National Transportation Safety Board

Washington, DC 20594

Highway Accident Brief

Accident No.:	HWY-00-FH011
Accident Type:	Motorcoach run-off-the-road
Location:	Eastbound State Highway 50 near milepost 273, Canon City, Colorado
Date and Time:	December 21, 1999, about 9:05 p.m.
Vehicle:	1999 Setra 59-passenger motorcoach
Owner/Operator:	Sierra Trailways, Inc.
Vehicle Damage:	Motorcoach destroyed
People on Board:	Sixty—driver and 59 passengers
Injuries:	Three fatalities Thirty-three serious and 24 minor

Accident Description

About 9:05 p.m. on December 21, 1999, a 1999 Setra 59-passenger motorcoach, operated by Sierra Trailways, Inc. (Sierra Trailways), was traveling eastbound on State Highway 50 along a 7-mile-long downgrade west of Canon City, Colorado, when it began to fishtail[1] while negotiating a curve near milepost (MP) 272.3. At the time, the motorcoach was traveling 63 mph. The speed limit on the descent was 65 mph, with an advisory speed limit of 55 mph on the curves along this section of the roadway. The driver recovered the vehicle from the fishtail, and the motorcoach gained speed as it descended the mountain. Approximately 36 seconds later,[2] as the motorcoach was traveling about 70 mph, the driver lost control of the vehicle on a curve. The motorcoach drifted off the right side of the road, struck MP 273 and a delineator,[3] returned to the road, rotated clockwise 180 degrees toward the centerline, and departed the north side of the roadway backward. The vehicle rolled at least 1.5 times down a 40-foot-deep embankment and came to rest on its roof. (See figures 1 and 2.) The driver and 2 passengers were killed; 33 passengers sustained serious injuries and 24 sustained minor injuries.

[1] An action in which the rear end of a vehicle slides from side to side out of control while moving forward.

[2] Time sequence derived from the Detroit Diesel Electronic Controls electronic control module (ECM) installed on the engine.

[3] Delineators are light-retroreflecting devices mounted in series at the roadway edge to indicate the roadway alignment.

NTSB/HAB-02/19

Figure 1. Photograph of motorcoach at final rest position.

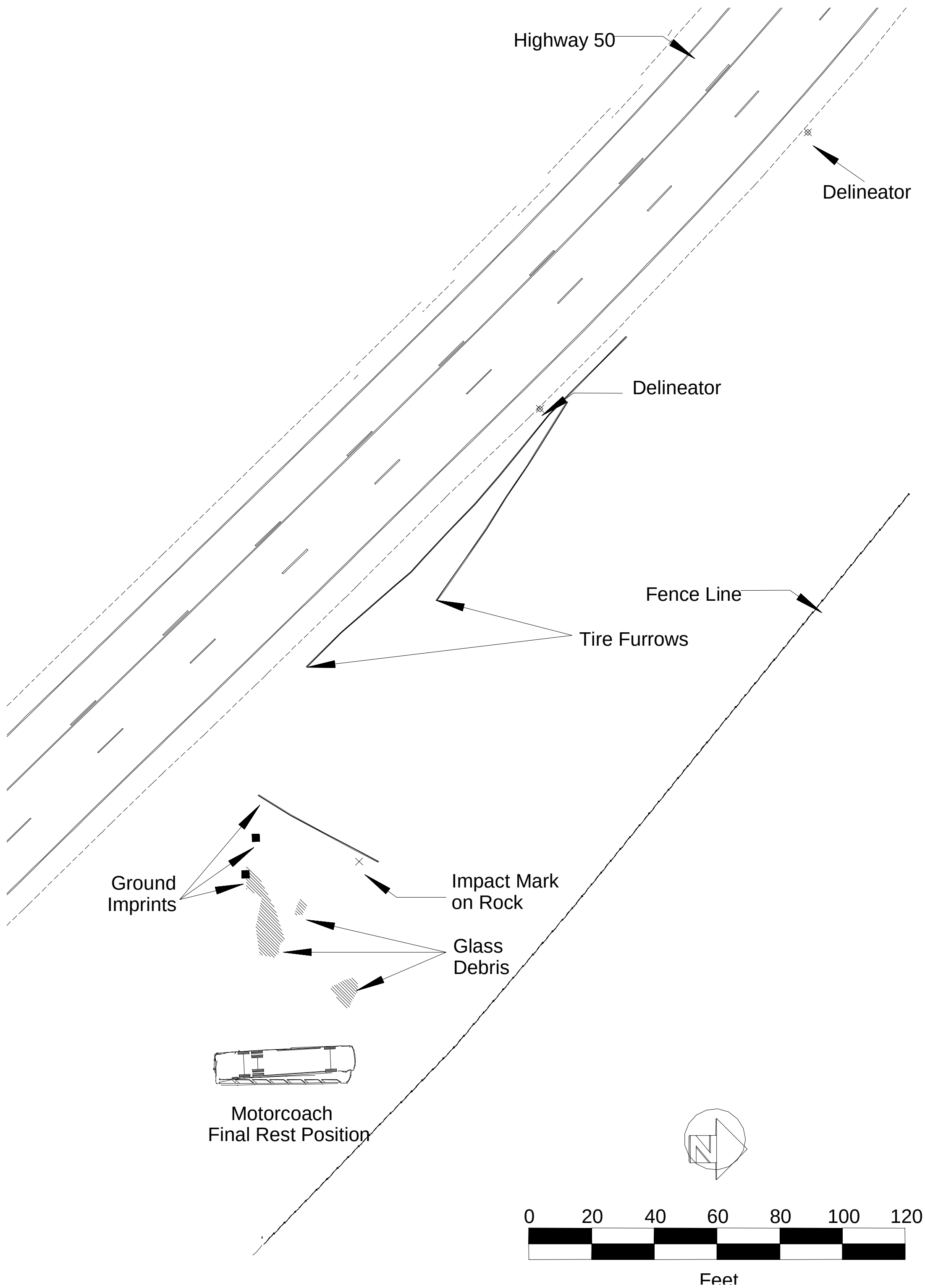

Figure 2. Diagram of accident

The temperature at the time of the accident was in the low 20ºs F with light snow. A Colorado Department of Transportation road crew had been salting and sanding the road throughout the day and reported in a postaccident interview that parts of the roadway were icy. Passengers also described patches of ice and snow on the roadway.

The accident occurred on the return leg of a 6-day (December 17 through 22, 1999) church-sponsored ski trip that originated from the Houston, Texas, area. Four motorcoaches, one of which was owned and operated by Sierra Trailways, were hired for the trip. The distance from Houston to Crested Butte, Colorado, was approximately 1,118 miles. Sierra Trailways had assigned a different driver to operate the motorcoach between Houston and Amarillo, Texas, a one-way distance of about 598 miles. The accident driver was assigned to operate the motorcoach between Amarillo and Crested Butte, a one-way distance of about 520 miles.

The trip from Houston had started about 7:00 p.m. on December 17. On that same day, the accident driver flew from Houston to Amarillo, spent the night at a hotel, and met the bus in Amarillo about 5:00 a.m. on December 18. He then drove the bus to Crested Butte, which his driver's log indicated took 10 hours. According to one witness, the trip to the resort was uneventful, and the accident driver appeared to be a "capable and safe" driver.

Investigators were unable to determine the accident busdriver's activities during his 3-day stay at Crested Butte. According to his wife, who was interviewed after the accident, the busdriver was not usually very active between trips, and he probably spent his time reading or walking.

On December 21 at 8:00 a.m., the busdriver called a tow truck operator to jump start the battery in the motorcoach, which had remained parked during the 3-day stay in Crested Butte. The busdriver checked out of his hotel room between 12:00 p.m. and 1:00 p.m. According to one passenger, the return trip to Amarillo began about 5:30 p.m., an hour before the scheduled departure.

The distance from Crested Butte to Canon City is approximately 150 miles through canyons and mountainous passes. Witnesses stated that the busdriver had driven cautiously through Monarch Pass, a mountainous area with steep and winding slopes about 1.5 hours west of Canon City, and gained speed as he left the pass. Witnesses reported that the bus fishtailed shortly before the accident.

A National Transportation Safety Board simulation of events before the accident, using witness reports, physical evidence, and data downloaded from the Detroit Diesel Electronic Controls IV[4] (DDEC IV) ECM[5] installed on the engine, indicated that the fishtail probably

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[4] Detroit Diesel's fourth generation control module.

[5] The DDEC IV ECM provides operational data for a vehicle and its engine that are used primarily for diagnostic purposes. Maintenance and fleet managers can draw on the data to review and assess driving

occurred around the curve at MP 272.3. Although the ECM data did not differentiate between application of the brakes and activation of the retarder, [6] investigators were able to determine that the retarder activated before the curve and remained active as the bus entered the curve.[7] The combination of the longitudinal friction for the retarder and the lateral friction required to steer through the curve at 63 mph exceeded the available friction, and the bus fishtail was initiated at the drive axles. The retarder, when applied, requires longitudinal friction at the drive axle wheels. The simulation indicated that if the same longitudinal deceleration that was obtained for the bus using the retarder had been distributed to all six wheels using the bus's antilock brake system (ABS), the bus would have negotiated the curve without losing control because the longitudinal force would have been lower at each wheel.

A retarder/steering-induced wheel slip at the drive axle would have triggered an ABS event,[8] resulting in the retarder being automatically deactivated and the transmission lockup clutch being disengaged, which would have allowed the motorcoach to roll forward with little resistance. A few seconds after the fishtail, the DDEC IV data indicated that the busdriver shifted the transmission into neutral, which took the reverse torque off the drive axle and prevented the retarder from reactivating.[9] Witnesses reported that the busdriver seemed to regain control of the motorcoach at that time.

Data from the DDEC IV indicated that the motorcoach continued to slowly gain speed as it descended the mountain and that the busdriver stepped on the brakes six times before the crash. Five brake applications were held for about 1 second[10] and did not result in a reduction in speed.[11] One brake application lasted about 3 seconds and resulted in a 1.5-mph decrease in speed.

As the motorcoach approached MP 273, it yawed[12] to the right, departed the roadway shoulder, and went onto the dirt. Physical evidence indicated that the bus struck MP 273 and a delineator before the busdriver was able to steer the motorcoach back onto the pavement. The simulation suggested that the busdriver's steering input was such that it probably angled the bus

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performance and its impact on the wear of the vehicle and its engine. The recorded data include trip activity, speed versus rpm, engine load versus rpm, periodic maintenance, engine usage, and hard brake activity.

[6] When active, a vehicle retarder provides a supplemental means of slowing a vehicle, thereby reducing brake wear. A retarder brakes only the drive axle and is activated when a driver releases the throttle. The transmission retarder on the accident motorcoach functioned by creating resistance to slow the transmission output shaft, which is connected to the main drive shaft that ultimately turns the wheels.

[7] Investigators primarily used the DDEC IV "hard brake" report to reconstruct the preaccident and accident events. A "hard brake" report includes data from the previous 1 minute prior to the braking event and 15 seconds after its occurrence. The "hard brake" data relate to vehicle speed at the drive axle, engine rpm, percent throttle, percent engine load, brake use, and clutch use. Brake application is not necessary to trigger a "hard brake" report if the drive axle wheels decelerate at a rate of 7 mph per second or more.

[8] An ABS event occurs when wheel slip is detected by the ABS. Such an event can occur when a driver is braking with the service brakes (brake pedal) on a slippery surface, when retarder/steering-induced wheel slip is detected, or when a vehicle is sliding and wheel slip is detected by the ABS.

[9] The Allison operator's manual states, "If you let the vehicle coast in N (Neutral), there is no engine braking and you could lose control." Had the driver instead placed the retarder lever in the "off" position, the reverse torque would have been taken off the drive axle and the driver would have been able to downshift on the straightaways and use engine resistance to help slow the motorcoach.

[10] According to Detroit Diesel engineers, a single application, representing 1 second on the DDEC "hard brake" report, can be from 1/40 second to 1 39/40 seconds long. The DDEC records brake applications that result in a minimum of 3.5 pounds per square inch of pressure or more.

[11] During four of the five brake applications, the speed of the bus increased 0.5 to 1.0 mph.

[12] Turned by angular side-to-side motion.

toward the north embankment on the opposite side of the roadway. The busdriver subsequently steered to the right, initiating a 180-degree-clockwise rotation of the motocoach, and the vehicle traveled backward down the opposite lane. Evidence indicated that the motorcoach's left-rear bumper struck another delineator on the left side of the road, and the bus proceeded backward down the north embankment, rolling at least 1.5 times on its side before coming to rest on its roof.

Accident Driver

From 1979 to 1989, the 72-year-old accident busdriver had worked as a dump truck driver for Roy Trucking of Houston and, from 1989 to 1990, as a Greyhound motorcoach driver for RLR Contract Services of Houston. Sierra Trailways employed the busdriver in March 1990. The Sierra Trailways president described the busdriver as very diligent and one of the company's best drivers, noting that the busdriver always took the bus operator's manual with him on his trips. The president reported that the accident busdriver had driven to Colorado ski resorts about 50 times since he was hired. He added that the busdriver was familiar with the accident route, having driven to Crested Butte seven times before this trip. The president believed that this trip was the first time that the busdriver operated a Setra bus equipped with a transmission retarder in the mountains during winter.[13] The busdriver had received little training on the use of the transmission retarder from either Setra or Sierra Trailways.[14]

Postaccident toxicological analysis on the driver found therapeutic levels of a sinus or cold medication and no evidence of alcohol or drugs of abuse.

Transmission Retarder

The seven-position retarder lever[15] on the accident motorcoach was found in the second highest retarder position. Safety Board investigators found that the retarder lever could be moved easily from setting to setting; consequently, the true position of the retarder lever could not be determined reliably from the physical evidence. Data from the transmission electronic control unit[16] (ECU) could not be used to determine the retarder setting because the ECU did not store this information. DDEC IV data and the Safety Board's accident simulation indicated that the retarder was on a high setting[17] at the time of the fishtail. Both the Setra operator's manual and Allison Transmissions (Allison) operator's manual that accompanied the bus warned that the retarder should be turned off when driving the motorcoach on a slippery surface. The Allison manual states, "Using the retarder on wet or slippery roads can be like jamming on the brakes – your vehicle may slide out of control. To help avoid injury or property damage, turn the retarder enable to OFF when driving on wet or slippery roads."

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[13] The Sierra Trailways president stated that he believed that the busdriver had driven to the Colorado mountains during the summer of 1999 in a Setra motorcoach equipped with a transmission retarder.

[14] A videotape that accompanied each Setra bus introduced drivers to the retarder control lever. The tape did not describe the retarder functional characteristics or include information on retarder use under various road conditions. Sierra Trailways used this videotape to acquaint drivers with the new Setra buses.

[15] Six power levels and an "off" position.

[16] An ECU is a diagnostic tool that technicians use to identify and evaluate system faults quickly and accurately. Heavy vehicle components, such as the engine, transmission, and ABS, are generally equipped with their own ECU. Safety Board investigators have found ECU data useful in identifying causal and contributory factors to accidents.

[17] The lever was quite likely set on one of the three higher power levels.

The accident motorcoach was not the vehicle usually assigned to the busdriver. In October 1998, the driver began operating a 56-seat 1999 Setra and logged about 62,600 miles on that vehicle. Both the 1999 Setra motorcoach and the accident vehicle were equipped with an ABS and an integral hydraulic retarder mounted at the rear of the transmission (transmission retarder). For about a year prior to driving the 56-seat 1999 Setra, the busdriver had operated a 1998 Prevost model H3-45. This Prevost motorcoach was equipped with an ABS and an engine retarder, which is generally less powerful than a transmission retarder.[18] Before operating the 1998 Prevost motorcoach, the busdriver had operated other Prevost models equipped with engine retarders.

The Safety Board has investigated a number of truck accidents that have involved the use of retarders during slippery road conditions. The most notable of these occurred in 1985 in Decatur, Texas, when a two-axle truck tractor, pulling two empty 27-foot van trailers, lost control on a slippery 3-percent downgrade and departed the roadway.[19] Investigators determined that the loss of control was initiated by the tractor's engine retarder, which was set at its maximum level. The Safety Board issued recommendations to the National Highway Traffic Safety Administration (NHTSA), the International Brotherhood of Teamsters (IBT), the American Trucking Associations, Inc. (ATA), and engine retarder manufacturers.[20] In response to these recommendations, NHTSA distributed copies of the booklet *A Professional Truck Driver's Guide on the Use of Retarders* to motor carriers and other interested parties; the engine retarder manufacturers revised their manuals to include specific instructions on the use of their retarders on slick surfaces and installed new instructional dashboard placards on all new vehicles; the IBT addressed retarder use in its commercial driver's license training for members and by urging its members to comply with advisory placards provided by the engine manufacturers; and the ATA informed its members of the retarder issues from the Decatur accident in its *Transport Topics* and *Trucking Safely* magazines. The Safety Board has not issued recommendations on retarder safety to motorcoach-related industries and associations.

Braking System

Despite the fishtail about a mile before the accident site, the driver did not, or was unable to, reduce the speed of the motorcoach as it continued downhill. On December 22 and 23, 1999, Safety Board and Colorado State Patrol investigators conducted a preliminary brake inspection on the accident bus and found a small leak in a fitting for the service intake to the right-drive-axle air chamber. On February 3 and 4, 2000, the Safety Board and the Colorado State Patrol, together with Bendix Commercial Vehicle Systems, a manufacturer of air brake control components, and Setra personnel, conducted a full inspection of the braking system. When the brake system's damaged parts (the air chamber, push rod, and slack adjuster on the left drive axle and the service hose and fitting on the right drive axle) were replaced and the auxiliary air system isolated, investigators found no leaks or irregularities in the system.

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[18] Richard Radlinski, instructor. "Braking Performance of Heavy Commercial Vehicles," Society of Automotive Engineering Seminar, September 10 and 11, 2001, Troy, Michigan.
[19] NTSB-FTW-85-H-TR38.
[20] Safety Recommendations H-89-38 and -40 through -44. Safety Recommendation H-89-38 has been classified "Closed – Acceptable Alternate Action." The other recommendations have been classified "Closed – Acceptable Action."

During the full inspection, investigators downloaded the contents of the ABS's ECU. The contents included two fault codes, which is the maximum number of faults that the ECU can store. The faults pertained to errors in the right-front and right-rear modulator valves.[21] An engineer from the Robert Bosch Corporation (Bosch), an ABS manufacturer, believed that the modulator valve fault codes were due to low voltage from a drained battery. Checking the voltage with a voltmeter, the engineer found it to be 12.42 volts. (The Bosch ABS's ECU operates on a 24-volt system.) When the motorcoach batteries were charged to 24 volts, the codes did not reappear. Further examination of the ABS using a standard checklist uncovered no problems.

On August 16, 2000, Safety Board investigators and a Setra field representative drained the motorcoach battery in an attempt to reproduce the modulator valve fault codes found during the February 3, 2000, inspection of the ABS. The battery was drained from 24 volts to 11.2 volts,[22] and no fault codes registered.

On February 16, 2001, Setra and Bosch engineers and Safety Board investigators again tried to replicate the fault codes. After charging the battery to 24 volts, it was drained twice to about 11 volts. The modulator valve fault codes could not be reproduced. An undervoltage code did appear at 12 volts and at 11.8 volts.

Fault codes such as those detected by the ABS's ECU are designed to either limit the ABS function or revert the braking completely to conventional air brake control. The Setra operator's manual states, "In the event of the fault occurring, the driver can usually still call upon the conventional service brakes. However, in some cases, braking action might be slightly reduced." The fault codes were not dated or time stamped, nor were they labeled "active" or "inactive."[23] Investigators could not determine whether the faults occurred at the time of the accident, several months before the accident, or after the accident. The absence of status or time stamping for the fault codes negated the codes' usefulness as a diagnostic or investigative tool. Also, because the ABS's ECU was designed to store no more than two fault codes, additional fault codes may have been present that were ignored or overwritten by the ABS's ECU.

Engine Transmission

During postaccident inspection of the motorcoach, data were downloaded from the transmission ECU, and five fault codes were discovered. Two fault codes originated during the postaccident download itself.[24] Two other fault codes occurred before the accident trip and would not have interfered with the driver's control of the bus.[25] The fifth (code 22-16), an

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[21] A modulator valve is an electro-pneumatic control valve that contains the solenoids used to precisely modulate brake air pressure during an ABS event.

[22] Between 11 and 12 volts are needed to power the ignition; no testing could be done when the voltage dropped below that level.

[23] An "active" fault code indicates the fault still exists; an "inactive" fault code indicates the fault has been rectified.

[24] The ECU registered nine ignition cycles, which were probably recorded during the initial Safety Board and Colorado State Patrol vehicle inspections that occurred during the 2 days after the accident. When these data were downloaded, the information on two fault codes indicated that the engine had not been cycled since their registration, a sign that they occurred during download.

[25] An engine speed sensor code (22-14) occurred two ignition cycles before the accident trip. This fault would not have affected the transmission's ability to shift gears but can result in harsh shifts. A throttle message

"output shaft speed sensor" fault, indicated that before or during the accident, the transmission experienced either an interruption in its electrical contact with the shaft speed sensor or the transmission ECU sensed a speed change so rapid that it determined this change to be "unreasonable."

Under normal operation, the output shaft speed sensor only allows the driver to shift into neutral or into a gear appropriate to the current speed of the bus. When code 22-16 is registered, the driver is prevented from shifting into any gear, the engine retarder is disabled, and the lockup clutch is disengaged. Attempting to correct the fault would require a driver to stop the motorcoach, turn off the ignition, and then restart the ignition. During interviews, no passenger mentioned the bus stopping after it left Crested Butte. When discovered, the output shaft speed sensor fault (code 22-16) was inactive, indicating that the condition that triggered it was no longer present. The transmission ECU fault codes were not time stamped, so investigators were unable to determine when the fault occurred or whether the fault had any effect on the operation of the bus before or during the accident.

On August 16, 2000, Safety Board investigators and Allison technicians conducted electrical continuity testing between the shift control and the output shaft speed sensor. The test results indicated no defects.

Summary

When the motorcoach fishtailed at MP 272.3, the transmission retarder was engaged, even though witnesses reported sporadic ice and snow. Following this fishtail, the driver shifted into neutral, thereby disengaging both the transmission retarder and eliminating any retarding torque provided by the transmission. As the motorcoach continued to descend the roadway, the driver lightly applied the service brakes (now his only means of braking) several times. Why this sequence of events occurred was the focus of the Safety Board's investigation.

Sierra Trailways and witness' accounts suggest that the accident driver was a safe and conscientious bus operator. Postaccident toxicology analysis was negative for alcohol and drugs of abuse. Although the busdriver had been awake since 8:00 a.m. on the day of the accident, neither witnesses nor his actions suggested behavior consistent with fatigue, and the Safety Board is not aware of any serious medical conditions that would have affected his performance.

Although the busdriver had received little training from Setra or Sierra Trailways on the functional characteristics of transmission retarders, he had substantial experience driving commercial vehicles, including at least 10 years' driving motorcoaches. He had made approximately 50 trips to Colorado ski resorts, including 7 trips to Crested Butte, using engine retarder-equipped motorcoaches. Even though his final trip to Crested Butte was his first using this transmission retarder-equipped motorcoach, the driver had recently logged about 62,000 miles on an identically equipped motorcoach. Additionally, the Setra and Allison operator's manuals specifically warn against retarder use during slippery road conditions.

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fault (66-00) occurred 12 ignition cycles before the accident trip. This fault also would not have affected the transmission's ability to shift gears.

The Safety Board conducted extensive postaccident analyses on the accident vehicle. No mechanical problems were found with the transmission or any other vehicle components, and although some minor problems may have existed with the service brakes, these problems would not have significantly reduced the busdriver's ability to brake. Additionally, data from the vehicle's transmission ECU and the ABS ECU were of limited diagnostic and investigative value.

The Safety Board could not determine why the driver had the retarder engaged during icy roadway conditions, why he shifted the transmission into neutral after the fishtail, and why he chose not to apply the brakes more vigorously prior to the accident.

Probable Cause

The National Transportation Safety Board determines that the probable cause of this accident was the motorcoach driver's inability to control his vehicle under the icy conditions of the roadway; the driver initiated the accident sequence by inappropriately deciding to use the retarder under icy conditions. Why the busdriver did not, or was unable to, slow the vehicle before the crash could not be determined.

Recommendations

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

To the Federal Motor Carrier Safety Administration:

> Develop, in cooperation with the United Motorcoach Association and the American Bus Association, a booklet that educates motorcoach drivers on the different types of retarders and on their use during low-friction-coefficient road conditions. Then, distribute this information to motorcoach carriers and other interested parties. (H-02-33)

To the United Motorcoach Association and the American Bus Association:

> Work with the Federal Motor Carrier Safety Administration to develop a booklet that educates motorcoach drivers on the different types of retarders and on their use during low-friction-coefficient road conditions. Then, distribute this information to motorcoach carriers and other interested parties. (H-02-34)

To the Institute of Electrical and Electronics Engineers and the Society of Automotive Engineers:

> Work together, as part of your initiative to establish on-board vehicle recorder standards, to develop standards for brake and transmission electronic control units that require those units to store a full history of electronic fault codes that are time stamped using a recognized clock synchronized with other on-board event data recording devices. (H-02-35)

BY THE NATIONAL TRANSPORTATION SAFETY BOARD

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