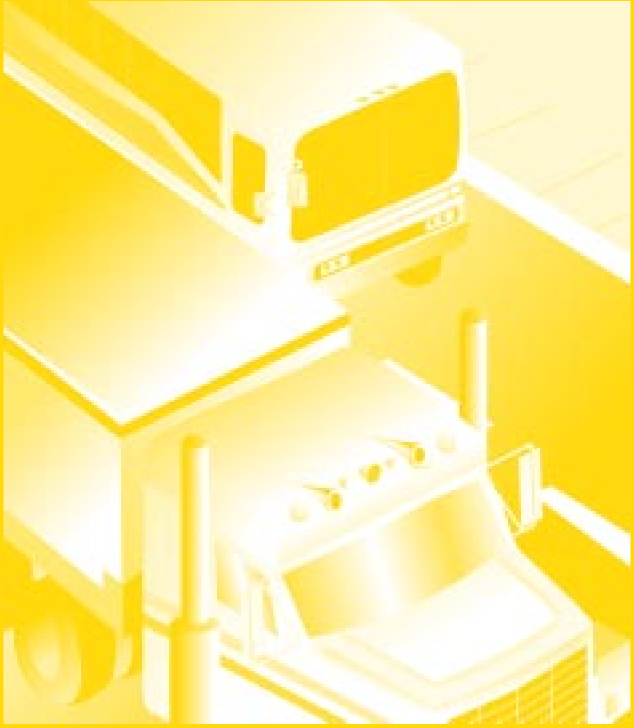
NTSB/HAR-02/03
PB2002-916203

Highway Accident Report

# Collision Between Truck-Tractor Semitrailer and School Bus Near Mountainburg, Arkansas on May 31, 2001



National Transportation Safety Board
Washington, D.C.

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## Collision Between Truck-Tractor Semitrailer and School Bus Near Mountainburg, Arkansas on May 31, 2001

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PB2002-916203
Notation 7490
Adopted September 4, 2002

National Transportation Safety Board
490 L'Enfant Plaza, S.W.
Washington, D.C. 20594

**National Transportation Safety Board. 2002. *Collision Between Truck-Tractor Semitrailer and School Bus Near Mountainburg, Arkansas, on May 31, 2001.* Highway Accident Report. NTSB/HAR-02/03. Washington, DC.**

**Abstract:** On May 31, 2001, near Mountainburg, Arkansas, a Gayle Stuart Trucking, Inc., truck-tractor semitrailer collided with a 65-passenger school bus operated by the Mountainburg, Arkansas, Public Schools. Three school bus passengers were fatally injured; two other passengers received serious injuries. Four passengers, the school bus driver, and the truckdriver sustained minor injuries.

The major safety issues discussed in this report are the poor condition of the tractor semitrailer brakes, inadequate motor carrier inspections and oversight, the use of propane tanks on school buses, and occupant protection within school buses.

As a result of its investigation, the Safety Board made recommendations to the Federal Motor Carrier Safety Administration, the National Highway Traffic Safety Administration, the Commercial Vehicle Safety Alliance, the National Fire Protection Association, and spring brake manufacturers. The Safety Board reiterated a recommendation to the U.S. Department of Transportation.

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# Contents

# Acronyms and Abbreviations

| | |
|---|---|
| **ASHTD** | Arkansas State Highway and Transportation Department |
| **AASHTO** | American Association of State Highway and Transportation Officials |
| **ArvinMeritor** | ArvinMeritor, Inc. |
| **Bendix** | Bendix Commercial Vehicle Brake Systems |
| **CDL** | Commercial Driver's License |
| **CFR** | *Code of Federal Regulations* |
| **CVSA** | Commercial Vehicle Safety Alliance |
| **DOT** | U.S. Department of Transportation |
| **EMTs** | emergency medical technicians |
| **FHWA** | Federal Highway Administration |
| **FMCSA** | Federal Motor Carrier Safety Administration |
| **FMCSRs** | *Federal Motor Carrier Safety Regulations* |
| **FMCSR** | Federal Motor Carrier Safety Regulation |
| **FMVSSs** | *Federal Motor Vehicle Safety Standards* |
| **Haldex** | Haldex Brake Systems |
| **Hammond** | Hammond Yellow Coach Lines, Inc. |
| **I-540** | Interstate 540 |
| **Kenworth** | Kenworth Truck Company |
| **MCSAP** | Motor Carrier Safety Assistance Program |
| **MUTCD** | Manual on Uniform Traffic Control Devices |
| **NFPA** | National Fire Protection Association |
| **NHTSA** | National Highway Traffic Safety Administration |
| **OMC** | Office of Motor Carriers |
| **psi** | pounds per square inch |
| **SH-282** | State Highway 282 |
| **Stuart Trucking** | Gayle Stuart Trucking, Inc. |

# Executive Summary

On May 31, 2001, about 3:28 p.m. central daylight time, a southbound Gayle Stuart Trucking, Inc., truck-tractor semitrailer exited Interstate 540 at State Highway 282 near Mountainburg, Arkansas. The driver was unable to stop at the stop sign at the bottom of the ramp. The 79,040-pound combination unit was traveling approximately 48 mph when it entered the intersection and collided with the right side of a westbound, 65-passenger, 1990 Blue Bird Corporation school bus operated by the Mountainburg, Arkansas, Public Schools. The school bus rotated approximately 300 degrees clockwise and overturned; the body, which partially separated from the chassis, came to rest on its right side on the eastbound shoulder of State Highway 282. The tractor semitrailer continued across the roadway, rotated about 60 degrees clockwise, overturned, and came to rest on its left side.

Three school bus passengers seated across from the impact area were fatally injured; one was partially ejected. Two other passengers, one of whom was seated in the impact area, received serious injuries, and four passengers had minor injuries. The school bus driver and the truckdriver both sustained minor injuries.

The Safety Board determines that the probable cause of the accident was the truckdriver's inability to stop the tractor semitrailer at the stop sign at the bottom of the ramp due to the reduced braking efficiency of the truck's brakes, which had been poorly maintained and inadequately inspected. Contributing to the school bus passengers' injuries during the side impact were incomplete compartmentalization and the lack of energy-absorbing material on interior surfaces.

The major safety issues discussed in this report are the poor condition of the tractor semitrailer brakes, inadequate motor carrier inspections and oversight, the use of propane tanks on school buses, and occupant protection within school buses.

As a result of its investigation, the Safety Board makes recommendations to the Federal Motor Carrier Safety Administration, the National Highway Traffic Safety Administration, the Commercial Vehicle Safety Alliance, the National Fire Protection Association, and spring brake manufacturers. The Safety Board reiterates a recommendation to the U.S. Department of Transportation.

# Factual Information

## Accident Narrative

On May 31, 2001, about 3:28 p.m. central daylight time, a southbound Gayle Stuart Trucking, Inc., (Stuart Trucking) truck-tractor semitrailer exited Interstate 540 (I-540) at State Highway 282 (SH-282) near Mountainburg, Arkansas. The driver was unable to stop the tractor semitrailer at the stop sign at the bottom of the ramp. The 79,040-pound tractor semitrailer was traveling approximately 48 mph when it entered the intersection and collided with the right side of a westbound, 65-passenger, 1990 Blue Bird Corporation school bus, traveling about 50 mph, and operated by the Mountainburg, Arkansas, Public Schools. The school bus rotated approximately 300 degrees clockwise, overturned, and came to rest on its right side on the eastbound shoulder of SH-282. The tractor semitrailer continued across SH-282, rotated about 60 degrees clockwise, overturned, and came to rest on its left side.

### *Truck*

The truckdriver departed his home in Vandalia, Missouri, on May 28, 2001, for a 4-day trip through Iowa, Missouri, and Arkansas. On May 31, the day of the accident, the driver stated that he awoke about 8:00 a.m., conducted a 30-minute pretrip inspection, and departed Kingdom City, Missouri, where he had slept in his sleeper berth the previous night. He had picked up a load of bean meal in Mexico, Missouri, earlier that morning (approximately 1:44 a.m., according to the bill of lading) and was en route to Atkins, Arkansas (see figure 1). The driver stopped near Joplin, Missouri, about 1:30 p.m. for a sandwich.

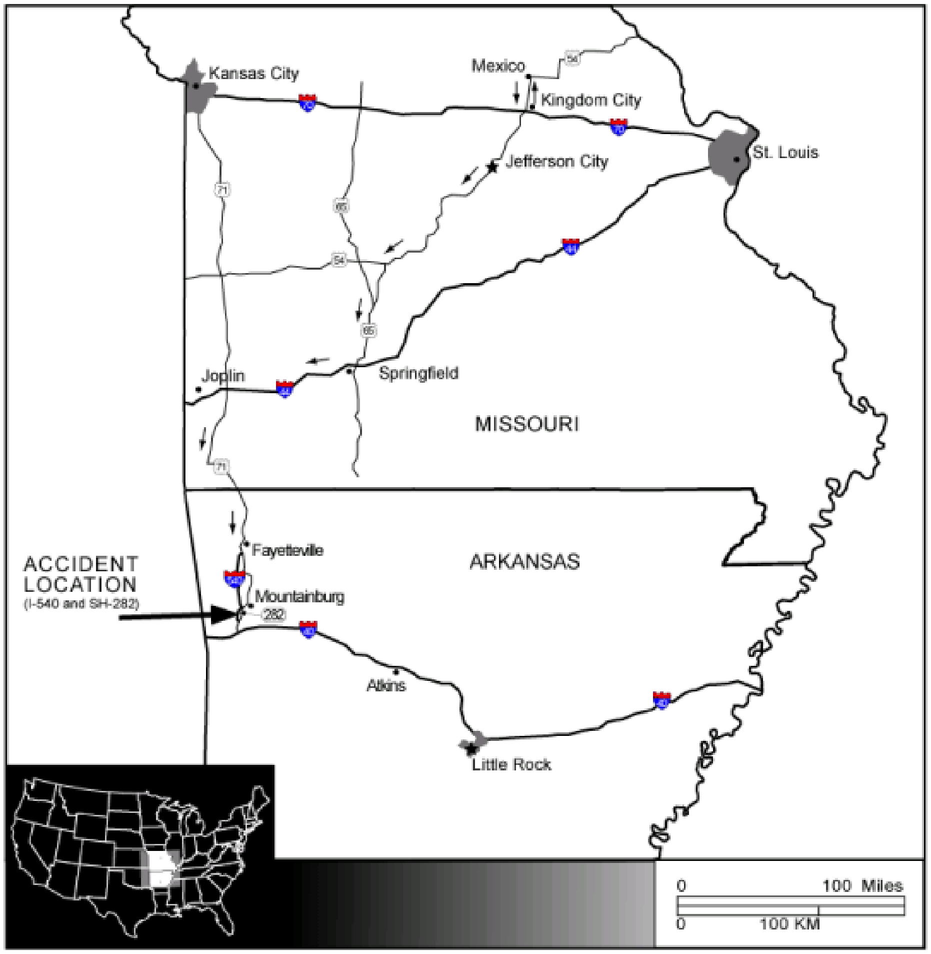


**Figure 1.** Truck route.

The driver said that in the vicinity of Fayetteville, Arkansas, he determined that he would need fuel near Mountainburg, where he knew of a truck stop on SH-282. The driver stated that he had stopped at the truck stop on several occasions while traveling northbound on I-540, but had not exited there before while traveling southbound. About 3:28 p.m., as the driver was southbound on I-540, he exited the ramp to SH-282; he estimated his speed to be approximately 20 to 25 mph, and he indicated that his truck was in sixth gear. He said that he attempted to downshift and brake at the top of the ramp, but the brakes did not operate. He stated that he continued to apply the brakes but was unsuccessful in slowing the vehicle, and it continued to accelerate down the ramp. The driver indicated that as he approached the intersection, he did not see any traffic ahead and was unable to see any traffic on westbound SH-282 due to a berm to the left (east) of the ramp. The driver said that he planned to try to stop the vehicle by proceeding directly across SH-282 and onto the upgrade of the I-540 southbound entrance ramp. As he entered the intersection, the driver stated that he saw the westbound school bus and was unable to avoid the collision.

### School Bus

The school bus picked up students at Mountainburg Elementary School about 2:50 p.m., drove to Mountainburg High School to pick up more students, and departed the high school between 3:00 and 3:05 p.m. for the afternoon route home. The bus had made three stops on the route to unload students before dropping off a student at a truck stop on SH-282 and proceeding westbound on SH-282 at a driver-estimated speed of 45 mph. The driver stated that as he was nearing the ramp, he heard a passenger shout that a truck was not going to stop at the stop sign on the ramp. The driver said he briefly looked to his right, glimpsed the truck, and heard the loud sound of the collision.

### Collision

The tractor semitrailer hit the bus on the right side in the area of the rear axle. The truck continued south across SH-282, traveled 73 feet from the point of impact, rolled on its left side, and traveled an additional 78 feet, rotating about 60 degrees clockwise (see figures 2 and 3). The school bus traveled 96 feet southwest from the area of impact, rotating about 300 degrees clockwise. The body, which partially separated from the chassis, rolled onto its right side, while the chassis remained partially upright (see figure 4).

## Injuries

**Table 1.** Injuries.[1]

| INJURIES | SCHOOL BUS DRIVER | TRUCKDRIVER | BUS PASSENGERS | TOTAL |
|---|---|---|---|---|
| **Fatal** | 0 | 0 | 3 | 3 |
| **Serious** | 0 | 0 | 2 | 2 |
| **Minor** | 1 | 1 | 4 | 6 |
| **None** | 0 | 0 | 0 | 0 |
| **Total** | 1 | 1 | 9 | 11 |

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

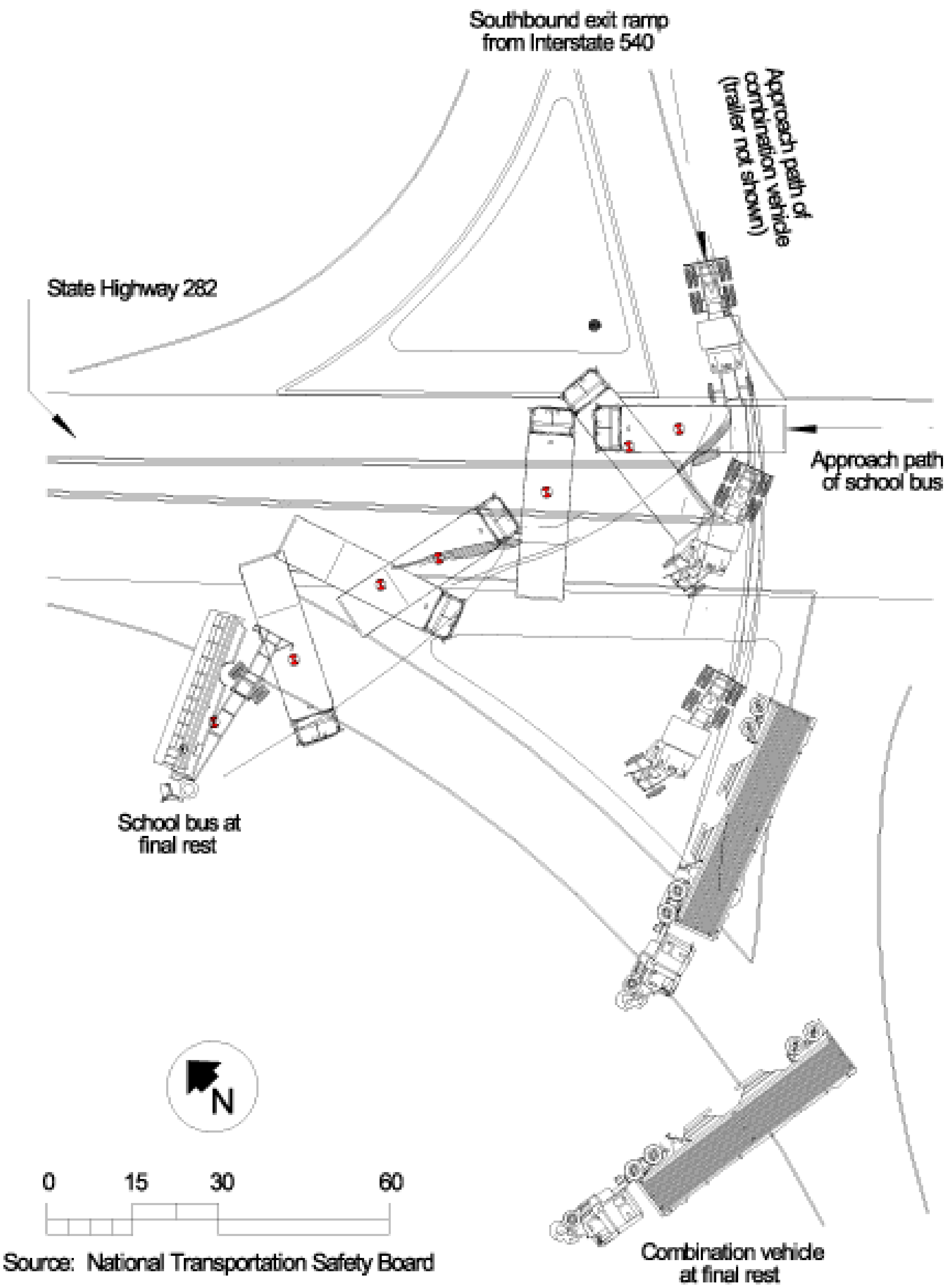


**Figure 2.** Postcrash accident scene.

**Figure 3.** Tractor semitrailer, postaccident.


**Figure 4.** School bus, postaccident.

## Medical and Pathological Information

The truckdriver's minor injuries included contusions on the right side of his head, upper right arm, and left shoulder. The busdriver's minor injuries included contusions on the left side of his face, left shoulder, and left hip. Because of a coronary condition, he was hospitalized after the accident as a precaution.

The passengers who sustained minor injuries were seated in seats 1A, 2A, 2C, and 2E (see figure 5). The passenger in seat 1A sustained a contusion on the left side of his scalp. The passenger in seat 2A sustained a contusion on the left side of her scalp and a possible contusion or laceration of the spleen. The passenger in 2C sustained lacerations and contusions on the right elbow, and the passenger in seat 2E had lacerations and contusions on her right elbow and on the back of both knees.

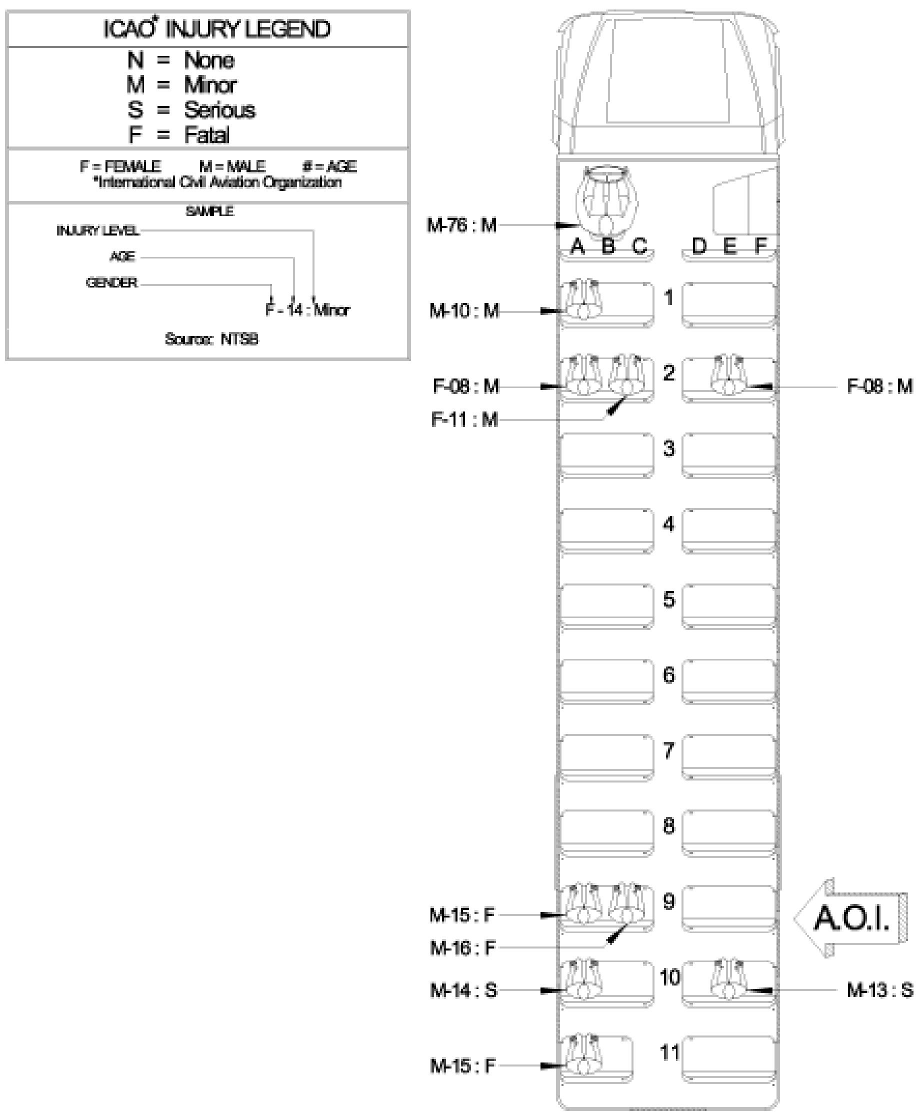


**Figure 5.** Mountainburg school bus seating chart.

Two seriously injured passengers were seated in the rear of the bus. One was seated in the area of impact (seat 10E) and sustained lacerations to his head and elbow and a closed head injury. The other, seated across from the area of impact (seat 10A), sustained multiple spinal fractures and a fractured right arm and leg.

The three fatally injured passengers were seated across from the area of impact. The passenger in seat 9A sustained a fractured skull, fractured left clavicle, three fractured ribs, and a compound fracture of the left leg; the passenger in 9C sustained multiple lacerations and contusions, a right pelvic fracture, a liver laceration, a right renal laceration, ruptured right hemidiaphragm, and vena cava injury; the passenger in 11A, who was partially ejected, had a skull fracture, multiple spinal fractures, and a fractured left tibia.

## Toxicological Tests

*Federal Motor Carrier Safety Regulations* (FMCSRs)[2] required that postaccident alcohol and drug testing[3] be performed on both the truckdriver and the busdriver. The postaccident toxicological tests on the truckdriver, conducted by Arkansas State Police and Crawford Memorial Hospital, were negative for alcohol and other drugs. A sample was sent to the Civil Aerospace Medical Institute to test for Cetirizine, the main component of Zyrtec, an allergy medication.[4] Test results were negative. Results of postaccident toxicological tests conducted by the Arkansas State Police for the school bus driver were negative for alcohol and other drugs.

## Survival Aspects

### *Emergency Response*

The Crawford County Communications Center and the Mountainburg Police Department received notification of the accident at 3:29 p.m. The Mountainburg police chief arrived on scene at 3:31 p.m. and two rescue vehicles arrived at 3:35 p.m. The rescue vehicles were manned by eight firefighters, five of whom were qualified first responders and emergency medical technicians (EMTs). A triage area, where the injured were evaluated and treated, was established on the left side of the school bus. After the triage site was set up, a Lifeflight Air Ambulance (helicopter) was dispatched from Branson, Missouri, about 45 minutes flying time from the accident site. Four additional fire departments and one ambulance service, comprising 25 fire fighters and EMTs, three rescue vehicles, a pumper truck, and seven ambulances, responded to the accident. By

[2] Title 49 CFR Part 382.303.

[3] Title 49 CFR Part 40.21 requires that drug testing be done for marijuana, cocaine, opiates, amphetamines, and phencyclidine.

[4] The driver stated that he occasionally took Zyrtec for allergies on an as-needed basis.

3:45 p.m., the ambulances had transported eight of the injured passengers, the busdriver, and the truckdriver from the scene (the helicopter was not needed). One partially ejected passenger (seat 11A) was under the bus. He was extricated by 3:52 p.m. and pronounced dead at the scene. At the postaccident critique attended by all participating agencies, the consensus was that the response was timely and resources were adequate, according to the on-scene police and firefighters.

### *Survivability*

The truckdriver said he was wearing his lap belt only; the truck was equipped with a separate shoulder belt. He said that during the accident sequence his leg became wedged under the dashboard due to the deformation of the cab. After the truck came to rest, he was able to slide the seat back to free his leg and climb out through the broken windshield.

The school bus driver stated that he was wearing his lap belt (the bus was only equipped with a lap belt), which was found tied in a knot during postaccident examination but still usable; no striations were found on the belt webbing. The driver reported that he was unable to get out of the lap belt after the bus came to rest because the weight of his body against the belt jammed the buckle and prevented him from unlatching it. One of the passengers unlatched the driver’s belt. The driver reported that he struck his head, elbows, and chest on the interior of the bus as it rolled over.

The busdriver and two passengers (seats 1A and 2B) were able to exit from the bus on their own via the rear emergency door. The busdriver helped the seriously injured passenger in seat 10E exit the bus. EMTs and passersby removed two fatally injured passengers (seats 9A and 9C), one seriously injured passenger (seat 10A), and two passengers with minor injuries (seats 2A and 2D) from the bus. EMTs extricated the third fatally injured passenger (seat 11A) from underneath the bus; this passenger had been partially ejected through the right side window at row 11.

The passenger in the front of the bus said that at the end of the impact sequence, he was lying on the “floor,” which, postcollision, was the right side of the bus. The passenger in seat 10E said he was lying on the right side of the bus when it came to rest and that the passenger in seat 9A was laying across his legs. Evidence indicates the passengers in the back of the bus struck the ceiling, right side windows, and sidewall during the impact sequence.

## Damage

Both the school bus and truck tractor were completely destroyed. The semitrailer received minor damage and the load was unusable.

## Driver Information

### *Truckdriver*

The 25-year-old truckdriver possessed a current Missouri class A Commercial Driver's License (CDL), with no restrictions or endorsements, issued on March 15, 1999, and scheduled to expire on March 15, 2002. A review of the driver's record revealed a speeding conviction while driving a personal vehicle on November 19, 2000, and a failure-to-keep-right conviction while driving a commercial vehicle on July 30, 1999. The driver had a valid medical certificate that was issued on May 7, 2001, and scheduled to expire on May 7, 2003.

Interviews with the truckdriver and an examination of his employment records showed that he started driving commercial vehicles professionally in March 1999. Stuart Trucking was his first employer. He subsequently worked for McDowell Farms of Perry, Missouri; Target Aluminum of Vandalia, Missouri; and Jennings Implement of Curryville, Missouri, from June 2000 to April 2001. He returned to Stuart Trucking in April 2001.

The truckdriver acknowledged that the logs he kept between May 28 and 31, 2001, were not accurate because he had reconstructed his activities and completed the logs at the end of each day. Safety Board investigators reconstructed the driver's off-duty rest times based on an interview with the driver, fuel receipts, bills of lading, and travel times between locations. Table 2, which follows, shows the driver's stated rest time, the times on the receipts, and the driver's likely hours of sleep during the days prior to the accident.

The driver stated that he was in good general health, but occasionally suffered from a chronic back problem stemming from a childhood injury. He said he was not experiencing back pain on the day of the accident. He also suffered from a dust allergy and occasionally took Zyrtec for relief of symptoms. He said he last used the medication 2 weeks before the accident, and toxicological tests did not reveal any Zyrtec in the driver's blood. The driver's medical records did not indicate any other medical conditions.

**Table 2.** Driver's off-duty/rest times.

| DATE | DRIVER'S STATED REST TIMES | RECEIPTS | LIKELY TIMES OF SLEEP | TOTAL SLEEP (HOURS) |
|---|---|---|---|---|
| **MAY 26** | 0100-0900 (Home) | | | 8.0 |
| **MAY 27** | 0100-1000 (Home) | | | 9.0 |
| **MAY 28** | 0001-1030 (Home)<br>2330-2400 (Truck, Mt. Pleasant, Iowa) | 2053 (Bowling Green, Missouri)<br>2330 (Mt. Pleasant, Iowa) | 0001-1030<br>2330-2400 | 10.5<br>0.5 |
| **MAY 29** | 0001-0500 (Truck, Mt. Pleasant, Iowa)<br>0900-1100 (Truck, Davenport, Iowa) | 1250 (Davenport, Iowa)<br>1756-1821 (Eddyville, Iowa) | 0001-0500 | 5.0 |
| **MAY 30** | 0001-0630 (Truck, Mexico, Missouri)<br>1300-1400 (Truck, Siloam Springs, Arkansas) | 0714 (Kingdom City, Missouri)<br>1247-1508 (Siloam Springs, Arkansas)<br>1629-1736 (Noel, Missouri)<br>2310 (Meta, Missouri) | 0001-0630 | 6.5 |
| **MAY 31** | 0230-0830 (Truck, Kingdom City, Missouri) | 0144 (Mexico, Missouri) | 0230-0800 | 5.5 |

### *School Bus Driver*

The 76-year-old school bus driver possessed a current Arkansas class B CDL, with a passenger endorsement and a school bus restriction, that was issued on April 7, 1999, and scheduled to expire on March 18, 2003. A review of the busdriver's record revealed no traffic convictions. He had been involved in a traffic accident on February 15, 2001; while exiting school property, the bus struck the right side of a passenger car as he entered the roadway. No one was injured and the busdriver was not cited for the accident. The busdriver had passed his most recent annual physical examination on August 1, 2000, as required by the Mountainburg Public Schools.[5] He had been driving school buses for 14 years and had been driving this route for 3 years.

## Vehicle and Wreckage Information

### *Truck-Tractor Semitrailer*

The accident vehicle, a 1989 Kenworth Truck Company (Kenworth) model T600A conventional-cab, three-axle tractor, was equipped with a nine-speed transmission and had a sleeper berth; it was towing a two-axle, 43-foot hopper[6] semitrailer, model DWH-400,

[5] All school bus drivers are required to have an annual physical prior to the beginning of each school year.

built by Wilson Trailer Company in 1996. The tractor, leased to Stuart Trucking, was powered by a six-cylinder Caterpillar diesel engine without an engine brake; it was originally equipped with an electronic control module that had been removed in 1999. Both the odometer, which read 2,967.2 miles at the time of the accident, and speedometer had been replaced.[7] The tractor had a wheelbase of 222 inches and a curb weight of 16,805 pounds. According to Stuart Trucking records, the tractor had received its mandatory annual inspection, performed by an employee of Stuart Trucking, on April 17, 2001; the inspection form listed all brake components as "OK." Prior to that inspection, the tractor had been idle for about 2 years.

The hopper, owned by Stuart Trucking and used to haul grain and animal feed, weighed about 10,100 pounds empty. It had received its annual inspection, performed by an employee of Stuart Trucking, on July 3, 2000; the inspection form listed all brake components as "OK." The hopper had been used as a spare at least once a month for about 18 months prior to the accident.

**Brakes.** A Safety Board postaccident examination revealed that all three tractor axles had air brakes (see figure 6) with standard S-cam/drum foundation (service) brakes (see figure 7) fitted with manual slack adjusters.[8] The semitrailer (hopper) had air brakes with standard S-cam/drum foundation brakes; its two axles had automatic slack adjusters. The third axle of the tractor and both trailer axles had emergency-parking spring brakes.

**Background.** About 95 percent of large (26,000 pounds or greater) commercial vehicles are equipped with air brakes with S-cam/drum foundation brakes. The purpose of the service brake components is to convert air pressure into mechanical forces used to decelerate the vehicle. Once air has been directed through lines and valves, it reaches a brake chamber (see figure 6). Brake chambers vary in size and provide a wide range of output forces. Compressed air flows into the brake chamber, where it acts on a pressure plate attached to a pushrod. The air forces the pressure plate to move, extending the pushrod with a force proportional to the air pressure applied to the brake chamber. (This movement is referred to as the pushrod stroke or travel.) Under ideal circumstances, a pressure of 40 pounds per square inch (psi) supplied to a brake chamber with a pressure plate of 30 square inches (a Type 30 brake chamber) results in 1,200 pounds of force on the pushrod. This ideal situation excludes any losses due to friction, loose bearing surfaces, or component stretch and expansion. Such losses reduce actual pushrod forces.

[6] A hopper is a box-shaped container with a funnel at the bottom used for delivering grain and other agricultural products.

[7] Because the original electronic speedometer did not work when the engine control module was removed, the speedometer was replaced.

[8] A slack adjuster multiplies and converts the force from the pushrod into torque on the shaft running perpendicular to the brake drum, rotating the S-cam and spreading the brake shoes inside the brake drum. A manual slack adjuster is adjusted by the operator, who turns the adjusting nut to compensate for lining wear so the pushrod is not required to extend farther out than it is able. An automatic slack adjuster performs this function automatically.

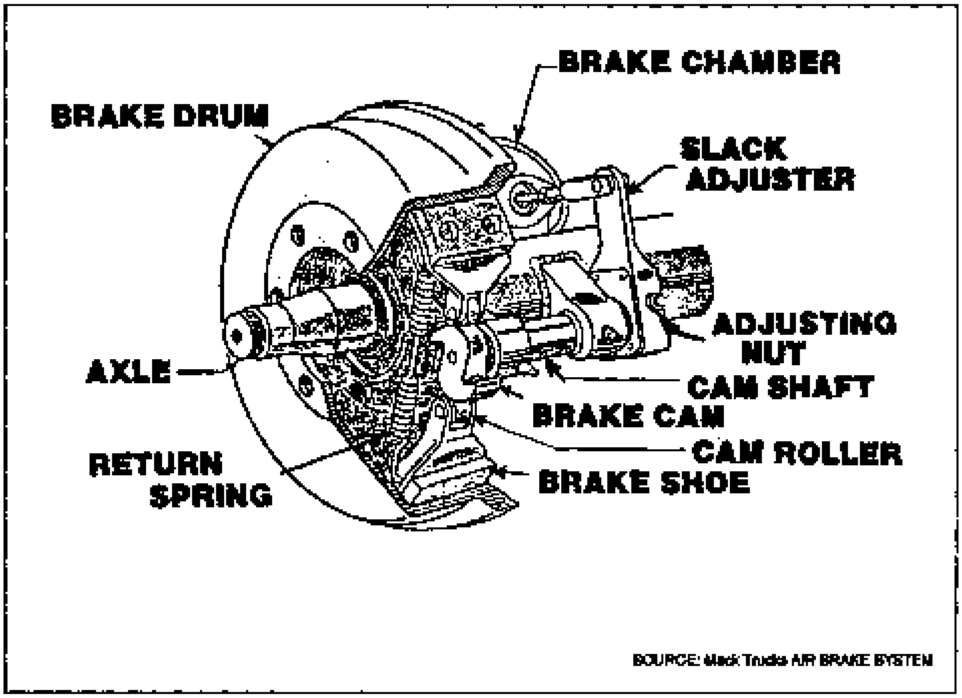


**Figure 6.** Brake diagram.

In an S-cam air brake system, the pushrod is attached to one end of a lever called a slack adjuster (see figure 7). The slack adjuster multiplies and converts the force from the pushrod into torque on the shaft running perpendicular to the brake drum. As the pushrod is extended from the brake chamber, the slack adjuster rotates, in turn rotating the shaft connected to it. The S-cam also rotates, spreading the brake shoes inside the brake drum. When the brake shoes are spread apart, the brake linings (riveted to the shoes) come into contact with the inside of the brake drum. The friction created slows the rotation of the brake drum and, thus, the wheel and the vehicle.

To compensate for lining wear, slack adjusters are equipped with an adjusting mechanism. If they were not, the pushrod would be required to extend continually farther out as the lining wore down until the pressure plate in the brake chamber came into contact with the bottom of the brake chamber. Known as “bottoming out” a brake chamber, the resulting pushrod stroke is the maximum stroke listed in the manufacturer’s brake literature. Bottoming out results in no braking because the pushrod cannot travel far enough to rotate the S-cam sufficiently to expand the brake shoes so that they make contact with the drum. Manual slack adjusters must be adjusted by hand with a wrench, while automatic slack adjusters compensate for lining wear without being adjusted manually.

During postaccident inspection, investigators measured the brake stroke for each of the brakes with 90 psi of air supplied.[10] Of the 10 brakes on the tractor semitrailer, 8 were found to be out of adjustment or nonfunctional.

**Table 3.** Brake types and manufacturers.

| AXLE | CHAMBER SIZE | SLACK ADJUSTER | EMERGENCY PARKING/SPRING BRAKE | CAGING PORT |
|---|---|---|---|---|
| 1 Left (tractor) | T-20 | Midland Manual | None | None |
| 1 Right (tractor) | T-20 | Midland Manual | None | None |
| 2 Left (tractor) | T-30 | Midland Manual | None | None |
| 2 Right (tractor) | T-30 | Midland Manual | None | None |
| 3 Left (tractor) | T-30/30 | Midland Manual | Remanufactured | Standard |
| 3 Right (tractor) | T-30/30 | Midland Manual | Anchorlok | Standard |
| 4 Left (trailer) | T-30/30 | Rockwell Automatic | Midland | Standard |
| 4 Right (trailer) | T-30/30 | Rockwell Automatic | Anchorlok | Fixed Integrated |
| 5 Left (trailer) | T-30/30 | Rockwell Automatic | Midland | Standard |
| 5 Right (trailer) | T-30/30 | Rockwell Automatic | Anchorlok | Fixed Integrated |

Table 4 shows the adjustment for each brake. The driver stated that he and the owner of the tractor (his father) had installed manual slack adjusters on the second and third axles of the tractor on May 27, 2001, as preventive maintenance, because the old slack adjusters would not "take grease." The owner said he adjusted the brakes on the second and third axles at that time by tightening the shoe against the drum and then backing off the adjusting nut about 1/2 turn. The owner also stated that he liked the steering axle brakes (first axle) to be adjusted "loose" and backed off the adjusting nut 3/4 turn.

[10] Because of accident damage, the tractor brakes were operated using the brake pedal and shop air; the trailer brakes were operated from the brake pedal of an auxiliary tractor compressing its own air.

**Table 4.** Brake adjustment.

| AXLE | MAXIMUM STROKE ALLOWED* | MEASURED STROKE | NOTES |
|---|---|---|---|
| 1 Left (tractor) | 1 3/4 inches | 2 1/8 inches** | |
| 1 Right (tractor) | 1 3/4 inches | 2 3/8 inches** | |
| 2 Left (tractor) | 2 inches | 2 3/8 inches** | |
| 2 Right (tractor) | 2 inches | 2 1/4 inches** | |
| 3 Left (tractor) | 2 inches | 1 7/8 inches** | Parking/emergency brake spring broken, restricting pushrod travel; no dust cover |
| 3 Right (tractor) | 2 inches | 2 1/2 inches** | No dust cover |
| 4 Left (trailer) | 2 inches | 1 1/2 inches | Parking/emergency brake spring broken; no dust cover |
| 4 Right (trailer) | 2 inches | 1 3/4 inches** | Incorrectly installed brake chamber |
| 5 Left (trailer) | 2 inches | 1 inch** | Parking/emergency brake spring broken, restricting pushrod travel; no dust cover |
| 5 Right (trailer) | 2 inches | 1 1/2 inches | |

* Manufacturers' recommended maximum adjustment length.
** Out of adjustment or not functioning properly.

The driver reported that he checked his brakes about 8:00 a.m. on the day of the accident by doing a walk-around inspection and looking at the brakes while the parking brake was on. He said that the brakes did not appear to need adjustment, although he noticed that the right-front axle brake chamber was rusted. He stated that he did not climb beneath the vehicle to observe the brakes. To check manual slack adjusters on S-cam brakes, according to the *Model Driver's Manual for Commercial Vehicle Driver Licensing*:

> A driver should park on level ground and chock the wheels to prevent the vehicle from moving. He must then turn the parking brake off in order to move the slack adjuster by hand. If the slack adjuster moves more than one inch where the push rod attaches then it probably needs adjustment.[11]

The driver said that the brakes on the tractor were adjusted weekly, even though doing so might not be necessary, and he described to investigators the correct procedure for adjusting brakes. He also stated a preference for adjusting the trailer axle brakes "loose" to prevent the trailer from slipping in wet and other conditions. He said that he had

[11] American Association of Motor Vehicle Administrators, *Commercial Driver License Manual Version 2.0* (Arlington, VA: AAMVA, 1996).

not personally adjusted the brakes on the trailer but was present when the mechanic at Stuart Trucking did so 2 to 3 weeks before the accident.

Safety Board investigators conducted tests on June 2, 2001, to determine whether the trailer brakes were operational. The trailer was connected to a truck tractor and driven at 20 mph and 40 mph. When the service brakes were applied at both speeds, only the 4L (fourth axle, left side) and 5R (fifth axle, right side) trailer brakes locked, and the tires slid on the roadway; wheels 4R (fourth axle, right side) and 5L (fifth axle, left side) were free rolling with the brakes fully applied.

Investigators tested the semitrailer's emergency-parking brakes,[12] using an auxiliary tractor to pull the trailer on the cement pavement, on June 6, 2001. When the emergency-parking brake was applied, only the 5R wheel locked. When pulled on gravel on a slight downhill slope, both the 4L and 5R wheels locked. In all tests, the 4R and 5L wheels rolled freely.

On September 27, 2001, Safety Board staff and Arkansas Highway Police met with Haldex Brake Systems (Haldex)[13] personnel to test the four Midland Brake, Inc., (Midland) manual slack adjusters from the tractor (axles 2 and 3) and to examine and disassemble the spring brakes. The manual slack adjusters for axles 2 and 3 were fitted onto a test spline and rotated manually. All four adjusters functioned properly. When disassembled, the emergency-parking brake spring on brake 3L was found broken into three pieces. The broken spring disabled the emergency-parking brake and restricted the service brake pushrod return by 3/8 inch.

During the postaccident inspection, investigators discovered that the angle between the pushrod and the slack arm on brake 4R was greater than the 90 degrees that specifications allowed. When measured against a slack adjuster template, the pushrod was about 1 inch shorter than the pushrod on the left side of the trailer, causing the greater angle. According to the manufacturer, the automatic slack adjuster was bottoming out, thus preventing full release of the pushrod and preventing the brakes from automatically adjusting. The 4R brake drum was rusty and the brake did not appear to be functioning.

On July 12, 2001, Safety Board staff met with ArvinMeritor, Inc., (ArvinMeritor)[14] personnel to examine and disassemble the automatic slack adjuster on brake 4R and found it to be nonfunctional. Disassembly of the component revealed that the piston retaining ring[15] was broken, probably, according to ArvinMeritor personnel, as a result of the angle between the pushrod and slack arm, which, in turn, disabled the

[12] All tractors and semitrailers are required to be equipped with emergency-parking brakes. In this and most cases, the brake operates by means of a spring that expands to apply the brakes when the air pressure drops.

[13] Midland, now owned by Haldex, manufactured two of the three broken spring brakes and examined the third as a courtesy. Midland manufactured all of the manual slack adjusters.

[14] ArvinMeritor is a supplier of commercial vehicle components, including air brakes.

[15] The piston retaining ring creates the clearance gap for the actuator piston, which is part of the adjusting mechanism. If the ring is broken, the clearance gap cannot be created, preventing adjustment.

automatic slack adjuster. When reassembled with a new piston retaining ring, the automatic slack adjuster functioned as designed. An outside mechanic had replaced the spring brake chamber on the right fourth axle (semitrailer) on June 5, 1997. Often, to replace a spring brake chamber, the pushrod must be cut and realigned.

When disassembled during the inspection at Haldex, the spring in brake 4L's emergency-parking brake chamber was found to be in two pieces and a white coloration, consistent with the presence of salt, was present inside the brake chamber. The interior brake drum surface was shiny. The service brake appeared to function normally during dynamic testing on the roadway.

The parking/emergency brake spring was found to be in three pieces when brake 5L was disassembled. After a manual caging bolt was installed, the chamber retracted an additional 5/8 inch, indicating that the broken spring was preventing full pushrod release, according to Haldex personnel. The spring was fractured in such a way that it prevented full return of the pushrod; thus, the automatic slack adjuster did not have the minimum 1½ inches of stroke necessary to activate the adjusting mechanism. When disconnected from the air chamber, the automatic slack adjuster operated properly on a test device.

Four of the six spring brakes on axles 3, 4, and 5 were equipped with standard caging ports, none of which had dust covers to keep out contaminants. The other two spring brakes were equipped with fixed integrated caging bolts,[16] which do not require dust covers.

Investigators also measured brake shoe lining thickness. On brake 5R, the lining was 3/16 inch, or 1/16 inch less than the required minimum of 4/16 inch; all other brake shoes were in compliance with minimum requirements. The brake drums were examined and the inside diameters measured. While none of the drums exceeded the manufacturers' maximum service diameter, they did approach it, making them more susceptible to brake heat than new drums because less drum mass was available to absorb the heat. The drums on brakes 1R, 4R, and 5L exhibited rust.

The tread depths on all tires met FMCSRs and Commercial Vehicle Safety Alliance (CVSA) requirements of 4/32 inch on the front tires and 2/32 inch on the remaining tires. TRW, Inc., personnel disassembled and examined the steering gear on August 7, 2001, and found no defects.

According to an Arkansas Highway Police mechanic and ArvinMeritor staff, the general condition of the brake system on the trailer was poor. At the Safety Board's request, inspectors from the Missouri Division of Motor Vehicle and Railroad Safety conducted postaccident vehicle inspections on 12 Stuart Trucking vehicles (see "Management Information" section); they found that grease was absent at the fittings and brake camshaft bushings, suggesting a lack of periodic lubrication. The inspectors stated that Stuart Trucking staff did not seem to be knowledgeable and that some of the defects noted were obvious and did not appear to be recent.

[16] An integrated caging bolt is a bolt in the spring brake case that is turned to release the spring brakes.

**Damage.** The tractor sustained damage to the front part of the frame, which was bent to the right about 10 degrees; the entire cab was shifted rearward, the windshield and right door window were broken, and both doors were damaged. The engine was dislodged from its mount, and parts within the engine compartment, as well as the front engine support, were broken;[17] the left fuel tank was dislodged and the right fuel tank was punctured; and the muffler stack was broken off. Due to accident damage, the tractor lights could not be tested to determine whether they were operational. The hopper trailer's front left upper clearance lights were damaged, the left side of the trailer was scraped, both outside left trailer wheels were bent, and the tires were flat.

### *School Bus*

The 65-passenger, 1990 Blue Bird Corporation school bus had a Chevrolet model 60 chassis with a V-8, 366-cubic inch engine reconfigured to operate with propane. The school bus was equipped with a four-speed General Motors Corporation manual transmission with a two-speed differential, power-assisted steering, hydraulic brakes with a dual master cylinder, and a motorized booster pump.

The tire tread depths exceeded FMCSRs and CVSA requirements. After the accident, the front brakes were tested and operated properly. The rear brakes could not be tested because of a severed hydraulic line caused by collision damage. The lights that were not damaged in the accident operated during postaccident testing.

The bus had 10 rows of three-passenger bench seats on both sides of the bus. The eleventh row had a three-passenger bench seat on the right side and a two-passenger bench seat on the left side to accommodate the vehicle's one emergency exit door at the rear. Buses manufactured before September 1, 1994, were only required to have one emergency exit door.[18]

The school bus had been retrofitted with a 66.5-gallon propane tank located 34 inches forward of the rear axle on the right side, about 4 inches behind the caged gasoline tank, which had been drained (see figure 8). The propane tank was mounted outside the frame and was secured by two steel straps. The cylindrical propane tank, manufactured by Brunner Engineering and Manufacturing, was 64 inches long and 18 inches in diameter. The tank shell was 0.187 inch thick and the heads (ends of the tank) were 0.173 inch thick. The tank was equipped with an overfill protection device valve, designed to vent in case of overfill or fire. Part of the valve was inside the propane tank and part outside; if the outer part of the valve was damaged or destroyed, gas flow to the engine was supposed to shut off automatically.

[17] The pressurized power steering line was broken at the steering gear box, the input shaft to the steering box was separated at the universal joint, the flywheel housing and bell housing were broken, damage indentations were present on the firewall, the gearshift lever was broken off at the isolated pin, the air filter assembly was damaged, and the batteries were dislodged.

[18] Title 49 CFR 571.217.S5.2.3.4.

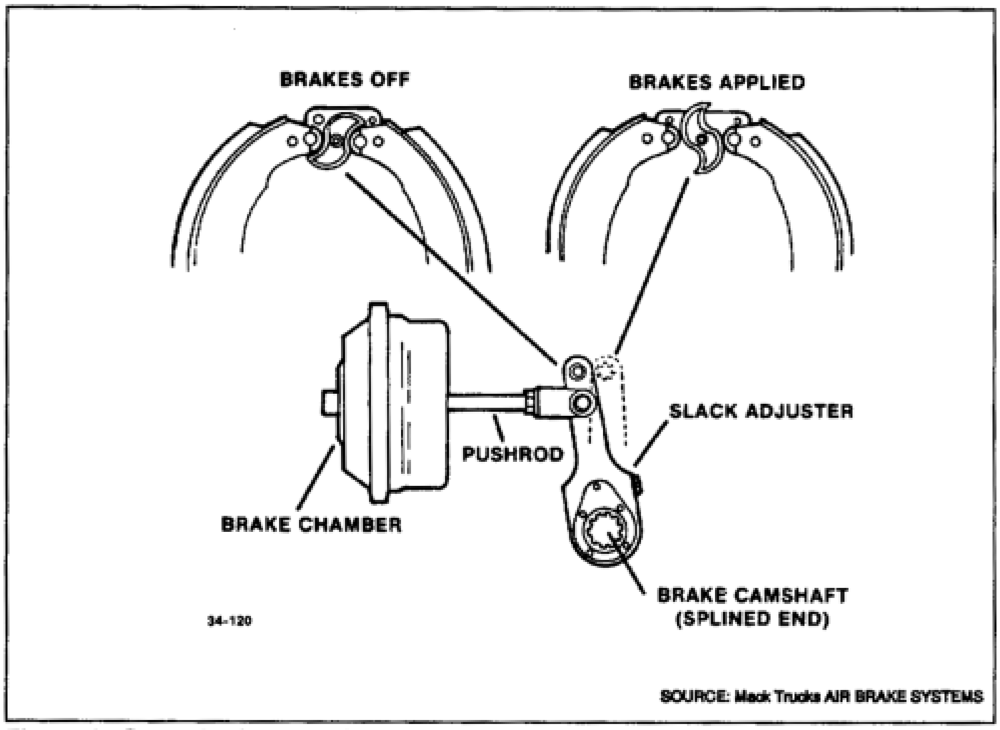


**Figure 7.** S-cam diagram.

Air brakes, when heated due to repeated applications, can also cause bottoming out, resulting in loss of braking capability. When heavy vehicle air brakes heat up, several components can be adversely affected. Heated brake drums expand, thereby increasing the distance that the brake shoes must move so that the lining contacts the drum; as a result, the S-cam must be rotated farther, requiring an extra, or reserve, pushrod stroke. (The reserve stroke refers to the distance remaining before the pressure plate in the brake chamber contacts the bottom of the chamber at the time of brake application.) If little reserve stroke remains on a cool brake (when brakes are out of adjustment), a hot brake can easily use up the small amount of extra stroke. If the brakes become too hot and do not have enough reserve stroke left, the pressure plate can bottom out in the chamber and the shoes will not contact the brake drum. Bottoming out causes an air-braked vehicle to lose its braking capability when descending a grade. It usually takes place when brakes near the limit of adjustment are repeatedly applied during a long descent.

**Accident Vehicle Brakes.** Table 3 lists the accident vehicle brake types, slack adjuster types and manufacturers, spring brake manufacturer, and type of spring brake caging port.[9]

[9] A caging port is a hole in the spring brake assembly into which a tool can be inserted to release the spring brake in the event that the vehicle needs to be towed.


**Figure 8.** School bus propane tank.

Mountainburg Public Schools began converting school buses to propane fuel in the mid-1980s because propane was about 75 cents cheaper per gallon than regular gasoline. When the price of propane rose in the mid-1990s, the school district stopped converting the school buses because the savings were minimal; at the time of the accident, the school district had two propane-fueled buses on regular routes and two spares.

With the assistance of the Mountainburg Public Schools transportation supervisor, Butane Gas Company of Mountainburg installed the tank on the accident bus some time in the early 1990s. The supervisor said that he was not aware that installation of the tank had to comply with any special regulations. The owner of Butane Gas Company stated that his firm followed all National Fire Protection Association (NFPA) and National Highway Traffic Safety Administration (NHTSA) regulations, as well as instructions from the manufacturer, in installing the tank.

The *National School Transportation Specifications and Procedures*[19] recommends that all propane tanks, including those installed on vehicles, comply with NFPA standard 58,[20] which specifies requirements for the propane tanks themselves and for their placement and installation. The NFPA requires that propane tanks be located where the possibility of damage is minimized. It states that containers in the rear of vehicles should be protected by substantial bumpers; those near the engine or exhaust system should be shielded from direct heating. Containers should not be mounted on the roof, ahead of the

[19] The *National School Transportation Specifications and Procedures* is a compilation of guidelines, not requirements, for school transportation. Representatives from industry and most of the States develop and modify the guidelines every 5 years.

[20] *National School Transportation Specifications and Procedures*, *2000 Revised Edition* (Warrensburg, Missouri: Missouri Safety Center, 2000), p. 16.

front axle, or behind the rear axle and should not protrude beyond the vehicle's sides or top. Containers mounted between the axles should have ample road clearance and should not be lower than the lowest point of the body, frame, engine, or transmission. The NFPA further requires that the container be securely mounted to prevent jarring loose, slipping, or rotating.

Neither the *National School Transportation Specifications and Procedures* nor the NFPA standards require cages surrounding propane tanks on school buses or crash tests for propane tanks installed on school buses. The *Federal Motor Vehicle Safety Standards* (FMVSSs) issued by NHTSA require that all fuel tanks installed by the original equipment manufacturer meet crash test standards; manufacturers comply with this requirement by placing cages around fuel tanks. NHTSA generally can only regulate equipment placed on vehicles when originally manufactured; the FMVSSs do not apply to aftermarket equipment, such as the retrofitted propane tank on the accident bus.[21]

Exterior damage to the school bus was limited to the right side and right roof area, extending 7 feet 2 inches from a point 2 feet forward of the right rear corner (see figure 9). The primary point of impact was in the area of the rear axle on the right side. After impact, the body partially separated from the chassis, which remained attached to the body below the driver's section. The propane tank, located underneath the floor on the right side of the bus about 4 feet forward of the impact area, was not damaged. The emergency exit door, located at the rear of the bus, was operable after the accident. The boarding door, which was underneath the bus when it came to rest, could not be opened.


**Figure 9.** School bus damage.

[21] NHTSA regulates new vehicles and items of equipment. If equipment is installed after the first consumer purchase, 49 *United States Code* 30122 is relevant to the product. It states that a manufacturer, distributor, dealer, or motor vehicle repair business may not knowingly make inoperative any part of a device or element of design installed on or in a motor vehicle or equipment in compliance with an applicable motor vehicle safety standard.

Inside the bus, intrusion occurred between rows 5 through 11; the area of greatest intrusion, approximately 25 inches, was between rows 7 and 8. The seats on the right in rows 6, 7, 8, and 9 shifted to the left, blocking the center aisle. The inboard seat legs and horizontal seat supports were fractured in rows 7 through 11 on the right side. The floor joints separated behind the busdriver's seat and at rows 5, 7, and 9; the linoleum flooring remained intact, so no openings were created. On the left side windows, glazing remained intact, except for the window adjacent to row 9; the glazing was broken on all right side windows, except for the top window adjacent to row 7.

## Highway Information

### *Highway Design*

The accident occurred at the intersection of SH-282 and the exit ramp from southbound I-540 (see figure 10). Construction on this part of I-540 began in January 1987, and it opened to traffic in January 1999. The exit ramp from southbound I-540 to SH-282 was completed summer 1999. Arkansas State Highway and Transportation Department (ASHTD) records show that no accidents were reported in the intersection for the 2 years that it had been open.

The exit ramp (see figure 11) from I-540 is a 15-foot-wide paved concrete lane, with tined surface texture, bordered by 6-foot paved asphalt shoulders to the west and 4-foot paved asphalt shoulders to the east, each delineated with thermoplastic edge lines. The exit ramp, as measured from the gore area[22] to the intersection curb line of SH-282, is approximately 1,342 feet long, with a difference in elevation of about 85 feet. The only ramp curvature is a horizontal curve as the ramp transitions from the interstate. The average grade of the ramp is about 6 percent; the steepest grade is 9.42 percent, encompassing a distance of about 293 feet and ending about 413 feet from the end of the ramp, after which the ramp transitions to a 0.03 percent grade 69 feet before the intersection, as measured on scene.

[22] The gore area is the triangular piece of land between the interstate and the ramp as the ramp transitions away from the interstate.

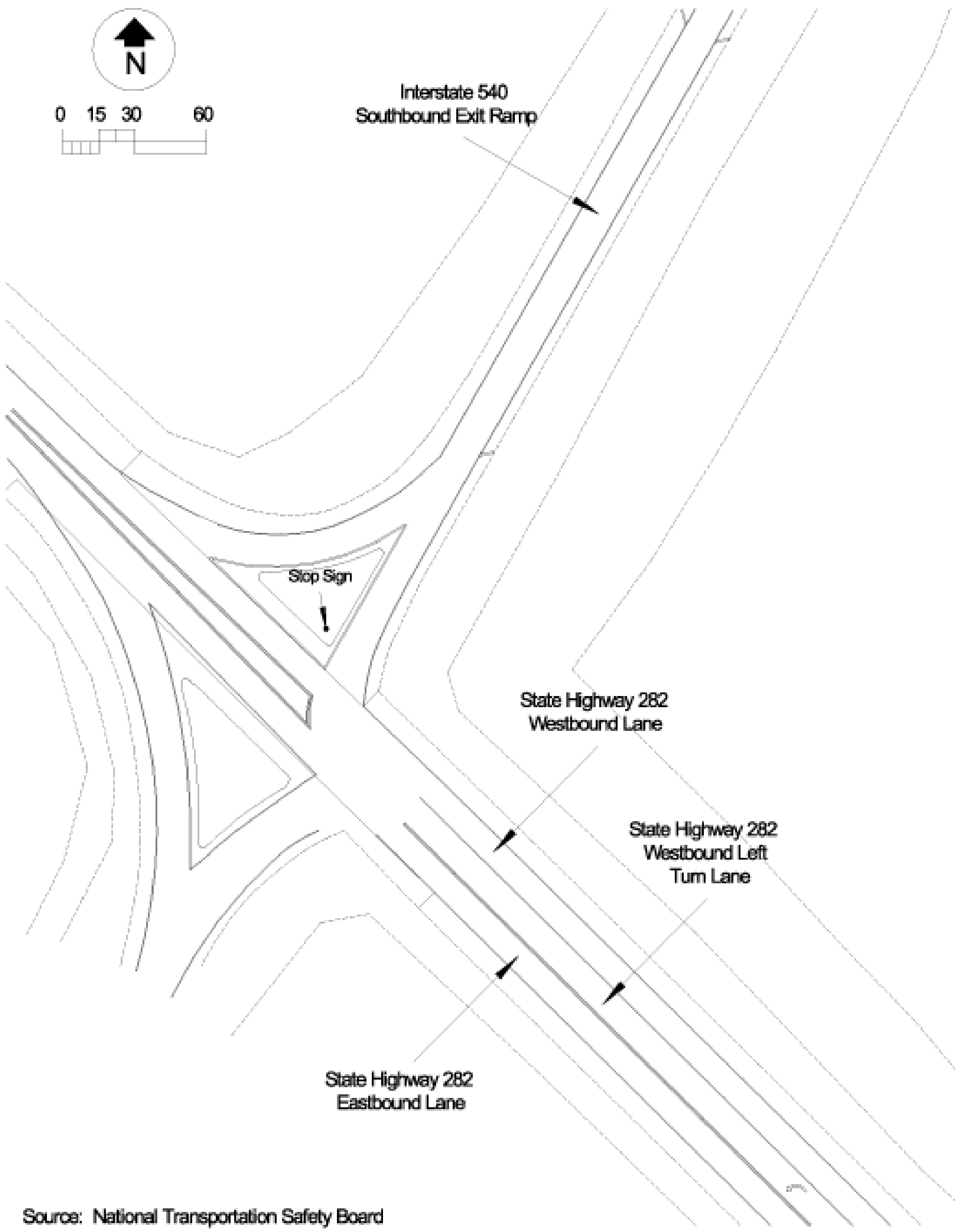


**Figure 10.** Intersection of ramp from I-540 south and SH-282.

**Figure 11.** Exit ramp from I-540 south to SH-282.

A 36-inch stop sign[23] was in place on the traffic island north of the intersection. An advance traffic control sign indicating "stop ahead"[24] was about 581 feet north of the stop sign in the grassy right-of-way on the right side of the exit ramp. A recreational area guide sign[25] was approximately 191 feet north of the "stop ahead" sign. Following the accident, the ASHTD installed additional signing. The ASHTD replaced the 36-inch stop sign with a 48-inch stop sign and erected another 48-inch stop sign on the left side of the ramp. It placed an additional 48-inch "stop ahead" sign on the left side of the ramp across from the original one, which is approximately 581 feet north of the stop sign. The ASHTD added a third 48-inch "stop ahead" sign on the right side of the ramp, approximately 881 feet north of the stop sign, and moved the recreation guide sign to the left side of the ramp.

The speed limit on I-540 is 70 mph for cars and 65 mph for trucks. No advisory speed signs are present on the exit ramp. In placing signage at the ramp, the ASHTD followed the *Manual on Uniform Traffic Control Devices* (MUTCD) guidelines, which state that a warning sign should be used to call attention to unexpected conditions and should be based on an engineering study or judgment.[26] The ASHTD did not believe these conditions applied at this ramp.

A review of the I-540 construction plans indicates that the truck descended four hills (and ascended three) between the Bunyard tunnel and the accident location (see

[23] U.S. Department of Transportation, Federal Highway Administration, *MUTCD 2000: Manual on Uniform Traffic Control Devices, Millennium Edition* (Washington, DC: FHWA, 2000), section 2B.04 (sign R1-1).

[24] MUTCD, section 2C.26 (sign W3-1a).

[25] MUTCD, section 2H.01.

[26] MUTCD, sections 2C.01 and 2C.02.

figure 12). While traveling southbound from the tunnel, the truck descended an average grade of 2.7 percent (steepest grade was 4.9 percent) over 3.84 miles; an average grade of 2.3 percent (steepest grade, 4.1 percent) over 3.40 miles; and an average grade of 1.8 percent (steepest grade, 2.5 percent) over 0.47 mile. On its approach to the ramp, the truck was descending an average grade of 3.3 percent (steepest grade, 4.4 percent) over 0.66 mile.

The annual average daily traffic for I-540 in 2000, as tabulated by the ASHTD, was 14,600 vehicles, of which about 21 percent were trucks. A 24-hour traffic count on June 13, 2001, showed that 36.7 percent of the 312 vehicles exiting onto the southbound ramp from I-540 were trucks. The June 13 ASHTD traffic count showed that trucks accounted for 32.3 percent of the 460 eastbound and 13.2 percent of the 988 westbound vehicles on SH-282.

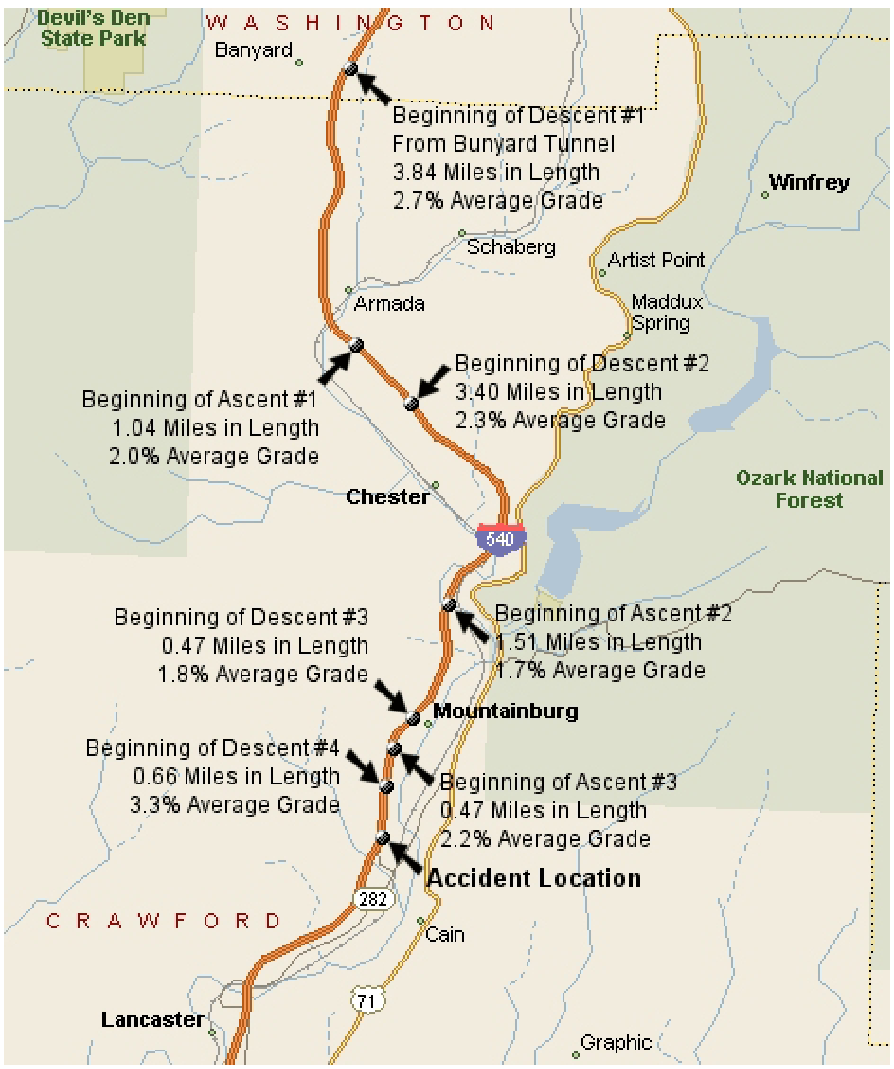


**Figure 12.** Grade map.

In the vicinity of the accident, SH-282 is a two-way, two-lane paved asphalt roadway running east-west. At the time of the accident, a combination of painted markings and raised, mountable concrete islands (2 inches high at the edges and 6 inches high overall) channelized the traffic lanes on both sides of the intersection. A left turn lane, about 12 feet wide, was available for westbound traffic turning onto the entrance ramp to southbound I-540. The east and westbound traffic lanes were about 11 feet wide and bordered by paved shoulders about 8 feet wide and delineated by painted edge lines. Standard pavement markings (a yellow painted double centerline) divided opposing lanes of traffic. The speed limit for SH-282, as posted on a sign approximately 1 mile east of the accident site, was 55 mph.

### *Tire Marks*

The truck-tractor semitrailer produced multiple tire marks beginning on the east shoulder of the exit ramp, about 30 feet north of the area of impact, and continuing southwest across the intersection. The left front tire created a scuff mark,[27] and a series of chips in the asphalt surface were in line with the scuff mark. From the area of impact, the longest tire mark, about 89 feet, traversed the south traffic island and continued toward the area where the truck tractor came to rest. The truck-tractor semitrailer produced multiple north-south scrape marks[28] after the unit had rolled onto its left side.

Investigators observed no tire marks on SH-282 leading to the area of impact. The school bus produced multiple tire marks beginning at the area of impact and continuing southeast intermittently over a distance of about 110 feet. The longest tire marks terminated in the area where the school bus came to rest. The school bus produced a single deep scrape mark that ran west to east at the area of impact; investigators found no other scrape marks related to the collision.

## Operational Information

### *Gayle Stuart Trucking*

Stuart Trucking began operating as a for-hire interstate carrier[29] of agricultural commodities, grain, feed, hay, and dry bulk in Vandalia, Missouri, in 1988; the company also conducted farming operations. At the time of the accident, the motor carrier owned 16 tractors and 23 trailers; leased[30] 3 tractors and 2 trailers; and traveled about 1.777 million miles annually. The motor carrier reported 17 full-time drivers, including 3 who drove leased vehicles, on its payroll.

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[27] Scuff marks result when a tire slides while the wheel is still rotating.

[28] Scrape marks are produced when any part of a vehicle, other than the tires, contacts the ground while the vehicle is still in motion.

[29] Operating under USDOT number 376158 and ICC number 213891.

[30] The lease agreement is a contract stipulating the contractor's responsibilities regarding insurance, maintenance, driver control, and payment. The contractor is responsible for maintaining the vehicle.

The motor carrier used State United Laboratories of Omaha, Nebraska, for pre-employment, random, and postaccident drug testing. State United Laboratories conducted random tests every 3 months, testing 1 to 6 drivers each period.

### *Mountainburg Public Schools*

Mountainburg Public School District includes three schools—a high school, a middle school, and an elementary school. It covers 197 square miles and the school buses transport 790 students more than 111,250 miles annually; in addition, activity trips account for about 25,000 miles. At the time of the accident, the school district had 12 school bus routes, 11 full-time busdrivers, 2 part-time drivers, and 10 substitute drivers.

The school district uses a local medical clinic to conduct alcohol and drug testing of its busdrivers. Safety inspections are conducted on the school buses before the school year begins and at midyear. All district school buses are equipped with cellular telephones for communication with the school district and maintenance shop and for emergencies.

The Arkansas State Department of Education trains the district's school bus drivers. In August, the department conducts annual recertification of school bus drivers, covering topics such as driving techniques, loading and unloading procedures, bus stop location, and changes in operating procedures. In 2000, the school district superintendent conducted an additional meeting with the bus drivers before the school year began; it covered areas such as reporting times, policies and procedures, problems that developed since the previous school year, and route changes.

## Management Information

### *Gayle Stuart Trucking Company*

The Stuart Trucking corporate structure comprised a president, vice president, and safety manager. Company officials said they conducted telephone interviews with previous employers listed on a driver's application and that the company's insurance carrier provided motor vehicle driving records on all drivers.

Before starting work at Stuart Trucking, according to company officials, drivers received 3 hours training in hopper-bottom trailer operation, brake adjustment procedures, and logbook entry. The motor carrier reported that it held safety meetings every 6 months attended by all drivers; the meetings covered issues such as driving procedures, loading and unloading trucks, and load securement. The motor carrier said that it conducted periodic recurrent training in logbook entry, trailer cleaning, and other operational problems. The accident driver had attended the safety meetings but had not attended any recurrent training. Stuart Trucking did not conduct mountain-driving training.

Company practice was for all drivers to be home on weekends, according to the carrier, and drivers turned in their logbooks each week for auditing by company safety personnel, who reported no problems with the accident driver's logbook prior to the accident. Nonetheless, Safety Board investigators found errors when they reviewed the logbook, and the driver admitted to falsifying his logbook. In its June 1, 2001, compliance review, the Federal Motor Carrier Safety Administration (FMCSA) found at least one instance of falsified logbooks during its compliance review of Stuart Trucking. In comparing several other drivers' logbooks with data from a Global Positioning System on the trucks that tracked and recorded truck locations over the previous 10 days, inspectors found that the logbook entries correlated with the truck locations.

Stuart Trucking employed one mechanic, who also drove for the company and worked on farm equipment. Title 49 Part 396.25, "Qualification of Brake Inspectors," states that the brake inspector is any employee of the motor carrier or any other person who is responsible for ensuring that all brake inspections, maintenance, service, or repair meet Federal standards. The CFR goes on to say that the brake inspector is required to be certified 1) by participating in a training program sponsored by a brake or vehicle manufacturer or a Federal or State agency or 2) by having experience performing brake maintenance or inspection for a period of at least 1 year. Additionally, any employee who is responsible for the inspection, maintenance, service, or repair of any brakes on commercial vehicles must meet the minimum qualifications. Stuart Trucking's mechanic had more than 1 year of experience performing brake maintenance and service. Stuart Trucking reported that neither its drivers nor its mechanic had the required certification, and the owner said he was not aware of the regulation.

On December 5, 1989, the Federal Highway Administration's (FHWA's) Office of Motor Carriers (OMC), now the FMCSA, conducted a safety review of Stuart Trucking that resulted in a satisfactory rating. Following this accident, the FMCSA conducted a compliance review on June 1, 2001, that resulted in a conditional rating for the driver factor because of the following violations:

- Using a driver who was not medically examined and certified during the preceding 12 months;
- Failing to retain inquiries into the driver's driving record in the qualification file;
- Requiring or permitting a driver to drive more than 10 hours;
- Requiring or permitting a driver to drive after having been on duty 15 hours; Not adhering to the 70-hour rule;[31] and
- Entering a false report of records-of-duty status.

The review did not mention the missing "Qualified Brake Inspector" certification.

[31] The 70-hour rule limits drivers to 70 hours of working-driving time within 8 consecutive days.

The motor carrier received an unsatisfactory rating for the accident factor because its accident rate was 1.688 recordable crashes per million miles traveled.[32] The combination of a conditional rating in one factor and an unsatisfactory rating in another resulted in an overall conditional rating, which Stuart Trucking still maintained in August 2002. The review noted that the motor carrier's maintenance records were in compliance with the FMCSRs requirements.

The FMCSA did not inspect any vehicles during the 2001 compliance review; it included only information from roadside inspections in the compliance review report. Title 49 CFR Part 385 requires vehicle inspections during a compliance review if fewer than 3 trucks were inspected during roadside inspections in the previous year or if more than 34 percent of roadside inspections in the previous year resulted in trucks being placed out of service. In the 12 months before the accident, the FMCSA had conducted 29 roadside inspections on Stuart Trucking vehicles, four of which (14 percent) were placed out of service for brake adjustment violations. Therefore, FMCSA inspectors were not required to inspect the carrier's vehicles during the compliance review. Other out-of-service violations noted in the roadside inspections related to logbooks, equipment, and alcohol.

Following the accident, Safety Board investigators asked the Missouri Division of Motor Vehicles and Railroad Safety to inspect all of the motor carrier's vehicles at the terminal and on the road. Of nine vehicles inspected at the motor carrier's facility, four had out-of-service defects (a 44 percent out-of-service rate).[33] Of three units inspected on the road, one was placed out of service for inoperative stop lamps; one driver was placed out of service for logbook violations. According to company officials, Stuart Trucking conducted general maintenance, including brake adjustment, every 15,000 miles and extensive maintenance every 30,000 to 40,000 miles. The Missouri inspectors stated that Stuart Trucking staff seemed to be lacking in knowledge of maintenance and that some defects found were obvious and did not appear to be recent.

### *Federal Oversight*

The Motor Carrier Safety Act of 1984 directed the U.S. Secretary of Transportation to establish procedures to determine the safety fitness of commercial motor vehicle owners and operators engaging in interstate and foreign commerce. Subsequently, the FHWA promulgated a set of safety fitness standards and established a methodology for determining whether a carrier has adequate safety management controls to ensure acceptable compliance with the safety requirements. As a result of the Motor Carrier Safety Act of 1990 and a 1997 rulemaking, the FHWA modified the original methodology.

[32] Carriers that operate in an area more than 100 miles in radius and that have an accident rate greater than 1.5 recordable crashes per million miles traveled receive an unsatisfactory rating (see 49 CFR Part 385, appendix B).

[33] These defects included brakes out of adjustment, defective or inoperative brakes, defective leaf spring assemblies, defective axle positioning parts, suspension cracks, and inoperative rear turn signals.

Six factors (see table 5) provide the basis for determining a carrier's safety rating, that is, the degree to which the carrier is in compliance with the FMCSR and therefore meets the safety fitness standard. Each factor is rated satisfactory, conditional, or unsatisfactory. A satisfactory rating means the carrier has not violated any acute regulations (see definition below) or shown a pattern of noncompliance with critical regulations for that factor. A conditional factor means the carrier has violated one acute regulation or has a pattern of noncompliance with critical regulations. An unsatisfactory rating means the carrier has violated two or more acute regulations or has patterns of noncompliance with two or more critical regulations. Factor 6, the accident factor, is based on the number of accidents in relation to the carrier's size.

**Table 5.** Motor carrier safety rating factors.

| FACTOR | APPLICABLE FMCSRs OR OTHER CRITERION |
|---|---|
| Factor 1 – General | Parts 387 and 390 |
| Factor 2 – Driver | Parts 382, 383, and 391 |
| Factor 3 – Operational | Parts 392 and 395 |
| Factor 4 – Vehicle | Part 393 and 396 |
| Factor 5 – Hazardous Materials | Parts 171, 177, 180, and 397 |
| Factor 6 – Accident | Recordable Preventable Rate |

Acute violations of the FMCSRs or Hazardous Material Regulation are those that demand immediate corrective action regardless of the motor carrier's overall safety posture. For example, requiring or permitting the operation of a vehicle declared out of service before repairs are made (49 CFR 396.9[c][2]) is an acute violation.

Critical violations are regulatory violations that indicate breakdowns in a motor carrier's management controls. For instance, requiring or permitting a driver to drive after having been on duty for 15 hours (49 CFR 395.3[a][2]) is a critical violation.

The rating for the first five factors and the accident rate for the 12 months before the review are entered into a rating table, which is used to establish the motor carrier's safety rating (see table 6). Each of the six factors is given equal weight.

**Table 6.** Motor carrier safety rating table.

| FACTOR RATING | | SAFETY RATING |
|---|---|---|
| **Number of Unsatisfactory Ratings** | **Number of Conditional Ratings** | **Resultant Safety Rating** |
| 0 | 2 or less | Satisfactory |
| 0 | more than 2 | Conditional |
| 1 | 2 or less | Conditional |
| 1 | more than 2 | Unsatisfactory |
| 2 or more | 0 | Unsatisfactory |

### *State Oversight*

**Missouri.** The Missouri State Police administer the Motor Carrier Safety Assistance Program (MCSAP)[34] in Missouri, and the State Police handle motor carrier enforcement and roadside inspections. The Division of Motor Carrier and Railroad Safety conducts terminal audits similar to those conducted by the FMCSA, and the division conducted the follow-up inspection of Stuart Trucking requested by Safety Board investigators.

**Arkansas.** In Arkansas, the MCSAP is administered by the Arkansas Highway Police, which is the primary enforcement agency for all laws pertaining to axle and gross weights, the movement of oversize loads or vehicles, vehicle licensing, motor fuel tax, and special distillate motor vehicle fuel tax. The Arkansas Highway Police conduct all motor carrier enforcement.

## Meteorological Information

At the Fort Smith, Arkansas, Regional Airport, approximately 23 miles from the accident site, the weather was partly cloudy with winds from the west at about 13 mph at 3:53 p.m. on May 31, 2000. The temperature was 69° F and the dew point was 60°.

[34] The MCSAP is a Federal program administered by the FMCSA that provides funds to the States and U.S. Territories in support of commercial motor vehicle safety.

## Tests and Research

### *Sight Distance*

Safety Board investigators conducted sight distance tests after the accident. At a driver eye height of 74 inches[35] above the pavement, a motorist could see the stop sign from the transition area[36] to the end of the ramp, a distance greater than that prescribed by the American Association of State Highway and Transportation Officials (AASHTO). The "State park" sign then in place north of the "stop ahead" sign could impede a motorist's view of the "stop ahead" sign from a distance of 684 feet until the driver was about 569 feet from the "stop ahead" sign (see figure 13). Since the accident, Arkansas has moved the "State park" sign to the other side of the ramp, where it does not impede a driver's view of the "stop ahead" sign, and has added "stop ahead" signs. When the ramp was constructed, it was cut into existing terrain, and a grass berm runs parallel to and east of the ramp. A stop sign for traffic exiting I-540 onto SH-282 is in place at the intersection. Safety Board visibility test results showed that, when stopped at the intersection, a driver has a clear line of sight to the east exceeding 582 feet. A driver on westbound SH-282 is not able to see traffic on the exit ramp until the driver is 51 feet east of the intersection.

### *Brake Heat Tests*

From September 5 to 7, 2001, Safety Board investigators measured the brake temperatures[37] of 65 tractor semitrailers traversing the same ramp used by the accident truck. Table 7 lists the daily average brake temperatures for each axle.

As brakes heat up, for example, through repeated application, the drum expands, requiring a greater stroke for the same brake force, and the lining friction decreases. Stroke can increase by about 0.1 inch per 100° F.[38] At temperatures above 700° F, even a well-adjusted brake can reach out-of-adjustment limits, requiring more than 0.5 inch of additional stroke, and the brake may run out of stroke before the shoe contacts the drum.

Brake linings are composed of glue and strengthening material, and when they become hot, the glue softens and begins to melt. As a result, the linings become slick and provide less friction, no longer offering the same level of resistance to the rotation of the drums. When brake lining temperatures exceed 500 to 600° F, the friction between the lining and the drum drops abruptly, further reducing the brake system's ability to provide a retarding force for the vehicle.

[35] AASHTO assumes a driver's eye height is 70 to 94 inches for large trucks and uses 94 inches for design purposes. The Safety Board investigator who conducted the tests has an eye height of 74 inches.

[36] The transition area, which is adjacent to the gore area, is the curved portion of the ramp as it departs from the interstate.

[37] Investigators used an infrared thermometer (Omega OS533) and took measurements directly from the exterior of each brake drum.

[38] U.S. Department of Transportation, Federal Highway Administration, *Evaluation of Brake Adjustment Criteria for Heavy Trucks*, FHWA-MC-94-016 (Washington, DC: FHWA, 1995), p. 8.

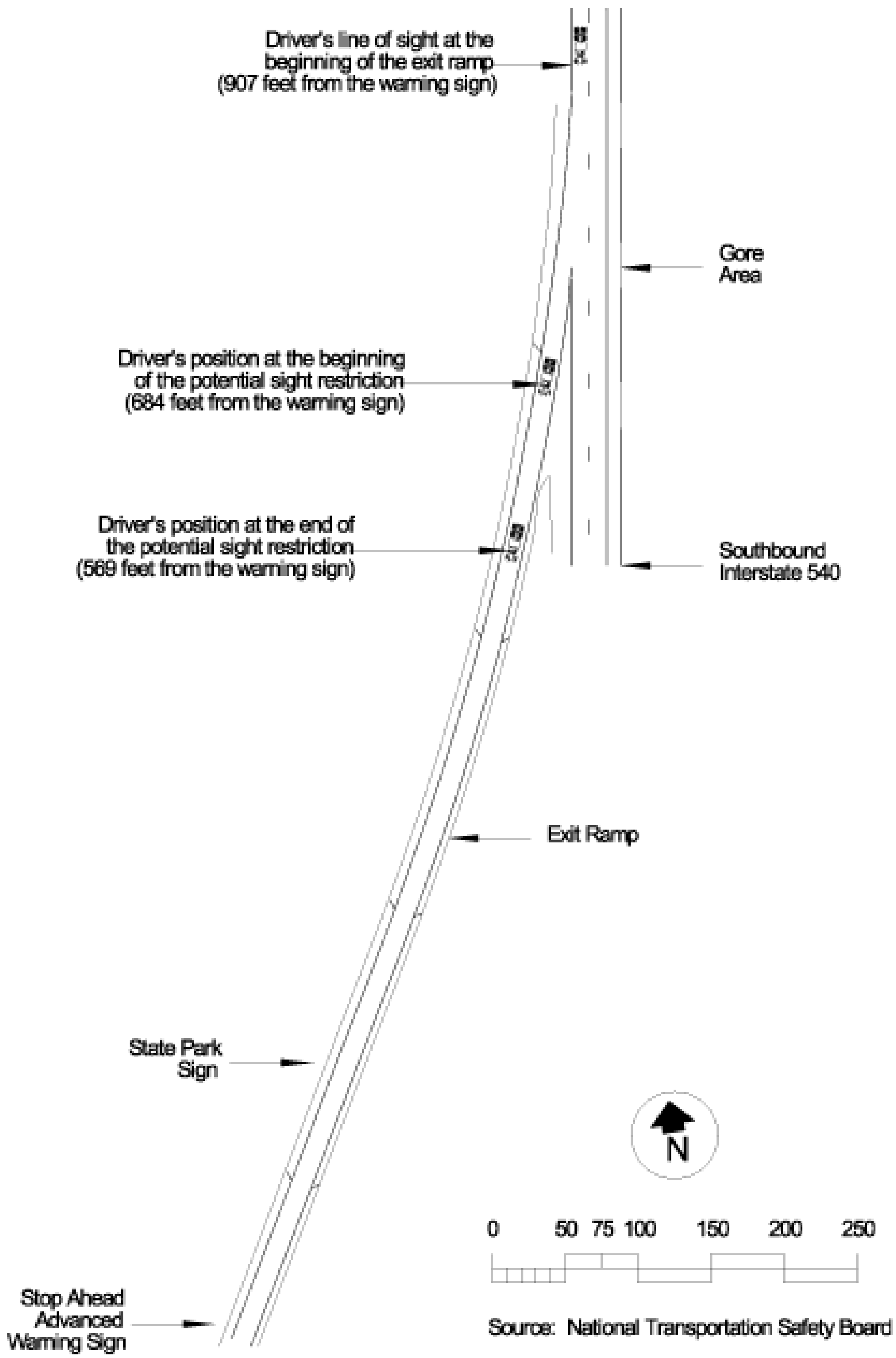


**Figure 13.** Ramp sight distance.

**Table 7.** Average brake temperature (° F).

| | AXLE 1 LEFT | AXLE 2 LEFT | AXLE 3 LEFT | AXLE 4 LEFT | AXLE 5 LEFT |
|---|---|---|---|---|---|
| **September 5** | 127 | 225 | 232 | 247 | 265 |
| **September 6** | 121 | 244 | 258 | 258 | 251 |
| **September 7** | 133 | 201 | 209 | 221 | 234 |

If some brakes are out of adjustment, the brakes that are within adjustment provide a disproportionate share of the braking, thus heating more rapidly, further reducing overall braking efficiency more quickly.[39] Rockwell International tested the effects of poorly adjusted brakes in the late 1980s.[40] Researchers used various initial brake temperatures to compare brakes fully adjusted with brakes backed off beyond the recommended stroke. At 150° F, the average stopping distance from 60 mph for a 55,000-pound truck-tractor semitrailer increased 34 percent when brakes were backed off beyond the recommended stroke, and at 400° F, the stopping distance increased 76 percent.

The accident truck, which was not equipped with an engine retarder, descended four grades over the 11.3 miles from Bunyard tunnel to the exit ramp onto SH-282. A grade severity computer analysis[41] showed that, had the driver used his brakes to slow on the first three downgrades, he may have noticed some degradation in the accident tractor semitrailer's braking capability, since the temperature exceeded 900° F at the bottom of the second downgrade. The brakes would have cooled somewhat on the upgrades and on the third descent,[42] resulting in the tractor semitrailer's brake temperature at the top of the final hill reaching approximately 800° F.

The grade severity computer analysis also showed that if all the brakes had been properly adjusted, they would have heated to 119° F at the top of the ramp and to 234° F when the vehicle reached the final stop at the end of the ramp.

[39] National Transportation Safety Board, *Heavy Vehicle Airbrake Performance,* Safety Study NTSB/SS-92/01 (Washington, DC: NTSB), p. 31.

[40] Leonard C. Buckman, *Commercial Vehicle Braking Systems: Air Brakes, ABS and Beyond* (Warrendale, PA: Society of Automotive Engineers, 1988), p. 79.

[41] The Grade Severity Rating System (GSRS) is a computer program developed under an FHWA-funded project. The purpose of the GSRS is to assist highway engineers in signing grades in order to reduce the number of runaway heavy trucks. The GSRS also predicts the brake temperature as a vehicle travels down the grade.

[42] The average grade on the third descent was 1.7 percent, so not much braking was needed; the truck's aerodynamic drag was 1.4 percent.

### *Simulation*

Using the HVE system[43] and the SIMON[44] and EDSMAC4[45] software programs, Safety Board investigators simulated the tractor semitrailer's final ascent and descent to the accident site and the collision with the school bus. Based on the physical evidence, the EDSMAC4 simulation showed that the tractor semitrailer's speed immediately prior to impact was about 48 mph and the school bus was traveling about 50 mph. The simulation results indicated that the tractor semitrailer's postimpact speed was about 48 mph and that the bus's postimpact speed was about 39 mph. The simulation also showed that the berm to the left of the ramp and the truck's left mirror may have interfered with the truckdriver's view of the bus as the two vehicles approached the intersection.

To simulate the truck's braking capability as the brakes heated due to repeated application during the descent, investigators obtained truck brake performance data related to temperature from ArvinMeritor. The data terminated at 603° F. Safety Board staff extrapolated that data to take into account the higher temperatures for this tractor semitrailer during the descent with the brakes out of adjustment. Staff incorporated into the SIMON simulation a braking strategy that entailed pumping the brakes using 30 pounds per square inch of pressure for 3 seconds.[46] This strategy, according to the FHWA, is the most efficient method of braking. The simulation showed that the tractor semitrailer was traveling 55 to 60 mph at the bottom of the third descent, reduced its speed as it traveled up the last ascent to between 22 and 27 mph at the crest, and was traveling 29 to 34 mph in sixth gear at the top of the ramp. On the final descent prior to the ramp, the simulation showed that the driver was able to apply the brakes about seven times to prevent the tractor semitrailer from accelerating, but the brakes continued to heat to the point that with each subsequent brake application, the truck's braking force decreased and the truck gained more speed, even while the brakes were applied, accelerating to 48 mph at impact.

[43] The Engineering Dynamics Corporation developed HVE, a Human, Vehicle, Environment system, for engineers and scientists to use as a simulation tool to study vehicle and occupant kinematics.

[44] Simulation Model Non-linear, or SIMON, allows users to simulate the response of one or more vehicles to driver inputs and environmentally related factors. It is designed to fully utilize the HVE Brake Designer.

[45] EDSMAC4, or the Engineering Dynamics Corporation Simulation Model of Automobile Collisions, fourth revision, permits simulation of single- or multiple-vehicle crashes and is based on SMAC, which Calspan developed for NHTSA.

[46] Paul S. Fancher, Christopher B. Winkler, et al., *Influence of Braking Strategy on Brake Temperature in Mountain Descent*, UMTRI-92-11/FHWA/MC-93/002 (Washington, DC: FHWA). This publication recommends applying 20 psi on a truck with adjusted brakes, but because of this truck's poor brake condition, 30 psi was used.

## Other Information

### *Brake Data*

Currently, data are not available that provide information on the extent to which brakes cause or contribute to truck-related accidents. The U.S. Department of Transportation (DOT) is conducting a study on large truck crash causation that is scheduled to be completed in 2004. According to the FMCSA, the report will contain such data.

In 1990, the Safety Board inspected 1,520 vehicles and found that 56 percent of the trucks inspected had been placed out of service for brake violations; that figure included 46 percent placed out of service for out-of-adjustment brakes.[47,48] Results of a 1996 National Fleet Safety Survey found that 29 percent of trucks randomly inspected at roadside were placed out of service; about 49 percent of the out-of-service violations were brake-related.[49]

The CVSA sponsors Operation Air Brake annually to promote and reinforce the need for drivers to check and adjust air brake systems and to educate drivers on the serious risks associated with operating a heavy vehicle that has inadequate brakes.[50] The results of inspections conducted on six occasions during Operation Air Brake in 2000 and 2001[51] showed that, on average, 13 percent of commercial vehicles inspected were placed out of service for having brakes out of adjustment. An average of 9.6 percent of brakes equipped with manual slack adjusters were out of adjustment and 4.3 percent of brakes equipped with automatic slack adjusters were out of adjustment. Approximately 65 percent of the brakes checked had automatic slack adjusters.

### *Brake Adjustment Methodology*

Automatic slack adjusters have been offered as optional equipment since the late 1960s and have been required on all new commercial vehicles since October 20, 1994. Brake adjustment indicators have also been required on all new commercial vehicles since October 20, 1994. Any vehicle manufactured before that date does not have to be retrofitted and can continue to operate using manual slack adjusters.

Two common methods are used to measure brake adjustment on S-cam brakes, which are the most frequently used type of service brake. Using the manual method, one person, who pulls on the pushrod by hand or uses a pry bar, can measure the stroke.

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[47] NTSB/SS-92/01, p. 39.

[48] A vehicle is out of service if 20 percent or more of its brakes are out of adjustment.

[49] Terry Shelton, "Truck Brake Statistics in the U.S." *Report of Proceedings of the North American Brake Safety Conference, September 15-16, 2000* (Toronto, Canada: CVSA, 2001), p. 12.

[50] John Meed, "Operation Air Brake Report," *Report of Proceedings of the North American Brake Safety Conference, September 15-16, 2000* (Toronto, Canada: CVSA, 2001), p. 15.

[51] The CVSA conducted the inspections on the same days in a number of States. In May 2000, the inspections took place in 27 States; in September 2000, in 22 States; in October 2000, in 25 States; in May 2001, in 28 States; in September 2001, in 29 States; and in October 2001, in 17 States.

According to Allan C. Wright, author of a book on air brakes, "one half inch [stroke] is ideal" when using the manual method; "the maximum allowable stroke, before readjusting, is one inch."[52] This method can result in inconsistent measurement due to variables such as the strength of the person pulling the pushrod, the length of the pry bar, or the force exerted on the pry bar. The second, more accurate method requires two people, one to apply the brake to an air pressure of 80 to 90 psi and another to measure the stroke.

Ideally, a brake shoe should be adjusted as close as possible to the drum without dragging (the shoe touching the drum). The American Trucking Association's Technology and Maintenance Council recommends backing off the adjusting nut until the wheel turns freely, making the stroke as short as possible without the brakes dragging.[53] This adjustment can also be accomplished without jacking up the vehicle by backing off the adjustment nut while simultaneously hitting the drum with a small hammer or wrench. When the "dull thud" becomes a "ringing sound," the adjustment nut should no longer be turned, since the ideal shoe-drum clearance has been reached. Bendix Commercial Vehicle Brake Systems (Bendix) recommends adjusting the slack adjuster so that the pushrod travels 3/8 inch when manually extended to contact the brake shoes with the brake drums.[54]

Determining when to adjust the brakes depends on many variables, including terrain traveled, weight of load, use of engine retarders, size of brakes, miles traveled, age of brakes, and driver's braking habits. As explained in the Safety Board's 1992 study of *Heavy Vehicle Airbrake Performance*, industry recommendations for the adjustment interval varied: Kenworth suggested the pushrod travel be checked and adjusted every 6,000 miles; Bendix suggested every month, 300 operating hours, or 8,000 miles; and Rockwell International and Eaton Corporation suggested adjustment be made whenever the pushrod stroke exceeded adjustment limits.

### Spring Brakes

Federal regulations require that a vehicle be held by mechanical means (without use of electrical power) when parked after all air has been bled out of the system.[55] When the vehicle is operating, a continual supply of air to the emergency-parking chamber compresses the power spring so that the spring applies no force to the pushrod. When air is released from the chamber, the spring force moves the chamber pushrod, applying the service brakes. The operational life of the power spring depends on factors such as the quality of the spring material, spring size, application cycle, and exposure to natural elements (water and salt, for example). According to Haldex, springs under adverse conditions, such as salt-treated roadways and frequent use, may last only 1 or 2 years before they need to be replaced; Holland Anchorlok[56] springs are guaranteed for 6 years.

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52 Allan C. Wright, *Airbrakes From the Driver's Seat* (Richmond, British Columbia, Canada: Presto Print Limited, 1984), p. 17.

53 "TMC Recommended Practice," RP 609A, 2001.

54 <www.bendix.com/downloads/service_date_sheet/manualslacks.pdf>.

55 Title 49 CFR Part 571.121.S5.6.3.2.

56 Haldex purchased Anchorlok in January 2002.

A broken spring, which is difficult to detect, can reduce emergency-parking brake forces or render the emergency-parking brake inoperable, and the broken spring pieces can be displaced, thus shortening the pushrod stroke or preventing the automatic slack adjuster from functioning. The extent of the broken spring problem is undetermined. Radlinski and Associates, a brake consulting firm, reported to investigators that in an inspection of 11 five-axle combination trucks at a large firm with an excellent maintenance program, an inspector found an average of two broken spring brakes on each tractor semitrailer.

Broken spring brakes are not an out-of-service item if detected during CVSA inspections, nor is visual examination of spring brakes an inspection item. Regulations do not require use of dust covers over the caging port to prevent contaminants from getting into the spring brake assembly.

# Analysis

Truck-tractor semitrailers represented 4 percent of all vehicles on the road in 2000 and accounted for 8 percent of vehicle miles driven; 12 percent of fatalities occurred in accidents involving these vehicles.[57] The Safety Board has investigated numerous accidents involving tractor semitrailers in the past 30 years and made many safety recommendations related to truck brakes, which are the most common reason trucks are placed out of service. The Mountainburg accident again clearly demonstrates that when brakes do not function properly, they compromise vehicle safety, sometimes with tragic consequences.

Statistically, school buses are one of the Nation's safest modes of transportation; on average, fewer than 10 passengers die each year as a result of school bus accidents. The fatalities that do occur, as in the case of the Mountainburg accident, generally happen when a train or large truck strikes a bus laterally. In this accident, the brakes on the truck were out of adjustment, thereby degrading its braking capability, and the truck was unable to stop before colliding with the school bus.

In the following analysis, the Safety Board will first exclude those factors that did not cause or contribute to the accident and then examine those factors that were causal or otherwise had a role. The discussion will focus on the poor condition of the brakes, inadequate motor carrier inspections and oversight, the use of fuel tanks on school buses, and occupant protection within school buses. The Safety Board has addressed these issues in previous accident investigations and will consider them below in the context of relevant safety recommendations from the earlier investigations.

## The Accident

### *Exclusions*

The accident occurred in midday when the weather was clear and dry. Postaccident inspection of the school bus revealed no mechanical problems. Results of postaccident drug and alcohol tests for both the truckdriver and the busdriver were negative. Both drivers held valid commercial driver's licenses and medical certificates. The roadways were in good condition and complied with AASHTO guidelines; the interstate and ramp signing was in compliance with the MUTCD. Emergency response was timely and adequate. The school bus was traveling about 50 mph at the time of the collision; the speed limit on SH-282 was 55 mph. The truckdriver admitted that he had falsified his logbooks to appear to be in compliance with Federal hours-of-service rules, and he later

[57] U.S. Department of Transportation, National Highway Traffic Safety Administration, *Traffic Safety Facts 2000: Large Trucks*, DOT HS 809 325 (Washington, DC: NHTSA, 2001).

described his actual work and rest times to Safety Board investigators. Until May 28 (3 days before the accident), he was off duty at home for 3 days, where he said he maintained a normal work-rest cycle, that is, awake and active during daylight hours and resting during nighttime hours. During the 3 days before the accident, he said he slept in the truck's sleeper berth each night, maintaining a normal work-rest cycle. Investigators compared data available from fuel receipts and bills of lading for the accident vehicle against travel times between locations on the driver's route and found no conflict with the work-rest cycle he described. The driver's schedule did not include the required 8 hours off-duty time, and the truckdriver obtained 5.5 to 6.5 hours of sleep per night.

However, the accident scenario does not indicate that the driver was fatigued. He successfully steered the truck onto the exit ramp and applied the brakes in an attempt to slow the truck before the accident. Had the driver not applied the brakes, the truck would have been traveling much faster due to the downgrades on the interstate and ramp. While investigators could not determine whether the driver was fatigued, his actions just prior to the collision do not suggest that fatigue was a factor in this accident.

The Safety Board concludes that there was no evidence of drug or alcohol use by the drivers and that the weather, mechanical condition of the school bus, design and signing of the highways, emergency response, and truckdriver fatigue did not contribute to the accident.

### *Accident Discussion*

The tractor semitrailer did not stop for the stop sign at the bottom of the ramp because the brakes, all of which were either out of adjustment, poorly maintained, or overheated, could not provide enough retarding force. The driver said he slowed his vehicle prior to the exit and, as he was departing I-540, applied the brakes to slow further, but the vehicle did not respond. He stated that he saw the stop sign at the end of the ramp and realized that he would be unable to stop the vehicle or, given the truck's speed, make the turn onto SH-282 without overturning the vehicle. Therefore, he decided to continue across the highway and up the opposite ramp in an attempt to slow the truck. The driver hoped that traveling up the entrance ramp to I-540 would reduce vehicle speed sufficiently to allow him to bring it under control. As the simulation indicated, he could not see the school bus on SH-282 because the berm to the left of the ramp and the truck's left mirror obstructed the driver's view of the bus as the two vehicles approached the intersection. Before impact, the tractor semitrailer was traveling an estimated 48 mph and the school bus was traveling about 50 mph. The simulation showed that the tractor semitrailer's speed at separation was about 48 mph and that the bus's postimpact speed was about 39 mph.

As the grade severity computer analysis and the simulation showed, the driver probably used his brakes to maintain speed as he descended the first three downgrades from the Bunyard tunnel. Each time he applied the brakes, the brake temperatures increased. At the bottom of the second descent, the brake temperatures exceeded 900° F, according to results of the grade severity computer analysis, and the brakes quite likely could provide little braking force. At this point, the driver may have perceived that the brakes were not functioning properly. He probably did not suspect a serious problem with the brakes because his father had installed slack adjusters on the tractor 4 days earlier.

The driver was familiar with the location of the Mountainburg exit and the hills near it because he had driven this route often, but he stated that he had never exited onto SH-282 from I-540 southbound. He would not have had to apply the brakes too forcefully to maintain speed going down the third descent because of its moderate grade. At the bottom of the third descent near the sign for the exit, the simulation showed that the tractor semitrailer was traveling 55 to 60 mph. The simulation also indicated that the driver did not accelerate while going up the third ascent, probably in an effort to limit his speed so that he would not have to use his brakes extensively as he neared the exit ramp. At the top of the third ascent, the tractor semitrailer's speed was 22 to 27 mph, and as the vehicle traversed the final descent, the driver probably pulsed the brakes with about 30 psi of pressure to maintain speed. As the vehicle neared the ramp, the brakes heated beyond the point at which they could slow the vehicle. The driver stated that he noticed this loss of braking near the top of the ramp and tried to downshift, but to no avail. Even applying more pressure, as the driver said he did, would not have provided sufficient braking force to slow the vehicle on the ramp's steep grade, since the brakes were almost useless due to heating at this point. The tractor semitrailer continued to accelerate until impact.

The truckdriver was unable to stop his vehicle because the brakes did not provide enough retarding force when he applied them. The vehicle's braking efficiency[58] at ambient temperature, excluding heat effects, was calculated to be 0.35, that is, the tractor semitrailer brakes produced 35 percent of the stopping force that they could have produced if the brakes had been fully adjusted and functioning. The braking efficiency was reduced to this level because five brakes were out of adjustment and three others were not functioning; four of these eight brakes provided no braking force whatsoever.

Traveling down several grades before reaching the exit ramp would have increased brake temperature, further decreasing braking efficiency. The truck was not equipped with an engine retarder, so the driver had to rely solely on the brakes and downshifting to slow the truck on the downgrades. The engine control module had been removed, allowing the engine rpm to increase and further reducing the engine's ability to slow the vehicle when it was in gear. The driver stated that he began slowing the truck on the interstate prior to the exit ramp because he was unfamiliar with the ramp.[59] Using the brakes, drag, and gravity to slow the truck from an estimated 60 mph to a driver-reported speed of 25 mph (simulated speed of 29 to 34 mph) would have caused the brake drums to expand, thereby increasing the stroke required to apply braking force by approximately 0.1 inch per 100° F. The brake drums would have expanded to the point that the brake shoes could no longer apply pressure to the drums, even with the pushrod fully extended. The simulation showed that the brake lining temperature exceeded 500° F, significantly reducing the friction

[58] Braking efficiency calculations take into account air pressure, chamber size, stroke length, slack length, drum radius, rolling radius of the wheels, and weight on each wheel.

[59] However, simulations show that the driver began to slow before the last descent and maintained the slower speed down the last descent prior to the ramp. The truck would not have been able to slow from 60 mph to 25 mph on the last downgrade due to the condition of the brakes.

between the lining and the drum. At this point, the truck had almost no braking capability. Simulations confirm that brake temperatures under such conditions would have rendered all of the truck's brakes out of adjustment. Even the brakes that were within adjustment prior to heating (4L and 5R) left no skid marks on the ramp, indicating that these brakes could not apply enough retarding force to lock the wheels. The Safety Board concludes that poorly adjusted and nonfunctional brakes, together with the resulting high temperatures in the functioning brakes, reduced the truck's braking efficiency to such an extent that the truckdriver was unable to stop the vehicle at the end of the ramp.

## Truck Brakes

### *Recommendation History*

The Safety Board has been concerned about proper brake adjustment for more than 25 years. Previous investigations have resulted in several safety recommendations relating to brake adjustment that are relevant to the Mountainburg accident.

**Brake Adjustment Guidelines.** In 1975, the Safety Board investigated an accident involving a tractor semitrailer that lost braking capability while descending a steep grade near Bishop, California.[60] The vehicle began accelerating at a point 5 to 5 ½ miles from a truck parking area, where the driver had stopped to adjust the brakes. While attempting to negotiate a curve, the trailer separated from the tractor, overturned in front of a pickup and attached camper-trailer traveling in the opposite direction, and struck the other vehicle, causing it to burst into flames and killing all seven occupants. As a result, the Safety Board recommended that the FHWA:

> H-75-17
>
> Develop and disseminate throughout the motor carrier industry, an "On Guard" bulletin alerting drivers of commercial vehicles equipped with externally adjustable braking systems of: a) the need to be familiar with company policies and practices with respect to on-road adjustment of brakes; b) methods and techniques for detecting potential or existing problems in adjustment; c) the scope of the problem in insuring proper brake adjustment; d) methods or techniques for the proper on-road adjustment of braking systems currently and generally in use.

In response, the FHWA developed a bulletin entitled "Danger-Driver Adjusted Brakes," which was circulated to all carriers for display on bulletin boards and distribution to drivers and safety supervisors. The Safety Board classified this recommendation "Closed—Acceptable Action" on October 20, 1977.

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[60] National Transportation Safety Board, *Francisco Flores Truck/Pickup Truck with Camper and Trailer Collision, U.S. Route 395, Bishop, California, June 29, 1974,* Highway Accident Report NTSB/HAR-75/05 (Washington, DC: NTSB/1975).

A similar recommendation resulted from the Safety Board's 1992 safety study on heavy vehicle airbrake performance. The Safety Board recommended that the National Private Truck Council, the Owner-Operator Independent Driver Association, and the American Trucking Associations work with one another:

> H-92-67, -72, and -74
>
> To complete and distribute to member carriers appropriate brake maintenance materials that clearly establish standard inspection techniques (including adjustment indicators), inspection and adjustment interval guidelines, and an adjustment method (covering both manual and automatic slack adjusters) for S-cam brakes on heavy vehicles. Encourage members to provide a copy of the information to each driver of a heavy vehicle and to each mechanic who services heavy vehicles.

On July 29, 2002, the Safety Board classified this recommendation to the National Private Truck Council "Closed—Unacceptable Action/No Response Received."

In 1993, the Owner-Operator Independent Driver Association produced and distributed more than 15,000 copies of a brake videotape and accompanying booklet entitled *What's Stopping You?* that stressed the importance of regular preventive brake maintenance, provided an overview of roadside inspection procedures, and warned of the potentially serious consequences of mismatching brake components. Also included was information from the FHWA and the University of Michigan Transportation Research Institute on downhill braking techniques. The Safety Board classified the recommendation to the Owner-Operator Independent Driver Association "Closed—Acceptable Action" on January 30, 2001.

Through its maintenance council, the American Trucking Associations developed a training video on how to conduct truck brake inspection and maintenance. In 1992, the American Trucking Associations informed the Safety Board that efforts were under way with the FHWA's OMC to develop a method carriers could use to establish an appropriate brake adjustment interval for their own operations. The FMCSA Web site now contains a comprehensive list of brake maintenance materials and guidelines. The Safety Board classified the recommendation to the American Trucking Associations "Closed—Acceptable Action" on July 16, 2002.

The intent of the safety recommendations issued in 1975 and 1992 was to inform carriers and drivers of the need to maintain brake adjustment and to perform the adjustment properly, but the materials may not have reached or been used by all carriers. Safety Board investigators were unable to determine whether Stuart Trucking received any of these materials. Informing drivers about standard inspection techniques and adjustment methods is an important first step in proper brake maintenance. Although the Mountainburg driver described to investigators the correct procedure for adjusting brakes, he apparently did not apply that knowledge in the case of the accident vehicle.

**Automatic Slack Adjusters and Out-of-Adjustment Indicators.** Beginning in 1978, the Safety Board made several safety recommendations to require that vehicles be equipped with automatic slack adjusters and out-of-adjustment indicators.[61] In 1977 and 1978, the Safety Board investigated five accidents in which commercial vehicle drivers were unable to maintain speed control on downgrades. The major causal factor in four of these accidents was improper adjustment of the vehicles' service brakes, and in the fifth, the trailer brakes were totally inoperative. In two instances, the owners and operators had failed to ensure that the vehicles were safe for operation before they were dispatched.

In its 1992 study of *Heavy Vehicle Airbrake Performance*, the Safety Board issued safety recommendations that superseded those resulting from the investigations conducted in the 1970s and 1980s. The Board cited numerous brake deficiencies, including serious instances of out-of-adjustment brakes, as causal or contributing factors in the accidents investigated to support the 1992 safety study. The Safety Board urged NHTSA to:

H-92-50

Require that air-braked vehicles be equipped with visible adjustment indicators that will allow one person to check the level of adjustment.

H-92-51

Expedite the proposed rulemaking to require automatic adjusters on vehicles equipped with airbrake systems.

NHTSA issued a final rule on October 20, 1992, amending FMVSS 121, "Air Brake Systems," and FMVSS 105, "Hydraulic Brake Systems," to require automatic brake adjusters on all air-braked and hydraulic-braked vehicles manufactured after October 20, 1994. Consequently, the Safety Board classified both recommendations "Closed—Acceptable Action" on December 21, 1992.

The Safety Board also recommended that the FHWA:

H-92-57

Encourage the installation of vehicle brake adjustment indicators on all vehicles equipped with airbrake systems for easy detection of adjustment levels.

In 1995, the FHWA published a report entitled *Evaluation of Brake Adjustment Criteria for Heavy Trucks*, which presented analyses, findings, and recommendations concerning the brake adjustment criteria of the "North American Uniform Driver-Vehicle Inspection Criteria for Heavy Trucks." The FHWA also issued a final rule requiring motor carriers that have vehicles manufactured on or after October 20, 1994, to retain automatic brake adjustment indicators. Therefore, the Safety Board classified this recommendation "Closed—Acceptable Action" on February 5, 1996.

[61] Safety Recommendations H-78-48 and H-88-30 were superseded by Safety Recommendation H-92-50. Safety Recommendations H-81-1 and H-88-32 were superseded by Safety Recommendation H-92-51.

The safety recommendations issued in 1992 resulted in the Federal requirement that all commercial vehicles manufactured after 1994 have automatic slack adjusters and brake adjustment indicators, which were in place on the trailer involved in the Mountainburg accident. The tractor was built prior to the rulemaking requiring the use of these systems. While the automatic slack adjusters did maintain the adjustment on two of the trailer's brakes, they could not maintain proper adjustment on two other brakes because of broken springs and an improperly installed spring brake. Automatic slack adjusters can only function as designed if the other brake components are properly installed and maintained.

### *Accident Vehicle*

**Brake Adjustment.** The tractor semitrailer in the Mountainburg accident was equipped with manual slack adjusters on the tractor brakes and automatic slack adjusters on the trailer. Eight of the 10 brakes were either out of adjustment or nonfunctional at the time of the accident, and 4 brakes were unable to provide any braking force, even without taking into account heat buildup and drum expansion.

The driver said that the tractor brakes were last adjusted on May 27, 2001, when he and the owner had installed manual slack adjusters on the second and third axles of the tractor. The owner admitted that he did not keep the front axle brakes fully adjusted and backed them off ¾ turn. According to accepted maintenance practices, brakes should only be backed off either until the drum turns freely or a maximum of 3/8 to ½ turn. NHTSA has conducted extensive research to evaluate the need for front steering axle brakes. Following a series of tests, the agency concluded:

> Drivers were clearly able to achieve better performance with full front brakes than without under all circumstances. They stopped in shorter distances under full control with full front brakes. Without front brakes, best stopping distances were 5 to 130 percent longer and drivers were more likely to lose control.[62]

Because the front brakes on the accident vehicle had not been adjusted properly, they were either out of adjustment or close to being out of adjustment at the start of the trip, decreasing the braking ability of the front axle brakes. The drum on axle 1R was rusty, indicating that the brake shoe was not contacting the drum when the brakes were applied, so this brake provided no braking force at all.

The owner of the truck had installed manual slack adjusters on the second and third axles of the tractor 4 days before the accident. He said he adjusted the brakes at that time using prescribed procedures, that is, turning the adjusting nut until the shoes touched the drums and then backing off the adjusting nut ½ turn. The driver said he watched Stuart Trucking's mechanic adjust the brakes on the trailer 2 or 3 weeks before the accident.

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[62] U.S. Department of Transportation, National Highway Traffic Safety Administration, *A Demonstration of the Safety Benefits of Front Brakes on Heavy Trucks*, DOT HS 807 061 (Washington, DC: NHTSA, 1986).

When some brakes are out of adjustment, the remaining brakes must provide greater braking force whenever they are applied in order to stop the vehicle, increasing the rate at which they wear and thus become out of adjustment. The brakes on the first axle (1R and 1L) provided limited braking force because they were improperly adjusted (1R provided no braking force for a period of time before the day of the accident, as evidenced by the rusted brake drum reported by the driver). Brakes on axles 3L, 4R, and 5L could not provide much, if any, braking force since they were nonfunctional owing to poor maintenance and other broken components. Therefore, the remaining 5 brakes (3 on the tractor and 2 on the trailer) had to provide the braking force for 10 brakes.

Heat can also speed the rate at which brakes become out of adjustment. When some brakes on a vehicle are out of adjustment, those brakes that are within adjustment heat more rapidly because of the additional workload placed on them. Following the accident, the only brakes found to be within adjustment were those without broken components and equipped with automatic slack adjusters, which compensated for pushrod slack, adjusting accordingly.

The truck had only been driven about 1,600 miles, primarily on level roadways, since the new manual slack adjusters had been installed on May 27, or 4 days before the accident. Even so, during postaccident inspection, investigators found that the brakes were out of adjustment. According to industry representatives from Kenworth and Bendix, brakes should require adjustment every 6,000 to 8,000 miles. The Safety Board concludes that the six brakes on the tractor were out of adjustment either because the owner had not properly adjusted them, or because the brakes became out of adjustment due to a disproportional workload, or both.

The driver said that he did a visual inspection of the brakes on the day of the accident and did not find them to be out of adjustment. The *Commercial Driver's License Manual* recommends that during a pretrip inspection, the driver, at a minimum, pull on the pushrod and measure the stroke. If the stroke exceeds ½ to 1 inch, the brakes should be adjusted. Postaccident inspection showed that the stroke on five of the six tractor brakes exceeded 2 inches and that one other (3L), on which the stroke was restricted to 1 7/8 inch by a broken spring, also needed adjustment. Accident damage would not have affected the brakes' stroke.

The driver did not follow recommended practice for measuring stroke during the pretrip inspection, and a visual inspection did not allow him to determine that the brakes were out of adjustment. While the CDL practice is only recommended, not mandatory, it is an important part of the pretrip inspection because of the safety-related nature of the brake system and the possible consequences, as in the case of this accident, when brakes are not adjusted properly. The Safety Board concludes that the driver did not conduct a sufficiently thorough pretrip inspection on either the tractor or the trailer to discover the brake deficiencies.

As 49 CFR 383.111(e)(4) and (g)(5) state, all commercial vehicle operators must have knowledge of procedures for conducting safe and accurate pretrip inspections and knowledge of airbrakes. Title 49 CFR 383.113 requires that all CDL applicants demonstrate pretrip inspection skills pertaining to airbrakes, including the ability to determine brake conditions and proper adjustment. Interviews with the accident driver indicated that he knew how to adjust brakes. While the accident driver did have a CDL, he did not demonstrate that he was knowledgeable about procedures for conducting a safe and accurate pretrip inspection on the day of the accident or about the consequences of not conducting a thorough pretrip inspection. However, 49 CFR 396.13(a) only stipulates that a driver be satisfied that the motor vehicle is in safe operating condition before driving it; the regulations specify neither what must be done during a pretrip inspection, nor which procedures must be performed daily on a vehicle.

The Safety Board has investigated other accidents in which pretrip inspection procedures were lax as well. On March 2, 1999, near Santa Fe, New Mexico, a motorcoach began descending a 14-mile mountainous roadway, and halfway down, the driver found that the brakes were providing no retarding force.[63] The driver lost control of the bus, and it departed the right side of the roadway, crashed into a rock embankment, and overturned. Investigators found that four of the bus's six brakes were out of adjustment at the time of the accident and two brakes were nonoperational. Company mechanics did not routinely examine driver pretrip inspection forms and did not know whether company drivers completed pretrip inspections. The busdriver reported that in the 10 months he had worked for the company, he had never completed a pretrip vehicle inspection. A review of company maintenance records revealed that some drivers were occasionally completing vehicle inspection reports.

Had the Mountainburg and Santa Fe drivers been required to measure the stroke on each brake and to determine its adjustment before they began driving on the day of the accident and had they fulfilled such a requirement, they may have discovered that some brakes were out of adjustment and taken appropriate corrective action. The Safety Board believes that the FMCSA should revise CFR 396.13, Driver Inspection, to require minimum pretrip inspection procedures for determining brake adjustment.

**Spring Brakes.** Of six brakes on the tractor semitrailer equipped with spring brakes for emergency-parking brake application (axles 3, 4, and 5), three had broken springs. The 3L brake spring was broken in three pieces, restricting total stroke by 3/8 inch. Thus, even though the 3L brake appeared to be within adjustment at 1 7/8 inches, it was not.

The 4L brake spring was broken in two pieces, and dynamic testing of the vehicle showed that the broken spring did not prevent service brake application; the service brakes even locked during one test. When the emergency-parking brake was applied during another test, the 4L brake provided some braking force (the service brake locked on gravel but not on concrete), indicating the emergency-parking brake force was reduced due to the broken spring, but was not completely eliminated.

[63] National Transportation Safety Board, *Motorcoach Loss of Control and Overturn, New Mexico State Route 475, March 2, 1999,* Highway Accident Brief NTSB/HAB-01/01 (Washington, DC: NTSB, 2001).

The 5L brake spring was also broken and blocking the pushrod, thereby limiting pushrod stroke and preventing it from reaching the minimum 1½ inches necessary for the automatic adjuster to begin readjustment. During testing, 5L did not provide any braking force when either the emergency-parking brake or the service brake was applied. In other words, both the emergency-parking brake and the service brake were nonfunctional.

Thus, a broken spring, in addition to reducing the braking ability of the emergency-parking brake or rendering it inoperable, can have a detrimental effect on the service brakes, as was the case in this accident. Broken springs on two of the vehicle's three brakes prevented proper brake adjustment, thereby contributing to a reduction of the tractor semitrailer's braking efficiency.

The caging that houses brake springs makes detection of broken springs difficult because access to the closed chamber is restricted. One method of detection involves inserting an optical device called a borescope into the caging port. Another entails inserting a finger inside the caging port, but doing so can be extremely dangerous during roadside inspections; if the truck moves, the spring breaks, or the driver applies or releases the parking brake, the inspector can be injured. If the spring brake is equipped with an integrated caging bolt, then it has no port for accessing the spring. Brake springs are neither a CVSA out-of-service item nor an inspection item. However, as this accident demonstrates, broken springs can have safety consequences when they prevent proper adjustment of the service brake or decrease the braking capability of the emergency-parking brake. The Safety Board concludes that because of the spring brake design, examining the springs to determine whether they were broken was difficult on three of the truck's brakes. Therefore, the Safety Board believes that the manufacturers should develop a spring brake that allows inspectors or mechanics to view components safely to determine whether the spring is broken. Safety Board staff participates in CVSA committees, and once the spring brakes are redesigned, staff will work with the CVSA to incorporate inspection of spring brake components into the vehicle inspection criteria.

Springs break for various reasons, including exposure to the elements, number of brake applications, age, or material properties. Contaminants can enter spring brake chambers through the caging ports unless dust covers (small caps) are in place to prevent contaminants from entering. These contaminants, such as salt and water, can weaken the material properties of the spring, making it more susceptible to breakage. On the accident vehicle, dust covers were missing on all four spring brakes that had standard nonintegrated caging ports. Evidence of a white substance, probably salt deposits, was present inside the 4L spring chamber, and salt can corrode a spring, leading to its failure. The Safety Board concludes that dust covers on the caging ports of the accident vehicle's spring brakes would have reduced the chance of corrosion to the spring, possibly prolonging the life of the spring and, in turn, the life of the emergency-service brakes. The Safety Board believes that the CVSA should include spring brake caging port dust covers as an inspection item during Motor Carrier Safety Assistance Program roadside inspections.

## Motor Carrier Inspection and Oversight

### *Recommendation History*

The Mountainburg accident is one of many in which the Safety Board has identified the inadequacy of motor carrier inspections, including compliance reviews, as cause for concern. In 1995, for example, the Safety Board investigated a motorcoach accident in which the bus overturned when it entered an exit ramp in Indianapolis, Indiana;[64] 2 passengers sustained fatal injuries and 13 sustained serious injuries. Postaccident inspection of the vehicle revealed out-of-adjustment brakes; as a result, the bus had only 50 percent braking efficiency, which probably contributed to the accident. The OMC conducted an after-accident compliance review of the operator, Hammond Yellow Coach Lines, Inc., (Hammond) that resulted in an unsatisfactory rating (10 of 10 vehicles reviewed were placed out of service) and a subsequent out-of-service order because of noncompliance within 45 days of the proposed unsatisfactory rating.

However, Hammond already had significant safety problems before the accident and yet was still permitted to operate. The OMC had inspected Hammond nine times between 1987 and 1995. In 1993, the OMC gave Hammond an unsatisfactory rating, citing the carrier's accident rate and hours-of-service violations; 3 months later, the agency upgraded that rating to satisfactory. In 1994, the OMC used Indiana State Police terminal inspection results to determine the rating for its compliance review. Because of the high number of vehicles (63 percent) meeting out-of-service criteria, Hammond received a conditional rating for the vehicle factor component of the compliance review. But the OMC rated all other factors satisfactory, resulting in an overall rating of satisfactory and Hammond continued to operate with unsafe vehicles. Following the Indianapolis accident, the Safety Board asked the DOT to:

> H-99-6
>
> Change the safety fitness rating methodology so that adverse vehicle and driver performance-based data alone are sufficient to result in an overall unsatisfactory rating.

On December 14, 1999, the OMC (now FMCSA) responded that it expected to issue a notice of proposed rulemaking calling for a more performance-based means of determining carrier fitness to conduct commercial motor vehicle operations. The OMC stated that it would take into account the Safety Board's recommendation, along with any comments received, in developing a new rating system. The Safety Board classified the recommendation "Open—Acceptable Response" on March 17, 2000, based on the expected notice of proposed rulemaking. Safety Recommendation H-99-6 was also added to the Safety Board's Most Wanted Transportation Safety Improvements list to increase the public's awareness of and support for action to adopt safety steps that can help prevent accidents and save lives. Since then, the FMCSA has developed a rating system that

[64] National Transportation Safety Board, *Selective Motorcoach Issues*, Highway Special Investigation Report NTSB/SIR-99/01 (Washington, DC: NTSB, 1999).

allows it to focus compliance reviews on the carriers who have had safety problems in the past. On July 12, 2002, the FMCSA advised the Safety Board that it would address Safety Recommendation H-99-6 in an upcoming notice of proposed rulemaking on "Safety Fitness Procedures." Like Hammond, the carrier in the Indianapolis accident, Stuart Trucking had significant safety defects on the accident vehicle and other vehicles, numerous driver violations, and unqualified brake inspectors, yet was still permitted to operate.

### *Compliance Reviews*

Stuart Trucking's most recent compliance review prior to the Mountainburg accident took place on December 5, 1989, and resulted in a satisfactory rating. Following the accident, the FMCSA conducted a compliance review that resulted in a conditional rating for factor 2 (driver factor), an unsatisfactory rating for factor 5 (accident factor), and a conditional rating overall. FMCSA staff did not inspect any vehicles during this review, even though the accident was vehicle-related. They relied instead on the motor carrier profile report, which listed 29 roadside inspections in the previous 12 months, resulting in four out-of-service vehicles (14 percent), all with out-of-adjustment brakes. The regulations at 49 CFR Part 385, Appendix B, state that if fewer than 34 percent of vehicles (the national average) inspected in the previous 12 months (when more than three vehicles receive roadside inspections) are placed out of service, then the carrier is rated satisfactory for the vehicle factor, as was the case in the postaccident compliance review of Stuart Trucking.

Safety Board investigators were concerned that the FMCSA did not inspect any of Stuart Trucking's vehicles. This accident involved a vehicle in which 8 of 10 brakes were out of adjustment and the carrier's mechanic was not a qualified brake inspector, suggesting that more vehicles may have had brake problems than were detected in the 12 months of roadside inspections, yet the FMCSA did not inspect any vehicles during the compliance review immediately following this accident. Consequently, the Safety Board asked the Missouri Division of Motor Vehicles and Railroad Safety to conduct an additional review of the carrier and inspect all its vehicles. Of 12 vehicles examined, 5 vehicles (42 percent) had out-of-service violations. Not only did this review reveal an out-of-service rate higher than the FMCSA recorded in its compliance review, but investigators also determined that the brakes had not been maintained properly. Improper maintenance, which cannot be detected without conducting vehicle inspections, can be telling as to the condition of a carrier's vehicles. The Safety Board concludes that based on the inspection conducted by the Missouri Division of Motor Vehicles and Railroad Safety that followed the accident, had FMCSA staff inspected Stuart Trucking's vehicles during the 2001 compliance review, the carrier would probably have received a conditional rating in factor 4 (vehicle factor) instead of a satisfactory rating.

The FMCSA's overreliance on roadside inspections when conducting compliance reviews may lead to underestimating the number of out-of-service vehicles. As noted above, the percentage of out-of-service vehicles found during the terminal inspection of Stuart Trucking was triple that found during the previous 12 months of roadside inspections. The Safety Board is concerned that carriers may be operating unsafe vehicles that are not detected during a roadside inspection or compliance review and that, as a result, the carrier's rating may be inaccurate because it misrepresents the proportion of out-of-service vehicles. The FMCSA will not conduct a terminal inspection if three or more of a company's vehicles received roadside inspections in the previous 12 months. But the vehicles that receive roadside inspections may not be representative of the entire fleet. The Safety Board believes that the FMCSA should require that vehicle inspections of a motor carrier's fleet be conducted during compliance reviews.

Furthermore, even if its vehicle factor rating had been changed as a result of the 2001 compliance review, Stuart Trucking's overall rating would have remained conditional. Under current compliance review procedures, one unsatisfactory factor rating and two or fewer conditional factor ratings result in an overall conditional rating. The 2001 rating for Stuart Trucking underscores the failure of compliance reviews to identify unsafe carriers. This carrier had not been rated in more than 11 years at the time of the accident. Despite having unsafe vehicles on the road, no qualified brake inspectors, and numerous driver violations, Stuart Trucking still received a conditional rating.

The tragic consequences of this accident add urgency to the Safety Board's Safety Recommendation H-99-6 to change the safety fitness rating methodology. The FMCSA continues to respond that it plans to issue a notice of proposed rulemaking that would lead to a more performance-based safety fitness rating system. To date it has not done so. Therefore, the Safety Board reiterates Safety Recommendation H-99-6 to the DOT urging it to change the safety fitness rating methodology so that adverse vehicle and driver performance-based data alone are sufficient to result in an overall unsatisfactory rating.

### *Qualified Brake Inspector*

Title 49 CFR Part 396.24, "Qualification of Brake Inspectors," requires that each brake inspector successfully complete an apprenticeship program or a training program or have a certificate or experience totaling 1 year; in addition, the motor carrier must maintain evidence of qualifications. Stuart Trucking's mechanic, who was responsible for maintaining most of the company's tractors and trailers, had not received any formal training in brake inspection, although he did have more than 1 year of experience and, under current rules, was eligible for certification. The owner said that he was not aware of the regulations requiring anyone who inspects or maintains brakes to be certified.

Although the person responsible for maintaining the brakes on the trailer of the accident vehicle had experience in brake maintenance, the condition of the trailer's brakes belied this experience, since three of the trailer's four brakes had broken parts or were nonfunctional at the time of the accident. Two brakes (4L and 5L) had broken springs, and during installation of one spring brake (4R), the pushrod was cut too short, rendering the automatic slack adjuster inoperable. Stuart Trucking's mechanic did not detect the latter problem in the 4 years between installation of the 4R spring brake in 1997 and the accident. In fact, brakes 4R and 5L had quite likely been inoperative for some time, since the brake drums were rusted, indicating the shoes had not been in contact with the drums. A qualified mechanic should have noticed this problem during routine maintenance and inspections.

In addition, the absence of grease at the fittings and brake camshaft bushings suggested a lack of periodic lubrication, and the Arkansas Highway Police and ArvinMeritor staff both commented on the poor overall condition of the trailer's brake system. During their follow-up vehicle inspection, Missouri Division of Motor Vehicle and Railroad Safety inspectors stated that Stuart Trucking staff's knowledge of truck maintenance seemed to be lacking; these inspectors also noted that some defects they found were obvious and did not appear to be recent. A brake inspector with sufficient training and knowledge would probably have identified the problems with the brakes on this semitrailer and fixed the brakes so that they were operative. The Safety Board concludes that the Stuart Trucking mechanic lacked proper training in brake maintenance and inspections, did not detect the poorly adjusted or inoperative brakes on the trailer, and did not perform recommended maintenance.

The Safety Board has investigated other accidents in which a motor carrier did not use a certified brake inspector to perform maintenance on its vehicles. In the aforementioned accident near Santa Fe in 1999, investigators found that the steering and drive axle brakes were out of adjustment, that the auxiliary weight-bearing axle brakes were not operational because they were "cammed over,"[65] and that both drums were worn beyond the manufacturer's acceptable limits. During postaccident inspection of the carrier by the New Mexico Motor Transport Division, all but two of the inspected motorcoaches were placed out of service due to mechanical defects, most of which were related to the brake systems. The carrier did not keep brake mechanic qualification records, as required, and none of the three company mechanics interviewed could adequately describe the maximum brake adjustment levels for the brakes on the motorcoaches, how to conduct a vehicle brake inspection, or how to adjust brakes.

Under the current compliance review process, the FMCSA does not consider violation of 40 CFR 396.25 "critical." Thus, if a motor carrier does not have a qualified brake inspector, it does not affect the carrier's rating. In fact, in its compliance review of Stuart Trucking, the FMCSA did not even note that a qualified brake inspector certificate was not on file. The Safety Board believes that during compliance reviews, the FMCSA should rate companies as unsatisfactory in the vehicle factor category if the mechanics and drivers responsible for maintaining brake systems are not qualified brake inspectors.

As the Mountainburg and Santa Fe accidents demonstrate, experience working in a maintenance shop is not always sufficient to ensure that a mechanic has the knowledge necessary to maintain a truck brake system. The FMCSA is remiss in permitting mechanics to work on brakes without knowing whether they have the requisite skills in brake maintenance. The Safety Board believes that the FMCSA should revise 49 CFR 396.25, Qualifications of Brake Inspectors, to require certification after testing as a prerequisite for qualification and specify, at a minimum, formal training in brake maintenance and inspection.

[65] A condition in which the S-cam rotates beyond the service brake cam rollers and remains lodged in this position. The cause is generally a combination of out-of-adjustment brakes, worn brake shoes, and an excessively worn drum.

## Fuel Tanks

### *Recommendation History*

While it has not made specific recommendations addressing retrofitted propane tanks on school buses, the Safety Board has recommended protecting fuel tanks on school buses to minimize the risk of fire. On February 29, 1972, a 1961 sedan ran a stop sign near Reston, Virginia,[66] and collided with a school bus carrying four children. The impact ruptured the school bus fuel tank, knocked it from the bus, and disabled the school bus service door. A fire ensued in the sedan due to gasoline spilled from the ruptured and detached school bus fuel tank, which was in a vulnerable location and lacked crash protection design features. The Safety Board urged that NHTSA and the Vehicle Equipment Safety Commission:

> H-72-2
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> In consideration of the unnecessary hazards posed by locating school bus fuel tanks adjacent to service doors, act promptly to determine the "best" and "safest" location for school bus fuel tanks and to specify such location, as well as any protective shield or structural changes, to minimize the likelihood that a collision which might disable the service door or the emergency exit will also initiate a school bus fuel tank fire, and vice versa.

NHTSA replied that the rigorous side- and rear-impact barrier collision test requirements of FMVSS 301 afforded a high level of protection for fuel systems on all vehicles up to 10,000 pounds gross vehicle weight rating. In addition, on September 19, 1974, the agency stated that a program to develop fuel system integrity tests for large school buses was planned. Such tests were later incorporated into FMVSS 301, and the Safety Board classified the recommendation "Closed—Acceptable Action" on September 6, 1985.

On May 14, 1988, a pickup truck traveling north in the southbound lanes of Interstate 71 struck a southbound church activity bus head-on near Carrollton, Kentucky.[67] The church bus fuel tank was punctured during the collision sequence and a fire ensued, engulfing the bus. The busdriver and 26 bus passengers were fatally injured, 34 passengers received minor to serious injuries, and 6 passengers were not injured. As a result of its investigation of this accident, the Safety Board asked that NHTSA:

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[66] National Transportation Safety Board, *School Bus/Automobile Collision and Fire Near Reston, Virginia, on February 29, 1972*, Highway Accident Report NTSB/HAR-72/02 (Washington, DC: NTSB, 1972).

[67] National Transportation Safety Board, *Pickup Truck/Church Activity Bus Head-on Collision and Fire Near Carrollton, Kentucky, on May 14, 1988*, Highway Accident Report NTSB/HAR-89/01 (Washington, DC: NTSB, 1989).

H-89-6

> Revise Federal Motor Vehicle Safety Standard 301 to provide additional protection for school buses in severe crash situations based on an evaluation of the merits of relocating fuel tanks, providing additional structure to protect fuel system components, and frangible valves in critical locations.

NHTSA replied on August 16, 1989, enclosing copies of an advance notice of proposed rulemaking to make the crash standards more stringent. In an April 11, 1991, letter, NHTSA stated that responses to the advance notice of proposed rulemaking did not provide clear direction for proposing changes to FMVSS 301. Thus, for the next step, NHTSA said it was considering several options, including a research program to develop the technical information necessary to evaluate ways to improve the fuel system integrity of buses. On October 20, 1995, NHTSA reported that those commenting on the advance notice of proposed rulemaking agreed that FMVSS 301 was adequate and that manufacturers generally comply with the requirements by adding a cage around the fuel tank. The Safety Board classified the recommendation "Closed—Acceptable Action" on May 15, 1996, citing its understanding that school bus manufacturers generally comply with stringent regulatory crash test requirements for large school bus fuel systems by adding a cage around the fuel tank.

These safety recommendations, issued over the past 3 decades, encouraged NHTSA and the school bus manufacturers to make fuel tanks on school buses safer. However, none of NHTSA's fuel tank safety requirements for school buses apply to propane tanks.

### *Mountainburg Accident School Bus*

The propane tank, which had been retrofitted on the accident school bus, was installed in accordance with NFPA Standard 58, "Standard for the Storage and Handling of Liquefied Petroleum Gases." The Safety Board is concerned that this standard does not adequately protect propane fuel systems during a crash. Unlike gasoline and compressed natural gas systems, which are fitted onto school buses by the manufacturer, propane and other retrofitted fuel systems are not required to meet NHTSA crash test standards specified in FMVSSs 301 and 303. These standards require that gasoline and compressed natural gas systems mounted on a vehicle withstand a barrier crash test. Propane systems must pass no such test, and NHTSA cannot even regulate propane system testing because propane systems are aftermarket installations and therefore not subject to NHTSA safety standards. Most States (Idaho is the only exception) require that propane systems meet NFPA standards. While propane systems must have a discharge valve, this valve will not prevent a fire from occurring during a severe crash if the fuel system is compromised.

To further protect gasoline and diesel fuel tanks on school buses from being compromised, school bus manufacturers place them within a cage, even though not required to do so. In fact, a rigid safety cage enclosed the manufacturer-installed fuel tank on the accident school bus. The propane tank did not have such protection. As discussed above, the Safety Board has investigated school bus crashes in which cages did not enclose fuel tanks, and severe fires and loss of life ensued. The Safety Board concludes that catastrophic fires involving vehicles equipped with propane tanks could happen because these tanks are not protected from collision and, thus, could rupture if struck. The Safety Board believes that the NFPA should amend Standard 58, Storage and Handling of Liquefied Petroleum Gas, to require that (1) propane fuel systems installed in school buses be protected and (2) propane fuel systems meet the equivalent to FMVSS 301 crash protection standards.

Current legislation generally prohibits NHTSA from regulating aftermarket equipment installed on vehicles. However, in this case, the children riding on the school bus did not receive the same level of protection as those children riding on buses equipped with gasoline, diesel, or compressed natural gas tanks, which NHTSA does regulate. The Safety Board believes that NHTSA should obtain the authority, as necessary, and include propane fuel system integrity standards for aftermarket installations in the FMVSSs.

## Occupant Kinematics and Survival Factors

### *Recommendation History*

In its special investigation report on bus crashworthiness issues,[68] adopted on September 21, 1999, the Safety Board found that some passengers not seated in the direct intrusion area were seriously or fatally injured in school buses involved in lateral impacts with large vehicles and rollovers. The Safety Board concluded:

> Current compartmentalization is incomplete in that it does not protect school bus passengers during lateral impacts with vehicles of large mass and in rollovers, because in such accidents, passengers do not always remain completely within the seating compartment.

The Safety Board recommended that NHTSA:

> <u>H-99-45</u>
>
> In 2 years, develop performance standards for school bus occupant protection systems that account for frontal impact collisions, side impact collisions, rear impact collisions, and rollovers.

In response to this recommendation, NHTSA is conducting a study to develop ways to enhance the safety of the interior environment for school bus passengers. The agency completed front and side impact full-scale crash testing on large school buses and published the results of the frontal impact restraint testing in May 2002. One of its conclusions was that requiring lap belts on large school buses would have little, if any, benefit in reducing serious or fatal injuries in severe frontal crashes. NHTSA also found that use of lap/shoulder belts could provide some benefit on large school buses, potentially

[68] National Transportation Safety Board, *Bus Crashworthiness Issues*. Highway Special Investigation Report NTSB/SIR-99/04 (Washington, DC: NTSB, 1999).

saving one life per year, if used properly 100 percent of the time. NHTSA recommended that seat heights be increased from 20 inches to 24 inches to prevent passenger override in a collision and that standardized test procedures be developed for voluntarily installed lap/shoulder belts.

The side impact testing and research report will not be completed until spring 2003. Preliminary test results show that crash test dummies away from the impact area do not travel across the width of the bus and strike the sidewall,[69] contrary to what the Safety Board has observed in accident investigations. The Safety Board is concerned about NHTSA relying on the one side impact test as indicative of all severe side impact crashes. The impact point was soft (not an axle) and the collision energy was absorbed by the deformation. Furthermore, the crash test lacked an angular velocity or acceleration measurement, thereby invalidating any comparisons between the test and real world crashes. Injury values were low for dummies away from the impact area. The Safety Board classified Safety Recommendation H-99-45 "Open—Acceptable Response" on April 18, 2001.

During a train-school bus collision at a highway-rail grade crossing in Conasauga, Tennessee, on March 28, 2000,[70] six passengers were seriously injured or killed because they struck surfaces within the bus, such as nonenergy-absorbing seat frames and sidewall components, which are exempt from FMVSS passenger protection standards. On December 11, 2001, following its investigation of this accident, the Safety Board asked that NHTSA:

> <u>H-01-40</u>
>
> Develop and incorporate into the Federal Motor Vehicle Safety Standards performance standards for school buses that address passenger protection for sidewalls, sidewall components, and seat frames.

On April 23, 2002, NHTSA responded that it is addressing this issue as part of a research program scheduled to be completed in spring 2003. If protection is deemed feasible, NHTSA said it will upgrade FMVSS 222, "School Bus Passenger Seating and Crash Protection," to include requirements for passenger protection at sidewalls, sidewall components, and seat frames. The Safety Board classified this recommendation "Open—Acceptable Response" on July 16, 2002.

In the Mountainburg accident, Safety Board investigators also found that occupant motion, similar to that seen in previous accidents, resulted in injuries to passengers who

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[69] The side impact crash test was conducted on a bus equipped with a rear engine; thus the center of gravity was further rearward than in a front-engine bus because the weight was concentrated at the rear rather than the front. This difference could affect the angular velocity and acceleration (which were not measured) experienced by the occupants in the rear of the bus.

[70] National Transportation Safety Board, *Grade Crossing Accident Involving a CSX Corporation Freight Train and a Murray County, Georgia, School District School Bus, Conasauga, Tennessee, on March 28, 2000*. Highway Accident Report NTSB/HAR-01/03 (Washington, DC: NTSB, 2001).

did not remain within their seating compartment and traveled across the width of the bus during impact.

### *Mountainburg Accident School Bus*

During the Mountainburg collision sequence, the bus rotated about 300 degrees clockwise about the front axle. At the end of the accident sequence, the bus body became partially separated from the chassis and rolled onto its right side.

The occupants in the front of the bus at first probably experienced limited lateral acceleration and motion forward and toward the right because of their proximity to the front of the bus and the rotation of the bus about the front axle. Occupants at the rear of the bus quite likely moved forward and toward the right more rapidly than those in the front due to the bus's rotation about the front axle and the greater lateral acceleration they experienced. Because the passengers in the front were seated close to the bus's point of rotation (the front axle), they did not experience the high lateral and rotational accelerations experienced by those seated further from the front axle. All passengers in the front of the bus received less serious injuries than those seated in the back.

The passengers in the rear of the bus were subjected to the impact force, tractor intrusion, and lateral and rotational accelerations imparted to the bus during the collision sequence. The passenger in seat 10E on the right was directly in the area of impact but survived. Because of his proximity to the side of the bus where the impact occurred and the subsequent intrusion, the difference in relative velocity between his body and the side of the bus was minimal. His serious injuries resulted from being in direct line with the impact forces; his injuries were predominantly on the right side of his body and included lacerations to his head, face, and shoulder from glass fragments and a closed head injury.

The passengers seated on the left side of the bus in the rear were probably thrown forward and across the width of the bus toward the striking truck. They did not remain within their seating compartment during impact because compartmentalization, the current occupant protection strategy inside large school buses, only provides protection during frontal impacts. Three of these passengers (in seats 9A, 9C, and 11A) received fatal injuries, primarily to the head and upper torso, most likely as a result of being thrown from their seating compartment and striking nonenergy-absorbing surfaces, including the ceiling, sidewalls, and window frames, after traveling the width of the bus. The passenger in seat 11A may also have sustained injuries as a result of being partially ejected through the right side window of the bus, which rolled on top of him. The passenger in seat 10A sustained serious injuries. In previous accidents, investigators found that passengers possibly struck other passengers during lateral collisions. In this case, the passengers seated across from (seat 10E) or in front of (seat 9C) the passenger in seat 10A may have protected him from more severe or even fatal injuries as they moved out of their compartmentalized seating area. The Safety Board concludes that the impact and subsequent rotation of the bus caused passengers seated in the rear to be thrown from their seating compartment and into the area of intrusion; incomplete compartmentalization and impact with nonenergy-absorbing surfaces within the bus contributed to the serious and fatal injuries sustained by these passengers.

The Safety Board addressed the issue of incomplete compartmentalization and the lack of energy-absorbing material on interior surfaces in its special investigation report on bus crashworthiness issues and in its investigation report on the Conasauga accident. This accident demonstrates again the need for NHTSA to continue its work on occupant protection for lateral impacts and its work to reduce the nonenergy-absorbing surfaces within school buses. Both efforts have the potential to reduce injuries to those occupants seated outside the area of impact.

# Conclusions

## Findings

1. There was no evidence of drug or alcohol use by the drivers; the weather, mechanical condition of the school bus, design and signing of the highways, emergency response, and truckdriver fatigue did not contribute to the accident.

2. Poorly adjusted and nonfunctional brakes, together with the resulting high temperatures in the functioning brakes, reduced the truck's braking efficiency to such an extent that the truckdriver was unable to stop the vehicle at the end of the ramp.

3. The six brakes on the tractor were out of adjustment either because the owner had not properly adjusted them, or because the brakes became out of adjustment due to a disproportional workload, or both; the driver did not conduct a sufficiently thorough pretrip inspection on either the tractor or the trailer to discover the brake deficiencies.

4. Because of the spring brake design, examining the springs to determine whether they were broken was difficult on three of the truck's brakes.

5. Dust covers on the caging ports of the accident vehicle's spring brakes would have reduced the chance of corrosion to the spring, possibly prolonging the life of the spring and, in turn, the life of the emergency-service brakes.

6. Based on the inspection conducted by the Missouri Division of Motor Vehicles and Railroad Safety that followed the accident, had the Federal Motor Carrier Safety Administration inspected Stuart Trucking's vehicles during the 2001 compliance review, the carrier would probably have received a conditional rating in factor 4 (vehicle factor) instead of a satisfactory rating.

7. The Stuart Trucking mechanic lacked proper training in brake maintenance and inspections, did not detect the poorly adjusted or inoperative brakes on the trailer, and did not perform recommended maintenance.

8. Catastrophic fires involving vehicles equipped with propane tanks could happen because these tanks are not protected from collision and, thus, could rupture if struck.

9. The impact and subsequent rotation of the bus caused passengers seated in the rear to be thrown from their seating compartment and into the area of intrusion; incomplete compartmentalization and impact with nonenergy-absorbing surfaces within the bus contributed to the serious and fatal injuries sustained by these passengers.

## Probable Cause

The National Transportation Safety Board determines that the probable cause of the accident was the truckdriver's inability to stop the tractor semitrailer at the stop sign at the bottom of the ramp due to the reduced braking efficiency of the truck's brakes, which had been poorly maintained and inadequately inspected. Contributing to the school bus passengers' injuries during the side impact were incomplete compartmentalization and the lack of energy-absorbing material on interior surfaces.

# Recommendations

As a result of this accident, the National Transportation Safety Board makes the following safety recommendations:

**To the Federal Motor Carrier Safety Administration:**

Revise 49 *Code of Federal Regulations* 396.13, Driver Inspection, to require minimum pretrip inspection procedures for determining brake adjustment. (H-02-15)

Require that vehicle inspections of a motor carrier's fleet be conducted during compliance reviews. (H-02-16)

Revise 49 *Code of Federal Regulations* 396.25, Qualifications of Brake Inspectors, to require certification after testing as a prerequisite for qualification and specify, at a minimum, formal training in brake maintenance and inspection. (H-02-17)

During compliance reviews, rate companies as unsatisfactory in the vehicle factor category if the mechanics and drivers responsible for maintaining brake systems are not qualified brake inspectors. (H-02-18)

**To the National Highway Traffic Safety Administration:**

Obtain the authority, as necessary, and include fuel system integrity standards for aftermarket installations in the *Federal Motor Vehicle Safety Standards*. (H-02-19)

**To the Commercial Vehicle Safety Alliance:**

Include spring brake caging port dust covers as an inspection item during Motor Carrier Safety Assistance Program roadside inspections. (H-02-20)

**To the National Fire Protection Association:**

Amend National Fire Protection Association Standard 58, Storage and Handling of Liquefied Petroleum Gas, to require that (1) propane fuel systems installed in school buses be protected and (2) propane fuel systems meet the equivalent to Federal Motor Vehicle Safety Standard 301 crash protection standards. (H-02-21)

**To Spring Brake Manufacturers:**

> Develop a spring brake that allows inspectors or mechanics to view components safely to determine whether the spring is broken. (H-02-22)

The National Transportation Safety Board also reiterates the following recommendation:

**To the U.S. Department of Transportation:**

> Change the safety fitness rating methodology so that adverse vehicle or driver performance-based data alone are sufficient to result in an overall unsatisfactory rating for the carrier. (H-99-6)

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**Adopted: September 4, 2002**

# Appendix A

## Investigation and Public Hearing

The National Transportation Safety Board was notified of the Mountainburg, Arkansas, accident on May 31, 2001. An investigative team was dispatched with members from the Washington, D.C.; Fort Worth, Texas; Denver, Colorado; and Atlanta, Georgia, offices. Groups were established to investigate human performance; motor carrier operations; and highway, vehicle, and survival factors.

Participating in the investigation were representatives of the Federal Motor Carrier Safety Administration, the Arkansas State Police, and the Arkansas State Highway and Transportation Department.

No public hearing was held; no depositions were taken.

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