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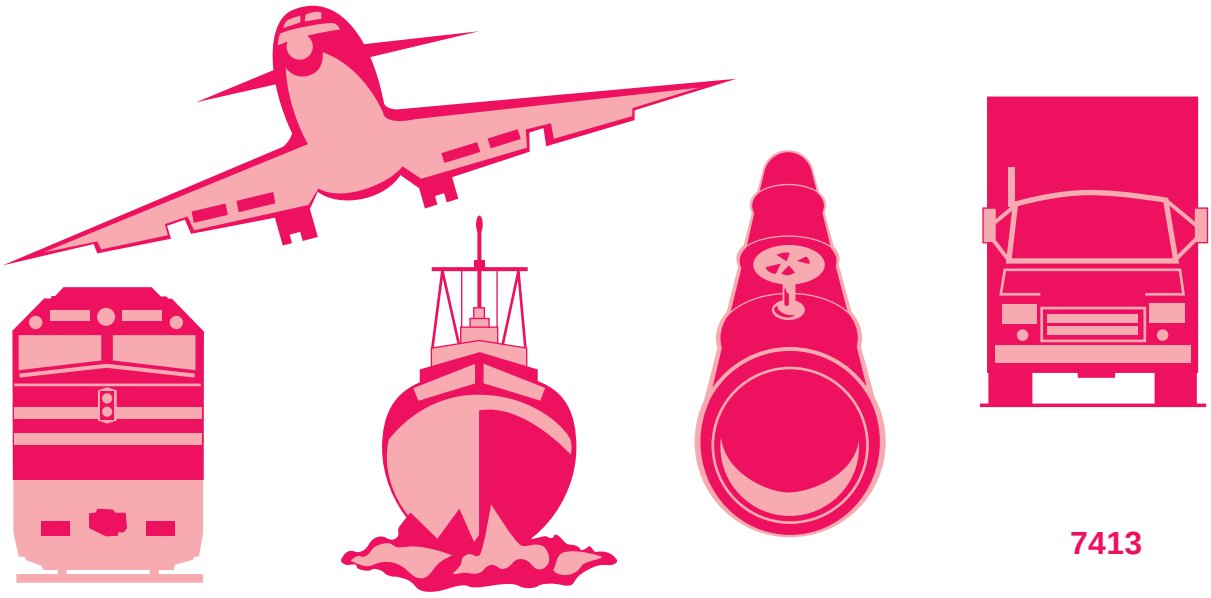
NATIONAL TRANSPORTATION SAFETY BOARD

WASHINGTON, D.C. 20594

RAILROAD SPECIAL INVESTIGATION REPORT

MARYLAND TRANSIT ADMINISTRATION
LIGHT RAIL VEHICLE ACCIDENTS AT THE
BALTIMORE-WASHINGTON INTERNATIONAL
AIRPORT TRANSIT STATION
NEAR BALTIMORE, MARYLAND
FEBRUARY 13 AND AUGUST 15, 2000



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Railroad Special Investigation Report

Maryland Transit Administration Light Rail Vehicle Accidents at the Baltimore-Washington International Airport Transit Station Near Baltimore, Maryland February 13 and August 15, 2000

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

Abstract: In 2000, the Maryland Transit Administration experienced two similar accidents in the same location just 6 months apart. Both accidents involved the failure of a light rail vehicle train to stop at the designated stopping point at the Baltimore-Washington International Airport Light Rail Station (BWI Airport Station). The Safety Board's investigation of the two accidents indicated that, although the direct cause of each accident was different, aspects of the Maryland Transit Administration rail transit operation common to the two accidents influenced both their outcomes. The first accident occurred about 2:37 p.m. on February 13, 2000, when Maryland Transit Administration train 24, en route from Baltimore to the BWI Airport, struck the hydraulic bumping post at the terminus of track No. 1 at the BWI Airport Station and derailed. The second accident occurred about 7:14 a.m. on August 15, 2000, when Maryland Transit Administration train 22, en route from Baltimore to the BWI Airport, struck the hydraulic bumping post at the terminus of track No. 2 at the BWI Airport Station and derailed.

The safety issues discussed in this report are the adequacy of requirements governing the use of prescription and over-the-counter medications by light rail vehicle operators, the effect of sleeping disorders on the performance of light rail vehicle operators, and the adequacy of the event recorders.

As a result of its investigation, the Safety Board issued safety recommendations to the Federal Transit Administration, U.S. rail transit systems, and the Maryland Transit Administration.

Contents

Acronyms and Abbreviations

APTA -- American Public Transportation Association
BWI Airport Station -- Baltimore-Washington International Airport Light Rail Station
CFR -- *Code of Federal Regulations*
FRA -- Federal Railroad Administration
FTA -- Federal Transit Administration
LRV -- light rail vehicle
MDOT -- Maryland Department of Transportation
MTA -- Maryland Transit Administration

Introduction

In 2000, the Maryland Transit Administration (MTA)[1] experienced two similar accidents in the same location just 6 months apart. Both accidents involved the failure of an MTA light rail vehicle (LRV) train to stop at the designated stopping point at the Baltimore-Washington International Airport Light Rail Station (BWI Airport Station). In both cases, the train struck a hydraulic bumping post apparatus at the end of the track. The Safety Board's investigation of the two accidents indicated that, although the direct cause of each accident was different, aspects of the MTA rail transit operation common to the two accidents influenced both their outcomes. Consequently, the Safety Board developed a special investigation report to address the safety factors affecting both accidents.

The first accident occurred about 2:37 p.m. (eastern standard time) on February 13, 2000, when MTA train 24 (composed of a single LRV), en route from Baltimore to the BWI Airport, struck the hydraulic bumping post at the terminus of track No. 1 at the BWI Airport Station and derailed. The force of the collision detached the bumping post from the track, and the front of the train, which was lodged against the bumping post, was elevated about 3 1/2 feet into the air. Train 24 carried 26 people (25 passengers and 1 operator), 18 of whom were injured. Five of those injured had serious injuries. The MTA estimated the cost of the accident at $924,000.

The second accident occurred about 7:14 a.m. (eastern daylight time) on August 15, 2000, when MTA train 22 (composed of two LRVs), en route from Baltimore to the BWI Airport, struck the hydraulic bumping post at the terminus of track No. 2 at the BWI Airport Station and derailed. The bumping post separated from its attachment to the track and came to rest in an inverted position. The leading LRV of the train came to rest on top of the overturned bumping post and about 4 1/4 feet up in the air. The roof of this LRV was partially embedded into the ceiling structure of the terminal building. Train 22 carried 22 people (21 passengers and 1 operator), 17 of whom were injured. None had life-threatening injuries. The MTA estimated the cost of the accident at $935,000.

This special investigation report discusses the following safety issues:

- The adequacy of requirements governing the use of prescription and over-the-counter medications by LRV operators,
- The effect of sleeping disorders on the performance of LRV operators,
- The adequacy of the event recorders.

As a result of its investigation of these accidents, the Safety Board makes recommendations to the Federal Transit Administration, U.S. rail transit systems, and the MTA.

[1] In 2000, when the accidents detailed in this report occurred, the MTA was called the Mass Transit Administration. On October 1, 2001, the MTA changed its name to the Maryland Transit Administration.

Factual Information

February 13, 2000, Accident[1]

Accident Narrative

The operator of train 24 said he reported for duty at the Maryland Transit Administration (MTA) light rail operations center at North Avenue Yard in downtown Baltimore, Maryland, on February 13, 2000, at 9:30 a.m. (eastern standard time) for his 10:01 a.m. assignment as an operator on the Central Light Rail Line System. (See figure 1 for the layout of the Central Light Rail Line System.) He said that he spoke to the train dispatcher when he reported for duty. He said he received a light rail vehicle (LRV) train at the sign-up location, performed an equipment inspection, and started revenue service from Pennsylvania Station in downtown Baltimore to the Baltimore-Washington International (BWI) Airport Station at 10:44 a.m.[2] He said he arrived and departed the BWI Airport Station and was relieved at the University of Baltimore/Mount Royal Station between 12:15 and 12:30 p.m. The operator said this trip was uneventful and, when asked about the stop at the BWI Airport Station, he said he had stopped his train about 20 feet from the "high block."[3]

The operator said that during his break period (which he recalled as beginning about 12:30 and ending about 1:40 p.m.), he had asked the train dispatcher for "a couple of aspirins" because he had a headache. He said he took the aspirins and lay down for about an hour. He said that after his break period, he took over operation of train 24 at the University of Baltimore/Mount Royal Station about 1:42 p.m., proceeded north to Pennsylvania Station, and departed Pennsylvania Station southward at 1:51 p.m. in revenue service. Train 24 was composed of a single LRV and traveled along main track No. 1.

The operator said the trip from Pennsylvania Station to the BWI Airport Station was uneventful. He said he experienced no problems with the equipment, and he stopped at every station. The maximum authorized speed limit for the section of track from Pennsylvania Station to the BWI Airport Station was 50 mph.

One passenger told the Safety Board that he had a clear view of the operator at the North Linthicum Station (three stations before the BWI Airport Station). The passenger said that the operator received a green signal at the station and then sat motionless for 10 to 15 seconds while the train remained stationary. He recalled that the operator then shook his head and body before beginning to move the train forward.

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[1] See appendix A for an accident brief on this accident.

[2] LRVs typically require only a single vehicle operator, and usually no other crewperson is on the train.

[3] The *highblock* is a raised concrete platform with handrails designed to assist in the loading and offloading of disabled passengers. The highblock is the normal designated stopping point for trains.

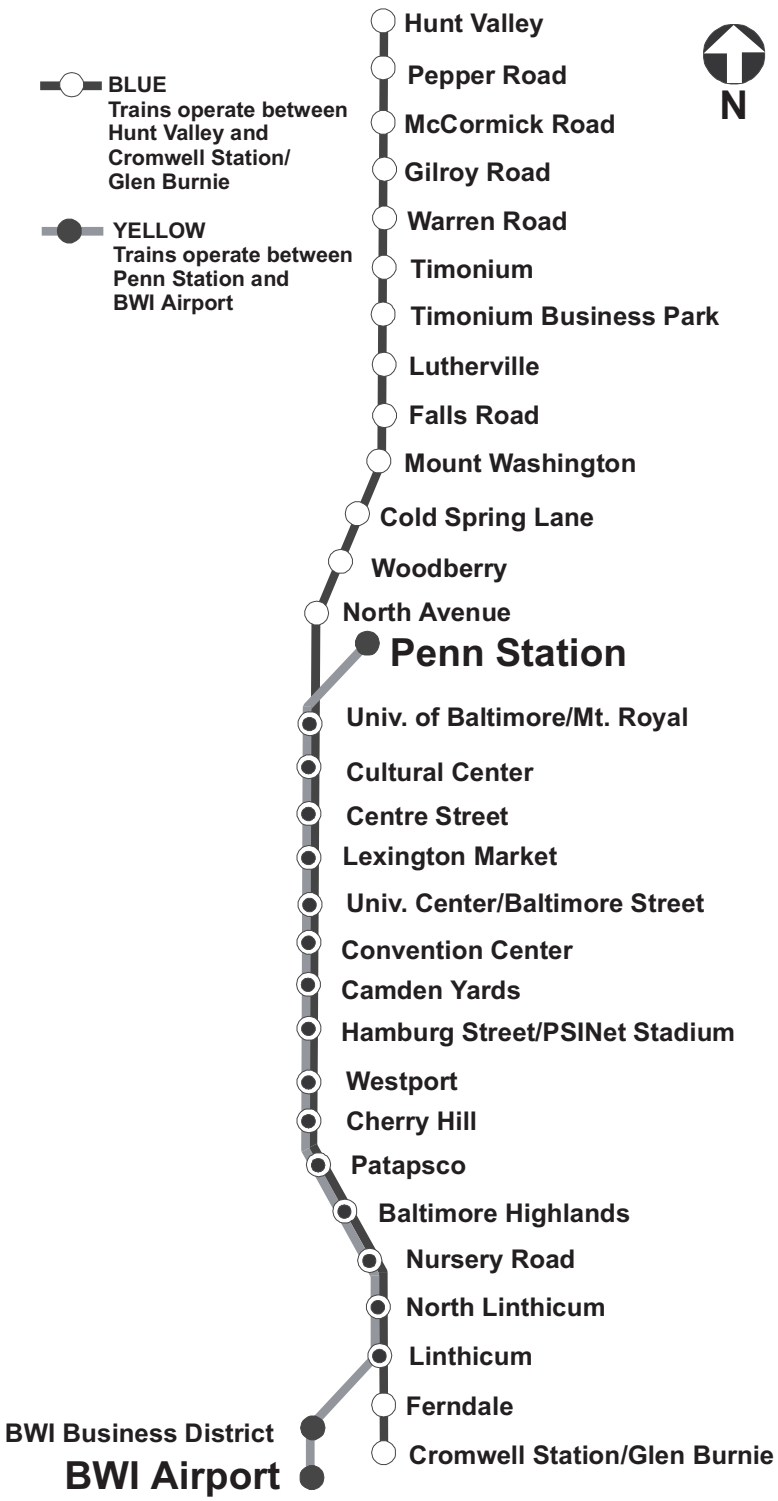

Figure 1. Layout of the MTA Central Light Rail Line System.

The last station stop before the BWI Airport Station was the BWI Business District Station. The operator said the BWI Business District Station stop was routine; one person boarded and no one detrained. From the BWI Business District Station to the BWI Airport Station, the maximum authorized speed was 15 mph. Safety Board investigators asked the operator to describe the portion of the trip between the BWI Business District Station and the BWI Airport Station. He said:

> The weather was still overcast. The signals were working fine. I didn't run any of them. Went on in. Blew the horn at both of the stations—I mean, grade crossings. And went on in and took my time going on in. And that was it.

The operator said the last signal for his train before the BWI Airport Station (signal BWI 15-6 at milepost 115) displayed a yellow aspect.[4] According to several passengers, train 24 did not stop or slow at the BWI Airport Station but continued through the station until it struck the hydraulic bumping post[5] at the end of the station track. During postaccident interviews, several passengers told investigating law enforcement officials that it appeared to them that the operator may have fallen asleep before the impact.

About 2:37 p.m., upon its collision with the bumping post, the train derailed. The force of the collision detached the bumping post from the track, and the front of the LRV, which was lodged against the bumping post, was raised about 3 1/2 feet into the air. (See figure 2.)

When asked to describe the collision, the operator said:

> People started getting up to get off. The next thing I know, 'boom.' I looked around, pulled back. I saw it right there at me. I went up into the window.

Safety Board investigators asked whether the operator had attempted to stop the train by applying the brakes. With respect to the train brakes, the operator was unclear but did not indicate that he had applied them. With respect to the emergency brakes, he stated:

> I was up on that bumping post that quick. I don't even know if I hit the mushroom [emergency stop button] or not. All I knew, I was up in the window and came back down on the floor. And I was out. I don't know if I was out for—I don't know how many seconds I was out, but I knew I was out.

(See figure 3 for photograph of cab interior, showing emergency stop button.)

[4] A *yellow aspect* calls for the operator to proceed prepared to stop at the next signal.

[5] A *bumping post* is an apparatus located just before the physical end of a rail track. It is designed to stop runaway railcars and absorb the kinetic energy should a railcar continue to travel past the designated stopping point and on toward the end of the track.

Figure 2. Two views of train 24 in the station following February 13, 2000, accident; top photo shows side view of train after it traveled into the end of the line, bottom photo shows close-up of front car resting on the bumping post.

Figure 3. LRV cab interior; arrow indicates emergency stop button.

The operator would not estimate how fast the LRV was traveling when it struck the bumping post. In attempting to explain the accident, he stated, "It [the LRV] just took off. I must have—when I turned around or something to see why are these people coming up there like that, I must have hit it, and it took off on me."

Injuries

Table 1. Injuries resulting from February 13, 2000, accident

Injury Type[a]	Crew, train 24	Passengers, train 24	Other	Total
Fatal	0	0	0	0
Serious	0	5	0	5
Minor	1	12	0	13
None	0	8	0	8
Total	1	25	0	26

[a] The categories in table 1 are based on the injury criteria defined at 49 *Code of Federal Regulations* 830.2, which the Safety Board uses in accident reports for all transportation modes.

Of the 18 people who experienced injuries, 13 had injuries affecting the head, neck, or throat, as documented in their medical records. Several of the paramedic responders to the accident told the Safety Board that they considered that some serious facial and neck injuries to passengers had likely resulted from impact with the LRV seating grabrails.[6] The paramedics' observations were consistent with statements made by some of the injured passengers. Of the seven injured passengers who responded to the Safety Board's questionnaire concerning this accident, two ascribed their injuries to striking a grabrail. A third recalled striking a seatback, without specifying which part of the seatback. A fourth injured passenger stated that he hit "a pole." (Some of the seatback grabrails had vertical metal stanchions attached to them. Vertical metal stanchions were also attached to the end panel by each car door.)

Damage

The MTA estimated the cost of the accident at $924,000.

LRV. The outside front center panel of the single LRV car that made up train 24 was dented inward 1 to 2 inches immediately below the windshield. The "A" (front) end of the two-segment car sustained localized exterior side-sheet panel distortion. The front propulsion truck had separated from the car body and was wedged against the rear support legs of the bumping post assembly. The pantograph assembly on the roof of the car body's "A" end was substantially damaged.

Bumping Post. As a result of the accident, both running rails apparently fractured at points immediately north of the bumping post assembly. The westernmost running rail was fractured at a bolt hole at the attachment of the bumping post assembly's front support leg. The easternmost running rail was fractured at a joint weld about 40 inches before the bumping post assembly. The bumping post had been pushed backward to the point at which its rear legs were firmly wedged against the vertical face of the concrete service platform that surrounded the track and ballast. The front of the bumping post assembly had rotated upward about 3 1/2 feet, having pivoted about its rear support leg members (forming an "A frame"). Despite being displaced, the bumping post assembly did not appear to be seriously damaged.

Train 24 Operator

During an interview following the February 13, 2000, accident, the operator described his day up to the accident as "an average day." He said that nothing had distracted him from his duties until the accident. He said he had felt rested when he reported for duty, although he said that his head had felt "filled up." When asked whether he had been alert and attentive, the operator responded that he had "tried to be." When asked whether he had dozed off any time after he began his second trip that day, the operator responded, "I couldn't tell you. I probably did doze. I don't know. But I doubt it. I probably did doze off." He also stated that he had "felt tired and nauseated all day."

[6] A *seating grabrail* is the handle bar that is fitted across the top of the seatback.

The operator said he had no deadline for completing his trip to the BWI Airport. He said he was familiar with the route between Pennsylvania Station and the BWI Airport Station.

Medical Factors. The operator was 53 years old at the time of the accident. He said he used reading glasses only to see close up. He said he had no difficulty seeing in the distance. He stated that he had no problems with his hearing.

The operator's most recent physical examination before the accident had been on May 18, 1999. Based on the results of the examination, the operator was recommended to continue as an operator and re-certified. The expiration date of his medical certificate was May 18, 2001. The physician who performed the examination noted that the operator's hypertension was "well controlled." He also referred to the operator's use of medication with the notation "blood pressure—two." The operator told the Safety Board that for the last several years he had taken the prescription medication Capozide twice daily to control high blood pressure.

The operator said that he had undergone oral surgery for a dental abscess in December 1999 and had been prescribed two medications, oxycodone and Tylenol 3 (acetaminophen with codeine), to alleviate the pain. He was also prescribed penicillin. His dentist prescribed the oxycodone and penicillin, and his personal physician prescribed the Tylenol 3. The operator recalled that both doctors told him the pain medications might cause drowsiness, and he acknowledged that he did become "a little drowsy" after he took them. The operator said that his regular physician was aware that he was employed by the MTA, but he was not sure whether the physician knew he operated a light rail train. He said that his dentist was not aware of his occupation.

MTA records contained an application for sick leave submitted by the operator on December 31, 1999. The form indicated that the operator suffered from a "dental abscess" and that he was unable to work from December 12, 1999, until January 2, 2000. It further indicated that the operator was initially treated for the condition on December 4, 1999, and last treated on December 22, 1999. The operator's personal physician checked "yes" to the following question on the form: "Is the patient able to perform his/her essential job duties?" The physician released the operator to return to duty on January 2, 2000.

The operator told the Safety Board that on the morning of the accident, he had taken one blood pressure pill, one Tylenol 3 pill, and one oxycodone pill. He said he had also taken two aspirins about noon. He said he had not used any other over-the-counter or prescription medications. He said he had not used alcohol or illicit drugs that day.

When asked whether the MTA had a policy with respect to an operator's use of medications, the LRV operator responded, "If you take it [medication], let them know." He said the MTA was aware that he took medication to control high blood pressure but was unaware he had been taking the pain-relievers oxycodone and Tylenol 3. When asked why he did not inform the MTA about the use of those medications, he stated, "It wasn't that much and I wasn't going to take it that long. I was hoping I wouldn't take it."

When the Safety Board interviewed the MTA contract physician[7] about the operator's use of prescription drugs, the contract physician said that the operator should have informed the MTA of his use of all prescription medications and should have taken himself out of service. The contract physician stated that, while the operator was not required to inform the MTA of his use of medications, it was expected that the operator would have done so.

MTA records showed that on June 20, 1994, the operator had tested positive for cocaine metabolites during a random urinalysis. He was removed from service effective June 24, 1994, and enrolled in a rehabilitation program. Over the following months, he underwent substance abuse treatment. The treatment included a number of urinalysis and Breathalyzer tests to detect drugs and alcohol (respectively), beginning on July 8, 1994, and concluding on September 11, 1996. A letter dated February 8, 1995, to the MTA from the medical review officer said that the operator "…is working and has been; he has fulfilled the SAP [substance abuse professional] recommendations as of 1/25/95."

A random alcohol test was administered to the operator on February 13, 1997. The results were negative. Some weeks later, the MTA directed the operator to report to a substance abuse professional, as the final step in completing his rehabilitation period. In a letter dated April 29, 1997, the substance abuse professional informed the MTA that the operator was continuing in recovery, and that further testing was not indicated.

The operator was subsequently tested for alcohol and drugs for "reasonable cause" on October 23, 1997, after he was involved in an accident (collision with a safety barrier). The results were negative for the presence of alcohol and drugs. This was the last time the operator was tested for alcohol or drugs until he provided breath and urine specimens after the February 2000 accident.

Work/Rest Routine. The Safety Board asked the operator to describe his work/rest schedule for the days preceding the accident, but the operator said he could not recall a detailed work/rest history. During an interview on February 14, 2000, the operator said that before the accident, he had been off duty his two regularly scheduled days, Thursday, February 10, and Friday, February 11. He said that he had taken a personal day on Saturday, February 12. He could not recall his sleep schedule for this period, except that he thought he had retired about 11:00 p.m. on February 12. He said that on the day of the accident, February 13, he had gotten up briefly between 7:00 and 7:30 a.m. He lay back down until between 8:00 and 8:30 a.m., at which time he arose.

[7] The contract physician served as the MTA's medical review officer and was responsible, among other duties, for tasks relating to the commercial driver's license renewal process and the MTA drug testing program.

MTA time sheets showed that the operator went on duty at 10:04 a.m. on February 13. They showed that he went on a break at 12:17 p.m. and returned to duty at 1:42 p.m. The accident occurred about 1 hour later. At the time of the accident, it appears that the operator had been awake for between 6 and 7 1/2 hours and on duty for about 4 1/2 hours.

Certification and Training. The MTA had initially hired the operator as a busdriver on September 6, 1974. He qualified as a light rail operator, the position he occupied at the time of the accident, effective June 10, 1993. To qualify for the position, the operator had to take a number of written tests. On June 7 and 8, 1993, the operator was given seven written tests pertaining to light rail operations. He was also given a written test that required him to name the stations throughout the MTA system. He received passing scores on all tests.

According to the MTA, the operator received 60 minutes of alcohol and drug training in a classroom setting in December 1994. The written training materials provided to him at that time included information about alcohol and illicit drugs, including marijuana, cocaine, amphetamines, phencyclidine, and opiates. The training did not address over-the-counter or prescription medications.

On July 2, 1995, the operator received LRV operator troubleshooting training. On March 6, 1996, he was given additional light rail operator tests, for which he received passing scores. On that same day, he received stop signal compliance training, at the conclusion of which he received a certificate of achievement.

When asked about previous accidents he had experienced as an LRV operator, the operator recalled that a truck had backed out and hit his train some years before in Baltimore. He also said that in 1996 or 1997, a train he was operating struck a barrier, for which he was assessed 3 days off. The MTA light rail transportation superintendent indicated that the operator had received MTA safety awards for accident-free operation in 1994 and 1996. (A number of MTA operators had received such awards.)

At the time of the accident, the operator had a class "B" commercial driver's license, issued on January 3, 1997, with an expiration date of January 5, 2002. On March 14, 2000, MTA police conducted a review of the Maryland Inter-Agency Law Enforcement System database and found no criminal or civil records on file regarding this operator. His license had not been suspended, revoked, or disqualified; and no points had been assessed as of the inquiry date.

Train 24 Mechanical

General Equipment. Train 24 consisted of a single-car LRV, which is a two-segment, electrically powered, self-propelled, six-axle, articulated passenger railroad car. The LRV could be operated as a single unit or in consists of up to three vehicles. The LRV operated on 750-volt DC current provided by overhead catenary and collected through a pantograph mounted on its roof. The LRV was manufactured by ADtranz at Elmira, New York, and accepted by the MTA on September 25, 1998.

The LRV was 95 feet long, 9 feet 6 inches wide, and 12 feet 6 inches tall when the pantograph was completely down. The LRV weighed 109,643 pounds, empty. It was designed to accommodate 84 seated and 177 standing passengers.

The LRV was equipped with electrical (dynamic or regenerative) and mechanical (friction) brakes, which included tread brakes and track brakes.[8] The operator could manually initiate the track brakes by pressing the TRACK BRAKES or EMERGENCY STOP push-button ("mushroom"). The LRV computer was programmed to automatically engage the track brakes when the master controller was moved to the FULL STOP position or when a trip stop violation occurred.

Preaccident Inspections. The LRV that made up train 24 received its annual inspection and maintenance beginning on October 8, 1999. The LRV's braking rate test was last performed during this annual maintenance and inspection. According to the results of the brake rate test, the LRV could stop from a speed of 23 mph in about 125 feet in service braking mode and in about 63 feet in emergency braking mode. The LRV had received its 45-day inspection and maintenance on January 6, 2000.

Postaccident Examinations

Track and Signal. The Safety Board's postaccident examination of the track and signals showed no evidence of tampering, vandalism, or electrical problems. Routine track and signal function tests were performed, and no exceptions were noted. The MTA signal maintenance, inspection, and testing records indicated that the equipment was in satisfactory condition and listed no exceptions that would have prevented proper operation. Examination of the rail did not reveal any scratch marks, signs of abrasion, or metal shavings.

Event Recorder. Each MTA LRV was equipped with an event recording system, a software package provided by ADtranz as an upgrade to the LRV's main computer system. The recording system did not continuously retain all data concerning the LRV's operation; a specific trigger had to activate the system's storage function. For the MTA system, the trigger that activated the recorder's storage function was the application of the LRV's track brakes while the LRV was traveling at least 10 mph. The system then stored the operational data from 30 seconds before until 30 seconds after the triggering event. The data were stored in one of two locations within the train's central computer memory.

During the morning of February 14, 2000, after the LRV was re-railed, the main battery power was restored to the LRV to permit access to the event recorder data. MTA personnel connected a laptop computer to the train's main computer using a serial cable. Investigators sent a series of commands to the LRV's computer to create a printout of all recorded parameters since the triggering event. This printout should have shown the data broken up by three data spikes—the first marking the beginning of the recorded event, the second (30 seconds later) showing the location of the actual triggering event, and the third

[8] *Track brakes* are devices that can apply additional braking directly to the track through use of electromagnets when more braking effort is needed, such as in emergency braking.

(30 seconds after the second) indicating the end of the recorded event. When the printout was created, investigators saw an initial spike, flat-line data for 60 seconds, and a second spike. No spike appeared at the point at which the triggering event should have been. Repeated attempts to capture these data led to identical results.

On February 15, 2000, after the LRV had been moved to the MTA's North Avenue Yard operations center, another attempt was made to download the event recorder data. When the event log was accessed, it showed a triggering event as occurring during the previous morning (February 14), shortly after investigators had initially accessed the accident data. At no time since the accident (February 13) had the train experienced an event that should have triggered the event recording system. At the time of the supposed second triggering event, the LRV was incapacitated and not moving, and no track brakes were applied.

Because the system was supposed to be capable of retaining two separate recorded events, investigators expected that the second triggering event would have occupied the second memory slot in the data log, but this memory slot was empty. The triggered event from the time of the accident that investigators had originally detected was no longer listed in the log.

ADtranz, the recorder manufacturer, was notified of the difficulties encountered with the event recording system. Several ADtranz representatives came to Baltimore to analyze the problem. Also, the downloaded data were sent to ADtranz for review. ADtranz could not identify the problem through data review. The ADtranz representatives who came to Baltimore studied the software schematics and ran tests on the rail car to determine why the recording system was malfunctioning. By studying the schematics, the representatives determined that the software was designed to store only one event at a time. Two memory slots were available, but the first slot was erased immediately after the second slot was filled, and vice versa. Accordingly, Adtranz determined that the software was acting as designed but not as requested by the customer, the MTA.

Extensive testing could not reproduce the recording of an event without an actual triggering event. The ADtranz representatives could not determine the cause of the malfunction. ADtranz was unable to identify and resolve the problem.[9]

Security Video Recorder. The MTA LRVs were equipped with video recording systems to enhance security on the LRVs. Each system consisted of six independent video cameras, a VHS video recorder, and a multiplexing unit. The six cameras were distributed through the LRV as three cameras per each half of the LRV, the two halves being separated by the car's articulation. Each LRV had two cameras facing out from the articulation, one directed at the left-hand door, the other at the right-hand door. Each LRV also had one camera at the opposite end of the LRV, above the cab door, facing directly down the center of the car.

[9] ADtranz is no longer in business.

Following the accident, the LRV's video equipment was brought back to the Safety Board lab for analysis. Because of the location of the cameras, the videotape showed no visible evidence of any collision. A time stamp on the tape provided by the multiplexing unit showed that the tape ended about the same time the accident occurred (recorder time 14:37:12).

On the videotape, Safety Board investigators were able to identify the image of the highblock at the far northern end of the BWI Airport Station platform to the left of the rear half of the car. Using measurements of the distance from this platform to the impact point and the time that each picture was taken from this location to the end of the tape, investigators calculated an estimated average speed of the train while traveling along this platform as 15.64 mph.

Meteorological

The National Weather Service reported that the weather at the BWI Airport at the time of the incident, in mid-afternoon daylight, was overcast and dry (no precipitation recorded) with wind from the southwest at 4 to 6 knots, visibility of 10 statute miles, and a temperature of 34° F. It was also reported that light rain/drizzle started about 1/2 hour after the incident.

Toxicological

Pursuant to requirements at 49 *Code of Federal Regulations* (CFR) 654.33 and 653.45, the operator provided a breath specimen for alcohol testing and a urine specimen for drug testing.[10] The breath specimen was obtained at 7:12 p.m. and the urine specimen at 7:20 p.m. on the day of the accident. No alcohol was present in the breath specimen. The urine specimen tested positive for benzoylecgonine, which is the metabolite of cocaine (quantified at 7,300 nanograms per milliliter), positive for morphine (2,000 nanograms per milliliter), and positive for codeine (2,100 nanograms per milliliter).

During his initial interview on February 14, 2000, the operator had said he had not used alcohol or illicit drugs before reporting for duty on the day of the accident. The Safety Board re-interviewed the operator to discuss the results of his postaccident toxicology tests. The operator was asked to explain how cocaine had entered his system. He responded that the pain associated with his oral surgery had been so severe he had resorted to self-medication using cocaine, which he believed would numb his gums. He said that late on Friday evening, February 11, between 11:30 p.m. and midnight, he had rolled two wet cotton balls in cocaine powder and placed them in the corners of his mouth. He said he then relaxed for some time, possibly several hours. He was unable to say how much cocaine he had used. The operator stated that he had not smoked, intravenously injected, or nasally ingested the drug. He said he knew that using cocaine was illegal and that he should not have had it in his system.

[10] As stated at 49 CFR 40.21(a), U.S. Department of Transportation postaccident drug testing regulations require that employers test for marijuana, cocaine, opiates, amphetamines, and phencyclidine.

The operator was asked whether he had received a copy of the MTA's August 1991 *Interim Rules and Instructions for Employees*, to which he responded that he believed he had. He was also asked whether he had received the "MTA Substance Abuse Prevention Policy," to which he responded that he believed a copy had been mailed to him. The MTA provided the Safety Board with a copy of a signed acknowledgement from the operator, dated January 9, 1995, that he had received a copy of this policy.

During the inspection of the accident train on the evening of February 13, 2000, Safety Board investigators found three pills in the cab's control compartment. The investigators provided the pills to an MTA police officer at the scene. The MTA police sent the pills to the Maryland State police laboratory in Pikesville, Maryland, for toxicological analysis.[11] The laboratory reported that "two red and white capsules, both with the inscription 'DPI658,' were identified as oxycodone and acetaminophen, and one white pill, bearing the inscription '93-150' and '3,' was identified as codeine and acetaminophen."

Emergency Response

Two Maryland Transportation Authority police officers[12] stationed at the airport were on routine foot patrol duty and standing at an airport police security podium inside the International Terminal Building (about 75 feet from the BWI Airport Station entrance door) when train 24 entered the station. They saw the LRV collide with the bumping post, and they immediately notified their communications dispatcher by portable radio. The communications center dispatched emergency resources to the scene. The resources that responded ultimately included 9 additional Maryland Transportation Authority police officers, 6 BWI fire and rescue units, 13 BWI fire and rescue personnel, 9 ambulances, and 18 paramedic personnel.

The MTA also dispatched emergency resources to the scene upon receiving notification, via a radio transmission from the train 24 operator, that the accident had occurred. Because of a misinterpretation on the part of the MTA, the MTA at first dispatched its response personnel to the grade crossing immediately north of the BWI Airport Station. These personnel were shortly thereafter redirected to the actual location of the accident by MTA operations control, which had gained additional information on the accident circumstances.

One of the two Maryland Transportation Authority police officers who had witnessed the collision arrived at the station platform moments after the accident occurred and attempted to gain entry to the car via the LRV's left front door. The officer had not received emergency access training with the LRV equipment and was unfamiliar with the external emergency door release mechanism (situated behind an access panel). As he

[11] Investigators asked the operator why his medication had been on the control cab floor. He said that the pills had been in his shirt pocket, and the accident impact caused them to fly out of the pocket.

[12] The Maryland Transportation Authority police, who operate from a command facility at the BWI Airport terminal, provide police services for the BWI Airport. The department's territory includes the entire airport facility, and foot-patrol duty stations for Maryland Transportation Authority officers include the International Terminal Building and the BWI light rail station.

approached the front door of the LRV, the officer saw a sign that read "manual door release" adjacent to the service door. Seeing the door release "service button" on the side of the car and believing that the sign referred to a manual door release mechanism, the officer pushed the button.[13] The service button did not open the door.[14] After a brief search for some other external door release mechanism, the officer called to the LRV passengers inside the car through the glass window in the LRV door. The officer told one of the passengers to access the interior emergency door release handle (located adjacent to the door) by breaking open the plastic security cover and then to pull the release handle. The passenger's action released the service door. The officer was then able to enter the LRV and begin assisting the passengers to exit the train.

Other responding police officers[15] and fire and rescue personnel arrived at the scene shortly thereafter and began assisting the passengers. Paramedic personnel also arrived and assumed principal responsibility for on-scene medical triage, stabilization, and transport of the injured. The BWI fire and rescue chief established his incident command location at the passenger "pick-up and drop-off zone" adjacent to main track No. 1. Fire and rescue personnel stabilized the front of the LRV using hydraulic jacks, pneumatic lifting bags, and portable cribbing blocks.

Responders transported the first injured person from the scene at 3:04 p.m. and the last injured person from the scene at 3:34 p.m. The remaining train 24 passengers were transported from the scene by 3:45 p.m.

August 15, 2000, Accident[16]

Accident Narrative

The train 22 operator told Safety Board investigators that he reported to work about 3:00 a.m. (eastern daylight time) on August 15, 2000, at the MTA light rail operations center at North Avenue Yard for his assignment as a Central Light Rail Line System LRV operator. The dispatcher who saw the operator before the operator went on duty said he did not notice anything unusual about the operator's appearance or demeanor at that time. The operator checked the condition of the train equipment and received the clearances required for the train's operation for his tour of duty.

The operator had completed one round-trip from Pennsylvania Station to the BWI Airport Station and was making another identical trip when the accident occurred.

[13] The LRVs were fitted with a door release service button on the LRV's exterior side panels, adjacent to the main service doors (eight per LRV). Pushing this button would open the main service doors. Signage next to the button read "PUSH TO OPEN."

[14] MTA light rail maintenance staff indicated that the door release service button may not have responded because of a lack of electrical power, due to the collision.

[15] The forces involved included BWI Airport police officers and mutual aid support from the MTA Police, the Anne Arundel County Police, and the Maryland State Police.

[16] See appendix B for an accident brief on this accident.

Train 22, a train consisting of two LRV units, was traveling down main track No. 2 for its approach to the BWI Airport Station.[17] From the BWI Business District Station to the BWI Airport Station, the maximum authorized speed was 15 mph.

The operator recalled that during the final portion of the southbound trip to the BWI Airport Station, he observed that the crossing gates for the last grade crossing before the station (at Fuel Farm Road) were down, that the speed of his train was lessening, and that the signal at milepost 115 (BWI 15-6) displayed a red over yellow aspect.[18] The train failed to stop at the BWI Airport Station and collided with the bumping post at the end of the station track about 7:14 a.m. The bumping post separated from its attachment to the track and came to rest in an inverted position with the front of the lead LRV resting on top of the overturned bumping post. The roof structure of the lead LRV was partially embedded into the (false) ceiling structure of the terminal building, which severed and dislodged some fire suppression system water sprinkler piping in the ceiling. (See figure 4.)

[17] Because of the effects of the February 13, 2000, accident at this station, the MTA had taken track No. 1 out of service at this location until repairs were made. (The MTA was unable to quickly obtain the equipment needed to make the repairs following the accident.)

[18] A *red over yellow aspect* tells the operator to proceed at restricted speed until the entire train has passed a signal displaying a more favorable aspect.

Figure 4. Two views of train 22 in station following August 15, 2000, accident; top photo shows side view of train after it struck the end of the line, bottom photo shows front car sitting on overturned bumping post.

The operator said that the signal was the last thing he saw before he went "out." He said he was not aware of anything until he returned to consciousness after the accident and found the train up in the air and emergency personnel boarding it. The operator was unable to say how long he had been unconscious or exactly what might have caused him to lose consciousness.

Injuries

Table 2. Injuries resulting from August 15, 2000, accident

Injury Type[a]	Crew train 22	Passengers train 22	Bystanders	Total
Fatal	0	0	0	0
Serious	0	0	0	0
Minor	0	17	0	17
None	1	5[b]	0	6
Total	1	22	0	23

[a] The categories in table 2 are based on the injury criteria defined at 49 CFR 830.2, which the Safety Board uses in accident reports for all transportation modes.

[b] The five passengers cited in this tabulation category were transported to local hospital(s) by local emergency response agencies, evaluated for injury, and then released, with no documented injury or treatment reported. Therefore, for the purposes of this tabulation, they were considered uninjured.

Of the 23 people on train 22, a total of 22 (all passengers) were transported from the scene to local hospitals for medical evaluation and/or treatment. Of the 22 people transported to local hospitals, 17 were documented as having received medical treatment, and 5 were documented as having been "examined and released" without receiving medical treatment. All those who were transported to local hospitals were released the same day.

On the scene, local emergency medical service responders conducted triage and stabilization (treatment) efforts within the forward car of the LRV. The emergency medical service responders told the Safety Board that arm, leg, facial/neck, and spine injuries had apparently been sustained by a number of forward-facing LRV passengers; the injuries appeared to have resulted from passenger impacts with the seatbacks and seating grabrail elements. The emergency medical service responders indicated that the injuries in this incident seemed less severe than those they had observed following the February 13, 2000, collision at this location.

Damage

The MTA estimated the cost of the accident at $935,000.

LRV 5006 (lead car). The "A"-end coupler assembly and the related electrical and communications cables were extensively damaged. Many car body-mounted major components showed evidence of movement from impact by fractions of an inch. The slewing ring at the articulated (middle) truck was off center by about 1/16 inch. The triangular catenary anchor mounted to the airport building ceiling tore a long rectangular hole through the roof of the car's "A" end. This hole destroyed the pantograph assembly and traction motor blower housing.

LRV 5050 (trailing car). Impact forces cut the pantograph shear pin. The "A"-end coupler deformation tube was collapsed or pushed inward about 5 inches by the collision.

Bumping Post. Both running rails, to which to the bumping post apparatus support legs were secured, had fractured. One of the running rails appeared to have fractured at a bolt hole, and the other appeared to have fractured at a joint weld, about 57 inches before the front support leg of the bumping post apparatus. The bumping post apparatus sustained impact damage, consisting of visible scoring or scraping damage and loss of paint, measuring about 13 inches in length, on the hydraulic cylinder piston ram element in the area immediately adjacent to the cylinder casing face. The exposed length of the piston ram element was about 30 inches.[19]

Train 22 Operator

During his interview with Safety Board investigators on August 16, 2000, the train 22 operator said that he had "blacked out" before the impact with the safety barrier at the BWI Airport Station.[20] He said that, with respect to the day of the accident, he was unable to remember anything after about milepost 115 (location of the last signal before the BWI Airport Station) until he regained consciousness after the accident and saw emergency personnel boarding the train. He said that he had never previously blacked out.

Medical Factors. The operator, who was 48 years old at the time of the accident, told investigators that he had been off duty with a chronic back problem for about 2 months before the accident and had returned to work the day before the accident. He stated that he had not used alcohol or illegal drugs before the accident. The operator said that his vision was 20/20 and that his hearing was fine. Medical records identified the operator as obese.

MTA records showed that the operator's most recent physical examination before the accident took place on August 18, 1999, at which time he was medically recertified as an operator. The MTA records also showed that the operator sustained an on-the-job

[19] The bumping post manufacturer indicated that the design of this equipment provides for the piston ram element to return to its pre-impact length on being struck.

[20] The train 22 operator made similar statements about blacking out to MTA personnel who arrived on the scene shortly after the accident.

injury, coded as a worker's compensation injury, on June 13, 2000. As a result, he was disabled and unable to perform his duties from June 19 until July 15, 2000. He resumed his duties on July 16, 2000. Two days later, on July 18, 2000, he sustained another on-the-job injury, also coded as a worker's compensation injury. MTA records contained a disability slip dated August 7, 2000, indicating that the operator was under a physician's care from August 8 until August 13, 2000. He was permitted to return to work on August 14, 2000, the day before the accident. The operator said that no MTA physician had evaluated him upon his return to duty on August 14, 2000.

Records obtained from the train 22 operator's personal physician showed that she had examined him on several occasions in March and June 2000 for hypertension and neck pain. The operator said that his personal physician was aware of his occupation.

The operator said he had taken 5 mg of Norvasc at about 1:30 p.m. on August 12, 2000, and 10 mg of cyclobenzaprine and 500 mg of Naproxen at about 3:00 p.m. on August 14, 2000. Amlodipine, known by the trade name Norvasc, is a prescription medication most commonly used to treat high blood pressure. It is also indicated for the treatment of angina (chest pain due to reduction in blood flow to the heart). Cyclobenzaprine is a prescription muscle relaxant, known by the trade name Flexeril. Precautions accompanying the medication note that it may impair mental and/or physical abilities required for the performance of hazardous tasks, such as operating machinery or driving a motor vehicle. Naproxen is an anti-inflammatory medication, available over the counter under the trade name Aleve. It is most commonly used to mitigate mild pain or temporarily reduce fever.

The operator recalled that sometime between February and August 2000, he showed one of his prescription medications[21] to the MTA light rail superintendent and another MTA supervisor. He said that the medication container had carried a safety warning about operating machinery. He said that the MTA light rail superintendent told him that the medication was a pain-reliever and that it was up to the operator to determine whether he was fit to work. The operator said that several days later he became concerned about the medication and wanted the MTA light rail superintendent to sign a pamphlet that accompanied it. He said that, as this official was unavailable, he approached an MTA supervisor. He recalled that the supervisor had advised him to use caution and signed the pamphlet. When asked by the Safety Board to produce the signed pamphlet, the operator was unable to do so.

On August 17, 2000, the Safety Board asked the MTA light rail superintendent about the operator's statements. The superintendent said that he was unable to remember specifically whether this operator had approached him with a question about medication use. He recalled that several operators had approached him with questions about medication use. He told the Safety Board that he had responded by informing them that using medications could cause drowsiness and that, if they were drowsy, they should not operate a train.

[21] The train 22 operator said he had used five prescription medications in the year before the accident.

On October 18, 2000, the Safety Board discussed the operator's statements with the MTA supervisor the operator had named. The supervisor told the Safety Board that he could not specifically recall the operator having shown him any medication, although he thought it possible that during general conversation the operator may have mentioned that he was taking medications. The MTA supervisor said he was certain he did not sign any document or pamphlet that pertained to any aspect of medication use or associated warnings for the operator.

The operator said that he was not aware of definite MTA policies or procedures concerning medication use. He said that following the February 13, 2000, accident at the BWI Airport Station, he had heard two conflicting views on this issue—first, that the MTA had procedures, directives, bulletins, or a policy that addressed use of medications, and, conversely, that no such policies or procedures existed. He said that after the February 2000 accident, the MTA appeared to have heightened awareness about prescription medications (particularly those that bore warnings), but he had heard nothing about prescription drugs from anyone associated with the MTA since about March 2000.

Work/Rest Routine. When asked whether he had felt rested on the day of the accident, the operator responded that he had. The Safety Board asked the operator to describe his work/rest schedule for the days preceding the accident. The operator recalled that he awoke about 8:00 a.m. on Friday, August 11, 2000, ran several errands, and returned home at noon. He said he left to travel to Philadelphia, Pennsylvania, about 1:30 p.m. and returned to Baltimore by 1:30 a.m., Saturday, August 12, at which time he retired. He arose that day about noon and remained at home until about 8:00 p.m., when he went out for dinner. He said that he returned between 10:30 and 11:00 p.m., at which time he retired for the evening. He said he awoke at 10:00 a.m., Sunday, August 13, and prepared for and went to church. He returned home by about 3:30 p.m. and lay down about 4:00 p.m. He said that he did not actually sleep but rested from then until about 10:00 p.m., when he retired to bed for the evening. He recalled that he awoke the following morning, Monday, August 14, about 2:00 a.m., and arrived for work by 3:00 a.m. He said that he worked until 11:10 a.m. and returned home. He retired for the evening between 5:00 and 6:00 p.m. and awoke the following morning, Tuesday, August 15, at 2:00 a.m. He said that he arrived for work about 3:00 a.m. At the time of the accident, he had been awake for about 5 hours 15 minutes and on duty for about 4 hours 15 minutes. The operator's work/rest history is displayed in table 3.

Table 3. Train 22 operator's work/rest history information

Day	Time	Activity	Sleep Obtained That Night
August 11	8:00 a.m. 1:30 a.m. (August 12)	Woke up To bed	10 1/2 hours
August 12	12:00 p.m. (noon) 11:00 p.m.	Woke up To bed	11 hours
August 13	10:00 a.m. 4-10:00 p.m. 10:00 p.m.	Woke up Rested To bed	4 hours
August 14	2:00 a.m. 3:00 a.m. 11:10 a.m. 5-6:00 p.m.	Woke up Reported for duty Went off duty To bed	8-9 hours
August 15	2:00 a.m. 3:00 a.m. 7:14 a.m.	Woke up Reported for duty Accident occurred	---

Certification and Training. MTA records showed that the LRV operator was originally hired on September 27, 1974, as a bus operator. He remained in that position until March 3, 1994, when he was certified as an LRV operator, the position he held at the time of the accident. MTA training records showed that between February 28 and March 2, 1994, the operator was given and passed seven light rail operator training tests. On July 18, 1995, he took light rail troubleshooting training. On March 21, 1996, he was given stop signal compliance training and re-administered light rail operator testing, which he passed. The operator said that he had never received any alcohol or drug training. MTA records showed two disciplinary reports for the operator.

First, on June 27, 1994, the operator was cited for "Violation of MTA substance abuse and rehabilitation agreement." The operator had tested positive for cocaine on March 7, 1994, and was removed from service. The operator requested and was granted a leave of absence from March 17 to April 17, 1994, during which time he entered phase 1 of rehabilitation. The operator tested positive for cocaine on March 18, 25, and 30 and on April 1, 1994. He repeatedly tested negative for illicit drugs between April 4 and June 16, 1994. Phase 2 of his rehabilitation began on April 26 and lasted until July 26, 1994. On or about June 27, he again tested positive for cocaine and was cited for a violation of the MTA substance abuse and rehabilitation agreement. He continued in the rehabilitation program and provided numerous specimens. He was evaluated by a substance abuse professional on February 24, 1995, and was reinstated on April 10, 1995. The operator continued to provide specimens (negative for drugs) until June 2, 1997, at which time the substance abuse professional recommended that no further follow-up testing be conducted.

Second, in a July 9, 1999, disciplinary report, the operator was cited by the MTA for the following complaints: "Moved train without proper authority" and "Reversed train without permission, resulting in derailment." After the MTA's investigation of the related incident, he was reinstated and ultimately charged 3 days of lost time.

At the time of the August 2000 accident, the operator had a class "B" commercial driver's license, issued on April 8, 1996, with an expiration date of August 12, 2001. At the request of the Safety Board, the MTA police conducted a review of the Maryland Inter-Agency Law Enforcement System database for the operator on August 30, 2000. The review found no criminal or civil records on file. The operator's license had not been suspended, revoked, or disqualified; and no points had been assessed.

Train 22 Mechanical

Train 22 comprised two LRVs (LRVs 5006 and 5050) that had been coupled to form a two-car consist. Each of the LRVs of train 22 was structurally identical to and similarly equipped as the single LRV of train 24, which was described earlier.

Postaccident Examinations

Track and Signals. Postaccident inspection showed that the catenary system on main track No. 1 into the BWI passenger platform, which had been damaged during the February 13, 2000, accident, was not yet restored. Before the August 2000 accident, train operations into the BWI passenger station had been restricted to loading and unloading passengers on the track No. 2 side. Examination of the rail did not reveal any scratch marks, signs of abrasion, or metal shavings.

Switch W115 was blocked and clamped in the reverse position, lining all train movements into track No. 2. The selector lever on switch W115 was taken out of the "Motor" position and locked in the "Hand" position. With the selector lever of switch W115 in the "Hand" position, the most permissive aspect that the signal system would permit signal BWI 15-6 to display was a red over yellow aspect.

All signal units and signal cases were securely locked. No grounds or short circuits were found. The sight line to the signals was not obstructed, and speed limit signs were posted. The MTA signal maintenance, inspection, and test records indicated that the equipment was in working condition and listed no exceptions that would have prevented the signal equipment from operating properly.

Event Recorder. After the accident, the appropriate computer boards were removed from each LRV and given to Safety Board investigators. The following day, a Safety Board vehicle recorder specialist brought the computer boards to the MTA's North Avenue Yard for download and readout. Because no triggering event had occurred (no brake application), no data were recorded for this accident by either LRV's event recorder system.

Security Video Recorder. The MTA chief of police took possession of the security videotapes from both LRV cars upon his arrival at the scene. The security tapes were brought back to the Safety Board laboratory for analysis.

The videotape from the first car showed the train's operation until the accident. The tape showed no visible evidence of any collision. A time stamp written on the tape by

the multiplexing unit showed that the tape ended about the same time that the accident occurred.[22]

The six cameras allowed the inside of the entire LRV to be viewed. However, window glare from the sun made it difficult to identify any landmarks that the train had traveled past. From the video system on the first LRV, Safety Board investigators were able to isolate and identify one image outside the right side of the LRV's rear half and one image outside the left side of the LRV's front half. The landmarks were identified as the divergence of the rails into two parallel tracks shortly before the train reached the platform and the corner of the wall of the airport building near the end of the track. Measurements of the distance the train traveled between these two camera shots, coupled with the elapsed time between the two shots, allowed investigators to estimate an average speed for the train while traveling between these two points as 12.37 mph.

Meteorological

About 7:00 a.m. on August 15, 2000, local weather conditions were reported to be clear, in daylight, with a temperature of about 68º F.

Medical and Toxicological

Toxicology. Pursuant to Federal postaccident toxicological testing regulations, the operator provided a breath specimen at 10:54 a.m. and a urine specimen at 11:00 a.m. on August 15, 2000 (about 3 hours 45 minutes after the accident occurred). Medical personnel at Mercy Hospital, Baltimore, obtained a blood specimen for medical evaluation. The Safety Board subpoenaed portions of the blood and urine specimens, which subsequently underwent independent toxicological analysis at the Civil Aeromedical Institute in Oklahoma City, Oklahoma. All specimens tested negative for the presence of alcohol and illegal drugs. None of the test results indicated the presence of the prescription muscle relaxant cyclobenzaprine (Flexeril). The urine specimen tested at the Civil Aeromedical Institute revealed the presence of amlodipine.

Sleep Disorder Review. On August 18, 2000, the train 22 operator's personal physician noted in her records that the operator had been involved in a light rail accident 3 days before and had lost consciousness. About 2 weeks later, the physician referred the operator to a sleep specialist because she suspected that the operator might be suffering from a sleep disorder. On September 5, 2000, the operator was clinically tested for sleep disorders at Good Samaritan Hospital in Baltimore. The hospital developed a sleep study report for the operator that indicated a diagnosis of "severe obstructive sleep apnea syndrome." Obstructive sleep apnea (also known as OSA) is a chronic and debilitating sleeping disorder that is often present for years or even decades before it is diagnosed. Excessive daytime sleepiness is almost uniformly present in people who suffer from obstructive sleep apnea.

[22] The car computer time was compared to the actual time. The car computer's time was off by about 2 hours 42 minutes, so the time was corrected to make up for this inaccuracy.

Typically, obstructive sleep apnea in an adult is exhibited after the subject goes to sleep. Snoring proceeds at a regular pace for a time, often becoming louder, but is then interrupted by a long, silent period during which no breathing occurs (apnea). The apnea is then interrupted by a gasp for breath, and then the snoring returns to its regular rate. During apneic periods, the oxygen level in the blood declines dramatically. Persistent low levels of oxygen (hypoxia) cause the person to awaken repeatedly, often without being aware of having done so. The obstruction of breathing that invariably results in gasping for air prevents the person from reaching deeper stages of sleep. Individuals who suffer from the disorder awaken poorly rested and, because they have been unable to obtain restorative, uninterrupted sleep, go through the day feeling fatigued and disoriented.

The Good Samaritan Hospital's report stated that the operator reported to the examining sleep specialist physician that he had "excessive daytime sleepiness sometimes." The report stated that the operator had a self-reported Epworth Sleepiness Scale[23] value of 14. The values of the Epworth Sleepiness Scale range from 0 to 24. Epworth Scale values for a person without excessive sleepiness would be 10 or less, while values 11 through 24 indicate significant sleepiness.

The medical testing conducted on September 5, 2000, determined that the operator demonstrated a respiratory disturbance index[24] of 106 episodes per hour. A normal respiratory disturbance index would be less than 5 episodes per hour; an index of 30 episodes per hour is considered to represent severe disturbance.

The examination also included the operator's sleep latency.[25] Individuals who are not sleep-deprived will, on average, have a sleep latency of about 20 minutes. That is, such people normally take about 20 minutes to fall asleep when placed in a dark, quiet room.[26] Under such conditions, the operator was found to fall asleep within a period considerably shorter than 20 minutes.

The Safety Board sent the hospital's report to the director of the Center for Sleep and Respiratory Neurobiology at the University of Pennsylvania Medical Center, Philadelphia, Pennsylvania. The director found "There is no question, based on the data you sent me, that he [the operator] has severe sleep apnea associated with excessive sleepiness." The director also stated that he would "expect the driver to be excessively sleepy and at risk for falling asleep inappropriately."[27]

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[23] The *Epworth Sleepiness Scale* is a questionnaire designed to measure the general level of daytime sleepiness, called the *average sleep propensity.* The average sleep propensity is a measure of the probability of falling asleep in a variety of situations. The conceptual basis of the Epworth Sleepiness Scale involves a four-process model of sleep and wakefulness. An individual's sleep propensity at any particular time is a function of the ratio of the total sleep drive to the total wake drive, with which it competes.

[24] The *respiratory disturbance index* is the number of breathing pauses or decrements per hour of sleep.

[25] An individual's *sleep latency* is the amount of time before the onset of a measurable sleep cycle.

[26] Association of Sleep Disorders Centers Task Force on Daytime Sleepiness: *Sleep*, 9(4): 519-524 (Raven Press, 1986).

[27] Quotes are taken from a November 16, 2000, facsimile communication from the director of the Center for Sleep and Respiratory Neurobiology at the University of Pennsylvania Medical Center, Philadelphia, Pennsylvania, to the Safety Board.

According to the National Institutes of Health, obstructive sleep apnea is a common condition, affecting more than 12 million Americans.[28] The American Sleep Apnea Association "conservatively estimates" that 10 million people remain undiagnosed.[29] Obstructive sleep apnea occurs in all age groups and in both sexes but is more common in men. One organization reports that 4 percent of middle-aged men and 2 percent of middle-aged women have sleep apnea accompanied by excessive daytime sleepiness.[30] Risk factors include being male, being overweight, and being over 40 years old. People most likely to have or develop obstructive sleep apnea include those who snore loudly, are overweight, or have high blood pressure. People with some physical anomaly in the nose, throat, or other parts of the upper airway are also prone to develop obstructive sleep apnea.

Some sleep experts believe it may be possible to detect which safety-sensitive employees may have a potential sleeping disorder by using questionnaires and/or structured interviews and clinical data.[31] The Union Pacific and CSXT Railroads told the Safety Board that they are implementing questionnaire-based programs (provided by vendors) to identify employees who may be disposed to have sleep disorders. The CSXT Railroad told the Safety Board that, as part of a comprehensive sleep disorders screening and treatment program that began in August 1998 and was administered by a confidential third party,[32] it mailed a questionnaire designed to detect people who might be disposed to have sleep disorders to 2,386 employees on its Florence Service Lane (in South Carolina). Of the 248 self-selected responses received, 136 responders were determined to be "at risk" for sleep apnea. Of those "at risk" employees, almost half agreed to participate in an overnight sleep evaluation. As a result of further diagnosis, 43 employees with sleep apnea were successfully treated and, of these, 42 are continuing with appropriate therapy on a long-term follow-up basis.

The Union Pacific Railroad informed the Safety Board that it offered approximately 2,000 employees and their family members on the Fort Worth (Texas) Subdivision the opportunity to participate in sleep disorder screening. The project began with an awareness campaign; then, a questionnaire concerning disposition to sleep disorders was mailed to the employees' homes. Individuals who returned questionnaires that indicated they might be at risk were assisted in obtaining clinical diagnoses. The data generated from these efforts are undergoing analysis by a confidential third party.

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[28] Information obtained in early 2001 from the Home page of the National Sleep Foundation <http://sleepfoundation.org>.

[29] Information obtained in early 2001 from the Home page of the American Sleep Apnea Association <http://sleepapnea.org>.

[30] Information obtained in early 2001 from <http://www.apneanet.org>.

[31] K. Kump, C. Whalen, P.V. Tishler, I. Brower, V. Ferrette, K.P. Strohl, C. Rosenberg, and S. Redline, "Assessment of the Validity and Utility of a Sleep-Symptom Questionnaire," *American Journal of Respiratory Critical Care Medicine*, 1994; Volume 150(3): pp. 735-741. And T. Ploch, C. Kemeny, G. Gilbert, W. Cassel, and J.H. Peter, "Significance of a Screening Questionnaire for Diagnosis of Sleep Apnea," *Pneumologie*, March 1993; 47 Supplement 1: pp.108-111.

[32] The CSXT Railroad told the Safety Board that it used a confidential third party to protect the anonymity of its employees.

Emergency Response

The investigation identified four approximately simultaneous "initial" notifications of this incident that took place almost immediately after the accident. They occurred when Maryland Transportation Authority police officers patrolling nearby were alerted by the impact noise, when two telephone calls (one to MTA police via 911 and one to the Maryland Aviation Administration[33] operations center at the airport) were placed from the accident scene, and when a "water flow alarm," which was automatically transmitted to BWI fire and rescue, was triggered.[34] BWI fire and rescue, police, emergency medical, and other emergency services resources from the BWI Airport, as well as mutual aid resources, responded to the accident. The MTA also responded with emergency resources.

About 20 Maryland Transportation Authority police officers were dispatched to the scene; they assisted in the initial emergency extrication effort and provided site security. The responding officers indicated that they did not have trouble in gaining immediate access to the LRV. (Some of those responding stated that they had learned how to access the LRV during the February 2000 accident.) Other responding mutual aid police officers and fire and rescue personnel arrived at the scene shortly thereafter and assisted in the Maryland Transportation Authority effort. Paramedic personnel then arrived at the scene and assumed principal responsibility for on-scene medical triage, stabilization, and transport of the injured.

The first responding unit from BWI fire and rescue arrived at the scene at 7:20 a.m., and 12 BWI fire and rescue emergency vehicles responded to the scene, with 28 BWI fire and rescue personnel. Following the prescribed incident response protocol, a BWI fire and rescue chief assumed responsibility as incident commander and established his incident command location adjacent to station track No. 1. BWI fire and rescue personnel stabilized the front of the LRV, using hydraulic jacks, pneumatic lifting bags, and portable cribbing blocks.

Fifteen ambulances responded to the scene, of which seven were used to transport patients to local medical facilities. About 20 emergency medical personnel responded to the scene, including the State medical director and the BWI medical director.

Patient triage was reportedly completed at 7:30 a.m. The first patient transported from the scene to a hospital was transported via ambulance at 7:43 a.m. Ten patients with injuries assessed by paramedic personnel as "not life-threatening" were transported via commercial motorcoach to a local hospital for evaluation at 8:25 a.m. The last patient transported from the scene to the hospital departed via ambulance at 8:27 a.m.

[33] The Maryland Aviation Administration, which is a Maryland Department of Transportation agency, owns and operates the BWI Airport.

[34] The accident severed water sprinkler lines of the fire suppression system in the ceiling of the light rail terminal. This event automatically triggered a *water flow alarm* to BWI fire and rescue services.

Information for Both Accidents

Track and Signals

Track. The track structure on the Central Light Rail Line is predominantly a single track main with sections of double track. MTA tracks are constructed with #115 continuous welded rail, manufactured by Bethlehem Steel.

The trackage right-of-way approaching the end of the track, where both accidents took place, is approximately level and tangent. The BWI Airport Station has two service tracks, which MTA light rail operations refer to as the No. 1 service track (the western-most track) and the No. 2 service track (the eastern-most track), respectively. The two service tracks are parallel and adjacent to each other, with a track-center distance[35] of about 30 feet. Each track can accommodate up to a three-car train. The tracks can be used interchangeably, but the No. 1 track is designated for principal use at this station.

The posted speed limit for approaching the station was 15 mph. The double main track enters the platform area on a descending grade of 0.70 percent. The main track serves both sides of the concrete BWI passenger platform. The north end of the platform has a highblock to assist in the loading and offloading of disabled passengers. In the case of both accidents, a Cullen-Western-Hayes, Inc., WH bumping post was in place at the end of the track to protect the terminal area from railcar intrusion. The bumping posts were fixed to the rail with track bolts and were designed to stop runaway railcars and absorb the shock should a collision occur.

Signals. Movement on the line is governed by operating rules and instructions and the signal indications of an automatic interlocking signal system with automatic block signals between interlockings. The signal system uses four-aspect colorlight-type signals. On the BWI Airport extension, signals can display the following:

Rule	Aspect	Indication
4.4.1	Red	Stop
4.4.2	Yellow	Proceed prepared to stop at next signal
4.4.3	Green	Proceed
4.4.4	Red over yellow	Proceed at restricted speed until entire train has passed a signal displaying a more favorable aspect

[35] *Track-center distance* is the distance from the centerline of one track to the centerline of the other.

The distance from the last block signal, BWI 15-6, governing the route traveled by both accident trains (February and August 2000) to the northern end of the BWI Airport Station platform is about 360 feet. The distance from the northern end of the platform to the bumping post is about 330 feet. Sight lines are clear and unobstructed from signal BWI 15-6 to the end of the line.

MTA Operations

General. The MTA operates the Central Light Rail Line System, a surface-level, light rail passenger transit operation that runs LRVs between Hunt Valley and Glen Burnie, Maryland, with two track extensions: (1) from the University of Baltimore/Mount Royal to Pennsylvania Station and (2) from Linthicum to the BWI Airport Station. The MTA's Central Light Rail Line System is a 30-mile system that interfaces with MTA bus, MTA subway, and Maryland Rail Commuter systems. It operates principally on private right-of-way trackage, although a segment of its trackage, slightly less than 2 miles long, operates in a street environment (on embedded running rails in the pavement) with highway vehicle traffic, in downtown Baltimore.

The BWI Airport light rail extension, at the end of which both accidents occurred, is about 4.8 miles long. The total distance from Pennsylvania Station to the BWI Airport Station is about 11 miles. From Pennsylvania Station to the Camden Yards Station, the LRV tracks run through city streets.

The MTA light rail superintendent told the Safety Board that the MTA provides service between Baltimore (Pennsylvania Station) and the BWI Airport Station from 6:00 a.m. to 11:00 p.m. Monday through Friday, from 8:00 a.m. to 11:00 p.m. Saturday, and from 11:00 a.m. to 7:00 p.m. Sunday. The superintendent said that ridership was estimated at 28,000 on weekdays, 17,000 on Saturdays, and 10,000 on Sundays. The MTA has 53 LRVs in its fleet.

The MTA light rail superintendent indicated that the MTA organization comprises about 73 operators, 24 supervisors, 5 chief supervisors, and 5 dispatchers. The dispatchers report directly to the superintendent.

The current operating rulebook for the MTA light rail is the *Interim Rules and Instructions for Employees*, dated August 1991. The MTA director of transit operations approved the rulebook in 1991. The light rail superintendent said that the MTA updates the rulebook by issuing rail transportation bulletins.

Rule 3.19 of the MTA's *Interim Rules and Instructions for Employees* states:

> Safety Stop: When making a stop at terminals, operators must use caution and allow sufficient braking distance, determined by condition of rail, to bring train to a stop not less than five feet from end of track, bumping post, or train ahead.

Most of the MTA's LRV operators became LRV operators after serving for a number of years in another operational capacity, such as busdriver, for the MTA. Opportunities to become LRV operators were offered mainly on a seniority basis.

The MTA told the Safety Board that the MTA did not have a program to identify safety-sensitive employees for sleeping disorders. In a fatigue management survey of 155 transit agencies conducted by the American Public Transportation Association (APTA),[36] 16 agencies (of the 141 agencies that responded to the question) reported that they provide preplacement screening for sleep disorders, while 12 agencies (of the 134 agencies that responded to the question) reported that their periodic operator physicals include screening for sleep disorders. The Federal Transit Administration (FTA) does not require rail transit agencies to have screening programs to detect safety-sensitive employees who may have sleeping disorders.

According to the MTA light rail superintendent, MTA light rail operators are trained for 8 weeks before becoming operators. This training includes familiarization with the MTA *Interim Rules and Instructions for Employees*. Before the BWI accidents in 2000, the MTA did not provide recurrent training to its operators.[37]

Medication and Prohibited Substance Requirements. Section 1.6 of the MTA *Interim Rules and Instructions for Employees* is entitled "ALCOHOL, ILLEGAL SUBSTANCES, AND MEDICATION." Section 1.6.2 states

> Employees reporting for duty or while on duty, must not possess or be under the influence of intoxicants, including alcohol, Controlled Substances, or any other substance which may impair job performance.

On February 16, 2000, the MTA provided the Safety Board with an undated copy of the *Mass Transit Administration Policy on Substance Abuse Prevention*. Title III, Section A, of this document states, "It is the policy of the Mass Transit Administration to take an active role in combating substance abuse throughout its public transportation operations."

Title III, Section B, of the policy states that the MTA dedicates itself to

- Embracing and promulgating all appropriate initiatives that have a goal of substance abuse prevention,
- Promoting and increasing understanding of the dangers associated with substance abuse through education and training,
- Encouraging and assisting employees in confronting and rehabilitating substance abuse problems, and
- Removing from the public payroll any employees who are convicted of the unlawful manufacture, distribution, dispensing, possession, or use of a controlled substance in the workplace.

[36] APTA is a private, nonprofit, international trade association that represents the North American transit industry. APTA has more than 1,270 member organizations, which include transit systems, academic institutions, and State associations and departments. APTA members serve more than 90 percent of those people using public transport in the United States and Canada. The MTA is an APTA member.

[37] Since the two BWI accidents, the MTA has told the Safety Board that it intends to provide recurrent operator training.

With respect to random drug testing, the MTA told the Safety Board that it follows the requirements at 49 CFR Part 653, including having a random drug testing program with provisions for appropriate follow-up to positive results, as well as having specific requirements for treatment programs and the employee's returning to duty. The MTA cited 49 CFR 653.63(d), which states that

> The substance abuse professional shall determine the frequency and duration of follow-up testing for a covered employee. Such employee shall be required to take a minimum of six follow-up drug tests with verified negative results during the first 12 months after returning to duty. After that period of time, the substance abuse professional may recommend to the employer the frequency and duration of follow-up drug testing, provided that the follow-up testing period ends 60 months after the employee returns to duty. In addition, follow-up testing may include testing for alcohol, as directed by the substance abuse professional….

The chief of the MTA benefits section, whose office is responsible for administering the alcohol and drug testing program within the agency, told Safety Board investigators in February 2000 that the MTA had no specific requirement for employees to inform the MTA about their use of prescription medications. The chief stated that the MTA followed applicable FTA regulations (49 CFR Part 653) pertaining to substance abuse. In subsequent correspondence, dated June 22, 2000, the chief responded to a Safety Board inquiry as to what would have happened had the train 24 operator told the MTA about his use of prescription pain-relieving medications when he returned to work in early January 2000. He wrote, "The current MTA Substance Abuse Prevention Policy does not address this topic. If it did, procedures would presumably be outlined also."

In a letter to the Safety Board dated June 12, 2000, the MTA light rail superintendent indicated (in reference to employees returning to work after being off for sick leave) that the agency does "not positively know whether a safety sensitive employee is on medication when they return to work."

On October 3, 2000, the MTA provided the Safety Board with written material about the history of the MTA drug and alcohol policy and a summary of related recent activities. Included in this document was the statement that in 1995 the MTA and Amalgamated Transit Union Local 1300 adopted FTA alcohol and drug testing regulations "as a basis for the MTA's drug and alcohol testing policy." The document also noted that the MTA and Local 1300 had been working toward the development of comprehensive drug and alcohol policies, and that the MTA had hired a consulting firm to

> Conduct an independent assessment of our substance abuse program and recommend additional improvements to our drug and alcohol policies, including prescription and over-the-counter medication and fitness for duty evaluations.

The FTA drug testing regulations at 49 CFR Part 653, "Prevention of Prohibited Drug Use in Transit Operations," make no specific reference to the use of prescription and/or over-the-counter medications by transit vehicle operators or other safety-sensitive employees. The Federal Railroad Administration (FRA) regulations at 49 CFR 219.101-

103 address the use of controlled substances and medications by employees covered under FRA rules as detailed below:

> **Sec. 219.101 Alcohol and drug use prohibited.**
> (b) Controlled substance. "Controlled substance" is defined by Sec. 219.5 of this part. Controlled substances are grouped as follows: Marijuana, narcotics (such as heroin and codeine), stimulants (such as cocaine and amphetamines), depressants (such as barbiturates and minor tranquilizers), and hallucinogens (such as the drugs known as PCP and LSD). Controlled substances include illicit drugs (Schedule I), drugs that are required to be distributed only by a medical practitioner's prescription or other authorization (Schedules II through IV, and some drugs on Schedule V), and certain preparations for which distribution is through documented over the counter sales (Schedule V only).
>
> **Sec. 219.102 Prohibition on abuse of controlled substances.**
> On and after October 2, 1989, no employee who performs covered service may use a controlled substance at any time, whether on duty or off duty, except as permitted by Sec. 219.103 of this subpart.
>
> **Sec. 219.103 Prescribed and over-the-counter drugs.**
> (a) This subpart does not prohibit the use of a controlled substance (on Schedule II through V of the controlled substance list) prescribed or authorized by a medical practitioner, or possession incident to such use, if
>
> > (1) The treating medical practitioner or a physician designated by the railroad has made a good faith judgment, with notice of the employee's assigned duties and on the basis of the available medical history, that use of the substance by the employee at the prescribed or authorized dosage level is consistent with the safe performance of the employee's duties;
> >
> > (2) The substance is used at the dosage prescribed or authorized; and
> >
> > (3) In the event the employee is being treated by more than one medical practitioner, at least one treating medical practitioner has been informed of all medications authorized or prescribed and has determined that use of the medications is consistent with the safe performance of the employee's duties (and the employee has observed any restrictions imposed with respect to use of the medications in combination).
>
> (b) This subpart does not restrict any discretion available to the railroad to require that employees notify the railroad of therapeutic drug use or obtain prior approval for such use.

The above restrictions require consultation with a medical practitioner. Most over-the-counter medications are not covered by the regulation,[38] and no requirement is indicated for documentation of medical consultation.

[38] There are substances that may be purchased without a prescription for which over-the-counter sales must be documented. Even though these substances are available over the counter, they are considered controlled medications. (Certain codeine-containing cough syrups fall into this category.)

Oversight. The FTA required the Maryland State legislature to designate a department to oversee the MTA.[39] The Maryland Department of Transportation (MDOT) was assigned the responsibility of providing MTA safety oversight. In fulfilling that responsibility, MDOT has the power to audit and observe all ongoing operations at the MTA. The MTA and MDOT both report to the Secretary of Transportation for the State of Maryland.

System Safety Program Plan. Federal regulations at 49 CFR 659.31 require that fixed guideway transit systems such as the MTA's Central Light Rail Line System must develop and implement a system safety program plan that complies with the guidelines provided in APTA's *Manual for the Development of Rail Transit System Safety Program Plans*. According to this APTA document, a system safety program plan for such a rail transit system "establishes the Safety philosophy of the whole organization and provides the means of implementation." APTA identifies the overall goal of system safety program plans for fixed guideway transit systems as

> To identify, eliminate, minimize, and/or control safety hazards and their attendant risks by establishing requirements, lines of authority, levels of responsibility, and accountability, and methods of documentation for the organization.[40]

A system safety program plan is a formal written document that identifies all safety-related responsibilities and assigns the fulfillment of these responsibilities to appropriate areas within the organization. It also establishes the specific safety objectives and procedures of the organization. Each transit system develops its own system safety program plan.

Once the program is in place, the transit system maintains internal oversight of its own system safety program plan to ensure that all responsibilities are being fulfilled and coordinated through monthly audits conducted by departmental safety officers and annual audits carried out by the system safety department. The State regulatory agency responsible for the transit system conducts mandatory audits of the system safety program plan's effectiveness every 3 years. Under its Safety Management Audit Program, APTA will also provide, if requested and funded by the transit system, triennial formal evaluations of how well a transit organization's system safety program plan has been implemented.

In 1997, while the MTA was developing a system safety program plan, APTA performed an audit of the MTA and identified areas that needed corrective action. The summary page of the APTA Preliminary Audit Report, dated June 15, 1998, stated that the audit team found that

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[39] These regulations came about through rulemaking resulting, in part, from the Safety Board's findings in its safety study on *Oversight of Rail Rapid Transit Safety,* adopted on July 23, 1991 (NTSB/SS-91/02). In this safety study, the Safety Board encouraged increased Federal involvement in State and local oversight of rail rapid transit systems.

[40] APTA, *Manual for the Development of Rail Transit System Safety Program Plans* (Washington, D.C.: APTA, 1999), p. 8.

> [MTA] Management is aware of the safety goals and objectives stated in the System Safety Plan. However, Management should establish and document more maintenance and safety technical personnel training programs; establish and ensure that all facets of system maintenance are fully coordinated with its safety functions.

In the preliminary report, the APTA auditors stated that the majority of MTA managers were unfamiliar with the MTA's system safety program plan and that, in many cases, MTA managers did not have a clear understanding of system safety or their respective roles in carrying out the system safety program plan. The APTA report further stated that the distribution of the system safety program plan was not complete and its implementation had not been properly tracked.

In January 2000, the MTA hired a contractor to address the corrective action plans identified in the APTA audit. Among the actions the contractor was hired to undertake was the implementation of the system safety program plan. The contractor told the Safety Board that she considered the MTA system safety program plan she was provided by the MTA in January 2000 to be ineffective. She said that when she began work on the program, she believed some members of the MTA operations management did not accept the validity of the overall system safety program plan concept. She stated that it has been her experience that many operations-driven systems, such as the MTA, do not recognize the need for system safety programs. The contractor said that she had conflicts with the MTA superintendent of operations as she worked on the system safety program plan and that the superintendent would not comply with her requests to assist in planning the system safety program plan.

Members of the MTA system safety department stated during interviews that the MTA system safety program plan had not been a working document before the contractor was brought in to implement it. One employee stated, "I mean, it [the system safety program plan] was something that was put together because it was mandated, but it wasn't something that we actually lived by."

On December 1, 2000, the MTA underwent a significant management reorganization, during which a number of managers were given positions involving system safety. Among other developments, the MTA hired a new director of safety, created the position of assistant director of safety, and added six more people, including a system safety specialist, to the MTA safety staff.

Between January and March 2001, the contractor hired to implement the MTA's system safety program plan completed the writing of the program and conducted 4 hours of training on the program for all MTA operations managers. The contractor also helped the MTA carry out several internal audits of its new system safety program plan before her contract expired in March 2001.

Since March 2001, the MTA has assigned its new system safety specialist (hired in December 2000) to redraft the system safety program plan provided by the contractor so that it more closely suits the MTA's specific needs.

MDOT has been overseeing the MTA's system safety activities. Since 1997, MDOT has periodically met with the MTA concerning the corrective actions indicated by the 1997 APTA audit of the MTA. In July 2000, MDOT completed its State oversight plan and presented it to the MTA. In May 2000, a contractor hired by MDOT conducted the mandatory triennial audit of MTA system safety, and MDOT has presented corrective action plans to the MTA based on the findings of the 2000 audit. In addition, MDOT participated in both of the BWI accident investigations and proposed postaccident safety improvements.

Survival Aspects

Bumping Post. A bumping post assembly typically functions as a safety device to afford end-of-track protection where the railroad "rolling stock" equipment must come to an absolute stop (or it will roll off the end of the track). The bumping post assembly is attached to the running rails at the end of the track segment and is designed to absorb kinetic energy when a moving railroad car contacts it.

Identical Cullen-Western-Hayes, Inc., WH hydraulic bumping post assemblies were installed at the ends of the main No. 1 and 2 tracks when both accidents took place at the BWI Airport Station in 2000. (See figure 5.) This bumping post incorporates a mechanical striking block assembly that employs a kinetic energy absorption feature. The bumping post's striking face is one end of a piston ram element, which, when it is contacted by a railroad car coupler, exerts sufficient force to cause the piston ram element to telescope inside a (closed-end) hydraulic cylinder sleeve. The attempted compression and subsequent flow of hydraulic medium[41] passing through a precision-sized orifice in the piston ram, as it travels the length of its stroke, results in energy absorption.

Figure 5. Type of Cullen-Western-Hayes, Inc., WH hydraulic bumping post assembly involved in both accidents.

[41] The particular bumping posts at the BWI Airport Station terminus employed compression of pneumatic gas, rather than hydraulic fluid, as the energy transfer medium.

The performance specification for the bumping post assembly cited by the manufacturer was a 700,000-pound "maximum reaction force" throughout its 30-inch stroke, an energy absorption capacity of 1.4 million pound-feet, and a piston ram element/stroke length of 30 inches. Engineering documentation submitted by the manufacturer indicated that the bumping post structure could accommodate the impact loading of a moving railcar.[42] The manufacturer's documentation concerning the installation of the bumping posts stated that

> INSTALLATION SITE SHOULD NOT HAVE ANY RAIL JOINTS BETWEEN THE BUMPING POST AND THE NEAREST SET OF TRUCKS OF THE CONTACTING CAR. WHEN INSTALLED IN BALLASTED TRACK, THE RAIL SHOULD ALSO EXTEND AT LEAST THREE TIE SPACES BEYOND THE REAR OF THE BUMPING POST.

Seating. The MTA LRVs use seat assemblies and grabrails produced by the American Seating Company of Grand Rapids, Michigan. Passenger seating on the LRVs in the MTA fleet is provided on both sides of a longitudinally oriented center aisle passageway. The seats are configured in a combination of transverse and longitudinally mounted seat assemblies. The longitudinally mounted seats (which provide seating for 12 passengers per car) are attached to the car body floor in a pedestal arrangement and are designed with a flip-up feature to provide space for wheelchairs.

The transverse-mounted model 850 BLR1 seats (which provide seating for 72 passengers per car) are attached to the car body sidewall in a pin-mounted cantilever arrangement. The seat assembly consists of stainless steel stamped components, with the seatback elements contoured and recessed into the seat frame, which is fitted with fabric cushion padded inserts. The transverse passenger seat assemblies are fitted with 7/8-inch-diameter stainless steel grabrails, located across the top of the seatback. The American Seating Company offers an alternate design for the seating grabrail made of a "vandal resistant energy absorbing" thermoplastic. (See figure 6 for photographs of seats equipped with two types of grabrails.)

[42] The manufacturer's "Collision Energy" calculations indicated (to the effect) that the Cullen-Western-Hayes, Inc., WH bumping post could structurally tolerate a 10-mph impact of a three-car LRV train (with passengers).

Figure 6. Top photograph shows LRV seats equipped with stainless steel grabrail (without a vertical stanchion); bottom photo shows seats equipped with thermoplastic grabrails (with a vertical stanchion).

Tests and Research

Impact Calculations. During its investigation, the Safety Board made calculations based on the available facts about the LRVs involved to determine the force of the impacts that took place during the two BWI accidents that occurred in 2000. The calculations indicated that the amounts of kinetic energy transferred into the Cullen-Western-Hayes WH bumping posts during the collisions were about 934,800 pound-feet in the February 13, 2000, accident and about 1.15 million pound-feet in the August 15, 2000, accident. The Safety Board's calculations showed that in a hypothetical collision between a Cullen-Western-Hayes WH bumping post and a three-unit LRV train filled to occupant capacity, traveling at the posted speed of 15 mph, the kinetic energy that could be transferred into the bumping post upon such an impact would be about 3.6 million pound-feet.

The Safety Board further calculated the deceleration "G forces"[43] that the LRV passengers were exposed to during the accidents. The average level of G forces experienced along the LRV longitudinal axis within the car during the accidents were about -1.81 G for the February 13, 2000, accident and about -0.23 G for the August 15, 2000, accident.

Regulatory Requirements. The Safety Board reviewed current Government regulations that would apply to light rail or transit passenger equipment crashworthiness and related passenger safety issues. The review of current FRA and FTA regulations indicated that there are no existing requirements that apply to LRV crashworthiness and related passenger safety issues.

The Safety Board also reviewed existing self-regulatory standards or recommended practices within the light rail and transit communities.[44] Although LRVs are not subject to these standards, APTA publishes the *Manual of Standards and Recommended Practices for Passenger Rail Equipment,*[45] which contains a section addressing the "Standard for Seating in Commuter Rail Cars." Within this standard, APTA details both static and dynamic testing requirements to ensure that the seats remain fixed to the rail car under normal loading conditions and during crash conditions. In addition, the standard specifies a dynamic longitudinal 8-G crash pulse used for sled testing to simulate a rail car crash.

The Safety Board contacted American Seating, the manufacturer of the model 850 BLR1 railcar seats on the LRVs used by the MTA, to determine the level of crashworthiness testing performed on these specific seat designs. American Seating indicated that energy absorption testing was conducted on a model similar to the model 850 BLR1 seat assembly; the testing is referred to as the "Grabrail Head Form

[43] A "G" is a unit of force equal to the gravity exerted on a body at rest. Negative G force values indicate deceleration.

[44] Literature available from APTA was reviewed. In addition, literature from the Association of American Railroads, a railroad industry trade association, was reviewed.

[45] APTA, *Manual of Standards and Recommended Practices for Passenger Rail Equipment*, July 1, 1999 *(*Washington, D.C: 1999).

Impact Test."[46] American Seating also indicated that it typically follows APTA's Standard Bus Procurement Guidelines[47] when designing new seating systems but that the seat design used in the accident LRVs was developed before the release of the guidelines.

The Safety Board, in its review of the grabrail testing previously conducted by American Seating, found that the seat type tested was not the same configuration as found in the MTA LRV fleet[48] and therefore requested American Seating to demonstrate grabrail head form impact tests on an exemplar model 850 BLR1 railcar seat.

Grabrail Head Form Impact Testing. This energy absorption testing, in which the grabrails were struck, longitudinally, by a 15-pound head form traveling at 15 mph, was conducted with Safety Board staff present. The tests were performed on two configurations of seats with stainless steel grabrails (with and without a vertical stanchion) and two configurations of seats with thermoplastic grabrails (with and without a vertical stanchion). Six different impact locations along the grabrails were tested. The testing produced a range of Head Injury Criteria[49] values, all of which were well below the threshold value of 1,000.[50] The highest recorded Head Injury Criteria value resulting from the testing was 377, which occurred when a stainless steel grabrail with a vertical stanchion was struck. The lowest value recorded from this testing was 76, which occurred when a thermoplastic grabrail without a vertical stanchion was struck.

Other Information

Postaccident MTA Actions. In the aftermath of the two BWI accidents, the MTA has taken a number of actions to improve its system safety.

For instance, as LRV trains approach the BWI Airport Station, they must now stop at a red signal and then make a route selection at a push button before entering the station. This red signal is protected by a trip stop. The speed limit for trains entering and leaving the station has also been reduced to 5 mph. Trip stops and friction buffer stop end-of-line collision protection have been provided for all four terminal stations on the MTA system, including the BWI Airport Station.

The MTA has installed new interior and exterior emergency door release signage on all its LRVs. The MTA also performed equipment familiarization and emergency

[46] The Federal Government does not require this testing, and its adequacy has not been established for LRVs.

[47] APTA Technical Specification, *Standard Bus Procurement Guidelines*, pp. 51-56, April 28, 1999. This standard details both static and dynamic testing for the bus seats. The dynamic testing subjects the seats to a 10-G deceleration and evaluates the energy absorption of the seating system based on the maximum head and femur loads to ATDs placed within the seating section.

[48] The model 850 seat configuration tested by the seat manufacturer involved a different (floor/wall) attachment arrangement and did not include a vertical stanchion support element; both factors were identified as potentially influential to the impact test results.

[49] See 49 CFR 571.201, Section 7, "Performance Criterion," which describes the Head Injury Criteria equation used to develop the data.

[50] APTA's Standard Bus Procurement Guidelines specify a maximum Head Injury Criteria value of 400.

procedures training with BWI fire and rescue employees (June 2000), carried out equipment and familiarization training for the Maryland Transportation Authority police (September 2000), and conducted an emergency drill with fire and rescue personnel from surrounding jurisdictions (November 2000). Additional drills took place in 2001.

The MTA told the Safety Board, through an August 16, 2001, fax communication, that it intends to "explore the redesign" of its LRV passenger seatback grabrails and to "change the design of the rails and/or locate more impact-resistant materials for future rail car orders."

With respect to its drug and alcohol policy, the MTA put into effect (in September 2000) a new policy that provides for terminating all safety-sensitive employees who test positive in an incident-based or reasonable suspicion alcohol or drug test. The MTA also hired a consultant to conduct an independent assessment of the MTA's drug and alcohol policies. The consultant's recommendations included improving the MTA's substance abuse treatment program, implementing prescription and over-the-counter drug policies, providing fitness-for-duty evaluations, and giving additional substance abuse training to employees and managers. The MTA is working to effect the consultant's recommendations and told the Safety Board that it has developed, but not yet enacted, a draft "prescription drug, over-the-counter drug, and fitness for duty" policy.

The MTA has had an independent contractor conduct a safety assessment of its light rail operations. The assessment was completed in October 2000, and the MTA has developed a corrective action plan based on the contractor's assessment.

In March 2001, the MTA held a fatigue awareness training program for managers, operators, and maintenance staff. In September 2001, some MTA personnel took part in the Transportation Safety Institute's Fatigue Awareness Seminar. The MTA also informed the Safety Board that it is developing its own fatigue awareness training program and policy.

The MTA completed a revision of its Light Rail rulebook in April 2001. Training on the rulebook is part of the new annual recertification program for all operators, maintenance supervisors, and track access and control personnel.

Previous Safety Recommendations. As a result of its investigation of the collision involving two New York City subway trains on the Williamsburg Bridge in Brooklyn, New York, on June 5, 1995,[51] the Safety Board issued Safety Recommendations R-96-20 and -21 to the FTA and APTA, respectively.

[51] National Transportation Safety Board, *Collision Involving Two New York City Subway Trains on the Williamsburg Bridge in Brooklyn, New York, June 5, 1995*, Railroad Accident Report NTSB/RAR-96/03 (Washington, D.C: 1996).

R-96-20

In cooperation with the American Public Transit Association, develop a fatigue educational awareness program and distribute it to transit agencies to use in their fitness for duty training for supervisors and employees involved in safety-sensitive positions.

R-96-21

Assist the Federal Transit Administration in developing a fatigue educational awareness program for transit agencies to use in their fitness for duty training for supervisors and employees in safety-sensitive positions.

In a letter dated May 1, 1999, the FTA informed the Safety Board that a fatigue awareness program had been incorporated into the Transportation Safety Institute's core curriculum.[52] The institute's Fatigue Awareness Seminar includes modules that discuss the major types of sleeping disorders, including sleep apnea. Based on the FTA's response, the Safety Board classified Safety Recommendation R-96-20 "Closed--Acceptable Action" on January 11, 2000. APTA responded to Safety Recommendation R-96-21 by conducting research on the effects of fatigue on human performance and assisting the FTA in developing a fatigue awareness program that has been incorporated into the Transportation Safety Institute's core curriculum. Accordingly, Safety Recommendation R-96-21 is classified "Closed—Acceptable Action."

In August 1986, following its investigation of several accidents involving operators of rail rapid transit trains who had used prescription or over-the-counter drugs,[53] the Safety Board sent a letter to the Urban Mass Transportation Administration (predecessor agency to the FTA), which stated that the Urban Mass Transportation Administration "should take the lead in developing and implementing regulations to address the growing concerns about drug use (licit and illicit) by rail rapid transit operating employees." The Safety Board's letter further stated that "The framework for the control of alcohol and drug use has already been developed by the FRA's regulations and, with certain appropriate modifications, may be made applicable to rail rapid transit systems." The Safety Board recommended that the Urban Mass Transportation Administration:

[52] The Transportation Safety Institute is a major training and technical assistance organization for the U.S. Department of Transportation, providing safety and security training to all department administrations and other Federal, State, and local agencies, as well as to private industry. The institute began conducting training in transit safety in 1976. The courses include a full range of training in bus and rail safety. Since it began in 1976, the transit program has trained more than 60,000 students.

[53] National Transportation Safety Board, *Rear End Collision of Two Chicago Transit Authority Trains near the Montrose Avenue Station, Chicago, Illinois, August 17, 1984*, Railroad Accident Report NTSB/RAR-85/11 (Washington, D.C: 1985); *Metropolitan Atlanta Rapid Transit Authority, Atlanta, Georgia, December 3, 1984*, Railroad Accident Investigation ATL-85-FR004; and *Rear End Collision of Metro Dade Transportation Administration Train Numbers 172-171, 141-142, Miami, Florida, June 26, 1985*, Railroad Accident Report NTSB/RAR-86/02 (Washington, D.C: 1986).

R-86-36

Require rail rapid transit systems to institute procedures and information systems to inform employees of the deleterious effects on work performance of some over-the-counter and prescription drugs.

R-86-37

Require the removal of employees from safety-sensitive positions if the rail rapid transit medical department determines that the employees' use of a prescription drug will affect their work performance.

In Safety Recommendations I-89-4 through -12, issued to the Secretary of Transportation in 1989, the Safety Board continued to address the uniform implementation of testing programs in all modes of transportation. The Board urged the Secretary of Transportation to include rail rapid transit in the then-ongoing efforts to address these safety recommendations and, if necessary, to seek the legislative authority to do so. Consequently, Safety Recommendations R-86-36 and -37, which were issued to the Urban Mass Transportation Administration to address testing programs only in the rail rapid transit industry, were classified "Closed—Acceptable Action/Superseded" as a result of Safety Recommendations I-89-4 through -12.

The Safety Board recommended, in its report on a 1993 train derailment in Mobile, Alabama,[54] that the U.S. Department of Transportation:

I-94-5

Require the modal operating administration to develop and disseminate bulletins, notices, circulars, and other documents that call attention to the need for an employee reporting procedure concerning the use of medication (over-the-counter and prescription) while on duty and that the U.S. Department of Transportation urge the transportation industry to develop and implement informational and educational programs related to this subject.

In August 1995, the Safety Board classified this recommendation "Closed—Acceptable Action," after the U.S. Department of Transportation issued the following statement to be used by all its modal operating administrations:

The U.S. Department of Transportation reminds all U.S. Department of Transportation industries of the potential threat to public safety caused by the on-duty use of some over-the-counter and prescription medications by persons performing safety-sensitive duties. As a result, we strongly urge all transportation industry employers to include in their employee training materials appropriate information to address this issue.

[54] National Transportation Safety Board, *Derailment of Amtrak Train No. 2 on the CSXT Big Bayou Canot Bridge Near Mobile, Alabama, September 22, 1993*, Railroad Accident Report NTSB/RAR-94/01 (Washington, D.C: 1994).

On January 13, 2000, the Safety Board issued safety recommendations concerning medication issues to the U.S. Department of Transportation, its modal agencies (including the FTA),[55] and the U.S. Food and Drug Administration. The Safety Board issued the following safety recommendations to the U.S. Department of Transportation:

> I-00-1
>
> Establish, in coordination with the Federal Motor Carrier Safety Administration, the Federal Railroad Administration, the Federal Transit Administration, and the U.S. Coast Guard, comprehensive toxicological testing requirements for an appropriate sample of fatal highway, railroad, transit, and marine accidents to ensure the identification of the role played by common prescription and over-the-counter medications. Review and analyze the results of such testing at intervals not to exceed every 5 years.
>
> I-00-2
>
> Develop, with assistance from experts on the effects of pharmacological agents on human performance and alertness, a list of approved medications and/or classes of medications that may be used safely when operating a vehicle.
>
> I-00-3
>
> Expressly prohibit the use of any medication not on the U.S. Department of Transportation's list of approved medications (described in I-00-2) for twice the recommended dosing interval before or during vehicle operation, except as specifically allowed, when appropriate, by procedures or criteria established by the applicable modal administration (the Federal Aviation Administration, the Federal Motor Carrier Safety Administration, the Federal Railroad Administration, the Federal Transit Administration, or the U.S. Coast Guard).
>
> I-00-4
>
> Evaluate the applicability of the restrictions (for vehicle operators) described in I-00-2 and -3 to transportation employees in all safety-sensitive positions. If appropriate, implement such restrictions within 2 years of their implementation for vehicle operators.

The U.S. Department of Transportation replied to these recommendations in a July 31, 2000, letter. With respect to the rail and rail transit aspects of Safety Recommendation I-00-1, the Department stated:

> The FRA has in place an extensive and effective post-accident toxicological testing program. Following a qualifying accident, the FRA conducts drug and alcohol testing on all fatally injured employees and a large percentage of surviving employees. Tests are conducted for the five illegal drugs for which the DOT tests plus two of the more common prescription medications. The FRA program also has the capability of testing for any additional prescribed or OTC medications that may have contributed to the cause of the accident. In the past, the

[55] Safety Recommendations R-00-5 through –8.

> FRA has provided urine, blood, and tissue specimens to the Safety Board for additional testing following certain major train accidents. We are not aware of any instances where the Safety Board has found any additional drugs or OTC medications in these specimens, and the FRA's post-accident testing over the years has never indicated a causal relationship between the use of prescription medications and the crash event…. the FTA [does] not have statutory authority to require post-accident toxicological testing of safety-sensitive personnel who are killed in an accident.

In its July 31, 2000, response, the U.S. Department of Transportation also stated, with respect to Safety Recommendations I-00-2 through -4, that:

> We do not believe it is feasible to develop a list of approved medications that may be safely used by safety-sensitive employees and employers. Currently, the *Physicians Desk Reference*, which lists most of the prescription medications available, is a volume of over 3,000 pages; the publication for OTC medication is also large. To develop a list which would be continuously up to date is virtually impossible. There would always be a "lag time" in which certain new drugs are not listed, other drugs would have stopped being manufactured and have been dropped from the list, and still others would have their names changed. Another problem is that such a list would not address the interaction of different drugs. Very few individuals would spend the time and effort to review drug interaction, especially if a health care provider approved their prescription medication. The development of a list (I-00-3) that expressly prohibits use of medications over twice the recommended dosing interval is fraught with the same problems identified above for the establishment of a list approving certain medications. In reference to I-00-4, there is no distinction between vehicle operators and other transportation safety-sensitive personnel in the Department's regulations regarding drug testing. The same constraints placed on vehicle operators related to drugs are placed on all safety-sensitive transportation personnel. In summary, DOT shares your concern about the potential impact of the use of prescription and OTC medications by safety-sensitive transportation personnel. The Department does not believe a list of approved drugs is the correct approach.

In addition to the safety recommendations issued in January 2000 to the U.S. Department of Transportation and its modal agencies concerning over-the-counter and prescription medication use, the Safety Board asked the U.S. Food and Drug Administration to:

> I-00-5
>
> Establish a clear, consistent, easily recognizable warning label for all prescription and over-the-counter medications that may interfere with an individual's ability to operate a vehicle. Require that the label be prominently displayed on all packaging of such medications.

The U.S. Food and Drug Administration proposed that a joint U.S. Food and Drug Administration/Safety Board public meeting_to include interested parties from the Government, the transportation and pharmaceutical industries, and academia_be held to discuss the various transportation safety issues concerning potentially sedating and

impairing medications. Safety Board staffers worked with U.S. Food and Drug Administration personnel to plan and establish the agenda for the meeting, which was held on November 14 and 15, 2001, at Safety Board headquarters. Accordingly, the Safety Board's reply to the U.S. Department of Transportation's response to Safety Recommendations I-00-1 through –4 has been deferred until the discussion at the meeting has been fully reviewed and considered and the U.S. Department of Transportation has been provided an opportunity to update its response subsequent to its participation in the public meeting.

On November 14, 1996, as a result of the Safety Board's investigation of an accident on the Washington Metrorail system,[56] the Safety Board issued Safety Recommendation R-96-46 to the FTA, which called for the FTA to:

> R-96-46
>
> Develop, with the assistance of the American Public Transit Association, guidelines for the monitoring/recording devices that capture critical performance and event data for rapid rail transit cars and urge transit agencies to install these devices on new and rehabilitated cars.

The FTA, with APTA, prepared a report, dated June 1998, entitled *Event Recorders for Rail Rapid Transit Systems*. In a letter dated September 4, 1998, the FTA provided the Safety Board with a copy of the report and indicated that the report would be distributed to transit agencies developing specifications for rehabilitated and new rapid transit vehicles and that the FTA would urge the installation of the devices. The report explored the effectiveness and efficiency of using event recorders on rapid rail cars. It presented and analyzed data; defined various aspects of using accident/incident event recorders; included a cost, feasibility, and benefit analysis; and identified the technical requirements for these devices in rapid rail transit. Based on this response, the Safety Board classified Safety Recommendation R-96-46 "Closed—Acceptable Action" on January 6, 1999.

When, on November 14, 1996, the Safety Board issued Safety Recommendation R-96-46 to the FTA, it also issued Safety Recommendation R-96-47 to APTA. The recommendation asked APTA to:

> R-96-47
>
> Develop, with the assistance of the Federal Transit Administration, guidelines for the monitoring/recording devices that capture critical performance and event data for rapid rail transit cars and urge transit agencies to install these devices on new and rehabilitated cars.

In addition to working with the FTA to develop the 1998 report on *Event Recorders for Rail Rapid Transit Systems*, APTA has, through various APTA-sponsored

[56] National Transportation Safety Board, C*ollision of Washington Metropolitan Area Transit Authority Train T-111 with Standing Train at Shady Grove Passenger Station, Gaithersburg, Maryland, January 6, 1996*, Railroad Accident Report NTSB/RAR-96/04 (Washington, D.C: 1996).

conferences and symposiums, urged transit agencies to install these devices on new and rehabilitated cars. Based on this information, Safety Recommendation R-96-47 is classified "Closed—Acceptable Action."

Event Recorder Regulations. The FTA has issued no regulations that apply to event recorders on LRVs.

The FRA regulations concerning the requirements for event recorders on railroad locomotives are at 49 CFR 229.135. These regulations do not apply to event recorders on LRVs. According to the railroad locomotive safety standard definitions provided at 49 CFR 229.5(g):

> (g) Event recorder means a device, designed to resist tampering, that monitors and records data on train speed, direction of motion, time, distance, throttle position, brake applications and operations (including train brake, independent brake, and, if so equipped, dynamic brake applications and operations) and, where the locomotive is so equipped, cab signal aspect(s), over the most recent 48 hours of operation of the electrical system of the locomotive on which it is installed. A device, designed to resist tampering, that monitors and records the specified data only when the locomotive is in motion shall be deemed to meet this definition provided the device was installed prior to [insert the effective date of the rule] and records the specified data for the last eight hours the locomotive was in motion.

APTA Event Recorder Working Group. APTA is sponsoring a working group called the "APTA Rail Transit Standards Development Vehicle Inspection and Maintenance Committee" that is addressing event recorders on rail transit vehicles. It consists of representatives from APTA, various transit properties, consultants, and appropriate government entities. The committee is addressing only inspection and maintenance standards and recommended practices for rail transit event recorders. The committee's recorder standard is expected to detail maintenance intervals and techniques for data, voice, and image recording systems (where available) on transit vehicles. The group defers to the Institute of Electrical and Electronics Engineers standard for any recommended operational and crashworthiness standards. The committee expects to have a final draft standard for rail transit event recording systems by the end of 2002.

Analysis

General

Both accidents occurred during daylight hours, under satisfactory visibility and track conditions. During postaccident investigations, investigators found nothing that indicated that either train 24 or train 22 had any mechanical defects or deficiencies that contributed to the accidents. Postaccident examinations of the signal system determined that the equipment had not been tampered with or vandalized before either accident. All evidence indicated that the track and rail signal systems had operated as designed during both accidents.

February 13, 2000, Accident

About 2:37 p.m. (eastern standard time) on February 13, 2000, MTA train 24, composed of a single LRV, traveling on the Central Light Rail Line System on a routine trip from Baltimore to the BWI Airport struck a hydraulic bumping post apparatus at the end of the BWI Airport extension line and derailed.

During postaccident interviews, the operator stated that the last signal before the BWI Airport Station (signal BWI 15-6 at milepost 115) was yellow. This signal aspect authorized him to "proceed prepared to stop at next signal." He expressed uncertainty whether he had applied either the train brakes or the emergency brakes before the train struck the bumping post. Several passengers stated, during their postaccident interviews, that the LRV continued through the station without slowing or stopping until it struck the bumping post. Security videotape evidence viewed after the accident indicated that the average speed of the train while traveling along the BWI Airport Station platform was 15.64 mph, and the Safety Board found no physical track evidence (scratch marks, abrasions, or metal shavings) that would have been consistent with severe braking at the accident site. The Safety Board concludes that the train 24 operator failed to apply the brakes to stop his train at the BWI Airport Station on February 13, 2000.

Because the conditions under which train 24 was operating were normal and the Safety Board could not find any mechanical reasons why the operator failed to stop the LRV at the BWI Airport Station, the Safety Board evaluated factors that might have affected the operator's performance during his approach to the station.

The operator described February 13, 2000, up to the accident as "an average day," and said that nothing had distracted him from his duties. Nevertheless, evidence suggests that he was operating his train in a state of reduced alertness. Some of his postaccident statements indicated that he was confused about what had happened, and some of his comments about his own condition were equivocal or contradictory. He told investigators

that he had felt rested when he reported for duty but also said that he had "felt tired and nauseated all day" and that his head had felt "stuffed up." When asked whether he had dozed off at any time after he began operating the train to the BWI Airport on the accident trip, the operator responded, "I couldn't tell you. I probably did doze. I don't know. But I doubt it. I probably did doze off."

The operator told the Safety Board that on the morning of the accident day, he had taken one blood pressure pill, one Tylenol 3 (which contains codeine), and one oxycodone pill. The Tylenol 3 and oxycodone were pain-relievers that had been prescribed to the operator after he had undergone surgery for a dental abscess in December 1999. According to the operator, the prescribing physicians had told him the pain medications might cause drowsiness, and he said that he did become drowsy after he took them. The Safety Board is aware that the use of oxycodone and Tylenol 3 can result in sedation and may impair judgment and performance.

Pursuant to postaccident drug testing regulations at 49 CFR 653.45 and 654.33, the operator provided a breath specimen at 7:12 p.m. and a urine specimen at 7:20 p.m. on the day of the accident. (Thus, both specimens were taken about 5 hours after the accident.) The breath specimen was negative for alcohol. Toxicological test results for the urine sample revealed the presence of codeine, morphine (the active substance to which codeine is primarily converted in the body), and the metabolite of cocaine. These findings were consistent with the operator's statements regarding his non-use of alcohol and his use of prescription medication but not with his statements regarding illegal substance use.

For some time after the accident, the operator had denied that he had used any illegal drugs before the accident, but when he was informed of the toxicological test results, he conceded that he had recently used cocaine. In his revised account, he claimed that very late in the evening on February 11 (about 1 1/2 days before the accident), he had rolled two wet cotton balls in cocaine powder and placed them in his mouth to relieve the pain associated with his abscess condition.

The Safety Board does not find the operator's revised story credible. Given the expected rate at which cocaine metabolizes, the test results indicate relatively recent use of cocaine rather than use more than 30 hours before the accident. The cocaine in the operator's system was almost certainly ingested within the 24 hours preceding specimen collection and was likely taken within the 12 hours before the specimen was obtained.

Because no blood from the operator was available for analysis, the times and amounts of ingestion cannot be more accurately determined, and it is not possible to definitively determine from these data whether the operator was impaired by cocaine at the time of the accident. Acute withdrawal from cocaine primarily results in depression and fatigue, and the operator could have been suffering from these symptoms even if he were not intoxicated by cocaine at the time of the accident.

Postaccident statements from passengers indicated that the operator appeared to have been fatigued or otherwise impaired as the LRV approached the BWI Airport Station. One passenger told the Safety Board that he saw the operator fail to respond for 10 to

15 seconds after the LRV received a green signal at a location three stations before the BWI Airport Station. He recalled that the operator then shook his head and body before he began to operate the train. Several passengers even said that it appeared to them that the operator had fallen asleep before the accident occurred.

Given that the operator did not brake the LRV on the approach to the BWI Airport Station, that he had taken prescription drugs liable to cause drowsiness on the day of the accident and cocaine within hours before the accident, and that the passengers saw the operator behave in a sluggish and inattentive manner shortly before the accident, the Safety Board concludes that the effects of prescription pain-relieving medications and/or recent cocaine use impaired the performance of the train 24 operator on February 13, 2000.

In 1994, this operator had tested positive for cocaine during a random drug test. He had successfully completed the required MTA rehabilitation plan, and the substance abuse professional responsible for his case told the MTA on April 29, 1997, that further testing for illegal substances was not indicated. Federal drug testing regulations at 49 CFR 653.63(d) state that the substance abuse professional is responsible for establishing the specifics of the follow-up testing program. The regulations further state that after the first 12 months of testing (with negative results), the substance abuse professional may recommend "the frequency and duration of follow-up drug testing, provided that the follow-up testing period ends 60 months after the employee returns to duty." This operator had fulfilled the MTA's treatment program and returned to duty by February 1995, about 5 years before this accident occurred.

Regarding his use of prescription medication, the operator told the Safety Board that he believed he was required to inform the MTA about using the medications prescribed for his oral surgery in December 1999, which he continued to use from the time he returned to work in early January 2000 until the day of the accident. However, he stated that he never informed anyone at the MTA that he was taking those medications.

August 15, 2000, Accident

About 7:14 a.m. (eastern daylight time) on August 15, 2000, MTA train 22, which was composed of two LRVs, en route from Pennsylvania Station in downtown Baltimore to the BWI Airport, failed to stop at the BWI Airport Station. The train continued through the station, struck the hydraulic bumping post at the end of the track, and derailed.

The operator told the Safety Board that he had reported to work on the day of the accident about 3:00 a.m. He had completed one round-trip from Pennsylvania Station to the BWI Airport Station and was returning to the BWI Airport Station on a second trip when the accident occurred at 7:14 a.m. He recalled that, during the last segment of the trip to the airport, he saw that signal BWI 15-6 at milepost 115 displayed a red over yellow aspect, which required him to proceed at restricted speed and to be prepared to stop at the station.

The operator said that the signal aspect (on a signal about 690 feet before the point of collision) was the last thing he saw until sometime after the accident. He said that the next things he remembered were his train being up in the air (on the bumping post) and emergency personnel boarding it. Presumably, the operator lost consciousness sometime after he saw the signal at milepost 115. He was unable to say how long he had been unconscious or exactly what might have caused him to lose consciousness. He said he had not had any previous blackout experiences.

Because the operator lost consciousness well before the accident occurred and had no recollection of the events immediately preceding the accident, it seems that the blackout incapacitated the operator so that he could not perform his necessary duties, including braking, as the train approached the BWI Airport Station. Therefore, the Safety Board concludes that the train 22 operator did not apply the brakes to stop his train at the BWI Airport Station on August 15, 2000. The Safety Board looked for possible reasons for the operator's blackout.

Medication Use

One factor that could have affected the operator's alertness on the day of the accident was his use of prescribed medications. The operator told the Safety Board that he had been off duty with a chronic back problem for about 2 months before the accident and had returned to work the day before the accident. The operator said he was taking prescribed medications for high blood pressure and chronic back and neck pain at the time of the accident.

About 3 hours 45 minutes after the accident, the train operator provided breath and urine specimens, pursuant to Federal postaccident toxicological testing regulations. In addition, medical personnel at Mercy Hospital in Baltimore obtained a blood specimen for medical evaluation purposes, and the Safety Board subpoenaed portions of the blood specimen for additional testing. All specimens tested negative for the presence of alcohol and illegal drugs. Consequently, the Safety Board concludes that the train 22 operator was not impaired by alcohol or illegal drugs at the time of the August 15, 2000, accident.

The urine specimen indicated the presence of amlodipine, a prescription medication used principally to control hypertension. The Safety Board considers that the presence of this medication would not typically impair performance.

Although the operator indicated that he had been taking the prescription muscle relaxant cyclobenzaprine (Flexeril) for back pain, none of the test results indicated the presence of this medication. In fact, cyclobenzaprine would likely not be detected in the blood at the levels typically prescribed, so the operator could have had some of this medication in his system. The operator said, however, that he had last taken 10 mg of cyclobenzaprine about 3:00 p.m. on August 14, 2000, which would have been about 16 hours before the accident occurred. It is unlikely that such a dosage of this medication, taken so many hours before the accident occurred, would have significantly impaired the operator's mental and/or physical abilities at the time of the accident. Nevertheless, the

Safety Board cannot absolutely dismiss this medication as a possible contributory source of operator impairment, although it was not the primary cause of the operator's blackout.

Obstructive Sleep Apnea

The Safety Board considered extreme sleepiness as a possible explanation for the train 22 operator's blackout. Little immediately apparent evidence supported this possibility. The operator said he had felt rested before the accident. His work and rest schedule indicated that in the days preceding the accident, he had had about 10 1/2 hours of sleep in the night of August 11 to 12, about 11 hours of sleep in the night of August 12 to 13, about 4 hours of sleep in the night of August 13 to 14 (plus about 6 hours that day of what the operator characterized as "rest"), and 8 to 9 hours of sleep in the night of August 14 to 15. While this schedule was somewhat irregular, the operator did have adequate opportunity to obtain an average of more than 8 hours of sleep per night.

After the accident, however, the operator's physician became concerned that the operator's unexplained loss of consciousness on the day of the accident might have been caused by a sleeping disorder. On September 5, 2000, on the advice of his physician, the operator underwent an evaluation by a sleep medicine specialist. The evaluation results indicated that the operator suffered from severe obstructive sleep apnea.

During the assessment, the operator told the examining sleep specialist physician that he had "excessive daytime sleepiness sometimes." The evaluation indicated that the operator had a self-reported Epworth Sleepiness Scale value of 14, while an Epworth Sleepiness Scale value for a person without excessive sleepiness would be 10 or lower.[57] In addition, the medical testing determined that the operator demonstrated a respiratory disturbance index of 106 episodes per hour. A normal index would be less than 5 episodes of disturbance per hour, while an index indicating "severe" disturbance would be anything above 30 episodes per hour. Therefore, the operator had more than 21 times the number of breathing pauses per hour than is considered normal and more than 3 times the number of breathing pauses per hour than is considered severely disturbed. In addition, the evaluation showed that the operator's sleep latency period (the time it took for him to fall asleep under optimum conditions) was shorter than that of an individual who is not sleep-deprived.

The Safety Board sent the full results of the operator's medical sleep evaluation to the director of the Center for Sleep and Respiratory Neurobiology at the University of Pennsylvania Medical Center for assessment. This expert strongly supported the diagnosis of severe obstructive sleep apnea and considered the operator at risk for falling asleep inappropriately. Based on its review of the sleep evaluation evidence and the verification of the evaluation findings by an independent expert, the Safety Board concludes that the train 22 operator was suffering from severe obstructive sleep apnea at the time of the August 15, 2000, accident.

[57] The Epworth Sleepiness Scale has a range of 0 to 24. Epworth Scale values for a person without excessive sleepiness would be 10 or less, while values 11 through 24 indicate significant sleepiness.

Obstructive sleep apnea is a medical condition that chronically prevents those affected by it from obtaining restful sleep, creating circumstances that result in persistent fatigue no matter how much sleep is obtained during any period. Medical authorities agree that excessive daytime sleepiness is almost uniformly present in people who suffer from obstructive sleep apnea, and constant fatigue is one of the symptoms of the disorder. Because he had severe obstructive sleep apnea, the operator almost certainly had severe and persistent fatigue. He likely was so accustomed to his habitual condition of tiredness that he did not even clearly recognize that he was fatigued. On the morning of the accident, this unrelieved fatigue appears to have caused the operator to fall asleep while he was operating the train during the approach to the BWI Airport Station.[58] Consequently, the Safety Board concludes that the chronic fatigue he was experiencing due to undiagnosed obstructive sleep apnea likely caused the train 22 operator to fall asleep as the LRV train approached the BWI Airport Station on August 15, 2000.

An estimated 10 million people in the United States have undiagnosed obstructive sleep apnea.[59] This is due in large part to a lack of awareness about and appreciation of the symptoms of the disease. Its hallmarks, such as snoring and persistent fatigue, are often considered mere annoyances rather than possible symptoms of a medical condition. Consequently, people with sleep apnea frequently dismiss the indicators as insignificant. A person educated about the disease, however, might recognize them as symptoms of the condition and seek appropriate medical treatment. Similarly, if transit agencies were better educated about and focused more attention on such disorders, they might be more aware of those employees likely to have sleeping disorders and be better equipped to help employees with sleeping disorders treat the conditions safely and effectively. Consequently, the Safety Board concludes that better education about the risks posed by sleeping disorders, the indicators and symptoms of such disorders, and the available means of detecting and treating the conditions could help transit agencies and their employees reduce the risk of safety-sensitive employees being impaired by chronic fatigue.

As a result of its investigation of the collision involving two New York City subway trains on the Williamsburg Bridge in Brooklyn, New York, on June 5, 1995,[60] the Safety Board issued Safety Recommendations R-96-20 and -21 to the FTA and APTA, respectively.

[58] It should be noted that the Safety Board has previously investigated an accident in which a transit train operator fell asleep while operating a train, resulting in a collision with another train. The accident is detailed in Railroad Accident Report NTSB/RAR-96/03, *Collision Involving Two New York City Subway Trains on the Williamsburg Bridge in Brooklyn, New York, June 5, 1995*. In the Williamsburg Bridge case, the operator's condition was not attributable to a sleeping disorder.

[59] Information obtained in early 2001 from the Home page of the American Sleep Apnea Association <http://sleepapnea.org>.

[60] Railroad Accident Report NTSB/RAR-96/03.

R-96-20

In cooperation with the American Public Transit Association, develop a fatigue educational awareness program and distribute it to transit agencies to use in their fitness for duty training for supervisors and employees involved in safety-sensitive positions.

R-96-21

Assist the Federal Transit Administration in developing a fatigue educational awareness program for transit agencies to use in their fitness for duty training for supervisors and employees in safety-sensitive positions.

In a letter dated May 1, 1999, the FTA informed the Safety Board that a fatigue awareness program had been incorporated into the Transportation Safety Institute's core curriculum. Based on the FTA's response, the Safety Board classified Safety Recommendation R-96-20 "Closed--Acceptable Action" on January 11, 2000. APTA responded to Safety Recommendation R-96-21 by conducting research on the effects of fatigue on human performance and assisting the FTA in developing the fatigue awareness program that has been incorporated into the Transportation Safety Institute's core curriculum. Accordingly, Safety Recommendation R-96-21 is classified "Closed—Acceptable Action."

Although not specifically requested in Safety Recommendations R-96-20 and -21, the Transportation Safety Institute's Fatigue Awareness Seminar includes modules addressing the major types of sleeping disorders, including sleep apnea. Such information, once it filters down to individual transit operations and employees, should help heighten awareness of the risks posed by such sleeping disorders and how these risks may be alleviated. Before the BWI accidents took place in 2000, the MTA did not attempt to educate its employees or managers about how sleeping disorders could negatively affect the safety of the transit environment and about how such problems could be identified and addressed. Following the accidents, in 2001, some MTA personnel participated in fatigue awareness training, including the Transportation Safety Institute's fatigue awareness training. In addition, the MTA began developing its own fatigue awareness training program and policy.

The Safety Board is pleased with these MTA efforts in the area of fatigue awareness and encourages the MTA to develop a systematic and comprehensive program that will ensure that MTA employees are kept aware of the various safety issues involving fatigue, particularly fatigue caused by sleeping disorders. As indicated by the August 2000 accident at the BWI Airport Station, such disorders can have significant system safety consequences. Given that a sleeping disorder may affect the performance of an operator employed by any rail transit system, all such systems would benefit from including a sleeping disorder component in their fatigue programs. Therefore, the Safety Board believes that U.S. rail transit systems should ensure that their fatigue educational awareness programs include the risks posed by sleeping disorders, the indicators and symptoms of such disorders, and the available means of detecting and treating them.

According to some experts, it may be possible to identify safety-sensitive employees who may have a sleeping disorder by using questionnaires and/or structured interviews and clinical data.[61] One method to determine whether testing for a sleeping disorder might be warranted would be to administer a prescreening questionnaire designed to extract information about the employee's general physical characteristics, sleeping habits, and daytime functioning. The Epworth Sleepiness Scale used in the early stages of the sleep medicine evaluation of the train 22 operator is an example of such a prescreening questionnaire.

Once the individual completes the prescreening questionnaire, it could be evaluated by medical experts to determine whether the individual possesses predisposing factors associated with a sleeping disorder, including being male, being overweight, being over 40 years old, having high blood pressure, having some physical anomaly of the upper airway, and having sleeping and waking behaviors (such as snoring) indicative of a sleeping disorder. (The train 22 operator had all these predisposing criteria.) On the basis of such an evaluation, the employee could then either be recommended for clinical medical evaluation or determined to be at lower risk for sleep disorders.

The Union Pacific and CSXT Railroads have begun to use programs that rely on specially designed prescreening questionnaires to determine their employees' predisposition to sleeping disorders. The data from the first Union Pacific program are still being evaluated, but the initial CSXT program enabled the railroad to identify 43 employees with sleep apnea and have them treated for the disorder.

Medication Reporting Requirements

During these investigations, the Safety Board learned that, although the MTA had substance abuse requirements addressing the use of alcohol and illicit drugs, it did not specifically require that safety-sensitive employees report their use of prescription and over-the-counter medications before operating equipment. Rule 1.6.2 of the MTA *Interim Rules and Instructions for Employees* prohibited employees from reporting for duty or being, while on duty, under the influence of "intoxicants, including alcohol, or Controlled Substances, *or any other substance which may impair job performance*." (Italics added.) The MTA, however, did not define "any other substance which may impair job performance" as including prescription or over-the-counter medications, many of which have side effects that can impair alertness and other job performance factors.

Both operators in the BWI 2000 accidents had been on medical leave for extended periods shortly before their respective accidents. Both had been prescribed medications that had possible side effects that included fatigue and drowsiness. Regarding the MTA's

[61] K. Kump, C. Whalen, P.V. Tishler, I. Brower, V. Ferrette, K.P. Strohl, C. Rosenberg, and S. Redline, "Assessment of the Validity and Utility of a Sleep-Symptom Questionnaire," *American Journal of Respiratory Critical Care Medicine*, 1994; Volume 150(3): pp. 735-741. And T. Ploch, C. Kemeny, G. Gilbert, W. Cassel, and J.H. Peter, "Significance of a Screening Questionnaire for Diagnosis of Sleep Apnea," *Pneumologie*, March 1993; 47 Supplement 1: pp.108-111.

policy about employees who had been on medical leave, the MTA light rail superintendent stated in a June 12, 2000, letter to the Safety Board that the MTA does "not positively know whether a safety-sensitive employee is on medication when they return to work."

Prescription and over-the-counter medications can significantly affect the performance of people taking them. Many such medications can make the patient drowsy or dizzy, affect vision or hearing, or bring about other physical conditions that could reduce the effectiveness of a safety-sensitive employee. It appears that the MTA's policy regarding prescription and over-the-counter medications was to allow the employee to make the final determination whether he or she was fit for duty while taking a medication. But the MTA itself had no mechanism by which it could review the appropriateness of the employee's decision.

The physical condition of an employee who carries out safety-sensitive duties should be of vital interest to any rail transit system management. Management is responsible not only for the well-being of that employee but of the passengers and coworkers the employee's actions affect. Some medications, even when they are taken as prescribed or recommended, may have the effect of degrading employee performance. In some cases, legal substances such as over-the-counter and prescription drugs can impair the condition of an employee nearly as readily as illegal drugs. Consequently, the Safety Board concludes that because the MTA did not require safety-sensitive employees to report their use of prescription and over-the-counter medications, it lacked information that could have had a bearing on the condition and performance of such employees.

Safety-conscious rail transit agencies must consider an employee's use of substances, whether legal or illegal, that could negatively affect the employee's performance and put passengers and coworkers at risk. If use of a prescription or over-the-counter medication brings into question the performance of an employee responsible for safety-sensitive duties, the employee can be temporarily reassigned to non-safety-sensitive duties while taking the medication. But management cannot reassign its employees if it does not know that they are using prescription or over-the-counter medications that might cause impairment. Through postaccident interviews, the Safety Board found that the two operators involved in the BWI accidents each had a different perception about the MTA's policy concerning an operator's responsibility for reporting medication use. The train 24 operator was taking the pain-relievers oxycodone and Tylenol 3 when he returned to work. He did not tell anyone at the MTA that he was taking the medications, but he was under the impression that he was supposed to inform someone. The train 22 operator had been prescribed and was taking pain medications to deal with chronic back and neck pain, and at least one of the medications may have carried a safety warning about operating machinery. The train 22 operator stated that he did not believe he was obligated to show these medications to his MTA supervisors but that he had done so on two occasions.

Thus, the operator in the February 2000 accident believed he was supposed to report his medication use but failed to do so, while the operator in the August 2000 accident did not think he was obligated to report medication use, although he said he tried to report it. At the same time, the chief of the MTA benefits section told the Safety Board

that the MTA did not require employees to inform the MTA about their using prescription medications, while the MTA's contract physician told the Safety Board that employees were expected to report medication use in at least some cases. On the basis of the inconsistency evident at all levels within the organization about what was required for an employee to fulfill the policy, the Safety Board concludes that MTA managers and employees were confused about the requirements for reporting medication use to the MTA.

The chief of the MTA benefits section told the Safety Board that the MTA followed applicable FTA regulations pertaining to substance abuse and that, consistent with those regulations, the MTA had no specific requirement that employees in safety-sensitive positions inform the MTA about their use of prescription and/or over-the-counter medications. The Safety Board reviewed the FTA drug regulations at 49 CFR Part 653 and found no explicit reference to the use of prescription and/or over-the-counter medications by safety-sensitive employees.[62] Other rail transit organizations may also infer from the lack of FTA regulations concerning the use of prescription and/or over-the-counter medications that they do not need to require their employees to report their use of prescription and over-the-counter drugs. Therefore, because the MTA may be only one of a number of rail transit organizations that do not require their safety-sensitive employees to report their use of prescription and over-the-counter medications, the Safety Board believes that U.S. rail transit systems should require employees in safety-sensitive positions to inform their supervisors when they are using prescription or over-the-counter medications so that qualified medical personnel may determine the medication's potential effects on employee performance, and train the employees about their responsibilities under the policy.

In contrast to the FTA's lack of such requirements, the FRA regulations at 49 CFR 219.103 specifically address the use of prescription and over-the-counter medications by employees covered under FRA rules. The regulations permit covered employees[63] to use such medications, as determined by a physician or treating medical practitioner, if "use of the substance by the employee at the prescribed or authorized dosage level is consistent with the safe performance of the employee's duties." The FRA regulations also require that, in the event that more than one medical practitioner is treating the employee, at least one practitioner must be informed of all medications the employee is taking and must conclude that the use of the medications is consistent with safe employee performance. Moreover, the FRA regulations explicitly state, "This subpart does not restrict any discretion available to the railroad to require that employees notify the railroad of therapeutic drug use or obtain prior approval for such use."

[62] At the time of the accidents in 2000, 49 CFR Part 653, "Prevention of Prohibited Drug Use in Transit Operations," was in effect. Effective August 2001, Part 653 was superseded by 49 CFR Part 655, "Prevention of Alcohol Misuse and Prohibited Drug Use in Transit Operations." The Safety Board's review of the new FTA regulations at 49 CFR Part 655 found that they are also silent on the use of prescription and over-the-counter medications by safety-sensitive employees.

[63] In this context, *covered employees* are those who have been assigned to perform service subject to the Hours of Service Act.

The Safety Board is concerned about the disparity between the FTA and FRA regulations concerning substances liable to cause employee impairment. Because FTA regulations do not specifically address the use of prescription and over-the-counter medications by safety-sensitive employees, rail transit operations, unlike railroad operations under the jurisdiction of the FRA, may not consider that they have the authority to monitor medication use by safety-sensitive employees. In contrast to the railroads regulated by the FRA, which may carry both freight and passengers, the rail transit systems regulated by the FTA are responsible primarily for the transport of passengers. Therefore, the Safety Board concludes that, in the interests of passenger safety, rail transit systems should be at least as rigorous as FRA-regulated systems concerning possible sources of operator impairment. In the view of the Safety Board, the need for rail systems to be aware of medication use by operators is more pressing than ever when passenger safety is at risk. Consequently, the Safety Board believes that the FTA should authorize and encourage rail transit systems to require their employees in safety-sensitive positions to inform the rail transit system about their use of prescription and over-the-counter medications so that the rail transit system can have qualified medical personnel determine the medication's potential effects on employee performance.

MTA System Safety

The investigations of the BWI accidents in 2000 indicated that impaired operators caused both accidents; the train 24 operator was impaired by prescription pain-relieving medications and cocaine, and the train 22 operator was impaired by severe obstructive sleep apnea. Although the Safety Board appreciates that no employee oversight program is perfect, the Board is concerned that, within about 6 months, two significantly impaired employees operated LRV trains, resulting in two accidents that put passengers and employees at risk. Consequently, the Safety Board examined the system safety approach used by the MTA at the time of these accidents.

The MTA told the Safety Board that it used a system safety program plan as the basis for its overall safety policy. The Safety Board considers the appropriate use of system safety program plans by rail transit systems to be a reliable means of establishing and maintaining safe operations because such plans, when fully implemented, provide the standard for safe procedures in all operational departments, and periodic audits (monthly, yearly, and triennially) confirm that the safety standards are being satisfied. Audits are conducted by the organization itself, by the State regulatory agency, and (upon request) by APTA. A well-drafted and fully implemented plan would ensure that the organization's approach to safety concerns was systematic, consistent, and verifiable. In the case of the BWI accidents, for example, the plan, had it been properly developed and carried out, would have ensured that the MTA's drug and alcohol policies were clearly communicated to all personnel and that emergency drills were conducted on a regular basis. Depending on the specific elements of the program, it might even have provided more effective means of identifying operators with performance problems.

The Safety Board found, however, that the MTA's efforts to put its system safety program plan into service did not indicate that the MTA management was fully committed to and involved in the system safety program.

The limited nature of the system safety program plan's application to MTA operations appears to have been recognized within the MTA. Members of the MTA system safety department, which was responsible for carrying out the system safety program plan, told the Safety Board that before January 2000, implementation of the MTA system safety program plan had not been energetically pursued. In reference to the system safety program plan, one department employee said, "It was something that was put together because it was mandated, but it wasn't something that we actually lived by."

Those who reviewed the MTA system safety program plan from outside the MTA also expressed doubts about the success of the program. The 1998 preliminary report of the 1997 APTA audit of the MTA stated that the APTA auditors found that most MTA managers were unfamiliar with the system safety program plan and that many MTA managers did not seem to fully understand system safety or to appreciate management's role in fulfilling the system safety program plan. The APTA report further stated that the system safety program plan had not been comprehensively distributed and that the MTA had not adequately tracked the progress of the system safety program plan's implementation.

The contractor hired by the MTA in January 2000 to put the system safety program plan into effect told the Safety Board that the system safety program plan that the MTA had initially provided her was not adequate to address the MTA operation. She also said that in the early stages of her effort, some of the MTA operations management accepted neither the existing system safety program plan nor even the necessity of having such a plan. She further stated that the MTA operations superintendent refused to cooperate with her as she worked to develop and implement the system safety program plan.

Since the BWI accidents, however, the MTA has taken action to forward the implementation of its system safety program plan. About 4 months after the August 2000 accident, the MTA underwent a management reorganization, which appears to have put in place managers more receptive to the system safety program plan concept. The MTA also hired additional safety personnel at this time. The contractor hired by the MTA to put the system safety program plan into effect completed the writing of the program in early 2001. She conducted 4 hours of training on the program for all MTA operations management and helped the MTA carry out internal audits of its new program before her contract expired in March 2001. Since March 2001, the MTA has assigned its own system safety specialist (hired in December 2000) to rewrite the MTA system safety program plan to tailor it more closely to MTA operations.

In addition, following the accidents, the MTA had an independent contractor conduct a safety assessment of its light rail operations. The assessment was completed in October 2000, and the MTA has developed a corrective action plan based on the contractor's assessment. The MTA also completed a revision of its Light Rail rulebook in April 2001. A new annual recertification program for all operators, maintenance

supervisors, and track access and control personnel includes training on the revised rulebook.

Further, in May 2000, MDOT had a contractor carry out its triennial audit of MTA system safety. Since that time, MDOT has been working with the MTA to implement corrective actions based on the results of the 2000 audit.

Therefore, the Safety Board concludes that before the two accidents at the BWI Airport Station in 2000, the MTA had not successfully implemented a comprehensive system safety program plan throughout all levels of the organization; however, efforts to do so are now underway.

Equipment Issues

Bumping Posts

Engineering documentation submitted by the Cullen-Western-Hayes bumping post manufacturer indicated that the bumping post structure could accommodate the impact loading of a three-car light rail train moving at 10 mph. However, the manufacturer presented no evidence demonstrating that the bumping post could safely stop such a train as might be encountered at the BWI Airport Station location (traveling at 15 mph or more with a full passenger load).

According to the Safety Board's calculations, based on the specifications provided by the manufacturer and available LRV weight, speed, and other data, this bumping post design had insufficient kinetic energy attenuation capacity for the combination of potential train speeds and/or train weights that might be encountered at the BWI Airport Station location. The manufacturer's performance specification for the bumping post assembly stated that the bumping post had a kinetic energy absorption capacity of about 1.4 million pound-feet. Safety Board calculations showed that the approximate amounts of kinetic energy transferred into the Cullen-Western-Hayes WH bumping posts in the February and August 2000 BWI Airport Station accidents were about 934,800 pound-feet and 1.15 million pound-feet, respectively. Both these energy levels are below the 1.4 million pound-feet specification cited by the manufacturer, and yet the bumping posts did not function successfully in either collision. (The failures were due to improper installation of the bumping posts, which will be discussed later in this section.)

Even if the bumping post assembly could fulfill its specified kinetic energy absorption capacity of 1.4 million pound-feet, its capacity would still be deficient in some scenarios that could quite likely occur at the BWI Airport Station. The Safety Board's calculations demonstrated that in a hypothetical "worst-case scenario" collision between a train and the bumping post at the BWI Airport Station, involving a three-unit LRV train filled to occupant capacity traveling at 15 mph,[64] the kinetic energy that could be

[64] The posted speed limit approaching the station was 15 mph.

transferred into the bumping post upon such an impact would be about 3.6 million pound-feet. The Cullen-Western-Hayes WH bumping post system, even if it performed up to its own specification, could only absorb about 40 percent of the kinetic energy of this worst-case impact.

The Safety Board further calculated that the bumping post design provided an insufficient deceleration stopping distance, which allowed substantial deceleration G forces to be exerted upon the LRV occupants. The average level of G forces experienced by the LRV occupants in the 2000 BWI accidents, along the LRV's longitudinal axis, were about -1.81 G for the February accident and about -0.23 G for the August accident.[65] A "safe stop" can be accomplished by providing a longer stopping distance (as compared to that found in the Cullen-Western-Hayes WH bumping post system), which is available in alternate design end-of-track protection equipment.

The Safety Board concludes that the Cullen-Western-Hayes WH bumping posts installed on both service tracks at the BWI Airport Station were the wrong end-of-track protection devices for this location because their kinetic energy absorption capacity was inadequate for some light rail operations possible at this location and their design did not provide an adequate deceleration stopping distance for the BWI Airport Station stop.

In addition, the bumping posts had been installed in such a way that they could not perform optimally. Postaccident technical examination of the bumping post equipment at the BWI Airport Station showed that the bumping post assemblies on both service tracks had not been installed in accordance with the manufacturers' installation instructions. In both cases, the running rail joints had been situated, contrary to the manufacturer's directions, too close to the base of the bumping post assembly, so that the anchorage of the bumping post assembly could not benefit from the weight of the front half of the LRV that it was intended to service. Consequently, the Safety Board concludes that the bumping posts at the BWI Airport Station struck during the February and August 2000 accidents had been improperly installed.

Since the August 2000 accident, the MTA has replaced the Cullen-Western-Hayes WH hydraulic bumping post equipment at the terminus at the BWI Airport Station with friction buffer stop equipment. The Safety Board reviewed the friction buffer stop apparatus and found it to be an engineered "energy retardation device" that is fitted to the running rails of stub-end tracks and employs a "friction shoe" clamping mechanism that secures the assembly to the head of the running rail. When struck, the friction buffer stop is pushed along the running rail surface in a controlled manner. As the device moves along the rails, the kinetic energy of the moving rail vehicle is transferred into heat energy in the buffer stop's friction shoe, causing the vehicle to come to a stop. The friction buffer stop equipment should provide improved energy attenuation protection and end-of-line collision protection at the BWI Airport Station. Before the August 2000 accident, the Central Light Rail Line System had friction buffer stop equipment installed on all its stub-

[65] The impact also resulted in substantial downward G forces, which could not be quantified in this investigation. These downward forces may also have caused some of the injuries.

end station tracks except the BWI Airport Station. Since the August 2000 accident, friction buffer stop equipment has been installed at the BWI Airport Station.

Seat Assembly

The MTA LRVs have seat assemblies and grabrails that are produced by the American Seating Company. Information provided by the seating manufacturer indicated that the seats are subjected to limited testing to determine their crashworthiness properties. The entire seating system has not been, nor is it required to be, subjected to full static and dynamic tests.

Generally speaking, using energy-attenuating seat structures and assemblies may reduce the likelihood and severity of passenger injuries resulting from a collision. Further, seat designs focusing on the seatback's ability to contain the passenger within the seat may reduce the passenger's exposure to less occupant-friendly surfaces inside the LRV.

The Safety Board documented a number of facial and neck injuries in the February and August 2000 BWI accidents that reportedly resulted from passenger impacts with the transverse-mounted passenger seatbacks and stainless steel seat grabrails. The steel grabrails were not wrapped or covered with any energy-attenuating material.

Despite the passenger head and neck injuries resulting from these accidents, the Safety Board did not find compelling evidence that the stainless steel seating grabrails on the LRVs involved in the BWI accidents had inadequate energy absorption capabilities. According to the results of energy absorption testing conducted by American Seating, in which the stainless steel and the thermoplastic grabrails of LRV seats were struck with equal force by a head form, the Head Injury Criteria values calculated were generally somewhat higher for the stainless steel grabrails than for the alternative thermoplastic grabrails. However, the two sets of Head Injury Criteria values resulting from the testing—for the grabrails made of stainless steel and those made of thermoplastic—were both well below the threshold value of 1,000 and even below APTA's guideline value of 400 for bus grabrails.

Since the accidents at the BWI Airport Station in 2000, the MTA has communicated to the Safety Board its intention to explore the redesign of its LRV seatback grabrails. The MTA has further stated that it ultimately intends to change the design of the stainless steel grabrails and/or use more energy-attenuating materials in its future rail car procurements. The Safety Board encourages the MTA to pursue this course of action.

Event Recorders

The two BWI investigations showed that each MTA light rail car contains a system for preserving a limited amount of train performance data in the event of an incident that meets a specific triggering requirement (in this case, an application of the track brakes at a train speed of at least 10 mph). The system consists of a software package that modifies the LRV's central computer system so that performance data may be stored within the car

computer's memory. The data saved cover from 30 seconds before until 30 seconds after the triggering event.

When investigators first examined the available event data for the February 2000 accident, they determined that the event recorder had recorded a triggering event that occurred about the time of the accident. Further analysis, however, showed that the data recorded were inconsistent with the known facts of the accident event (that an LRV had collided with a bumping post).

A day after the initial examination of the recorder and its data, investigators found that the recorder had in the meantime documented another triggering event, which occurred after the postaccident data download. The time that the recorder showed as the occasion of this second triggering event preceded any postaccident movement of the LRV; the car was at rest throughout this period. Consequently, investigators determined that the LRV did not, in fact, experience a valid triggering event at this time. The data from the second triggering event overwrote the data from the event that had occurred on the day of the accident, even though the MTA had requested that the system be set to allow two separate triggering events to be saved before overwriting. The manufacturer was unable to explain exactly why and how these problems occurred.

In addition to the problems encountered while attempting to access the February 2000 accident data, the Safety Board identified several other specific weaknesses in the MTA's event recorder system. One significant deficiency is the dependence of the system on a trigger to begin recording. The accident scenarios presented by the two accidents at BWI, as well as many other potential accident scenarios, would not necessarily provide the triggering event necessary to activate the recording system. Also, the amount of time captured by this system (30 seconds before the trigger and 30 seconds after the trigger, for a 1-minute total) does not provide enough information to determine how the train was being operated before the accident. Sometimes trending data are helpful to determine unsafe operating practices, and no such data are available on this system. Installing a system that continually monitors and records data can eliminate this deficiency. FRA regulations at 49 CFR 229.5(g) state that an event recorder should monitor and record data "over the most recent 48 hours of operation of the electrical system of the locomotive on which it is installed." Having the previous 48 hours of operational data available increases the likelihood that trend data will be available if needed for the investigation.

Another major deficiency of the current MTA recording system is its reliance on the functionality of the car's computer system. In an accident, the car's computer system could be compromised. Installing a recording system as an integral part of the computer system leaves the recording vulnerable not only to the trauma associated with the accident itself, but also to any electronic anomalies present in the computer. Having a separate, self-contained recording system would eliminate the possibility of the computer system compromising the recorded data.

A final weakness in the current recording system is its reliance on the car's central power source. The possibility exists for the car to lose power during an accident sequence. Under such a circumstance, the unpowered recording system could fail to receive and

record significant operational and performance data during the accident's progression. Providing nominal battery back-up power to the recording system for several moments after power is lost would eliminate this deficiency and ensure that all relevant operational data are stored and kept ready for analysis.

Given the irregularities in the data recording and retention encountered following the February 2000 accident and the deficiencies of the system detailed above, the Safety Board concludes that the event recording system in place on the MTA light rail cars is inadequate to serve as a reliable accident investigation tool. Therefore, the Safety Board believes that the MTA should install, on all its LRVs, independent event recorders that record and retain the most recent 48 hours of data, store data in nonvolatile memory, and have a back-up power source that would enable the entire recording system to function if electric power is lost to the car.

No current Federal regulations apply to event recorders on LRVs. On November 14, 1996, as a result of the Safety Board's investigation of an accident on the Washington Metrorail system,[66] the Safety Board issued Safety Recommendation R-96-46 to the FTA, which called for the FTA to:

> R-96-46
>
> Develop, with the assistance of the American Public Transit Association, guidelines for the monitoring/recording devices that capture critical performance and event data for rapid rail transit cars and urge transit agencies to install these devices on new and rehabilitated cars.

The FTA, with APTA, prepared a report, dated June 1998, entitled *Event Recorders for Rail Rapid Transit Systems*. In a letter dated September 4, 1998, the FTA provided the Safety Board with a copy of the report and indicated that the report would be distributed to transit agencies developing specifications for rehabilitated and new rapid transit vehicles and that the FTA would urge the installation of the devices. The report explored the effectiveness and efficiency of using event recorders on rapid rail cars. It presented and analyzed data; defined various aspects of using accident/incident event recorders; included a cost, feasibility, and benefit analysis; and identified the technical requirements for these devices in rapid rail transit. Based on this response, the Safety Board classified Safety Recommendation R-96-46 "Closed—Acceptable Action" on January 6, 1999.

When, on November 14, 1996, the Safety Board issued Safety Recommendation R-96-46 to the FTA, it also issued the parallel Safety Recommendation R-96-47 to APTA. The recommendation asked APTA to:

[66] Railroad Accident Report NTSB/RAR-96/04.

R-96-47

Develop, with the assistance of the Federal Transit Administration, guidelines for the monitoring/recording devices that capture critical performance and event data for rapid rail transit cars and urge transit agencies to install these devices on new and rehabilitated cars.

In addition to working with the FTA to develop the 1998 report on *Event Recorders for Rail Rapid Transit Systems*, APTA has, through various APTA-sponsored conferences and symposiums, urged transit agencies to install these devices on new and rehabilitated cars. Based on this information, Safety Recommendation R-96-47 is classified "Closed—Acceptable Action."

APTA is also sponsoring a working group called the "APTA Rail Transit Standards Development Vehicle Inspection and Maintenance Committee." The group's efforts are limited to providing inspection and maintenance standards and recommended practices for event recorders on rail transit vehicles. The committee expects to have a final draft standard for recording systems for rail transit vehicles by the end of 2002.

Conclusions

Findings

1. The train 24 operator failed to apply the brakes to stop his train at the Baltimore-Washington International Airport Station on February 13, 2000.

2. The effects of prescription pain-relieving medications and/or recent cocaine use impaired the performance of the train 24 operator on February 13, 2000.

3. The train 22 operator did not apply the brakes to stop his train at the Baltimore-Washington International Airport Station on August 15, 2000.

4. The train 22 operator was not impaired by alcohol or illegal drugs at the time of the August 15, 2000, accident.

5. The train 22 operator was suffering from severe obstructive sleep apnea at the time of the August 15, 2000, accident.

6. The chronic fatigue he was experiencing due to undiagnosed obstructive sleep apnea likely caused the train 22 operator to fall asleep as the light rail vehicle train approached the Baltimore-Washington International Airport Station on August 15, 2000.

7. Better education about the risks posed by sleeping disorders, the indicators and symptoms of such disorders, and the available means of detecting and treating the conditions could help transit agencies and their employees reduce the risk of safety-sensitive employees being impaired by chronic fatigue.

8. Because the Maryland Transit Administration did not require safety-sensitive employees to report their use of prescription and over-the-counter medications, it lacked information that could have had a bearing on the condition and performance of such employees.

9. Maryland Transit Administration managers and employees were confused about the requirements for reporting medication use to the Maryland Transit Administration.

10. In the interests of passenger safety, rail transit systems should be at least as rigorous as Federal Railroad Administration-regulated systems concerning possible sources of operator impairment.

11. Before the two accidents at the Baltimore-Washington International Airport Station in 2000, the Maryland Transit Administration had not successfully implemented a comprehensive system safety program plan throughout all levels of the organization; however, efforts to do so are now underway.

12. The Cullen-Western-Hayes WH bumping posts installed on both service tracks at the Baltimore-Washington International Airport Station were the wrong end-of-track protection devices for this location because their kinetic energy absorption capacity was inadequate for some light rail operations possible at this location and their design did not provide an adequate deceleration stopping distance for the Baltimore-Washington International Airport Station stop.

13. The bumping posts at the Baltimore-Washington International Airport Station struck during the February and August 2000 accidents had been improperly installed.

14. The event recording system in place on the Maryland Transit Administration light rail cars is inadequate to serve as a reliable accident investigation tool.

Recommendations

As a result of its investigation of both accidents discussed in this report, the National Transportation Safety Board makes the following safety recommendations:

To the Federal Transit Administration

Authorize and encourage rail transit systems to require their employees in safety-sensitive positions to inform the rail transit system about their use of prescription and over-the-counter medications so that the rail transit system can have qualified medical personnel determine the medication's potential effects on employee performance. (R-01-25)

To U.S. rail transit systems

Require employees in safety-sensitive positions to inform their supervisors when they are using prescription or over-the-counter medications so that qualified medical personnel may determine the medication's potential effects on employee performance, and train the employees about their responsibilities under the policy. (R-01-26)

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. (R-01-27)

To the Maryland Transit Administration

Install, on all your light rail vehicles, independent event recorders that record and retain the most recent 48 hours of data, store data in nonvolatile memory, and have a back-up power source that would enable the entire recording system to function if electric power is lost to the car. (R-01-28)

BY THE NATIONAL TRANSPORTATION SAFETY BOARD

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Chairman

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Member

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Member

GEORGE W. BLACK, JR.
Member

Adopted: December 11, 2001

Appendix A – Accident Brief on February 13, 2000, BWI Accident

National Transportation Safety Board
Washington, D.C. 20594
Railroad Accident Brief

Railroad Accident Number:	DCA-00-MR-004
Rail System:	Maryland Transit Administration Central Light Rail Line System
Train:	Light Rail Vehicle Train 24
Accident Type:	Collision with bumping post
Location:	Baltimore-Washington International Airport light rail transit station
Date and Time:	February 13, 2000, at 2:37 p.m.
Fatalities/Injuries:	No fatalities; 18 injuries (5 serious)

About 2:37 p.m. (eastern standard time) on February 13, 2000, Maryland Transit Administration (MTA)[67] train 24 (composed of a single light rail vehicle [LRV]), en route on the Central Light Rail Line System from Baltimore, Maryland, to the Baltimore-Washington International (BWI) Airport, struck the hydraulic bumping post[68] at the BWI Airport Station and derailed. The force of the collision detached the bumping post from the track, and the front of the train, which was lodged against the bumping post, was elevated about 3 1/2 feet into the air. Train 24 carried 26 people (25 passengers and 1 operator), 18 of whom were injured. Five of the injured had serious injuries. The MTA estimated the cost of the accident at $924,000.

Accident

The train 24 operator reported for duty at the MTA light rail operations center in downtown Baltimore on February 13, 2000, at 9:30 a.m. for his 10:01 a.m. assignment as an operator on the Central Light Rail Line System. He began revenue service from

[67] In 2000, when this accident occurred, the MTA was called the Mass Transit Administration. On October 1, 2001, the MTA changed its name to the Maryland Transit Administration.

[68] A *bumping post* is an apparatus located just before the physical end of a rail track. It is designed to stop runaway railcars and absorb the kinetic energy should a railcar continue to travel past the designated stopping point and on toward the end of the track.

Pennsylvania Station in downtown Baltimore to the BWI Airport Station at 10:44 a.m. He arrived at and departed the BWI Airport Station and was relieved at the University of Baltimore/Mount Royal Station between 12:15 and 12:30 p.m. The operator said this trip was uneventful.

During his break period (between about 12:30 and 1:40 p.m.), the operator asked the train dispatcher for "a couple of aspirins" because he had a headache. The operator said he took the aspirins and lay down for about an hour. After his break, he took over operation of train 24 at the University of Baltimore/Mount Royal Station about 1:43 p.m., proceeded north to Pennsylvania Station, and departed Pennsylvania Station at 1:51 p.m. southward in revenue service. Train 24 was composed of a single LRV and traveled along main track No. 1.

The operator said he experienced no problems with the equipment, and he stopped at every station during the trip from Pennsylvania Station to the BWI Airport Station. The maximum authorized speed limit for the section of track from Pennsylvania Station to the BWI Airport Station was 50 mph.

One passenger told the Safety Board that he had a clear view of the operator at the North Linthicum Station, which is located three stations before the BWI Airport Station. The passenger said that the operator received a green signal at the station and then sat motionless for 10 to 15 seconds while the train remained stationary. He recalled that the operator then shook his head and body before beginning to move the train forward.

From the next to last station on the line to the BWI Airport Station, the maximum authorized speed was 15 mph. The operator said the last signal for his train before the BWI Airport Station (signal BWI 15-6) displayed a yellow aspect. A yellow signal aspect calls for the operator to proceed prepared to stop at the next signal. According to several passengers, train 24 did not stop or slow at the BWI Airport Station but continued through the station until it struck the hydraulic bumping post at the end of the track. During postaccident interviews, several passengers told investigating law enforcement officials that it appeared to them that the operator may have fallen asleep before the impact.

Safety Board investigators asked the operator whether he had attempted to apply any brakes to stop the train. With respect to the train brakes, the operator was unclear but did not indicate that he had applied them. With respect to the emergency brakes, he said he did not know whether he had applied them.

Operator

During initial interviews, the operator said that he had undergone oral surgery for a dental abscess in December 1999 and had been prescribed two medications, oxycodone and Tylenol 3 (acetaminophen with codeine), to alleviate the resultant pain. The operator was aware that the pain medications could cause drowsiness, and he acknowledged that he did become "a little drowsy" after he took them.

The operator told the Safety Board that on the morning before the accident, he took one blood pressure pill,[69] one Tylenol 3 pill, and one oxycodone pill. He also said that he took two aspirins about noon. He said that he did not use any other over-the-counter or prescription medications. He said he did not use alcohol or illicit drugs on the day of the accident.

Pursuant to regulations at 49 *Code of Federal Regulations* 654.33 and 653.45, the operator provided a breath specimen for alcohol testing and a urine specimen for drug testing about 5 hours after the accident. No alcohol was present in the breath specimen. The urine specimen tested positive for benzoylecgonine, the metabolite of cocaine (quantified at 7,300 nanograms per milliliter), positive for morphine (2,000 nanograms per milliliter), and positive for codeine (2,100 nanograms per milliliter).

For some time after the accident, the operator had denied that he had used any illegal drugs before the accident, but when he was informed of the toxicological test results, he conceded that he had recently used cocaine. In his revised account, he claimed that very late in the evening on February 11 (about 1 1/2 days before the accident), he had rolled two wet cotton balls in cocaine powder and placed them in his mouth to relieve the pain associated with his abscess condition.

The Safety Board does not find the operator's revised story credible. Given the expected rate at which cocaine metabolizes, the test results indicate relatively recent use of cocaine rather than use more than 30 hours before the accident. The cocaine in the operator's system was almost certainly ingested within the 24 hours preceding specimen collection and was likely taken within the 12 hours before the specimen was obtained.

Probable Cause

The Safety Board determines that the probable cause of the February 13, 2000, accident at the Baltimore-Washington International Airport rail transit station was the train 24 operator's impairment by illicit and/or prescription drugs, which caused the operator to fail to stop the train before it struck the bumping post at the terminus.

Adopted: December 11, 2001

[69] The operator told the Safety Board that for the last several years he had taken the prescription medication Capozide twice daily to control high blood pressure.

Appendix B – Accident Brief on August 15, 2000, BWI Accident

National Transportation Safety Board
Washington, D.C. 20594
Railroad Accident Brief

Railroad Accident Number:	DCA-00-MR-006
Rail System:	Maryland Transit Administration Central Light Rail Line System
Train:	Light Rail Vehicle Train 22
Accident Type:	Collision with bumping post
Location:	Baltimore-Washington International Airport light rail transit station
Date and Time:	August 15, 2000, at 7:14 a.m.
Fatalities/Injuries:	No fatalities; 17 injuries

About 7:14 a.m. (eastern daylight time) on August 15, 2000, Maryland Transit Administration (MTA)[70] train 22 (composed of two light rail vehicles [LRVs]), en route from Baltimore, Maryland, to the Baltimore-Washington International (BWI) Airport, struck the hydraulic bumping post[71] at the BWI Airport Station and derailed. The bumping post separated from its attachment to the track and came to rest in an inverted position. The leading LRV of the train came to rest lodged on top of the bumping post and about 4 1/4 feet up in the air. The roof of this LRV was partially embedded into the ceiling structure of the terminal building. Train 22 carried 22 people (21 passengers and 1 operator), 17 of whom were injured. None had life-threatening injuries. The MTA estimated the cost of the accident at $935,000.

Accident

The train 22 operator reported to work at 3:00 a.m. on August 15, 2000, at the MTA light rail operations center for his assignment as a Central Light Rail Line System

[70] In 2000, when this accident occurred, the MTA was called the Mass Transit Administration. On October 1, 2001, the MTA changed its name to the Maryland Transit Administration.

[71] A *bumping post* is an apparatus located just before the physical end of a rail track. It is designed to stop runaway railcars and absorb the kinetic energy should a railcar continue to travel past the designated stopping point and on toward the end of the track.

LRV operator. The operator had completed one round-trip from Pennsylvania Station in downtown Baltimore to the BWI Airport Station and was making another identical trip when the accident occurred. Train 22, a two-LRV-unit train, was traveling down main track No. 2 during its approach to the BWI Airport Station.[72]

The operator recalled that signal BWI 15-6, the last signal before the BWI Airport Station, displayed a red over yellow aspect. A red over yellow signal aspect tells the operator to proceed at restricted speed until the entire train has passed a signal displaying a more favorable aspect. The LRV failed to stop at the BWI Airport Station and collided with the bumping post at the end of the track about 7:14 a.m. The bumping post separated from its attachment to the track and came to rest in an inverted position with the front of the lead LRV resting on top of the overturned bumping post.

The operator said that the signal was the last thing he saw before he went "out." He said he was not aware of anything until he returned to consciousness after the accident and found that the train was up in the air and emergency personnel were boarding the train. The operator was unable to say how long he had been unconscious or exactly what might have caused him to lose consciousness.

Operator

About 2 weeks after the accident, the operator's physician referred the operator to a sleep specialist because she suspected that the operator might be suffering from a sleep disorder. On September 5, 2000, the operator was clinically tested for sleep disorders at Good Samaritan Hospital in Baltimore. The hospital developed a sleep study report for the operator that indicated a diagnosis of "severe obstructive sleep apnea syndrome." Obstructive sleep apnea is a chronic and debilitating sleeping disorder that is often present for years or even decades before it is diagnosed. Because excessive daytime sleepiness is almost uniformly present in people who suffer from obstructive sleep apnea, chronic fatigue is one of the symptoms of the disorder.

The Safety Board sent the hospital's report to the director of the Center for Sleep and Respiratory Neurobiology at the University of Pennsylvania Medical Center, Philadelphia, Pennsylvania. This expert's review of the report found "There is no question, based on the data you sent me, that he [the operator] has severe sleep apnea associated with excessive sleepiness." The director of the Center for Sleep and Respiratory Neurobiology also stated that he would "expect the driver to be excessively sleepy and at risk for falling asleep inappropriately."[73]

[72] Because of the effects of a February 13, 2000, accident at this station, the MTA had taken track No. 1 out of service at this location until repairs were made.

[73] Quotes are taken from a November 16, 2000, facsimile communication from the director of the Center for Sleep and Respiratory Neurobiology at the University of Pennsylvania Medical Center, Philadelphia, Pennsylvania, to the Safety Board.

Probable Cause

The Safety Board determines that the probable cause of the August 15, 2000, accident at the Baltimore-Washington International Airport rail transit station was the train 22 operator's severe fatigue, resulting from undiagnosed obstructive sleep apnea, which caused the operator to fall asleep so that he could not brake the train before it struck the bumping post at the terminus.

Adopted: December 11, 2001