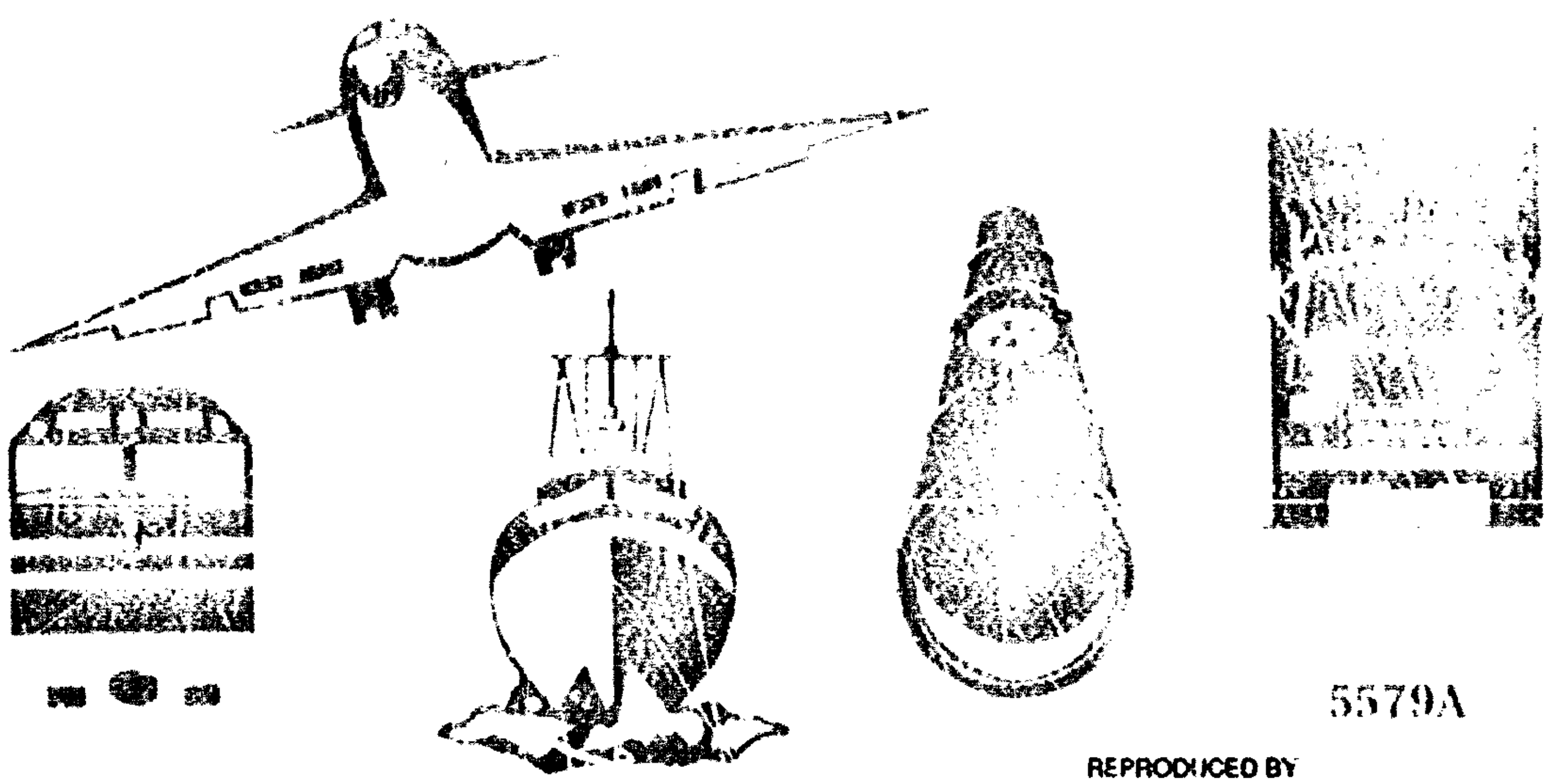
PB93-916201
NTSB/HAR-93/01

NATIONAL TRANSPORTATION SAFETY BOARD

WASHINGTON, D.C. 20594

HIGHWAY ACCIDENT REPORT

MAYFLOWER CONTRACT SERVICES, INC., TOUR BUS PLUNGE FROM TRAMWAY ROAD AND OVERTURN CRASH NEAR PALM SPRINGS, CALIFORNIA JULY 31, 1991



5579A

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HIGHWAY ACCIDENT REPORT

ADOPTED: April 13, 1993

NOTATION 5579A

Abstract: On July 31, 1991, a 1989 72-passenger school bus operated by Mayflower Contract Services, Inc., was traveling eastbound on undivided, two-lane Tramway Road from the Palm Springs, (California) Aerial Tramway parking lot. During the descent, the bus increased speed, left the road, plunged down an embankment, and collided with several large boulders. The busdriver and 6 passengers were killed; 47 passengers were injured.

The safety issues discussed in this report are the adequacy of busdriver training in mountain driving techniques and proper transmission operation in mountainous terrain, motor carrier inspection and maintenance programs, State regulations on school bus inspection and maintenance procedures, school bus occupant protection, and traffic control devices on Tramway Road and traffic control standards applicable to private roads.

As a result of its investigation, the Safety Board issued safety recommendations to the Federal Highway Administration, the State of California, the California Department of Education, the California Highway Patrol, the Mount San Jacinto Winter Park Authority, the National Committee on Uniform Traffic Laws and Ordinances, the American Association of State Highway and Transportation Officials, the National Association of State Directors of Pupil Transportation Services, the General Motors Corporation Allison Transmission Division, and Mayflower Contract Services, Inc.

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EXECUTIVE SUMMARY

At 3:24 p.m. on July 31, 1991, a 1989 72-passenger school bus operated by Mayflower Contract Services, Inc., was traveling eastbound on undivided, two-lane Tramway Road from the Palm Springs (California) Aerial Tramway parking lot. On board the bus were 45 girl scouts and 8 adult advisors. During the descent, the bus increased speed, left the road, plunged down an embankment, and collided with several large boulders. The busdriver and 6 passengers were killed; 47 passengers were injured.

The National Transportation Safety Board determines the probable cause of this accident was the loss of speed control while descending Tramway Road because of the busdriver's use of improper driving techniques for mountainous terrain. Contributing to the accident were the out-of-adjustment brakes, which had not been detected in the Mayflower Contract Services, Inc., maintenance reporting and inspection procedures.

The safety issues discussed in this report include the adequacy of:

- busdriver training in mountain driving techniques and proper transmission operation in mountainous terrain,
- motor carrier inspection and maintenance programs,
- State regulations on school bus inspection and maintenance procedures,
- school bus occupant protection, and
- traffic control devices on Tramway Road and traffic control standards applicable to private roads.

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INVESTIGATION

The Accident

At 3:24 p.m. on July 31, 1991, a 1989 72-passenger school bus (accident bus) operated by Mayflower Contract Services, Inc., was traveling eastbound on undivided, two-lane Tramway Road from the Palm Springs (California) Aerial Tramway parking lot. The accident bus was manufactured and usually operated as a school bus. In contract service on the day of the accident, it was one of five vehicles being used to transport a Girl Scout party on a tour of California attractions. On board the accident bus were 45 girl scouts and 8 adult advisors.

After completing the tramway tour, another school bus transporting about 50 girl scouts was the first vehicle in the group to leave the parking lot and to travel eastbound toward Palm Springs; a minivan driven by an advisor was second; the accident bus was third; another minivan driven by an advisor was fourth; and a small special needs bus with about 10 passengers was last.

Based on witness descriptions of vehicular spacing, the first bus left the parking lot 2 to 3 minutes before the accident bus. The second minivan's driver reported that while directly behind the accident bus, she noticed no unusual activities, such as repeated flashing of the brake lights or swaying of the bus body. After following the accident bus for a short distance, she let the special needs bus pass her vehicle so her minivan would be last in the caravan.

The special needs busdriver reported that while following the accident bus, he initially noticed nothing unusual as the two vehicles descended the grade. However, about 1.3 miles from the parking lot as they approached a curve, where a guardrail was installed (see figure 1), the accident bus increased its speed. He then saw the accident bus brake lights repeatedly go on and off as the accident bus continued to increase speed and to pull away from his vehicle.

Two passengers in the right-side sixth row of the accident bus reported their radios and headphones fell to the floor. The aisle-seat passenger slid partially into the aisle as the accident bus negotiated a turn and said "it felt like riding a roller coaster."

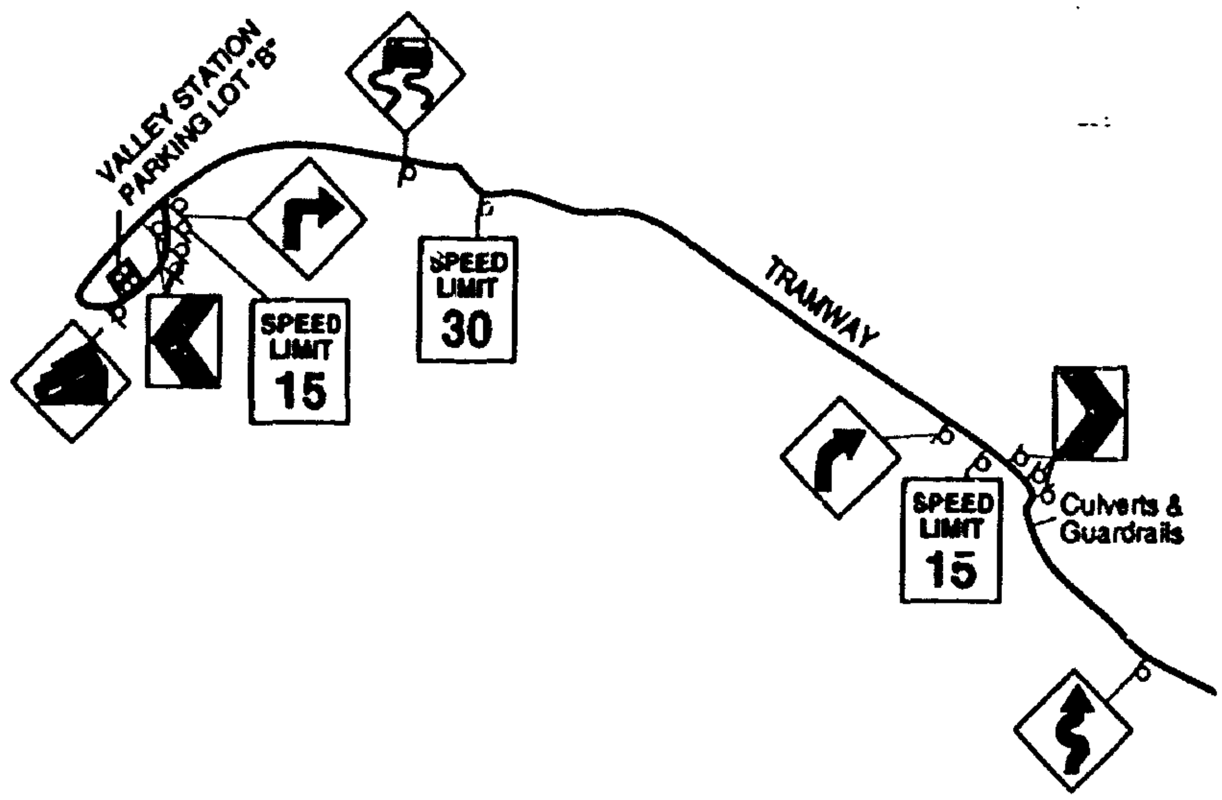
An adult in the second seat row behind the busdriver reported that after she noticed the accident bus increase speed, she yelled to the busdriver to slow down, but he did not respond. She saw the busdriver repeatedly pump the brakes, heard the air in the brake system release, and then told the busdriver to apply the emergency brakes. The busdriver responded that he could not, "nothing was working," and "everything's failed." Several passengers reported they heard a loud noise or bang as the accident bus traveled downgrade increasing speed. The busdriver and one or more passengers warned that the brakes had failed and that everyone should brace himself because the accident bus was about to crash. Two passengers reported that the busdriver grabbed the microphone of his two-way radio, then dropped it.

As the accident bus speed continued to increase, the busdriver began to honk the horn. Then, the accident bus crossed into the opposing lane and passed one or more vehicles on the left, including the minivan traveling ahead. The minivan driver reported that she was on her car phone talking to someone at the next tour destination when she looked in her rear view mirror and saw the accident bus rapidly overtaking her minivan. She could hear the honking horn of the accident bus as it passed her. Realizing that the accident bus was about to crash, she ended her phone conversation and had begun to dial 911 when she saw the accident bus plunge off the right side of the road at a left curve and crash. At the same time, the driver of the bus traveling first in the caravan reported that she saw the accident bus behind her for 2 or 3 seconds as it left the road 2.7 miles from the tramway parking lot. She then stopped her bus and went back to aid the injured.

After leaving the road, the accident bus traveled across the shoulder, plunged down an embankment, and collided with several large boulders. The accident bus body, which came to rest on its left side and steering axle, separated from the chassis. (See figure 2.) The busdriver and 6 passengers were killed; 47 passengers were injured.

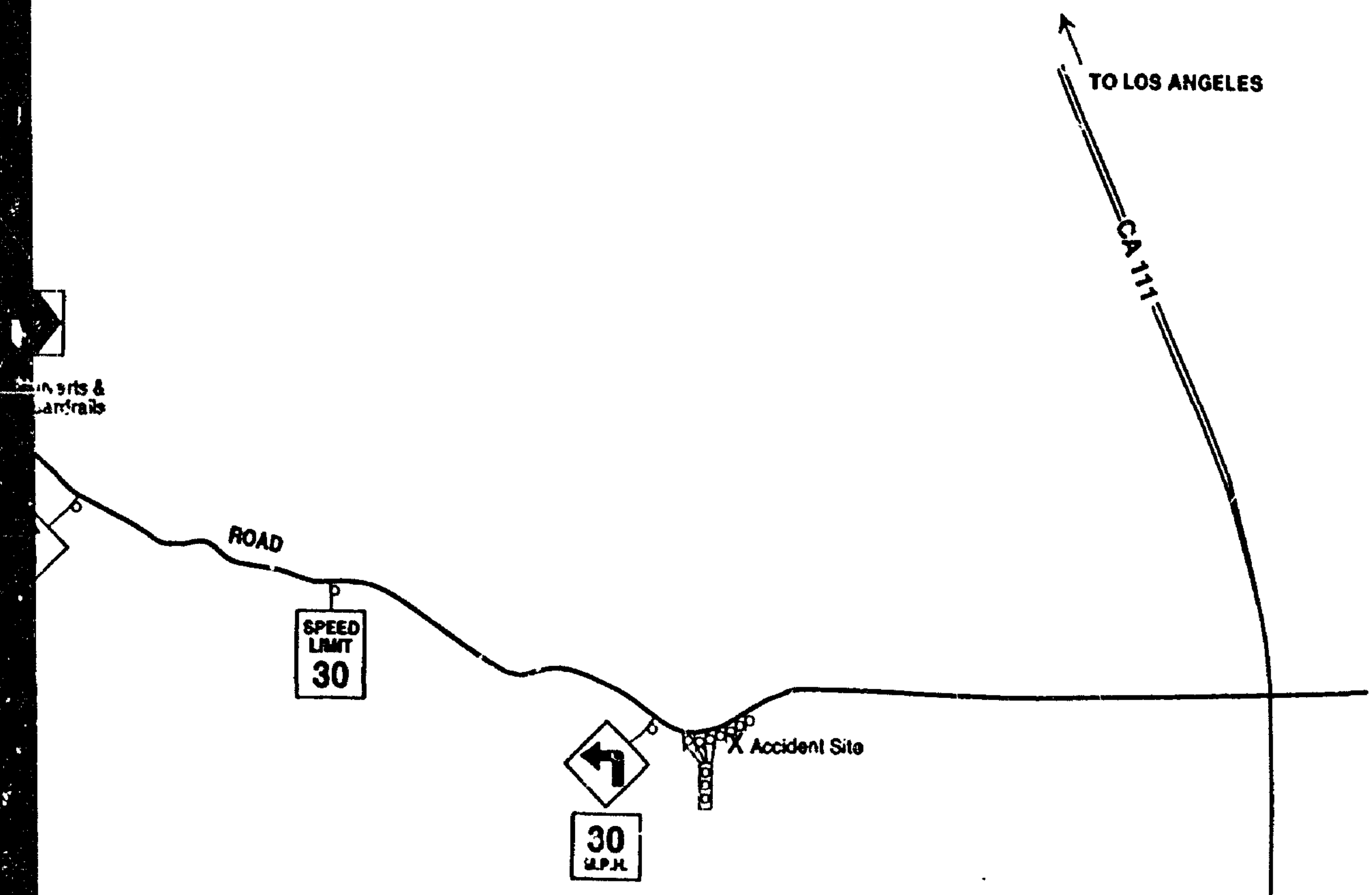
Emergency Response

The incident was under the control of a Palm Springs police captain, who established a command post and triage center at the road edge. Injured passengers were treated at the scene and transported within 1 hour 14 minutes to local hospitals. Within 24 minutes of the first rescue unit's arrival, the most seriously injured were transported by helicopter to the nearest trauma center, about 4 miles from the accident site. The last injured person was removed from the bus within 57 minutes after the incident was reported to the police.



TRAMWAY ROAD
Signing at Time of Accident
for
Downhill (Eastbound) Traffic
City of Palm Springs
California

Figure



gure 1. – – Tramway Road schematic.

Figure 2.--Accident bus at final rest position.

Injuries

Injury Table[1]

Injuries	Drivers	Passengers	Total
Fatal	1	6	7
Serious	0	12	12
Minor	0	35	35
Total	1	53	54

Busdriver Information

License and Driving Violation Record.--The 23-year-old male busdriver held a school bus certificate (passenger transportation endorsement), issued April 18, 1990. He had a valid California class B (commercial driver) license restricted to conventional buses with automatic transmissions only, issued April 25, 1990. He had no other State's license.

The California Department of Motor Vehicles (DMV) records indicate that 10 days before his school bus certification, the busdriver had two violations: failure to provide financial responsibility and failure to properly display license plates. The California Highway Patrol (CHP) records indicated that because of these violations, his driver's license had been suspended on August 26, 1990. His license was reinstated on August 30 after he filed an SR-22 (proof of financial responsibility) with the DMV. The busdriver had no outstanding traffic warrants at the time of the accident.

Medical.--The busdriver had a medical examination on March 22, 1990. He had normal vision and hearing and was not under medication. No medical conditions that would preclude his fitness for duty were noted, and he was issued a medical certificate. Nothing indicates that the busdriver's physical condition had changed since his certification.

Preaccident Activities.--The busdriver's sister stated that the day before the accident, the busdriver drove a bus on a day trip to a water park. About 4:30 p.m., he arrived home, ate dinner, and then went to the exercise gym about 7:30 p.m. He returned home between 9 and 9:30 pm., showered, and went to bed about 10 p.m. This was his usual routine in the evening.

According to the busdriver's sister, on the accident morning the busdriver probably awoke between 5:30 and 6 a.m., ate

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[1]Based on the injury criteria of the International Civil Aviation Organization, which the Safety Board uses in accident reports for all transportation modes. See appendix B for an injury table based on the Abbreviated Injury Scale (AIS) of the American Association for Automotive Medicine.

breakfast, and arrived at the Mayflower terminal in Fontana, California, about 6:30 a.m. His sister, who was also a Mayflower busdriver, had arrived at the terminal before him, and the dispatcher had asked her to do a pretrip inspection of the accident bus so it would be ready when the busdriver arrived. Unaware that the accident bus had already been inspected, the busdriver inspected it again and left the Fontana terminal with the other school buses about 7 a.m.

He drove the accident bus to the Palm Springs Oasis Resort, picked up passengers, and proceeded to the Braille Institute in Rancho Mirage. After several hours, the buses left the institute and traveled to the Aerial Tramway, where about 2 hours later, they began the descent down Tramway Road.

Training and Experience.--On March 19, 1990, the busdriver began his training at the Mayflower Fontana terminal. He received 54 hours of instruction that included 21 hours of behind-the-wheel training on a conventional school bus equipped with an automatic transmission, hydraulic power steering, and power-assisted hydraulic brakes. The typical vehicle training consisted of subjects such as engine control, transmission, driving proficiency, defensive driving, turns, winding roads, railroad crossings, and waterlogged and wet roads. The busdriver's training record form indicated that he had also received training in uphill/downhill maneuvering, which included rollback, engine control, speed control, brake use, and parking uphill and downhill.

California has no designated mountain driving training curriculum. However, Mayflower did provide some training on steep grades. A line item on the busdriver's training record form indicates completion of bus handling training under winding road and mountainous conditions. The licensing instructor testified that on April 1 and 2, 1990, the busdriver received about an hour of mountain driving training over a hilly section of Lytle Creek Road near the Fontana terminal. The busdriver drove a conventional, 42-passenger bus with an automatic transmission and power-assisted hydraulic brakes. The instructor did not know if the training bus had the same type of automatic transmission as the accident bus.

On April 9, 10, and 11, the busdriver continued his training with 14 hours of instruction in pretrip inspections, dual-air brake systems, transmission operation, and winding road driving on a transit-type bus equipped with an automatic transmission and a dual-air brake system. In addition, the busdriver received 5 1/2 hours of behind-the-wheel training on dual-air brake and automatic-spring brake systems.

Mayflower records indicate that the busdriver received no mountain driving training after April 1990. In addition, the Mayflower chief trainer stated that since June 1990, the busdriver had not been dispatched to drive in mountainous terrain similar to Tramway Road.

Vehicle Information

The 1989 model TC-2000 school bus was manufactured by the Blue Bird Body Company and purchased new by Mayflower. It had power steering, a diesel engine, and a model AT 545 four-speed automatic transmission from the Allison Transmission Division of General Motors Corporation. It was equipped with a Federal Motor Vehicle Safety Standards (FMVSS) 121-approved, dual air-mechanical, cam drum brake system that had front axle clamp type 20 brake chambers and rear axle clamp type 24/30 and emergency/parking brake chambers. All brakes had 5 1/2-inch manual slack adjusters.

The bus interior contained a center aisle with 12 forward-facing passenger seats on each side that could accommodate 3 passengers per seat. In front of each first passenger seat was a padded restraining barrier. The driver seat was lap-belt equipped; the passenger seats were not. Twelve split-type adjustable windows were on the right side, and 11 were on the left. The right front door consisted of two leaves that folded in. One emergency exit door was at the rear, and another was near the center on the left side.

The estimated gross weight of vehicle, passengers, and baggage was 22,722 pounds.

Damage.--Except for the floor at the driver station, the bus body had separated from the chassis. The front bumper had separated and the front windshield had shattered. The top-front exterior sheet metal had been pushed rearward to the first seat row, completely exposing the driver station and step well. The front axle rested 60 feet from the chassis. Both frame rails had buckled forward right of the rear axle, which had partially dislodged.

The roof was crushed rearward to the second seat row. The right side had buckled inward from the boarding door, which was torn from its hinges, about 12 feet rearward, bending the three forward window frames and breaking glass. (See figures 3 and 4.) The full-front inboard crush extended to the third seat row. Forced rearward, the crushed sheet metal had destroyed the driver station, instrument panel assemblies, boarding area, passenger safety barriers, and the first two seat rows. The floor had buckled upward about 3 inches from right to left at the front wheel wells.

Figure 3.-- Accident bus front after removal from accident site.

Figure 4.--Similar bus front.

The entire left side of the bus was crushed inboard, causing all window frame supports to buckle and to fracture at the top attachment points. The window support brackets at the first four windows were separated from the bus body. All left-side window glass was missing. The window framework and its glass had detached from the supports and were beneath the bus.

The left sidewall had crushed inward from seat row 10 rearward about 11 feet. The sheet metal surrounding the windows and the electrical access panel buckled inboard. The side walls below the windows were in relative alignment. At the left-rear corner over the last two seat rows, the roof line was pushed inward to the aisle. Viewed from above, the roof was skewed counter-clockwise with the front section leftward and the rear section rightward.

The left-side emergency door was open, and its locking assembly attached to the bus body was bent. The left-side emergency door release handle functioned properly, as did the rear emergency door release handle. Glass was missing from the rear emergency door and the two rear windows.

The diesel fuel tank was damaged on the underside near the forward bulkhead and on the topside along the forward inboard edge. The front retaining strap was broken at its lower attachment point; the fuel lines' end fittings were fractured at their attachment point. One rubber fuel line was cut where it crossed the front retaining strap. The tank was not breached, and its guard remained securely fastened to the chassis.

All tires were free of any visible preimpact defects, and their tread depth exceeded the Federal minimum standard.[2]

Parking and Emergency Brake System.--In addition to service brakes, which acted on both front and rear axle wheels, the accident bus had mechanisms for rear axle brake application in park and in an emergency. Service brakes are applied by compressed air acting against a push rod; however, rear axle parking and emergency brakes are applied mechanically by a spring in each rear axle brake chamber. When released, the spring expands against the push rod and results in a parking or emergency brake application. Whether the push rod is activated by compressed air or by spring, it acts on the same brake components, which results in braking from friction between the linings and the drums. If push rod travel is excessive, a parking or emergency brake application will not improve braking efficiency over a service brake application because all systems rely on push rod travel being within proper adjustment limits.

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[2]Title 49 Code of Federal Regulations (CFR), Chapter III, Subchapter B, Appendix G 10.a(1)b(7).

To set the parking brake, the operator manually pulls a control knob on the instrument panel to actuate valving that releases air pressure in the spring chamber. The spring force activates the brake chamber push rod. The parking system remains set until recharged with air or the spring is manually compressed or caged with a hand tool.

The emergency brake operates automatically when an unexpected loss of air pressure occurs in the brake system. Loss of air can occur from an air system rupture, a compressor failure, or repeated brake applications at a rate greater than the compressor's capacity to replenish the air available for braking. If the pressure drops to 60 pounds per square inch (psi), an audible and visual alarm alerts the operator. When the pressure drops between 30 and 45 psi, the same spring that sets the parking brake automatically applies the emergency brake.

Brake System Reassembly, Reconstruction, and Testing.--All wheel brake linings on the accident bus were free of oil or grease contamination, and their thickness exceeded the Federal minimum standard.[3] The front steering axle brake push rod travel was measured at the accident scene using 90 psi air supplied from a CHP portable compressor. After removal to a shop, the steering axle brakes push rod travel was measured again with 90 psi shop air. The test results were as follows:

	Accident Scene	Shop	Maximum Allowable Stroke[4]
Left	2 3/8 inches	2 5/16 inches	1 3/4 inches
Right	2 1/4 inches	2 1/4 inches	1 3/4 inches

The measured push rod stroke on the left side was 5/8 inch and on the right side was 1/2 inch beyond the allowable limit (cold). (See appendix D.)

The rear axle was equipped with clamp type 24/30 dual service and parking/emergency air chambers. On the right rear wheel, the brake chamber and bracket were damaged beyond repair. To measure push rod stroke, new brake parts were installed with the push rod clevis located as the original. The slack adjusters installed on the axle brake assemblies were used without changing preaccident adjustment settings. The rear axle brakes were functionally tested, and the push rod stroke was measured with 90 psi shop air. The test results were as follows:

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[3]Title 49 CFR, Chapter III, Subchapter B, Appendix G 1.(6)(a-d).

[4]For type 20 brake chambers, 49 CFR, Chapter III, Subchapter B, Appendix G 1.(5).

	Shop	Maximum Allowable Stroke[5]
Left	1 3/4 inches	1 3/4 inches
Right	1 11/16 inches	1 3/4 inches

Both push rod strokes were within the allowable limit. (See appendix D.)

Inspections.--Safety Board investigators reviewed the inspection forms and repair orders for the accident bus to develop the following:

Brake Adjustment History

9/24/90	brake inspection adjustment made	1,609 miles since last inspection
10/9/90	brake adjustment (vehicle condition report [VCR] noted brake problem)	1,211 miles since last inspection
10/22/90	brake replacement front and drums	929 miles since last service
11/9/90	brake adjustment (VCR noted brake problem)	1,422 miles since last service
11/26/90	brake replacement rear and drums	986 miles since last service
12/28/90	brake inspection adjustment made	2,276 miles since last service
1/25/91	brake inspection	2,199 miles since last inspection
2/23/91	brake replacement front	1,933 miles since last inspection
3/21/91	brake inspection	2,213 miles since last service
4/19/91	brake inspection	1,265 miles since last inspection
4/29/91	brake adjustment (VCR noted brake problem)	1,599 miles since last inspection
5/20/91	brake inspection	1,512 miles since last service
6/24/91	brake inspection adjustment made	2,143 miles since last inspection

[5] For type 24/30 brake chambers, 49 CFR, Chapter III, Subchapter B, Appendix G 1.(5).

Brake Adjustment History (continued)

7/19/91	brake inspection	318 miles since last inspection
7/31/91	accident	1,134 miles since last inspection

Inspection History

8/22/90 A inspection[6]/summer maintenance 23,717 miles
(notes, none)

8/29/90 CHP annual recertification 23,812 miles

9/24/90 A inspection 25,326 miles
(notes, none)

10/22/90 A inspection 27,456 miles
(notes, need front brakes and drums)

11/26/90 A inspection 29,874 miles
(notes, all brake shoes [on rear axle] thin need replace)

12/28/90 A inspection 32,150 miles
(notes, adjust parking brake)

1/25/91 A inspection 34,349 miles
(notes, right IS [inside] rear dual low tread)

2/23/91 A inspection 36,332 miles
(notes, need brake adjustment, need front brakes)

3/21/91 A inspection 38,545 miles
(notes, none)

4/19/91 A inspection 39,810 miles
(notes, none)

5/20/91 A inspection 42,921 miles
(notes, left rear tire worn)

6/24/91 A inspection 45,064 miles
(notes, right front tire uneven worn--left rear dual tire worn)

7/19/91 A inspection 45,382 miles
(notes, none)

7/31/91 accident 46,516 miles

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[6] The motor carrier's basic, monthly inspection, as required by the CHP.

Repair Order History

10/22/90	#99127	replaced front brake shoes and drums
11/09/90	#7894	adjusted all slack adjusters
11/26/90	#103807	installed (rear) brake shoes and drums
12/28/90	#10319X	adjusted parking brake
1/25/91	#103385	replaced right rear tires
2/28/91	#103915	changed filter repair leak (fuel), road call
3/08/91	#103611	replaced front brake shoes and seals
4/17/91	#104182	replaced air warning regulator, repaired fuel at tank
4/19/91	#104182	adjusted brakes
7/10/91	#149077	replaced two front tires

The maintenance form for the July 19, 1991, A inspection indicates the brakes were inspected and no service was performed. It lists only two items for service or repair: 1) battery cables and hold down bracket 2) check or change fuel filters. The mechanic who performed the last inspection stated that he had made no brake adjustments.

Transmission.--The accident bus was equipped with an Allison AT 545 automatic transmission, which is a four-speed medium-duty commercial automatic transmission with four forward gears and one reverse gear. Manufactured by the Quadrastat Corporation, the dash-mounted gear selector had been installed by the chassis manufacturer. The vertical gear selection display had a detent and a locking pawl for each position.

For vehicle operation on a level road, the transmission will perform for the given range selection as follows:

R-(reverse)--rearward vehicle movement from stopped position.

N-(neutral)

D-4-(drive)--first gear, with engine running in stopped vehicle. As vehicle accelerates, the control valve upshifts the transmission into second, third, and fourth gear range as specified engine rpm are reached. As vehicle slows to stop, the control valve downshifts the transmission in reverse order. Selected usually for normal driving.

D-3-(third range)--inhibits upshift pattern at third range under same conditions as in drive. Downshift starts in third range and continues as in drive. Maintains engine rpm in high torque range for improved performance when loaded and operated at slower speeds. Used for downgrade speed control with engine compression and service brakes.

D-2-(second range)--inhibits upshift pattern at second range under same conditions as in drive. Downshift starts in second range and continues as in drive. Used normally for speed control on very steep downgrades and for off road.

D-1-(first range)--inhibits shift out of first range and downshift. Used normally for off road and for very slow speed control on steep downgrades.

As with most automatic transmissions, the Allison AT-545 transmission allows the operator to move the gear selector lever to another gear range position detent while the vehicle is in motion. If the operator shifts from a higher range to a lower range, such as from fourth to third, the actual gear range shift would occur only when the vehicle speed slows enough to avoid overspeeding the engine. This safeguard feature prevents engine and transmission damage from overspeed.

When the vehicle operates on a downgrade and in a gear range other than drive, the transmission also provides an engine overspeed safeguard. If vehicle momentum drives the engine beyond its maximum governed rpm setting and into the overspeed range, the control valve upshifts the transmission to the next higher gear range; however, the transmission gear selector remains in the position chosen by the driver before upshift occurred.

Overspeed can cause valve train damage that can slow or stop the engine as well as internal damage that can seize the engine. Engine destruction from overspeed will usually result in driver loss of vehicle control because the air compressor for the brake system and the power steering pump, both vital to control the vehicle, depend on engine power.

Bus Operator Manuals.--The Allison transmission manufacturer furnishes an operator manual for each transmission it delivers. Blue Bird includes this manual with its package of manuals for every bus it manufactures. All manuals are also available upon request from either Blue Bird or Allison.

The Allison manual contains an overview of the automatic transmission in the introduction and describes the gear ranges for the model in the shift selector section. It also includes a description of each gear range operating use and warning notes about unsafe operations and any usage that could cause transmission or engine damage. This section ends with the following caution:

> The transmission incorporates a hold feature to prohibit upshifting above the range selected during normal driving. For downhill operation; however, the transmission may upshift above the highest selected gear when the engine governed speed is exceeded and damaging engine overspeed is a possibility.

In the driving tips section, the manual states:

> USING THE ENGINE TO SLOW THE VEHICLE OR EQUIPMENT: To use the engine as a braking force, shift the range selector to the next lower range. If the vehicle is exceeding the maximum speed for a lower gear, use the service brake to slow the vehicle.

Blue Bird also provides its own bus operator manual that discusses the proper gear selection when using engine braking to descend a steep or long grade. In describing the Allison automatic transmission, the manual states:

> CAUTION: In the lower ranges (1, 2 and 3) the transmission will upshift above the highest gear selected when the recommended engine governed speed for that gear is exceeded.

The training coordinator at the Mayflower terminal and the busdriver's behind-the-wheel instructor testified that neither had seen the operator manual for the automatic transmission, and the instructor had not been aware of the Allison automatic transmission upshift capability. In addition, neither the California Board of Education Train-the-Trainer program nor the Mayflower in-house training program discusses this upshift feature in their training syllabuses.

Highway Information

Within the Palm Springs city limits, Tramway Road is owned and maintained by the Mount San Jacinto Winter Park Authority. The 3.7 mile, private, two-lane highway provides access from California Route 111 to the Palm Springs Aerial Tramway Valley Station. The road splits into a one-way loop road just below the valley station to the adjacent parking lots. (See figure 1.)

The 12- to 15-foot-wide travel lanes are made of asphaltic concrete, last sealed in August 1990; the 3- to 5-foot-wide shoulders are surface treated with bitumen. Along the complete road length, the sideslopes and embankments contain large boulders and sparse vegetation.

Design.--The design plans required 22 horizontal curves from the top of the two-way section to the accident curve (2.7 miles). The accident curve was designed as a simple 350-foot radius curve with a 12.0-percent superelevation. However, a postaccident survey indicates the accident curve is not a simple curve as designed, but three simple curves (uphill, middle, and downhill) with radii of 750, 350, and 650 feet, respectively. The maximum superelevation is 5.5 percent in the downhill lane and 11.0 percent in the uphill lane. A 213-foot approach tangent connects to the 750-foot radius curve.

The road grade after leaving the loop road at the valley station is 12.6 percent for 500 feet; for the next 500 feet, the 15.7-percent grade is the steepest grade on the road. The accident curve grade is 9.4 percent. From the loop road to the accident curve, the average grade is 9.3 percent.

A yellow centerline separates each lane on the two-way section. It has no edgeline pavement marking. The original design plans did not include no-passing zone markings in advance of the accident curve; however, a no-passing zone, marked by two solid yellow lines, was installed in advance of and throughout the accident curve in the 1980s.

The design plans specified various information, warning, and regulatory signs, including a DOWN GRADE TRUCKS USE LOW GEAR (W52R)[7] sign for downhill traffic just below the drop-off area but above parking lots A and B. A second and a third sign, TRUCKS USE LOW GEAR, are 0.65 and 1.97 miles downhill, respectively, from the first sign. These signs were added in June 1964. However, only one grade warning sign, a HILL sign (W7-1)[8] located where the plans required the W52R sign, was in place at the time of the accident. Other signs in place also varied from the plan specifications. A SPEED LIMIT 35 MILES, specified at 0.45 miles downhill of the loop road junction, was missing at the time of the accident.

As a result of its investigation of a 1974 highway accident near Bishop, California,[9] which occurred on a long steep grade, the Safety Board issued the following recommendation to the FHWA:

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[7]California Department of Public Works, *Traffic Manual*, (Sacramento, California, 1955), p. 8-502.3K.

[8]Federal Highway Administration (FHWA), *Manual on Uniform Traffic Control Devices* (MUTCD), U. S. Government Printing Office, (Washington, D. C., 1988), p. 2C-13.

[9]Highway Accident Report--*Francisco Flores Truck/Pickup Truck with Camper and Trailer Collision, U.S. Route 395, Bishop, California, June 29, 1974* (NTSB/HAR-75/5).

H-75-18

> In cooperation with the motor carrier industry and driver organizations, determine what critical roadway characteristics information should be available, especially to drivers of commercial or other larger vehicles, to assure their safe descent of long/steep highway grades.

In its final response to this recommendation in March 1980, the FHWA stated:

> During 1976 and 1977, FHWA conducted research into driver information needs for safe operation on long/steep grades. . . . The effort resulted in the addition to the *Manual on Uniform Traffic Control Devices* of three warning signs giving information as to grade length and steepness.

The actual signing for maximum speeds for Tramway Road downhill traffic consists of a 15-mph-limit posting on the one-way loop road before entering the two-way road, a 30-mph-limit posting 0.42 miles downhill, a 15-mph-limit posting 0.75 miles downhill, and a 30-mph-limit posting 0.80 miles downhill. Several other chevron, turn, curve, and winding road signs are posted to alert downhill drivers of changes in alignment. A turn sign with a 30-mph placard is 280 feet before the accident curve. (See figure 1.) Near the entrance to Tramway Road, a warning sign stating STEEP GRADE TURN OFF AIR CONDITIONER gives notice to drivers traveling up the road.

On the two-way section 1.3 miles from the exit of parking lot B, a W-beam guardrail is at a 500-foot-radius reverse curve that traverses a steep embankment and a culvert. No other guardrail is installed on Tramway Road.

The authority had conducted no traffic volume counts for Tramway Road. Based on group sales records, the general manager estimated that 400 passenger cars and 2 buses made the round-trip per day. Ten percent of the buses were estimated to be school buses. No estimate of delivery trucks was given.

The regular inspection and maintenance of the tramway facility is done by in-house crews who replace and add signs as necessary. These crews have no specific traffic engineering experience, and no engineering studies on the placing of signs have been made. (The MUTCD states that traffic control device decisions should be made based on engineering studies.) An outside contractor installs pavement markings. The length of some no-passing zones has been increased from that shown on the original design plans.

As required by a resolution adopted by the Mount San Jacinto Winter Park Authority, an engineering consulting firm performs an annual facilities inspection. However, this firm primarily conducts aerial tramway inspections and has no specific expertise in traffic engineering. Before the accident, the most recent inspection was conducted in August and September 1990. In its conclusions and recommendations, the report stated that "a map of all road signs. . .should be made showing locations, size, type, etc." and that "information signs, smoking, elevation, etc., should be used and recorded. These bring awareness to the steepness of the road." The same recommendations had been made in four previous reports. The authority general manager testified that he did not know what the concern was about the road, although he thought the consultant might be suggesting that the placing of elevation signs was an information service.

Accident Records.--The authority maintains an accident file for the property, and motor vehicle accidents are part of this general file. The authority records since 1963 include 17 motor vehicle accidents. The authority documents but does not investigate accidents.

The authority records indicate that one nonfatal and one fatal accident occurred at the accident curve in 1980. In both accidents, a vehicle ran off the road while traveling downgrade, with excessive speed and alcohol reportedly involved.

If notified, the Palm Springs Police Department investigates accidents on Tramway Road that involve personal injury or fatality. Since August 1, 1992, the police department has been part of a computerized network called Desert Information Management Enforcement (DIME). Using the DIME system, the police department enters all injury and fatal motor vehicle accidents that occur on both public and private roads in the Palm Springs jurisdiction, including the Tramway Road.

Road Marks.--About 550 feet of striated, curved tire marks attributed to the accident bus began in the opposing traffic lane, crossed over the downhill lane and shoulder, and lead to the embankment where the bus dropped off. The tire marks stopping at the edge of the embankment indicates that the bus dropped off at this point. Site measurements indicate a 40-foot-horizontal and 6-foot-vertical trajectory before the bus came to rest. (See figure 5.)

Motor Carrier Operations

With its home office in Overland Park, Kansas, Mayflower Contract Services operates in 26 States. Its total fleet is about 7,700 school buses, which includes 8 models like the accident bus; in California, it operates about 800 buses. The accident bus was the only Blue Bird Model TC-2000 based at the Fontana terminal, which operates about 83 active buses and houses 9 spare units. The average bus age at this terminal is 3 years.

The Fontana terminal operates a school bus and a charter contract service. The accident bus operated intrastate and was not required to meet Federal motor carrier regulations; however, for the accident trip, it was required to meet the California vehicle code tour bus operator requirements. The vehicle inspection and maintenance requirements for school buses and charter/tour buses are essentially the same. Tour buses have a time requisite (45 days) to meet inspection requirements, while school buses have a higher standard that includes a mileage requisite in addition (3,000 miles or 45 days, whichever occurs first). As the accident bus was used in dual service, it was required to meet the higher standard and to have records maintained for that standard.

The school bus service is the main operation, and the charter contract service operates when the school year is over. The CHP has oversight for both operations. When a bus is placed in service for regular and activity school use, the CHP conducts an inspection for State and Federal school bus regulatory compliance.

Vehicle Maintenance and Inspection.--The Fontana maintenance shop has five service bays and a parts department with about a $12,000 inventory. The maintenance crew consists of one lead mechanic who supervises five regular mechanics (mechanic to vehicle ratio of 1 to 17). The school bus industry's generally accepted ratios[10] are:

> one (1) mechanic for each twenty (20) buses when the fleet is composed of vehicles with an average of three (3) years of service or less.
>
> one (1) mechanic for each ten (10) buses when the fleet is composed of vehicles with an average of eight (8) or more years of service.
>
> one (1) mechanic for each fifteen (15) vehicles when the average age of the fleet falls between the two extremes.

The California Department of Education (DOE) does not provide training to school bus mechanics, and the State does not require or issue mechanic certifications. The maintenance crew at the Fontana terminal learned their trade through years of on-the-job training and an occasional short course provided by the bus systems' manufacturers. According to the lead mechanic, he had been with Mayflower about 1 year and had over 40-years experience as a

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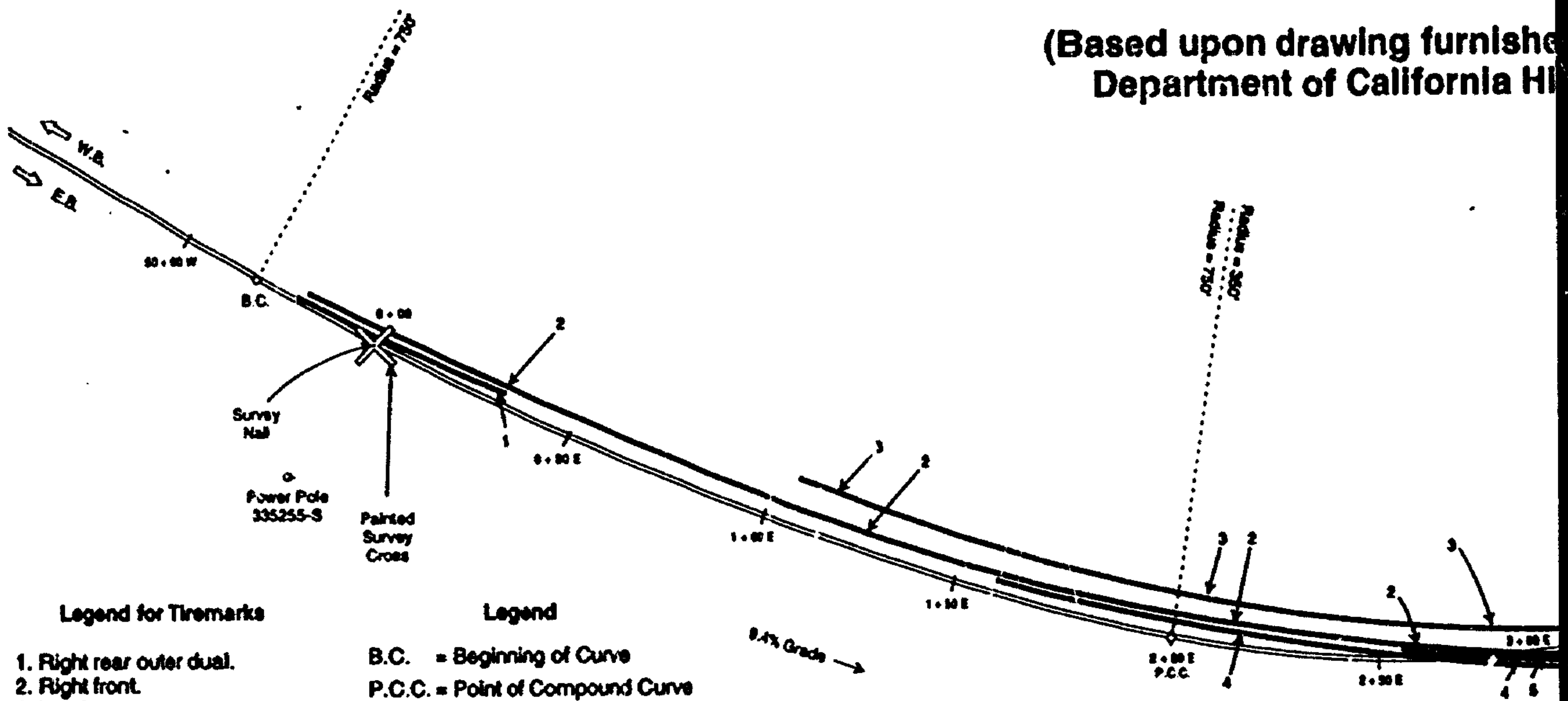
[10] Farmer, Ernest, *School Bus Maintenance: Getting the Job Done*, National School Bus Report, December 1990.

(Based upon drawing furnishe
Department of California Hi



Legend for Tiremarks

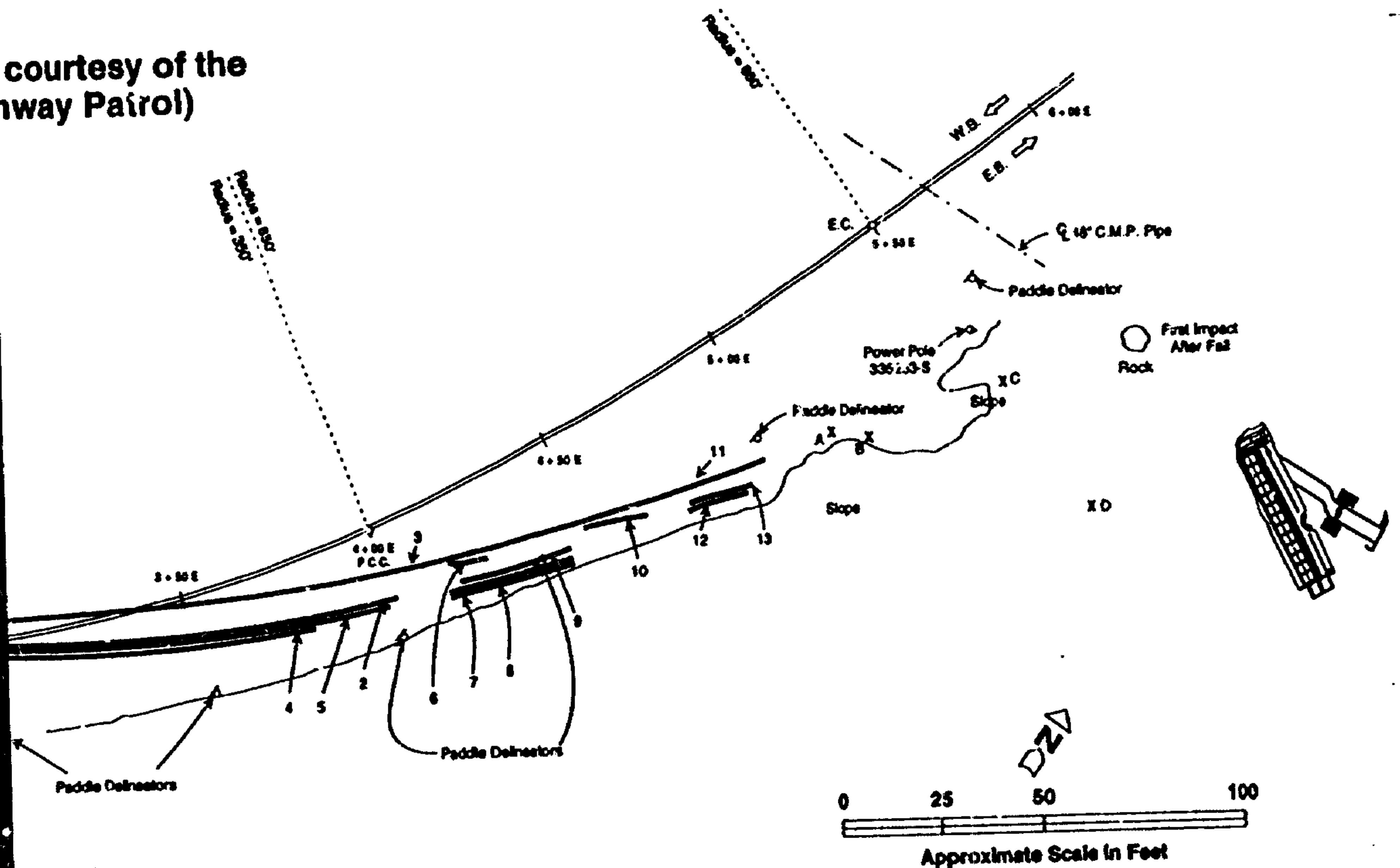
1. Right rear outer dual.
2. Right front.
3. Left front.
4. Right rear outer dual.
5. Right rear inner dual.
6. Left rear inner dual.
7. Furrow - right rear outer dual.
8. Furrow - right rear inner dual.
9. Furrow - right front.
10. Furrow - left rear inner dual.
11. Furrow - left front
12. Furrow - left rear outer dual.
13. Furrow - left rear inner dual.

Legend

B.C. = Beginning of Curve
P.C.C. = Point of Compound Curve
E.C. = End of Curve
■ Shoulder
A=Brake Chamber Diaphragm
B=1/2 Brake Chamber
C=Brake Chamber Diaphragm
D=1/2 Brake Chamber
Note: Stations are along marked double yellow center line

Figure 5. – – Tramway R

courtesy of the
hway Patrol)



ad evidence diagram.

mechanic. He stated that he was unaware of the engine overspeed protection feature of the Allison automatic transmission.

Mayflower's maintenance service interval for the accident bus was 30 days (monthly) or 3,000 miles, whichever occurred first. This service interval meets the California Code of Regulations (CCOR) requirement for school bus vehicle inspection and maintenance.

The State does not require a specific inspection form be used to meet the requirements of its vehicle inspection and maintenance code. However, the CHP does have a sample form and allows motor carriers to copy and use it. Under the brake inspection section, item 24 reads "to check brake adjustment" (to check/inspect the brakes for proper adjustment and then readjust if the brakes are near or out-of-adjustment). The CHP sample form has a signature line for the inspector to sign, as required by the CCOR.

In the California operations, Mayflower had been using the CHP form until May 1991; then it changed to a company-developed form (1040-008 Rev. 5/89) used companywide. This form lacks a signature line for the inspector to sign, as required by the CCOR. Under the brake inspection section, item 4, line N reads "adjust air brakes."

According to a Mayflower witness, the mechanics followed the same method for brake inspection with the new form as they did with the old form. The witness explained the meaning of the marked boxes on lines M and L in this section:

> If the "OK" box is marked and the "Repair" box is blank, then the item was inspected and did not require any service or repairs.
>
> If both the "Ok" and "Repair" boxes are marked and has the mechanic's initials, then the item required service or repairs. On the back of the inspection forms, the inspector would explain what service or repairs were needed for the repair boxes checked. The mechanic performing the service or repairs initials the form indicating completion.

Accident Bus.--The monthly inspection and repair order file for the accident bus showed its last brake adjustment was made at the monthly A inspection on June 24, 1991. Under the "adjust air brakes (if applicable)" entry, both the "OK" and the "Repair" box were marked; the latter box had the mechanic's initial.

On July 19, 1991, another mechanic did the next A inspection (the last before the accident). On the inspection report, the "OK" box was marked, but the "Repair" box was blank, which indicates the brakes were inspected but no service or repairs were required.

When interviewed, the mechanic confirmed that he made no brake adjustments at that time. He explained that he inspects bus brakes by first looking at the brake shoes to check the lining thickness. He then uses a screwdriver to pry the slack adjuster arm to check the push rod movement. He said that an inch or more of throw would be necessary in the push rod before it needs adjustment.

Two methods can be used for a brake adjustment check. Method 1 generally requires two people, and method 2 requires one person.

(1) Determine the brake chamber size. Make a 100 psi application to the service brakes and measure the push rod stroke. Using the chart[11] compare the actual chamber stroke to the recommended maximum stroke to determine if brake adjustment is required.

(2) Determine the slack adjuster arm length. Measure push rod stroke by manually extending push rod until brake shoes contact drum. Refer to chart. Movement longer than the allowable stroke indicates that the brake needs to be adjusted.

Using method 2, the accident bus maximum allowable push rod stroke, on both front and rear axles, would be 1 1/4 inches before brakes need to be adjusted.

Pretrip Inspection.--The Mayflower driver who regularly drove the accident bus during the previous school year reported that during routine pretrip inspection she tested the parking brake by activating its control, placing the bus in forward gear, and attempting to move the bus. If the bus did not move easily, the parking brake was effective. She also reported that before leaving the terminal, she would accelerate the bus and then stop to determine if the brakes worked properly. However, the bus had no passenger load when this test was performed.

The California vehicle code requires that a driver inspect the vehicle before operation and submit a written vehicle condition report (VCR) to the motor carrier after each tour of duty. The VCR should state the vehicle condition and recommend any repairs deemed necessary; a negative VCR should indicate no defects. Motor carriers are required to have drivers submit a VCR, to have defects corrected before the vehicle is driven on the highway, and to retain VCRs for at least 30 days.

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[11]Bendix Heavy Vehicle Systems Division, Service Data No. SD-05-1.

No VCR was found in the accident bus maintenance file for the trip on July 25, 1991. That busdriver stated that she had a problem with the brakes stopping the bus when loaded with passengers, which she did not notice before pick up or after drop off. When she returned to the Mayflower terminal at 10 p.m., the office was closed, and she could not obtain a VCR form to report the bus brake problems she experienced. Off work Friday through Monday, she returned to work on Tuesday, July 30. By then, the brake problem she had experienced the previous Thursday had been forgotten, and she, therefore, never reported it to Mayflower.

On July 30, another Mayflower driver operated the accident bus, loaded with passengers, down Mount Palomar. The trip included an approximate 3-mile descent on a winding, mountainous road. She reported that during the descent, she kept the transmission in first or second gear, used the brakes only minimally, and experienced no difficulty in maintaining speed control. On the July 30 VCR submitted to Mayflower, she reported no defects on the bus.

Meteorological Information

On the day of the accident, the weather was clear and dry.

Medical, Pathological, and Toxicological Information

According to police investigators, 14 passengers (11 survivors and 3 fatalities) were fully ejected into a terrain depression beneath the bus. Eight passengers were partially ejected, and 22 passengers and the busdriver were not ejected from the bus. The busdriver was not wearing the available lap belt. If the other nine passengers were ejected is not known. (See figure 6 for injury distribution details.)

Postaccident tests of the busdriver's blood were negative for alcohol and other drugs.

Tests and Research

Friction Coefficient.--On August 5, 1991, using a similar bus loaded with ballast to approximate the weight of the accident bus, test skidding was performed on the Tramway Road on an average 9-percent-downgrade section approaching the accident site. Over 110 feet long, the test skid marks were straight and indicated locked wheels sliding over the road surface. From a 40-mph-average initial speed, the bus could be stopped in about 120 feet, yielding a calculated friction coefficient of 0.43.

Maximum Comfortable Curve Speed Calculations.--According to the American Association of State Highway and Transportation Officials (AASHTO), the curve speed at which discomfort from centrifugal

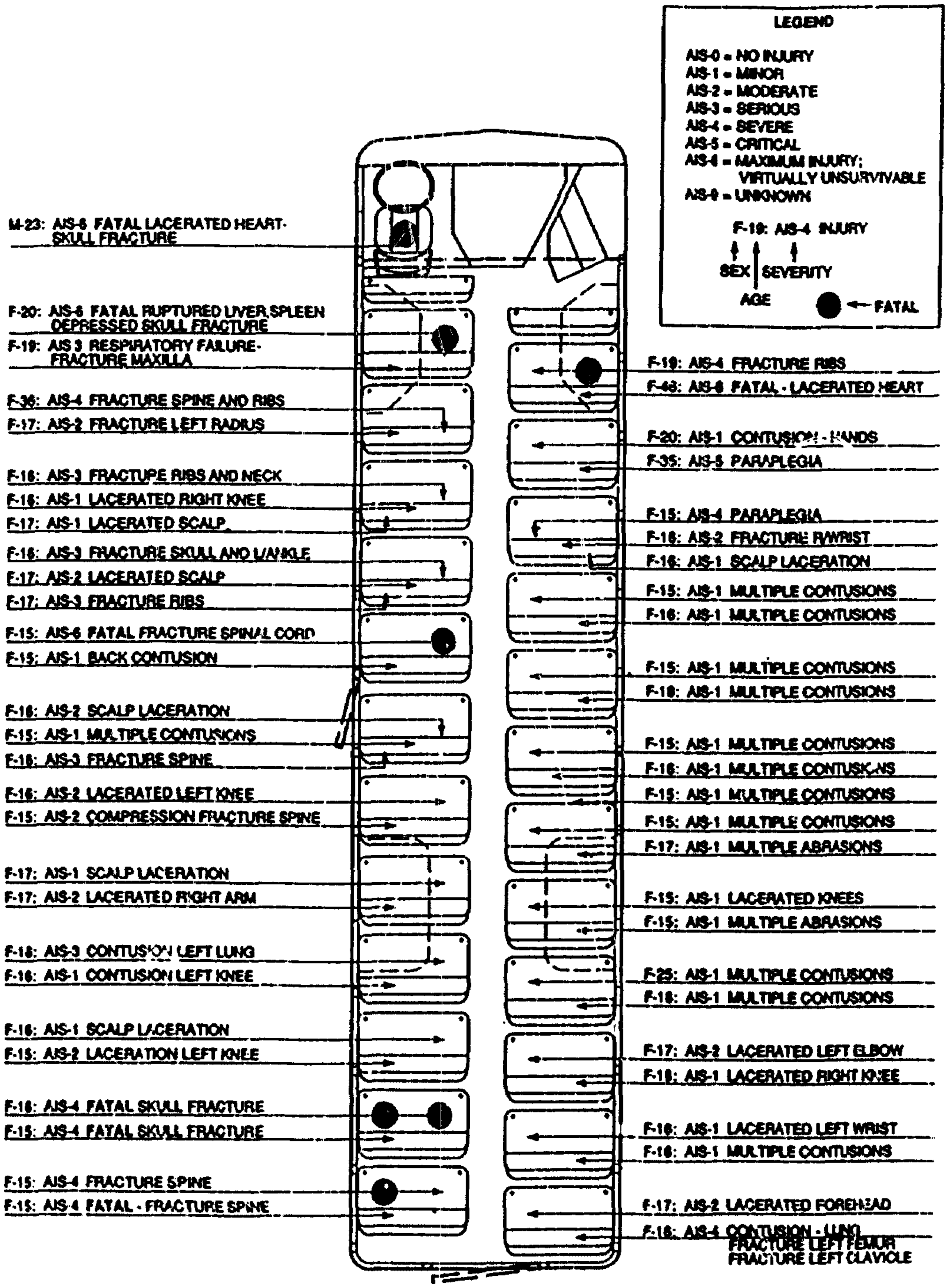

Figure 6.--Bus occupant seating and injury distribution diagram.

force is evident can be accepted as a design control for the maximum allowable amount of side friction.[12] Tests indicate that a maximum side friction factor of 0.16 is recommended for speeds to 60 mph.[13]

Where the special needs busdriver reported that the accident bus began to increase speed, the curve radius was calculated at 329 feet. Using the friction factor of 0.16, the maximum comfortable curve speed was calculated at 28 mph. The maximum speed at which the test bus could negotiate the curve without leaving the road was calculated at 46 mph, using the friction coefficient of 0.43.

The curve where the accident bus left the road had a 440-foot radius. Using the same friction calculators, the maximum comfortable speed and possible speed without leaving the road was computed at 37 mph and 57 mph, respectively.

Air Compressor, Governor, and Torque Converter.--In September 1991 under Safety Board supervision, the air compressor, governor, and torque converter were removed from the accident bus, installed on a similar bus, and tested. All components performed normally.

Control Valve Module Computations - Upshift Point Speeds.--During the on-scene investigation, an Allison service engineer tested the automatic transmission control valve module from the accident bus. The control valve module, which governs all transmission operating functions, can be adjusted to match the shift points to a particular engine and vehicle combination. The shift points were within factory specifications.

The reported test results were expressed as rpm of the transmission output shaft, which the Safety Board converted to the following speeds in mph:

Shift From Gear Range	Shift To Gear Range	Closed Throttle Upshift Speed	Full Throttle Upshift Speed	Engine Overspeed Upshift Speed
D-1	D-2	11.8 mph	14.8 mph	19.8 mph
D-2	D-3	17.8 mph	23.5 mph	31.1 mph
D-3	D-4	24.0 mph	37.6 mph	50.5 mph

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[12] *A Policy on Geometric Design of Highways and Streets*, American Association of State Highway and Transportation Officials, (Washington, D. C., 1990), p. 143.

[13] J. Barnett, "Safe Side Friction Factors and Superelevation Design," PROC. HRB, Vol. 16, Highway Research Board, (Washington, D. C., 1936), pp. 69-80.

These tests also indicated that the transmission could not be downshifted into third range while in fourth range, into second range while in third range, and into first range while in second range above 47 mph, 27.7 mph, and 17.7 mph, respectively. (See appendix E for complete test results.)

Automatic Transmission.--The bus used on August 5, 1991, for brake testing was again used in August 1992 for a road test to determine (1) the gear range required to climb the grade, (2) if the transmission would upshift to prevent engine overspeed while traveling down the grade, and (3) the proper balance of engine braking and service brake use for speed control on the grade.

The test concluded:

(1) For the majority of the upgrade, the automatic transmission control valve module gear range of choice was second range.

(2) In both road tests, using D-1 and D-2, respectively, the test bus transmission upshifted due to engine overspeed. This condition developed very rapidly early in the descent.

(3) The trip down Tramway Road required continuous application of the service brakes to maintain the bus speed below the engine overspeed limits.

The accident bus transmission control valve module test speeds compared to the road test speeds of the similar bus and the manufacturer specifications follow:

Test Run	Accident Bus Transmssion Vavle Module Test Speeds	Test Bus Speeds	Manufacturer Specifications
No. 2	19.8 mph	26.6 mph	19.5 - 25.4 mph
No. 3	31.1 mph	33.6 mph	29.3 - 36.2 mph

Brake Drums, Brake Shoes, and Gear Selector.--The four brake drums, the eight brake shoes, and the dash-mounted gear selector from the accident bus were examined at the Safety Board laboratory.

The brake drum examination revealed that the underlying crack surfaces were clean and shiny without any long-term corrosion. The fracture features were typical of an overstress break in cast iron material. Both the right and left rear drums showed similar blue discoloration to the contact surfaces. The left drum only had abnormal microstructure, indicating exposure to temperatures over 1300 °F followed by rapid cooling. Under high magnification, no visual defects were noted on the eight brake shoes or lining.

The gear selector operating handle, locking pawl, and detent slots were also examined under high magnification. Neither damage to the operating handle or base mount nor cracks or overstress in the locking pawl or detent slots was evident. The gear selector operating handle had been found at the accident site in the D-3 position.

Other Information

Federal Motor Vehicle Safety Standards.--Because the accident bus was manufactured after April 1, 1977, it was required to meet the following standards promulgated by the National Highway Traffic Safety Administration (NHTSA).

FMVSS 217, School Bus Window Retention and Release, establishes requirements for the retention of windows other than the windshields in buses and the operating forces, the opening dimensions, and the markings for pushout bus windows and other emergency exits.

FMVSS 220, School Bus Rollover Protection, establishes performance requirements for school bus rollover protection.

FMVSS 221, School Bus Body Joint Strength, requires that an inside or outside body panel be fastened so that it holds to the member where joined when subjected to force of 60-percent tensile strength of the weakest joined member. This standard attempts to reduce deaths and injuries from the structural collapse of school bus bodies during crashes.

FMVSS 222, School Bus Passenger Seating and Crash Protection, provides for occupant crash protection through the use of strengthened, closely spaced, padded seat backs and padded restraining barriers installed in front of the first row seats in large school buses. This standard attempts to reduce deaths and injuries from occupant impact with structures within the school bus during crashes and sudden driving maneuvers.

FMVSS 301, Fuel System Integrity, establishes fuel system requirements for large school buses. This standard attempts to reduce deaths and injuries from fuel spillage fires during crashes.

California Driver Training Requirements.--The DOE, CHP, and DMV have joint responsibility for training and qualifying school busdrivers. The DOE develops regulations involving school buses and training requirements and courses for school busdrivers. It trains and certifies busdriver instructors. The CHP tests and certifies school busdrivers and inspects busdriver records and school bus preventive maintenance records. The DMV issues, suspends, or revokes busdriver certificates and ensures that applicants and holders of special driver certificates maintain eligibility requirements. Together, the three departments form a system that trains, tests, and certifies school busdrivers and that regulates the school bus industry.

As defined by California vehicle code, original applicants for school busdriver certification must complete a minimum 40-hour instruction course, which must include at least 20 hours of classroom instruction and 20 hours of behind-the-wheel training. Classroom instruction covers material in the *California Highway Patrol Passenger Transportation Safety Handbook* that includes general provisions, driver authorities, and regulations governing school bus operations. Behind-the-wheel training includes defensive driving, emergency bus handling, mountain driving, passenger loading and unloading, and engine and speed control.

All training is documented on a DOE-issued student training record form, which is used by motor carriers to show hours of classroom, in-service, and behind-the-wheel training. The form is signed by a state-certified instructor. The student must pass a final written test after completing the 40-hour course.

In addition to medical certification, first-aid training, and background checks, the student must pass a CHP-conducted driving test, which includes a pretrip bus inspection. Student familiarity with all gauges, instruments, and controls on the bus must be demonstrated, and special emphasis is placed on brake systems and operation. Applicants for school bus certification are restricted to operate the same type school bus used for the testing, which is noted on the license. The CHP issues a temporary certificate after the student passes the driving test, and the DMV issues a permanent license later.

Under a provision in the DOE code, State-certified instructors may delegate behind-the-wheel instructors, who do not have to be State-certified, to assist in training. However, only State-certified instructors may sign the training record form that indicates completion of required training. Minimum standards for delegate instructors are the same as for State-certified instructors, except 1 year experience as a school busdriver preceding selection as a delegate and completion of all training in the latest edition of *Instructor's Behind-the-Wheel Guide for California's Bus Driver's Training Course* are required. Delegates must successfully complete a driving performance test and pass a written test on current laws, regulations, and policies to ensure that they have the same basic knowledge and skills as the State-certified instructors. State-certified instructors administer both tests.

<u>Colorado Mountain Driving Training</u>.--In 1985, the Colorado DOE established an annual instructional workshop that involves (1) learning all rules and regulations that pertain to school bus operation, (2) how to conduct behind-the-wheel training and how to evaluate driver performance, (3) in-service training with

experienced drivers (an 8-hour requirement, annually), (4) mountain driving training. (The mountain driving segment was established because numerous accidents involving commercial vehicles occurred in the Colorado mountains.) The workshop is offered to State-certified driver instructors and in-training instructors.[14] While Colorado State law requires mountain driving training for some school busdrivers, Colorado neither makes the workshop mandatory nor provides a mountain driving endorsement on commercial driver licenses (CDLs) for operators who drive in the mountain areas.

The mountain driving workshop segment was increased to a 3 1/2-day course after a June 1989 accident in the mountains that involved a school activity bus. The first day is classroom instruction on bus mechanical systems, brakes and air-brake systems, and retarders. The students examine the bus mechanical systems of the system models used. The remainder of the course time involves driving in the mountains, where emergency braking techniques, proper use of all types of transmissions (including Allison), and emergency stopping scenarios are practiced, as well as traversing a 7-percent grade that includes starting at the top, selecting the proper gears, and applying the proper brake down the grade. Other scenarios practiced include four-wheel lockup and an exercise in which the student simulates engine loss, transmission braking, brake loss, and no-retarder conditions.

As of July 1, 1992, Colorado law requires that:

> the driver of any school bus, as defined. . . owned or operated by or for any school district in this state shall have successfully completed training, approved by the department of education, concerning driving on mountainous terrain, as defined. . .and driving in adverse weather conditions.

California Commercial Drivers License Requirements.--On January 1, 1989, under the federally sponsored CDL program, new standards took effect in California. Since then, the CDL has been available to all commercial truck and busdrivers, and all commercial vehicle drivers must have obtained a CDL by April 1992. The DMV-issued *California Commercial Driver Handbook* specifically addresses mountain driving and covers the use of gears, proper braking, and escape ramps. Driver knowledge of mountain driving is subject to testing on the CDL written examination.

The California vehicle code in its vehicle safety regulations states that:

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[14]The National Association of State Directors of Pupil Transportation Services (NASDPTS) is considering the workshop for national certification as a training program.

> the Department of the California Highway Patrol shall adopt reasonable rules and regulations which, in the judgment of the department, are designed to promote the safe operation of vehicles described in. . .the Education Code.

On November 14, 1991, the CHP School Bus Advisory Committee met and discussed driver proficiency in mountain driving techniques and proper use of automatic transmissions. Commercial carrier regulations (CCRs) state that "the motor carrier require each driver to demonstrate that the driver is capable of safely operating each different type of vehicle or vehicle combination." A subcommittee was formed to study the issues and to recommend changes to the CCR, if warranted.

On April 14, 1992, the subcommittee proposed to the CHP that motor carriers require all passenger vehicle drivers, under the auspices of a qualified state-certified busdriver instructor or delegate behind-the-wheel instructor, demonstrate mountain driving proficiency in the type vehicle to be driven. Also, motor carriers would be required to maintain driving proficiency records for mountain terrain and intercity driving. Proficiency would be reestablished within 12 months after CDL renewal. The CHP did not adopt these recommended changes to the CCR because of the cost to develop new training.

The California DOE has revised its training record form to include the following note:

> Motor Carriers should require all drivers of passenger vehicles to demonstrate driving proficiency in the operation of a type I transit bus and/or conventional bus and a type II bus in the terrain and conditions listed below before driving such vehicle(s) in the presence of a State-Certified Bus Driver Instructor or Delegated Behind-the-Wheel Trainer of the appropriate class or an instructor who has received a certificate from the Transportation Safety Institute of the United States Department of Transportation indicating he/she has completed the Mass Transit Instructor Orientation Training (Train the Trainer) course. The employer of a driver of a passenger vehicle should require each driver to re-establish their proficiency within 12 months after renewal of their Commercial Driver License.

On the form, the DOE has also changed the designation from "mountain driving" under the vehicle training code to "Mountains 6% grade or more" under the terrain and conditions codes. The revised training record form places responsibility on the motor carrier to train for mountain driving as well as other conditions, such as snow, ice, and night driving.

Vehicle Retarders.--Operated at driver discretion, vehicle retarders provide braking forces through the driveline. These devices are typically used in heavy commercial vehicle operations on vehicles with air brake systems, diesel engines, and both manual and automatic transmissions. Heavy duty trucks, which encounter greater tare load variations, use retarders more than transit, intercity, or school buses.

The more prevalent engine and exhaust retarders operate by restricting the air flow through the engine combustion chamber or exhaust manifold. These retarders require the transmission to be in gear to transmit retardation torque through the driveline, and the proper choice of gear ratio by the driver is important. Also available are electromagnetic and hydraulic retarders, which use eddy current or fluid shear mechanisms to provide resistance to the vehicle driveline.

According to the Blue Bird Body Company, only a small percentage of its bus production is equipped with retarders, of which the majority are electromagnetic. The accident bus was not equipped with a retarder.

In 1991, Colorado enacted legislation that prohibited the seating of passengers in front rows or next to emergency exits on any school bus, operated in mountainous terrain, that is not equipped with a retarder.

ANALYSIS

General

Based on the available evidence, the Safety Board concluded that neither the weather nor road surface conditions contributed to the accident. The busdriver was physically qualified and was not impaired from fatigue, alcohol, or drugs. Except for the out-of-adjustment brakes, no preexisting vehicle defects, which could have caused or contributed to the accident, were found.

The Accident

To determine the dynamics of the accident, the Safety Board considered the following:

(1) If tire marks attributed to the bus resulted from braking or some other action;

(2) The bus speed at selected points on Tramway Road to determine the possible gear range in which the bus operated;

(3) If the busdriver selected an improper gear range to descend Tramway Road;

(4) If an improper gear selection was made, was the designed braking capacity of the bus adequate to regain speed control; and

(5) If the automatic upshift overspeed protection feature of the Allison automatic transmission contributed to the accident.

Tire Marks.--During the August 1991 test, skid marks made by the similar bus were straight and indicated locked wheels sliding over the road surface. The tire marks attributed to the accident bus immediately before it ran off the road were curved and striated. These tire marks did not result from locked wheels and skidding but from the tires sideslipping while rotating on the road surface. The Safety Board concludes that the yaw tire marks were not caused by braking and indicate the busdriver was attempting to steer around the curve when the bus left the road.

Speed Estimates.--Using the radius of the yaw marks and the friction coefficient established in the August 1991 test, calculations indicate that the accident bus was traveling about 64 mph where the yaw marks began. Calculations using the horizontal and vertical distances of its fall indicate the bus was traveling about 48 mph when it left the road. (See figure 5.)

The special needs busdriver stated that the accident bus started pulling away from his vehicle near a curve where a guardrail was installed, which was 1.3 miles from the tramway parking lot. In addition, several accident bus passengers noticed the bus traveling at an increased speed and reported one passenger slid to the left from the right-side aisle seat partially into the aisle. Being thrown to the left could only occur when the bus was making a right turn; the smallest radius right curve the bus negotiated after leaving the one-way loop road was at the guardrail/culvert. (See figure 1.)

Using the AASHTO side friction factor of 0.16, calculations indicate that at the guardrail/culvert the maximum comfortable curve speed was 28 mph. Using the 0.43 friction coefficient established in the August 1991 test, calculations indicate that at 46 mph the accident bus would have left the road at that location. Although one passenger slid into the aisle as the bus negotiated this curve, it did not leave the road; therefore, the bus was traveling between 28 and 46 mph when it negotiated the curve 1.3 miles from the parking lot at the guardrail/culvert.

Gear Selection.--On July 30, the busdriver who operated the accident bus down Mount Palomar (the preceding trip to the accident trip) reportedly maintained speed control during the descent with minimal brake usage by selecting the D-1 or D-2 gear range and experienced no automatic transmission upshift. For Tramway Road descent tests with a similar bus, braking to prevent overspeed upshifts was necessary as soon as the descent began when D-1 and D-2 were selected. The tests indicated the need for braking when the lowest gear range was selected. Therefore, regardless of the gear selected, the accident busdriver was also using his brakes when he began the descent. Brake usage for maintaining speed control would depend on which gear range was selected: the D-1 range requires the least braking, and the D-4 (Drive) range requires the most braking.

During the Mount Palomar descent with ineffective steering axle brakes and marginally adjusted drive axle brakes, speed control was maintained through a combination of proper gear range selection and minimal braking. The Safety Board concludes that the bus transmission would have been effective for maintaining speed control, with minimal braking, if first or second gear range had been selected for the Tramway Road descent.

Tests and computations determined that under normal (nonoverspeed) conditions, the transmission would shift from second to third between 17.8 and 23.5 mph[15] and would shift from third to fourth between 24 and 37.6 mph. Since the bus negotiated the curve at the guardrail/culvert between 28 and 46 mph, the Safety Board concludes that the bus was in at least third forward gear range and may have been in fourth gear range when it negotiated the curve.

As designed, the bus transmission only upshifts to prevent an overspeed when engine rpm exceed normal operating range. Should an unexpected automatic upshift occur, which allows an appreciable speed increase, it is likely that any busdriver who had not expected an upshift would attempt to slow the vehicle. Typical attempts include selecting a lower gear range, applying the brakes repeatedly, or activating parking or emergency brake control. The minivan driver, who initially followed the accident bus after it left the parking lot, as well as the special needs busdriver, who also followed the accident bus, reported that the accident bus operated normally, with its speed under control, until reaching the guardrail/culvert where its speed increased. No significant speed increases were noted before the guardrail/culvert. At this point, the special needs busdriver observed the repeated rear brake lamp illuminations begin. Because the busdriver made no observed attempts to significantly slow the bus until speed control was lost, the bus had been operating as expected, and the busdriver had probably not experienced any unexpected transmission upshifts.

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[15]Upshift at 18 mph with closed throttle, upshift at 24 mph with full throttle.

After the accident, the gear selector was found in the third forward gear position, and no crash damage to its locking mechanism, which may have caused the gear selector position to change, was evident. The last movement of the gear selector lever before the crash was therefore into the third forward gear range position. Because a downshift is a likely action the busdriver may have used to regain speed control, the movement into third may have been from fourth (drive) gear range after speed control was lost. However, the busdriver would not have upshifted from D-1 to D-2 to regain speed control. Therefore, the Safety Board concludes that the bus was in third or fourth gear range at the guardrail/culvert because the busdriver had selected that range and not because the transmission automatically upshifted.

Regardless of the gear selected, the bus was in fourth gear range when it began leaving the yaw marks that indicated a 64 mph speed. Because tests revealed that the transmission would not downshift from fourth to third until the speed was reduced to 47 mph, the bus remained in fourth gear for the 550 feet it left tire marks before leaving the road.

Brake Adequacy.--Postcrash brake adjustment measurements and air brake manufacturer data indicate that the steering axle brake force available was minimal under cool (70 °F) conditions and that heat-generated drum expansion would effectively reduce the available steering axle braking force to nearly zero. (See appendix D.) In addition, the drive axle brakes were at or near recommended readjustment levels. The bluing of the drive axle brake drums indicates severe overheating (laboratory analysis confirmed temperatures reached about 1300 °F). Because the blued surface was not subsequently worn, the overheating occurred immediately before the accident and with resultant drum expansion further degraded braking capability. The Safety Board concludes that the busdriver was unable to regain speed control of the bus because its braking capacity was degraded due to out-of-adjustment steering axle brakes and marginally adjusted drive axle brakes, which became ineffective after overheating and subsequent brake drum expansion.

From the 64 mph speed where tire marks began, the bus decelerated 16 mph to the 48 mph speed where it left the road. The accident bus traveled about 550 feet while decelerating the 16 mph. The data indicate an average 0.10 friction coefficient[16] that the Safety Board attributes to friction generated by the sideslipping tires on the road surface rather than to braking by the bus.

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[16]A 0.10 friction coefficient is the friction equivalent of a tire sliding on smooth ice. J. Stannard Baker, *Traffic Accident Investigation Manual*, The Traffic Institute, (Evanston, Illinois: Northwestern University, 1975), p. 210.

Using the friction coefficient determined by the August 1991 skid testing, calculations indicate that with optimally adjusted brakes that were not overheated, the bus could have stopped in 318 feet from 64 mph, the speed it was traveling where the yaw marks began. If the busdriver was relying on the transmission to maintain speed control and it was lost due to automatic upshifts, the Safety Board concludes that with optimally adjusted brakes that were not overheated and with proper transmission use, the bus design braking capacity was adequate to safely complete the Tramway Road descent.

Several witnesses observed that the busdriver repeatedly applied and released the bus brakes to regain speed control. The repeated air application in the brake system would cause air depletion in the reservoir, resulting in an automatic mechanical spring brake application on the drive axle wheels. Some passengers reported hearing a loud noise or bang, which was probably due to either the automatic application of the spring-loaded parking brakes after air depletion or the manual activation of the parking brake in an attempt to regain speed control.

Allison Automatic Transmission.--Tests indicated that speeds between 13.3 (closed throttle) and 19.3 (full throttle) mph were necessary before the transmission would downshift from third to second gear. Since analysis determined that the accident bus was traveling above this speed range when it negotiated the curve at the guardrail/culvert, the transmission could not be forced to downshift into second, thereby negating transmission use for regaining speed control. Measurements and computations indicated that the accident bus was traveling 64 mph where the tire yaw marks began at the curve. Tests revealed that the transmission would normally upshift from third to fourth between 24.0 and 37.6 mph and would automatically upshift from third to fourth at 50.5 mph to protect against engine overspeed. If the busdriver had selected and kept the selector lever in third gear, the bus would have automatically upshifted from third to fourth before the yaw marks began. However, any automatic upshift from third to fourth occurred after the busdriver had lost speed control. Because of the vehicle's degraded braking capacity, he could not decrease speed to effect a downshift.

The Safety Board concludes that although the Allison automatic transmission feature that permits automatic upshifts did not cause or contribute to this accident, an upshift occurrence may be the first warning that the transmission can no longer help maintain speed control and immediate action must be taken to reduce speed to effect a downshift back into the desired gear range. Therefore, the Safety Board believes that the California DOE and Mayflower should expand the school and tour busdriver training curriculum to include automatic transmission upshift characteristics and proper transmission operation in mountainous terrain. The Safety Board also believes that the NASDPTS should encourage its membership to incorporate similar training, where appropriate, into each school jurisdiction busdriver training curriculum.

To enable busdrivers to operate this transmission feature effectively, the Safety Board believes that Allison should furnish an advisory label with newly manufactured Allison automatic transmissions that have the automatic upshift feature. Allison should recommend to transmission purchasers that the label be mounted on each vehicle where it is clearly visible to the busdriver.

Driver Performance and Training

To determine knowledge or skill level, the most reliable method is to test and evaluate performance. Neither California nor Mayflower had specific performance criteria for judging proficiency in mountain driving techniques. This lack of performance criteria precluded an evaluation of the quality of mountain driving training that the accident busdriver had received.

California requires no mountain certification or behind-the-wheel training for a driver license to operate a school or tour bus. Mayflower provided about an hour of behind-the-wheel mountain driving training to the accident busdriver and thus exceeded the California minimum training requirements. The Safety Board found no evidence that the busdriver had driven in mountainous terrain since his behind-the-wheel mountain driving training in April 1990. It is possible that when assigned the accident trip, any acquired skill or knowledge had been lost through disuse.

The busdriver's instructor stated that during the mountain training he told busdrivers to use the same gear ascending and descending a grade. The busdriver should have also known the *California Commercial Driver Handbook* instruction about selecting a gear one range lower than that needed to ascend the same grade. Tests indicated that with the gear selector in drive the transmission downshifted into second gear range while ascending most of Tramway Road and at the top downshifted into first gear range. The accident busdriver must have been aware of these downshifts when ascending Tramway Road. Following the instructor or the handbook, the busdriver would have selected second gear range or first gear range, respectively, to descend Tramway Road.

However, the evidence indicates that the busdriver selected third and possibly fourth gear range before speed control was lost. Whether third or fourth gear range was selected, the busdriver either disregarded his instructions or was unaware of the significance of the transmission downshifts he should have observed while ascending Tramway Road. The Safety Board concludes that although the busdriver met all requirements for a California Class B license and had received training to operate in the mountains, he did not use proper techniques for driving in mountainous terrain. Although the California DOE has revised its position to require mountain training, the Safety Board believes it should also develop a specific curriculum for the initial and the recurrent training of school and tour busdrivers in mountain driving techniques and require those busdrivers to complete this training before driving in mountainous terrain.

Vehicle Maintenance

The Mayflower busdriver who experienced a problem with the accident bus brakes on July 26 failed to file a VCR. In addition, Mayflower failed to ensure that a VCR for the bus trip 6 days before the accident had been filed and reviewed before allowing the bus to operate. The previous driver had experienced difficulty stopping the bus under load, and the most likely cause of an inability to stop under load would be out-of-adjustment brakes.

Evidence available to the Safety Board indicates that Mayflower promptly investigated and, where appropriate, corrected all reported brake-related vehicle problems. Had a VCR been submitted after the July 26 trip, the brakes probably would have been properly adjusted before the accident bus was redispatched. Therefore, the Safety Board believes that Mayflower should institute procedures to verify that a VCR is submitted promptly by each busdriver after operating a vehicle. The Safety Board also believes that the CHP should require motor carriers verify that a VCR is submitted promptly by each school and tour busdriver after operating a vehicle.

The specified pretrip inspection procedures, which included applying the parking brake and then attempting to pull the vehicle ahead, as well as test stopping an unloaded vehicle, could not have detected that the front brakes were out of adjustment. The parking brakes applied only the rear axle brakes, and an unloaded vehicle test stop would not load the brake system sufficiently to exhibit the degraded condition of the front brakes. Under these conditions, only an inspection by a qualified person of the front brakes that included push rod travel measurement from release to full application could have determined an adjustment was needed.

The Mayflower vice president of maintenance stated that the notation on the July 19 preventive maintenance inspection report under "Adjust air brakes (if applicable)" meant that the accident bus brakes had been adjusted. However, the Mayflower mechanic who performed this inspection stated that he did not adjust the brakes during that inspection.

Mayflower records indicate that the accident bus traveled 1,134 miles between the July 19 inspection and the July 31 accident. Although the brake lining wear rate per mile can vary because of terrain traveled and driver use, it is unlikely the front brake linings wore to the extent that the push rod travel increased from

1 inch (at which point the mechanic who performed the July 19 inspection stated he would readjust the brakes) or less to 2 1/4 inches or more in 1,134 miles. The data indicate that the mechanic either failed to inspect the front brakes or failed to follow his criteria for readjustment. In either case, the Safety Board concludes that the brakes were not adjusted at the last inspection 12 days before the accident, and the steering axle brakes were out of adjustment at the time of the accident.

An ambiguity exists in the California brake inspection regulations, as written, that require brakes on school buses be "inspected" every 30 days (45 days for buses used in tour or charter service) and in the Mayflower policies and procedures. From the statements of the Mayflower vice president of maintenance and the Mayflower mechanic who performed the July 19 inspection, the form entry "Adjust air brakes (if applicable)" meant to adjust brakes in all cases and to adjust brakes if needed, respectively.

The Safety Board believes that to "inspect" push rod travel on air/mechanical brakes (to determine if adjustment is necessary) takes at least as much time and effort as the actual adjustment itself. A requirement that brakes be adjusted during each brake system inspection would therefore impose no additional burden on maintenance personnel responsible for periodic brake inspection and adjustment. In addition, such a requirement would eliminate ambiguities that lead to differing interpretations, as occurred in this case, of the meaning of "inspect" as presently contained in California regulations and in Mayflower policies and procedures.

Therefore, the Safety Board believes that the California Highway Patrol should require that all school and tour bus air/mechanical brakes with manual slack adjusters be fully adjusted at each required inspection. The Safety Board also believes that Mayflower should require in its inspection and maintenance operations that all school and tour bus air/mechanical brakes with manual slack adjusters be fully adjusted at each required inspection. Furthermore, the Safety Board believes that the NASDPTS should encourage its membership to require that all school and tour bus air/mechanical brakes with manual slack adjusters be fully adjusted at each required inspection.

Automatic Slack Adjusters

After several accident investigations that involved commercial vehicles losing control on steep downgrades due to out-of-adjustment brakes, the Safety Board published the safety study *Braking Deficiencies on Heavy Trucks in 32 Selected Accidents* (NTSB/SS-88/06). As a result of the safety study, the Safety Board issued on December 12, 1988, Safety Recommendation H-88-30, which asked NHTSA to:

> Publish a final rule by June 1990 that will require automatic slack adjusters on all new trucks equipped with air/mechanical brake systems.

NHTSA responded on April 17, 1989, as follows:

> This agency will continue to monitor the voluntary usage of automatic adjusters on heavy trucks and trailers. In recent discussions with representatives of the American Trucking Associations and the Truck Trailer Manufacturers Association, they indicated that current estimates for the installation rates of automatic brake adjusters are between 45 and 50 percent on new vehicles. NHTSA expects to finish the final report on in-use performance of large truck brake adjusters this summer with publication in the fall. Based on available data, it appears that at least one automatic brake adjuster performs satisfactorily under all operating conditions of highway use typical of U.S. trucking operations. Conclusions regarding the performance of the others in the test program are more difficult to make either because of the lack of sufficient valid data, design changes, and/or termination of the design.

NHTSA promised a copy of the final report on brake adjuster performance after publication. On May 24, 1989, the Safety Board classified the recommendation "Open--Acceptable Response" based on the above response.

On May 3, 1991, NHTSA published a Notice of Proposed Rulemaking (NPRM) *Federal Motor Vehicle Safety Standards; Hydraulic Brake Systems and Air Brake Systems; Automatic Brake Adjusters*. The NPRM included a discussion of Safety Board findings for out-of-adjustment brakes on heavy vehicles and cited Safety Recommendation H-88-30. The proposed rule includes amendments to 49 CFR 571 section 105:

> Each vehicle shall be equipped with a service brake acting on all wheels. Wear of the service brake shall be compensated for by means of a system of automatic adjustment, which maintains brake adjustment within the manufacturer's recommended adjustment limits.

and section 121:

> Each vehicle shall be equipped with a service brake acting on all wheels. Wear of the service brake shall be compensated for by means of a system of automatic adjustment, which maintains brake adjustment within the manufacturer's recommended adjustment limits. The condition of service brake adjustment shall be provided by a brake adjustment indicator, that is discernable when viewed with 20/40 vision, using an ordinary flashlight.

On April 29, 1992, the Safety Board issued its safety study *Heavy Vehicle Airbrake Performance*. The study focuses on brake system issues and addresses the systemic problems associated with heavy vehicle brake-related accidents. Based on these concerns, the Safety Board issued Safety Recommendation H-92-51 that requested NHTSA expedite the proposed rulemaking to require automatic adjusters on vehicles equipped with airbrake systems.

On October 20, 1992, NHTSA amended FMVSS 121, Air Brake Systems, to require automatic brake adjusters on all air-braked vehicles with external adjustment mechanisms. As a result, the Safety Board has classified Safety Recommendations H-88-30 and H-92-51 "Closed--Acceptable Action."

The NHTSA studies and the Safety Board brake performance study concluded that vehicles equipped with automatic slack adjusters maintain a significantly higher brake adjustment level. If automatic slack adjusters had been installed on the accident bus, it is probable that the proper adjustment level for the front brakes would have been maintained.

Vehicle Retarders

The lack of auxiliary speed control was not a causal factor in this accident. Vehicle retarders provide an added safety measure of speed control assistance but are not designed to stop a vehicle. Correct driver speed control practices and properly maintained brakes are the primary preventions for downhill runaway accidents.

Survival Aspects

The accident bus sustained severe full front and left rear crush damage. Its interior remained intact although the chassis and body separated. The frontal collapse negated the padded restraining barriers as passenger crash protection; however, the padded, high-backed seats provided crash protection outside the principal crush areas. No fuel tank rupture, fire, major body component separation, or seat failure occurred. The Safety Board concludes that the bus body performed as intended by FMVSS 221

(School Bus Body Joint Strength), 222 (School Bus Passenger Seating and Crash Protection), and 301 (Fuel System Integrity).

Six fatalities were seated in the major crush areas and sustained injuries typical of severe upper body crushing. The seventh fatality, who was seated on the left side in row five, had a fractured neck of undetermined origin. Three fatalities were found underneath the left side of the bus in a terrain depression. Given their location near demolished windows, these passengers probably fell from the accident bus after it came to rest rather than being ejected during the crash sequence.

The survivors' injury patterns (see figure 6) indicate their proximity to the bus body crush and impact points and are typical of blunt and crush injuries, such as spine and rib fractures and internal organ contusions.

School Bus Occupant Protection

It is unlikely that the bus passengers would have benefited from lap belt use. In this accident, six of the seven fatalities were seated in the major crush areas. Most surviving passengers sustained minor injuries. If belted, the survivors' injuries probably would have been no less severe.

Sixty-five percent of the bus passengers were seated outside the major impact or crush areas. That 89 percent of them sustained minor or moderate injuries attests to the effectiveness of the crash protection afforded by compartmentalization features in the bus interior.

The Safety Board safety study *Crashworthiness of Large Poststandard School Buses* (NTSB/SS-87/01) noted:

> "Compartmentalization" is considered passive protection because no action (such as buckling a lap belt) is needed by a school bus passenger to obtain protection. Protection is automatically provided by the high backed, padded seats placed close together. Compartmentalization essentially is the concept of a "friendly interior. . . ."
>
> Based on the findings of this study, the Safety Board does not recommend that States or school districts allocate funds to retrofit or order large poststandard school buses with lap belts for passengers. The Safety Board also does not recommend that Federal school bus safety standards be amended to require that all new large school buses be equipped with lap belts for passengers. The safety benefits

> of such actions, both in terms of reduced injuries for school bus passengers and in seat belt use habit formation, have not been proven. . . .
>
> The Federal school bus safety standards, providing for "compartmentalization," worked well in the Safety Board-investigated crashes to protect school bus passengers from injury in all types of accidents. Ninety percent of the unrestrained passengers in the accidents in the Safety Board's school bus study received only minor or no injuries.

The Safety Board has not seen any evidence in the last 5 years that would alter the findings and conclusions as outlined in the safety study.

Highway Factors

Inspection and Maintenance.--The authority maintenance personnel regularly inspected the highway pavement and shoulders. In addition, an engineering consultant made an annual inspection and had not noted traffic engineering deficiencies, which was probably due to the consultant's lack of expertise in this discipline.

Alignment.--The curves and steep grades require drivers to maintain a safe speed by braking and/or shifting into a low gear. The safe speed is dependent, in part, upon the design speed, which is influenced by the terrain character. Since the existing horizontal alignment of Tramway Road differs from the original design and as-built plans, the Safety Board can not determine the safe speed of the accident curve from the plans.

Although the geometry of the actual curve is not in accordance with recommended practice, a driver traveling at the 30 mph speed limit can negotiate the curve safely and comfortably. The 30 mph speed limit is below the design-recommended 35 mph and the estimated design 40 mph. Although the 30 mph speed limit was apparently not established on the basis of engineering and traffic investigation, it is reasonable considering the road grade and alignment.

Signing.--Although the Tramway Road speed limit and speed advisory signs are not based on engineering studies, they probably did not contribute to this accident since the busdriver was unable to maintain these speeds. More important to this highway, especially for trucks and buses, is the signing for the steep grade. The long steep grade before the accident curve provides sufficient distance for an improperly geared and/or braked vehicle to exceed the safe speed.

The severe downgrade limits driver ability either to control maximum speed on the curve approach or to properly reduce speed. Near the bottom of Tramway Road, drivers traveling uphill are exposed to a sign which reads STEEP GRADE TURN OFF AIR CONDITIONER; however, it serves a different purpose than the HILL warning sign and may be forgotten by the return trip. Because the road is flanked on both sides by steeper mountains, the grade severity is not apparent to a motorist unfamiliar with descending the grade. Therefore, adequate signing for this long steep grade is a necessity.

The average 9.3-percent grade for the 2.7 miles of road from the top to the accident site meets the California *Traffic Manual* and the MUTCD guidelines for a HILL sign. A HILL symbol sign is in place just beyond the parking area; however, this placement is poor because the bus parking area is downhill from the sign. Although the accident busdriver may have seen it before he parked and again when walking to the bus after the tramway trip, he could not see it on the trip down. Since the other two HILL signs indicated on the plans (which are downhill from the parking lot) are missing, the busdriver had no warning of the hill once he began his descent.

When a HILL symbol sign is installed, the California *Traffic Manual* requires that a supplemental plaque indicating the percent grade, with or without a mileage plague, be used. None is posted on the HILL sign. Because Tramway Road is private, the authority does not have to follow the MUTCD or the California *Traffic Manual*. However, the highway is open to the public and the authority was created by the State, so it would be reasonable to expect adherence to the California manual.

A sign in the bus parking area that both describes grade steepness and length and depicts road curvature ahead would be another informational feature. Such signs have been used successfully in conjunction with the standard recommended signs in the MUTCD, and the plan is known as total-concept signing.

In the FHWA report *Improving the Highway System by Upgrading and Optimizing Traffic Control Devices*, the author concluded that:

> deficient information display is a major source of driver error.... since deficiencies in the information system cause errors to occur, and since proper traffic control devices reduce errors and aid drivers at hazardous locations, upgrading the highway information system to MUTCD standards and optimizing it where required will enhance safety and efficiency.

The Safety Board concludes that had the signs been in conformance with the California *Traffic Manual*, the busdriver would have had additional cues to select a lower gear range to descend Tramway Road. Therefore, the Safety Board believes that the authority should bring all traffic control devices on Tramway Road into conformance with the California *Traffic Manual*.

Private Versus Public Road.--The transition from a publicly maintained road to a privately owned road is often subtle and indistinguishable. The general public cannot readily differentiate the private Tramway Road from a public thoroughfare, although an informational sign at the entrance states that they are entering a private road.

Private roads also may not be maintained in accordance with standards applicable to public roads. The planning, design, and installation of signs and striping were the responsibility of authority personnel who had no training or experience in traffic engineering or in the application of the *Manual on Uniform Traffic Control Devices*, the California *Traffic Manual*, or the *California Department of Parks and Recreation Manual*. The engineering consultant who did the annual facilities inspection for the authority was also untrained and inexperienced in traffic engineering. Because the authority staff and engineering consultant lacked the necessary traffic engineering expertise, inadequate signing for the steep downgrade resulted.

MUTCD Application to Private Roads.--Because Tramway Road is private property, the authority was not required to follow the MUTCD. The authority purchased its signs from a supplier to governmental jurisdictions and, therefore, used the standard signs found in the MUTCD. Traffic control devices, where necessary, should conform to the MUTCD and be installed and properly maintained on both public and private roads. Some Tramway Road signing was inadequate or improper since the authority conducted no traffic engineering studies for sign usage or placement.

The MUTCD suggests that jurisdictions without qualified staff engineers should seek assistance from the State highway department, the county, a city, or a traffic engineering consultant. The authority could have used interagency agreements or contracts and required the engineering consultant to subcontract for expert traffic engineering advice.

In a December 9, 1990, AASHTO policy resolution, it strongly recommended the use of the MUTCD for private roads. The American Public Works Association, the American Association of Chiefs of Police, the International Union of Police Association (AFL/CIO), the National Sheriff's Association, and the American Traffic Safety Services Association (ATSSA) also endorse the need for the MUTCD use. In addition, the Institute of Transportation Engineers has a longstanding policy that traffic control devices installed on private property comply with MUTCD provisions.

The ATSSA has recommended that the MUTCD general provisions state that uniform traffic control devices apply to private property where public travel is encouraged. This would include highways such as Tramway Road; however, it also would include all shopping centers, subdivision developments, and arenas, which appears to be a rather broad application. Some States have more narrowly defined the applicability of the MUTCD or their own manual to private facilities based on parking space numbers. This lacks uniformity from State to State.

The National Safety Council publication *Manual on Classification of Motor Vehicle Traffic Accidents* has adopted the term, trafficway. This term includes public and private roads and more narrowly defines private roads. NHTSA defines the term as any road, street, or highway open to the public as a matter of right or custom for moving persons or property from one place to another.

The Safety Board concludes that private roads open to the public are not subject to the same signing and traffic control standards as public roads. Therefore, the State of California should amend the California Vehicle Code to include the NHTSA definition of trafficway to ensure uniformity of traffic control devices on public and private roads and require that the California *Traffic Manual* sections regarding traffic control devices apply to trafficways. The Safety Board believes that the FHWA, the National Committee on Uniform Traffic Laws and Ordinances, and AASHTO should adopt the NHTSA definition of trafficway to ensure uniformity of traffic control devices on public and private roads and that, where appropriate, the MUTCD or each State traffic manual applies to trafficways.

CONCLUSIONS

Findings

1. Neither the weather nor road surface conditions contributed to the accident. The busdriver was physically qualified and was not impaired from fatigue, alcohol, or drugs. Except for the out-of-adjustment brakes, no preexisting vehicle defects were found.

2. The yaw tire marks were not caused by braking and indicate the busdriver was attempting to steer around the curve when the bus left the road.

3. The bus was traveling between 28 and 46 mph when it negotiated the curve 1.3 miles from the parking lot at the guardrail/culvert, about 64 mph where the yaw marks began, and about 48 mph when it went into the air after leaving the road.

4. The bus was in at least third forward gear range and may have been in fourth gear range when it negotiated the curve at the guardrail/culvert.

5. The bus was in third or fourth gear range at the guardrail/culvert because the busdriver had selected that range and not because the transmission automatically upshifted.

6. The busdriver was unable to regain speed control of the bus because its braking capacity was degraded due to out-of-adjustment steering axle brakes and to marginally adjusted drive axle brakes, which became ineffective after overheating and subsequent brake drum expansion.

7. With optimally adjusted brakes that were not overheated and with proper transmission use, the bus design braking capacity was adequate to safely complete the Tramway Road descent.

8. The bus transmission would have been effective for maintaining speed control, with minimal braking, if first or second gear range had been selected for the Tramway Road descent.

9. The Allison automatic transmission feature that permits automatic upshifts did not cause or contribute to this accident.

10. Although the busdriver met all requirements for a California Class B license and had received training to operate in the mountains, he did not use proper techniques for driving in mountainous terrain.

11. Mayflower Contract Services, Inc., failed to ensure that a vehicle condition report for a bus trip 6 days before the accident had been filed and reviewed before allowing the bus to operate.

12. The brakes were not adjusted at the last inspection 12 days before the accident, and the steering axle brakes were out of adjustment at the time of the accident.

13. The bus body performed as intended by Federal Motor Vehicle Safety Standards 221 (School Bus Body Joint Strength), 222 (School Bus Passenger Seating and Crash Protection), and 301 (Fuel System Integrity).

14. It is unlikely that the bus passengers would have benefited from lap belt use; if belted, the survivors' injuries probably would have been no less severe.

15. Sixty-five percent of the bus passengers were seated outside the major impact or crush areas; that 89 percent of them sustained minor or moderate injuries attests to the effectiveness of the crash protection afforded by compartmentalization features in the bus interior.

16. Had the signs been in conformance with the California *Traffic Manual*, the busdriver would have had additional cues to select a lower gear range to descend Tramway Road.

17. Private roads open to the public are not subject to the same signing and traffic control standards as public roads.

Probable Cause

The National Transportation Safety Board determines the probable cause of this accident was the loss of speed control while descending Tramway Road because of the busdriver's use of improper driving techniques for mountainous terrain. Contributing to the accident were the out-of-adjustment brakes, which had not been detected in the Mayflower Contract Services, Inc., maintenance reporting and inspection procedures.

RECOMMENDATIONS

As a result of its investigation, the National Transportation Safety Board made the following recommendations:

-- to the Federal Highway Administration:

> Adopt the National Highway Traffic Safety Administration definition of trafficway to ensure uniformity of traffic control devices on public and private roads. (Class II, Priority Action) (H-93-10)
>
> In cooperation with the States, require that, where appropriate, the *Manual on Uniform Traffic Control Devices* or each State traffic manual applies to trafficways to ensure uniformity of traffic control devices on public and private roads. (Class II, Priority Action)(H-93-11)

--to the State of California:

Amend the California Vehicle Code to include the National Highway Traffic Safety Administration definition of trafficway to ensure uniformity of traffic control devices on public and private roads. (Class II, Priority Action) (H-93-12)

Require that the California *Traffic Manual* sections regarding traffic control devices apply to trafficways to ensure uniformity of traffic control devices on public and private roads. (Class II, Priority Action) (H-93-13)

--to the California Department of Education:

Expand the school and tour busdriver training curriculum to include automatic transmission upshift characteristics and proper transmission operation in mountainous terrain. (Class II, Priority Action) (H-93-14)

Develop a specific curriculum for the initial and the recurrent training of school and tour busdrivers in mountain driving techniques and require those busdrivers to complete this training before driving in mountainous terrain. (Class II, Priority Action) (H-93-15)

--to the California Highway Patrol:

Require that motor carriers verify that a vehicle condition report is submitted promptly by each school and tour busdriver after operating a vehicle. (Class II, Priority Action) (H-93-16)

Require that all school and tour bus air/mechanical brakes with manual slack adjusters be fully adjusted at each required inspection. (Class II, Priority Action) (H-93-17)

-- to the Mount San Jacinto Winter Park Authority:

Bring all traffic control devices on Tramway Road into conformance with the California *Traffic Manual*. (Class II, Priority Action) (H-93-18)

-- to the National Committee on Uniform Traffic Laws and Ordinances:

Adopt the National Highway Traffic Safety Administration definition of trafficway to ensure uniformity of traffic control devices on public and private roads. Class II, Priority Action) (H-93-19)

-- to the American Association of State Highway and Transportation Officials:

Adopt the National Highway Traffic Safety Administration definition of trafficway to ensure uniformity of traffic control devices on public and private roads. (Class II, Priority Action) (H-93-20)

-- to the National Association of State Directors of Pupil Transportation Services:

Advise your membership of the facts and circumstances of this accident and encourage them to incorporate automatic transmission upshift characteristics and proper transmission operation in mountainous terrain, where appropriate, into each school jurisdiction busdriver training curriculum. (Class II, Priority Action) (H-93-21)

Encourage your membership to require that all school and tour bus air/mechanical brakes with manual slack adjusters be fully adjusted at each required inspection. (Class II, Priority Action) (H-93-22)

-- to the Allison Transmission Division:

Furnish an advisory label with newly manufactured Allison automatic transmissions that have the automatic upshift feature. Recommend to transmission purchasers that the label be mounted on each vehicle where it is clearly visible to the busdriver. (Class II, Priority Action) (H-93-23)

--to Mayflower Contract Services, Inc.:

Expand the school and tour busdriver training curriculum to include automatic transmission upshift characteristics and proper transmission operation in mountainous terrain. (Class II, Priority Action) (H-93-24)

Institute procedures to verify that a vehicle condition report is submitted promptly by each busdriver after operating a vehicle. (Class II, Priority Action) (H-93-25)

Require in your inspection and maintenance operations that all school and tour bus air/mechanical brakes with manual slack adjusters be fully adjusted at each required inspection. (Class II, Priority Action) (H-93-26)

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April 13, 1993

APPENDIXES

APPENDIX A

INVESTIGATION AND HEARING

Investigation

On July 31, 1991, about 9 p.m., the Safety Board dispatched an investigative team with members from Washington, D.C., Seattle, Washington, and Los Angeles, California. On August 1, on-scene team members established investigative groups for human performance, highway and environment, vehicle, and survival factors.

Representatives of National Highway Traffic Safety Administration, the California Highway Patrol, the Palm Springs Police Department, the Mount San Jacinto Winter Park Authority, the Allison Transmission Division of General Motors Corporation, the Blue Bird Body Company, and Mayflower Contract Services, Inc., participated in the investigation.

Public Hearing

During the hearing on October 31 and November 1, 1991, in Los Angeles, representatives of the Federal Highway Administration, the National Highway Traffic Safety Administration, the California Highway Patrol, the California Department of Transportation School Transportation and Freeway Operations sections, the Colorado Department of Education, the Palm Springs Police Department, the Mount San Jacinto Winter Park Authority, the National Coalition for School Bus Safety, the Allison Transmission Division of General Motors Corporation, and Mayflower Contract Services, Inc., testified.

APPENDIX B

AIS Injury Table[1]

Injuries	Busdriver	Passengers	Total
AIS-1 Minor	0	25	25
AIS-2 Moderate	0	10	10
AIS-3 Serious	0	6	6
AIS-4 Severe	0	8	8
AIS-5 Critical	0	1	1
AIS-6 Unsurvivable	1	3	4
AIS-9 Unknown	0	0	0

[1]Conforms to the Association for the Advancement of Automotive Medicine 1990 revised abbreviated injury scale.

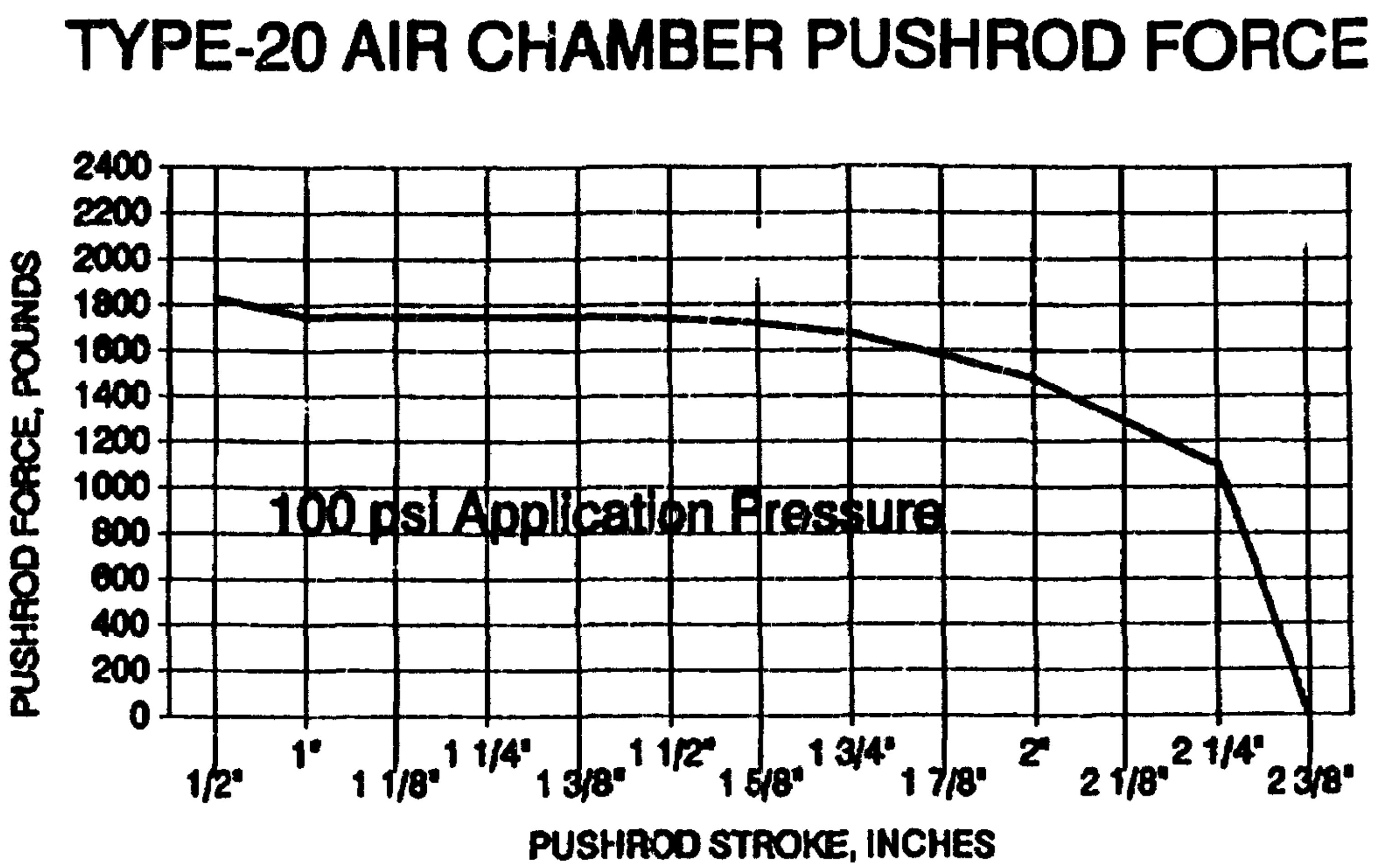
APPENDIX C

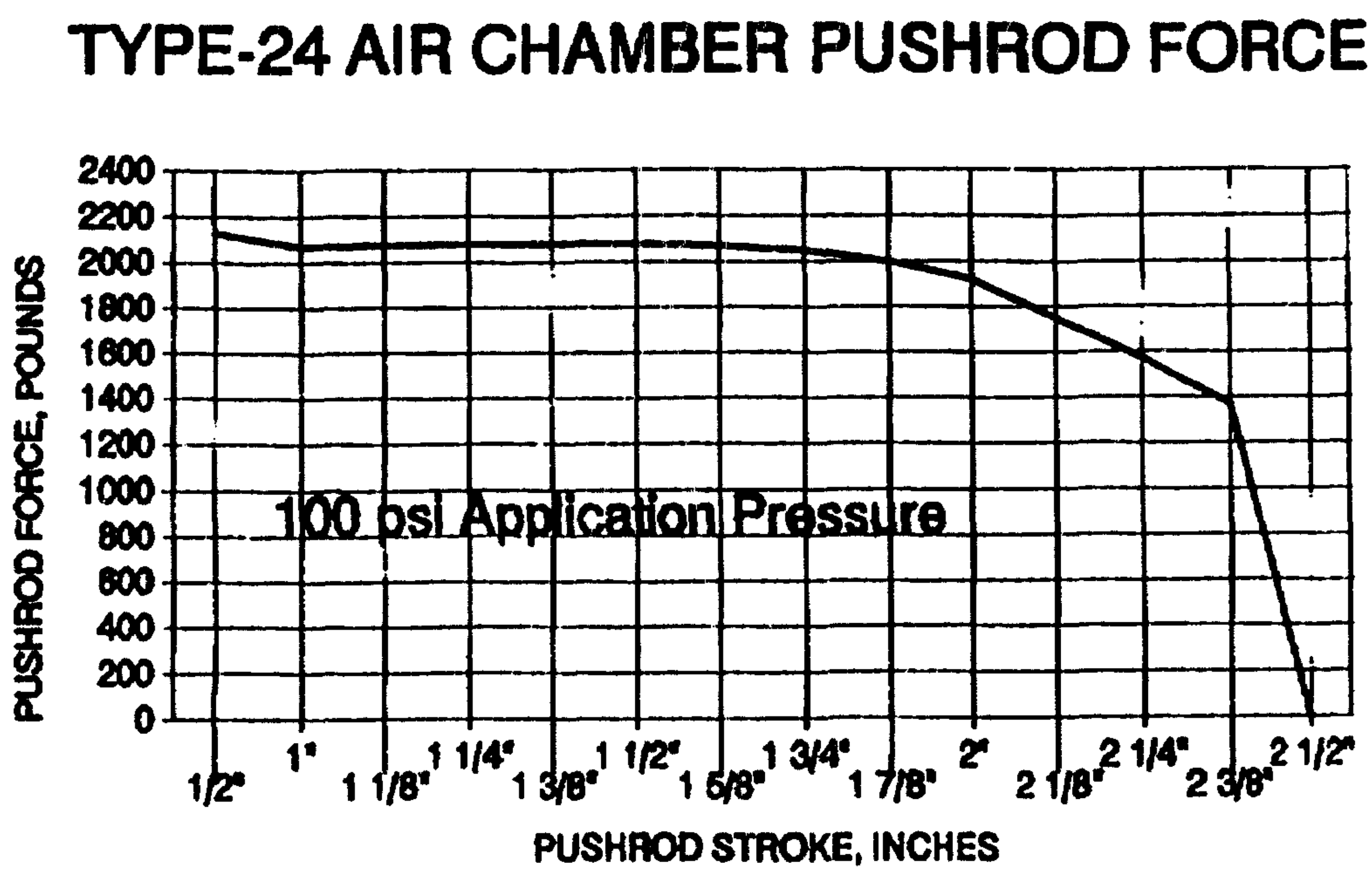
BUSDRIVER INFORMATION

Richard Gonzales was 23 years old and unmarried. In April 1990, he was licensed to operate school buses in California and was employed by Mayflower Contract Services, Inc., to drive school buses.

APPENDIX D

APPLICATION CHARTS FOR TYPE 20 AND 24 BRAKE CHAMBERS AT 100 PSI





—— SOURCE: Rockwell International

APPENDIX E

ACCIDENT VEHICLE CONTROL VALVE BODY SHIFT POINT SPECIFICATIONS, TEST RESULTS, AND CALCULATED SPEEDS IN MPH AT UPSHIFT/DOWNSHIFT RPM

Test 1 - Full Throttle Upshifts
(upshift points with accelerator pedal in maximum fuel position)

Selector Position	Shift	Specified RPM	Speed	Actual RPM	Speed
Drive 4	1 - 2	580 - 640	14.4 - 15.9	628	14.8
Drive 4	2 - 3	935 - 1070	23.2 - 26.6	994	23.5
Drive 4	3 - 4	1455 - 1595	36.2 - 39.7	1593	37.6

Test 2 - Closed Throttle Upshifts
(upshift points with accelerator pedal in minimum fuel position)

Selector Position	Shift	Specified RPM	Speed	Actual RPM	Speed
Drive 4	1 - 2	383 - 505	9.5 - 12.5	503	11.8
Drive 4	2 - 3	753 - 798	18.7 - 19.8	753	17.8
Drive 4	3 - 4	787 - 1064	19.6 - 26.5	1017	24.0

Test 3 - Upshift Inhibit - Closed Throttle
(upshift points at which transmission will shift above highest selected gear range to prevent an engine overspeed)

Selector Position	Shift	Specified RPM	Speed	Actual RPM	Speed
Drive 1	1 - 2	786 - 1023	19.5 - 25.4	838	19.8
Drive 2	2 - 3	1180 - 1456	29.3 - 36.2	1315	31.1
Drive 3	3 - 4	1968 - 2270	49.0 - 56.5	2137	50.5

Test 4 - Full Throttle Downshifts
(downshift points with accelerator pedal in maximum fuel position)

Selector Position	Shift	Specified RPM	Speed	Actual RPM	Speed
Drive 4	4 - 3	1247 - 1449	31.0 - 36.0	1389	32.8
Drive 4	3 - 2	805 - 910	20.0 - 22.6	818	19.3
Drive 4	2 - 1	408 - 565	11.6 - 14.0	551	13.0

Test 5 - Closed Throttle Downshifts
(downshift points with accelerator pedal in minimum fuel position)

Selector Position	Shift	Specified RPM	Speed	Actual RPM	Speed
Drive 4	4 - 3	510 - 740	12.7 - 18.4	658	15.5
Drive 4	3 - 2	435 - 620	10.8 - 15.4	566	13.3
Drive 4	2 - 1	40 - 370	1.0 - 9.2	601	7.1

Test 6 - Downshift Inhibit - Closed Throttle
(downshift points when next lower gear range is selected with accelerator pedal in minimum fuel position)

Selector Position	Shift	Specified RPM	Speed	Actual RPM	Speed
Drive 3	4 - 3	1820 - 2120	45.3 - 52.8	1989	47.0
Drive 2	3 - 2	1060 - 1350	26.4 - 33.6	1175	27.7
Drive 1	2 - 1	660 - 900	16.4 - 22.4	749	17.7