

Collision Between Two Massachusetts Bay
Transportation Authority Green Line Trains
Newton, Massachusetts
May 28, 2008



Accident Report

NTSB/RAR-09/02
PB2009-916302



**National
Transportation
Safety Board**

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PB2009-916302
Notation 8126A
Adopted July 14, 2009

Railroad Accident Report

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**National
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Safety Board**

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

National Transportation Safety Board. 2009. *Collision Between Two Massachusetts Bay Transportation Authority Green Line Trains, Newton, Massachusetts, May 28, 2008*. Railroad Accident Report NTSB/RAR-09/02. Washington, DC.

Abstract: On May 28, 2008, about 5:51 p.m., eastern daylight time, westbound Massachusetts Bay Transportation Authority Green Line train 3667, traveling about 38 mph, struck the rear of westbound Green Line train 3681, which had stopped for a red signal. The accident occurred in Newton, Massachusetts, a suburb of Boston. Each train consisted of two light rail trolley cars and carried two crewmembers—a train operator at the front of the lead car and a trail operator in the second car. The operator of the striking train was killed; the other three crewmembers sustained minor injuries. An estimated 185 to 200 passengers were on the two trains at the time of the collision. Of these, four sustained minor injuries, and one was seriously injured. Total damage was estimated to be about \$8.6 million.

In the course of its investigation of this accident, the NTSB identified the following safety issues: lack of a positive train control system on the Massachusetts Bay Transportation Authority light rail system, lack of coordination between crewmembers on Massachusetts Bay Transportation Authority light rail trains with regard to signal indications, inadequate requirements for Massachusetts Bay Transportation Authority train operators to report possible signal malfunctions, and lack of screening of rail transit operators for possible obstructive sleep apnea. As a result of its investigation of this accident, the NTSB makes recommendations to the Federal Transit Administration, all U.S. rail transit agencies, and the Massachusetts Bay Transportation Authority. The National Transportation Safety Board also reiterates one safety recommendation to the Massachusetts Bay Transportation Authority.

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Acronyms and Abbreviations

BMI	body mass index
DOT	U.S. Department of Transportation
FMCSA	Federal Motor Carrier Safety Administration
FTA	Federal Transit Administration
MBTA	Massachusetts Bay Transportation Authority
NTSB	National Transportation Safety Board
US&S	Union Switch & Signal

Executive Summary

On May 28, 2008, about 5:51 p.m., eastern daylight time, westbound Massachusetts Bay Transportation Authority Green Line train 3667, traveling about 38 mph, struck the rear of westbound Green Line train 3681, which had stopped for a red signal. The accident occurred in Newton, Massachusetts, a suburb of Boston. Each train consisted of two light rail trolley cars and carried two crewmembers—a train operator at the front of the lead car and a trail operator in the second car. The operator of the striking train was killed; the other three crewmembers sustained minor injuries. An estimated 185 to 200 passengers were on the two trains at the time of the collision. Of these, four sustained minor injuries, and one was seriously injured. Total damage was estimated to be about \$8.6 million.

The National Transportation Safety Board determines that the probable cause of the May 28, 2008, collision of two Massachusetts Bay Transportation Authority Green Line trains in Newton, Massachusetts, was the failure of the operator of the striking train to comply with the controlling signal indication, likely as a result of becoming disengaged from her environment consistent with experiencing an episode of micro-sleep. Contributing to the accident was the lack of a positive train control system that would have intervened to stop the train and prevent the collision.

The safety issues identified during this accident investigation are as follows:

1. Lack of a positive train control system on the Massachusetts Bay Transportation Authority light rail system,
2. Lack of coordination between crewmembers on Massachusetts Bay Transportation Authority light rail trains with regard to signal indications,
3. Inadequate requirements for Massachusetts Bay Transportation Authority train operators to report possible signal malfunctions, and
4. Lack of screening of rail transit operators for possible obstructive sleep apnea.

As a result of its investigation of this accident, the National Transportation Safety Board makes recommendations to the Federal Transit Administration, all U.S. rail transit agencies, and the Massachusetts Bay Transportation Authority. The National Transportation Safety Board also reiterates one safety recommendation to the Massachusetts Bay Transportation Authority.

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Factual Information

Synopsis

On May 28, 2008, about 5:51 p.m., eastern daylight time,¹ westbound Massachusetts Bay Transportation Authority (MBTA) Green Line train 3667, traveling about 38 mph, struck the rear of westbound MBTA Green Line train 3681, which had stopped for a red signal. The accident occurred in Newton, Massachusetts, a suburb of Boston. (See figure 1.) Each train consisted of two light rail trolley cars² and carried two crewmembers—a train operator at the front of the lead car and a trail operator in the second car. The operator of the striking train was killed; the other three crewmembers sustained minor injuries. An estimated 185 to 200 passengers were on the two trains at the time of the collision. Of these, four sustained minor injuries, and one was seriously injured. Total damage was estimated to be about \$8.6 million.

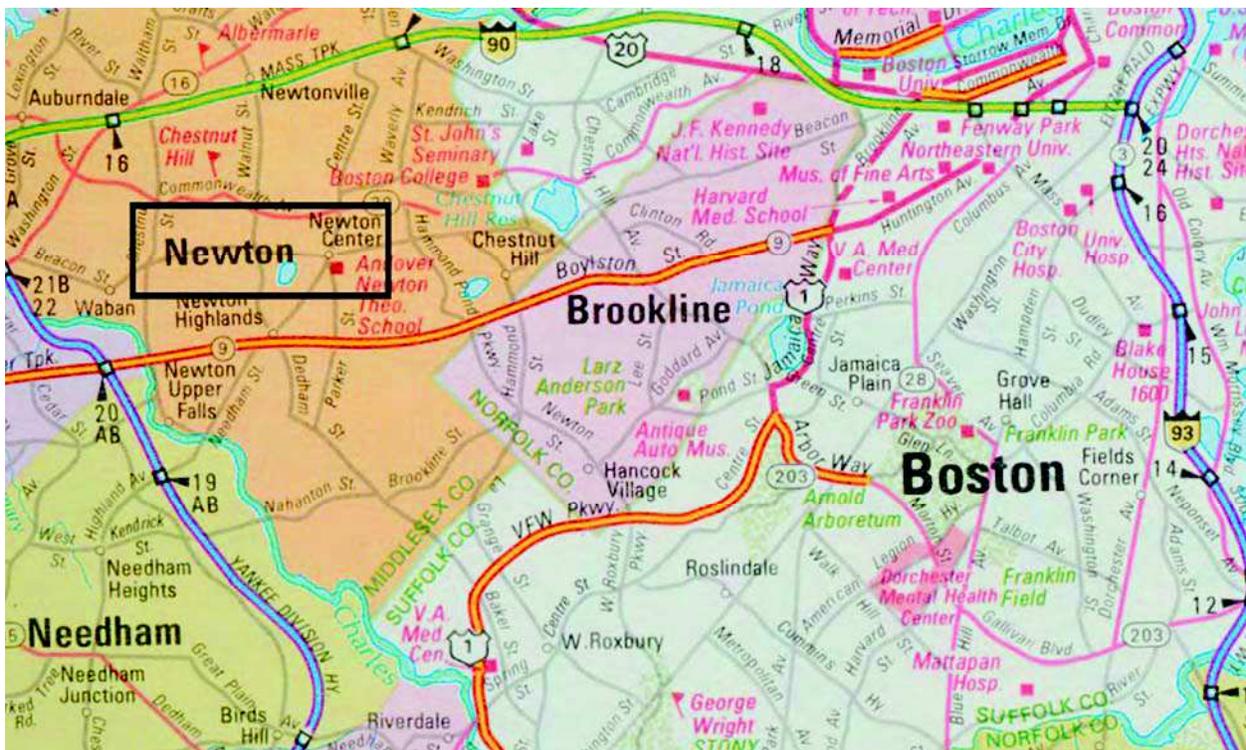


Figure 1. Accident location.

¹ All times referred to in this report are eastern daylight time.

² The two cars, which were permanently coupled and traveled as a unit, actually constituted a single No. 7 surface railcar. For the purposes of this report, each such unit involved in this accident will be referred to as a “train” consisting of two cars with individual car numbers.

The Accident

On May 28, 2008, the two crewmembers (the operator and the trail operator³) of train 3681 (the struck train) reported for their second tour of duty of the day⁴ at 2:52 p.m. and 2:50 p.m., respectively, in Riverside, Massachusetts. The operator and the trail operator of train 3667⁵ (the striking train) reported for their afternoon tours of duty at 4:35 p.m., also at Riverside. Both crews operated on the D Branch of the MBTA Green Line from Riverside eastward to Government Center in Boston, where the trains moved around a loop track then returned westward to Riverside. Both trains consisted of two light rail trolley cars. (See figure 2.)



Figure 2. Two-car MBTA Green Line train similar to the two trains involved in this accident.

(Photo copyright Richard Panse <<http://world.nycsubway.org/us/boston/index.html>>)

³ The operator in the lead car runs the train while the trail operator in the last car operates the doors and makes announcements over the public address system.

⁴ All of the train operators involved in this accident worked split shifts. They operated trains during the morning-to-noontime rush periods then returned for the evening rush.

⁵ Train numbers are derived from the number of the lead car.

The trail operator of the striking train said that when he and the operator reported for work, an inspector certified them as fit for duty. He said he had noticed nothing unusual about the operator's demeanor, behavior, appearance, or attitude. He said that when he and the operator took charge of their train, they performed a cursory visual inspection before departing. During the first several miles of the run, they conducted a successful brake test. The trail operator said that he had noted a problem with the public address system in that he was unable to override the automatic prerecorded announcements to make modifications regarding station stops or to provide other information. He stated that he had attempted to call both the train operator and the operations center on the radio to notify them of the problem with the public address system but that he could not reach either party. This suggested to him that the radio might be malfunctioning.

Crewmembers of the struck train reported nothing out of the ordinary during their afternoon run until about 5:50 p.m., when the train operator observed that signal H-66, about 1,666 feet west of Waban station, was displaying a single red aspect. (See figure 3.) MBTA rules state that a train encountering such a signal must stop and hold short of the signal for 1 minute before proceeding at restricted speed not to exceed 10 mph while being prepared to stop short of a car, train, or other obstruction. The operator of the struck train stated that he held his train for the specified time even though the track ahead was clear and he saw no reason for the red signal. The operator told National Transportation Safety Board (NTSB) investigators that he had encountered a red aspect at signal H-66 with the track ahead clear on one of his morning runs on the day of the accident. He stated that at that time he reported the red signal to the Operations Control Center and was told that it had been previously reported; however, there was no MBTA record of a trouble report being filed for the signal at this location.

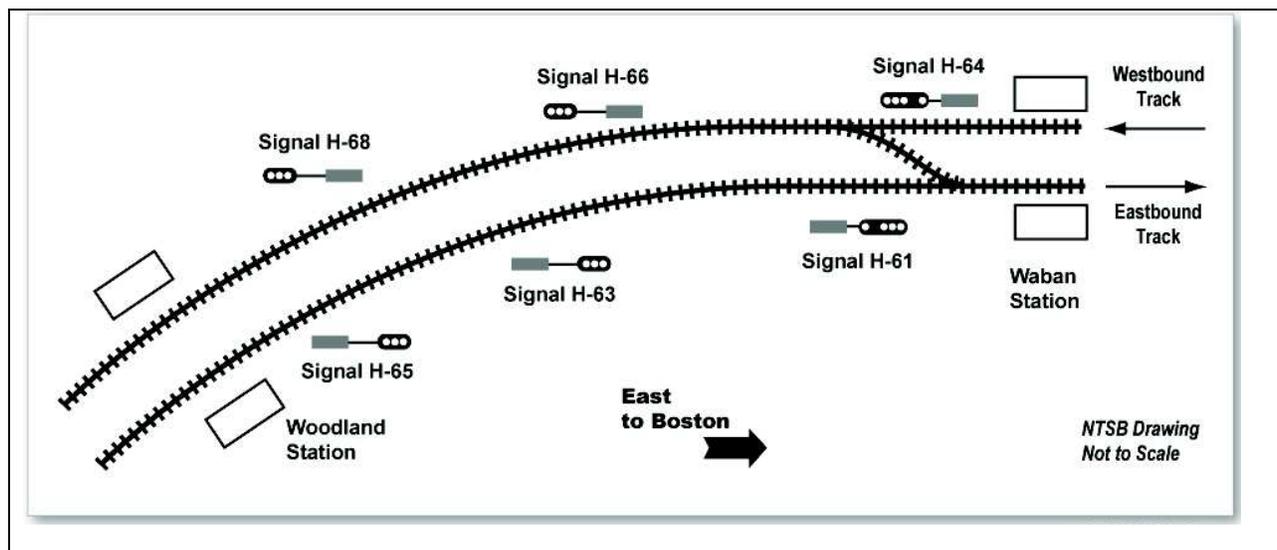


Figure 3. Signal layout between Waban and Woodland stations on D Branch of MBTA Green Line.

Meanwhile, train 3667, which was travelling behind train 3681, arrived at Waban station, where it stopped to discharge and pick up passengers. The trail operator of train 3667 said that his tour of duty up until that time had been uneventful except for the problems with the public address system and possibly the radio.

The presence of stopped train 3681 at signal H-66 just ahead caused signal H-64, at the west end of Waban station, to also show a single red aspect. The trail operator of train 3667 stated that he remained on the train while it served Waban station and that, from his position in the operator's compartment of the rear car, he could not see the aspect of signal H-64.

The red signal indication at H-64 required that the operator of train 3667 hold for 1 minute before proceeding at no more than 10 mph. However, according to the trail operator, the train instead departed Waban as usual (after a stop of 20 to 30 seconds) and accelerated normally. Because the trail operator could not see the red aspect being displayed by signal H-64 and because MBTA rules did not require that the operator call out signal indications over the radio, the trail operator was not aware that his train should have remained stopped briefly before proceeding at reduced speed. He said he therefore had no reason to think anything was wrong when the train began to move westward after the station stop. He said he assumed the train was operating under a clear signal and was accelerating to the maximum authorized track speed of 40 mph for that location.

Just ahead of train 3667, train 3681 was beginning to move after being stopped at signal H-66 as required by MBTA rules. The operator said that shortly after his train began to accelerate, he heard a loud noise like an explosion from the rear of the train but felt no significant movement. Thinking that a car had derailed, he stopped his train, then noticed smoke coming from the rear of the train. He said he left the cab and walked back to the rear, where he saw that his train had been struck by a following train. He said he noticed that his trail operator was on a cell phone attempting to contact the control center.

Based on data retrieved from the fault loggers⁶ aboard each of the four cars involved in the accident, the striking train was travelling about 38 mph at the time of impact, and the struck train, which was just beginning to accelerate, was travelling about 3.4 mph.

The trail operator of the struck train stated that she had been unaware of the approach of a train from the rear when she heard an explosion and was knocked out of her seat. When she recovered from the impact, she became aware of passengers screaming and yelling. She said that she assisted some of her passengers from her car and then went back to see what had happened. She stated that she had seen fire and lots of smoke and heard screaming coming from the striking car. She also noted that the front of the striking train had collapsed and folded down so that the front of the car was unrecognizable.

The trail operator of the striking train said that his train had continued to accelerate normally until it suddenly decelerated, throwing him against his operating console. (The investigation determined that impact occurred less than 40 seconds after the train departed Waban station.) He said that at the same time he heard a loud noise and noticed smoke coming from outside the car. He stated that he had not felt any uneven motion and did not discern any brake application before the impact. Postaccident inspection of the rails did not identify any streak marks consistent with an emergency brake application. The trail operator had not heard

⁶ A *fault logger* is a maintenance and troubleshooting device that provides a snapshot of selected parameters. It does not provide a continuous recording of parameters as event recorders do.

anything from the train operator, but, he said, that was not unusual, and he still believed his radio to be malfunctioning. He was, however, able to contact the operations center by radio to report the accident. (The investigation determined that the intercom between the two operating compartments on the train had been inoperative at the time of the accident.)

The trail operator of the striking train said he initially assisted passengers in detraining, then went forward to assess the situation. He said he observed extensive damage to the front of the lead car and found the operator wedged in the crushed cab. He said he attempted to assess her condition but she was unresponsive. He then continued to assist passengers attempting to exit the train.

Emergency Response

Newton Fire Department

At 5:54 p.m., a resident of a home adjacent to the right-of-way called 911 and reported that two Green Line trains had collided and that there was fire.⁷ Elements of the Newton Fire Department and Newton Police Department were dispatched at 5:57 p.m. and began arriving at the accident scene at 5:59 p.m.

Fire companies first gained access to the accident site from an adjacent roadway. A neighboring golf course was used for a second access point and a landing zone. A triage area was also established at the golf course. Firefighters found the striking train operator trapped in the crushed cab compartment. They checked for signs of life but could not feel a pulse.

Firefighters first attempted, unsuccessfully, to gain access to the crushed cab by cutting through the railcar floor. They continued to work on the front and on the side of the cab area while they made a second attempt to access the cab by placing a steel beam under and across the width of the damaged car then lifting the beam with jacks. After additional lifting and cutting of the cab structure, the operator was removed from the train about 12:51 a.m. on May 29.

MBTA

An MBTA superintendent of maintenance coordinated with emergency responders at the accident scene during the response. After checking in with emergency responders, he walked around the accident site to assess the situation. He called for extra MBTA personnel and maintenance trucks to respond. He also requested that the Braintree rescue unit respond.⁸

While efforts were ongoing to extricate the striking train operator, the superintendent suggested to a firefighter that MBTA personnel could further lift and reposition the train to help give responders better access to the crushed cab area. The offer was at first declined. Later in the

⁷ The reported fire, which the Newton Fire Department extinguished quickly, was a small grass fire caused by electrical arcing.

⁸ This rescue unit was funded by the MBTA and was staged at the Braintree Fire Department.

evening, after further extrication efforts proved unsuccessful, MBTA personnel were allowed to lift the train as the superintendent had suggested.

Injuries

The operator of train 3667, the striking train, was killed in the collision. The cause of death was determined to be multiple blunt force injuries to the head, chest, neck, torso, and pelvis.

The operator and trail operator of train 3681, the struck train, and the trail operator of train 3667 sustained minor injuries and were taken to Newton-Wellesley Hospital. They were then taken to the MBTA medical clinic, where they were tested for alcohol and illegal drugs.

One seriously injured passenger was air-evacuated to Boston Medical Center; two passengers with minor injuries were transported to St. Elizabeth's Hospital in Boston; and two were transported to Metro West Medical Center in Metick, Massachusetts. All the injured passengers had been aboard the striking train. (See table 1.)

Table 1. Injuries.

Injuries ^a	Train Crew	Passengers
Fatal	1	0
Serious	0	1
Minor	3	4

^a Title 49 Code of Federal Regulations 830.2 defines a fatal injury as: any injury that results in death within 30 days of the accident. A serious injury is defined as: an injury which requires hospitalization for more than 48 hours, commencing within 7 days from the date the injury was received; results in a fracture of any bone (except simple fractures of the fingers, toes, or nose); causes severe hemorrhages, nerve, muscle, or tendon damage; involves any internal organ; or involves second or third degree burns, or any burns affecting more than 5 percent of the body surface.

Damage

MBTA car 3667, the lead car of the striking train, was destroyed in the accident. It sustained substantial crush damage and also derailed as a result of the collision. (See figure 4.) The second car of the striking train, 3706, sustained minor damage. MBTA car 3703, the second car of the struck train, was severely damaged. The lead car of the struck train, 3681, was derailed with minor damage. The total damage was estimated to be about \$8.6 million.

Both trains were examined in detail at the MBTA's Riverside shop on May 30 and 31, 2008. Damage to the lead car on the struck train and to the trailing car of the striking train was found to be minimal. Damages to the lead car of the striking train and to the trailing car of the struck train are detailed below.



Figure 4. Crushed lead car of striking train.

Train 3667—Striking Train

Train 3667 was operating A-end forward. (See figure 5.) In the A-end, the operator's cab and A1 door were crushed toward the rear and under the car body. This crushed area extended for a distance of 121 inches from the front of the cab. From the first row of passenger seats to the center doors, the ceiling was sloped downward, and it angled toward the right side of the front of the car. The floor in this area was buckled upward.

The B-end of the train (car 3706) was generally intact. Windows were secure, and the doors were functional. The first passenger seat behind the operating compartment was unlatched from its pedestal and leaning rearward. The double seat behind the B2 door was slightly loose. A restraining latch on the pedestal secures the seat bottom to the pedestal. The latch normally attaches to a bar beneath the seat. The restraining latch was found on the outside of the seat.

Train 3681—Struck Train

Train 3681 was operating B-end forward. In the A-end (the end that was struck—car 3703), the operator's cab and the A1 door were crushed toward the front of the car body. This crushed area extended from the front of the cab for a distance of 120 inches. The floor began to

buckle upward near the third row (from the rear of the car) of passenger seats. From this point to the rear of the car, the floor sloped downward.

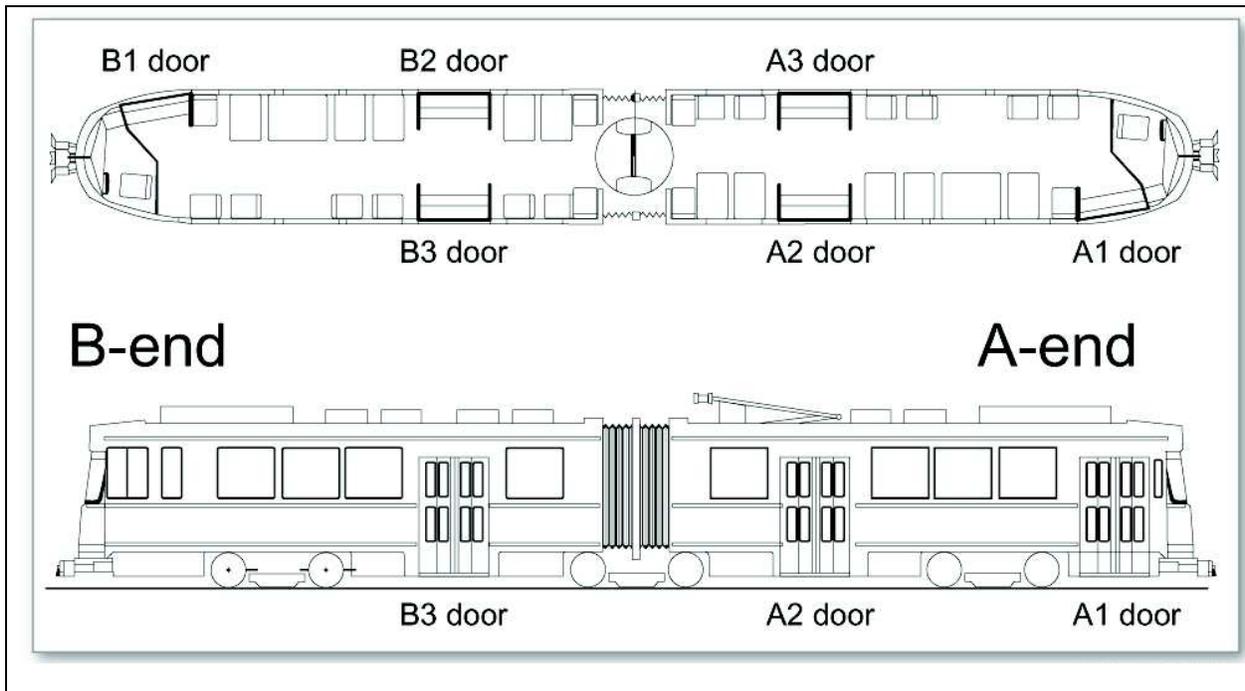


Figure 5. Each train involved in accident consisted of two permanently coupled cars, as shown in drawing. Car 3667 was A-end and lead car of striking train; car 3681 was B-end and lead car of struck train.

The anticlimber⁹ of car 3703 was raised upward and toward the left side (in the direction of travel) of the car. The center of the anticlimber had been moved 13 inches to the left of its normal centerline. The anticlimber's highest point measured 39 1/8 inches above the top of the rail, and the centerline measured 38 7/8 inches above the top of the rail.

All three doors on the struck car were functional. On the left side of the car, one window was separated from its frame. On the right side of the car, one window was shattered. The remaining windows were intact. In the center of the car above the center truck, interior ceiling body panels were torn.

The B-end of the train (car 3681) car was generally intact. Windows were secure, and the doors were functional.

⁹ An *anticlimber* is a component on each end of the car that is designed to resist vertical forces and, thereby, prevent one car being overridden by another in a collision.

Personnel Information

Train 3667—Striking Train

Operator. The operator of train 3667, who was fatally injured in the accident, was a part-time streetcar operator hired in 2007. As a part-time employee, she was limited to working a maximum of 6 hours per day. The dates of her physical examination and annual training were current with her qualification as an operator.

A Green Line light rail instructor who had met the operator in August 2007 and had become her instructor with daily contact from September 19 until October 9, 2007, said that the operator “was a great student, very bright, very smart.” She said she was not aware of anything in her life that might have been a basis for distraction or preoccupation from performing her duties.

An MBTA light rail instructor who had worked with the operator from October 10 until October 14, 2007, said that the operator “was an excellent student. She followed the rules and regulations. She enjoyed her job.” The two became friends and spoke by phone four to five times per week. The instructor said she was not aware of anything in the operator’s life that may have been a distraction or that would have interfered with her ability to safely operate a trolley.

According to MBTA records, the operator worked Monday through Friday and was off Saturday and Sunday. Her normal early shift began at 11:57 a.m. and ended at 1:22 p.m. Her afternoon shift began at 4:35 p.m. and ended at 8:59 p.m. This is the shift the operator worked on Wednesday, May 28, the day of the accident, as well as on the previous day, Tuesday, May 27. Monday had been a holiday, and the operator worked an early shift from 9:58 a.m. until 2:45 p.m. and an afternoon shift from 4:18 p.m. until 5:25 p.m. At the time of the accident, she had been on duty for about 1 hour and 15 minutes. An examination of the operator’s cell phone records showed that she had used her cell phone twice during her morning shift and once during her afternoon duty shift. The cell phone was not in use at the time of the collision. MBTA policy strictly prohibits the use of cell phones while operating any MBTA vehicle.

Interviews with those familiar with the train operator’s routine indicated that she normally went off duty about 9:00 p.m. and arrived home between 10:00 and 10:30 p.m., at which time she retired for the evening. Interviews also revealed that a friend of the operator phoned her each morning at 6:30 a.m. “to say hello.” Her normal days off were Saturday and Sunday.

Trail Operator. The trail operator of train 3667 was hired by the MBTA in 2007 as a part-time streetcar operator and completed his initial training in January 2008. He told investigators that he awoke on May 28 at 4:40 a.m., began his morning tour at 6:42 a.m., and completed that tour at 9:30 a.m. He then returned home and remained there until he reported for his evening tour, which began at 4:35 p.m.

At the time of the accident, he had been on duty for about 1 hour and 15 minutes. He characterized his workload on the afternoon of the accident as “average.” An examination of the

trail operator's cell phone records showed that he had not used his cell phone during his duty shift.

Train 3681—Struck Train

Operator. The operator of train 3681 was hired by the MBTA in 1985 as a bus operator. He was assigned to trolley service as a streetcar operator in 1988 and completed his MBTA recertification in 2008. He was classified a full-time streetcar operator.

The operator stated that on Wednesday, May 28, he had worked a morning tour that began at 7:15 am and ended just before noon. He said he then went home and took a nap before returning for his second tour, which began at 2:52 p.m. He characterized his workload on the day of the accident as "moderate" with no problems with the equipment. An examination of the operator's cell phone records showed that he had not used his cell phone during his duty shift.

Trail Operator. The trail operator of train 3681 was hired by the MBTA on May 15, 2006, as a part-time streetcar operator. She became a full-time operator on June 23, 2007. She told investigators she awoke at 6:00 a.m. on May 28 and went on duty at 7:57 a.m. MBTA records show that she was off duty from 12:44 p.m. until 2:50, at which time she returned to duty for her second tour of the day. She would have gone off duty at 6:05 p.m. At the time of the accident, she had been awake for almost 12 hours and on duty for about 3 hours. An examination of the trail operator's cell phone records showed that she had not used her cell phone during her duty shift.

Medical and Toxicological Information

After the accident, the MBTA arranged to have the surviving crewmembers of the accident trains undergo postaccident toxicological testing as required by U.S. Department of Transportation (DOT) regulations. Testing was conducted for ethyl alcohol and for five illegal drugs: cannabinoids, cocaine metabolites, opiates, amphetamines, and phencyclidine. The results were negative for the presence of alcohol and the tested drugs.

The Office of the Chief Medical Examiner for the Commonwealth of Massachusetts performed the toxicological tests on the fatally injured operator of the striking train and found no evidence of the use of alcohol or illegal drugs. Additional test specimens were then sent to the Civil Aerospace Medical Institute in Oklahoma City, Oklahoma, for independent toxicological analysis. The results were negative for the presence of alcohol and illegal drugs; however, doxylamine¹⁰ was present in the urine but was not detected in her blood. The MBTA requires:

that safety-sensitive employees consult with Medical Operations before using prescription or over-the-counter medications that contain alcohol or other substances that may impair their ability to perform safety-sensitive duties.... A Medical Operations physician or nurse will make the determination as to whether

¹⁰Doxylamine is found in over-the-counter medications used in the short-term treatment of insomnia (difficulty falling asleep or staying asleep).

the employee's use of the medication could impair the employee's performance or jeopardizes the safety of the employee, his/her co-workers and/or the public.¹¹

The investigation found no evidence that the operator of the striking train had reported the use of a medication containing doxylamine.

A complete autopsy performed on the operator by the Office of the Chief Medical Examiner of Massachusetts noted only the presence of a large acne-type lesion on her abdomen, with a large surrounding area of swollen skin. The report contained no notation of any other preexisting medical condition, specifically noting no abnormalities upon examination of the heart, lungs, or brain.

The operator's August 6, 2007, history and physical examination form recorded the operator's height as 66 1/2 inches, weight as 243 pounds, and blood pressure as 140/80. The form did not contain any inquiries of an operator regarding sleep disorders, sleeping problems, snoring, or daytime sleepiness.

Meteorological Information

It was daylight at the time of the accident, the skies were clear, there were light winds of 5 mph, and the temperature was 68° F. Visibility was 10 miles. This information was recorded by the National Oceanic and Atmospheric Administration's surface weather station in Boston, about 10 miles east of Newton.

Site Description

Newton, Massachusetts, is a city of about 83,800 (2000 data) in Middlesex County, the most populated county in the state. Newton is a suburban area consisting of 13 villages located 6 miles west of Boston. The MBTA Green Line operates through five of the villages and has seven station stops within the city. (See figure 6.) Beginning at Chestnut Hill in the east, trains move over the Green Line westward to Newton Center. The track then turns to the southwest to Newton Highlands and Eliot. At Eliot, the Green Line swings back to the northwest through Waban and Woodland before ending at Riverside. The MBTA operates about 154 trips in each direction by 48 trains daily, with fewer movements on the weekend.

The MBTA's ridership for all modes¹² makes it the nation's fifth largest mass transit system. The system serves a population in excess of 4.6 million residing in 175 towns and cities within the greater Boston metropolitan area. The average weekday ridership for the entire system is about 1.1 million passenger trips.

¹¹ *Massachusetts Bay Transportation Authority Drug and Alcohol Policy and Testing Program*, Effective: August 1, 2001, pp. 3-4.

¹² This includes buses; commuter, heavy, and light rail; and trackless street cars.

The accident occurred between the Waban and Woodland stations, which are 4,300 feet apart. Normal transit time between the two stations ranges from 73 seconds to 2 minutes. The point of impact was determined to be 1,408 feet from the west end of the Waban station.

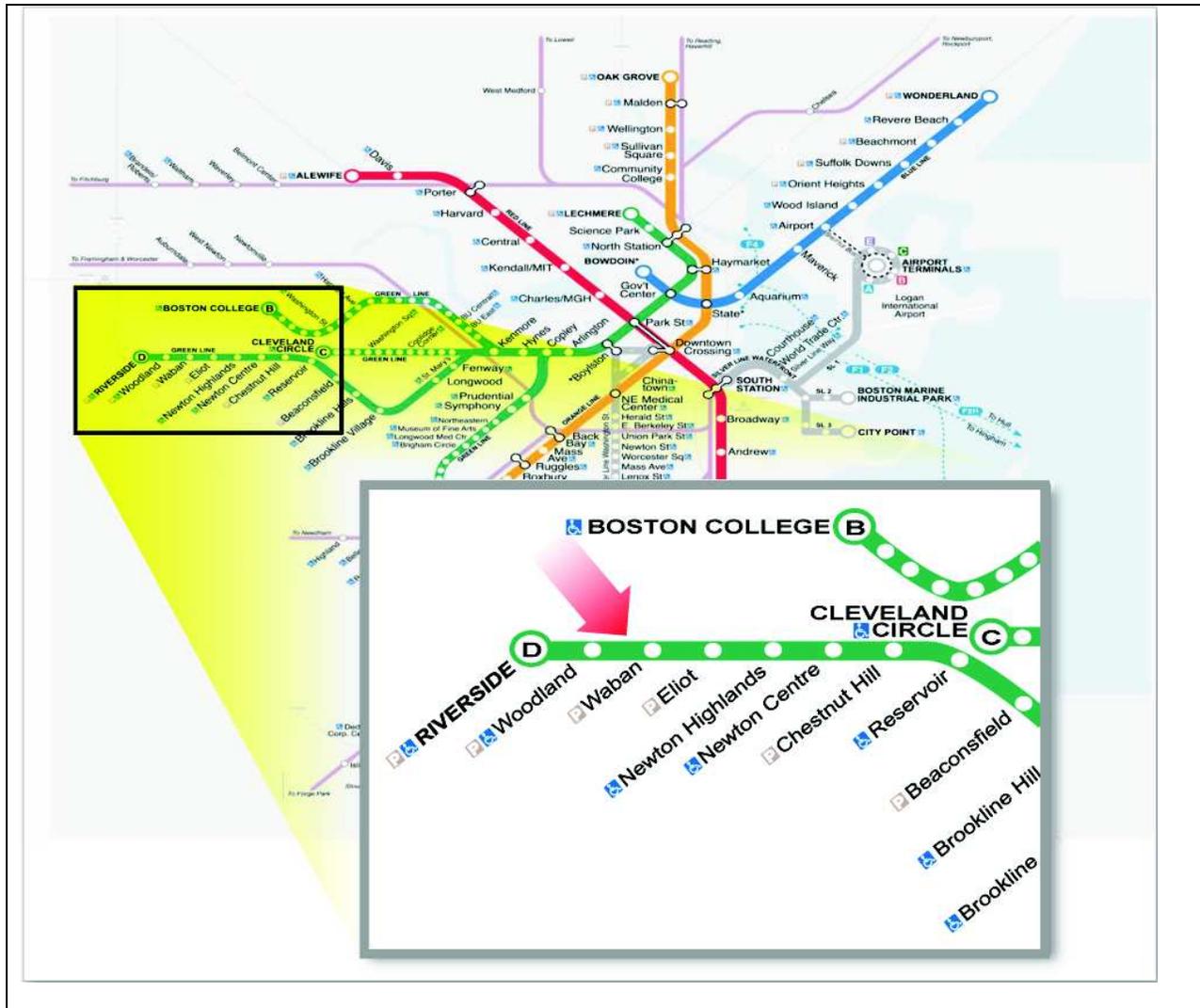


Figure 6. Partial diagram of MBTA commuter rail system. Inset arrow indicates accident location on D Branch of the Green Line.

Operations Information

General

The Riverside station is on the D Branch of the MBTA Green Line. Trains originating from Riverside travel east to Government Center, loop, and then return west to their originating station. Train movements on the D Branch are governed by signal indications provided by an automatic block signal system. Operators control their trains based on indications displayed by wayside signals. MBTA trains operating on the Green Line do not incorporate systems such as the following: trip stops (mechanical arms or electrical inductors that slow or stop a train if the

operator fails to comply with a signal indication), cab signals (a display of signal aspects inside the operating compartment, sometimes incorporating audible warnings of restrictive signals), or positive train control (a system that automatically intervenes if a train operator fails to comply with signal indications or speed restrictions).

Because MBTA Green Line trains are governed by automatic signal indication, they do not need written authority from a train dispatcher to occupy main tracks. Consequently, train dispatchers in the MBTA Operations Control Center do not normally issue any documents to MBTA trains except when non-revenue equipment, such as maintenance trucks or inspection cars, is operating on the route. Control center dispatchers monitor operations and become involved in train movements only when circumstances require it, such as when workers are present along the right-of-way. Control center dispatchers also maintain service logs of equipment defects and failures.

The train dispatcher on duty at the time of the accident stated that the Green Line D Branch route was relatively self-dispatching and that he had no real involvement in the movement of these trains. He stated that the train crews have the ability and responsibility to route their trains by lining switches themselves; they do not rely on the train dispatcher to line switches. Because operations on this line are governed strictly by signal indications, the dispatcher does not issue train orders for MBTA Green Line operations.

MBTA operating employees are governed by MBTA hours-of-service restrictions. The MBTA's Rule 12A, "Limitation of Work Hours," places limits on duty and is based on an order from the Massachusetts Department of Public Utilities issued on January 12, 1980. Under the order, covered employees may not work more than 16 consecutive hours and are required to receive at least 6 hours off-duty time before going on duty. The rule also prohibits a covered employee from working more than 60 hours in a 7-day workweek.

Operating Rules Relevant to Accident

Rules for Trainpersons and Other Employees of the Light Rail Lines specifies the required procedures for complying with wayside signals. Regarding signal H-64, near the west end of Waban station, the rules state that (because of a permanent speed restriction in that area) a train departing Waban station on a permissive aspect shall not exceed 25 mph until reaching a "resume" sign 871 feet past the signal.

Other applicable rules include the following:

Rule 19. "Attention to Duty"

All employees have an inherent responsibility to pay attention to their duties at all times. To insure a safe operation of any vehicle and to maintain a high level of professionalism....

Rule 55. "Restricted Speed"

Proceed at a speed NOT EXCEEDING TEN (10) MILES PER HOUR: the Operator must watch for a broken rail or a switch not properly lined and must stop their car or train short of a car, train or other obstruction....

Rule 56. "Observance of Signals"

(a) Operators will be held to a strict observance of the indication given by automatic block and interlocking signals: also by hand, flag or lantern signals. (b) The use of automatic block signals in no way relieves Operators from exercising the greatest care and vigilance.

Mechanical Information

Each train consisted of two Kinki Sharyo Type 7 trolley cars. The striking train consisted of cars 3667 (the lead car) and 3706 coupled in tandem. The struck train consisted of cars 3681 (the lead car) and 3703. The trains were driven by electric motors receiving power from a 600-volt overhead catenary system.

All four cars were in the MBTA series 3600-3719 and were built by Kinki Sharyo Co., Ltd. Cars 3667 and 3681 were built in 1988; cars 3703 and 3706 were built in 1997. Each car was designed to carry 50 passengers seated and 151 standing with an operation maximum load of 269 passengers. The vehicles weighed 85,500 pounds each and were 74 feet long. Each car had three two-axle trucks. The outboard trucks¹³ were powered; the center truck was non-powered. The train operator's compartment was at the left front of the lead car. The operator's right foot activated pedals for braking and accelerating. A "dead man" pedal activated by the operator's left foot had to remain depressed or the train brakes would automatically apply to stop the train. The operating compartment in the rear car, usually occupied by the trail operator was the same as the one in the lead car. Both operating compartments had a "mushroom" button that activated emergency braking.

Investigators examined inspection and maintenance records for all four cars involved in this accident. The records indicated that all inspections and scheduled maintenance had been performed as required. The previous year's maintenance records for the lead car (car 3667) on the striking train showed that all reported defects had been corrected.

Pre-Departure Tests

Trains 3681 and 3667 were prepared for service by the MBTA mechanical department on the evening of May 27, 2008, and then placed in a ready location for departure the next morning. An outbound operator is required to inspect the equipment and report any defects. The MBTA yardmaster was not informed of any defects being identified with either train during the initial inspection, nor was the MBTA control center notified of any defective condition during the day.

¹³ *Outboard trucks* refers to the wheel arrangement at each end of a car consisting of two solid axles, left and right side frames, and an electric motor.

Postaccident Inspection of Striking Train

The cars, 3667 and 3706, of the striking train, were given initial inspections at the accident site and more detailed inspections after the equipment was moved to the MBTA Riverside maintenance facility. Before the cars were removed from the accident site, all the brakes were applied on both cars in their original at-rest positions.

Initial and subsequent inspections revealed that the brake pads of the two cars were slightly worn but with service life remaining. The rotors displayed a work-polished surface with no apparent signs of overheating, scoring, or checking in the contact areas. Wheel profiles were all well within MBTA standards. No binding or chafing was observed between any components or between the trucks and their respective car bodies. No evidence was found that anything had dragged along the track structure before the accident.

Track Information

General

The portion of the MBTA Green Line on which the accident occurred consists of two main tracks: an outbound, or westbound, track and an inbound, or eastbound, track. The two main tracks are oriented geographically east to west between the Waban and Woodland stations, with the outbound track to the north of the inbound track. The track grade ascends slightly from Waban to Woodland. Trains departing Waban station proceed on the west main track and pass signal H-64 on straight track before travelling under an overhead bridge and over a switch for a crossover from the eastbound to westbound main tracks. After this crossover is a 2° curve about 500 feet long. Just to the west of this curve is signal H-66, where train 3681 had stopped moments before the collision.

The main track is owned, inspected, maintained, and operated by the MBTA. The track structure at the point of collision consists of continuous 115-pound welded rail¹⁴ affixed to wooden cross ties resting on double shoulder tie plates held in place by spikes or Pandrol¹⁵ fasteners. The track structure is held in place with granite ballast. The section of track at the point of collision showed no signs of improper drainage.

The entire Green Line is powered by a 600-volt overhead catenary system that provides the energy for train movements on both main tracks. The catenary system is affixed to steel poles spaced about 100 feet apart and placed outside of the clearance envelope of the tracks.

Track Inspections

MBTA policy calls for main track to be inspected three times weekly with at least 1 calendar day between inspections. Bimonthly switch certification reports are also required.

¹⁴ *Continuous welded rail* consists of rail sections that have been welded together in lengths greater than 400 feet.

¹⁵ *Pandrol* is a type of rail fastener that clips to the rail and is screwed into the cross tie.

MBTA track inspectors had inspected the tracks in the accident area earlier on the day of the accident and had noted no defects. Investigators reviewed the two previous sets of inspection records for the crossover between the Waban and Woodland stations and did not take any exceptions.

Investigators reviewed the MBTA's inspection records for D Branch main track between Reservoir and Riverside covering the period from February 29, 2008, to May 28, 2008. The records indicated that all inspection criteria had been met. Switch inspection records for the previous 4 months did not identify any exceptions for the switches east of the point of collision. After the accident, on May 29 and 30, 2008, a walking track inspection was conducted that covered portions of the main track preceding the point of collision. No defects were noted.

Permanent Speed Restriction

In the area of the derailment, the main tracks were maintained for 40-mph operation, which was the maximum authorized speed between the Waban and Woodland stations. However, the MBTA had placed a permanent 25-mph speed restriction on the westbound main track over the turnout of the crossover from eastbound to westbound track. The track segment with the speed restriction begins 215 feet west of the Waban station and continues for 667 feet. Because of the proximity of the speed-restricted track segment to Waban station, a train operator could manage the acceleration of the train out of the station so that it would not reach 25 mph until after it has passed over that segment.

Signal Information

General

The automatic block signal system in use on the D Branch of the MBTA Green Line incorporates four-aspect Union Switch & Signal (US&S) color light type signals and US&S hand-operated switch machines operating in conjunction with 25-hertz a.c. track circuits. Dual-filament 10-volt lamps illuminate signal heads. Signals in this territory are arranged for single-direction running on each track. The signal system is configured to display the aspects and indications shown in Table 2.

Table 2. Green Line signal aspects and indications.

Aspect	Indication
Red over Red	Stop
Red	Stop. Proceed after 1 minute at restricted speed. (Proceed, prepared to stop short of a train, car, or other obstruction and watch for broken rail or switch not properly lined, not exceeding 10 mph to next signal).
Yellow	Proceed prepared to stop at next signal.
Green	Proceed at authorized speed.

Postaccident Inspection/Testing of Signal System

Representatives from the MBTA and the Massachusetts Department of Public Utilities participated with NTSB investigators in the postaccident field inspection and testing of the signal system in the accident area. Because of the age of the signal system, it did not incorporate a signal data recorder.

The postaccident inspection found all signal units, signal cases, and switches locked and secured, with no indications of tampering or vandalism that would interfere with the operation of the signal system. Relay positions were consistent with the physical location of the accident trains and the displayed signal aspects. None of the signal units or switches was damaged in the accident.

The collision resulted in the wreckage of the two trains occupying track circuits H-66 and H-64. This condition resulted in signals H-66 and H-64 both displaying the appropriate red aspect. After the train wreckage was removed from the track circuits and the signal was tested, signal H-66 continued to display a red aspect when, during the tests, it should have displayed green. A subsequent visual inspection identified two locations with broken rail bonds.¹⁶ At these locations, the rail ends had been double bonded, and the breaks in some of the bonds appeared to be fresh, suggesting that they likely occurred during removal of the wreckage. But the breaks in other bonds were rusted over, indicating that they had been in that condition before the accident.¹⁷ In order to conduct postaccident testing, all the bonds were replaced, after which signal H-66 displayed the appropriate *clear* signal indication (green aspect) with no trains on the track circuits.

Operational tests of signals H-64 and H-66 showed both signals to be performing as designed. After testing, the relays from signals H-64 and H-66 were removed and taken to the MBTA relay shop where they were bench tested and where operating values were recorded. All the relays were operating within specifications.

No exceptions were identified with either the design or operation of the MBTA signal system. All tests indicated that the signal system was working as designed with lamp voltages to signals H-64 and H-66 within acceptable limits.

Signal Maintenance Records

Investigators examined MBTA maintenance records for signals H-64 and H-66, as well as for the switches for the crossover. The MBTA requires that signal inspections be performed monthly. The records indicated that all signal tests and inspections had been conducted in accordance with MBTA requirements. Test and inspection records indicated that the ground tests, monthly tests, wayside signal, and switch obstruction tests were performed for both crossover switches in April 2008. Insulation resistance testing was performed in 1993. Relays

¹⁶ *Bonds* are wires that form a connection between the ends of rail sections in order to maintain electrical continuity across a joint.

¹⁷ The signal system was designed so that, in the event of a malfunction of a system component, the affected signal would display its most restrictive indication. For signal H-66, this was a single red aspect.

were tested in 2006. All test records indicated that the signal system was functioning as designed. A review of MBTA monthly signal inspection reports for the previous 6 months did not identify any exceptions to signal performance in the vicinity of the accident.

MBTA Rules Regarding Anomalous Signal Displays

MBTA signal and switch rules require certain actions when a train operator encounters an imperfectly displayed or defective signal. The procedures are explained in MBTA Rules 59 and 60(a), which state the following:

Rule 59:

A. An interlocking signal imperfectly displayed, such as where there is no light or a white light, is a defective signal. The indication is STOP. Under no circumstances are Operators to pass through interlocking signals imperfectly displayed except under personal direction by an authorized person.

B. An automatic block signal imperfectly displayed such as when there is no light or a white light, or more than one light at points where one light normally shows, is a defective signal. The indication is STOP. Wait one (1) minute, and then proceed at restricted speed. (Proceed, prepared to stop short of a car, train, or other obstruction and watch for broken rail or switch not properly lined, not exceeding ten (10) miles per hour).

C. At locations where there is a crossover with facing point switches, you will find on the automatic block signal a multiple number of aspects. With no aspect, Operators must wait for orders from an authorized person to proceed. It's the Operator's responsibility to see that the switches are properly set before passing on its points and proceed at a speed no greater than ten (10) mph.

The conditions described in (a), (b) and (c) above must be reported at once to the first Official reached or the OCC [operations control center] dispatcher.

Rule 60(a) Flagging by signals – Central District, Highland Branch, High Speed Operations:

(a) Signal Holding Red or is Defective: When a block signal holds red or is defective, the Motorperson [train operator], after waiting one (1) minute, will proceed at restricted speed (proceed, prepared to stop short of car, train or other obstruction and watch for broken rail, switch not properly aligned, not exceeding TEN (10) MILES PER HOUR) to the next signal.

The operator of the struck train in this accident stated that signal H-66 was displaying a single red aspect when he encountered it just before the collision. He said he stopped his train for the required 1 minute before proceeding even though he could see that no other trains were occupying the block. He did not report the red signal aspect to the Operations Control Center on the accident trip, even though he could see that the track ahead was clear, nor did MBTA rules require that he do so.

Because of an absence of train operator reports regarding red aspects at signal H-66, investigators were not able to determine how long the signal had been displaying a red aspect before train 3681 arrived. Investigators did determine that after the broken bonds were replaced, signal H-66 displayed an aspect correct for the conditions. Investigators also determined that at the time of the accident, signal H-64 was displaying a proper single red aspect for the striking train because of the presence of the stopped train in the block governing that signal.

Governmental Oversight of MBTA

Federal Transit Administration

A part of the DOT, the Federal Transit Administration (FTA) administers funding to public transportation systems throughout the United States. Unlike administrations within the DOT whose authority stems from the Constitution's Interstate Commerce Clause, the FTA was authorized using the General Welfare Clause. It therefore received from Congress no regulatory authority. Title 49 *United States Code* Section 5334(b) specifically prohibits the secretary of transportation from regulating the operation, routes, or schedules of a public transportation system.

The primary enforcement mechanism available to the FTA is the ability to withhold Federal funds from states that do not comply with the terms and conditions of its Federal assistance agreement. In response to passage of the Intermodal Surface Transportation Efficiency Act of 1991, the FTA implemented the State Safety Oversight Program, which placed the responsibility for rail transit safety on the states maintaining public transit systems. The FTA has established minimum safety requirements that all states and rail transit agencies must adhere to in order to receive Federal funding. These requirements address the techniques that are to be used to conduct inspections and testing, the required maintenance audits and inspection programs, and the procedures to be used for employee training and certification.

Massachusetts Department of Public Utilities

The MBTA is subject to oversight by the FTA through the offices of the Massachusetts Department of Public Utilities Transportation Oversight Division, which has developed and implemented a System Safety Program Plan comprising 21 safety elements defined in Title 49 *Code of Federal Regulations* Part 659. The MBTA's safety department is responsible for an annual internal audit of compliance with a portion of the plan elements so that over a 3-year period, compliance with all 21 elements will have been audited. The results of these audits are provided as annual reports to the Department of Public Utilities.

The MBTA provided investigators with the annual report of internal audits for 2007. Investigators focused on the sections for safety and security and right-of-way. The report states the following:

While the MBTA Safety Department provides management oversight to the implementation of and adherence to the Authority's System Safety Program Plan,

the success of this plan is largely dependent on the safety culture that is fostered within each department and work group throughout the Authority. To achieve this, management staff is expected to define, understand, and integrate effective safety practices into the day-to-day work activities, to ensure that the safety of employees, passengers and guests remain a top priority.

The Safety Program Plan states that critical safety department activities include the following:

...developing and implementing programs to increase public, passenger and employee safety awareness; reporting preventive and corrective solutions for identified safety hazards; establishing and maintaining safety guidelines through employee training programs.

MBTA Employee Performance Monitoring

Chapter 8 of the Safety System Program Plan addresses rules and procedures compliance by MBTA employees. The section does not include a requirement that MBTA supervisors conduct field tests of operating employees in order to determine overall compliance with operating rules.

According to MBTA officials, observations of operating personnel on Green Line trains and buses were not formalized at the time of this accident. Most observations of employee performance were made during chance meetings of supervisory employees and operating crews, although some operational checks resulted from customer complaints or were done randomly based on supervisor availability.

The MBTA had established no formal efficiency testing program that would, through check rides, planned observations, or set-up situations, provide a comprehensive evaluation of employee rule compliance. Supervisors did document instances in which an employee was observed violating an operating or safety rule, but the total number of observations was not recorded. The MBTA was unable to provide investigators with a detailed history of the deceased operator's performance history during her relatively short period of employment.

On February 14, 2009, the MBTA, through issuance of a standard operating procedure, established a safety rules compliance program designed to:

provide for unannounced operational testing, inspection and observations under the various operating conditions of the system during operation to determine the extent of compliance with operating rules, policies and procedures, Special Instructions, Special Orders, Special Bulletins, training, etc. By performing these inspections, the Authority's goals are to:

- Reduce accidents caused by human error.
- Improve and enhance the vigilance of employees to comply with established rules and procedures.

- Determine the degree of compliance with established rules to improve compliance.
- Focus attention on rules and areas where there is a need to improve employees' knowledge, training and skill level.
- Incorporate lessons learned into existing training Programs.
- The new procedure was also designed with the following objectives:
 - To serve as reinforcement for established rules and procedures.
 - To establish a 'baseline' of documentation that tracks an individual employee's compliance with operating rules absent of an accident investigation.
 - Allows management, training staff and supervisory personnel to assess trends and incorporate this information into established training Programs.
- 5. Allows an individual employee the opportunity for additional training/instruction if an issue with compliance is identified (before an accident/incident occurs).

For rail operations, the procedure contains schedules, instructions, and forms for evaluating employees with regard to compliance with speed restrictions, door procedures, signal indications, and cab operating procedures. According to MBTA representatives, as of May 21, 2009, the agency had conducted 2,088 employee compliance audits under the new procedures with a pass rate of 97.6 percent.

Sight-Distance Tests

On June 1, 2008, investigators conducted sight-distance tests at the accident site. The weather at the time the tests were begun was partly clear skies (some clouds), and temperatures were in the 70s. The tests began about 5:20 p.m.

The MBTA provided two train sets for the tests. The simulated struck train traveled westward from Waban station and stopped east of signal H-66, where the standing train had held at the red signal before the accident.

In the first two test scenarios, the simulated striking train was positioned at different positions within Waban station with the operator in the normal seated position on the left side of the cab. From all tested positions, investigators could clearly see the aspect of signal H-64.

The third through sixth test scenarios were designed to determine how soon after leaving Waban station the striking train operator could have seen the rear of the train stopped ahead. The tests revealed that the operator would have had the first, partial, view of the rear of the stopped train when the striking train was about 1,037 feet (linear rail distance) away. A better view of the rear of the stopped train and its markers lights was obtained when the striking train was 910 feet away. From a distance of 764 feet, the operator would have had an unobstructed view of the rear

of the stopped train and would have been able to see that the train was stopped on the westbound track.

In the sixth scenario, the simulated striking train returned to the Waban station to view signal H-64 at the approximate time of day the accident train would have encountered the signal. Investigators reported having a clear view of the signal and its aspect.

For the seventh scenario, the position of the simulated standing train was marked, and the train was moved. The simulated striking train then departed the station on a permissive signal and proceeded westward. The test train operator complied with the permanent 25-mph speed restriction in place over the switch on the westward track. At the end of the speed-restricted track segment, the operator resumed acceleration until the train reached a speed of 38 mph. At that point, about 7 seconds and 394 feet from the point of impact, the test operator initiated normal (full service) braking. The train came to a stop 25 feet short of the mark indicating the rear of the standing train.

Other Information

MBTA Actions Taken Since Accident

MBTA officials reported to the NTSB that, in the wake of the accident, the agency took the following actions:

In the weeks following the accident, MBTA management initiated a pilot program to assist in the development of a comprehensive rules compliance program. The pilot program culminated in the issuance of the previously discussed February 14, 2009, standard operating procedure regarding rules compliance testing. As part of that program, the agency also implemented a data tracking system that allows management to detect trends in rules compliance so that enforcement procedures or training may be modified as necessary.

The director of subway operations instituted a Human Factors Task Group that is reviewing accident data to identify ways to prevent accidents caused by human error. The group meets monthly and includes management representatives from the areas of operations, training, safety, labor relations, human resources, and occupational health services.

Before the accident, the MBTA had adopted a requirement that newly procured vehicles be equipped with event recorders. Currently, for heavy rail, all Blue Line No. 5 cars have event recorders. For light rail, all No. 8 cars have event recorders. For commuter rail, all locomotives and control cars have event recorders.

A pilot program to evaluate an automatic train operation system on one MBTA rail line has been developed and is pending funding. Typical automatic train operation systems incorporate controlled speed, programmed station stopping, door operation, performance level modification, and other functions traditionally assigned to the train crew.

Emergency Preparedness

The MBTA has an agreement with the state Department of Public Utilities to conduct an annual transit emergency response exercise. The MBTA also conducts training for local emergency responders. The training, which consists of an 8-hour course for new recruits and a refresher course for experienced responders, includes subway and light rail operations and safety procedures. The training is offered at the request of fire departments and, for light rail, covers right-of-way safety, electrical safety, and vehicle familiarization, including jacking procedures.

An 8-hour light rail program was conducted for the Newton and Brookline fire departments on May 14, 2007. Eleven attendees participated in this training. A 2-hour refresher was also conducted on May 14, 2007, with 16 attendees from the Newton Fire Department participating in the training.

Fault Loggers

Each of the cars involved in the accident was equipped with three fault loggers. The primary purpose of the fault loggers is to facilitate maintenance and troubleshooting; they do not serve as traditional event recorders. They are triggered whenever a fault is generated on board the train, and they store vehicle information relating to the fault at the time it was generated. The fault loggers thus provide only a snapshot of selected parameters.

Each fault logger samples independently and will not necessarily register the same faults as other loggers on a particular car or train. The “A” and “B” loggers on each car monitor the wheel truck assemblies at either end of the car, while the “C” logger monitors the center, non-powered, truck assembly. Data from the fault loggers on the trains involved in this accident were downloaded and used to determine the speed of each train at the time of impact.

Analysis

Exclusions

NTSB investigators reviewed the signal system and performed postaccident signal testing. The postaccident examination revealed that the signal system was configured to allow for safe train operations and to provide adequate stopping distances. Signal H-64, just west of the Waban station, was showing the proper red aspect (because of the stopped train ahead) when the striking train departed the station, and the signal was clearly visible from the operating compartment of the striking train. Investigators also examined the MBTA train equipment and reviewed maintenance records. The equipment that was tested, including the braking systems, worked as intended. The track and structures had been maintained within the appropriate tolerances. All surviving crewmembers stated that the workload up until the time of the accident had been moderate, with nothing abnormal to report. Toxicological tests of all crewmembers were negative for alcohol and illegal drugs. A review of employee records indicated that the operators and trailing operators of both trains were trained and qualified to perform their duties. None of the crewmembers were using a cell phone or radio at the time of the accident. The weather was warm with clear skies; neither precipitation nor sunlight affected the visibility of the signals. The operator of the struck train had stopped in accordance with MBTA rules when his train encountered the red aspect at signal H-66. The train was already beginning to move forward when it was struck. The NTSB therefore concludes that the following were neither causal nor contributory to the accident: weather conditions, equipment performance, track condition, crewmember use of alcohol or illegal drugs, crewmember use of cell phones, crew training and qualifications, or the performance of the crew of the struck train.

Elements of the Newton fire and police departments were dispatched to the scene of the accident within 6 minutes and arrived within about 8 minutes. They established a triage area and arranged for the evacuation of the injured. An MBTA superintendent also arrived quickly and requested additional MBTA resources and additional rescue personnel. The NTSB therefore concludes that the emergency response to this accident was timely and appropriate.

The Accident

Under normal conditions, a train departing Waban station will accelerate toward the next station stop at Woodland, about 4,300 feet away. The trip from station to station takes anywhere from 73 seconds to 2 minutes in the absence of any obstructions. About 215 feet from Waban station, a train will encounter a sign restricting train speed to 25 mph beginning at that point. After another 667 feet, a sign indicates that speed can be resumed to the 40-mph limit imposed on that track segment. In practice, the speed restriction typically does not require any unusual action on the part of the operator in that a westbound train can accelerate out of Waban station so that it will not reach 25 mph before the end of the speed restriction area.

On the day of the accident, train 3681, the struck train, arrived at and served the Waban station shortly before the arrival of train 3667, the striking train. Train 3681 departed the station normally and accelerated until encountering signal H-66, which, because of broken bond wires, was displaying a red aspect even though the track ahead was clear. By this time, train 3667, the

striking train, was approaching or entering Waban station. According to the operator of train 3681, he stopped his train short of the red signal H-66 in accordance with MBTA rules.

The presence of train 3681 caused signal H-64, just outside Waban station, to also display a red aspect. Seeing this aspect, the operator of train 3667 should have held short of signal H-64 for 1 minute before proceeding at a speed not to exceed 10 mph while looking out for other trains or obstructions. According to the train operator of the striking train, on the day of the accident, the train served the station normally. He did not indicate that the train held at the station any longer than usual. Instead, he said the train began to accelerate normally out of the station.

Operating the train after the station stop would have required that the operator wait until the doors were closed and then, while depressing the dead man pedal, move her right foot from the brake pedal to the accelerator pedal. She must have performed these actions on the day of the accident without waiting the required 1 minute, in violation of the signal indication being displayed by signal H-64.

If the operator had simply failed to observe or note the red aspect at signal H-64, she had more than ample time to correct the mistake. Postaccident sight-distance tests showed that she would have had a partial view of the stopped train when the trains were still 1,037 feet apart. After traveling 127 feet farther, she would have had a full view of the rear of the train and its marker lights. After another 146 feet, she would have had an unobstructed view of the stopped train and would have been aware that it was on the same track as her train. At any of these points, she could have slowed her train and prevented the accident. In fact, the sight-distance tests showed that even if the operator had achieved a speed of 38 mph and waited until the trains were only 394 feet apart, she could have used normal (not emergency) braking to bring her train to a safe stop short of a collision.

Performance of Operator of Striking Train

The NTSB considered why the operator of the striking train did not comply with the signal indication and subsequently failed to take actions to avoid the accident even though she had ample opportunity to do so. Discounting an intentional and willful disregard for her own safety and that of the passengers, for which the investigation found no evidence, the only reasonable explanation is that the operator, during or slightly after beginning to accelerate out of Waban station, lost awareness of her environment.

The thorough autopsy performed on the operator by the state's chief medical examiner revealed no preexisting medical condition that would have had the potential for causing this loss of awareness, and no postmortem evidence was found that the operator suffered a sudden medical event that would have precipitated a loss of consciousness. Instead, the evidence indicates that the most likely explanation of the operator's loss of awareness is that she experienced a micro-sleep¹⁸ episode shortly after departing Waban station.

¹⁸ A *micro-sleep* is an episode of sleep that may last from a fraction of a second up to 30 seconds or more. Although often associated with sleep disorders such as sleep apnea, narcolepsy, or hypersomnia, episodes of micro-sleep can occur in any individual suffering from fatigue or inadequate sleep.

The operator worked a regular schedule and was not subject to irregular work/rest cycles, which have been shown to promote fatigue. According to her family and acquaintances, she normally retired between 10:00 and 10:30 p.m. and was called by a friend at 6:30 a.m. each day. Her normal schedule would thus have provided her with an 8-hour period within which to obtain sleep. However, the investigation could not determine whether the operator had maintained this schedule in the days leading up to the accident.

The drug doxylamine, commonly found in over-the-counter sleep aids, was found in the operator's urine. This suggests that she might have taken the medication because she had some trouble sleeping during at least one of the several nights leading up to the accident but that she had not used the medication since the night before the accident at the latest. The operator was found to have a lesion on her abdomen that would likely have been painful enough to have interfered with her ability to gain restful sleep, and she may have taken the doxylamine to counter that pain or discomfort. The fact that the medication was not found in the operator's blood makes it unlikely that she would have been impaired by it on the day of the accident.¹⁹

The circumstances of this accident included several additional factors that placed the operator at risk for diminished alertness and for subsequently lapsing into episodes of micro-sleep. The 5:51 p.m. time of the accident coincided with the later afternoon low of the human circadian rhythm, a time of day in which studies have shown that individuals can fall asleep rapidly.²⁰ Moreover, the low level of muscular activity required of the seated operator and her relatively low workload are both factors that have been established as contributors to diminished alertness.²¹

Based on the operator's height and weight at the time of her last physical examination, she had a calculated body mass index (BMI) of 38.6. By this calculation, the operator would have been considered obese (a BMI greater than 30 constitutes obesity). Obesity is significantly associated with an increased risk for obstructive sleep apnea. In one study, obstructive sleep apnea was exhibited in more than 50 percent of patients with an average BMI of 40.0.²²

Obstructive sleep apnea is associated with fatigue and significant cognitive and psychomotor deficits that are at least partially reversible with appropriate treatment.²³ Accident rates have been shown to be considerably higher in drivers with obstructive sleep apnea than in

¹⁹ The presence of the medication in the operator's urine but not in her blood indicates that the medication had already been metabolized and that its effects had subsided.

²⁰ U.S. Congress, Office of Technology Assessment, *Biological Rhythms: Implications for the Worker*, OTA-BA-463 (Washington, DC: U.S. Government Printing Office, September 1991).

²¹ M. Moore-Ede, *The Twenty-Four Hour Society: Understanding Human Limits in a World That Never Sleeps* (Reading, MA: Addison-Wesley Publishing Company, 1993).

²² O. Resta and others. "Sleep-Related Breathing Disorders, Loud Snoring and Excessive Daytime Sleepiness in Obese Subjects." *International Journal of Obesity-Related Metabolic Disorders*. May 2001; 25(5): pp. 669-675.

²³ L. Ferini-Strambi and others. "Cognitive Dysfunction in Patients with Obstructive Sleep Apnea (OSA): Partial Reversibility After Continuous Positive Airway Pressure (CPAP)." *Brain Research Bulletin*. June 30, 2003; 61(1): pp. 87-92.

those without the disorder.²⁴ The Federal Motor Carrier Safety Administration (FMCSA) medical review board recently recommended that the FMCSA require screening for obstructive sleep apnea in all drivers with a BMI over 30. The NTSB concludes that the operator of the striking train was at a high risk for having undiagnosed sleep apnea and that she may have been chronically fatigued as a result of the condition.

Once the operator had departed Waban station, she likely would have had no operational matters to attend to other than those routine and long-practiced tasks, such as controlling train speed, that would almost be second nature to an experienced person operating along a familiar route. Such a low demand on her mental resources, in concert with fatigue from poor sleep quality due to discomfort and/or to undiagnosed sleep apnea, likely caused her to become relaxed and to disengage from her environment consistent with lapsing into a micro-sleep sometime after she departed Waban station. It is possible that if she observed the red signal at Waban station, she proceeded based on the belief that any train ahead would clear by the time her train arrived. She may have intended to hold her train's speed below 10 mph through the block, but during an episode of micro-sleep, the train would have continued to accelerate. The NTSB therefore concludes that the operator of the striking train failed to respond appropriately to the controlling signal indication or to take advantage of several opportunities to slow or stop the train and to prevent the accident likely because she experienced a micro-sleep episode after departing Waban station.

In its investigation of an August 15, 2000, accident involving the Maryland Transit Administration Central Light Rail Line System at the Baltimore-Washington International Airport light rail transit station,²⁵ the NTSB identified as an element of the probable cause the previously undiagnosed obstructive sleep apnea of the train operator. The condition caused the operator to fall asleep and fail to brake the train before it struck a bumping post at the terminus.

As a result of that accident investigation, the NTSB issued the following safety recommendation to all U.S. rail transit systems:

R-01-27

Ensure that your fatigue educational awareness program includes the risks posed by sleeping disorders, the indicators and symptoms of such disorders, and the available means of detecting and treating them.

In March 20, 2002, and June 18, 2002, responses to Safety Recommendation R-01-27, the MBTA informed the NTSB that it did not have a formal fatigue awareness program but that, in response to the NTSB recommendation, it had completed an introductory fatigue awareness campaign and that:

²⁴ J. Teran-Santos, A. Jimenez-Gomez, and J. Cordero-Guevara. "The Association Between Sleep Apnea and the Risk of Traffic Accidents." Cooperative Group Burgos-Santander. *New England Journal of Medicine*. March 18, 1999; 340(11): pp. 847-851.

²⁵ *Maryland Transit Administration Light Rail Vehicle Accidents at the Baltimore-Washington International Airport Transit Station Near Baltimore, Maryland, February 13 and August 15, 2000*, Railroad Special Investigation Report NTSB/SIR-01/02 (Washington, DC: National Transportation Safety Board, 2001).

The Wellness Program will continue to provide informational material to our employees. In addition, the MBTA University's Wellness Institute will collaborate with the Operations division in designing a fatigue education program.

The MBTA also responded that its medical clinic would "enhance" its data collection sheets "to include specific questions on the signs and symptoms of sleep disorders."

Based on these responses, the NTSB, on May 17, 2002, classified Safety Recommendation R-01-27 "Open—Acceptable Response."

During the investigation of the Newton, Massachusetts, accident, NTSB investigators examined material currently provided formally by the MBTA to its train operators with regard to fatigue and sleep disorders. This material consisted of a single audio-visual slide titled "Fatigue/Drowsiness" and a single paragraph in the current *Green Line Light Rail Vehicle Operation Defensive Driving Manual*. The paragraph in the operator's manual quotes the text of the audio-visual slide and states, in part:

All you need to do is get enough rest. Most people need 8 hours of sleep per night. Know what sleep you require and take care of yourself by getting the proper rest.

Based on the examination of these materials, the NTSB believes that the MBTA continues to have a fatigue awareness program that fails to adequately address potential sleep disorders among its train operators. Thus, the agency has not appropriately responded to the intent of Safety Recommendation R-01-27. The NTSB therefore reclassifies Safety Recommendation R-01-27 "Open—Unacceptable Response" and reiterates this recommendation to the MBTA.

With regard to revisions or enhancements the MBTA indicated to the NTSB that it would make to its medical data collection form, the form continues to lack any inquiries about sleep disorders, snoring, or any difficulties with sleep. Such inquiries could provide a basis for identifying train operators and others in safety-sensitive positions who are at risk for obstructive sleep apnea or other disorders so that those individuals can receive additional evaluation and, if necessary, appropriate treatment.

The NTSB concludes that the MBTA continues to have an inadequate fatigue awareness program to educate train operators about the risks of fatigue and an inadequate program to identify and address potential sleep disorders for its train operators. Further, given the seriousness of the risks posed by undiagnosed sleep apnea among transit operators, the NTSB recommends that, not only the MBTA, but all U.S. rail transit agencies should review their medical history and physical examination forms and modify them as necessary to ensure that they elicit specific information about any previous diagnosis of obstructive sleep apnea or other sleep disorders and about the presence of specific risk factors for such disorders. The NTSB further recommends that all U.S. rail transit agencies establish a program to identify operators who are at high risk for obstructive sleep apnea or other sleep disorders and require that such operators be appropriately evaluated and treated.

The NTSB also believes that the Federal Transit Administration should promote awareness, throughout the transit industry, of the safety risks associated with sleep disorders and should assist transit agencies in developing programs to minimize that risk. The NTSB therefore recommends that the Federal Transit Administration develop and disseminate guidance for operators, transit authorities, and physicians regarding the identification and treatment of individuals at high risk for obstructive sleep apnea and other sleep disorders.

MBTA Signal Rules

Reporting of Anomalous Signal Aspects

The MBTA defines defective signals in Rule 59 of the *Rules for Trainpersons and Other Employees of the Light Rail Lines*. The rule defines a defective signal as one that is imperfectly displayed, typically with conflicting aspects or no aspect. In this accident, signal H-66—which caused the struck train to stop and thus created the conditions under which this particular accident could occur—was not imperfectly displayed. The only aspect illuminated was red, indicating *stop and proceed*. The reason the signal showed red was the presence of broken bond wires.

Operators of trains made to stop by the signal indication could easily see that the track ahead was unoccupied and that the signal was possibly displaying an inappropriate aspect. The investigation could not determine how long signal H-66 had been displaying red before the accident. While the operator of the struck train told NTSB investigators that he had observed a similar occurrence at this location on one of his trips that morning and that he had reported it, there was no record of a trouble report at this location. Because train operators are not required to report such apparent anomalies to the train dispatcher, maintenance employees may not be notified of a possible problem with the signal system and thus may not effect any necessary repairs. The NTSB concludes that the broken bonds associated with signal H-66 caused a delay that placed train 3681 in a position to be struck by train 3667. The NTSB further concludes that because MBTA operating rules do not require that train operators report signals displaying red when the block of track governed by that signal can be determined to be unoccupied, possible problems in the signal system could remain undetected and unrepaired, which could increase safety risks on the rail line. Signal aspects other than red can also appear to be inappropriate for the apparent track conditions, and these apparent anomalies should also be made known to MBTA dispatchers. The NTSB therefore recommends that the MBTA require that train operators immediately report to the train dispatcher any inappropriately displayed aspects and all red signal aspects they encounter when the block of track governed by that signal can be seen to be clear of other trains.

Notification of Restrictive Signals

When the striking train departed Waban station, the train operator did not know that the train was operating under a restrictive signal indication. If he had known, he might have been able to contact the train operator via the train intercom, had it been working, to question why the train did not hold for the specified time and, once it departed the station, why it was accelerating normally, as if under a *clear* signal indication. Even if the train operator had been disengaged from her duties at that time (assuming she was not so disengaged earlier that she failed to note

the red signal), such a call may have alerted her so that she could have responded in a way that would have prevented the accident. If she did not respond, the trail operator would have had the option of stopping the train. However, MBTA rules do not require that train operators keep other crewmembers informed of restrictive signal indications. By not being so informed, the other crewmembers are limited in their ability to participate fully in the operation of the train and are thus limited in their ability to implement effective crew resource management.

The NTSB concludes that, had the MBTA required train operators to inform trail operators of restrictive signal indications and had the operator of the striking train informed her trail operator of the restrictive signal indication just west of Waban station, the trail operator might have been able to prevent the accident by questioning the operator about the train speed or by applying the brakes. As it was, however, the trail operator did not know that anything was wrong until the moment of impact.

The NTSB therefore recommends that the MBTA require train operators to notify other train crewmembers when the train encounters a restrictive signal and to inform crewmembers of the operator's intended means of complying with the restrictions. This should also include a requirement that the other crewmembers acknowledge receiving this notification.

Positive Train Control

Four decades of NTSB investigations of railroad accidents have shown that the most effective means of avoiding train-to-train collisions is through use of a positive train control system that will automatically stop a train if the crew fails to comply with a signal indication. Previous investigations have identified a wide range of factors that can affect a train crew's response to signal indications, such as multiple simultaneous distractions, cell phone usage, dense fog, crew inattention, use of prescription medications, and fatigue.

This accident in Newton, Massachusetts, is another in a long series of accidents that could have been prevented had the territory been equipped with a positive train control system. Such a system could have detected that train 3667 was operating above the allowable speed of 10 mph as required by the signal indication at signal H-64 and could have provided an over speed warning or stopped the train if the operator failed to comply with the signal indication. The NTSB therefore concludes that this accident could have been prevented had the MBTA Green Line been equipped with a positive train control system that could have intervened to stop train 3667 before it could strike the rear of train 3681.

The Rail Safety Improvement Act of 2008 requires each class I, intercity, and commuter rail carrier (carriers regulated by the Federal Railroad Administration) to develop and submit to the U.S. Secretary of Transportation, within 18 months, its plan for the implementation of a positive train control system by December 31, 2015. Transit agencies that operate trolley, light rail, and heavy rail systems are not included in the requirements of the Rail Safety Improvement Act of 2008. The NTSB therefore recommends that the FTA facilitate the development and implementation of positive train control systems for rail transit systems nationwide. The NTSB further recommends the MBTA develop and implement a positive train control system for all of its rail lines.

Trolley Car Crashworthiness

The lead car of train 3667 (car 3667) and the trailing trolley car of train 3681 (car 3703) sustained substantial damage. Although the anticlimber showed indications of engagement, the forward end of car 3667 overrode the rear end of car 3703. The understructure and end structure failed on both trolley cars, resulting in the loss of more than 10 feet of survivable space on both cars. The operator's compartment was crushed such that the operator could not have survived this accident. The NTSB concludes that the failure of the structure of the trolley cars resulted in the catastrophic loss of survivable space.

There are no Federal standards for transit car crashworthiness. The NTSB addressed this issue during its investigation of the November 3, 2004, collision of two Washington Metropolitan Area Transit Authority Metrorail trains in Washington, D.C.²⁶ The last railcar of train 703 telescoped and overrode the leading end of the first railcar of train 105, sustaining a catastrophic loss of approximately 34 feet of survival space in the last railcar's passenger compartment. As a result of the accident, the NTSB made the following recommendation to the FTA:

R-06-6

Develop minimum crashworthiness standards to prevent the telescoping of transit railcars in collisions and establish a timetable for removing equipment that cannot be modified to meet the new standards.

The FTA responded in February 2008 that, in cooperation with the American Public Transportation Association and the American Society of Mechanical Engineers, it will develop new standards for light and heavy rail transit vehicles that incorporate crash energy management principles. The agency also noted that it is researching crash energy management specifications for overhauling the front ends of existing light rail vehicles. Based on this response, the NTSB has classified Safety Recommendation R-06-6 "Open-Acceptable Response."

²⁶ *Collision Between Two Washington Metropolitan Area Transit Authority Trains at the Woodley Park-Zoo/Adams Morgan Station in Washington, D.C., November 3, 2004*, Railroad Accident Report NTSB/RAR-06/01 (Washington, DC: National Transportation Safety Board, 2006).

Conclusions

Findings

1. The following were neither causal nor contributory to the accident: weather conditions, equipment performance, track condition, crewmember use of alcohol or illegal drugs, crewmember use of cell phones, crew training and qualifications, or the performance of the crew of the struck train.
2. The emergency response to this accident was timely and appropriate.
3. The operator of the striking train was at a high risk for having undiagnosed sleep apnea, and she may have been chronically fatigued as a result of the condition.
4. The operator of the striking train failed to respond appropriately to the controlling signal indication or to take advantage of several opportunities to slow or stop the train and to prevent the accident likely because she experienced a micro-sleep episode after departing Waban station.
5. The Massachusetts Bay Transportation Authority continues to have an inadequate fatigue awareness program to educate train operators about the risks of fatigue and an inadequate program to identify and address potential sleep disorders for its train operators.
6. The broken bonds associated with signal H-66 caused a delay that placed train 3681 in a position to be struck by train 3667.
7. Because Massachusetts Bay Transportation Authority operating rules do not require that train operators report signals displaying red when the block of track governed by that signal can be determined to be unoccupied, possible problems in the signal system could remain undetected and unrepaired, which could increase safety risks on the rail line.
8. Had the Massachusetts Bay Transportation Authority required train operators to inform trail operators of restrictive signal indications and had the operator of the striking train informed her trail operator of the restrictive signal indication just west of Waban station, the trail operator might have been able to prevent the accident by questioning the operator about the train speed or by applying the brakes.
9. This accident could have been prevented had the Massachusetts Bay Transportation Authority Green Line been equipped with a positive train control system that could have intervened to stop train 3667 before it could strike the rear of train 3681.
10. The failure of the structure of the trolley cars resulted in the catastrophic loss of survivable space.

Probable Cause

The National Transportation Safety Board determines that the probable cause of the May 28, 2008, collision of two Massachusetts Bay Transportation Authority Green Line trains in Newton, Massachusetts, was the failure of the operator of the striking train to comply with the controlling signal indication, likely as a result of becoming disengaged from her environment consistent with experiencing an episode of micro-sleep. Contributing to the accident was the lack of a positive train control system that would have intervened to stop the train and prevent the collision.

Recommendations

As a result of its investigation of the May 28, 2008, collision between two Massachusetts Bay Transportation Authority Green Line trains, the National Transportation Safety Board makes the following safety recommendations:

New Recommendations

To the Federal Transit Administration:

Facilitate the development and implementation of positive train control systems for rail transit systems nationwide. (R-09-08)

Develop and disseminate guidance for operators, transit authorities, and physicians regarding the identification and treatment of individuals at high risk for obstructive sleep apnea and other sleep disorders. (R-09-09)

To all U.S. rail transit agencies:

Review your medical history and physical examination forms and modify them as necessary to ensure that they elicit specific information about any previous diagnosis of obstructive sleep apnea or other sleep disorders and about the presence of specific risk factors for such disorders. (R-09-10)

Establish a program to identify operators who are at high risk for obstructive sleep apnea or other sleep disorders and require that such operators be appropriately evaluated and treated. (R-09-11)

To the Massachusetts Bay Transportation Authority:

Require that train operators immediately report to the train dispatcher any inappropriately displayed aspects and all red signal aspects they encounter when the block of track governed by that signal can be seen to be clear of other trains. (R-09-12)

Require train operators to notify other train crewmembers when the train encounters a restrictive signal and to inform crewmembers of the operator's intended means of complying with the restrictions. Include a requirement that the other crewmembers acknowledge receiving this notification. (R-09-13)

Develop and implement a positive train control system for all of your rail lines. (R-09-14)

Recommendation Reiterated in Report

To the Massachusetts Bay Transportation Authority:

R-01-27

Ensure that your fatigue educational awareness program includes the risks posed by sleeping disorders, the indicators and symptoms of such disorders, and the available means of detecting and treating them.

Recommendation Reclassified in Report

To the Massachusetts Bay Transportation Authority:

R-01-27

Ensure that your fatigue educational awareness program includes the risks posed by sleeping disorders, the indicators and symptoms of such disorders, and the available means of detecting and treating them.

Safety Recommendation R-01-27, previously classified “Open—Acceptable Response,” is reclassified “Open—Unacceptable Response” in the “Performance of Operator of Striking Train” section of this report.

BY THE NATIONAL TRANSPORTATION SAFETY BOARD

MARK V. ROSENKER
Acting Chairman

KATHRYN O’LEARY HIGGINS
Member

DEBORAH A. P. HERSMAN
Member

ROBERT L. SUMWALT
Member

Adopted: July 14, 2009

Appendix A

Investigation

The National Response Center notified the NTSB of the accident about 7:00 p.m. on May 28, 2008. The investigator-in-charge and other members of the NTSB investigative team were launched from the Washington, D.C., headquarters office and from the Chicago, Illinois; Gardena, California; and Jacksonville, Florida; field offices. Investigative groups were established in the areas of operations, track, signals, mechanical, human performance, survival factors, and event recorder issues. No hearings or depositions were held in conjunction with this accident. Member Kathryn O’Leary Higgins was the Board Member on scene.

Parties to the investigation included the Massachusetts Bay Transportation Authority, the Massachusetts Department of Public Utilities, and the Amalgamated Transit Union (Boston Carmen's Union).