National Transportation Safety Board

Washington, DC 20594

Highway Accident Brief

Accident Number:	HWY15MH004
Accident Type:	Bus roadway departure and collision with moving train
Location:	Interstate 20, Ector County, near Penwell, Texas
Date and Time:	January 14, 2015, 7:50 a.m.
Vehicles:	2015 Blue Bird Vision bus, modified for prison transport
	Union Pacific train ZLCMN2, consisting of 4 locomotives and 58 loaded railroad intermodal flatcars
Fatalities:	10
Injuries:	5

Crash Description

On Wednesday, January 14, 2015, about 7:50 a.m. local time, a 2015 Blue Bird Vision prison bus was traveling westbound on Interstate 20 (I-20) near Penwell, Texas, when it departed the roadway and collided with a moving train.[1] The bus, operated by the Texas Department of Criminal Justice (TDCJ), was occupied by 12 inmates and three correctional officers (including the driver).[2] The trip began about 4:40 a.m. at the John Middleton Transfer Facility in Abilene. The destination was the Rogelio Sanchez State Jail in El Paso (figure 1).

[1] This accident brief defines "prison bus" as a bus used to transport persons subject to involuntary restraint or confinement. The bus has features consistent with that purpose, including metal partitions for segregation areas and metal screens over windows.

[2] The term "inmate" is used throughout this brief, though the state of Texas uses "offender" as the generic term for a person under the supervision of the TDCJ.

Figure 1. Map showing bus route and crash location on I-20, near Penwell, Texas.

At the time of the bus roadway departure, a Texas Department of Public Safety (TxDPS) trooper was stopped on the right shoulder of I-20 westbound, investigating a previous crash. The video camera in that vehicle captured a portion of the crash sequence. The bus was traveling in the left lane at an estimated speed of 57 mph.[3] As the bus approached a two-lane bridge, it was positioned behind one truck-tractor semitrailer combination vehicle and alongside another combination vehicle.[4] A section of W-beam guardrail, damaged in a previous crash, was partially intruding into the left lane. Although the driver applied the brakes momentarily, the bus struck this section of the guardrail and moved sharply to the left.

The bus departed the left edge of the westbound roadway, overrode the previously damaged guardrail, entered the median, and became airborne between the westbound and eastbound parallel bridges. At the same time, a Union Pacific (UP) freight train was traveling southbound under the highway overpass. The bus fell about 20 feet onto an earthen area at the base of a concrete slope, on the east side of the railroad tracks, and continued forward, striking

[3] The travel speed for the bus was estimated from National Transportation Safety Board (NTSB) video analysis as 57 mph ±2 miles. The posted speed limit at this location is 75 mph.

[4] Where I-20 crosses over the railroad tracks, it transitions from a four-lane divided highway to two parallel two-lane bridges.

an intermodal flatcar. The train redirected the bus southward, and the left side of the bus collided with pillars supporting the eastbound bridge. The bus body and separated components came to rest along the east side of the tracks, about 220 feet south of the impact area (figure 2). Although the train stopped, it did not derail. (See "Railroad Tracks and Freight Train" for additional discussion.)

Figure 2. Aerial view of highway overpass with parallel bridges, railroad tracks, and final rest positions of bus body and components. (Source: TxDPS)

At the time of the crash, light mist precipitation was present with no snow accumulation. Icy road conditions on the eastbound approach had previously been reported, resulting in several single-vehicle crashes, including at least three median crossover crashes and damage to the guardrail.[5]

The prison bus crash resulted in 10 fatalities: two correctional officers (including the driver) and eight inmates. The remaining five bus occupants—one correctional officer and four inmates—sustained serious injuries and were transported to Medical Center Hospital in Odessa. No members of the train crew were injured.

[5] According to the Texas Department of Transportation (TxDOT), median crossover crashes were reported in this area on Tuesday, January 13, 2015, about 3:50 a.m., and on Wednesday, January 14, about 5:50 a.m. and 7:35 a.m.

Highway Information

The crash sequence began in the westbound lanes of I-20, east of milepost 103, near Penwell. At this location, I-20 is a four-lane divided highway, with two lanes in each direction. The asphalt travel lanes are 12 feet wide, with 10-foot-wide right shoulders and 4–4.5-foot-wide median shoulders. Rumble strips are located on both shoulders.

A 50-foot-wide median separates the eastbound and westbound lanes. A W-beam, test level 3 (TL-3) guardrail had been installed in the median, leading to the bridge, and adjacent to the westbound travel lane.[6,7] This 225-foot-long guardrail consisted of a 50-foot-long end treatment, a 157-foot-long main element, and an 18-foot-long thrie-beam transition into the concrete bridge railing. Warning signs reading "BRIDGE MAY ICE IN COLD WEATHER" are posted 750 feet in advance of each bridge.[8]

The posted speed limit at this location is 75 mph, and the average daily traffic is 13,748 vehicles. The 85th percentile speed is 76 mph for the westbound lanes and 77 mph for the eastbound lanes.[9] The total heavy vehicle count for this area is 6,192 trucks per day. Eight crashes—including one fatal, one injury, and six property-damage crashes—were reported between 2010 and 2014 in an area extending 0.5 mile east and west of the bridge.

Damaged Guardrail

The guardrail had been struck at least three times in the 28 hours preceding the crash of the prison bus. On Tuesday, January 13, about 3:50 a.m., a vehicle traveling eastbound lost control, traveled across the median, and struck the back side of the guardrail. TxDPS notified the Texas Department of Transportation (TxDOT) of the damage. About noon on that day, TxDOT staff assessed and photographed the damage and moved the guardrail from the roadway (figure 3).

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[6] TL-3 barriers are tested in accordance with the impact conditions found in National Cooperative Highway Research Program (NCHRP) Report 350, which are defined as a 62-mph impact using a 4,400-pound pickup truck at a 25-degree impact angle and using an 1,800-pound subcompact car at a 20-degree impact angle. See *Recommended Procedures for the Safety Performance Evaluation of Highway Features*, NCHRP Report 350 (Washington, DC: Transportation Research Board, 1993).

[7] (a) A W-beam is a steel beam rail element shaped in the form of a "W." (b) A thrie-beam is a steel beam rail element shaped in the form of a "W" but including an additional undulation.

[8] See *Manual on Uniform Traffic Control Devices* (MUTCD), section 2C.32, Surface Condition Signs. The sign is a modified version of sign W8-13 ("BRIDGE ICES BEFORE ROAD"). It may be used in advance of bridges to advise bridge users of winter weather conditions. (See also mutcd.fhwa.dot.gov/htm/2009/part2/part2c.htm, figure 2C-6; and *Texas MUTCD*, revision 2 [October 2014], sign designation [W8-13aT], www.TxDOT.gov/government/-enforcement/-signage/tmutcd.html, accessed August 19, 2015.)

[9] The 85th percentile speed refers to the speed at or below which 85 percent of vehicles are traveling. TxDOT conducted the speed study in November 2011 between mileposts 109 and 110.

Figure 3. Condition of guardrail along I-20 westbound on January 13, 2015, after it was struck by eastbound vehicle and moved off roadway. (Source: TxDOT)

TxDOT also placed traffic cones on the shoulder and posted a sign, about 750 feet in advance of the end treatment, warning of the damaged guardrail. The department's inspection and repair policy requires guardrail replacement as soon as practical after it is determined that a guardrail is no longer functional. This policy is consistent with the federal W-beam guardrail repair guidelines.[10] A work order to repair the guardrail was sent to the contractor on January 20, 2015; the work was completed on February 9, 2015.

On Wednesday, January 14, at least two other vehicles further damaged the guardrail. In two separate crashes, reported about 5:50 a.m. and 7:35 a.m., the eastbound vehicles lost control, crossed the median, and traveled through the area of the previously damaged guardrail. After the 7:35 a.m. crash and moments before the crash of the prison bus, a witness traveling westbound observed the guardrail wreckage protruding about 2 feet into the travel lane.

Following the bus crash, a section of the guardrail, including the end treatment, was displaced into the highway across both westbound lanes (figure 4). An inspection of the guardrail following its removal from the roadway revealed that about 207 feet had been damaged.

Figure 4. Orientation of guardrail across I-20 westbound lanes postcrash. (Source: TxDPS)

[10] See *W-Beam Guardrail Repair: A Guide for Highway and Street Maintenance Personnel*, FHWA-SA-08-002 (Washington, DC: Federal Highway Administration, 2008); (safety.fhwa.dot.gov/local_rural/training/-fhwasa08002/, accessed August 19, 2015).

The NTSB concludes that, by the time of the bus crash, the structural integrity of the guardrail had been compromised such that it could not provide its safety function. Although an intact TL-3 guardrail might not have the capability of fully redirecting the type of vehicle involved in this crash, it might have provided some resistance and kept the bus from traveling between the parallel bridges.

Snow and Ice Control

On Tuesday evening, January 13, TxDOT maintenance crews were briefed to expect freezing drizzle and rain during the overnight hours. Supervisors and crews from the Odessa and the Monahans maintenance offices responded to the forecasted event, applying either a brine solution or a granular solid mix of salt and pea gravel to major roads and bridges.[11,12]

The Monahans crew treated the crash site area, near milepost 103. To prevent ice buildup, the crew applied a 23.2 percent brine solution from mileposts 53 to 104. About 30 gallons of solution per lane mile was used in a continuous application.[13] The right lane of I-20 eastbound, near the crash site, was treated about 6:00 p.m. on January 13. The crew then treated the right lane of I-20 westbound, and the application truck was refilled with solution. About midnight, a different crew began applying the brine solution in the left passing lane of I-20 eastbound; this crew treated the bridges at the crash location about 2:00 a.m. on January 14. The truck was again refilled, and the crew continued to treat the left lane of I-20 westbound.

The crew supervisor followed behind the application truck, observing weather conditions and making sure that the brine solution was streaming properly onto the roadway. He recorded 30°–32°F temperatures.[14] He did not notice ice accumulation on the highway or bridges, and reported light misting-type drizzle as opposed to the forecasted freezing drizzle. Because no icing was evident, TxDOT did not activate the dynamic message sign located near milepost 82, about 23 miles west of the crash site, to inform drivers of the potentially adverse road conditions.

According to witnesses traveling westbound on I-20, traction was good at or near the crash site. The driver of a truck-tractor semitrailer traveling 55–60 mph on this segment of I-20 immediately following the bus crash recalled braking hard without losing traction. A driver traveling eastbound, who was involved in one of the previous crashes at this location, said that the pavement was damp but bare, without ice, snow, or standing water. He said that his first indication of any icing problem was when he spun out on the bridge and lost control. Similarly, several crash reports mentioned icy road conditions on the eastbound approach.

Although TxDOT staff did not directly document ice forming on the road, the cold temperatures combined with precipitation created an environment with a high potential for hazardous conditions. The NTSB concludes that TxDOT missed an opportunity to use available

[11] The Odessa maintenance district has 13 offices, including the Odessa and Monahans sections.

[12] Brine is a solution of salt (sodium chloride) in water.

[13] No anti-icing solution had been applied on Monday, January 12, before the guardrail was damaged by the crash in the early morning hours of January 13.

[14] Officially recorded temperatures in the area varied between 30°F and 32°F from 6:00 p.m. on January 13 until the crash occurred the following morning.

tools to warn motorists of the potentially adverse conditions on roadways and bridges, which could have prompted them to reduce travel speeds or take other precautions. In 2016, TxDOT revised the Odessa district snow and ice control plan, which included changing the dynamic message sign library for winter weather conditions and adding messages about pretreatment by maintenance crews (for example, "ICY CONDITIONS MAY EXIST – DRIVE WITH CAUTION").

The TxDOT *Snow and Ice Control Operations Manual* describes snow and ice control strategies using the concept of levels of service to determine equipment, materials, and personnel training requirements.[15] TxDOT assigns roadway treatment based on use, prioritizing treatment for routes with hospital, school, and emergency needs. In this case, the Odessa district snow and ice control plan identified I-20 and its bridges as having the highest priority for treatment. The state operations manual references the American Association of State Highway and Transportation Officials (AASHTO) anti-icing/roadway information systems computer-based training, which is modeled after the National Cooperative Highway Research Program (NCHRP) Report 526, *Snow and Ice Control: Guidelines for Materials and Methods*.[16,17] As reported by TxDOT, this was the first time the Odessa district had used liquid anti-icing materials. Further, none of the maintenance personnel had received the AASHTO training referenced in the TxDOT *Snow and Ice Control Operations Manual*.

The NTSB concludes that TxDOT properly established levels of service by categorizing I-20 as the highest priority for treatment, but it had not trained its personnel in accordance with the established snow and ice control guidelines and policy. Therefore, the NTSB recommends that TxDOT train its personnel responsible for snow and ice control using the AASHTO anti-icing/roadway computer-based winter weather training referenced in the state *Snow and Ice Control Operations Manual*.

NCHRP Report 526 describes application rates for 23.2 percent brine solution. The recommended application rates are based on the pavement temperature, dilution potential, and presence of an ice pavement bond.[18] Dilution potential is influenced by the cycle time between treatments, traffic speed, and traffic volume. Longer cycle times allow more precipitation to accumulate on the roadway between treatments. Higher speeds and traffic volume displace ice control chemicals from the roadway.

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[15] (a) See *Snow and Ice Control Operations Manual* (Austin, Texas: Texas Department of Transportation, 2012); (onlinemanuals.TxDOT.gov/TxDOTmanuals/sic/manual_notice.htm, accessed August 19, 2015). (b) This manual is consistent with best practices documented by the FHWA and the American Association of State Highway and Transportation Officials (AASHTO). (c) The level-of-service concept establishes measures of effectiveness that can be used in the evaluation process at various points during a storm event (that is, within-storm, end-of-storm, and poststorm conditions).

[16] This training, developed by AASHTO, includes seven lessons and provides a combined total of about 24 hours of instruction.

[17] See *Snow and Ice Control: Guidelines for Materials and Methods*, NCHRP Report 526 (Washington, DC: Transportation Research Board, 2004); (www.trb.org/NCHRP/Blurbs/163297.aspx, accessed August 19, 2015).

[18] Dilution potential relates precipitation, pavement conditions, pavement surface conditions, and operational conditions to selection of the snow and ice control material and application rate that will generally produce a successful result.

On January 13–14, each lane was treated only once.[19] The high traffic speeds and traffic volume created a situation where there was a strong likelihood of diluting the brine solution. In this case, the pavement temperature was estimated at 30°–32°F, with a high dilution potential and no ice pavement bond at the time of treatment. For the conditions observed in the crash area, NCHRP Report 526 recommends a 70-gallon-per-lane-mile application rate.[20]

The NTSB concludes that TxDOT application of the brine solution at a rate below the recommended level (30 gallons per lane mile instead of 70 gallons per lane mile) allowed the dilution of treatment and the subsequent ice buildup that occurred in the eastbound approach to the bridge—which contributed to the loss of control of several vehicles and the previous damage to and displacement of the guardrail. Therefore, the NTSB recommends that TxDOT revise its policies in accordance with the AASHTO anti-icing/roadway computer-based winter weather training and the NCHRP Report 526 guidelines, to include spot treatment of interstate highway bridge decks, use of abrasives, and proper application rates for liquid anti-icing chemicals to account for long cycle times.

Vehicle Damage

2015 Blue Bird Vision Bus

The accident vehicle was a 2015 Blue Bird Vision, one of 20 new buses built by Blue Bird Corporation and modified by the TDCJ to serve as prison transport vehicles. The bus had been in service for less than 6 months.

Metal partitions separated the bus interior into a driver's area, segregation area, general population area, and rear guard area (figure 5). The driver's area provided two seats for correctional officers, while the rear guard area provided one seat for a correctional officer. The windows along both sides of the bus were covered by perforated metal sheeting.

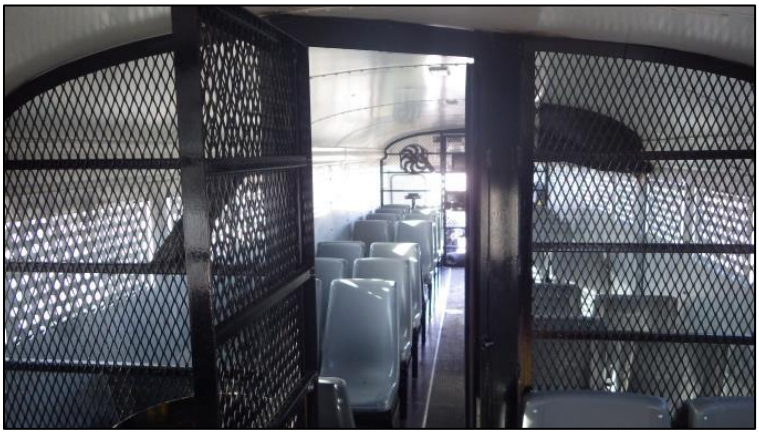

Figure 5. Interior of exemplar prison transport bus.

[19] The road treatment started at 6:00 p.m. on January 13 and ended around 2:00 a.m. on January 14, about 6 hours prior to the bus crash.

[20] See NCHRP Report 526, table A-5, www.trb.org/NCHRP/Blurbs/163297.aspx, accessed August 19, 2015.

Postcrash, the bus was found in pieces, as follows:

- Main portion of the bus body (figure 6).
- Chassis frame rails and rear axle.
- Front axle.
- Large section from the front of the bus, including the boarding door steps and seats in the driver's area.

Figure 6. 3D scan showing damage to front, roof, and left side of bus body, which is resting on a tow vehicle.

The engine, suspension components, drive shaft section, and exhaust system components were scattered throughout the postcrash debris. The main portion of the bus body sustained multiple side and roof impacts and was deformed in all directions. According to the respective manufacturers, no crash-related vehicle data can be recovered from the transmission or antilock brake system control modules. No brake pad or drum crack defects were observed. The engine control module was not located postcrash.

At the time of inspection, all tires were flat, damaged, and no longer seated on the wheels.[21] The guardrail end treatment and the left front tire on the bus were examined to investigate whether punctures observed in the tire were related to an impact with the end treatment.[22] NTSB investigators determined that the collision with the guardrail end treatment was not likely the cause of the puncture marks, based on their appearance, the damage to the end treatment, and a chemical analysis of scuff marks.[23]

[21] The bus was equipped with Hankook AH12, 11R22.5 tires. The tread depth for all tires was measured at 17/32 inch.

[22] See the materials laboratory factual report in the NTSB public docket for this investigation.

[23] The left front tire was most likely punctured by a round, painted object 5/8 inch in diameter. NTSB investigators found no evidence of tire failure prior to the collision.

Railroad Tracks and Freight Train

At the time of the bus roadway departure, a UP freight train with four locomotives and 58 intermodal flatcars was moving on the tracks located below the highway overpass. The train was traveling from Los Angeles, California, to Marion, Arkansas.

The bus collided with the 54th railcar, an articulated intermodal spine flatcar designed to carry highway semitrailers. According to the locomotive event data recorder, the train was traveling 46 mph at the time of the collision. The maximum authorized train speed in this area is 50 mph. None of the railcars derailed as a result of the impact, though two highway semitrailers were torn open—allowing cargo to be exposed and damaged (figure 7).

Figure 7. At left, two damaged semitrailers on intermodal flatcar. At right, closer view of damaged semitrailers. (Source: TxDPS)

The front end video data recorder from the lead locomotive contained no images of the bus or its impact with the train. The train crew did not witness the collision. The train event recorder in the lead locomotive indicated that emergency braking was first initiated by an air brake hose separation on the struck car. The crew stated that they had noticed decreasing brake pipe pressure from the end-of-train device mounted on the last railcar, at which point, the engineer applied emergency braking.

Injuries, Occupant Protection, and Emergency Response

Ten people died as a result of this crash, including the bus driver (who was a correctional officer), another correctional officer seated in the front of the bus, and eight inmates. A correctional officer seated in the rear of the bus and four inmates were seriously injured. They were transported to Medical Center Hospital in Odessa. None of the train crew were injured. Table 1 summarizes the injury data.

Table 1. Injury levels for bus driver, bus occupants, and train crew.

Injury Severity[a]	Bus Driver (Correctional Officer)	Bus Occupants (Correctional Officers)	Bus Occupants (Inmates)	Train Crew	Total
Fatal	1	1	8	0	10
Serious	0	1	4	0	5
Minor	0	0	0	0	0
None	0	0	0	2	2
Total	1	2	12	2	17

[a] Title 49 *Code of Federal Regulations* (*CFR*) 830.2 defines fatal injury as any injury that results in death within 30 days of the accident, and serious injury as any injury that: (1) requires hospitalization for more than 48 hours, commencing within 7 days from the date of injury; (2) results in a fracture of any bone (except simple fractures of fingers, toes, or nose); (3) causes severe hemorrhages, or nerve, muscle, or tendon damage; (4) involves any internal organ; or (5) involves second- or third-degree burns, or any burn affecting more than 5 percent of the body surface.

All 15 occupants of the prison bus were unrestrained at the time of the crash. Lap and shoulder restraints were available on the seats for correctional officers in the driver's area and in the rear area, though evidence indicates that the restraint systems were not being used. Both the driver and the correctional officer seated in the front were ejected during the crash sequence. Had their seat belts been worn, however, these occupants would probably still have sustained fatal injuries due to the severity of the crash and the catastrophic damage to the front of the bus. The seats for inmates are not required to be equipped with seat belts.[24]

Four local emergency services agencies responded to the scene of the crash, including the TxDPS, Ector County Sheriff's Office, Odessa Fire Department, and Odessa Police Department. The surviving passengers were not capable of evacuating the bus due to the extent of their injuries. Emergency responders reported difficulty extricating people due to their location in the bus, entanglement with other passengers, and handcuffed status (inmates were handcuffed in pairs for transport). The bus was not equipped with emergency roof hatches or emergency exit windows. Prison buses are exempt from the requirements of FMVSS 217, Bus Emergency Exit and Window Retention and Release.[25]

[24] Effective November 28, 2016, Federal Motor Vehicle Safety Standard (FMVSS) 208, Occupant Crash Protection, will require lap/shoulder seat belts for each passenger seating position in all new over-the-road buses, and in new buses other than over-the-road buses with a gross vehicle weight rating (GVWR) greater than 26,000 pounds. (An over-the-road bus has an elevated passenger deck located over a baggage compartment.) This requirement does not apply to transit buses, school buses, prison buses, and perimeter-seating buses.

[25] See 49 *CFR* 393.62(f), which exempts vehicles used for the transport of prisoners from emergency exit requirements.

The emergency response was timely and adequate. All necessary resources were available on scene to facilitate the extrication process.[26] Five ambulances responded to transport injured passengers to the hospital.

Driver Information

The Abilene–El Paso trip began about 4:40 a.m. at the John Middleton Transfer Facility. The driving distance to the Rogelio Sanchez State Jail in El Paso was about 461 miles, with a projected travel time of 7 hours. The crash occurred about 196 miles from Abilene, approximately 3 hours after departure. The correctional officer who was driving when the bus left Abilene was not the accident driver.

The accident driver, a 45-year-old male correctional officer, died as a result of the crash. He held a valid class B Texas commercial driver's license (CDL) with a "P" endorsement and a special restriction limiting him to government commercial vehicles and interstate travel only.[27]

Records obtained from a local clinic indicated no preexisting medical conditions that would have affected the driver on the day of the crash. A postcrash toxicology test was negative for alcohol or other impairing substances.[28] As a result of the driver's sustaining fatal injuries, no specific information was available on his sleep habits, either in general or in the days preceding the crash. However, based on cell phone provider records and work schedule information provided by the driver's employer, NTSB investigators estimate that he had 7.5 hours available to rest each day in the 3 days leading to the crash. According to cell phone records, the driver was not using his personal or employer-issued cell phone at or near the time of the crash.[29]

NTSB analysis of the video from the TxDPS vehicle estimated that when the bus encountered the guardrail in the left travel lane, it was traveling about 57 mph (posted speed is 75 mph). A truck-tractor semitrailer combination vehicle was ahead of the bus, and another combination vehicle was traveling in the right lane. The bus is seen in the video for only about 7 seconds. The video study estimated the following distance as 81 feet ±12 feet.[30] Therefore, the driver may have had limited time to react and respond to the road intrusion.

[26] See the survival factors factual report in the NTSB public docket for this investigation.

[27] (a) A class B CDL applies to any vehicle with a GVWR of 26,001 pounds or more; any one of those vehicles towing a vehicle that does not exceed 10,000 pounds GVWR; or any vehicle designed to transport 24 passengers or more, including the driver. (b) A "P" endorsement authorizes the operation of a vehicle transporting passengers.

[28] These substances included amphetamines, opiates, marijuana, cocaine, phencyclidine, benzodiazepines, barbiturates, antidepressants, and antihistamines.

[29] See the human performance factual report in the NTSB public docket for this investigation.

[30] A video analysis concluded that the distance between the rear of the combination vehicle and the front of the bus was 81 feet ±12 feet, which corresponds to 87 feet ±5 feet for a 40-foot trailer and 74 feet ±5 feet for a 53-foot trailer. See the video study report in the NTSB public docket for this investigation.

Probable Cause

The National Transportation Safety Board determines that the probable cause of the January 14, 2015, crash near Penwell, Texas, was the bus loss of control due to striking the portion of damaged guardrail intruding into the left travel lane of Interstate 20 westbound. Contributing to the crash was the displaced and damaged condition of the guardrail due to multiple previous impacts by other vehicles in separate crashes, attributed to icy road conditions in the eastbound lanes.

For additional details about this crash, visit http://dms.ntsb.gov/pubdms/ and search for NTSB accident ID HWY15MH004.

Recommendations

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

To the Texas Department of Transportation:

Train your personnel responsible for snow and ice control using the American Association of State Highway and Transportation Officials anti-icing/roadway computer-based winter weather training referenced in the state *Snow and Ice Control Operations Manual*. (H-16-5)

Revise your policies in accordance with the American Association of State Highway and Transportation Officials anti-icing/roadway computer-based winter weather training and the National Cooperative Highway Research Program Report 526 guidelines, to include spot treatment of interstate highway bridge decks, use of abrasives, and proper application rates for liquid anti-icing chemicals to account for long cycle times. (H-16-6)

BY THE NATIONAL TRANSPORTATION SAFETY BOARD

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