Collision of Union Pacific Railroad Train MGRCY04 with a Stationary Train
Granite Canyon, Wyoming
October 4, 2018

Accident Report

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PB2020-101016

National Transportation Safety Board

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Railroad Accident Report

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Abstract: On October 4, 2018, at 7:40 p.m. local time, eastbound Union Pacific Railroad freight train MGRCY04 (striking train) collided with the rear of stationary Union Pacific Railroad freight train MPCNP03 (stationary train) after cresting a hill and descending a grade for about 13 miles. The striking train consisted of 3 leading locomotives and 105 railcars. The locomotive engineer and conductor of the striking train were killed, and 3 locomotives and railcars 1 through 57 of the striking train derailed while the rear 5 railcars and the railcars positioned 8, 9, and 10 from the rear of the stationary train derailed. Damage was estimated by Union Pacific Railroad to be $3.2 million. As a result of this investigation, the National Transportation Safety Board makes new safety recommendations to the Federal Railroad Administration, the Association of American Railroads and the American Short Line and Regional Railroad Association, and the Association of American Railroads. The National Transportation Safety Board previously made safety recommendations to the Class I Railroads and the American Short Line and Regional Railroad Association in relation to this accident investigation.

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Abbreviations and Acronyms

AAR	Association of American Railroads
ASLRRA	American Short Line and Regional Railroad Association
BNSF	BNSF Railway
CAD	computer-aided dispatch
CFM	cubic feet per minute
CFR	*Code of Federal Regulations*
CN	Canadian National Railway
CSX	CSX Transportation
DP	distributed power
ECP	electronically controlled pneumatic
EOT	end-of-train
ETD	end-of-train device
FAA	Federal Aviation Administration
FRA	Federal Railroad Administration
GPS	global positioning system
HOT	head-of-train
HTD	head-of-train device
I-ETMS	Interoperable Electronic Train Management System
KCS	Kansas City Southern Railway
MHz	megahertz
MP	milepost
MP&E	Motive Power & Equipment
MTD	midtrain devices

NPRM	notice of proposed rulemaking
NTSB	National Transportation Safety Board
PSI	pounds per square inch
POC	point of collision
PTC	positive train control
RF	radio frequency
SCABT	single car air brake test
UHF	ultrahigh frequencies
UP	Union Pacific Railroad
µg/ml	micrograms per milliliter

Executive Summary

On October 4, 2018, at 7:40 p.m. local time, eastbound Union Pacific Railroad freight train MGRCY04 (striking train) collided with the rear of stationary Union Pacific Railroad freight train MPCNP03 (stationary train) after cresting a hill and descending a grade for about 13 miles. The striking train consisted of 3 leading locomotives and 105 railcars. The locomotive engineer and conductor of the striking train were killed, and 3 locomotives and railcars 1 through 57 of the striking train derailed while the rear 5 railcars and the railcars positioned 8, 9, and 10 from the rear of the stationary train derailed. Damage was estimated by Union Pacific Railroad to be \$3.2 million.[1]

As the train descended the grade, the locomotive engineer initiated a full-service brake application, however, the train's speed continued to increase. At milepost 529.95 the train was still accelerating, reaching 28 mph when the locomotive engineer initiated an emergency brake application. The event recorder indicated that information was being transmitted between the controlling locomotive and the rear railcar via a telemetry link for the previous 45 minutes. After the emergency brake application, the status of the communications system changed to "FR NC," which means front-to-rear no communication. The emergency brake request was not received at the end-of-train device, which would have initiated an emergency brake application at the rear of the train. Five minutes after the locomotive engineer initiated the emergency brake application, the end-of-train device still had not received the emergency brake request, and the train collided with the standing train at about 55 mph at milepost 527.1. Prior to the collision, the crew of the striking Union Pacific Railroad freight train reported problems with the train's air brake system and radioed the Union Pacific Railroad Harriman Dispatch Center to advise that they had accelerated to 51 mph and were unable to stop. The Union Pacific Railroad Harriman Dispatch Center notified the crew of Union Pacific freight train MPCNP03 and advised them to evacuate the train to avoid possible injury from the runaway train.

Probable Cause

The National Transportation Safety Board determines that the probable cause of the collision was the failure of the Union Pacific train MGRCY04 air brake system due to an air flow restriction in the brake pipe and the failure of the end-of-train device to respond to an emergency brake command. Contributing to the accident was the failure of Union Pacific Railroad to maintain the railcars in accordance with federal regulations, including regularly performing single railcar air brake tests. Further contributing to the accident were communication protocols, set by Federal Railroad Administration regulations and industry standards, that allowed extended time intervals for loss of communication notification between the head-of-train device and the end-of-train device without warning the train crew of the loss of communication.

[1] For more information, see the factual information and analysis sections of this report. Additional information about the accident investigation can be found in the public docket for this accident (NTSB case number RRD19FR001) by accessing the Accident Dockets link for the Docket Management System at https://data.ntsb.gov/Docket/Forms/searchdocket. For more information on our safety recommendations, see the Safety Recommendation Database at https://data.ntsb.gov/carol-main-public/basic-search.

Safety Issues

The safety issues identified in this accident include the following:

- **Railcar maintenance, inspection, and testing.** This investigation determined that Union Pacific Railroad end-of-railcar air hose assembly inspections did not identify issues that could cause fouling or air flow restrictions. Furthermore, single railcar air brake testing was not performed on six railcars, despite a requirement for this testing to be conducted at intervals of no more than 5 years. This testing could have identified defects likely to cause brake pipe air flow restrictions.

- **Limitations of emergency brake command to end-of-train device.** Investigators learned over the course of this investigation that after a train emergency brake application is initiated, a train's head-of-train device is designed to transmit an emergency brake application signal to the train's end-of-train device for 2 minutes. If a confirmation message is not received from the end-of-train device within that 2-minute time frame, the transmission of the emergency brake command stops. The 2-minute window when the signal is transmitted from the head-of-train device to the end-of-train device would not be extended if the locomotive engineer initiated another brake application during the initial 2-minute time frame.

- **Head-of-train and end-of-train communication loss duration.** Both Association of American Railroads standards and Federal Railroad Administration regulations specify that a communication failure message be displayed to a locomotive engineer after train telemetry communication has been lost for 16 minutes and 30 seconds or more. For this amount of time, train crews are without knowledge of the loss of the critical safety function associated with emergency braking provided by the end-of-train device.

- **Grade locations on railroad lines with communication loss.** Radio frequency limitations are common in the railroad environment. Factors such as train length, track curvature, and physical terrain obstructions can lead to loss of communication between the head-of-train and end-of-train devices. Railroads need to assess the grade territories over which they operate for continuous communication between these devices. When areas that are prone to communication loss are identified, railroads should take remedial action.

Findings

- None of the following contributed to this accident: the performance or fitness for duty of the train crew, the actions of the train dispatcher, the signal or positive train control system, or the track structure.

- The air flow from the brake pipe was restricted between the 9th and 10th railcars in the consist, which prevented the air brake signal propagation through the entire train.

- Had Union Pacific Railroad complied with the federal regulations outlined in Title 49 *Code of Federal Regulations* 232.305 and conducted single railcar air brake tests on the six railcars picked up in Laramie that were overdue for testing, any defective conditions—including those which may have led to a restriction of brake pipe air flow—would likely have been identified and repaired prior to the railcars being put into service.

- The communication protocol allowing 16 minutes and 30 seconds of time to elapse without alerting the crew of the inability to initiate emergency braking from the end-of-train device is excessive.

- The length of the train, curvature of the track, and obstructions due to physical terrain contributed to the loss of communication between the head-of-train device and the end-of-train device.

- The emergency brake command needs to be transmitted until received by the end-of-train device, rather than being terminated after 2 minutes.

- Had the striking train been equipped with electronically controlled pneumatic brake system technology, the emergency brake commands would have been received through the entire train, thereby applying the brakes on each railcar of the train, likely preventing the accident.

Recommendations

New Recommendations

To the Federal Railroad Administration:

- Revise Title 49 *Code of Federal Regulations* Part 232 to require more frequent communication checks between a head-of-train device and an end-of-train device. (R-20-28)

- Require that the emergency brake signal transmission is repeated until received by the end-of-train device. (R-20-29)

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

- Alert your member carriers to (1) conduct analysis of radio frequency propagation in grade territories over which they operate to identify areas where head-of-train device and end-of-train device communication may be lost and (2) make remediations to provide continuous head-of-train device and end-of-train device communication. (R-20-30)

To the Association of American Railroads:

- Revise your *Manual of Standards and Recommended Practices, Locomotive Electronics and Train Consist System Architecture*, Standard S-9152.v2.2, Paragraph 3.8.8 to develop a communication protocol that will continue to transmit an emergency air brake command to the end-of-train device until a confirmation message or a decrease in brake pipe pressure message is received by the head-of-train device. (R-20-31)

Previously Issued Recommendations

- Review and issue guidance as necessary for the inspection of end-of-railcar air hose configurations to ensure the air hose configuration matches the intended design. (R-19-41)

- Review and revise your air brake and train handling instructions for grade operations and two-way end-of-train device instructions to include: monitoring locomotive air flow meters, checking the status of communication between the head-of-train and end-of-train devices before cresting a grade, and the actions to take if the air pressure at the rear of the train does not respond to an air brake application. (R-19-42)

- Alert your member carriers to (1) inspect the end-of-railcar air hose configurations to ensure the hose configurations match the intended design and (2) review and revise their air brake and train handling instructions for grade operations and two-way end-of-train device instructions to include: monitoring locomotive air flow meters, checking the status of communication between the head-of-train and end-of-train devices before cresting a grade, and the actions to take if the air pressure from the rear of the train does not respond to an air brake application. (R-19-43)

1 Factual Information

1.1 Accident Synopsis

On October 4, 2018, at 7:40 p.m. local time, eastbound Union Pacific Railroad (UP) freight train MGRCY04 (striking train) collided with the rear of stationary UP freight train MPCNP03 (stationary train) after cresting a hill and descending a grade for about 13 miles.[1] The striking train consisted of 3 leading locomotives and 105 railcars. The locomotive engineer and conductor of the striking train were killed, and 3 locomotives and railcars 1 through 57 of the striking train derailed while the rear 5 railcars and the railcars positioned 8, 9, and 10 from the rear of the stationary train derailed. Figure 1 is an aerial view of the accident scene. Prior to the collision, the crew of the striking UP freight train reported problems with the train's air brake system and radioed the UP Harriman Dispatch Center to advise them they had accelerated to 51 mph and were unable to stop.[2] The UP Harriman Dispatch Center notified the crew of UP freight train MPCNP03 and advised them to evacuate the train to avoid possible injury from the runaway train. Damage was estimated by UP to be $3.2 million.[3]

[1] In this accident, both trains were traveling east; therefore, the designations "striking train" and "struck train" are used.

[2] Train air brakes are controlled by a brake pipe that spans the length of the train. Brakes are applied by reducing the air pressure in the brake pipe. Emergency brakes are applied by rapid venting of the brake pipe to atmosphere.

[3] For more information, see the factual information and analysis sections of this report. Additional information about the accident investigation can be found in the public docket for this accident (NTSB case number RRD19FR001) by accessing the Accident Dockets link for the Docket Management System at https://data.ntsb.gov/Docket/Forms/searchdocket. For more information on our safety recommendations, see the Safety Recommendation Database at https://data.ntsb.gov/carol-main-public/basic-search.

Figure 1. Aerial photograph of the collision at milepost 527.1. (Photo courtesy of UP.)

As the train descended the grade, the locomotive engineer initiated a full-service brake application; however, the train's speed continued to increase. At milepost (MP) 529.95 the train was still accelerating, reaching 28 mph when the locomotive engineer initiated an emergency brake application. This was the first time the train crew received a "Front-to-Rear, No Comm" message, indicating that they were no longer in communication with their end-of-train device (ETD). Although a signal was sent to the ETD, it was never executed. ETDs are discussed further in section 1.6.1. The train continued to accelerate. According to the radio recordings, about 2 minutes before the accident, the train dispatcher asked the crew of the striking train for a status report. The train crew responded that the train was still picking up speed, had reached 51 mph, and had no brakes. The train crew asked the train dispatcher to clear a path in front of them. Event recorder data indicates that about 2 minutes later, the train collided with the standing train at about 55 mph at MP 527.1.

The striking train originated in Green River, Wyoming, and was destined for Cheyenne, Wyoming. Granite Canyon, the point of collision (POC), was about 25 miles from Cheyenne. There was a crew change at Rawlins, Wyoming, the origin location of the Laramie Subdivision. At Laramie, the crew added 19 railcars to the head end of the train. The operating plan was to descend the grade and continue to operate under signal indications. Figure 2 shows the route of the striking train.

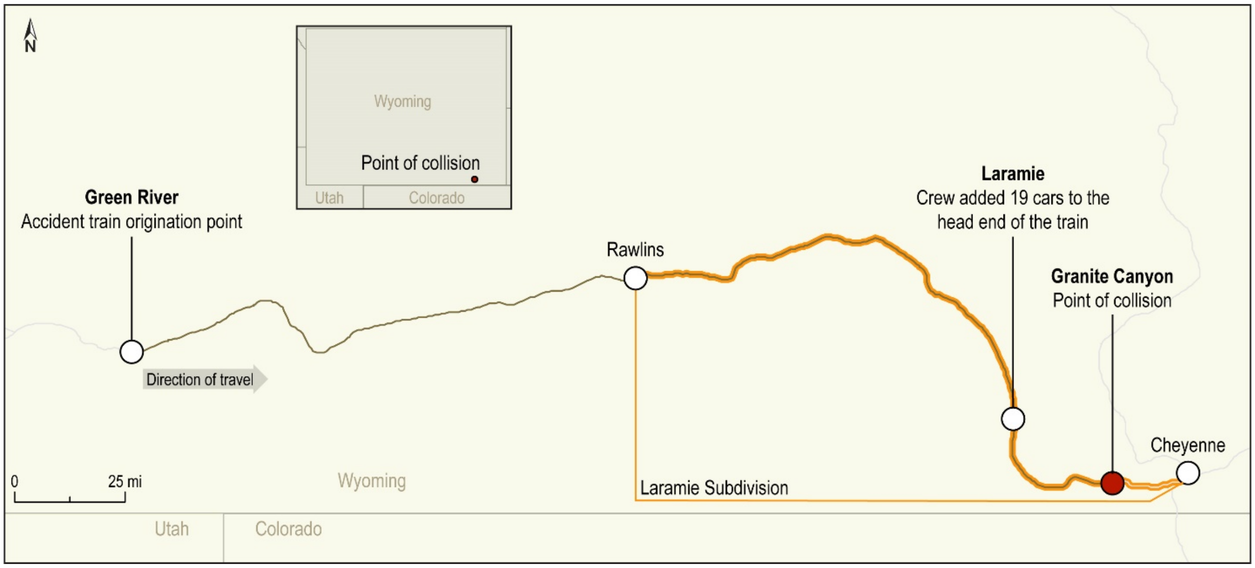

Figure 2. Graphic showing the striking train's route from Green River to Granite Canyon, Wyoming.

1.2 Site Description

The Laramie Subdivision extends from MP 682.8 in Rawlins, Wyoming, to MP 509.5 in Cheyenne, Wyoming, in a timetable east-west direction.[4] The maximum authorized timetable speed on the subdivision is 70 mph for freight trains and 79 mph for passenger trains with permanent speed restrictions between posted timetable mileposts.

The Laramie Subdivision consists of multiple main tracks with two main tracks between MP 513 and MP 544 and three main tracks between MP 544 and MP 550 with passing sidings.[5] In the accident area, the two main tracks are spaced with 13-feet 8-inch track centers. Leading up to the accident location, the striking train descended a grade ranging from 0 to 1.58 percent beginning at MP 540.49 to MP 510. From MP 530 to the POC at MP 527.1, trains are on a descending grade of 1.55 percent.

1.3 Operations

1.3.1 Applicable Operating Rules

Trains on the UP Laramie Subdivision were authorized and governed by signal indication. The territory was under centralized traffic control with the train dispatcher controlling the signals from Omaha, Nebraska, at the Harriman Dispatch Center. The employees were governed by the

[4] (a) Railroads divide their systems into divisions and subdivisions to manage the large network. (b) North Platte Area Timetable No. 5, effective December 11, 2017.

[5] *Passing sidings* are sections of track that are used for one train to pass another. One train exits the main track and enters the siding while the other train travels on the main track through the location.

General Code of Operating Rules and modifications provided by UP's special instructions, general orders, and track bulletins specific to the territory and the train.[6]

The two main tracks at the accident location ran geographically east and west. Both tracks had wayside signals to enable trains to operate in both directions on each track. The north track was main track 1 and the south track was main track 2. Positive train control (PTC) was active at the time of the accident.[7] The striking train was eastbound on main track 1 at the time of the accident.

The track around the POC met the definition of a "heavy grade," which the UP *Air Brake and Train Handling Rules* defines as track having at least a 1.0 percent grade for a distance of 3 miles or more (UP 2018).[8]

Although the maximum speed on the UP subdivision is 70 mph, UP heavy grade instructions required this train to operate at a maximum speed of 25 mph on the grade based on the assumed available braking effort provided by a combination of dynamic braking and the air brake system.[9] Air brakes and dynamic brakes are described in sections 1.3.2.1 and 1.3.2.2. Heavy grade instructions also required the locomotive engineer to crest the grade at 20 mph, 5 mph less than the allowed speed of 25 mph. When the air brake pipe pressure reduction used to control the speed of the train is greater than 18 pounds per square inch (psi), the rules required the locomotive engineer to apply the emergency braking system. Further, once the train reached 30 mph, the locomotive engineer was required to apply the emergency braking system.

1.3.2 Train Handling

The striking train's crew consisted of a locomotive engineer and a conductor. Each member of the train crew was qualified on the physical characteristics of the territory. Locomotive engineers use controls to manipulate the locomotive's throttle and the train's braking systems to control the train's speed. A locomotive engineer uses a train braking system, consisting of air brakes and dynamic brakes, to slow the train.

1.3.2.1 Air Brakes

Train air brakes are controlled by the lead locomotive and are designed to apply when air pressure in the brake pipe is reduced, and release when air pressure is increased. The purpose of this design is to allow the brakes to apply on all railcars and stop the train should the railcars be separated. The train brake pipe system is a series of rigid pipes and flexible air hoses that connect

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[6] The UP *General Code of Operating Rules* may be accessed through https://www.up.com/ert/gcor.pdf. Accessed June 14, 2020.

[7] *PTC* is an advanced train control system that uses communication-based and processor-based technology and must reliably and functionally prevent train-to-train collisions, overspeed derailments, incursions into established work zone limits, and movements of trains through switches in the wrong position.

[8] The percentage of grade is the number of feet the track rises or falls in a distance of 100 feet. For example, 1 percent ascending grade means that the track rises 1 foot in elevation for every 100 feet the equipment travels on the track. There is a higher risk level for trains operating on heavy grade as compared to level track.

[9] All train operation rules specific to heavy grades were found in UP rulebooks, timetables, special instructions, or daily track bulletins.

the railcars. All railcars in the train have air brake systems on board.[10] These air brake systems consist of air reservoirs that store pressurized air, and brake valves that route air to the brake components to either apply or release the brakes.

A brake pipe has two functions. First, it provides air flow throughout the train (provided by air compressors on the locomotive) which charges the air reservoirs on the individual railcars with air pressure for brake applications on those railcars. Second, once the railcar air reservoirs are charged, the locomotive engineer uses the brake pipe to communicate a brake application or brake release throughout the train by decreasing or increasing the pressure in the brake pipe using a brake valve in the locomotive. It is important for the locomotive engineer to know that the air reservoirs on the railcars are fully charged.

In this accident, the continuity status of the brake pipe, or the ability of the brake pipe to communicate a brake application or brake release throughout the train, was in question.[11] One of the tools a locomotive engineer uses to monitor the status of the braking system is an air flow meter. If the air reservoirs are filled on the individual railcars from the brake pipe, the locomotive air compressor and main air reservoirs provide a large volume of air to the brake pipe. The air flow meter monitors the flow of air from the locomotive to the brake pipe in terms of cubic feet per minute (CFM). The air flow meter will display a large air flow when the brakes have been released after an application. This is because the brake pipe is refilling the air reservoirs on the railcars with air pressure that was used to apply the brakes. The air flow meter can also show a large air flow if a leak develops in the air brake system, primarily in the brake pipe. Few trains are completely leak free and most trains have a minimum continuous flow of air displayed on the air flow meter. After noting the normal flow for a given train, a locomotive engineer will monitor for any variance of the air flow being provided to the train's brake pipe.

1.3.2.2 Dynamic Brakes

Dynamic braking is a feature of the locomotives in which the kinetic energy of the train is converted to electrical energy using its traction motors that cause the locomotives and the train to slow.[12] When the dynamic brakes are activated, the traction motors on the drive axles function as generators. This provides rotational resistance to the locomotive wheels. The electrical energy from the traction motors dissipates through a bank of resistor grids. This process slows the locomotive, thus slowing the train.[13]

1.3.3 Event Recorder Data and Recorded Air Flow

Event recorders equipped aboard locomotives record data such as train speed, brake valve control positions, and other information regarding train operations.[14] The event recorder also records data from the locomotive's air flow meter. As mentioned previously, the air flow meter

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[10] Each railcar has brake cylinders, reservoirs, levers, rods, valves, pipes, hoses, brackets, and shoes.

[11] The *continuity status* is the continuous flow of air throughout the train.

[12] A *traction motor* is a device that converts electrical energy into mechanical energy, which turns the locomotive wheels. It is mounted directly on each driving axle between the wheels of a locomotive truck.

[13] *Resistor grids* are configurations of resistors to dissipate electrical energy to handle large loads of electrical current.

[14] For more information on recorded parameters, see Title 49 *Code of Federal Regulations* (*CFR*) 229.135.

shows how much air the locomotive is providing to the brake pipe to compensate for leakage and to maintain the pressure needed for the brakes to operate correctly. Air flow below 20 CFM displays on the locomotive engineer's console as 0. In other words, the air flow meter is accurate down to 20 CFM, after which all flow is recorded as 0. The reduction of air flow to a low level can indicate an air flow restriction in the brake pipe.

Departing Laramie, the air brake system was still being charged following the air brake tests.[15] The air brake test will be discussed in more detail in section 1.5.2. When the train departed Laramie, the event recorder showed the air flow meter near 50 CFM. After about 15 minutes of charging the air brake system, the air flow meter dropped to 30 CFM.[16] For the most part, the air flow meter fluctuated between 27 and 30 CFM from that point until shortly before the time of the accident. There were two exceptions, which occurred when the locomotive engineer applied the dynamic braking and bunched the train.[17] At those times, the air flow meter dropped to 0 CFM. This first happened when the grade changed from ascending to descending and then returned to ascending at Dale Junction near MP 555. The second occurrence was after the train crested the top of Sherman Hill near MP 540 and the train bunched again. This time, the air flow meter remained at 0 CFM until the collision. A force and motion study was conducted to better understand the in-train forces associated with this collision which will be discussed in the analysis section of this report.[18]

When the train crested the grade at MP 540, the locomotive engineer applied dynamic braking to control the train speed. The dynamic braking alone was not enough to maintain the train speed, so the locomotive engineer made a minimum air brake application near MP 535.35 while traveling at 19 mph. At MP 531.80, at the same speed of 19 mph, the locomotive engineer made an additional air brake application attempting to control the train speed. With the train speed increasing, the locomotive engineer made a full-service (maximum service) air brake application, because the train speed had increased to 26 mph. At MP 529.95 the train was still accelerating, reaching a speed of 28 mph, when the locomotive engineer attempted an emergency brake application. For the previous 45 minutes of the trip, the event recorder had been displaying COMM OK with the ETD. However, 15 seconds after the attempted emergency brake application, the event recorder data indicated a communication status change to "FR NC," which stands for front-to-rear no communication. Five minutes after the locomotive engineer attempted to apply the emergency brake, the striking train collided with the standing train at MP 527.1 at a speed of about 55 mph.[19]

[15] *Charging* brakes involves filling them with air so they can be released.

[16] Title 49 *CFR* 232.205 states that the air flow cannot exceed 60 CFM.

[17] *Bunching* slows the train while going downhill allowing the slack, or distances between the mechanical couplers of each railcar, to compress, thereby better managing the in-train forces that occur when a train both climbs and descends heavy grades.

[18] For more information on the in-train forces, see the NTSB Force and Motion Study in the accident docket.

[19] This data was from the event recorder of the lead locomotive.

1.4 Crew Information

1.4.1 Locomotive Engineer

The locomotive engineer was hired as a brakeman by UP on August 7, 2006. After becoming a conductor in July 2012, he entered the locomotive engineer training program and was certified as a locomotive engineer on November 20, 2014. The locomotive engineer had a current certification under Title 49 *Code of Federal Regulations* (*CFR*) Part 240 due to expire on June 28, 2021.[20] He was qualified to operate trains throughout the UP system, and this route was his regular job assignment.

1.4.1.1 Operational Testing

Title 49 *CFR* 217.9 contains specific requirements for operational testing and observing employees as they perform their duties. UP maintains an operational testing program to monitor the performance compliance of employees operating trains. The purpose of the program is to observe crew activities when they are unaware that a supervisor is watching to ensure operating rules and procedures are followed. The locomotive engineer had been observed by five supervisors on 6 separate days in the 12 months prior to the accident. During those observations, he was tested a total of 47 times on 18 different operating rules. The railroad supervisors conducting the testing did not record any actions of noncompliance by the locomotive engineer in the 12 months prior to the accident.

1.4.1.2 Work/Rest Cycle

Table 1 shows the on/off duty times for the locomotive engineer for the 3 days prior to the accident. The duty times were within the hours-of-service regulations specified in 49 *CFR* Part 228.

Table 1. Locomotive engineer work/rest cycle.

Date	Rest Time	On Duty	Off Duty	Total Work Time
October 1		5:00 a.m.	11:00 a.m.	6 hours
October 2	OFF DUTY			
October 3	49 hours 15 minutes	12:15 p.m.	9:15 p.m.	9 hours
October 4 (accident date)	11 hours 30 minutes	8:45 a.m.	7:40 p.m. accident	10 hours 55 minutes

1.4.1.3 Training Record

The locomotive engineer had completed all required training programs for his position. He passed his most recent examinations in November 2017 with scores of 100 percent on operating rules, 97 percent on air brake testing, and 93 percent on hazardous materials awareness.

[20] Title 49 *CFR* Part 240 requires that locomotive engineers pass a written knowledge examination and performance skills examination every 3 years to be certified.

1.4.1.4 Fitness for Duty

The locomotive engineer passed a medical, hearing, and vision examination to obtain his locomotive engineer certification in June 2018.[21] NTSB investigators reviewed the locomotive engineer's 2006 preemployment medical examination record and 2018 occupational medical examination, neither of which identified any significant medical conditions. The engineer's most recent Federal Railroad Administration (FRA)-required medical examination from March 2018 documented no abnormalities in visual acuity, visual field, or color-vision testing.

1.4.1.5 Autopsy

The forensic pathology consultant who performed the autopsy found no evidence of significant natural disease in the locomotive engineer. The cause of death was severe and diffuse crushing injuries; the manner of death was accident.

1.4.1.6 Toxicology

The Federal Aviation Administration (FAA) Forensic Sciences laboratory conducted postaccident toxicology testing and did not detect any ethanol in brain or muscle tissue samples.[22] Loratadine and its metabolite desloratadine were detected in the locomotive engineer's muscle and liver.[23] FRA postaccident toxicology testing of spleen samples were negative for tested drugs.[24]

1.4.2 Conductor

The conductor was hired by UP on March 9, 1998, as a track laborer. He moved through multiple positions in the engineering department, and transferred to the operating department on March 2, 2015, as a brakeman. He was first certified as a conductor on September 17, 2015. According to UP records, his last conductor certification was December 13, 2017, current through January 11, 2021.

1.4.2.1 Operational Testing

The conductor was observed by seven supervisors on 17 separate days in the 12 months prior to the accident. During those observations, he was tested a total of 144 times on 42 different operating rules and had complied with the railroad's rules and procedures properly for 139 of them.

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[21] Fitness for duty qualifications for locomotive engineers are outlined in 49 *CFR* Part 240.

[22] The FAA Forensic Sciences laboratory tests specimens for over 1,300 compounds including toxins, prescription, and over-the-counter medications and illicit drugs; information about these compounds can be found on the Drug Information Web Site (https://jag.cami.jccbi.gov/toxicology/).

[23] Loratadine is an allergy medication available over the counter and by prescription, often marketed with the name Claritin. It is generally considered not to be sedating or impairing.

[24] As part of FRA's postaccident forensic toxicology testing, Quest Laboratory tested specimens for amphetamines, barbiturates, benzodiazepines, cannabinoids, cocaine, ethyl alcohol, methadone, opiates/opioids, phencyclidine, tramadol, brompheniramine, chlorpheniramine, diphenhydramine, and doxylamine.

For each of the instances of noncompliance, he received coaching by a supervisor.[25] He was coached twice on the proper way to step off equipment, once on the proper way to wear a hooded sweatshirt to allow peripheral vision, once on properly facing the locomotive door when closing, and once on the importance of standing clear of a switch lever during its operation.

1.4.2.2 Work/Rest Cycle

Table 2 shows the on/off duty times for the conductor for the previous 3 days before the accident. The duty times were within the hours-of-service regulations specified in 49 *CFR* Part 228.

Table 2. Conductor work/rest cycle.

Date	Rest Time	On Duty	Off Duty	Total Work Time
October 1		7:00 a.m.	4:46 p.m.	9 hours 56 minutes
October 2	OFF DUTY			
October 3	38 hours 43 minutes	10:00 a.m.	8:49 p.m.	10 hours 49 minutes
October 4 (accident date)	11 hours 30 minutes	8:45 a.m.	7:40 p.m. accident	

1.4.2.3 Training Record

The conductor had completed all required training programs for his position. He had passed his most recent operating rules examinations in March 2017 with 98 percent on operating rules, 90 percent on air brake rules, and 87 percent on hazardous materials awareness.

1.4.2.4 Fitness for Duty

The conductor passed a medical, hearing, and vision examination to obtain his conductor certification in December 2017.[26] NTSB investigators reviewed the conductor's 1998 preemployment medical examination record; no significant medical conditions were identified. The conductor's most recent FRA-required medical examination from January 2017 documented no abnormalities in visual acuity, visual field, or color-vision testing. The record from the most recent examination did not include height, weight, vital signs, nor review of medications, medical history, or evaluation of sleep apnea risk.

1.4.2.5 Autopsy

The forensic pathology consultant who performed the autopsy found no evidence of significant natural disease in the conductor. The cause of death was multiple blunt force injuries; the manner of death was accident.

[25] During a *coaching* session, a supervisor typically provides additional training to an employee who either lacks a sufficient understanding of the rules or an inability to demonstrate the correct application of the rules. Although having a coaching session is recorded as a failure, it is not recorded in the employee's permanent file.

[26] Fitness for duty qualifications for conductors are outlined in 49 *CFR* Part 242.

1.4.2.6 Toxicology

The FAA Forensic Sciences laboratory conducted postaccident toxicology testing and did not detect ethanol in the conductor's blood. However, the blood testing detected the sedating antihistamine cetirizine at 0.041 micrograms per milliliter (µg/ml); the sedating antihistamine hydroxyzine at 0.044 µg/ml; the mild stimulant/asthma medication theophylline; the opioid agonist mitragynine at 0.571 µg/ml and its potent active metabolite 7-hydroxymitragynine at 0.069 µg/ml.[27] FRA postaccident toxicology testing of urine and blood samples were negative for its tested drugs.

1.5 Striking Train

UP Train MGRCY04 had 3 locomotives on the head end, 95 loaded railcars, and 10 empty railcars, weighed 12,417 tons and was 6,581 feet long. The locomotives were all forward facing for the eastbound direction of travel. UP 5412 was in the lead, UP 5842 was next, and UP 5003 was third in line.

1.5.1 Mechanical Inspection and Air Brake Test

The striking train originated in Green River, Wyoming, where qualified mechanical inspectors from UP performed a Class I initial terminal air brake test and predeparture inspection.[28] The railcars were positioned on tracks 19 and 20 for this testing, which used a yard test device and a jumper air hose.[29] Yard air was connected on the east end of both tracks with an ETD on the west end of track 20.[30] The ETD was tested on the rear of the train while the locomotives were not coupled to the train. A locomotive engineer tested the train's brakes by applying and releasing the brakes before departing Green River.[31]

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[27] Cetirizine is a sedating antihistamine available over the counter and by prescription, often marketed with the name Zyrtec; Hydroxyzine is a prescription sedating antihistamine used for treatment of anxiety and severe itching marketed under various names including Vistaril and Atarax; Theophylline is a prescription medication used to help reverse restricted airways in conditions such as asthma and other chronic lung diseases. Mitragynine and t-hydroxymitragynine are the primary psychoactive compounds found in the leaves of the southeast Asian kratom tree. It has stimulant effects at low doses and sedative effects at high doses. It is considered a drug of concern by the US Drug Enforcement Administration and the US Food and Drug Administration has asked that it be placed into the list of Schedule 1 drugs with high potential for abuse and no medical value.

[28] (a) Class I initial terminal air brake tests are required by 49 *CFR* 232.205. (b) Predeparture inspection is required by 49 *CFR* 215.13 and requires that railcars be inspected to determine compliance with FRA Railroad Freight Car Safety Standards. (c) *Qualified mechanical inspector* means a person who has received, as part of the training, qualification, and designation program required under 49 *CFR* 232.203, instruction and training that includes "hands-on" experience (under appropriate supervision or apprenticeship) in one or more of the following functions: troubleshooting, inspection, testing, maintenance, or repair of the specific train brake components and systems for which the person is assigned responsibility. This person should also possess a current understanding of what is required to properly repair and maintain the safety-critical brake components for their assigned responsibility. Further, the qualified mechanical inspector's primary responsibility includes work generally consistent with the functions listed in this definition.

[29] A *yard test device* simulates the air brake commands of a locomotive.

[30] *Yard air* means a source of compressed air other than from a locomotive.

[31] The locomotive engineer who tested the brakes was not the one involved in the accident. The accident crew replaced the originating crew at Rawlins.

Prior to the accident, the crew added 19 railcars to the head end of the train in Laramie, Wyoming, about 38 miles west of the accident location. The 19 railcars that were added to the front of the striking train consisted of 9 loaded hopper railcars and 10 loaded maintenance-of-way gondolas.[32] Railcars 1 through 9 were the hoppers and railcars 10 through 19 were the gondolas. The 10 gondola cars had been sitting in the Laramie, Wyoming, rail yard without use or maintenance for over 2 years, since August 2015. A local UP supervisor observed the crew adding the railcars to the train and performing an air test. The UP supervisor noted that the conductor used an air gauge at the rear of the 19 railcars and performed an air brake test on each of those railcars before adding them to the train. The crew then added the railcars to the train and performed another brake application and release test on the entire train. While waiting for the train dispatcher's authority to depart, the locomotive engineer applied the train brakes and performed a second test before leaving Laramie. At 4:56 p.m., the train departed Laramie and made no more stops before the accident.

1.5.2 Single Railcar Air Brake Test

FRA regulations require that all freight railcars in general service receive a single car air brake test (SCABT) no less than once every 5 years.[33] NTSB investigators reviewed the railcar maintenance history records for the train consist and discovered that 10 of the railcars had been sitting in Laramie, Wyoming, without use or maintenance since August 2015 and that 6 of the 19 picked-up railcars were overdue for a SCABT ranging from less than 1 month to slightly less than 2 years. According to the Association of American Railroads (AAR) *Manual of Standards and Recommended Practices Brakes and Brake Equipment*, Section E, the purpose of the SCABT device is to make a general check on the condition of the brake equipment on railcars as required in the AAR *Interchange Rules Field Manual* (AAR 2018, AAR 2018a).

1.5.3 Mechanical Evidence

While on scene, NTSB investigators noted several conditions with the striking train's braking system. In the pile of wreckage near the front of the consist, NTSB investigators found about 45 wheel sets that showed a bluish color, indicators of overheating and sliding.[34] (See figure 3.)

The braking system on the railcars near the front of the consist relied on brake beams to force the brake shoes against the wheels to slow or stop the train's movement. Brake shoes are affixed to the head of a brake beam using brake shoe keys. Investigators found multiple brake beams with signs of excessive braking; the brake shoes were worn to the backing plate and worn through to the brake head.[35] (See figure 4.)

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[32] (a) *Hopper railcars* are freight railcars, either open or covered, designed for handling bulk commodities. Hopper railcars have floor sheets that slope from the railcar sides and ends to form a series of pockets, or hoppers, which can discharge the bulk lading by gravity through hopper doors operated from outside the railcar when opened. (b) *Gondola railcars* are freight railcars with low sides and ends, a solid floor, and no roof.

[33] SCABTs are required by 49 *CFR* 232.305.c.

[34] *Wheel sets* contain the wheel, axle, and roller bearing assemblies.

[35] The backing plate is connected to the brake shoe.

Figure 3. Wheel set from the striking train. The blue discoloration indicates overheating.

Figure 4. Striking train's wheel set. Composite material is worn off the brake shoe.

NTSB investigators reviewed the wheel detector report from a cold wheel detector located about 7 miles from the accident location.[36] The report showed that axles 19 through 54, from railcars at the head end of the striking train, exhibited higher temperature readings than the remaining axles of the train.

A postaccident air brake test was conducted on the railcars from the striking train that did not derail. This test revealed no defects or conditions that would have negatively affected the train's performance or the brake pipe air flow. On December 20, 2018, investigators examined air brake hose assemblies recovered from the accident as well as representative new components and assemblies at the Strato, Inc. facility in Piscataway, New Jersey.[37] During these tests, investigators observed no changes in the air flow on the hoses recovered from the collision and new hoses tested in multiple scenarios designed to kink them, indicating that the air brake hose cannot be kinked without mechanical involvement.

1.5.4 Similar Incidents

According to UP, similar braking issues while descending in heavy grade territory occurred on November 23, 2018, west of Cheyenne, Wyoming. After applying the brakes (reducing the brake pipe pressure) to slow the train, the crew realized that the pressure reduction did not propagate to the rear of the train. The crew made several attempts to initiate an emergency brake application by toggling the emergency brake function on the head-of-train device (HTD). The first two attempts were unsuccessful. On the third attempt, the train went into emergency braking. Upon inspection, railroad employees discovered a kinked air hose, as seen in figure 5. When emergency braking was applied, the kinked hose prevented the venting of the brake pipe pressure from the front of the train to the rear. The third emergency brake application on the HTD led to successful communication with the ETD, which vented the brake pipe from the rear of the train.

[36] A *cold wheel detector* is a system installed along the track used to detect and identify railcar wheels that have different heat signatures from other wheels in the train. These detectors are used to identify possible braking or mechanical issues as the train is operating.

[37] Strato Inc., is the company that manufactured the air brake hoses that were used on the train that was involved in this accident.

Figure 5. Kinked end-of-railcar air hose on train involved in the November 23, 2018, incident west of Cheyenne, Wyoming. (Photograph provided by UP.)

On December 20, 2018, a UP mechanical employee discovered a similar kink in an air hose on an outbound train that had recently received end-of-railcar hose repairs from a railcar repair shop. The end-of-railcar hose was configured incorrectly which kinked the hose, as seen in figure 6.

Figure 6. Kinked intermediate end-of-railcar air hose that was discovered during an inspection after an end-of-railcar air hose arrangement was incorrectly applied. (Photograph provided by UP.)

1.6 Communications Devices

1.6.1 Head-of-Train Device to End-of-Train Device

There are two common methods used to communicate an emergency brake application from the controlling locomotive to the rear of a train: (1) an air pressure reduction that initiates from the front of the train and propagates along the train's brake pipe; and (2) a radio communication link between the train's HTD and ETD, which will vent the brake pipe air pressure, initiating from the rear of the train through the train's brake pipe. The HTD communication link with the ETD is automatically synchronized with the application of emergency brakes using the brake handle; in addition, by toggling a switch on the HTD, it can also be triggered independently to command an emergency brake application to the ETD. These two emergency brake application methods are intended to provide redundancy.

The radio communication link between the HTD and ETD was a long-range radio frequency (RF) link.[38] The RF link required a clear and unobstructed transmission path to reliably transmit and receive data between the two devices. Interferences to the RF link may occur when the signal is blocked, weakened, or reflected by physical objects such as hills, buildings, or bridges. RF interference from other devices operating in proximity can cause noise and weaken the signal.

[38] Electromagnetic radiation consists of electric and magnetic energy moving together through space at the speed of light. Radio waves emitted by transmitting antennas are a form of electromagnetic energy and are referred to as RF energy.

Electrical interference and environmental factors, such as lightning or fog, can also interfere with the RF signal.

At some railroad locations where the radio communication link between the HTD and ETD has been identified to be consistently compromised by terrain or obstacle interferences, railroads have installed wayside communication repeaters. Repeaters relay data packets between the HTD and ETD and, thus, eliminate or minimize some of the communication interferences. The use of distributed power unit locomotives in the middle or the rear of trains has also improved radio communication between the HTD and ETD by either relaying the data between the HTD and ETD or by transmitting and receiving with more powerful RF equipment on board locomotives operating at the rear of the train.

1.6.1.1 Postaccident Testing

The lead locomotive, UP 5412, was equipped with a Wabtec LCU-08 HTD, which was manufactured on May 9, 2004, and assembled with a Wabtec RE382 radio configured to operate in half-duplex mode.[39] The HTD was designed to operate at AAR-assigned ultrahigh frequencies (UHF). The device was transmitting at 452.9375 megahertz (MHz) and receiving at 457.9375 MHz. The device required a nominal operating voltage of 15 volts direct current for 8-watt transmissions and had the latest Wabtec operating software version installed.

Wabtec sold the HTD to GE Locomotives on May 27, 2004, and it was installed on a locomotive belonging to BNSF Railway (BNSF). In October 2011, BNSF contracted DPS Electronics to retrofit radios from Wabtec HTDs to Ritron Wireless Solutions DTX-454 narrow-band radios. BNSF transferred the HTD to UP, that then installed it on UP 5412.

Following the accident, the HTD was taken to Wabtec facilities for further examination and bench testing. A visual examination determined the electrical serial connector on the front panel was severely bent, but there was no indicated damage on the internal components. The retrofitted radio was functioning properly. This testing and locomotive event recorder data determined the HTD was operating within manufacturer specifications and no device air flow restrictions were identified.

Operational testing determined the behavior of the device during an emergency radio transmission as follows:

- As designed, the device would retry every second when the HTD does not receive emergency command acknowledgment from the ETD, (unsolicited pressure updates from the ETD do not count as emergency command acknowledgements).
- As designed, the HTD would retry every 4 seconds when it receives emergency acknowledgement, but the ETD brake pipe pressure does not drop below 5 psi.

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[39] *Half-duplex mode* is a type of communication in which data can flow back and forth between two devices, but not simultaneously. Each device in a half-duplex system can send and receive data, but only one device can transmit at a time.

- As designed, during normal operation, an emergency command is received from the locomotive computer and transmitted to the HTD. The HTD then sends the command to the ETD. During bench testing the "front-to-rear, no communication" message was received in the prescribed 15-second time frame.

- As designed, from the initial signal from the locomotive computer, the signal will be transmitted for 2 minutes, then it will stop sending the signal until another command for emergency braking is received. If a locomotive engineer initiates another emergency braking command during the 2-minute time frame, the 2-minute window is not extended. After the 2-minute window, the HTD will not send a signal unless directed again by the locomotive's computer. A locomotive engineer would have to initiate another emergency braking application attempt to initiate another ETD emergency command.

1.6.1.2 ETD Postaccident Testing

Train MGRCY04 was equipped with a two-way Wabtec Trainlink ETD that was designed to operate at AAR-assigned UHF frequencies. It was designed to transmit at 457.9375 MHz and receive at 452.9375 MHz.

When enabled, two-way ETDs allow train crews to use radio telemetry to initiate an emergency brake application from the rear of the train. The emergency braking pneumatic signal transmits from the locomotive through the train and is enhanced with a two-way ETD because similar braking can be concurrently activated from the rear of the train. The rapid reduction of brake pipe air pressure from both ends of a train should cause the brakes on all railcars to engage, up to and including any point where an air flow restriction in the train brake pipe, such as a kink in an air hose, might be located.

Following the accident, the two-way ETD on the striking train was shipped to the UP Telecom Service Center in Council Bluffs, Iowa, where it was examined and tested. A physical examination of the device did not identify any issues that prevented the device from operating properly.

Operational testing of the ETD's motion, generator output voltage, battery voltage, global positioning system (GPS), and air pressure was completed with no air flow restrictions identified. The ETD enclosure was opened and tested for battery voltage and radio specifications. The radio transmit/receive function met manufacturer specifications and the battery was measured at 12.5 volts. The ETD was found to be functioning properly.

1.6.2 Communication Evidence

Event recorder data from locomotive UP 5412 indicates that when the locomotive engineer of the accident train bunched the train with dynamic braking to descend the grade just prior to the accident, the recorded air flow dropped below 20 CFM. The train started to accelerate, and the locomotive engineer tried to compensate for the increase in speed by increasing the brake application. Before the train reached the 30-mph speed limit, the locomotive engineer made an emergency brake application, but the brake pipe pressure reduction did not propagate to the rear of the train, as indicated by the data logger from the ETD.[40]

The HTD in the lead locomotive transmitted a radio message to the ETD to initiate an emergency brake application after the locomotive engineer activated emergency braking. According to locomotive event recorder data, however, the ETD did not initiate an emergency application of the brakes from the rear of the train. The event recorder data indicated the "Front-to-Rear, No Comm" message was received at 7:35:11 p.m., which was 5 minutes prior to the collision.

The locomotive computer log was downloaded from the lead locomotive, UP 5412. The locomotive computer data logs captured additional HDT/EDT loss of communication events. These logs are outlined in appendix C.

1.6.3 Rules and Regulations Regarding Train Telemetry

FRA minimum safety standards regarding ETD communication protocols and timing requirements can be found in appendix D.

The AAR *Manual of Standards and Recommended Practices, Locomotive Electronics and Train Consist System Architecture,* Section K, Part II Standard S-9152 contains the requirements for communication systems between the lead locomotive and the rear car of freight trains (AAR 2016). Passages applicable to this accident are also found in appendix D.

1.6.3.1 Historical Perspective

On September 16, 1994, in a notice of proposed rulemaking (NPRM) the FRA listed requirements for two-way ETDs. Section 232.117(g) of the NPRM, which later became 49 *CFR* 232.405(g), said "the availability of the front-to-rear communications link shall be checked automatically at least every 10 minutes (*Federal Register*, 1994, 47676)."

On February 21, 1996, in a notice of public regulatory conference, FRA attempted to clarify this with the following statement: "Section 232.117(g) of the NPRM inadvertently contained '10 minutes' for this requirement; it should have read '10 seconds.'" In addition, it said, "FRA recognizes that currently available 2-way EOTs (end-of-train devices) have several optional features that could prove beneficial to railroads and although FRA recommends that railroads obtain as many of the optional features as they can when purchasing the devices, FRA does not intend to mandate their use and feels each railroad is in the best position to determine which features benefit its operation (*Federal Register*, 1996, 6610)."

Several parties commented on this clarification, including the manufacturers of the devices, stating that a 10-second requirement would be impossible to meet with current technology and would result in a battery drain within a short time. These commenters stated that FRA correctly

[40] A *data logger* is an electronic device that records data over time either with a built-in instrument or sensor or via external instruments and sensors.

proposed a 10-minute requirement in the NPRM as that was the industry standard at the time and had been the standard for devices used in Canada for several years.

In response to this notice, AAR recommended that a failure not be declared until communication between the HTDs and ETDs could not be established for 16 minutes and 30 seconds. This time frame was proposed based on the design of the devices, which automatically checks communication between the units every 10 minutes. If no response is received, the HTD automatically requests communication from the ETD 15 seconds later. If no response is received to that request, another request is made 6 minutes later; and if there is still no response, the HTD makes another request 15 seconds later. AAR based its response on the design of the HTDs and ETDs at the time, which is still current today (*Federal Register*, 1996, 6610). Since the 16 minutes 30 seconds represented an enforceable standard for determining when a loss of communication should be considered an en-route failure and no other commenters presented measurable criteria for such a failure, FRA adopted AAR's suggestion.

1.7 Signals and Positive Train Control

In the Laramie Subdivision, the UP authorized train movements with a traffic control system supplemented with an automatic cab system and enforced with a PTC system. Train movements were coordinated by a train dispatcher located at the Harriman Dispatch Center in Omaha, Nebraska. Train movements on the Laramie Subdivision were governed by operating rules, special instructions, timetable instructions, and the signal indications of the traffic control and automatic cab systems.

The signal system used coded track circuits for train occupancy detection. Wayside signals were colorlight and searchlight signals with upper and lower signal heads capable of displaying green, yellow, and red aspects for train movements in either direction.[41]

UP implemented the Interoperable Electronic Train Management System (I-ETMS) to comply with FRA regulations requiring PTC. I-ETMS was installed and functioning on UP Laramie Subdivision on the day of the accident.

I-ETMS was a safety-critical, "vital overlay" system used in conjunction with existing methods of operations that interfaces with existing signal systems, wayside devices, and office train dispatching systems.[42] I-ETMS provided the means to enforce compliance of movement authorities, speed restrictions, work zones, and switch positioning while retaining the existing field signal system and a computer-aided dispatch (CAD) system functioning as the primary means of maintaining train separation and protection.

[41] (a) *Colorlight signals* use a lamp for each colored lens. (b) *Searchlight signals* display color aspects by shining light through different colored lenses.

[42] (a) The *vital overlay* system is defined in 49 *CFR* Part 236, Subpart I, Section 236.1015 (e)(2). (b) The existing methods of operations include centralized traffic control, track warrant control, and automatic block signaling, among others. (c) Office train dispatching systems are commonly referred to as CAD.

1.8 Electronically Controlled Pneumatic Brake Systems

Neither of the trains involved in this accident were equipped with electronically controlled pneumatic (ECP) train brakes, which provide many safety improvements over conventional train air braking systems. The improvements include shorter stopping distance, reduction of in-train forces, reduction of railcar component wear, and reduction of depletion of the air in the air reservoir. This report briefly examines the constant communication and continuity of the train's braking system design feature of ECP brake systems. The striking train was not equipped with ECP brakes. A train equipped with an ECP braking system uses electrical cabling to send braking commands to all railcars. On ECP-equipped trains, the ECP system searches for air brake restrictions by performing self-diagnostic testing on each railcar and sending a message to the locomotive engineer. The ECP technology works in conjunction with the conventional air brake equipment. If the ECP braking system detects a disconnect in the cabling that goes through each railcar, the ECP logic will initiate an emergency brake application.

1.9 Track and Engineering

The Laramie Subdivision consisted primarily of multiple main tracks, with two tracks between MP 513 and MP 544 and three main tracks between MP 544 and MP 550 with passing sidings. In the accident area, the two main tracks were spaced with 13-feet 8-inch track centers. UP documentation indicated the 2017 total tonnage figure for each main track between MP 519.11 and MP 545.56 was about 126 million gross tons.

Eastbound freight trains traversed a descending grade ranging from 0 to 1.58 percent beginning at MP 540.49 to MP 510. From MP 530 to the POC at MP 527.1, trains were on a descending grade of 1.55 percent. At MP 527.5 on main track 1, trains traversed a left-hand curve (in relation to the direction of travel).

UP inspected and maintained the main track on this portion of the Laramie Subdivision to FRA track safety standards for Class 4 track.[43] UP did not operate any regularly scheduled passenger trains on the subdivision.

Significant track structure damage in the immediate area of the derailment prevented a detailed inspection of an intact track structure in the disturbed track area. Postaccident observations indicated that the track construction consisted of primarily 133-pound continuously welded rail, which was seated in 16-inch double-shoulder tie plates that lay between the bottom surface of the rail and the top surface of timber crossties. The rail was fastened through the tie plates to standard wooden crossties with spikes.

On October 6, 2018, investigators conducted a walking inspection from the POC to MP 530.8. The FRA inspector completed an inspection report showing no defects in the area of the derailment.

[43] FRA track safety standards are found in 49 *CFR* Part 213.

2 Postaccident Actions

2.1 NTSB Safety Recommendations

In response to this accident, on September 16, 2019, NTSB issued a safety recommendation report aimed at highlighting the following safety issues:

- Although rare, train brake pipe air flow restrictions occur.
- The radio communication between the two-way ETD and the HTD may not be continuous.
- The train crew may not be aware of any communication interruptions between the HTDs and ETDs because notifications of such interruptions do not initiate until there has been no two-way communication for a minimum of 16 minutes and 30 seconds.
- When an emergency brake signal is initiated, the HTD transmits the signal to the ETD for 2 minutes. If the HTD does not receive an acknowledgement signal from the ETD within that time, the transmission ends, and the system will not transmit another signal unless the train crew initiates it (NTSB 2019).

To address these safety concerns, on September 19, 2019, the NTSB issued the following safety recommendation to the Class I railroads:

> Review and issue guidance as necessary for the inspection of end-of-railcar air hose configurations to ensure the air hose configuration matches the intended design. (R-19-41)

On December 16, 2019, Canadian National Railway (CN) informed NTSB that it would issue instructions to its mechanical employees to “ensure repairs to end-of-railcar air hose components are done in accordance with the intended design” and would brief its inspectors to ensure configurations are functioning as designed.[44] Pending CN informing the NTSB when these revisions were completed, the NTSB classified CN’s response to Safety Recommendation R-19-41 as “Open—Acceptable Response.”

On December 19, 2019, Kansas City Southern Railway (KCS) informed the NTSB that it was issuing guidance to its mechanical employees on the inspection of the various air brake hose arrangements and how to identify evidence of wear and potential “pinch points.”[45] Pending issuance of that guidance, the NTSB classified KCS’s response to Safety Recommendation R-19-41 as “Open—Acceptable Response.”

In a January 21, 2020, letter to the NTSB, CSX Railroad (CSX) discussed its three-module training program for its mechanical employees that included discussion of air hose configurations

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[44] Letter from CN to NTSB, December 16. 2019.

[45] (a) Letter from KCS to NTSB, December 19, 2019. (b) *Pinch point* is a location that allows for mechanical fouling/pinching between structures or components of railcars.

and what steps employees should make to rectify identified defects.[46] Therefore, the NTSB classified CSX's response to Safety Recommendation R-19-41 as "Closed—Acceptable Action."

As of December 2020, BNSF, Canadian Pacific Railway, Norfolk Southern Railroad, and UP have not responded to the NTSB, and their responses to Safety Recommendation R-19-41 are classified "Open—Await Response." Amtrak replied on November 26, 2019, and its response to Safety Recommendation R-19-41 is classified "Closed—Acceptable Action."

On September 19, 2019, the NTSB also issued the following safety recommendation to the Class I railroads:

> Review and revise your air brake and train handling instructions for grade operations and two-way end-of-train device instructions to include: monitoring locomotive air flow meters, checking the status of communication between the head-of-train and end-of-train devices before cresting a grade, and the actions to take if the air pressure at the rear of the train does not respond to an air brake application. (R-19-42)

On December 16, 2019, CN provided the NTSB with evidence that it believed showed that its operating rules met the conditions of the recommendation.[47] On May 4, 2020, the NTSB asked CN to provide additional information regarding CN's instructions for monitoring air flow when changes occur in the train's draft status; the procedures that CN train crews use to verify that head-of-train (HOT) – end-of-train (EOT) communications are operative prior to descending a grade; and CN's rules addressing actions to take when the air pressure at the rear of a train does not respond to an air brake application.[48] Pending receipt of this additional information on May 4, 2020, CN's response to Safety Recommendation R-19-42 was classified "Open—Acceptable Response."

On December 19, 2019, KCS informed NTSB that its "car department personnel" would receive refresher training in 2020 on how braking systems function and proper hose configurations.[49] On May 12, 2020, NTSB requested that KCS describe the procedures train crews use to monitor locomotive air flow meters and to verify that HOT-EOT communications are operative prior to a train descending a grade. The NTSB also asked KCS to describe the actions train crews are to take when the air pressure at the rear of a train does not respond to an air brake application. Pending the answers to these questions, KCS's response to Safety Recommendation R-19-42 was classified "Open—Acceptable Response." [50]

As of December 2020, BNSF, Canadian Pacific Railway, Norfolk Southern Railroad, and UP have not responded to the NTSB, and their responses to Safety Recommendation R-19-42 are classified "Open—Await Response." Amtrak replied on November 26, 2019, and its response to Safety Recommendation R-19-42 is classified "Closed—Acceptable Action." CSX responded on

[46] Letter from CSX to NTSB, January 21, 2020.
[47] Letter from CN to NTSB, December 16, 2019.
[48] Letter from NTSB to CN, May 4, 2020.
[49] Letter from KCS to NTSB, December 19, 2019.
[50] Letter from NTSB to KCS, May 12, 2020.

January 21, 2020, and provided additional information on May 26, 2020, and its response to Safety Recommendation R-19-42 is also classified "Closed—Acceptable Action."

On September 19, 2019, the NTSB also issued the following safety recommendation to the American Short Line and Regional Railroad Association (ASLRRA):

> Alert your member carriers to (1) inspect the end-of-railcar air hose configurations to ensure the hose configurations match the intended design and (2) review and revise their air brake and train handling instructions for grade operations and two-way end-of-train device instructions to include: monitoring locomotive air flow meters, checking the status of communication between the head-of-train and end-of-train devices before cresting a grade, and the actions to take if the air pressure from the rear of the train does not respond to an air brake application. (R-19-43)

On December 10, 2019, ASLRRA sent an e-mail to its members linking to NTSB's Safety Recommendation Report, *Train Emergency Brake Communication* and describing the steps NTSB outlined in the report to avoid similar accidents in the future. As a result, on March 9, 2020, NTSB classified Safety Recommendation R-19-43 to ASLRRA "Closed—Acceptable Action."[51]

2.2 FRA Inspections

On October 11, 2018, FRA safety inspectors completed a mechanical records inspection of the railcars in the striking train's consist. This inspection revealed six railcars that had not had a SCABT within 5 years of the accident and one railcar that did not receive a SCABT during a covered event.[52] This is discussed further in section 3.3. FRA safety inspectors completed an inspection report documenting these defective conditions and issued the report to UP management.

In addition, FRA took exception to an air brake test conducted on the striking train in Green River, Wyoming. During that testing, the UP mechanical inspectors used one air gauge on two cuts of railcars with an air hose connecting the two separate cuts.[53] Title 49 *CFR* 232.217 (c)(2) states:

> Yard air pressure shall be 60 psi at the end of the consist or block of cars opposite from the yard test device and shall be within 15 psi of the regulator valve setting on yard test device.

To comply with this regulation, a rear end gauge must be applied to the rear of each cut of railcars.

The NTSB requested information from the FRA regarding postaccident actions the agency had taken. FRA replied on October 4, 2019, with a list of actions it has taken since the accident.

- FRA met with AAR, individual railroads, and labor representatives to evaluate the air hose arrangement of freight railcars similar to the one involved in the accident and to

[51] Letter from NTSB to ASLRRA, March 9, 2020.
[52] A *covered event* is a repair that requires a railcar be sent to a shop facility.
[53] *Cuts* are a block of multiple coupled railcars.

discuss how train crews successfully handle the loss of communication issues. They identified railcars with end-hose arrangements similar to those of the accident train and AAR issued an Early Warning document (EW-5331) for those railcars requiring inspection and repair.

- FRA discussed the circumstances of the accident with the entire FRA Motive Power and Equipment (MP&E) inspection team at the March 2019 Rail Safety Training Conference, focusing on obstructed air hoses, possible conditions that could contribute to the air flow restriction, and suggestions on how to identify these conditions during routine inspections.
- Regional FRA MP&E inspectors investigated two incidents with similar conditions and identified a similar condition on another railcar in UP's North Platte Yard.
- FRA worked with UP to evaluate the frequency of ETD communications issues in the accident area, resulting in additional repeaters being installed. This was also communicated to the AAR committee that deals with ETDs. FRA is also working with Canadian Pacific Railroad to develop training for railroad employees to identify the conditions that led to this accident.
- FRA included in the draft NPRM *Miscellaneous Amendments to Brake System Safety Standards and Codification of Waivers* its concerns with the safety risks associated with loss of communication events between the HTDs and ETDs (*Federal Register* 2020, 2494). FRA also said that it would be seeking comments on the frequency and duration of communication losses as well as potential technical solutions in the upcoming NPRM.

2.3 Union Pacific Railroad

2.3.1 Operational Testing

Following the accident, UP added the Laramie Subdivision to its grade operations audit list, conducting its first operations audit in March 2019. UP said that it plans to conduct annual operations audits of the Laramie Subdivision going forward. UP stated that prior to this accident, it conducted grade operations audits on territories that were over 3 miles long with grades over 1.8 percent. The grade operations audits included the following:

- Conducting reviews of incidents on grade territory throughout the industry.
- Reviewing the audit information with train crews prior to in-cab observations.
- Recording comments and findings after the trips are completed.
- Reviewing any instructions that are specific to that grade territory, usually found in the Subdivision page of the timetable.
- Further reviewing any recommendations or issues train crews believe should be addressed on grade territory over which they operate.

UP stated that the purpose of these audits is to ensure train crews understand grade operations and how they differ from other territories.

2.3.2 Mechanical Procedures

In December 2018, UP created and implemented training material that covered proper repair and inspection of railcar air hose arrangements. This training contained instruction on proper air hose supports, pinched air hoses, fittings, valves, brake rigging interference, wear marks, and dimensions.

In Green River, Wyoming, UP management revised the air brake testing procedures to meet the brake system safety standards for freight and other nonpassenger trains and equipment, ETDs, and requirements found in 49 *CFR* Part 232. The procedures now require a gauge (or equivalent) to be placed at the end of each cut of railcars to verify air pressure.

2.3.3 Radio Telemetry Repeaters

After the accident, UP installed 26 radio repeaters along the accident route and at a lower-density route nearby that runs from Dale Junction, Wyoming, to Speer, Wyoming. UP's goal was to provide continuous HTD/ETD repeater coverage between MP 520 and MP 545 on the Laramie Subdivision. UP focused on this area because the "high grade and winding track in this area create a challenging RF environment." To determine repeater placement, UP used RF propagation analysis software to model the radio locations that would provide continuous coverage throughout the targeted area.

3 Analysis

3.1 Introduction

On October 4, 2018, at 7:40 p.m. local time, eastbound UP freight train MGRCY04 collided with the rear of stationary UP freight train MPCNP03 after cresting a hill and descending a grade for about 13 miles. The striking train consisted of 3 leading locomotives and 105 railcars. The locomotive engineer and conductor of the striking train were killed, and 3 locomotives and railcars 1 through 57 of the striking train derailed the rear 5 railcars and the railcars positioned 8, 9, and 10 from the rear of the stationary train derailed. Prior to the accident, the crew of the striking UP freight train reported problems with the train's air brake system and radioed the UP Harriman Dispatch Center to advise them they had accelerated to 51 mph and were unable to stop. The UP Harriman Dispatch Center notified the crew of UP freight train MPCNP03 and advised them to evacuate the train to avoid possible injury from the runaway train. Damage was estimated by UP to be $3.2 million.

The NTSB found no evidence that any of the following contributed to the cause of the accident:

- **Train crew performance.** The crew of the striking train operated the train in accordance with UP operating rules and took appropriate actions in attempting to control the train's movement.
- **Train crew fitness-for-duty.** Based on the locomotive engineer's inputs that were recorded on the locomotive event recorder, as well as recorded radio communication of both crewmembers regarding the uncontrolled movement, the train crew did not appear to be impaired. Although potentially impairing substances were found in the conductor's blood during postaccident toxicology testing, investigators found no evidence that the conductor's medical condition or the impairing effects from his use of hydroxyzine and mitragynine played a role in the accident.
- **Train dispatcher actions.** A review of recorded radio communication revealed that the train dispatcher performed the required communications and took appropriate actions when notified of the runaway train.
- **Signal system.** The UP traffic control system functioned as designed.
- **Positive train control system.** The I-ETMS PTC system was operating as designed, but the train could not stop because the brakes were not functioning properly.
- **Track structure.** The FRA postaccident inspection of the accident site did not identify any track defects in the derailment footprint.

Based on these findings, the NTSB concludes that none of the following contributed to this accident: the performance or fitness-for-duty of the train crew, the actions of the train dispatcher, the signal or PTC system, or the track structure.

3.2 Train Brake Pipe Issues

There was no recorded data from the event recorder showing constant air flow prior to the striking train picking up the additional 19 railcars at Laramie, Wyoming; however, after the additional railcars were added and the air brakes were released, the recorded air flow that was being supplied to the train brake pipe stabilized at about 28 CFM. This happened only after the 19 railcars were added, indicating that a leak had been added to the system from those additional railcars.

While ascending the Sherman Hill grade, the air flow remained somewhat steady at 28 CFM. Before cresting the grade there is a slight dip in the track geometry that required the train crew to apply dynamic brakes to maintain proper speed while descending this portion of track.[54] While descending a grade with dynamic brakes only, all the slack is removed from between the mechanical couplers of each of the railcars that accumulated while ascending the grade and the slack then bunches up behind the locomotives. During this dip in track geometry and the bunching of railcars, the recorded air flow subsequently dropped to 0 CFM, which, as discussed in section 1.3.3, displays whenever the air flow drops below 20 CFM. After traversing this dip, the striking train began ascending Sherman Hill toward the crest. Again, the air flow returned to about 28 CFM. Upon cresting Sherman Hill, the striking train descended, heading toward the stationary train. While descending, the train crew applied dynamic braking again, subsequently bunching the railcars again. The recorded airflow again dropped below 20 CFM, displaying 0, and the train continued to accelerate. The train crew first applied service braking to control the train's speed. When that failed to slow the train, the train crew then applied the emergency brake which also failed to slow the train or put the train into emergency braking. The striking train continued down the grade where it ultimately collided with the stationary train at Granite Canyon, Wyoming.

As discussed in section 1.5.4, in November and December 2018, there were two incidents where kinked air hoses restricted air flow and interfered with application of the brakes throughout the train. These hoses were discovered to have been crushed between end hose arrangement brackets and a fixed object on the railcar. In those two incidents, one of the fixed components involved was the railcars' brake component, and the other was the railcars' draft arrangement bracket, as seen in figure 4. These two incidents restricted air from flowing to the rear of the train.

A detailed report from the cold wheel detector, located about 7 miles west of the accident site, indicated that axles 19-54 showed higher temperatures than the rest of the train's axles, evidence that only those axles were receiving the brake application. Axles 1-18 correspond to the axles on the three locomotives, and axles 19-54 would correspond with railcars 1-9 of the train consist, indicating that the brakes were not applied from railcar 10 through the end of the train. This is indicative that the air flow blockage was likely between the 9th and 10th railcars. The 10th railcar of the consist was the first gondola railcar and one of the railcars in the pickup that was overdue a SCABT.

Following the accident, NTSB investigators found multiple wheel sets toward the front of the train that showed signs of overheating and sliding, conditions such as bluing and flat spots.

[54] *Dynamic brakes* are electric brakes that only apply deceleration energy to the locomotives and not the railcars. They are used to decrease speed rather than stopping; however, they become less effective as the speed increases.

This indicates that only the brakes on the front of the train were functioning. Brake components in these railcars also showed signs of overheating with brake pad composition burned off to the metal backing plate and to the brake head. This is consistent with braking force occurring only in the locomotives and first nine cars. This, combined with the evidence from the cold wheel detector, indicates there was a restriction in the brake pipe during braking applications. When the brake pipe pressure reduction fails to propagate throughout the entire train due to a restriction, the brakes will only apply on the railcars from the locomotive to the blockage, in this case the first 10 railcars. With only a few railcars operating to slow or stop the train, the brake shoes for those railcars will show excessive wear and heat damage and the wheels will also show signs of overheating (bluing).

Based on this evidence, the NTSB concludes that the air flow from the brake pipe was restricted between the 9th and the 10th railcars in the consist, which prevented the air brake signal propagation through the entire train.

3.3 Single Railcar Air Brake Test

After departing Green River, Wyoming, with 86 railcars, the striking train was scheduled to stop in Laramie, Wyoming, to pick up an additional 19 railcars. Event recorder data from Green River, Wyoming, to Laramie, Wyoming, indicated that the striking train was operating with normal braking and acceleration events and air brake pressure was normal with no indications of abnormal air flow. In addition, recordings of the air flow coincide with normal air brake releases during train operations, including when descending the grade.

Six of the 10 gondola cars that were added to the train in Laramie were overdue a SCABT by a range of a few weeks to up to almost 2 years. All railcars are required by 49 *CFR* 232.305(b)(2) to receive a SCABT if a railcar is on a shop or repair track for any reason and has not received a SCABT within the previous 12 months. In addition, 49 *CFR* 232.305(c) requires that railcars receive a SCABT no less than every 5 years.

The AAR *Manual of Standards and Recommended Practices*, Standard S-486 states that the purpose of the SCABT device is to provide a means of making a general check on the condition of the brake equipment on railcars (AAR 2018). Part of this standard includes procedures for the inspection of the air brake hoses and other brake components. It also has partial procedures for testing the railcar for various mechanical issues. The NTSB concludes that had UP complied with the federal regulations outlined in 49 *CFR* 232.305 and conducted SCABTs on the six railcars picked up in Laramie that were overdue for testing, any defective conditions—including those which may have led to a restriction of brake pipe air flow—would likely have been identified and repaired prior to the railcars being put into service.

3.4 Communication Loss from HTD to ETD

The investigation determined both train telemetry devices were operating appropriately and within specifications. The loss of communication events captured on the locomotive event recorder and the locomotive computer data log were found to be associated with train length, track curvature, and physical terrain obstructions.

The HTD was transmitting at 8 watts of power and polling the ETD at least every 2 minutes. FRA regulations allowed the interval between checks of the communication link to be as long as every 10 minutes. Both AAR standards and FRA regulations specified that a communication failure message be displayed to a locomotive engineer after train telemetry communication had been lost for 16 minutes and 30 seconds or more.

The download from the computer log of the lead locomotive captured several loss of communication events between the HDT and the EDT. However, the duration of each individual event was less than 16 minutes and 30 seconds. Since each of these events lasted less than the minimum time duration requirement specified in FRA regulations and AAR standards, no indication of a loss of communication between the HTD and ETD was displayed to the locomotive engineer nor indicated on the event recorder.

According to event recorder data, the locomotive engineer initiated an emergency brake application at 7:34:56. Postaccident testing of the HTD indicated the HTD would transmit the emergency brake command to the ETD and transmit every second if the HTD did not receive an emergency command acknowledgment from the ETD. A front-to-rear loss of communication was recorded at 7:35:11, which was 15 seconds after the emergency brake application was initiated. The elapsed 15 seconds for the loss of communication indication to be displayed to the locomotive engineer was within the design specifications of the HTD.

Event recorder data does not differentiate between a loss of communication indication occurring due to 16 minutes and 30 seconds elapsed time between HTD and ETD communication, or due to 15 seconds elapsed time without an emergency brake command acknowledgement from the ETD. Therefore, NTSB investigators determined it was possible that a loss of communication between the HTD and ETD could have commenced 16 minutes and 30 seconds earlier, at 7:18:41. The amount of time that elapsed from the initiation of the emergency brake application until the accident was 5 minutes and 3 seconds.

A 1997 rulemaking based on the design of telemetry devices at that time discussed the 16 minutes and 30 seconds time frame before a loss of communication could be declared. However, technological advances such as improved battery design, air turbines and solar panels to extend the battery charge, and microprocessor-based systems with lower power consumption, have improved train telemetry device designs since the “Two-Way End-of-Train Telemetry Devices” rulemaking became effective on July 1, 1997 (*Federal Register*, 1997, 30461). The HTD involved in this accident was designed to check the ETD every 2 minutes and verify the communication link. In addition, the ETD was equipped with a turbine generator powered by the compressed air supplied by the locomotive for the brake system, which provided the capability to maintain a charge to the operating battery, thus ensuring a longer operating range of the device.

Based on the circumstances of this accident, the NTSB concludes that the communication protocol allowing 16 minutes and 30 seconds of time to elapse without alerting the crew of the inability to initiate emergency braking from the ETD is excessive. Therefore, the NTSB recommends that FRA revise 49 *CFR* Part 232 to require more frequent communication checks between HTDs and ETDs.

Since the HTD and ETD were found to be functioning properly after testing, it is presumed that RF interference occurred in the minutes prior to the accident. The NTSB concludes that the length of the train, curvature of the track, and obstructions due to physical terrain contributed to the loss of communication between the HTD and the ETD. Therefore, the NTSB recommends that AAR and ASLRRA alert their member carriers to (1) conduct analysis of radio frequency propagation in grade territories over which they operate to identify areas where HTD-ETD communication may be lost and (2) make remediations to provide continuous HDT-EDT communication.

3.5 Transmission of Emergency Commands

The train's HTD was designed to transmit an emergency brake application to the ETD for 2 minutes after an emergency brake application is initiated. If the HTD does not receive a reply confirmation message from the ETD, transmission of the emergency brake command would stop until another emergency brake application was initiated. If the locomotive engineer initiated another emergency brake application during the 2-minute time frame, the 2-minute window would not be extended. After that 2-minute window, the HTD would not automatically send an emergency brake command to the ETD. A locomotive engineer would have to attempt an additional emergency brake application no sooner than 2 minutes after the initial emergency brake application to initiate an ETD emergency brake command.

The NTSB concludes that the emergency brake command needs to be transmitted until received by the ETD, rather than being terminated after 2 minutes. Therefore, the NTSB recommends FRA require that the emergency brake signal transmission is repeated until received by the ETD. Furthermore, the NTSB recommends that the AAR revise its *Manual of Standards and Recommended Practices, Locomotive Electronics and Train Consist System Architecture*, Standard S-9152.v2.2, Paragraph 3.8.8 to develop a communication protocol that will continue to transmit an emergency air brake command to the ETD until a confirmation message or a decrease in brake pipe pressure message is received by the HTD.

3.6 Train Braking Systems

3.6.1 Pneumatic Brakes

Train braking systems today rely on a pneumatic brake system that uses brake pipe air pressure both to transmit the braking signal and to charge the air reservoir on each railcar in the train. A reduction in brake pipe air pressure causes a valve on each railcar to admit compressed air from the reservoir into the brake cylinder, resulting in a brake application. Three important limitations with this system are: it does not permit the railcar reservoirs to be recharged while the brakes are being applied, gradual railcar brake release is unavailable, and a brake pipe restriction may block the brake control signal, disabling brake application for railcars beyond the restriction. The last limitation occurred in this collision in Granite Canyon.

According to a 2006 report completed by Booz Allen Hamilton for the FRA, when the locomotive engineer applies the brakes, a brake pipe pressure reduction is initiated at the locomotive creating a pressure wave in the brake pipe that propagates down the length of the train at about two-thirds the speed of sound (FRA 2006). As the pressure reduction wave reaches each railcar, a control valve on the railcar activates a brake cylinder, which causes the brake shoes to apply to the wheels. On a train operating with a conventional air brake system, that is, with locomotives on the lead end only, the railcar brake application process is repeated sequentially until the air pressure reduction reaches the last railcar of the train. On trains operating with a two-way EOT device or with a trailing distributed power (DP) configuration, the propagation time for the air signal in the brake pipe to command all railcars to apply their brakes is reduced by about one-half.

The conventional pneumatic brake system has the powerful advantage of simplicity—it requires no additional electrical path (via train length cable or radio communication) or power supply on each railcar to apply the brakes, release the brakes, or charge the air reservoir. However, it also has the disadvantages of time delays for the brake application or release command to propagate along the brake pipe to each railcar, sequential railcar brake application, potentially incompatible in-train forces between braked and unbraked railcars, no option for gradual brake release, and the risk of a brake application communication failure due to a brake pipe blockage (such as the kinked or blocked air hose segment evidence discovered in this accident investigation).

Conventional air brake disadvantages are partially mitigated with the use of advanced train braking configurations, including DP, an EOT, and/or midtrain devices (MTD). Use of DP can directly reduce undesirable or incompatible in-train forces and provide parallel brake pipe access paths to communicate service and emergency brake applications, communicate service brake release requests, and supply the brake pipe with compressed air from the locomotive consist(s). Use of MTDs or an ETD can also provide parallel brake pipe access paths to communicate emergency brake application requests and can reduce equipment and track exposure to incompatible in-train forces.

Reliable radio communications are required between the lead locomotive consist and the DP locomotive(s), the ETD, or the MTD(s) to mitigate the conventional air brake disadvantages described above. Unfortunately, the quality of radio communications along the train length may vary due to track grade, track curvature, or local terrain obstructions or reflections, creating intermittent communication gaps (such as the extended radio communication gap between the lead locomotive consist and the ETD documented during this accident investigation).

3.6.2 ECP Brakes

ECP brakes are the most advanced train braking systems available for the freight rail industry today. ECP brake systems simultaneously send an electronic braking command to all equipped railcars in the train. All railcars and controlling locomotives in the train must be ECP equipped for the ECP brake system to work. ECP brakes can be installed as an overlay so that an equipped train can be operated either in ECP mode or pneumatic mode. Alternatively, ECP brakes can be installed in an ECP-only configuration so that the brakes on an equipped railcar will respond only to ECP signals or an emergency loss of brake pipe pressure.

According to a 2006 report completed by Booz Allen Hamilton for the FRA, the simultaneous application of ECP brakes in response to a locomotive engineer setting the brakes on all railcars in a train improves train handling during normal operations by substantially reducing stopping distances as well as by reducing longitudinal in-train forces acting along the train length as the train speeds up, slows down, or reacts to changes in grade and track curvature (FRA 2006).

ECP brake systems overcome the conventional pneumatic brake system disadvantages and the intermittent radio communications coverage problems associated with the use of DP locomotives, ETDs, and MTDs by adding an independent train-length electrical cable that continuously supports primary communications between the lead locomotive consist and each railcar. Brake application and release requests are communicated at the speed of light (nearly instantaneous) as opposed to the speed of sound, gradual railcar brake release is available, brake system status can be queried by the crew on an individual railcar basis, and the train brake pipe is available to continuously charge the air reservoir on each railcar.

In July 2015, the NTSB published its *Train Braking Simulation Study* to quantify the expected stopping distance of a train as a function of train braking type (conventional pneumatic, DP, or ECP) and a range of parameters including train mass, train speed, and track grade. Five different crude oil unit train consists were modeled in this study, with train lengths ranging from 78 to 156 railcars, speeds ranging from 10 to 60 mph, and track grades ranging from -2 to +2 percent (NTSB 2015).[55] The scope of the braking simulation study was limited to scenarios with a train line emergency initiated at the head-end locomotive on uniform grade tangent track with clean, dry rail. The trains were assumed to have no inoperative locomotives, no inoperative brakes, no wheel or railcar derailments, no collisions among railcars or with other obstacles, and no loss of communications among applicable electronic devices.

The study showed the benefits of advanced train braking systems come from three sources: reduced stopping distances (fewer railcars in a potential pileup), reduced vehicle kinetic energy (less energy available to puncture railcars in a pileup), and lower and more uniform in-train coupler forces (more compatible railcar-to-railcar interaction). Many railroads, including UP and BNSF, use DP locomotives to enable longer trains with the added benefits of improved in-train forces and braking performance.

3.6.3 ECP Systems in Use

According to a 2017 Government Accountability Office (GAO) report on ECP braking, railroads in the United States began testing and operating with ECP brakes as early as 1995. UP started using ECP brakes in limited operations in 1995. In 2007, FRA granted a waiver to some railroads allowing them to operate trains with ECP brakes on a limited basis for longer distances between brake inspections than required by FRA regulations for trains with conventional air brakes—3,500 miles for trains using ECP brakes compared to 1,000 miles for trains using conventional brakes. In 2008, FRA published a final rule that adopted the 3,500-mile distance between brake inspections for trains using ECP brakes (*Federal Register*, 2008, 61512). In 2010, FRA issued a new waiver to BNSF and Norfolk Southern, allowing them to jointly operate a train with ECP brakes for 5,000 miles between brake inspections. Those railroads jointly operated an ECP-equipped train from January 2015 to June 2016 under this waiver. However, despite the benefits of ECP brakes that the US Department of Transportation (DOT) described in its final rule,

[55] A *unit train* typically consists of the same railcar type, carries the same commodity in all railcars, and all railcars are shipped from the same origin to the same destination.

four of the five Class I railroads that have used ECP brakes no longer do so, and as of June 2016, only one Class I railroad operated trains with ECP brakes (GAO 2016). The NTSB is not aware of any freight railroad regularly operating an ECP-equipped train in the United States today. FRA recently reported that with the exception of one Amtrak (National Railroad Passenger Corporation) test train authorized to operate with ECP brakes, there are no ECP-equipped trains currently operating in the United States.

3.6.4 ECP Discussion

Advanced train brake systems can provide a significant safety advantage for freight trains. In this accident, the constant communication and continuity of an ECP-equipped train braking system could have prevented this accident. Although current ECP brake technology has been designed, field tested, and service proven, it has only been tested for unit trains in the United States, not mixed freight trains as was the case in this collision. According to a 2016 GAO report, the ECP braking systems stopped being used primarily due to reliability issues (GAO 2016).

As discussed in section 1.8, a train equipped with an ECP braking system uses electrical cabling to send braking commands to all railcars and conventional air brake equipment to apply and release the brakes. The ECP system searches for air brake restrictions by performing self-diagnostic testing on each railcar and sending a status message to the locomotive engineer. If a disconnect occurs in the cabling that goes through each railcar, the ECP system will detect it and initiate an emergency brake application. The ECP brake signal travels through an electric cable independent of the brake pipe, so an air flow restriction in the brake pipe would not affect the train's ability to apply all the railcar brakes. The NTSB concludes that had the striking train been equipped with ECP technology, the emergency brake commands would have been received through the entire train, thereby applying the brakes on each railcar of the train, likely preventing the accident.

4 Conclusions

4.1 Findings

1. None of the following contributed to this accident: the performance or fitness for duty of the train crew, the actions of the train dispatcher, the signal or positive train control system, or the track structure.

2. The air flow from the brake pipe was restricted between the 9th and the 10th railcars in the consist, which prevented the air brake signal propagation through the entire train.

3. Had Union Pacific Railroad complied with the federal regulations outlined in Title 49 *Code of Federal Regulations* 232.305 and conducted single railcar air brake tests on the six railcars picked up in Laramie that were overdue for testing, any defective conditions—including those which may have led to a restriction of brake pipe air flow—would likely have been identified and repaired prior to the railcars being put into service.

4. The communication protocol allowing 16 minutes and 30 seconds of time to elapse without alerting the crew of the inability to initiate emergency braking from the end-of-train device is excessive.

5. The length of the train, curvature of the track, and obstructions due to physical terrain contributed to the loss of communication between the head-of-train device and the end-of-train device.

6. The emergency brake command needs to be transmitted until received by the end-of-train device, rather than being terminated after 2 minutes.

7. Had the striking train been equipped with electronically controlled pneumatic brake system technology, the emergency brake commands would have been received through the entire train, thereby applying the brakes on each railcar of the train, likely preventing the accident.

4.2 Probable Cause

The National Transportation Safety Board determines that the probable cause of the collision was the failure of the Union Pacific train MGRCY04 air brake system due to an air flow restriction in the brake pipe and the failure of the end-of-train device to respond to an emergency brake command. Contributing to the accident was the failure of Union Pacific Railroad to maintain the railcars in accordance with federal regulations, including regularly performing single railcar air brake tests. Further contributing to the accident were communication protocols, set by Federal Railroad Administration regulations and industry standards, that allowed extended time intervals for loss of communication notification between the head-of-train device and the end-of-train device without warning the train crew of the loss of communication.

5 Recommendations

5.1 New Recommendations

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

To the Federal Railroad Administration:

1. Revise Title 49 *Code of Federal Regulations* Part 232 to require more frequent communication checks between a head-of-train device and an end-of-train device. (R-20-28)

2. Require that the emergency brake signal transmission is repeated until received by the end-of-train device. (R-20-29)

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

3. Alert your member carriers to (1) conduct analysis of radio frequency propagation in grade territories over which they operate to identify areas where head-of-train device and end-of-train device communication may be lost and (2) make remediations to provide continuous head-of-train device and end-of-train device communication. (R-20-30)

To the Association of American Railroads:

4. Revise your *Manual of Standards and Recommended Practices, Locomotive Electronics and Train Consist System Architecture*, Standard S-9152.v2.2, Paragraph 3.8.8 to develop a communication protocol that will continue to transmit an emergency air brake command to the end-of-train device until a confirmation message or a decrease in brake pipe pressure message is received by the head-of-train device. (R-20-31)

5.2 Previously Issued Recommendations

On September 16, 2019, the National Transportation Safety Board issued the following safety recommendations:

To the Class I Railroads:

1. Review and issue guidance as necessary for the inspection of end-of-railcar air hose configurations to ensure the air hose configuration matches the intended design. (R-19-41)

As of October 2020, this safety recommendation was classified "Open—Await Response" for BNSF, Canadian Pacific Railway, Norfolk Southern Railroad, and UP; "Open—Acceptable Response" for Canadian National Railway and Kansas City Southern Railway; and "ClosedAcceptable Action" for Amtrak and CSX Railroad.

2. Review and revise your air brake and train handling instructions for grade operations and two-way end-of-train device instructions to include: monitoring locomotive air flow meters, checking the status of communication between the head-of-train and end-of train devices before cresting a grade, and the actions to take if the air pressure at the rear of the train does not respond to an air brake application. (R-19-42)

As of October 2020, this safety recommendation was classified "Open—Await Response" for BNSF, Canadian Pacific Railway, Norfolk Southern Railroad, and UP; "Open—Acceptable Response" for Canadian National Railway, CSX Railroad, and Kansas City Southern Railway; and "Closed—Acceptable Action" for Amtrak.

To the American Short Line and Regional Railroad Association

3. Alert your member carriers to (1) inspect the end-of-railcar air hose configurations to ensure the hose configurations match the intended design and (2) review and revise their air brake and train handling instructions for grade operations and two-way end-of-train device instructions to include: monitoring locomotive air flow meters, checking the status of communication between the head-of-train and end-of-train devices before cresting a grade, and the actions to take if the air pressure from the rear of the train does not respond to an air brake application. (R-19-43)

On March 9, 2020, Safety Recommendation R-19-43 was classified "Closed—Acceptable Action."

BY THE NATIONAL TRANSPORTATION SAFETY BOARD

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Date: December 29, 2020

Appendixes

Appendix A. The Investigation

The National Transportation Safety Board (NTSB) was notified on October 4, 2018, that eastbound Union Pacific Railroad (UP) freight train MGCY04 had collided with the rear of stationary UP freight train MPCNP03 in Granite Canyon, Wyoming. The NTSB launched an investigator-in-charge and three investigative team members to investigate the accident on October 5, 2018.

Parties to the investigation included UP, the Federal Railroad Administration, the Brotherhood of Locomotive Engineers and Trainmen, and the International Sheet Metal, Air, Rail, and Transportation Workers-Transportation Division.

Appendix B. Consolidated Recommendation Information

Title 49 *United States Code* (*USC*) 1117(b) requires the following information on the recommendations in this report.

For each recommendation—

(1) a brief summary of the Board's collection and analysis of the specific accident investigation information most relevant to the recommendation;

(2) a description of the Board's use of external information, including studies, reports, and experts, other than the findings of a specific accident investigation, if any were used to inform or support the recommendation, including a brief summary of the specific safety benefits and other effects identified by each study, report, or expert; and

(3) a brief summary of any examples of actions taken by regulated entities before the publication of the safety recommendation, to the extent such actions are known to the Board, that were consistent with the recommendation.

To the Federal Railroad Administration:

Revise Title 49 *Code of Federal Regulations* Part 232 to require more frequent communication checks between a head-of-train device and an end-of-train device. (R-20-28)

Information that addresses the requirements of 49 *USC* 1117(b), as applicable, can be found in section 3.4 Communication Loss from HTD to ETD. Information supporting (b)(1) can be found in section 3.4 Communication Loss from HTD to ETD; (b)(2) is not applicable; and (b)(3) is not applicable.

Require that the emergency brake signal transmission is repeated until received by the end-of-train device. (R-20-29)

Information that addresses the requirements of 49 *USC* 1117(b), as applicable, can be found in section 3.5 Transmission of Emergency Commands. Information supporting (b)(1) can be found in section 3.5 Transmission of Emergency Commands; (b)(2) is not applicable; and (b)(3) can be found on page 25.

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

Alert your member carriers to (1) conduct analysis of radio frequency propagation in grade territories over which they operate to identify areas where head-of-train device and end-of-train device communication may be lost and (2) make remediations to provide continuous head-of-train device and end-of-train device communication. (R-20-30)

Information that addresses the requirements of 49 *USC* 1117(b), as applicable, can be found in section 3.4 Communication Loss from HTD to ETD. Information supporting (b)(1) can be found section 3.4 Communication Loss from HTD to ETD; (b)(2) is not applicable; and (b)(3) is not applicable.

To the Association of American Railroads:

Revise your *Manual of Standards and Recommended Practices, Locomotive Electronics and Train Consist System Architecture*, Standard S-9152.v2.2, Paragraph 3.8.8 to develop a communication scheme that will continue to transmit an emergency air brake command to the end-of-train device until a confirmation message or a decrease in brake pipe pressure message is received by the head-of-train device. (R-20-31)

Information that addresses the requirements of 49 *USC* 1117(b), as applicable, can be found in section 3.5 Transmission of Emergency Commands. Information supporting (b)(1) can be found in section 3.5 Transmission of Emergency Commands; (b)(2) is not applicable; and (b)(3) is not applicable.

Appendix C. Locomotive Computer Log

The following table lists the information from the computer log for the lead locomotive of UP striking train MGCY04.

Table 3. UP locomotive 5412 computer log.

Occur Time(GMT)	Reset Date	Fault Code	Incident Description	GPS Latitude	GPS Longitude	Speed
10/05/18 01:35:11		32-0005	ETD Front to Rear Comm Loss	41:5:59.2	-105:12:1.1	29.9
10/05/18 01:34:55	10/05/18 01:35:11	32-0009	ETD Emergency Commanded	41:5:56.6	-105:12:9.3	28.89
10/05/18 00:51:33	10/05/18 00:51:34	32-0006	ETD Front to Rear Comm Loss Restored	41:4:53.0	-105:25:39.0	25.6
10/05/18 00:47:48	10/05/18 00:51:32	32-0005	ETD Front to Rear Comm Loss			
10/05/18 00:25:19	10/05/18 00:25:20	32-0006	ETD Front to Rear Comm Loss Restored	41:6:51.2	-105:29:46.9	5.86
10/05/18 00:24:51	10/05/18 00:25:18	32-0005	ETD Front to Rear Comm Loss	41:6:53.6	-105:29:47.0	5.83
10/04/18 23:43:58	10/04/18 23:43:59	32-0006	ETD Front to Rear Comm Loss Restored	41:10:0.2	-105:32:39.4	12.83
10/04/18 23:38:52	10/04/18 23:43:57	32-0005	ETD Front to Rear Comm Loss	41:10:52.7	-105:32:54.9	12.86
10/04/18 22:56:21	10/04/18 22:56:22	32-0006	ETD Front to Rear Comm Loss Restored	41:18:31.5	-105:35:48.8	0.43
10/04/18 22:53:17	10/04/18 22:56:20	32-0005	ETD Front to Rear Comm Loss	41:18:31.5	-105:35:48.8	0
10/04/18 21:18:21	10/04/18 22:08:14	32-0010	ETD Emergency Confirmed			
10/04/18 21:18:19	10/04/18 21:18:21	32-0009	ETD Emergency Commanded	41:18:23.4	-105:35:51.1	0
10/04/18 19:56:05	10/04/18 19:56:05	32-0006	ETD Front to Rear Comm Loss Restored	41:27:58.7	-105:37:51.1	29.64
10/04/18 19:53:00	10/04/18 19:56:04	32-0005	ETD Front to Rear Comm Loss	41:29:13.0	-105:38:35.6	31.79
10/04/18 11:34:42	10/04/18 11:34:44	32-0006	ETD Front to Rear Comm	41:41:40.9	-107:49:36.7	21.28

Occur Time(GMT)	Reset Date	Fault Code	Incident Description	GPS Latitude	GPS Longitude	Speed
			Loss Restored			
10/04/18 11:33:14	10/04/18 11:34:42	32-0005	ETD Front to Rear Comm Loss	41:41:53.2	-107:50:9.9	22.57
10/04/18 10:52:44	10/04/18 10:52:45	32-0006	ETD Front to Rear Comm Loss Restored	41:37:27.2	-108:19:46.7	36.2
10/04/18 10:52:18	10/04/18 10:52:44	32-0005	ETD Front to Rear Comm Loss	41:37:23.2	-108:20:4.2	36.94

Appendix D. Rules and Regulations Regarding Train Telemetry

Federal Railroad Administration

Federal Railroad Administration (FRA) minimum safety standards regarding end-of-train devices can be found in Title 49 *Code of Federal Regulations* Part 232. Passages of particular relevance to this investigation are listed below.

Title 49 *CFR* 232.405

(3)(a) An emergency brake application command from the front unit of the device shall activate the emergency air valve at the rear of the train within one second.

(g) The availability of the front-to-rear communications link shall be checked automatically at least every 10 minutes.

Title 49 *CFR* 232.407

(g) …With regard to two-way end-of-train devices, a loss of communication between the front and rear units is an enroute failure only if the loss of communication is for a period greater than 16 minutes and 30 seconds. Based on the existing design of the devices, the display to a locomotive engineer of a message that there is a communication failure indicates that communication has been lost for 16 minutes and 30 seconds or more.

AAR Industry Standards

The AAR *Manual of Standards and Recommended Practices, Locomotive Electronics and Train Consist System Architecture*, Standard S-9152, contains the requirements for communication systems between the lead locomotive and the rear railcar of freight trains (AAR 2016).

Paragraph 2.1 Basic System Rear Unit (End-of-Train Device)

The rear unit shall determine the status of brake pipe pressure value and transmit this information to the cab unit for display to the locomotive engineer. The rear unit shall be designed for continuous duty service on the rear of trains. The design of the rear unit shall consider the nature and consequences of possible system failure modes in such a way that a fault tolerant design results.

Paragraph 2.1.7 Rear Unit Identification Provisions

Each rear unit will be assigned a unique identification code that will be transmitted along with the pressure threshold message to the cab unit. This code ensures that only data transmitted from the assigned rear unit will be accepted by the cab unit. In this way, rear unit messages from adjacent trains will be rejected by the cab unit. In order to maintain the interchangeability between rear units and cab units, the identification code must be reported and selected at the cab unit prior to the start of any train trip.

Paragraph 2.2 Basic System Cab Unit (Head-of-Train Device)

The cab unit shall receive data messages from the rear unit and display information to the locomotive engineer. The receiver and cab display unit located in the locomotive cab shall be designed for continuous duty service. The design of the cab unit shall consider the nature and consequences of possible system failure modes so that a fault-tolerant design results.

Paragraph 3.2 Brake Application

The front-to-rear transmission and rear-of-train equipment shall provide for application of train emergency air brakes, upon emergency train brake application by the locomotive engineer.

The front-to-rear transmission and rear-of-train equipment shall provide for application of train emergency air brakes upon manual selection by the locomotive engineer.

3.2.1 An emergency brake application command from the front unit must activate the emergency air valve typically within 1 second.

3.2.2 The rear unit shall send an acknowledgment message to the front unit immediately upon receipt of a brake application command. The front unit shall listen for this acknowledgment and repeat the brake application command if the acknowledgment is not correctly received.

3.2.3 The rear unit, on receipt of a properly coded command, will open a valve in the brake line and hold it open for a minimum of 15 seconds. This opening of the valve shall cause the brake line to vent to atmosphere.

Paragraph 3.8.6 Rear-to-Front Communications Failure

3.8.6.1 The cab unit shall declare a rear-to-front communications failure on rear-to-front radio link failures lasting for a duration of 5 minutes or greater. Rear-to-front radio link failures lasting less than 5 minutes shall not be declared as rear-to-front failures. This alarm shall be cleared on receipt of a valid EOT message on the selected ID.

Exception: Rear-to-Front Communications Failure shall not be declared when ID is set to 00000.

3.8.6.2 Display or indication of front-to-rear communication failure shall take precedence over rear-to-front communication failure.

Paragraph 3.8.7 Front-to-Rear Communications Failure

3.8.7.1 The cab unit shall declare a front-to-rear communications failure on front-to-rear radio link failures lasting for a duration of 16 minutes 30 seconds or greater. Front-to-rear radio link failures lasting less than 16 minutes 30 seconds shall not be declared as front-to-rear failures. This alarm will be cleared by the next successful front-to-rear/rear-to-front confirmation cycle (automatically or manually initiated). Minimum polling of at least once every 2 minutes must be maintained or as often as necessary to minimize loss of front-to-rear communications exceeding the 16 minute 30 second limit.

Exception: Front-to-Rear Communications Failure shall not be declared when ID is set to 00000.

3.8.7.2 This warning will be reset by the next successful front-to-rear/rear-to-front confirmation cycle (automatically or manually initiated).

3.8.7.3 A front-to-rear communication failure shall also be tested and declared during an attempted emergency activation paragraph 3.8.1.

<u>Paragraph 3.8.8 Front-to-Rear Message Retries</u>

The cab unit will handle data message retries as follows:

3.8.8.1 For emergency brake application commands, the retries will continue until a status update indicates that the rear unit has received the command by setting the confirmation bit in the update. Thereafter, if the rear brake pipe pressure has not been reduced to a level below 5 psi within 4 seconds, another retry will be made and again the confirmation bit looked for. This process will repeat up to a maximum time of 2 minutes after the last emergency switch activation. If a confirmation bit has not been received within 15 seconds of the initial or a 4-second retry emergency command, front-to-rear communication failure will be declared.

References

AAR (Association of American Railroads). 2018. *Manual of Standards and Recommended Practices, Section E, Code of Air Brake System Tests for Freight Equipment–Single Car Test, Standard S-486*. (Washington, DC: AAR).

----. 2018a. *Intermodal Interchange Rules Including Billing and Repair Procedures*. September 1, 2018. (Washington, DC: AAR).

----. 2016. *Manual of Standards and Recommended Practices, Section K, Part II, Standard S-9152.* (Washington, DC: AAR).

FR (*Federal Register*). 2020. Vol. 85, no. 10 (January 15).

----. 2008. Vol. 73, no. 201 (October 16).

----. 1997. Vol. 62, no. 107 (June 4).

----. 1996. Vol. 61, no. 35 (February 21).

----. 1994. Vol. 59, no. 179 (September 16).

FRA (Federal Railroad Administration). 2006. *ECP Brake System for Freight Service* Final Report, completed by Booz Allen Hamilton. (Washington, DC: US Department of Transportation, FRA).

GAO (Government Accountability Office). 2016. *Train Braking: DOT's Rulemaking on Electronically Controlled Pneumatic Brakes Could Benefit from Additional Data and Transparency*. GAO-17-22. (Washington, DC: GAO).

NTSB (National Transportation Safety Board). 2019. *Train Emergency Brake Communication*. RSR-19/02. (Washington, DC: NTSB).

----. 2015. *Train Braking Simulation Study.* (Washington, DC: NTSB).

UP (Union Pacific Railroad). 2018. *UP Air Brake and Train Handling Rules*. Updated September 19, 2018. (Omaha, Nebraska: UP).