log shows he noted the wayside signals, but he did not take action to respond to the signals when the engineer did not respond to them. Additionally, the sounding of the horn multiple times before the accident suggests that the engineer was awake, although perhaps not entirely aware of his surroundings. Fatigued operators can become disengaged from their tasks, make mistakes in judgment and action, and lose awareness of work contexts and demands; broadly, fatigued operators can fail to perform their jobs. Both UP crewmembers experienced similar fatigue-inducing conditions for several days before the accident, and then both became disengaged from safely operating the train in the time period leading up to the accident. Therefore, the NTSB further concludes that neither of the UP crewmembers controlled the train as they encountered and proceeded beyond the Advance Approach signal, likely because of fatigue-induced performance degradation.

2.3 UP Train Crew Medical Fitness for Work

In this accident, the UP train failed to slow and stop appropriately as the wayside signals indicated. The medical fitness of the BNSF train crew was not in question, and further analysis of the BNSF crew was not performed. Title 49 CFR 240.121(c) requires railroad engineers to meet the following vision criteria, and 49 CFR 240.201 requires railroad engineers to meet these criteria every 3 years:

(1) For distant viewing either:

(i) Distant visual acuity of at least 20/40 (Snellen)[14] in each eye without corrective lenses or

(ii) Distant visual acuity separately corrected to at least 20/40 (Snellen) with corrective lenses and distant binocular acuity of at least 20/40 (Snellen) in both eyes with or without corrective lenses;

(2) A field of vision of at least 70 degrees in the horizontal meridian in each eye; and

(3) The ability to recognize and distinguish between the colors of railroad signals as demonstrated by successfully completing one of the tests in appendix F to this part.

The FRA does not require a complete medical history, list of medications, or physical examination for railroad employees in safety-sensitive jobs. The UP performs a complete medical history and physical examination only as part of preemployment or return-to-work examinations, and limits the triennial medical evaluation to the minimum required by the FRA: vision testing and hearing screening. A review of medical records during the investigation revealed that both UP crewmembers had current physical examinations and, according to UP standards, were medically fit to perform their work duties.

2.3.1 UP Conductor

The conductor on the UP train was a 33-year-old man who had last undergone a railroad physical evaluation on May 14, 2010. This evaluation included an interval medical history only because he was returning to work after a furlough; he answered "no" to questions about events during the furlough interval directed at issues that might have affected his ability to work safely rather than more standard questions about his current state of health, for example, "Do you currently take any medications? Do you have any health conditions?" At this exam, he was 5 feet 10 inches tall and weighed 202 pounds (BMI 28.7). The conductor passed his hearing and vision testing.

Evaluation of the UP conductor in the hospital after the accident did not identify any chronic medical problems, and the conductor denied taking any medications. Postaccident toxicology testing required by the US Department of Transportation showed only medications administered as part of the conductor's postaccident medical care. In postaccident interviews conducted by the NTSB, the conductor stated he was in good health and he was able to describe the events that occurred in the minutes before and after the crash. The NTSB therefore concludes that the UP conductor had no known medical problems that would have interfered with the safe operation of the train.

[14] The *Snellen* chart measures visual acuity by comparing a person's ability to see relative to a person with normal vision. A person with 20/40 vision can accurately read information at a distance of 20 feet that a person with normal vision can accurately read at a distance of 40 feet.

2.3.2 UP Engineer

The UP engineer was 58 years old at the time of the accident. His last routine triennial medical certification exam occurred on July 20, 2012. At that visit only vision and hearing were tested; no questions were asked regarding medical problems or medications, and no other physical examination was performed. The medical record from the routine triennial physical examination contained no height or weight measurements nor any mention of medication use or chronic medical problems. In fact, the only time the engineer's UP medical record reflects the taking of a complete medical history and physical examination was in 1974, when the engineer was 19 years old.

Among the engineer's medical information in the UP files were records that demonstrate that the UP had access to evidence that the engineer had been diagnosed as diabetic and treated with insulin beginning in 1997. No further inquiry or ongoing evaluation of the engineer's health was required by the FRA or performed by the UP.

Review of personal medical records for the 2 1/2 years preceding the crash demonstrated that the engineer had good to fair control of his diabetes and did not identify any other medical concerns. The engineer's BMI during this period fluctuated between 34.4 and 36.4. However, there is no evidence from these records that a health care provider ever asked the engineer any questions about sleep disorders, fatigue, daytime sleepiness, or snoring. His neck circumference was not measured, although a neck circumference greater than 17 inches in a man correlates with an increased risk for the obstructive sleep apnea (Davies and Stradling 1990). He was notably tachycardic during all but one of these visits; it is unclear from the records if the tachycardia was noted by the physician. The source of the tachycardia was not investigated.

After the accident, the engineer stated he recalled "waking up" when the conductor shook him to get him out of the locomotive after the collision and complained that he could not recall events in the minutes to hours immediately before the accident. On evaluation in the ambulance and the emergency department, the engineer's blood sugar was normal without treatment or intervention, and he remained awake and neurologically normal. His extensive radiology evaluation was essentially normal. However, the engineer was persistently tachycardic in the hospital. Postaccident toxicology testing revealed only medications provided to the engineer during his medical care.

Postaccident evaluation by a neurologist for persistent amnesia surrounding the accident included MRI imaging of the brain and an EEG. Both of these were normal. Of note, the engineer discussed neurological symptoms preceding the accident including "having trouble with names and word finding and [that he] would lose track of what he is saying during sentences." The neurologist did not discuss issues related to daytime sleepiness, fatigue, snoring, or sleep disorders with the engineer, and no etiology for the amnesia was identified.

At the time of the accident, the engineer was obese with a BMI in the middle 30s. The engineer told investigators that his ex-wife had told him that he snored, although he was not aware of his snoring. Based on recent research on a cohort of middle-aged, mostly white, Midwestern men with similar levels of obesity, the likelihood that the engineer had at least mild

OSA (AHI $\geq$5)[15] at the time of the accident is about 61 percent, and the likelihood that he had untreated moderate to severe OSA (AHI$\geq$15) is about 30 percent (Peppard et al. 2013). Although sleep apnea has been associated with impaired glucose tolerance, the exact relationship between OSA and diabetes remains unclear (Reutrakul and Van Cauter 2014).

People with OSA have a significantly increased risk of motor vehicle crashes and other occupational injuries (Mulgrew et al. 2008, Lindberg et al. 2001, Basoglu and Tasbakan 2014). According to guidelines, shown in figure 6, for evaluating sleep apnea in commercial drivers developed by a joint task force of the American College of Occupational and Environmental Medicine, the National Sleep Foundation, and the American College of Chest Physicians, having an at-fault accident that may have been related to fatigue is sufficient to recommend an immediate out-of-service evaluation by a sleep physician (Hartenbaum et al. 2006).

Screening Recommendation for Commercial Drivers With Possible or Probable Sleep Apnea

Medically Qualified to Drive Commercial Vehicles If Driver Meets Either of the Following	In-Service Evaluation (ISE) Recommended If Driver Falls Into Any One of the Following Five Major Categories (3 mo maximum certification)	Out-of-Service Immediate Evaluation Recommended If Driver Meets Any One of the Following Factors
1. No positive findings or any of the numbered in-service evaluation factors	1. Sleep history suggestive of OSA (snoring, excessive daytime sleepiness, witnessed apneas)	1. Observed unexplained excessive daytime sleepiness (sleeping in examination or waiting room) or confessed excessive sleepiness
2. Diagnosis of OSA with CPAP compliance documented	2. Two or more of the following: a) BMI $\geq$35 kg/m^2; b) Neck circumference greater than 17 inches in men, 16 inches in women; c) Hypertension (new, uncontrolled, or unable to control with less than 2 medications).	2. Motor vehicle accident (run off road, at-fault, rear-end collision) likely related to sleep disturbance, unless evaluated for sleep disorder in the interim
	3. ESS $>$10	3. ESS $\geq$16 *or* FOSQ $<$18
	4. Previously diagnosed sleep disorder; compliance claimed, but no recent medical visits/compliance data available for immediate review (must be reviewed within 3-mo period); if found not to be compliant, should be removed from service (includes surgical treatment)	4. Previously diagnosed sleep disorder: d) Noncompliant (CPAP treatment not tolerated); e) No recent follow up (within recommended time frame); f) Any surgical approach with no objective follow up.
	5. AHI $>$5 but $<$30 in a prior sleep study or polysomnogram and no excessive daytime somnolence (ESS $<$11), no motor vehicle accidents, no hypertension requiring 2 or more agents to control	5. AHI $>$30

AHI indicates apnea–hypopnea index; BMI, body mass index; CPAP, continuous positive airway pressure; ESS, Epworth Sleepiness Scale; FOSQ, Functional Outcomes of Sleep Questionnaire; OSA, obstructive sleep apnea.

Figure 6. Recommendations for screening commercial drivers for obstructive sleep apnea.

As a result of determining that the engineer had several risk factors for OSA, the NTSB asked the engineer to voluntarily undergo a polysomnogram for the NTSB's investigative review following the accident. Although he initially agreed to undergo this testing, the engineer did not return the required paperwork, and the test plan proposed by the NTSB did not proceed. Based

[15] The apnea-hypopnea index (AHI) sums the frequency of episodes of apnea and hypopnea. Apnea is the complete absence of airflow though the mouth and nose for at least 10 seconds. Hypopnea 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. An AHI of less than 5 per hour is considered normal. An AHI of 5–15 is mild; 15–30 is moderate, and more than 30 events per hour is considered severe sleep apnea.

on the analysis above, however, and the engineer's presentation of risk factors for OSA, the NTSB concludes that the engineer on the UP train likely had undiagnosed OSA at the time of the accident, and this likely resulted in fatigue that contributed to this accident. The NTSB further concludes that there were at least a dozen opportunities for the UP engineer to have been screened for OSA during routine occupational health evaluations, but no such screening was performed.

2.3.3 Previous Rail and Transit Accidents Involving Obstructive Sleep Apnea

A number of previous railroad accidents investigated by the NTSB involving sleep apnea and fatigue have led to a series of safety recommendations to the FRA and a variety of railroads and rail transit agencies regarding the need to screen and adequately treat rail operators for the condition. These include a head-on rail collision 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) After the Clarkston accident, 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 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. (The current status of this safety recommendation is discussed below.)

Although the FRA created a medical working group as part of the Railroad Safety Advisory Committee (RSAC), there has never been any public output from that working group, and no action has been taken to further develop guidelines or require screening for or diagnosis of sleep disorders among railroaders. The NTSB therefore concludes that had the FRA developed and used a standard medical examination form that includes questions regarding sleep problems to determine the medical fitness of locomotive engineers, as was called for in Safety Recommendation R-02-24, the UP engineer likely would have been appropriately screened and evaluated for sleep apnea before this accident.

In April 2011, a rear-end collision occurred between a BNSF Railway freight train and a maintenance-of-way train near Red Oak, Iowa (NTSB 2012). The NTSB determined the probable cause of the accident was

> the failure of the crew of the striking train to comply with the signal indication requiring them to operate in accordance with restricted speed requirements and stop short of the standing train because they had fallen asleep due to fatigue resulting from their irregular work schedules and their medical conditions.

The medical conditions included probable sleep apnea, restless leg syndrome, and chronic insomnia, among others. The NTSB made two main medical safety recommendations as a result of that investigation. One safety recommendation was issued to the BNSF:

R-12-26

> Medically screen employees in safety-sensitive positions for sleep apnea and other sleep disorders. (Classified “Open—Acceptable Response” on December 18, 2012)

The second safety recommendation was issued to the FRA:

R-12-16

> Require railroads to medically screen employees in safety-sensitive positions for sleep apnea and other sleep disorders. (Classified “Open—Acceptable Response” on October 16, 2012)

An August 23, 2012, letter to the NTSB from the BNSF Vice President for Training and Operations Support included the following paragraph in response to Safety Recommendation R-12-26:

> Previous attempts by BNSF to require additional medical information about certain safety related medical conditions, specifically including attempts to obtain medical information on sleep apnea, met with stiff resistance from our labor organizations who alleged that these attempts to obtain medical information were in violation of various federal and state laws. Indeed, 10 unions filed charges with the Equal Employment Opportunity Commission alleging that the BNSF requirement violated the federal Americans with Disabilities Act. Those charges remain pending. Simply stated, until there are some federal standards on medical qualification for such conditions as sleep apnea, other sleep disorders or, medical conditions that affect an employee's ability to work safely, it will be difficult to obtain and use such information without facing a variety of legal challenges. BNSF believes such information may be lawfully used to improve safety without violating employee rights and is an active participant in FRA's Medical Standards Railroad Safety Advisory Council where this issue has been discussed.

Thus, at least one Class I railroad has been unable to accomplish appropriate evaluation for sleep disorders in the absence of regulation.

In October 2008 Congress enacted the Rail Safety Improvement Act of 2008 (RSIA) (Pub. L. No. 110-432, div. A) following a head-on collision between a passenger train and a freight train in Chatsworth, California (NTSB 2010). Section 103(a) of the RSIA directed the Secretary of Transportation to require that most passenger and freight railroads develop fatigue management plans and to adopt regulations requiring creation of these plans no later than 4 years after enactment of the Act. These fatigue management plans were to include methods to manage and reduce fatigue experienced by railroad employees in safety-related positions and to reduce the likelihood of accidents, incidents, injuries, and fatalities caused by fatigue. In addition, fatigue management plan requirements specified in the RSIA include “opportunities for identification, diagnosis, and treatment of any medical condition that may affect alertness or fatigue, including sleep disorders” (49 United States Code § 20156(f)(3)).

In the FRA's July 31, 2012, response to Safety Recommendation R-12-16, the FRA administrator wrote, "Currently, FRA, in conjunction with a working group of members from the Railroad Safety Advisory Committee, is developing a fatigue management regulation that will be responsive to the requirements set forth in the RSIA." However, the time limit set by Congress for the Department of Transportation to create and issue this regulation passed on October 16, 2012. As noted previously, the Railroad Safety Advisory Committee medical working group continues to meet, but there has been no public output regarding fatigue management and no proposed changes to existing regulations since it was created. The NTSB concludes that had the medical screening described in Safety Recommendation R-12-16 been in place, or had the fatigue management components required by the RSIA of 2008 been in place, the UP engineer likely would have been identified as at high risk for sleep disorders, which may have led to appropriate medical intervention. Therefore, the NTSB reiterates Safety Recommendation R-12-16 and reclassifies it as "Open—Unacceptable Response."

Most recently, the NTSB investigated a head-on collision between two freight trains in Goodwell, Oklahoma, in 2012, which occurred as a result of the engineer's inability to see and interpret wayside signals due to a chronic illness and deteriorating eyesight (NTSB 2013c). After that investigation, the NTSB classified the safety recommendation to the FRA from Clarkston (Safety Recommendation R-02-24, noted above), previously classified "Open—Acceptable Response," as "Closed—Unacceptable Action/Superseded" by Safety Recommendation R-13-21 to the FRA on June 18, 2013. Safety Recommendation R-13-21 reads as follows:

<u>R-13-21</u>

> 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.

On February 24, 2014, the NTSB classified Safety Recommendation R-13-21 "Open—Unacceptable Response." The NTSB therefore reiterates Safety Recommendation R-13-21.

2.4 Crew Resource Management

The circumstances of this accident raise concerns about train crew communication, coordination, and discipline on the UP railroad. The engineer and conductor failed to comply with four wayside signals in 3.7 miles that instructed them to slow and stop the train, yet the train passed all of those signals traveling about 50 mph. The UP conductor claimed that they were calling signals, and his logbook contains the relevant entries, but neither the conductor nor the engineer noticed or discussed the excessive speed of the train, the lack of throttle or braking control movements, or preparations to bring the train to a stop.

Both crewmembers are responsible for the overall safe and efficient movement of the train. While the engineer operates the train, the conductor ensures the train operates safely. Conscientious, alert, and attentive conductors not only call all signals with the engineer acknowledging, as the train proceeds, or vice versa, but they also discuss problems and anomalies encountered along the route.

Although the UP engineer was unable to account for his actions leading up to the accident, the UP conductor discussed his recollections of the accident trip in his interviews with NTSB investigators. The UP conductor said that before the accident he and the engineer called the signals, and he spent time entering signal information in his logbook, looking into the logbook with his head down. The conductor's logbook at appendix B indicates he noted the required information, up to and including the red or restricted signal ("R"). The UP conductors' log has just four columns: Location, Signal Name or Train Defect Detector announcement, Time, and Comment & Other Delays.[16] Making entries once a signal is observed and deciphered is a relatively quick task as are hearing and noting a Train Defect Detector announcement. Thus there does not appear to be any reason for the conductor to maintain a prolonged head-down posture once he had completed a logbook entry, especially given his responsibility to ensure safe train operations, which includes looking out for signals.

The conductor told investigators that he did not know the speed of the train, because the speedometer on his side of the cab was not working. Furthermore, the speedometer on the engineer's side of the cab—which he could have seen with minimal effort—was working. The NTSB is concerned that the conductor, an experienced trainman, claimed not to perceive train speed or lack of deceleration through nonvisual sensations, including vestibular, auditory, and proprioceptive. Further, although the conductor stated that he and the engineer called the signals during the trip, and his log shows he had entered the signals encountered as the train approached the Rockview Interlocking, it is unclear why the conductor did not take action sooner to slow and stop the train.

A critical shortcoming in the safety of US freight railroads is illustrated by this accident: crewmembers, individually or collectively, can be a single point of failure in situations requiring strict compliance with wayside signals for safe train movements. One approach to overcoming this safety hazard is improving crew coordination, communication, and discipline through crew resource management (CRM). CRM promotes safe operations by emphasizing the efficient use of all resources to achieve and maintain better coordination of activities, including crewmember proficiency, situation awareness, effective communication and teamwork, and strategies for appropriately challenging and questioning authority.

The NTSB has investigated railroad, marine, and aviation transportation accidents with inadequate CRM as a causal factor. After investigating a Norfolk Southern Corporation railroad accident in Butler, Indiana, the NTSB issued safety recommendations to the FRA, Class 1 railroads, the American Short Line and Regional Railroad Association, the Brotherhood of Locomotive Engineers, and United Transportation Union to work together to develop and implement CRM training for train crewmembers (NTSB 1999). More recently, the NTSB

[16] Trackside train defect detectors produce audible reports by radio of hot bearings, hot wheels, dragging equipment, or no defects.

concluded that the Canadian National Railway accident in Two Harbors, Michigan, and the UP accident in Goodwell, Oklahoma, might have been avoided if crewmembers had received CRM training (NTSB 2013b and 2013c). In these accidents, the crews had not received CRM training, and the crews failed to demonstrate effective coordination, communication, and discipline during critical work activities leading up to the accidents. These same characteristics were present with the UP crew in the accident in Chaffee. Therefore, the NTSB concludes that had crewmembers of the UP train received training in and practiced the principles of CRM, they may have demonstrated enhanced coordination, communication, and discipline during train operations, and the accident may have been avoided.

During the NTSB investigation of the UP accident in Goodwell, Oklahoma (NTSB 2013c), the UP Vice President of Safety, Security and Environment/Chief Safety Officer told the NTSB during an investigative hearing on February 26, 2013, that the company had many programs designed to enhance safety, including CRM training. However, at the time of the Goodwell accident, the UP had not implemented CRM for the employees who work on the subdivision where the accident occurred. The NTSB's investigation of the Chaffee accident has determined that again the UP has not implemented CRM for the employees who work on the subdivision where the accident occurred. Therefore, the NTSB concludes that the delay in implementing CRM throughout the UP has been and is likely to continue to be a contributing factor in accidents. The NTSB recommends that the UP develop and implement an accelerated schedule for delivering CRM training to all employees in safety-sensitive positions. In addition, the NTSB reiterates the following safety recommendation to the FRA:

R-13-7

> Require railroads to implement initial and recurrent crew resource management training for train crews. (Classified "Open—Acceptable Response," June 13, 2013.)

2.5 Locomotive Cab Audio and Video Recorders

Since the 1990s, the NTSB has recommended that the FRA require audio recorders inside locomotive cabs so that accident investigators can better understand the actions of crewmembers during the time period before an accident. In its investigation of the February 16, 1996, collision between a Maryland Rail Commuter train and an Amtrak train near Silver Spring, Maryland (NTSB 1997), in which no operating crewmembers survived, the NTSB was unable to determine whether crewmember activities leading up to the accident contributed to the accident. Consequently, the NTSB made the following safety recommendation to the FRA:

R-97-9

> Amend 49 *Code of Federal Regulations* Part 229 to require the recording of train crewmembers' voice communications for exclusive use in accident investigations and with appropriate limitations on the public release of such recordings. (The current status of this safety recommendation is discussed below.)

In the NTSB investigation of the Bryan, Ohio, railroad accident in 1999, with no surviving crewmembers (NTSB 2001), the NTSB reiterated this safety recommendation. In its response to the reiteration, the FRA stated that it

> has reluctantly come to the conclusion that this recommendation should not be implemented at the present time. … [The] FRA appreciates that, as time passes and other uses are found for recording media that may create synergies with other public and private purposes, the [NTSB's] recommendation may warrant reexamination.

Based on this response and further meetings, the NTSB classified Safety Recommendation R-97-9 "Closed—Unacceptable Action" on August 6, 2004.

Since the FRA's refusal to act on the recommendation of in-cab recorders, the NTSB has investigated additional accidents in which audio recorders, along with inward-facing video recorders, would have provided information to help determine probable cause and develop safety recommendations. For example, the NTSB investigated the July 10, 2005, collision of two Canadian National Railroad freight trains in Anding, Mississippi (NTSB 2007), which led to the following NTSB safety recommendation to the FRA:

<u>R-07-3</u>

> Require the installation of a crash and fire protected locomotive cab voice recorder, or a combined voice and video recorder, (for the exclusive use in accident investigations and with appropriate limitations on the public release of such recordings) in all controlling locomotive cabs and cab car operating compartments. The recorder should have a minimum 2-hour continuous recording capability, microphones capable of capturing crewmembers' voices and sounds generated within the cab, and a channel to record all radio conversations to and from crewmembers. (The current status of this safety recommendation is discussed below.)

Also, in the September 12, 2008, railroad accident in Chatsworth, California, a Southern California Regional Rail Authority (Metrolink) train collided head-on with a UP freight train, resulting in 25 fatalities (including the Metrolink engineer) and 102 injuries (NTSB 2010). From its investigation, the NTSB made two safety recommendations to the FRA:

<u>R-10-1</u>

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

> systemwide performance monitoring programs. (The current status of this safety recommendation is discussed below.)

When the NTSB issued Safety Recommendation R-10-1 to the FRA, it reclassified Safety Recommendation R-07-3 “Closed—Unacceptable Action/Superseded.” Safety Recommendation R-10-2 is the second issued to the FRA after the Chatsworth accident:

<u>R-10-2</u>

> Require that railroads regularly review and use in-cab audio and image recordings (with appropriate limitations on public release), in conjunction with other performance data, to verify that train crew actions are in accordance with rules and procedures that are essential to safety. (The current status of this safety recommendation is discussed below.)

The FRA has acknowledged the value of using audio- and image-recording technology in locomotives and cab cars; however, it has not taken action to implement the NTSB safety recommendations. On March 6, 2014, the RSAC undertook Task No. 14-01, to develop regulatory recommendations that address the installation and the use of recording devices in controlling locomotive cabs. The target completion date for this task is April 1, 2015. Safety Recommendations R-10-1 and -2 were classified “Open—Unacceptable Response” on August 14, 2013, because the FRA has not required locomotives and cab cars operated under 49 CFR Part 229 to be equipped with crash- and fire-protected inward- and outward-facing audio and image recorders in accordance with the NTSB’s recommendations.

The NTSB also investigated the September 30, 2010, collision of two CN trains in Two Harbors, Minnesota (NTSB 2013b). The NTSB noted that appropriate action had not been taken in response to Safety Recommendations R-10-1 and -2. In the investigation, the NTSB found that crewmembers of both trains had used cell phones in moving locomotives—a violation of railroad rules and FRA regulations. Moreover, the NTSB urged the FRA to “promptly initiate rulemaking activity for the audio and imaging requirements outlined in Safety Recommendations R-10-1 and -2” and reiterated these two safety recommendations, noting that FRA action on the recommendations would require locomotive manufacturers to implement important safety improvements. In the Two Harbors, Minnesota, accident report the NTSB reiterated Safety Recommendations R-10-1 and -2, stating the following:

> The NTSB is disappointed that more than four years after the deadliest passenger train accident in decades, the FRA has not acted on two recommendations that would protect railroad employees, as well as the public.

On April 17, 2011, the rear-end collision of two BNSF trains near Red Oak, Iowa (NTSB 2012), again demonstrated the need for in-cab recording devices to better understand railroad accidents that claim the lives of crewmembers and threaten public safety. During the Red Oak accident investigation, the NTSB determined that the crewmembers of the striking train had fallen asleep just before the collision. The NTSB concluded that “had an inward facing video and audio recorder been installed in the cab of the locomotive of the striking train, additional valuable information about the train crew’s actions before the collision would have been available." Moreover, the NTSB stated that "while video recorders will assist in the investigation of accidents, their value in preventing accidents cannot be overstated," and added that the installation of inward facing cameras could assist railroads in monitoring rules compliance and identifying fatigued engineers, which could prevent accidents.

In its report on the May 24, 2011, collision of two CSX trains in Mineral Springs, North Carolina (NTSB 2013a), the NTSB stated it was unable to determine why striking train crew failed to comply with a wayside signal since the crewmembers were killed and the cab was not equipped with either an inward-facing camera or an audio recorder. The NTSB is inhibited in its development of effective recommendations to improve safety when important information is unavailable to the investigation.

Many NTSB investigations since the issuance of Safety Recommendations R-10-1 and -2 have indicated that in-cab audio and video recorders could provide critical information about crew performance and the locomotive cab environment for accident investigations. Despite FRA's failure to act on these recommendations, the railroad industry has recognized the value of inward-facing cameras, and several companies have begun to implement them. After the Chatsworth accident (NTSB 2010), Metrolink was the first railroad to install inward-facing cameras. And in April 2013, the Kansas City Southern Railway Company announced plans to implement inward-facing cameras in locomotives operating on its properties in Mexico and, eventually, in the United States. In August 2013, as a result of the head-on collision at Goodwell, Oklahoma (NTSB 2013c), which occurred as a result of the engineer's inability to see and interpret wayside signals due to a chronic illness and deteriorating eyesight, the UP stated it would install inward-facing cameras in more than 5,000 locomotives, following an implementation plan for installing cameras in 2 locomotives in 2013, about 4,300 locomotives in 2014 and 2015, and 600 locomotives in 2016.

The NTSB is encouraged by railroad company actions to implement inward-facing cameras. However, the NTSB believes that more railroads need to install inward- and outward-facing audio and image recorders to provide reasonable and reliable means to capture valuable information about crewmember activities in locomotive operating compartments during the time before an accident. In the Chaffee accident, audio recorders in the locomotive cab could have recorded the crew calling the signals, and inward-facing cameras could have shown what the crewmembers were doing, or at least where they were and their positions, giving investigators insight into the cab environment and activity. The NTSB therefore reiterates Safety Recommendation R-13-26, issued in response to the Goodwell accident, to all Class 1 railroads:

R-13-26

> Install in all controlling locomotive cabs and cab car operating compartments crash- and fire-protected inward- and outward-facing audio and image recorders. The devices should have a minimum 12-hour continuous recording capability.

Additionally, although the RSAC recently undertook Task No. 14-01, the NTSB remains concerned that FRA's delayed action on Safety Recommendations R-10-1 and -2 leaves many safety lessons unlearned and further delays improvements for the safety of railroad operations.

The NTSB recognizes that opportunities to understand and improve railroad safety have been missed because vital information on crew activities is not yet available, and the missed opportunities are not infrequent. Therefore, the NTSB reiterates Safety Recommendations R-10-1 and -2 to the FRA.

2.6 Positive Train Control

In the NTSB's nearly 50 years of investigating railroad accidents, including hundreds of train collisions and overspeed derailments, accidents have been caused by mechanical defects, maintenance issues, and track failures. However, the biggest safety challenge is human error, which is an area where technology can be very helpful. Since 2005, the NTSB has completed 17 investigations of railroad accidents that could have been prevented or mitigated with positive train control (PTC). These 17 accidents claimed 55 lives and injured 943 more; the damages totaled hundreds of millions of dollars. In each of these accidents, the NTSB concluded that PTC would have provided critical redundancy that would have prevented the accident. Had such a system been in place where the Chaffee accident occurred, it would have intervened when the crew of the UP train failed to slow and ultimately stop the train before the Rockview Interlocking.

Although human error cannot be completely eradicated, PTC technology is capable of supplementing the human operation of trains. A PTC system provides safety redundancy by slowing or stopping a train that is not being operated in accordance with signal systems and operating rules, as was the case in each of the 17 accidents referenced above. For years, PTC has been in place on Amtrak trains in the Northeast and Michigan, but for PTC to reach its greatest safety potential, it must be widely implemented across the United States.

Because of the NTSB's repeated findings that technology-based collision avoidance systems could provide the needed safety redundancy to prevent rail accidents, PTC was placed on the NTSB's Most Wanted List at the inception of that list in 1990. Following the tragic head-on collision between a passenger train and a freight train in Chatsworth, California, on September 12, 2008, which resulted in 25 fatalities and more than 100 injuries, Congress enacted the RSIA. Section 104 of the Act requires each Class I railroad and each operator of regularly scheduled intercity or commuter rail passenger transportation to implement a PTC system on each main line over which intercity or commuter rail passenger transportation is operated, or over which poisonous-by-inhalation or toxic-by-inhalation hazardous materials are transported. The Act requires implementation by December 31, 2015. Encouraged by this legislative action, in October 2008 the NTSB's safety recommendation calling for PTC installation was classified as closed and was removed from the Most Wanted List. However, as a result of the May 2011 rear-end collision between two CSX freight trains in Mineral Springs, North Carolina (NTSB 2013a), and the collision of the two UP trains in Goodwell, Oklahoma (NTSB 2013c), the NTSB added PTC to the 2013 Most Wanted List.

The NTSB has long advocated the implementation of PTC systems to prevent train-to-train collisions. NTSB railroad accident investigations over the past 40 years have shown conclusively that the most effective way to avoid train-to-train collisions is through the use of

PTC systems that will automatically assume some control of a train when the train crew does not comply with the requirements of a signal indication.

No PTC speed enforcement or Stop-signal enforcement is installed in the area where this accident occurred. The UP is in the process of developing a PTC system, which would have prevented this accident had it been in operation. The NTSB concludes that had a PTC system been installed and used on the UP's Chester subdivision, this accident would have been prevented.

2.7 Highway Bridge Protection

The NTSB has investigated several accidents involving large trucks striking highway bridge piers that resulted in bridge collapses. Safety recommendations were subsequently issued to AASHTO and the Federal Highway Administration (FHWA) to develop pier protection guidance for bridge designers. These recommendations led to increasing the static impact point loading requirement for bridge piers; AASHTO published this requirement and a risk-based collision investigation procedure in the 2012 LRFD Manual.

However, the 2012 LRFD Manual requirements and guidelines apply only to bridges over highways that may be at risk for truck collisions, and similar requirements for bridges at risk of train collisions found in previous editions were removed from recent versions of the LRFD Manual. Older versions required bridge piers located within 30 feet of a highway or railway to have structural capacity to resist a 400 kip static load.

The 2012 LRFD Manual states in section 3.6.5.1 that unless the owner determines that site conditions indicate otherwise, abutments and piers located within a distance of 30 feet to the edge of a roadway shall be investigated for collision. Collision shall be addressed either by providing structural resistance or by redirection or by absorbing the collision load. Where the design choice is to provide structural resistance, the pier or abutment shall be designed for an equivalent static force of 600 kips. Where the design choice is to redirect or absorb the collision load, protection shall consist of an embankment; a structurally independent, crashworthy ground-mounted 54-inch-high barrier, located within 10 feet from the component being protected; or a 42-inch-high barrier located more than 10 feet from the component being protected.

The LRFD Manual states that one way to determine whether site conditions qualify for exemption from protection is to evaluate the annual frequency of impact from heavy vehicles. The LRFD Manual notes that design for vehicular collision force is not required if the annual frequency for a bridge to be hit by a heavy vehicle is less than 0.0001 for critical or essential bridges or 0.001 for typical bridges.[17]

About 4 percent of US highway bridges—24,103 bridges—span railroad tracks. The BNSF had seven other at-grade intersections—similar to the ones at Rockview and Chaffee—that are underneath or in proximity to highway bridges. The UP had 27 at-grade crossings within .125 miles of a highway bridge. FRA data indicate that from February through

[17] The determination of the annual frequency for a bridge pier to be hit by a heavy vehicle is derived from limited statistical studies performed by the Texas Transportation Institute.

May 2013 there was only one other collision of a train with a highway bridge, and it resulted in only minor damage.

Section 2.1.5 of the 1986 *AREA Manual for Railway Engineering* provided guidelines for pier protection: "Piers supporting bridges over railways located within 25 feet of the centerline of the railroad track shall be of heavy construction or shall be protected by a reinforced concrete crash wall ...." The manual did not define or describe "heavy construction." Thus the Highway M bridge piers were designed and constructed when the AREA manual did not specify the requirements of heavy construction. The NTSB therefore concludes that the Highway M bridge piers met the design standards in place in 1986–1988 when the bridge was designed and constructed.

In 2005, the AREMA manual's section on pier protection added the definition of "heavy construction," added an additional requirement for a 12-foot-high crash wall if the pier was less than 12 feet from the railroad track, and provided for pier protection when the horizontal clearance was more than 25 feet. The replacement Highway M bridge, built with a heavily constructed wall pier, met these new AREMA design requirements.

The new pier protection loading standard, described in the 2012 edition of the LRFD Manual, requires bridge piers to resist an equivalent static force of 600 kips. This force is based on information from crash tests of rigid columns by 80-kip tractor trailers at 50 mph. This is equivalent to 6.6 million foot-pounds of kinetic energy. By comparison, the 160,000-pound UP rail cars at 43 mph had about 9.86 million foot-pounds of kinetic energy, an increase in kinetic energy of about 48 percent. This figure represents the equivalent of only one rail car. In this accident, several UP cars struck the three-column bent assembly, fracturing all of the columns. It is unlikely that even the new design could withstand multiple impacts of this magnitude. Additionally, exemptions for collision load are not permitted in the rail environment as they are on highways based on lower levels of heavy truck traffic.

The FRA railroad accident database indicated that on a 10-year average from 2004–2013, about 1,319 derailments occur nationwide on all railroads. A review of the accident records indicated only four accidents occurred in which rail equipment damaged a highway bridge spanning railroad tracks between January and October 2013, and this was the only such accident in which the bridge collapsed. Therefore, the NTSB concludes that current pier protection standards adequately mitigate the risk of catastrophic bridge pier failures spanning railroad tracks.

3 Conclusions

3.1 Findings

1. The following were not factors in the accident: the qualification of the crewmembers on both trains; the mechanical condition of the trains; the dispatching activities; the signal systems; and alcohol use, drug use, and the use of portable electronic devices by the crewmembers on both trains.

2. The Union Pacific Railroad crew failed to comply with four wayside signals immediately preceding the collision.

3. As a result of their variable work schedules, both Union Pacific Railroad crewmembers experienced disruptions to their normal circadian rhythms for several days before the accident, and at the time of the accident both were experiencing fatigue caused by circadian disruption and the requirement to operate the train during the window of circadian low.

4. Neither of the Union Pacific Railroad crewmembers controlled the train as they encountered and proceeded beyond the Advance Approach signal, likely because of fatigue-induced performance degradation.

5. The Union Pacific Railroad conductor had no known medical problems that would have interfered with the safe operation of the train.

6. The engineer on the Union Pacific Railroad train likely had undiagnosed obstructive sleep apnea at the time of the accident, and this likely resulted in fatigue that contributed to this accident.

7. There were at least a dozen opportunities for the Union Pacific Railroad engineer to have been screened for obstructive sleep apnea during routine occupational health evaluations, but no such screening was performed.

8. Had the Federal Railroad Administration developed and used a standard medical examination form that includes questions regarding sleep problems to determine the medical fitness of locomotive engineers, as was called for in Safety Recommendation R-02-24, the Union Pacific Railroad engineer likely would have been appropriately screened and evaluated for sleep apnea before this accident.

9. Had the medical screening described in Safety Recommendation R-12-16 been in place, or had the fatigue management components required by the Rail Safety Improvement Act of 2008 been in place, the Union Pacific Railroad engineer likely would have been identified as at high risk for sleep disorders, which may have led to appropriate medical intervention.

10. Had crewmembers of the Union Pacific Railroad train received training in and practiced the principles of crew resource management, they may have demonstrated enhanced

coordination, communication, and discipline during train operations, and the accident may have been avoided.

11. The delay in implementing crew resource management throughout the Union Pacific Railroad has been and is likely to continue to be a contributing factor in accidents.

12. Had a positive train control system been installed and used on the Union Pacific Railroad's Chester subdivision, this accident would have been prevented.

13. The Highway M bridge piers met the design standards in place in 1986–1988 when the bridge was designed and constructed.

14. Current pier protection standards adequately mitigate the risk of catastrophic bridge pier failures spanning railroad tracks.

3.2 Probable Cause

The National Transportation Safety Board determines that the probable cause of the accident was the failure of the Union Pacific Railroad 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 Federal Railroad Administration to fully implement the fatigue management components required by the Rail Safety Improvement Act of 2008. Likely contributing to the engineer's fatigue was undiagnosed obstructive sleep apnea. Also contributing to the accident was inadequate crew resource management.

4 Recommendations

4.1 New Recommendation

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

To the Union Pacific Railroad:

> Develop and implement an accelerated schedule for delivering crew resource management training to all employees in safety-sensitive positions. (R-14-56)

4.2 Previously Issued Recommendations Reiterated in This Report

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

To the Federal Railroad Administration:

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

Safety Recommendation R-10-1 is classified "Open—Unacceptable Response."

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

Safety Recommendation R-10-2 is classified "Open—Unacceptable Response."

> Require railroads to implement initial and recurrent crew resource management training for train crews. (R-13-7)

Safety Recommendation R-13-7 is classified "Open—Acceptable Response."

> 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)

Safety Recommendation R-13-21 is classified "Open—Unacceptable Response."

To All Class 1 Railroads:

> Install in all controlling locomotive cabs and cab car operating compartments crash- and fire-protected inward- and outward-facing audio and image recorders. The devices should have a minimum 12-hour continuous recording capability. (R-13-26)

Safety Recommendation R-13-26 is classified as follows:

Recipient	Classification	Date
BNSF Railway Company	Open—Acceptable Response	December 24, 2013
Canadian National Railway	Open—Acceptable Response	March 20, 2014
Canadian Pacific Railway	Open—Await Response	--
CSX Transportation	Open—Acceptable Response	December 27, 2013
Kansas City Southern Railway Company	Open—Unacceptable Response	May 13, 2014
Norfolk Southern Corporation	Open—Acceptable Response	December 27, 2013
Union Pacific Railroad	Open—Await Response	--

4.3 Previously Issued Recommendation Reiterated and Reclassified in this Report

As a result of this accident investigation, the National Transportation Safety Board reiterates and reclassifies from "Open—Acceptable Response" to "Open—Unacceptable Response" the following safety recommendation:

To the Federal Railroad Administration:

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

BY THE NATIONAL TRANSPORTATION SAFETY BOARD

CHRISTOPHER A. HART
Acting Chairman

ROBERT L. SUMWALT
Member

MARK R. ROSEKIND
Member

EARL F. WEENER
Member

Adopted: November 17, 2014

Appendix A Investigation

The NTSB was notified on May 25, 2013, of the collision of a UP train and a BNSF train in Chaffee, Missouri. The NTSB launched an investigator-in-charge and two other rail investigative team members from its headquarters and one highway investigator from its Texas regional office. Robert L. Sumwalt accompanied the team and was the NTSB Board Member on scene.

The FRA, the UP, the BNSF, the Brotherhood of Railroad Signalmen, the Brotherhood of Locomotive Engineers and Trainmen, United Transportation Union, Missouri Department of Transportation, and Scott County, Missouri, were parties to the investigation.

Appendix B UP Conductor's Log

MAY-28-2013 18:19 DRURY LODGE

UNION PACIFIC RAILROAD
CONDUCTOR REPORT

This report must be completed by the Conductor of road freight trains on each trip or tour of duty. Conductors must keep reports in their possession of the last 5 round trips, which must be presented to managers upon request. Report all signals more restrictive than Clear (abbreviations may be used). Report all Train Defect Detector (TDD) announcements. Report other train delays.

Subdivision: 46, 47, 60 Train/Job ID: 2ASMAR 25

Conductor: [redacted] Engineer: [redacted]

Departure Date/Time: 05/24/13 22:10 Arrival Date/Time:

60 L [illegible] 0 Mty 60-cars 4782-T 5490-FT

Location	Signal Name or TDD Announcement	Time	Comments & Other Delays 252-A
267.1	TDD	2238	X NO 252
268.7	AA	2240	X 38 MPH
272.1	AD	2247	X 24 MPH
CPI274	DA	2250	Z 25 MPH
CPZ275	S/C	[illegible]	[illegible] good 35"
280.8	TDD	[illegible]	X NO 252
297.6	TDD	0001	X NO 252
295.5	AA	0003	X 35 MPH
307.4	TDD	0026	X NO 252
321.1	TDD	0046	X NO 252
329.9	TDD	0101	X [illegible] 252
CP0337	AA	0117	X 27 MPH
CP0338	AP	0120	X 10 MPH
92.7	TDD	0135	X NO 252
104.7	TDD	0156	X NO 252
117.0	TDD	0208	X NO 252
119.6	TDD	0213	X NO
CP0122	AA	0220	X 30 MPH
123.7	TDD	0221	X NO
127.7	AA	0225	X 40 MPH
128.0	TDD	0225	X NO 252
CP0129	A	0227	Z 70 MPH
CP0131	R		

Conductor Signature: ______________________

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