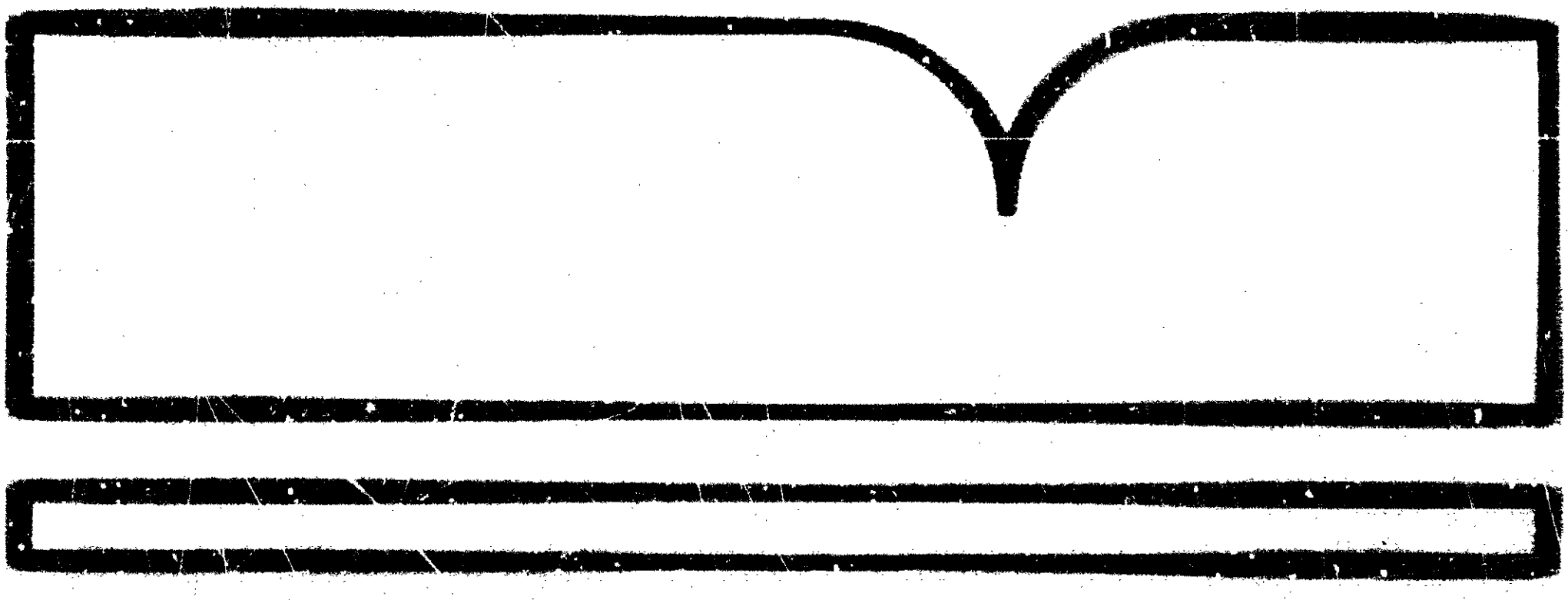
PB88-916201

Highway Accident Report
Tractor-Semitrailer/Intercity Bus
Head-on Collision Interstate 10
Beaumont, Texas, May 4, 1987

(U.S.) National Transportation Safety Board
Washington, DC

2 Feb 88



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16.Abstract

About 1:45 p.m. on May 4, 1987, while traveling eastbound on Interstate 10 (I-10) in Beaumont, Texas, a tractor-semitrailer (truck) operated by Graebel Van Lines, Inc. (GVL), jackknifed in the center lane, veered leftward across the left lane and median strip, and struck a Trailways bus traveling westbound on I-10 in the left lane. A small fire which started in the bus below the driver's seating area was quickly extinguished by a passerby. The busdriver and 5 bus passengers sustained fatal injuries, 17 bus passengers sustained serious to minor injuries, and 6 bus passengers were not injured. The truckdriver and helper sustained moderate and minor injuries, respectively. It was raining at the time of the accident.

The National Transportation Safety Board determines that the probable cause of this accident was the truckdriver's operation of a tractor-semitrailer at a speed too great for existing weather conditions while traveling on a section of lightly

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CONTENTS

EXECUTIVE SUMMARY

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The safety issues discussed in the report include:

1. Adequacy of the driver supervision and vehicle maintenance practices of the motor carrier;
2. highway pavement deficiencies and adequacy of highway maintenance practices in the State of Texas;
3. hydroplaning of commercial vehicles;
4. use of marginal tread depth of tires on commercial vehicles; and
5. crashworthiness of intercity and intracity buses.

The National Transportation Safety Board determines that the probable cause of this accident was the truckdriver's operation of a tractor-semitrailer at a speed too great for existing weather conditions while traveling on a section of lightly flooded highway pavement. Contributing to the loss of control of the tractor-semitrailer was the inadequate tread depth of the rear tractor tires, the inoperative speedometer, the low surface texture of the pavement, the low friction of the lightly flooded pavement, and the improper corrective maintenance of the highway.

The Safety Board reiterated its previous recommendation to the Texas Department of Highways and Public Transportation to develop a statewide comprehensive program for reducing skid accidents on low coefficient of friction roads. Also, the Safety Board made two recommendations each to the Federal Highway Administration, and one recommendation to the American Bus Associations (ABA), the United Bus Owners Of America (UBOA), and the American Trucking Associations, Inc., concerning the use of marginal tires on commercial vehicles. The Safety Board also recommended that the ABA and the UBOA advise their membership about the crashworthiness of plastic laminated materials used in the interior linings of buses.

NATIONAL TRANSPORTATION SAFETY BOARD
WASHINGTON, D.C. 20594

HIGHWAY ACCIDENT REPORT

TRACTOR-SEMITRAILER/INTERCITY BUS
HEAD-ON COLLISION
INTERSTATE 10
BEAUMONT, TEXAS
MAY 4, 1987

Adopted: February 2, 1988

INVESTIGATION

The Accident

About noon central daylight time on May 4, 1987, a tractor-semitrailer (truck) operated by Graebel Van Lines, Inc. (GVL), departed Houston, Texas, traveling eastbound on Interstate 10 (I-10). The truck was transporting a load of office equipment and household goods to Graebel/New Orleans Movers, Inc. (GNOM), a branch office of GVL in New Orleans, Louisiana. The truckdriver and a helper 1/ were aboard the truck. About 1:43 p.m., the truck reached the city limits of Beaumont, Texas. The truckdriver stated he was traveling about 45 mph at the time.

Meanwhile, about 12:30 p.m., Trailways bus No. 45616 departed Lake Charles, Louisiana, on a scheduled round trip run to Houston. The bus was scheduled to arrive in Houston at 3:15 p.m. and begin the return trip at 8 p.m., arriving in Lake Charles at 11:30 p.m. About 1:30 p.m., the bus departed Beaumont. A witness traveling behind the bus stated that the bus was traveling about 55 mph. After traveling 4 miles, the bus crested an overpass on westbound I-10.

About 1:45 p.m., the truck suddenly jackknifed in the center lane, veered leftward across the left lane and grass median strip of I-10, and struck Trailways bus No. 45616. Eleven passengers stated that the busdriver suddenly hit the brakes hard and that they felt the bus sliding.

The tractor separated from the fifth wheel connection of the semitrailer and came to a stop about 150 feet north of the westbound lanes. The semitrailer came to a stop in the westbound lanes about 50 feet from the point of impact. (See figure 1.) The truckdriver sustained moderate injuries and the helper sustained minor injuries.

1/ GVL requires drivers to have a helper with them at all times. The helper must be at least 18 years old.

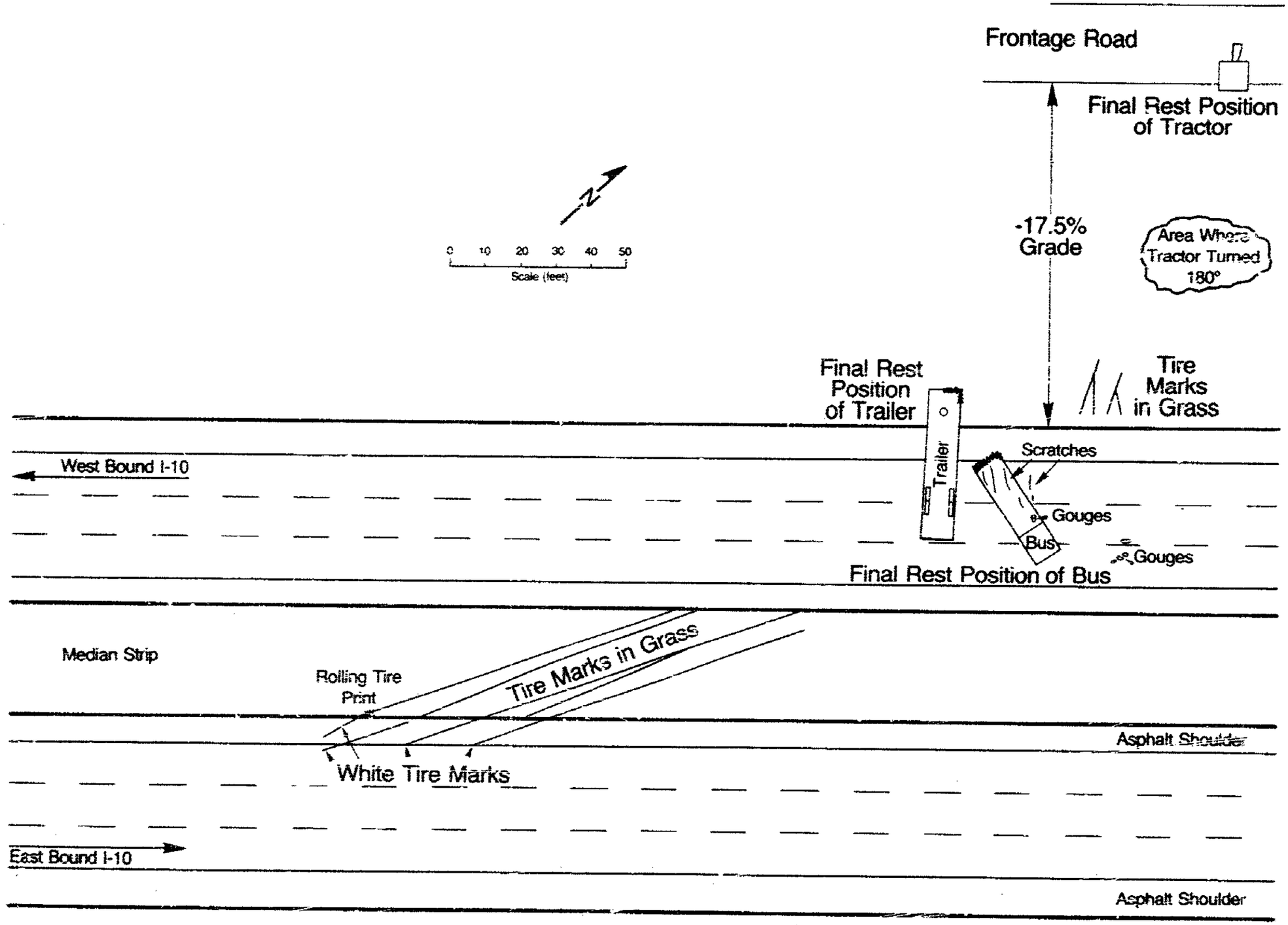


Figure 1.--Final rest position of vehicles.

The truckdriver said that he attempted to steer the truck "back to the right, but that it just kept going left." He also stated that "it appeared something in the front end of the truck broke."

The truck helper stated that the truckdriver started to slow the truck due to "traffic" and he guessed that "the truck was just too light for the trailer, or something, but it just whipped the truck around and we started sliding."

The driver of a tractor-semitrailer traveling in the same direction said that the accident truck had passed him about 2 miles before the accident scene traveling "well over 60 mph." Another witness stated that the truck was traveling about 57 or 60 mph, that the truck "suddenly veered sharply to the left," and that "the bus came over an overpass and hit it." The witness also stated that "at the time of the accident there was water on the road. It was slick, but there were no puddles."

The bus came to a stop about 50 feet from the point of impact. Four passengers were ejected from the bus and sustained fatal injuries. Several bus passengers opened the emergency side windows and helped other passengers to exit the bus. A small fire started in the bus below the driver's seating area and was quickly extinguished by a passerby.

The Beaumont Fire Department Emergency Communications Center (BFDECC) was notified of the accident at 1:48 p.m. Fire department rescue vehicles were on the scene 3 minutes later. A primary triage area was set up next to the bus and a secondary triage area was set up inside a nearby moving and storage company building. Seven ambulances arrived on the scene 7 minutes later. A total of 14 ambulances, 2 fire engines, and 26 fire department personnel reported to the accident scene. Fifteen State troopers who were participating in a class at the pistol range of the Texas Department of Public Safety were dispatched to the accident scene to close the road and to control traffic. Twenty-three Beaumont city police officers responded to the scene.

Injuries

	Driver	Passengers	Totals
Fatally Injured			
Maximum Injury, Virtually Unsurvivable (AIS-6)	1	5	6

Nonfatally Injured			
Serious (AIS-3)	0	2	2
Moderate (AIS-2)	1*	5	6
Minor (AIS-1)	0	11**	11
None	0	6	6
Total	2	29	31

*Truckdriver
**Includes Helper
Note: "AIS" refers to the Abbreviated Injury Scale of the American Association for Automotive Medicine.

The busdriver and a passenger who was seated in the right side, third row aisle seat were trapped and had to be extricated with the use of a tow truck and the Hurst "Jaws of Life" tool. The National Guard Armory was set up as a temporary morgue for the six fatally injured bus occupants. Injured persons were transported by ambulance to St. Elizabeth Hospital, Baptist Hospital, and Beaumont Medical Surgical Hospital, all located within about 4 miles northeast of the accident scene. One person was transported by a "Life Flight" helicopter to Baptist Hospital. All fire department units had returned to service by 4:17 p.m. The roadway was reopened at 5:30 p.m.

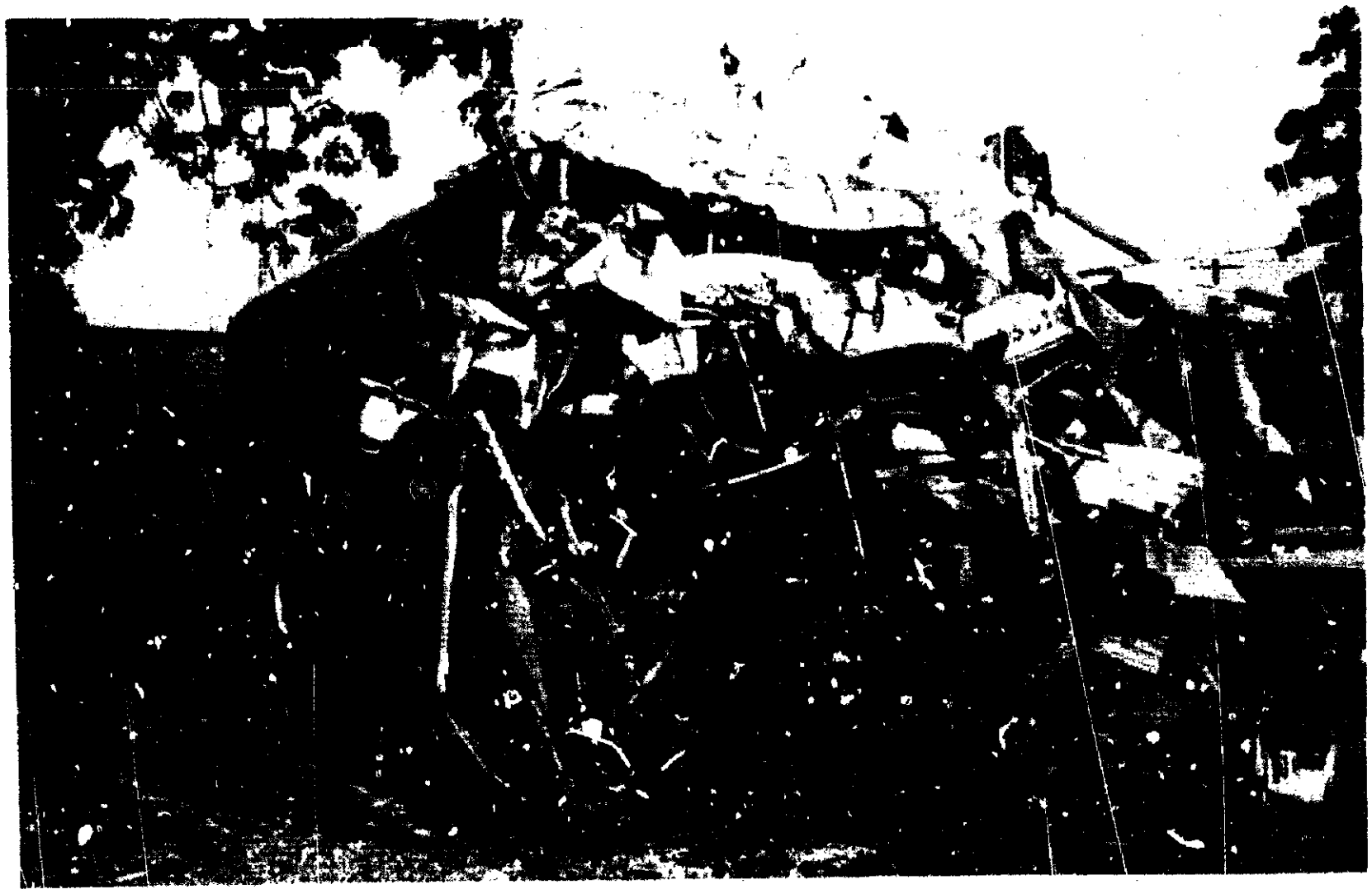
Vehicle Damage

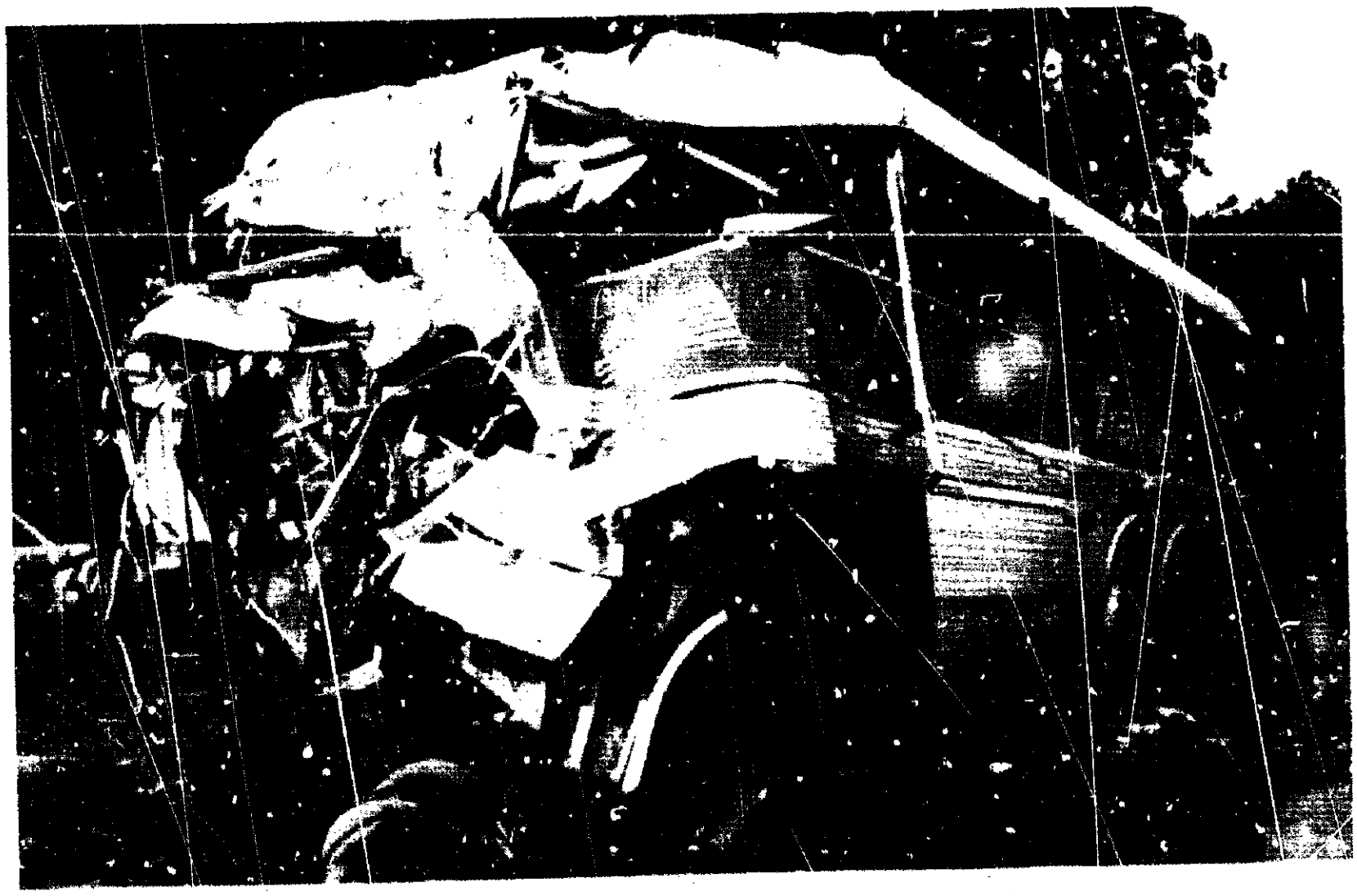
Bus.--The left side of the front was crushed 7.5 feet rearward and the right front was torn open and crushed 16.75 feet rearward. Both front tires were destroyed. The roof was buckled and bent downward, and jagged portions of sheet metal extended outward on both sides of the bus. A small area of fire and smoke damage was found just below the driver's seat. (See figures 2a and 2b.)

The first seven rows of seats on both sides of the bus were missing. Some of the front seats were ejected during impact, and many of the seats were removed from the bus by rescue personnel during the extrication of the passengers. All eight emergency side windows were found open.

The front axle, steering linkage, and dashboard were destroyed. The engine and drive train were mounted in the rear of the bus and were not damaged.

Truck.--The left rear corner and side of the tractor near the driver's door was smashed inward about 5 inches. The tractor frame extending rearward of the tractor cab was bent leftward about 56 inches. The fifth wheel had separated at its pivot joints, and the skid plate remained with the semitrailer after impact. The mounting plate and supports were not damaged. (See figures 3 and 4.)





Figures 2a and 2b.--Accident bus.

Figure 3.--Accident tractor.

Figure 4.--Accident semitrailer.

The right front half of the trailer was severely cracked and pushed rearward about 16 inches. The right front corner of the roof had buckled upward and the sheet metal was split open. About 10 feet of sheet metal covering the right front side of the trailer had split open exposing boxes and heavy wooden crates containing household furniture. A portion of the bus right front door hinge support pole was embedded in the lower middle section of the front of the trailer. (See figures 5a and 5b.)

Driver Information

The Busdriver.--The 44-year-old Trailways busdriver held a valid Class D (chauffeur) Louisiana driver's license which was due to expire on June 14, 1987, with no record of any violations. He had worked as a driver for Trailways for 17 years. He held a valid medical certificate dated March 19, 1987.

The busdriver had been driving the scheduled run between Lake Charles and Houston for about 2 months, 6 days a week. The schedule required the busdriver to go on duty at 11:30 a.m.; drive from Lake Charles, Louisiana, to Houston with a stopover in Beaumont; arrive in Houston at 3:15 p.m.; and go off duty. He would then return to duty at 8 p.m., begin the trip at 8:30 p.m., arrive in Lake Charles at 11:30 p.m., and go off duty.

The busdriver received 4 weeks of training when he was initially hired. In addition, he had 2 weeks of on-the-job training under the supervision of a senior driver. He was evaluated by his supervisor as an exceptional driver who continuously did an outstanding job in both driving and dealing with the public. On January 1, 1987, he received a 15-year safe driver award, having driven 900,256 miles without any preventable accidents.

The Truckdriver.--The 45-year-old truckdriver held a valid Class D (chauffeur) Louisiana driver's license. He held a valid medical certificate dated January 5, 1987.

The truckdriver stated that he had driven tractor-semitrailers long distance for approximately 19 years. He had worked for several moving and storage companies in the New Orleans area, including GNOM. Between 1975 and 1986, he occasionally drove trucks for Coleman American Moving Service, Inc., (CAMS) and Ambassador Moving Company (1983-84.) He was hired by GNOM in 1984, and after 1 1/2 years, he left the company and returned to CAMS. He returned to GNOM on December 10, 1986.

He had been employed by GNOM primarily as a local driver. The accident trip was the first long distance trip he had driven since being hired by GNOM. At GNOM, the truckdriver had worked his way through a normal job progression from entry-level helper's assistant to helper to driver. The general manager at

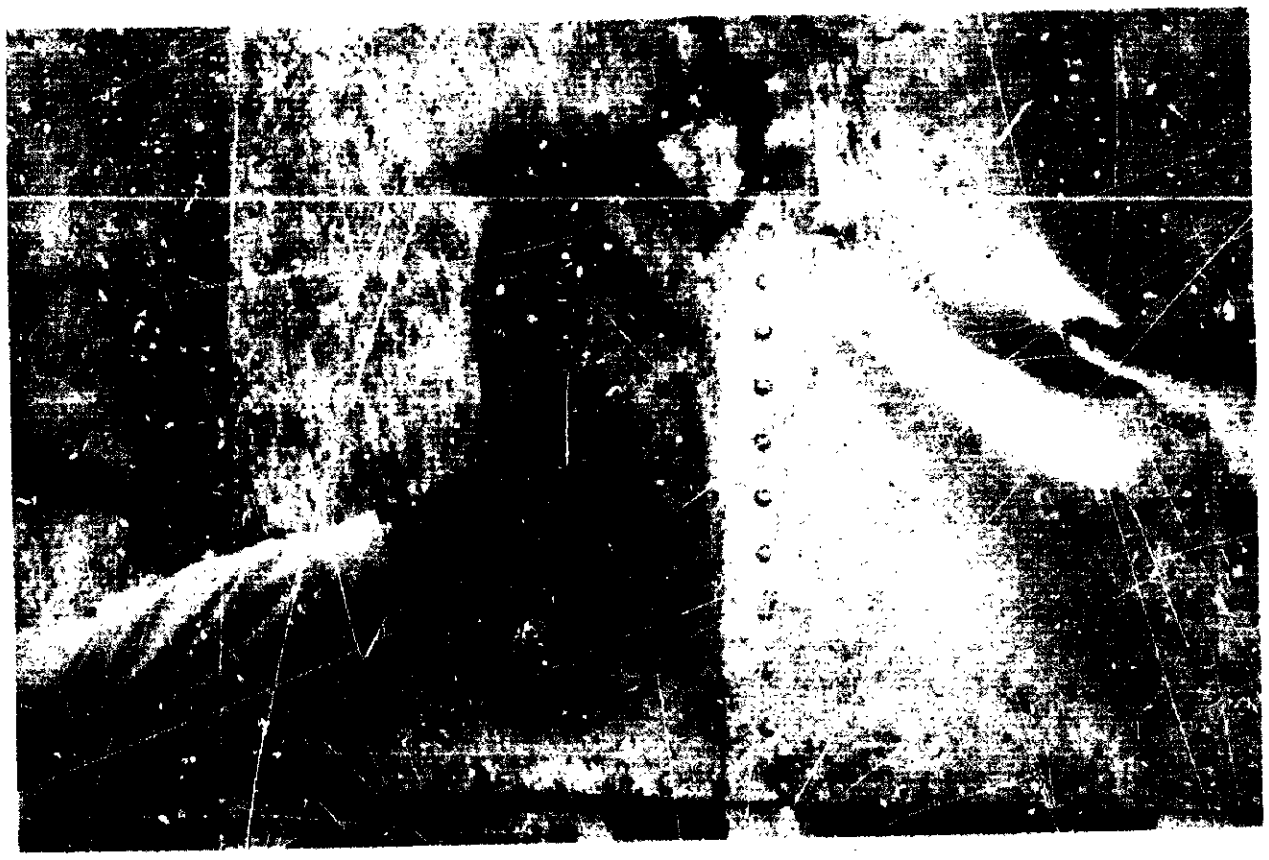


Figure 5a.--Bus door hardware found in semitrailer.

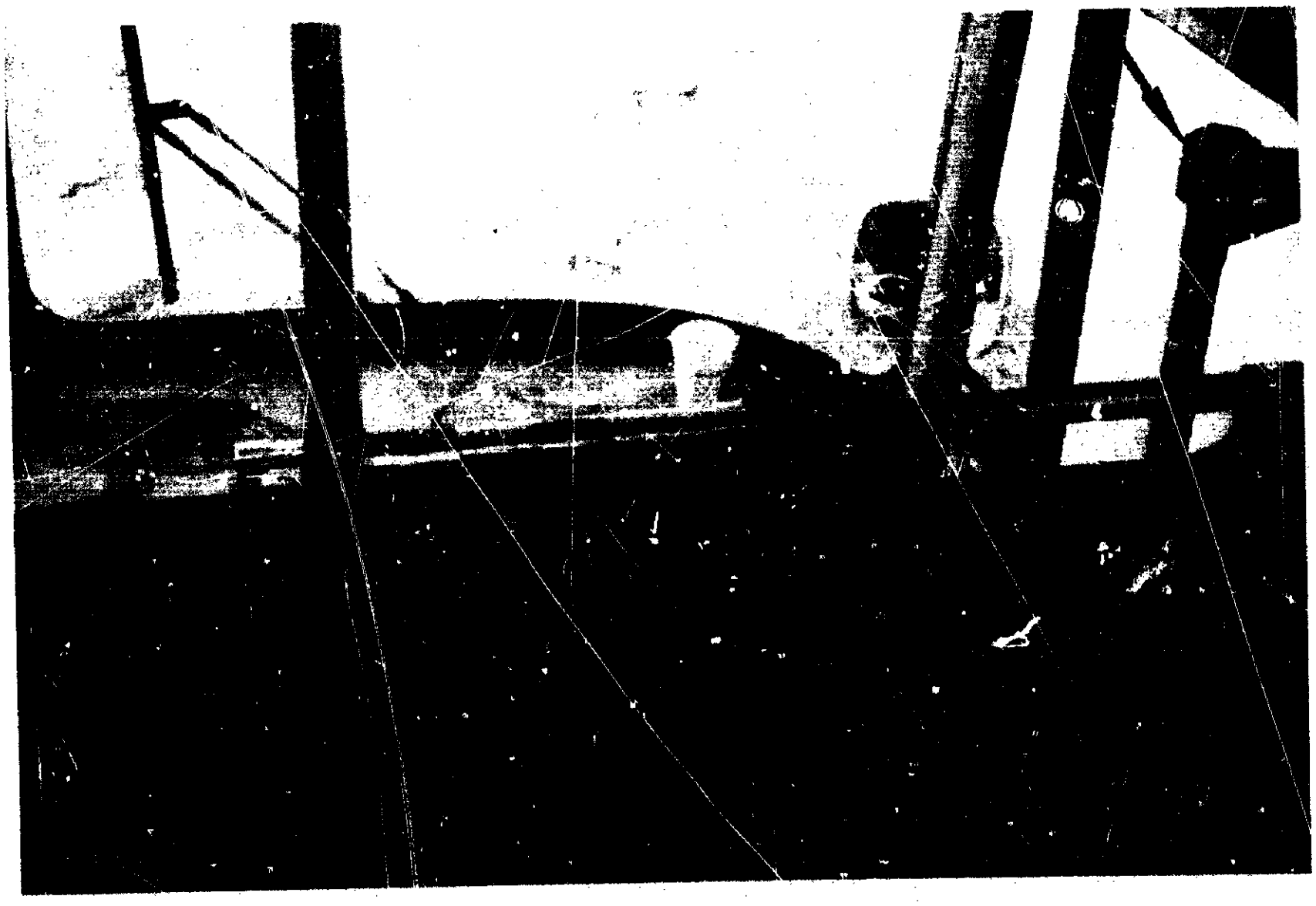


Figure 5b.--Bus door hardware.

GNOM said that the truckdriver was dependable, good at handling furniture, and was excellent at customer relations. The general manager also said that he did not know of any recent financial, medical, or emotional disruptions in the truckdriver's life.

Safety Board investigators were unable to locate any records that indicated the driver had received training from either GNOM or GVL. A review of the truckdriver's personnel file revealed that he had not missed any days of work since the beginning of the year.

A review of the CAMS' personnel records revealed a letter dated August 31, 1983, from the director of Safety of Atlas Van Lines, Inc., to CAMS, then an agent for Atlas Van Lines, Inc. The letter stated that the accident truckdriver ". . . is on indefinite probation . . . he is to short haul only." Inquiries regarding this statement indicated that the reason for the indefinite probation and the requirement to drive only short trips was due to a 1983 driving while intoxicated (DWI) conviction.

On his application the truckdriver listed a speeding conviction; however, the date was left blank. In answer to the question, "Have you ever been convicted for use of alcohol?", the driver checked "yes," indicating that it had occurred in New Orleans while he was driving a car. (This is the same DWI offense which occurred on November 5, 1982, for which the truckdriver was convicted on January 18, 1983.) He checked "no" to the question about being convicted for use of drugs. He checked "yes" that he was familiar with the U.S. Department of Transportation Federal Motor Carrier Safety Regulations and "yes" that he agreed to follow them.

A background investigation report conducted for GVL, dated February 17, 1987, showed that the truckdriver was eligible for rehire by both previous moving companies and that his performance was good insofar as equipment maintenance, logs and paperwork, adherence to policy, appearance, and attitude. Neither companies' records indicated that the truckdriver had been involved in any accidents. Under the comments listing "drinking problem" and "drug problem," the report showed "none."

A review of the truckdriver's driving record indicated a DWI conviction in 1983, two speeding convictions in 1986, and a reckless operation conviction in 1987. On July 9, 1987, the State of Louisiana issued an order to pick up the truckdriver's license to suspend him as a result of the 1983 DWI conviction. The Louisiana Department of Public Safety and Corrections advised that because of a changeover in computer systems, the procedures to suspend the truckdriver's license were not followed. Because of the Safety Board's request for the truckdriver's records of violations, his case was reviewed and the suspension flags set. However, his driving privileges were not suspended on May 4 at the time of the accident.

On April 30, 1987, 4 days before the accident, the truckdriver was stopped twice by law enforcement officers. At 9 a.m., the truck was stopped at a weigh station near San Antonio, Texas, for a truck inspection. Violations included a defect' headlamp, defective side marker lamps, a defective cleara.. lamp, defective turn signals, no warning devices, and a defective warning signal for air brakes. The truckdriver was issued a citation for defective warning signal for air brakes under Vernon's Civil Statute, 6701d, Article XIV, Section 132(J)(1), the Uniform Act Regulating Traffic on Highways. At 7 p.m. near Ft. Worth, Texas. the truckdriver was stopped and issued a speeding ticket for traveling 66 mph in a 55-mph zone.

Safety Board investigators spoke with the Texas Department of Public Safety trooper who conducted the truck inspection; however, he did not recall the particulars of the inspection. Although checking for hours of service violations is a routine part of a commercial vehicle inspection, the trooper stated that at the time of the inspection, he was not required to check for hours of service violations. He stated that in July 1987, he received training through the State of Texas Motor Carrier Safety Assistance Program (MCSAP) and that personnel would be authorized to check for hours of service violations beginning in June 1988.

On June 2, 1987, the truckdriver was driving a GNOM step-van near Hammond, Louisiana, when the van went out of control and he and a passenger were ejected and killed. 2/ The truckdriver had a blood alcohol content of 0.03 percent at the time of the accident.

Truck Helper.--The 38-year-old truck helper was hired by the truckdriver to assist in loading and unloading shipments. The helper is not employed to drive the truck. He stated that he did not drive any portion of the accident trip.

Truck Trip Route

The truckdriver's record of duty status was not found among the truckdriver's other records at the scene of the accident. However, based on information provided by the helper and supported by motel receipts, fuel receipts, weight tickets, and bills of lading, the truckdriver's activities during the last 8 days preceding the accident were reconstructed:

2/ Although the Safety Board worked closely with GVL and GNOM to obtain an interview with the truckdriver, neither GVL nor GNOM notified the Board that the truckdriver had been killed until 2 weeks after the accident.

On April 27, 1987, the truckdriver and the helper departed New Orleans about 2 a.m. and arrived in Jackson, Mississippi (206 miles), to pack a shipment of household goods. They completed packing boxes about 6:30 p.m. and stayed in a motel overnight. (Note: This day includes 5 hours of driving and 10 1/2 hours of packing.)

At 8 a.m. on April 28, they loaded the shipment, which included a pickup truck, onto the truck. They finished about 8 p.m. and departed Jackson at 9:30 p.m. en route to New Orleans. (Note: This day includes 11 hours of loading and 5 hours of driving.)

On April 29, the truckdriver and the helper arrived in New Orleans about 2 a.m., parked the truck at the GNOM terminal, and went home. Between 10 a.m. and 1 p.m., they returned to the GNOM terminal, loaded a small shipment, and then returned to their homes to rest; about 5 p.m., they departed for San Antonio, Texas (547 miles). (Note: This day includes 3 hours of loading and 16 1/2 hours of driving.)

On April 30, the movers arrived in San Antonio about 9:30 a.m. and unloaded the small shipment. They finished about 12:30 p.m. and departed for Oklahoma City, Oklahoma (477 miles). (Note: This day includes 3 hours of unloading and 15 hours of driving.)

About 4 a.m. on May 1, they arrived in Oklahoma City, parked, and slept at a truck stop, until daylight. About 8:30 a.m. they arrived at the residence and unloaded the pickup truck. They waited until noon for the shipper to arrive and then unloaded the remainder of the shipment. About 8:10 p.m., they departed for Tulsa, Oklahoma (105 miles), and stopped at a motel at 9:30 p.m. to sleep. (Note: This day includes 6 1/2 hours unloading and 3 hours of driving.)

At 7 a.m. on May 2, they resumed their trip, arriving in Tulsa about noon. They loaded a shipment, finishing about 4 p.m. and then departed for Dallas (257 miles.) They arrived in Dallas at 10 p.m. and parked at a truck stop. The truckdriver's brother picked them up in a passenger car and drove them to a motel where they stayed overnight. (Note: This day includes 11 hours of driving and 4 hours loading.)

The truckdriver's brother picked them up from the motel at noon on May 3 and they visited the truckdriver's family during the rest of the day. They ate a snack at a nephew's house, went to the brother's house where they ate dinner, watched television, and slept. The helper stated that he went to sleep about 3 p.m.

At 2 a.m. on May 4, the brother drove them to the truck. They departed for the Graebel/Houston Movers, Inc., (GHM) office in Houston (245 miles) and arrived about 9 a.m. They loaded some office equipment to be delivered to GNOM and departed at noon. (Note: This day includes 8 1/2 hours driving and 3 hours loading before the accident occurred.)

According to the helper's version of the schedule, in the previous 8 days, the truckdriver had driven 2,127 miles in 63 hours and had packed, loaded, or unloaded heavy boxes and furniture for 35 hours. At the time of the accident, they had driven 84 miles and had approximately 250 miles left to go.

Vehicle Information

Bus.--The 1977 Silver Eagle, 3-axle coach was owned and operated by Trailways Lines, Inc., 3/ of Dallas, Texas. It was registered in Washington, D. C., and had ICC authority to operate as a common carrier of passengers with 48-State charter authority. The bus was subject to Federal Motor Carrier Safety Regulations (FMCSR) 390-398.

The 46-passenger bus was equipped with an 8-cylinder diesel engine, a manual 4-speed transmission, air-mechanical service brakes, and power steering. The maximum speed for the bus is 66.6 mph.

Twelve double-unit seats were on the left, 11 double-unit seats were on the right, and a restroom was in the right rear of the bus. The 40-foot-long, 8-foot-wide, 11-foot-high bus had a wheelbase of 23.79 feet. A service record dated April 5, 1987, listed the registered miles as 1,054,567. The gross vehicle weight of the bus was 38,700 pounds. Approximate eye level for the accident busdriver was 89 inches above the road surface.

The bus was equipped with eight 1100R 24.5 steel-belted radial, regroovable tires. The tires on the bus had an average tread depth of 8/32 inch. 4/

Tractor-Semitrailer.--The 1976 General Motors Corporation (GMC) Model 9500, 2-axle tractor and the 1979 Kentucky tandum axle moving van were owned by GNOM and leased for interstate trips by GVL. The tractor weighed 7,050 pounds and the semitrailer weighed 32,000 pounds.

3/ On July 13, 1987, the assets of Trailways Lines, Inc., were acquired by Greyhound Lines, Inc.
4/ Title 49 CFR 393.75 states that tires shall have a tread groove pattern depth of at least 2/32 inch when measured in a major tread groove.

The tractor was equipped with a diesel engine, a 5-speed transmission with overdrive, air-mechanical service brakes, and manual steering. It was 8 feet wide and 13 feet 11 inches long from the front bumper to the rear axle with extra 3-foot-long frame rails. The fifth wheel pivot point on the tractor was 11 inches forward of the rear axle. The wheelbase on the tractor was 11 1/2 feet, and the track width was 6.5 feet.

The tires on the tractor-semitrailer were examined during the postaccident inspection. The tractor was equipped with two 10.00-R-20 radial tires on the steering axle and four 10.00-20 bias ply ties on the drive axle. The semitrailer was equipped with eight 10.00-20 bias ply tires. All tires except two were inflated to a pressure between 50 and 76 psi. The minimum tread was 4/32 inch for the tractor front tires, 2/32 inch for the tractor rear tires, and 4/32 inch for the semitrailer tires. All tires on the tractor and semitrailer were regroovable and equipped with inner tubes.

The seats in the tractor cab were "captain's style" chairs (not original equipment) which had been set in the original seat frames and were not permanently attached to the cab floor. The The preaccident condition of the lapbelt at the driver's position revealed that it was not useable. It had been cut in two, so only 8 inches of webbing was left and the latchplate was missing. The passenger's lapbelt was latched together on the seat underneath some packing blankets. The rubber foot pads were missing from the brake and acceleration pedals on the floor.

The trailer was 42 feet 10 inches long and 7 feet 11 inches wide. The trailer pivot point was 3 feet rearward of the front of the trailer.

A December 1985 entry in the maintenance record stated "assemble speedometer." However, the postaccident inspection revealed that the dash-mounted speedometer had been disconnected at the transmission and that the tachometer was inoperative at the time of the accident. Section 393.82 of the FMCSR states, "Every bus, truck, and truck-trailer shall be equipped with a speedometer indicating vehicle speed in miles per hour; which shall be operative with reasonable accuracy." State and Federal regulations, however, do not require that trucks be equipped with tachographs.

The wheels on the combination unit were equipped with air mechanical S-cam-type brakes, manual slack adjusters, and C-clamp-type brake chambers. The front (steering axle) wheels on the tractor had type 20 chambers and the rear axle of the tractor and the wheels on the tandem axle of the trailer had type 30 chambers. The brake chambers on the rear axle of the tractor and on both axles of the trailer had dual split system brakes with half of the brake being spring activated.

The air braking system of the tractor and semitrailer was tested separately using 100 psi; no air loss was detected. The front axle service brakes were tested; the pushrod stroke on the left side was 2 1/16 inch and on the right side, 2 1/4 inch. The manufacturer's recommended specification for readjustment is 1 3/4 inches. The rear axle tractor brakes were severely damaged from impact and could not be tested. The trailer brakes were tested, and the pushrod stroke measured 2 3/4 inch on the left side of the front axle and on the right side, 1 5/8 inch. The pushrod stroke measured 2 1/4 inch on the left side of the rear axle and on the right side, 2 1/2 inch. The manufacturer's recommended specification for readjustment is 2 inches. (See table 1.) The tractor front axle brake linings were dry and free of cracks. The wear pattern on the brake linings on all tractor wheels showed approximately 75 percent contact with the drums.

Table 1.--Measurement (in inches) of tractor-semitrailer air brake pushrod stroke.

Tractor	Left	Right	Recommended Stroke at which to Readjust	Chamber Type
Front axle	2 1/16	2 1/4	1 3/4	20
Rear axle	*	*	2	30
Trailer				
Front axle	2 3/4	1 5/8	2	30
Rear axle	2 1/4	2 1/2	2	30

*Accident damage prevented a functional test.

A crack was found in the tractor right rear brake diaphragm. The tractor left rear brake drum and lining were saturated with oil, grease, and dirt deposits. The oil seal was leaking on the left rear axle of the tractor. The brake shoe lining thicknesses on the tractor brakes were 10/32 and 11/32 inch. The brake shoe lining thicknesses on the trailer brakes were 6/32 and 7/32 inch. The FMCSR requires that brake linings be adequate in thickness to provide for safe and reliable stopping of the motor vehicle. New lining thickness is 24/32; rivet heads are 8/32 inch above the brake shoe.

The trailer brake hand control valve mounted on the steering column and the right side mirror were held in place with plastic packing tape.

The low air warning device was inoperable. The tractor was found to be in fifth gear. The maximum within gear speed at 2,325 rpm is 65.57 mph.

The Highway

General Information.--I-10 runs east and west from Jacksonville, Florida, to Los Angeles, California. It connects the cities of New Orleans, Beaumont, and Houston. The accident site is in a rural area inside the city limits of Beaumont, located in the eastern part of Texas.

I-10 at the accident site is a six-lane, divided highway with three 12-foot-wide lanes in each direction separated by a 32-foot-wide grass median strip and a 4-foot-wide asphalt median shoulder. Ten-foot-wide asphalt shoulders are located on each side of the highway. The eastbound right lane is a continuation of an on-ramp at an interchange about 1 mile west of the accident location and becomes an exit ramp at the next interchange east of the accident location. The majority of through eastbound traffic travels in the center lane through the accident location.

The posted speed limit is 55 mph. The average daily traffic volume in 1986 approximately 3 miles west of the accident site, was 26,000 vehicles. A classification count in 1986 indicates that about 30 percent of the traffic consists of trucks and/or buses.

The truckdriver lost control of the tractor-semitrailer in an area of the eastbound road that changed from a 0.10 percent upgrade to a 3.5 percent upgrade. The truck collided with the bus in the westbound lanes with a 3.5 percent downgrade. The accident site was on a straight section of roadway with a cross slope of 0.02 foot/foot.

Four 20-foot-long, faint, light-colored tiremarks were found on the eastbound side of I-10 about 460 feet from the overpass. The tiremarks extended diagonally from the left edge of the left lane, across the left shoulder, and continued in the form of furrows in the grass and dirt through the median strip. On the westbound side of the roadway, a series of scrapes and gouges were found in the left lane east of the tiremarks. (See figures 6a and 6b.)

Accident History.--According to the State of Texas accident records, seven accidents occurred in the area of the accident site (eastbound lanes) between January 1, 1984, and April 30, 1987. In two accidents, vehicles were sideswiped; in two accidents, vehicles struck roadway debris; in two accidents, vehicles failed to yield the right-of-way and struck other vehicles while entering the highway; and in one accident, a vehicle rear-ended another vehicle. None of the accidents were wet-weather related.

Figures 6a and 6b.--Tiremarks at accident site.

Highway Construction.- The highway at the accident site was completed in November 1963. The original surface was an 8-inch-thick, continuous-reinforced portland cement concrete 5/ pavement. In October 1980, the eastbound pavement was overlaid with an open-graded asphaltic concrete 6/ pavement surface to repair the concrete pavement and to increase the skid resistance. In March 1987, a leveling course was placed over the eastbound center lane to correct the rutting in the wheelpaths. A thin, densely-graded, asphaltic concrete 7/ pavement surface was placed over the leveling course. After the accident, in May and June 1987, the State of Texas performed work to level the uneven surface on several occasions. Safety Board investigators inspected this section of roadway in early September 1987 and found that the roadway appeared to have the same surface conditions as those existing at the time of the accident. However, the eastbound center lane showed evidence of shoving. 8/

At the time of the accident, no apparent irregularities existed in any of the travel lanes except the surface of the eastbound center lane. The asphalt in the center lane exhibited bleeding 9/ in the wheelpaths. Rutting was not evident, but the wheelpaths were flattened, which resulted in a rolling crown.

5/ A plastic and workable mixture composed of mineral aggregate, such as sand, gravel, crushed stone, or slag, interspersed in a binding medium of cement and water. When first combined, the listed materials form a plastic, workable mass which may be easily handled and shaped into any desired form. A short time after mixing, the concrete begins to stiffen or "set" because of chemical action between the cement and water in the mixture and, in a relatively short time, forms a dense, hard mass which possesses considerable compressive and flexural strength.

6/ A mix using a large percentage of uniform coarse aggregate that allows water to flow through the surface and into water channels between surface aggregates and particles below the surface until it reaches the side of the road. This surface is constructed less than 1 inch thick and is intended to reduce the potential for hydroplaning and spray from other vehicles.

7/ A plastic and workable mixture composed of mineral aggregate, such as sand, gravel, crushed stone, or slag, interspersed in a binding medium of asphalt. Densely-graded asphaltic concrete is recommended for thin resurfacing of pavements having high traffic volumes, as its service lives are relatively long when constructed properly.

8/ A form of plastic movement resulting in localized bulging of the pavement.

9/ Pavement "flushing" or "bleeding" is a condition which results when the upward movement of asphalt in an asphalt pavement forms a film of asphalt on the pavement surface.

Skid Tests.--The Texas Department of Highways and Public Transportation (TDHPT) conducted skid tests with a locked-wheel skid trailer to assess the friction properties of the wet pavement in the accident area in 1986 and 1987. The tests were conducted in accordance with the American Society for Testing and Materials (ASTM) Standard E-274.

A locked-wheel skid trailer measures the longitudinal friction coefficient developed between the wet pavement and a standard test tire that is braked while traveling at 40 mph and slides in the direction of travel of the trailer. The locked-wheel braking test simulates and measures the ability of friction between the tires and pavement to stop or slow a vehicle when the brakes lock the wheels. The standard test tire, which is constructed with automobile tire rubber compounds, has been found to be representative of the frictional quality of average automobile tires. However, large truck and bus tires are constructed with harder rubber compounds that wear better but have lower frictional quality than automobile tire compounds. Therefore, trailer tests using a standard test tire obtain higher test values than tests using truck or bus tires. 10/

All of the skid tests on the accident section of I-10 were performed using the same skid trailer. The April 1986 tests resulted in skid numbers (SN) from 37 to 48. 11/ The February 1987 tests had a range of SNs from 45 to 51. In both cases, there were no notes of bleeding or flushing. On May 6, 1987, at the request of the Safety Board, the TDHPT performed additional skid tests on the eastbound lanes at the accident site. (See table 2.)

10/ "Truck Tire Cornering and Braking Traction Study," Ensco, Inc., for the U.S. Department of Transportation, 1979, NHTSA-9-6227; and "Initial Tests on Stopping Distance and Spin-Out Characteristics of Regrooved Tires on Buses" Texas Transportation Institute, 1967.

11/ The skid number is the tire to pavement friction coefficient X 100 for a specified set of test conditions. Although there is no concensus of opinion on appropriate skid numbers for wet pavement surface, the State of Kentucky, a leader in skid resistance research, has developed the following criteria:

Above 39 - (Good) Skid Resistant
33 to 39 - Marginal
26 to 32 - Slippery
Below 26 - Very Slippery

Table 2.--Skid test results (wet data).

Lane	Location	Skid Numbers Low	High	Average
Right	Left Wheelpath	60	66	64
Center	Right Wheelpath	24	38	29
Center	Between Wheelpaths	45	53	48
Center	Left Wheelpath	23	27	25
Left	Right Wheelpath	64	66	65
Left	Between Wheelpaths	61	66	63
Left	Left Wheelpath	62	64	63

The open-graded asphalt surface placed on this section of roadway in 1980 is designed to permit water to enter the surface course and flow laterally. Such a surface reduces buildup of water between the surface of the roadway and the tires of a vehicle. It is a proven surface treatment used to reduce wet weather accidents on high speed roadways. Because of its "open graded" characteristics, it has low structural capabilities.

Sand patch tests were conducted to measure the pavement texture depth. 12/ The first test was conducted in the left wheelpath of the eastbound middle lane in the area where the tractor-semitrailer deviated toward the median strip. The test indicated a texture depth of approximately .0042 inch. Another test in the same area, but in the left wheelpath of the eastbound left lane, indicated a texture depth of .0472 inch.

Galloway et. al. 13/ recommended a minimum pavement texture depth of .04 inch, and Elsenaar 14/ et. al. recommended 0.015 to 0.031 inch for pavements with operating speeds of between 50 and 75 mph. Research conducted by the State of Texas in 1970 15/ indicated that low pavement surface texture was a significant contributor to wet weather accidents; there was a noticeable increase in the rate of wet weather accidents to vehicle-miles traveled at locations with texture depths of 0.035 inch or less.

On October 28, 1987, the Texas Highway Commission awarded a contract to remove and replace 2 inches of overlay, including the

12/ An indication of the coarseness and drainage quality of the pavement surface.
13/ "Tentative Pavement and Geometric Design Criteria for Minimizing Hydroplaning," Galloway et al., February 1975, FHWA-RD-11.
14/ "Pavement Characteristics and Skid Resistance," Elsenaar, Reinchert, and Sauterey, Transportation Research Record No. 622, 1976.
15/ "The Degree of Influence of Certain Factors Pertaining to the Vehicle and Pavement of Traffic Accidents Under Wet Conditions." Texas Highway Department, Research Report No. 133-3F, September 1970.

plant mix seal, with 1 1/2 inches of hot mix asphalt concrete. The accident site is to be milled and repaved in 1988.

Meteorological Information

On the day of the accident, the sky was overcast, winds were variable, and moderate thunderstorms were in the area. The temperature was 76° F with 74 percent humidity, and it was raining. Based on information from the National Weather Service stations at Galveston, Texas, and Lake Charles, Louisiana, western Beaumont was under the western edge of an easterly moving area of moderate thundershowers (0.2 to 1.1 inches of rain an hour). A line of intense thundershowers (4.5 to 7.1 inches of rain per hour) had passed over the accident site about 15 to 30 minutes before the accident.

Information from the Texas A & M University Agricultural Research Center in Beaumont and the Beaumont Water Plant showed that .16 inch of rain fell during the entire month of April. This area had not received any rain for 19 days before the accident.

Two witnesses at the accident site stated that it was raining steadily at the time of the accident. Two bus passengers stated that it was raining hard.

Medical and Pathological Information

Six bus occupants, including the busdriver, were fatally injured. Four of the fatally-injured bus passengers were ejected during the accident sequence. They were found 3 to 4 feet forward of the right front of the bus. Autopsies revealed that three bus passengers died as a result of massive head trauma. One bus occupant sustained a broken neck and another sustained a punctured heart. A passenger who was seated on the right side in the third row aisle seat and was trapped in the wreckage sustained skull fractures with destruction of brain tissue. The busdriver's death was attributed to multiple head and internal injuries and a skull fracture with marked destruction of brain tissue. It is not known whether or not he had been wearing his lapbelt at the time of the accident. A toxicological analysis of the busdriver's urine sample was negative for alcohol, opiates, and other drugs.

The surviving bus passengers sustained contusions, abrasions, and fractured bones. Two bus passengers seated in the fourth and fifth rows sustained serious injuries (AIS-3), a contused heart, and a closed head injury.

The truckdriver sustained a cerebral concussion and the helper sustained a cervical strain. Neither was wearing a lapbelt. A toxicological analysis of the truckdriver's blood and urine samples taken at the hospital 1 hour after the accident was negative for alcohol. The urine sample tested positive for a cannabinoid metabolite (THC-COOH) at a level of 59

micrograms/liter. 16/ The same cannabinoid metabolite was detected in the blood sample at a level of 11 micrograms/liter, although no THC (delta-9-tetrahydrocannabinol) was detected in the blood. No psychoactive ingredients were present. The blood sample also contained diazepam 17/ at a concentration of 15 micrograms/liter. The truckdriver's wife stated that he did not have medical problems and that she was not aware of any reason why he would have taken diazepam.

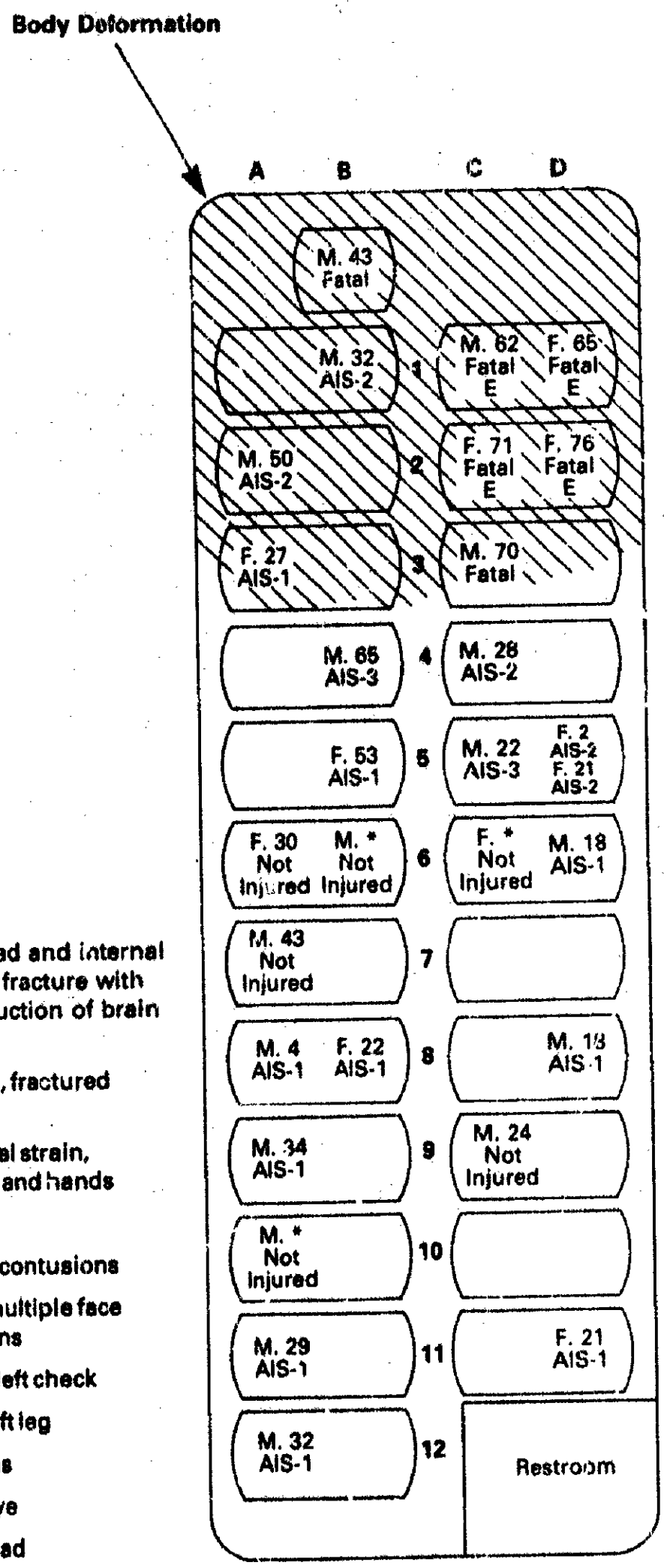
Survival Factors

The bus was equipped with a lapbelt at the driver's position. None of the passenger seats were equipped with lapbelts. The first three rows of double unit seats and floor were missing. The double unit seats in rows four through eight also were missing; however, rescue personnel reported removing these seats. The sides and roof of the bus were lined with a plastic laminate material commonly found in most intercity-type buses. Blood, hair, and tissue were found on the laminated material that had shattered and broken into sharp pieces in the front area on the sides and roof of the bus. Rescue workers resorted to using ladders (brought from the nearby moving and storage company) to climb through the emergency windows to assist the injured. Some rescue workers reported that they had to stand on the sides and hold the emergency windows open for other workers to evacuate the injured from the bus, which took up considerable room and left less space to facilitate the handling of the injured passengers. (See figure 7.)

Motor Carrier Operations

Graebel Van Lines, Inc., Operations.--The Graebel organization is comprised of 32 wholly-owned moving and storage companies, a 50-State household goods carrier, and an international forwarding company. While the Graebel companies have common ownership, each company is a separate entity. In addition, Graebel recently developed a small network of agents--moving and storage companies not owned by the Graebel organization--to perform origin and destination service on interstate relocations.

16/ One millionth of a gram.
17/ A prescription medication which is a central nervous system depressant, commonly used for the management of anxiety disorders. Additionally, diazepam is used to relieve preoperative stress; symptoms of other single, short duration, stressful events; and skeletal muscle spasms. Reported side effects include drowsiness, fatigue, and occasionally vertigo, confusion, sleep disturbances, and blurred vision.



AIS* Severity Code

1 Minor
2 Moderate
3 Serious
4 Severe
5 Critical
6 Maximum injury Virtually Unsurvivalbe

* American Association for Automotive Medicine: Abbreviated Injury Scale

Legend

AIS-3 M. 46 — Injury Severity ** Passengers Not Ejected

Sex Age

* — Unknown
E — Ejected

Busdriver - Multiple head and internal injuries, skull fracture with marked destruction of brain tissue.

1-B- Crushed right hand, fractured left wrist and ankle.

2-A- Concussion, cervical strain, lacerated forehead and hands

3-A- Scalp laceration

4-A- Heart and multiple contusions

5-B- Rib fractures and multiple face and scalp lacerations

8-A- Deep abrasions of left check

8-B- Contusion lower left leg

9-A- Multiple contusions

11-A- Contusion of left eye

12-A- Abrasion of forehead

1-C- Massive head, brain, and chest injuries

1-D- Massive head and chest injuries

2-C- Fracture and dislocation of cervical vertebra

2-D- Puncture of right vertricle of the heart

3-C- Skull fracture with marked destruction of brain tissue

4-C- Fractured pelvis and right forearm

5-C- Closed head injury and back contusion

5-D (2)- Cerebral concussion
5-D(21)- Fracture of lumbar spine

6-D- Cervical strain and contusions of both knees

8-D- Contusion of cervical spine

11-D- Multiple contusions

Figure 7. Bus seating chart noting occupant age, sex, injury severity, and seat location.

The moving and storage companies serve as the sales and service mechanism and as agents for GVL, the 50-State household goods carrier. GVL performs the interstate transportation of household goods and also serves as an administrative/technical resource for the entire Graebel system.

GVL, located in Wausau, Wisconsin, has held a 50-State operating authority granted by ICC to transport household goods as a common carrier in interstate or foreign commerce over irregular routes since July 28, 1982. In addition to operating under its own authority, GVL previously operated as an agent of Bekin Van Lines, Inc., until August 15, 1986.

GVL operations include approximately 2,000 people, 317 of whom are interstate drivers and 40 of whom are local drivers. The carrier operates 27 leased trucks, 322 leased truck tractors, 160 leased trailers, and 183 company-owned trailers. The main bulk of the drivers are owner/operators who contract with GVL to deliver loads. The contracts specify that the owners are responsible for their own vehicles, the trailers leased to them by GVL, and the shipments. Contracts are issued separately for each piece of equipment and are automatically renewed yearly unless GVL or the owner of the equipment terminates the lease.

GVL driver qualification requirements regarding traffic and criminal violations, accident history, and driving experience are over and above the requirements of the FMCSR. The formal training program deals primarily with packing, loading, unloading, and warehousing procedures. The portion of the training guide relating to driving addresses vehicle accident reporting procedures; defensive driving; safety tips; motor vehicle reports; co-drivers, helpers, and passengers; condition of equipment; inspection/maintenance records; and Department of Transportation (DOT) requirements.

According to the president of GVL, all drivers on interstate trips are required to call GVL in Wausau for dispatch orders. All interstate shipments are registered with the Wausau office and are tracked by Wausau to make certain of "on time" delivery. When the dispatcher gets a call from a driver, he enters the driver's last status and location into the computer. Changes can only be made on the computer through the Wausau office. A GVL manager stated that although a record of the accident truckdriver's shipment was in the computer, there was no record of any communication from the truckdriver during the week preceding the accident.

The accident truckdriver was employed by GNOM as a company driver; the helper stated that the truckdriver called GNOM each day. The GNOM manager explained that contract drivers normally call Wausau while on interstate trips and that the company

drivers normally call the local company where they are employed. The local office then relays information to GVL in Wausau. He stated that during the accident trip, the truckdriver called the New Orleans office several times daily to receive instructions.

Neither company had any dispatch records available on the accident truckdriver or trip. The manager at GNOM stated that the truckdriver probably was not keeping a record of duty status since he normally drove locally and was not required to comply with this regulation.

The carrier does not route drivers over specific highways. It assumes that drivers will take the shortest, safest route to their destination. No specific advice is given to drivers regarding routing; drivers are given the expected date of delivery and must meet the scheduled date. The exact time of delivery during that day is not set except that delivery normally must be made during regular business hours.

Drivers are paid by the individual branch offices for which they work. The accident truckdriver was paid a fixed hourly rate by GNOM and, for any overtime hours he worked, he was paid 1 1/2 times this fixed rate. However, when a company driver is dispatched on an interstate trip, as in this instance, he is paid on a commission basis.

GVL advised that all vehicle inspection and maintenance work was performed by the individual branch offices and that the Wausau office did not keep copies of any of these records. Branch offices are not required to prepare or submit written vehicle inspection reports.

On March 18, 1987, appropriate GVL managers, branch offices, and agents were advised in a memo from the safety operations manager that they are required to retain on file vehicle inspection reports on all equipment owned or leased by GVL. The memo requested inspection reports on all vehicles by May 31, 1987, and advised that inspections not completed by then would result in the disqualification of that equipment. GVL stated that it is in the process of polling the branch offices to establish a list of reputable independent inspection stations or dealerships to inspect the vehicles.

Although there were no formal inspection or maintenance reports, invoices were furnished to the Safety Board documenting replacement parts and work completed on the accident truck. The last inspection recorded for the accident tractor-semitrailer was April 1986; a preventive maintenance inspection on the semitrailer was conducted in November 1986.

Graebel/New Orleans Movers, Inc.--The Louisiana Public Service Commission (LPSC) authorized GNOM on May 18, 1983, to operate as a common carrier of special commodities over irregular routes by motor, handling household goods throughout the State of Louisiana. GNOM operations consists of 21 people, including 4 owner/operators and 6 driver/packers. The company operates six tractors, eight trailers, and a small 1-ton truck. The accident tractor and semitrailer were owned by GNOM office and were used primarily for local area shipments.

GNOM records indicated that the last maintenance work performed on the tractor was in June 1986, almost a year before the accident. The records show that in April 1986, new rear tires were mounted on the tractor and the vehicle was inspected. The maintenance records indicated that the last inspection on the semitrailer was performed in April 1986, and a preventive maintenance inspection was performed in November 1986. The last entry for the semitrailer was listed as exterior paint repairs in April 1987.

A cursory annual inspection by the city of New Orleans requires that a city inspector check vehicle lights, horn, windshield wipers, tires, steering assembly, exhaust system, and glass at a "break tag" inspection station. The inspection sheet, which corresponds with the New Orleans City inspection sticker found in the windshield of the accident truck, showed a different registration number than that of the accident truck.

Federal and State Oversight

Motor Carrier Operations.--The Office of Motor Carrier (OMC) is primarily responsible for the Federal oversight of motor carriers engaged in interstate commerce. The OMC normally conducts safety audits to determine if carriers are complying with the FMCSR. The OMC at times also conducts safety audits after a carrier is involved in a serious accident. Currently, about 300 OMC special agents enforce the FMCSR on more than 200,000 carriers nationwide.

On November 8, 1984, the OMC conducted a compliance review at GVL and issued the company a satisfactory rating. In July 1987, OMC conducted a safety compliance review at GVL and found that, although there were not a large number of violations for this size carrier, there were gaps in the company procedures which allowed violations to occur easily. OMC also found that, in the 365 days before the July 1987 review, GVL had 74

accidents, 17 of which were reportable. 18/ One accident which should have been reported was not. Forty-three accidents were deemed preventable by GVL. The accidents resulted in 7 fatalities and 14 injuries in a total of 10,230,981 miles driven.

OMC recommended that GVL:

- Require all drivers to notify dispatch of all enforcement stops.

- Establish a designated clinic for each branch office to perform DOT medical examination and certification of all drivers.

- Monitor drivers' hours of service closely, including examination of corresponding trip documents.

- Document and maintain the initial and in-service training of drivers in the driver qualification files.

- Enhance compliance and safety programs by conducting periodic reviews at the branch offices and addressing, as a minimum, the following subjects:

  - Hiring and qualification of drivers
  - Establishment of maintenance procedures and records
  - Use of seatbelts by drivers and helpers

The OMC assigned the carrier an overall safety rating of "unsatisfactory" and placed it in the Selective Compliance Enforcement Program. A followup compliance review of GVL will be conducted within 12 months of the July 1987 compliance review.

In a letter dated July 29, 1987, to the OMC in response to the compliance review, the president of GVL detailed specific program and procedure changes which the company intends to implement to assure compliance with the FMCSR. Basically, GVL plans to implement procedures to: (1) punish drivers and branch offices who allow unqualified drivers to drive, (2) require each office to identify an accredited medical facility to perform DOT

18/ According to 49 CFR 394.3, a reportable accident is an occurrence which involves a motor vehicle engaged in the interstate, foreign, or intrastate operations of a motor carrier who is subject to the DOT Act and which results in the death of a human being; bodily injury to a person who, as a result of the injury, immediately received medical treatment away from the scene of the accident; or total damage to all property aggregating $4,400 or more based on actual costs or reliable estimates.

medical examinations, (3) require notification of enforcement inspections of the drivers and vehicles, and (4) require new drivers to attend an orientation program on GVL policies and procedures.

In addition, GVL has set up an extensive vehicle maintenance program to regularly inspect and maintain all vehicles, both owned and leased. GVL plans to add supplemental staff to monitor drivers' hours of service, perform spot checks of co-driver operations, and adopt a computer enhancement which will prohibit access/update of any driver who had been placed "out of service."

State Compliance with FMCSR.--The OMC's efforts to enforce State compliance with the FMCSR is supplemented by State-operated programs funded in part by the Motor Carrier Safety Assistance Program (MCSAP), which is administered by the OMC. Each of the 45 MCSAP-participating States provides personnel who conduct roadside driver/vehicle safety inspections and initiate enforcement actions.

The State of Louisiana has adopted only the portion of the FMCSR pertaining to hazardous materials. However, proposed rulemaking is pending, and it is expected that the main portions of the FMCSR will be adopted in 1988.

The State of Texas adopted the FMCSR under Texas House Bill No. 908 which gave the Texas Department of Public Safety (DPS) the authority to implement the regulations. The DPS established a tentative date to begin implementing the FMCSR on January 1, 1988. However, on January 7, 1988, the DPS postponed the implementation date until September 1, 1989, after several members of the legislature brought it to their attention that certain groups of the trucking industry were not aware of the impact the regulations would have on their operations. Additionally, the Texas legislature is considering possible exemptions of certain requirements for private carriers who operate within the State. Meanwhile, the Federal Highway Administration (FHWA) has mandated that all States adopt and implement the Federal regulations under the MCSAP by October 1989.

Skid Accident Reduction Program.--The FHWA requirements for skid resistance pavements are contained in several documents, including the Highway Safety Program Standard 12 (HSPS No. 12) of CFR 23 1204. HSPS No. 12 requires every State to have a program that addresses highway design, construction, and maintenance to improve highway safety and that provides "standards for pavement design and construction with specific provisions for high skid resistance qualities." The standard also requires each State to have a "program for resurfacing or other surface treatment

with emphasis on correction of location or sections of streets and highways with low skid resistance and high or potentially high accident rates susceptible to reduction by providing improved surfaces."

Each State highway agency is encouraged to develop and manage a skid accident reduction program to reflect the individual needs and conditions within the State. The purpose of a skid accident reduction program is to minimize wet weather skidding accidents through: identifying and correcting sections of roadway with high or potentially high skid accident incidences; ensuring that new surfaces have adequate, durable skid resistance properties; and utilizing resources available for accident reduction in a cost-effective manner.

FHWA Technical Advisory T-5040.13, issued January 11, 1980, emphasizes continued support of the use of open-graded asphalt friction surfaces. The advisory states:

> The mixture should be laboratory tested for stripping. The high void content enhances any tendency to strip. If not tested, the asphalt should contain an anti-stripping additive.
>
> Any obstruction to lateral water drainage through the open-graded asphalt friction course should be avoided. Preferably, the open-graded mix should be placed from outside edge to outside edge of the shoulder.

The FHWA strongly encourages the States to use the open-graded asphalt mixture on all asphalt-wearing surfaces accommodating high speeds, particularly those surfaces accommodating high traffic volumes. The technical advisory lists specific research sources to assist the States in obtaining information on practices and experiences with the open-graded asphalt mix. The FHWA also offers technical support for mix design, construction, and maintenance of open-graded courses.

The Surface Transportation Assistance Act of 1978 requires each State to certify annually to the FHWA that its maintenance program for the interstate system meets the established guidelines.

TDHPT Interstate Maintenance Program.--The TDHPT does not have a maintenance program, guidelines, or a budget exclusively for the interstate system; however, most interstates would receive the highest priority in performance of maintenance because of traffic and functional classification. The primary goal of the TDHPT maintenance efforts is to provide the best level of service possible with available funds for the entire highway system.

In compliance with HSPS No. 12, Part II of the TDHPT Safety Maintenance Operating Division Manual states:

The surface texture of bituminous pavement is subject to adverse change as a result of aging, excessive asphalt, wearing, etc. Continuous surveillance of pavement texture should be made with particular attention being given to pavements which become slippery. Obvious slippery areas should be corrected as soon as practical, to the extent feasible under the prevailing conditions. When additional corrective action is necessary it should be scheduled and initated promptly.

The TDHPT is responsible for 81,500 centerlane miles of highway and is comprised of 24 decentralized geographic districts which are divided into 284 maintenance sections responsible for 254 counties. Each maintenance section is unique. District 20, which covers the Beaumont area, is responsible for the maintenance of 176 centerlane miles, including 22.6 centerlane miles of I-10. District 20 has no written guidelines requiring specific roadway maintenance duties other than those in the TDHPT Safety Maintenance Operating Division Manual. Generally, the section foreman or his assistants are expected to visually inspect each of their assigned highways at least once weekly, with the frequency of inspections increasing with the average daily traffic. According to TDHPT, District 20 visually inspects its interstate highway a minimum of three times daily. Cursory inspections also are made by administrative personnel while traveling to and from business trips and any irregularity is reported.

ANALYSIS

Accident Dynamics

The faint light-colored tiremarks in the eastbound lanes showed the path of the tractor as it entered the median strip in a jackknife configuration. The tiremarks across the width of the median strip to the westbound lanes indicate that the tractor continued to jackknife as it entered the westbound lanes at a 90° angle. Impact damage on the semitrailer indicates that the right front corner of the semitrailer initially struck the bus. Scrapemarks and gouges on the road surface indicate that the vehicles collided in the left westbound lane.

The force of the collision caused the frame rails of the truck tractor to bend severely to the left and caused the fifth wheel to separate from the tractor. The tractor continued across the westbound lanes, traveled down a 17 percent downgrade, rotated 180°, and struck a curb on the frontage road adjacent to the highway. It then rolled forward into the opposite curb (back toward the accident site) and came to rest about 150 feet from the point of impact. During the jackknife sequence, the left rear corner of the tractor struck the left side of the trailer.

The bus and semitrailer separated after impact and came to rest about 50 feet from the point of impact. The semitrailer was facing northbound, almost perpendicular to the roadway, and the bus was facing northwesterly at a 15° angle to the edgeline.

Vehicle Speeds

There was no physical evidence to indicate the paths taken by the vehicles after impact to their final rest positions. Therefore, the Safety Board simulated the departure angles using a scale diagram. Assuming that the bus was traveling straight in the westbound lanes before impact and that the truck was traveling at an approximate 20° approach angle across the median toward the bus, the tractor probably departed at a 44° angle to the northeast from the centerline, the trailer probably departed at a 29° angle to the northeast, and the bus probably departed at a 29° angle to the northwest.

Skid tests for automobile tires on wet open-graded asphalt have proven to have a drag factor of 0.6. Testing experience 19/ has shown that commercial vehicle tires (i.e., trucks and buses) tend to have a drag factor of 0.2 lower than autombile tires. Thus, the drag factor for the bus was estimated to be 0.4 for the wet westbound lane and for the tractor-semitrailer in the wet grass, 0.2. Through the use of conservation of momentum calcula-tions, 20/ the Safety Board determined that the most probable impact speed for the bus was 55 mph and for the truck, 53 mph. Based on the above, the preimpact speed of the truck at the time it went out of control in the eastbound lane was calculated to be about 63 mph.

The estimated speed of the truck was corroborated by witnesses traveling behind the truck who stated the truck was traveling at least 57 mph shortly before the loss of control. Also, the estimated speed of the bus was corroborated by a witness who stated that he was traveling around 50 mph when the bus passed him shortly before impact. Both speed estimates were below the maximum speed capabilities of the truck and bus, which were 65 and 66 mph, respectively. Based on the witness statements and calculated speeds, the Safety Board concludes that the truck was traveling between 57 and 63 mph when the loss of control occurred in the eastbound lane and about 53 mph when it struck the bus in the westbound lane. Concurrently, the bus was traveling between 50 and 55 mph when it was struck by the truck.

19/ Ensco,Inc., "Truck Tire Cornering and Braking Traction Study."

20/ Conservation of momentum is the principal that in a collision of two solid bodies no momentum (mass times velocity) is lost, the sum of the momentums of the two bodies is the same before and after the collision.

Loss of Control Sequence

In an attempt to determine why the truckdriver veered abruptly to the left into the median strip, the Safety Board considered two possible conditions that may have precipitated the accident. First, the tractor-semitrailer may have jackknifed during a slowing maneuver initiated by the truckdriver on the low friction, wet pavement. Second, the jackknife sequence may have been precipitated by partial hydroplaning of the truck on a thin film of water on this section of pavement.

With regard to the first condition, it is possible that the truckdriver may have applied his service brakes or slowed the truck through engine braking 21/ to reduce vehicle speed for slowing traffic ahead. Either situation would have made the truck subject to differential friction 22/ in the right and left wheelpaths of the center lane. Tests performed on wet pavement at the accident site in the center lane indicated that, at 40 mph, the average SN for the right and left wheelpaths were 29 and 25, respectively. If the truckdriver had attempted to slow by activating his service brakes or through engine braking, the tractor would have been subjected to a counterclockwise turning moment which would have rotated the front of the tractor about the wheelpath with the higher SN. Under these conditions, the rear of the tractor would have moved laterally to the right (rotated counterclockwise) away from the wheelpath with the higher SN of 29, thus realigning the tractor to the left of the centerline wheelpaths. The misalignment between the tractor and semitrailer could have precipitated the jackknife sequence. The wet, low friction wheelpaths and the poor condition of the tractor rear tires may have generated insufficient friction between the tires and the roadway surface to resist the lateral movement of the rear tires until they were displaced to the adjoining wheelpaths. With the traction capability of the tires regained in the adjoining wheelpaths, the entire truck would have been redirected off the roadway and toward the median strip at an approximate 20° angle. When either unit of a tractor-semitrailer goes out of alignment more than 15° while traveling at high speed, it is almost impossible to regain control of the vehicle.

The motorist following behind the tractor-semitrailer could not remember seeing the brake lights on the semitrailer activate just before the loss of control. Most witnesses indicated that the truck suddenly veered sharply to the left before entering the

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21/ Engine braking is truck deceleration due to rotational inertia of the engine and the drive train.

22/ Burnes, J. C., "Differential Friction: A Potential Skid Hazard," Transportation Research Record No. 602, 1976.

median strip. The truckdriver stated that he attempted to steer to the right to regain control of the vehicle but that the truck kept going to the left. Although the truckdriver did not mention in his statement whether or not he applied the brakes just before loss of control, the helper stated that the truckdriver started to slow down for traffic. It is possible that the loss of control and jackknife may have been precipitated by engine braking or because the truckdriver applied the brakes on the slick pavement.

The second condition which might account for the jackknife sequence is that the tractor may have hydroplaned while traveling across a section of roadway layered with a thin film of water. Under these circumstances, the jackknife sequence could have occurred so rapidly that the truckdriver would have had very little opportunity to react and take corrective action.

When highway pavements become flooded or puddled, at some critical speeds vehicles can encounter a phenomenon called tire hydroplaning. When a pneumatic tire operating under certain conditions on a wet highway does not displace the residual surface water beneath the footprint area (nominal tire-ground contact area) at a rate fast enough to permit the tire footprint to make total contact with the highway surface, the tire rides on a film of water over a part of or all of its footprint area 23/ and begins to hydroplane. The hydroplaning arises from the buildup of fluid pressure beneath the wetted tire footprint.

The buildup of fluid pressures stems from two separate fluid properties--viscosity and density. Dynamic hydroplaning (total hydroplaning from fluid density pressures) normally occurs when there is a complete loss of contact of the tire footprint with the highway surface. The accepted empirical formula for determining the minimum dynamic hydroplaning speed (mph) is 7.95 multiplied by the square root of the tire pressure divided by the footprint aspect ratio (V_p = 7.95) x (tire pressure/footprint aspect ratio)$^{1/2}$. The formula compensates for differences in tire construction and tire loading. 24/

Viscous (thin-film) hydroplaning or hydroplaning from viscous pressures, occurs when there is a partial loss of contact of the tire footprint with the highway surface. Viscous hydroplaning is potentially more dangerous than dynamic

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23/ Horne, Walter B., and Joyner, Upshur T., "Pneumatic Tire Hydroplaning and Some Effects on Vehicle Performance," Society of Automotive Engineers (970C), January 1965.
24/ "Truck Tire Hydroplaning--Empirical Confirmation of Horne's Thesis," Ivey, Don L., Texas A & M University, November 1984.

hydroplaning because it can occur at much lower vehicle speeds and with less water surface depth on the the pavement. However, it normally occurs only in conjunction with braking or significant yaw.

Dynamic or total hydroplaning can adversely influence vehicle performance. When dynamic hydroplaning conditions occur, the ability of pneumatic tires to develop braking and cornering forces for stopping and/or steering are drastically reduced or eliminated. It becomes extremely difficult for drivers to maintain the directional stability of nonarticulated vehicles, such as cars, straight trucks, and buses, and almost impossible for drivers to maintain the directional stability of articulated vehicles, such as tractor-semitrailers.

At the time of the accident, the temperature was 76° F. A steady rain, the first rainfall in Beaumont in 19 consecutive days, was falling at a rate of 0.2 to 1.1 inches an hour. Fifteen to 30 minutes before the accident, intense rain had fallen at a rate of 4.5 to 7.1 inches an hour.

With the rain intensity of 0.2 to 1.1 inch/hour, the cross slope of 0.02 foot/foot, the texture depth of 0.0042 inch, and the drainage path lane estimated to have been 48 feet, the road surface at the time of the accident probably was lightly flooded with a thin film of water 0.015 to 0.05 inch deep. The rainfall would have had a tendency to run down the 3.5 percent grade to the lower area of roadway (0.1 percent grade) rather than off the sides of the roadway because of the "flat" wheelpaths.

The minimum tread thickness for two of the rear tractor tires was 2/32 inch. With this tread depth, the ability of the tires to channel surface water out of the tire footprint area would have been greatly reduced, particularly at high speed, and would have caused the tires to be more susceptible to hydroplaning. In addition, the tire inflation pressures for the tractor rear tires varied considerably from 50 to 66 psi. Thus, the tires mounted on this axle had different minimum speeds at which hydroplaning could occur. This condition could cause potential handling problems for any type of large vehicle operating in lightly flooded pavement situations. Because the condition of the tractor rear tires adversely affected the minimum speed of hydroplaning and handling capability of the accident tractor-semitrailer during wet pavement operation, the Safety Board concludes that the poor condition of the tractor rear tires was causal in this accident.

The tractor was equipped with radial and bias ply tires with different inflation pressures on the front and rear axles; therefore, the minimum speed for total hydroplaning varied considerably. Based on tire data provided by the Goodyear Tire

and Rubber Company, 25/ the Safety Board calculated (using the previously mentioned empirical formula) the minimum hydroplaning speed for 10.00-20 new bias ply rear tires to be about 63 mph when pressurized to 50 psi. Using similar data for the 10.00 R-20 tires, the Safety Board calculated the minimum hydroplaning speed for the radial front tires to be about 70 mph when pressurized to 70 psi.

A 1984 study conducted by the Texas Transportation Institute (TTI) 26/ on hydroplaning of tractor-semitrailers determined that when highway lanes become flooded with a thin layer of water, 27/ the tractor tires can develop water drag forces. If the flooded pavement lane has differential water depths between the tractor right and left wheelpaths (created by the pavement cross slope), a rotational moment that develops about the tractor center of gravity (approximate position of fifth wheel) must be compensated for by rapid driver steering to maintain the tractor directional alignment in the traffic lane.

The TTI study also indicated that trucks are more susceptible to hydroplaning when they are equipped with smooth or badly worn tires, 28/ or are traveling on smooth (low friction) pavement surfaces. Vehicle tests indicated that the minimum speed for hydroplaning is further reduced when one or both of these factors are present.

Previous research on hydroplaning conducted by the National Aeronautics and Space Administration (NASA) Langley Research Center 29/ indicates that commercial vehicle operators should replace tires when about 85 percent of their original tread is worn away. Also, vehicle speed should be kept below the expected hydroplaning speed during wet pavement operation according to the tire pressure used, and tire pressures should be the same for all tires mounted on each axle. In addition, the research study indicates that pavement surfaces either should be treated with surface additives, grooving techniques, pavement texturing, or should be completely replaced when the original surface becomes worn smooth through aging or extensive traffic use.

With regard to the tractor involved in this accident, because of higher air pressure in the radial tires and good tread depth, the front tractor tires would have been able to negotiate the flooded surface without hydroplaning. However, because the rear tractor tires were in poor condition with minimal tread

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25/ Load Deflection data for a 10.00-20 bias ply tire and a 10.00 R-20 radial tire.
26/ Ivey, "Truck Tire Hydroplaning--Empirical Confirmation of Horne's Thesis."
27/ Water depth of about .025 inch.
28/ Worn to the point where approximately 2/32 inch tread remaining (± 0.1 inch).
29/ Horne and Joyner "Pneumatic Tire Hydroplaning and Some Effects on Vehicle Performance."

depth and lower tire pressure, when the rear tires entered the lightly flooded section, the cornering and braking forces on the rear tractor tires probably were reduced significantly (due to partial hydroplaning). The footprint area for the rear tires was partially lifted from the pavement surface. Also, because of initial water drag on all tractor tires, the tractor speed would have been partially reduced, and the semitrailer would have continued forward. Consequently, the loss of traction by the tractor rear tires and the road cross slope may have initiated a left turning moment about the fifth wheel, causing the rear of the tractor to rotate counterclockwise while the semitrailer continued in a straight alignment. This condition would have initiated a jackknife sequence. Moreover, the turning moment probably rotated the tractor so rapidly that the driver was unable to take corrective action.

Considering the weather and surface conditions at the accident site, the Safety Board was not able to establish conclusively which of the two conditions caused the tractor-semitrailer to jackknife and go out of control. However, in any event, the Safety Board concludes that the speed of the truck was too great for the highway conditions. As speed increases on wet pavement, available tire-to-pavement friction decreases. Also, high speeds increase vulnerability to dynamic hydroplaning. Therefore, any reduction in the travel speed of the tractor-semitrailer or increase in pavement friction would have improved the stability of the truck and would have reduced its vulnerability to hydroplaning.

Vehicle Mechanical Condition

Tires.--The speed at which partial hydroplaning and subsequent jackknife occurred was greatly reduced by the condition of the tractor rear tires. The minimum tread thicknesses of the rear tractor tires were marginal, and the tire pressures varied considerably.

FMCSR requires a minimum tread depth on the front axle tires of 4/32 inch and 2/32 inch tread depth for all tires mounted on any other axle. Therefore, the rear tractor tires met the minimum tread depth requirements and were in compliance with the applicable FMCSR. However, tests conducted by the Safety Board in conjunction with the investigation of an accident near Luling, Texas on November 16, 1980, 30/ indicate that the ability of a commercial tire to produce both braking and cornering traction on wet pavement is significantly reduced when the tire tread depth

30/ Highway Accident Report--"East Side Church of Christ Bus Skid and Overturn, U.S. Route 183, Near Luling, Texas, November 16, 1980" (NTSB-HAR-81-4).

is below 4/32 inch. Thus, any demand which was made on the accident truck by the truckdriver, such as braking, turning, or even engine braking on wet pavement at highway speeds could have exceeded the traction capabilities of the rear tires and could have precipitated the loss of control.

Commercial tires worn below a tread thickness of 4/32 inch should not be used for high-speed operation, particularly during wet pavement conditions. They are more susceptible to hydroplaning when inflation pressures are not properly maintained and may not generate adequate braking and cornering traction to maintain vehicle stability in high-speed maneuvers on wet pavement. In another accident investigation involving commercial vehicles, 31/ the Safety Board found that the inadequate tread depth of the rear tires was either a causal or contributing factor to the accident. Both the Luling and Ackerly accidents involved a loss of control on wet pavement at highway travel speeds.

The FHWA, which is responsible for developing and enforcing the FMCSR, is currently revising the existing vehicle inspection requirements specified in Part 393 of the FMCSR. These requirements also are being adopted in part or totally by most States through the MCSAP. The Safety Board believes that this would be a good opportunity for the FHWA to re-evaluate its current minimum tread depth requirements for commercial vehicles. The minimum tread depth criteria for a tire on any axle of a commercial vehicle should be at least 4/32 inch to ensure its safe operation particularly in wet pavement and inclement weather conditions.

Brakes.--The majority of service brakes on the tractor-semitrailer either were out of adjustment or were not functional. The postimpact inspection revealed that two of the four service brakes on the tractor were out of adjustment and that three of the four service brakes on the semitrailer were out of adjustment. Although the pushrod stroke could not be measured on the tractor rear brakes, the left brake drum and lining were contaminated with grease and oil deposits. Thus, one of the two service brakes on the tractor rear axle was not functional. Because of these discrepancies, at least six of a total of eight service brakes on the truck either were out of adjustment or were not functional. Although out-of-adjustment or nonfunctional brakes may have severely limited the braking performance of the truck, especially during panic stop maneuvers, the condition of the brakes probably was not causal in this accident since the loss of control could have occurred with the application of marginal or fully adjusted service brakes.

31/ Highway Accident/Incident Summary Reports--"Buses Owned or Chartered by Church Groups, near Ackerly, Texas, July 20, 1985" (NTSB/HAR-87/01/SUM).

The speedometer on the tractor had been inoperative for some time before the accident. Federal regulations require that commercial vehicles engaged in interstate operation be equipped with working speedometers to ensure that truckdrivers are aware of the vehicle speeds on a continuous basis to comply with all local and State speed ordinances. Although commercial drivers probably can estimate the speed of the vehicle with considerable accuracy without reference to a speedometer, the instrument is essential to the safe operation of large vehicles during inclement weather conditions. Therefore, the lack of an operative speedometer may have contributed to the accident. The Safety Board believes that GVL should make certain that all commercial vehicles are equipped with operable speedometers.

The Highway

The accident site was not a high accident location. The open-graded asphalt surface placed on the accident section of roadway in 1980 was designed to permit water to enter the surface course and flow laterally. An open-graded asphalt surface prevents buildup of water between the surface of the roadway and the vehicle tires, thus reducing hydroplaning. Because of its open-graded characteristics, the surface treatment (which has been proven to reduce wet weather accidents on high speed roadways) has low structural capabilities.

In March 1987, the TDHPT overlayed the center lane with a densely-graded asphaltic concrete pavement; the two outside lane surfaces remained open-graded. The asphalt overlay permitted water to enter and be trapped in the surface. The trapped water under the center lane surface caused the asphalt to be stripped from the aggregate.

The "free" asphalt bled 32/ to the surface and caused the pavement to have a very low texture depth. Pavement surfaces with low texture depth are likely to be less skid resistant than pavement surfaces with good drainage qualities. Sand patch tests conducted after the accident indicated that the surface texture for the center lane was 0.004. A 1976 research study noted that for wet pavements with texture depths of 0.007 to 0.015, vehicles are only occasionally able to exceed 50 mph. 33/ For wet pavement sections of roads on which moderate vehicle speeds between 50 and 75 mph are encountered, the texture depth should vary between 0.015 and 0.31. Thus, the Safety Board concludes that the surface texture for the center lane at the accident site was not adequate to support the high speed operation of all commercial vehicles.

32/ The rising of separated asphalt to the surface of the mixture.
33/ Elsenaar, Reinchart, and Sauterey, "Pavement Characteristics and Skid Resistance."

In addition, open-graded mixtures have very low structural qualities. Heavy truck traffic, as in the Beaumont accident, traveling on this type of surface will tend to "flatten" out the wheelpaths in the traffic lanes. The flat spots reduce drainage of the surface water in the lane and act as additional dams in the overlayed open-graded mix to make the pavement more susceptible to water buildup during heavy rain conditions. In view of this, the Safety Board concludes that the overlayed open-graded mix pavement in the center near the accident site contributed to the water buildup and eventual tractor-semitrailer loss of control.

Skid Resistance

The Safety Board has encouraged Federal and State agencies to adopt minimum criteria for skid resistance on wet pavements. However, the FHWA and many States, including Texas, have been reluctant to establish minimum skid resistance criteria. The TDHPT has no written guidelines or standards for detecting wet pavement problem locations or for initiating corrective actions resulting from low locked-wheel trailer test results, high accident rates, or other indications of wet pavement problems.

In its investigation of the wet pavement accident that involved an intercity-type bus traveling south on U.S. Route 183, a two-lane rural highway, near Luling, Texas, the Safety Board found that as the bus approached a curve and attempted to negotiate to the left, the rear tires lost traction. The bus skidded across the opposing lane of traffic and onto the shoulder before it could be steered back onto the highway. As it crossed the highway again, the bus spun 180° and slid into a drainage ditch where it struck the side of the ditch and overturned on its left side. Two passengers were killed; the busdriver and 35 passengers were injured.

In 1982, as a result of its concern about skid resistance on wet pavements and its investigation of several highway accidents involving commercial vehicles on wet pavement, including the Luling accident, the Safety Board recommended that the FHWA:

H-82-34

> Conduct and publish a comprehensive review of each State's skid accident reduction program to identify problem areas, to develop corrective recommendations where necessary, and to disseminate more widely innovative local practices of proven value and general applicability.

In its response, dated September 13, 1985, the FHWA indicated that it had increased its emphasis in the skid program area and had "issued a memorandum directing our region and division offices to conduct reviews of their State's skid

accident reduction programs using the guidelines and findings from the headquarters reviews." By April 1986, the FHWA had completed 21 individual reviews of State programs on skid accident reduction. However, the review of the Texas program by the regional office of the FHWA has not been evaluated by FHWA headquarters. The Safety Board reiterated Safety Recommendation H-82-34 in a recent bus accident involving a loss of control on wet pavement.

During its investigation of the wet weather, loss of control accident near Ackerly, Texas, on July 20, 1985, the Safety Board contacted the State of Texas concerning its skid accident reduction program. The Safety Board learned at that time that there were no uniform, statewide policies mandating skid resistance testing. Although the TDHPT is responsible for the State's road system, 24 district offices, each of which has access to skid testing equipment, are responsible for conducting the tests. Practices vary among regions of the State depending on a number of variables, such as weather conditions, monitoring of new surfaces, special projects, or problems observed by field personnel. There are no standardized, statewide policies for identifying wet pavement problem locations or improving the skid resistance at these locations. The State did not have a threshold skid number or a range of numbers to indicate that pavement surfaces are in need of analysis for corrective treatment.

As a result of its investigation, the Safety Board recommended that the TDHPT:

H-87-2

Develop a statewide comprehensive program for reducing skid accidents on low coefficient of friction roads. Include a design and maintenance policy for reducing potential problems associated with bleeding, partial width resurfacing, and differential friction.

In 1985 and 1986, the Safety Board's field office conducted four investigations which involved tractor-semitrailer jackknife accidents on wet roads in Texas. All four accidents occurred on highways that had a pavement irregularity, bleeding asphalt, or a highly polished pavement surface. The accidents resulted in two serious injuries and one minor injury. (See appendix C.)

On September 2, 1987, Safety Board investigators met with representatives from the TDHPT and the FHWA to discuss the skid resistance program. The TDHPT advised that the State of Texas has an ongoing construction and maintenance program with a total funding of $20 billion to spend each year for the next 3 years. However, TDHPT representatives have no current procedures or plans for dealing with the reduction of skid resistance accidents.

In a letter dated January 6, 1988, the TDHPT stated that Safety Recommendation H-87-2 has been reviewed extensively and has been judged impractical. It stated that costs would be prohibitive to skid test the 163,000 lanes-miles and that any data generated would be of limited value in identifying problem locations.

The intent of Safety Recommendation H-87-2 was not for the TDHPT to skid test the entire roadway system, but rather to implement a maintenance policy and a working program to identify and correct pavement problems. Currently FHWA requires such a program and the State of Texas, in order to comply with this requirement, has established a "Safety Maintenance Operating Division Manual." However, none of the 24 districts within the State are required to adhere to the manual or to any standard practices dealing with the maintenance of highway pavements. These districts mainly rely on visual inspections of the roadway by highway personnel.

The Safety Board firmly believes that the current State highway maintenance policies are inadequate and that a comprehensive program for skid accident reductions in which all districts must participate should be developed and implemented. A comprehensive program for skid accident reductions should include a maintenance policy for reducing potential problems associated with resurfacing pavements. Such a program could lead to a more effective identification of pavements with potential skid resistance problems. Therefore, the Safety Board reiterates Safety Recommendation H-87-2.

Drivers' Duty Hours

Busdriver.--The Safety Board believes that the length of the bus driver's regular workday, from an 11:30 a.m. check-in to an 11:30 p.m. checkout, possibly could have contributed to fatigue. His schedule included a 4- to 5-hour off-duty period in the middle of the workday. Although the bus company provides a room with recliner armchairs, a couch, and a television set for the drivers, the setting would not be as conducive to rest as a motel room or a driver's home. Busdrivers with layovers of 6 or more hours are provided with hotel rooms; however, the accident driver would not have qualified.

The accident busdriver had been working his regular schedule for several months and would have had an opportunity to adjust to it. The schedule also allowed the driver to sleep during normal sleeping hours. The fact that, during the accident sequance, the busdriver was able to brake in the short period just before collision indicates that he was alert and able to react quickly. Therefore, the Safety Board believes that fatigue on the part of the busdriver was not a factor in the accident.

Truckdriver.--Following the accident, the truckdriver's records of duty status were not found among the other records maintained in the tractor cab. The Safety Board later requested the records from the motor carrier and the truckdriver; however, no records of duty status were supplied either by the carrier or the truckdriver during the month after the accident. The manager at GNOM stated that the truckdriver probably did not keep any records of duty status since he normally drove locally and was not required to maintain a duty record. Therefore, the Safety Board concludes that the driver probably did not maintain a current driver's record of duty status and that he did not file the record in accordance with 49 CFR 395.8.

The Safety Board is concerned about the irregular working and sleeping hours which the truckdriver was keeping. Packing, loading, and unloading furniture and office equipment for 11 hours and then driving for 6 hours is a heavy workload. The heavy physical labor was completed during daylight hours, and the driving was typically started in early evening and lasted until 3 a.m. Even though this type of workload is considered typical in the household goods moving industry, the Safety Board believes that drivers working such irregular hours punctuated by brief periods of sleep are subject to the condition of cumulative fatigue. Although the truckdriver had been working this type of schedule on and off for 12 years, laboratory studies of human performance during periods of irregular work/rest cycles have shown that due to the circadian rhythm cycle, the body does not adapt to irregular work/rest cycles even over a period of time. 34/

In an attempt to reconstruct the truckdriver's hours of service during the workweek preceding the accident, several problems were encountered. A large portion of the schedule was obtained through an interview with the helper and according to the receipts, this schedule appeared to be an accurate one. However, several periods of time designated as driving time by the helper, appeared to be erroneous because the small amount of mileage would never have taken that long to drive. When questioned about this later, the helper restated the original schedule and said he could not remember anything else. One such instance was when they were in Oklahoma City and drove to Tulsa (105 miles) which the helper said took 5 hours. Another instance is when they were en route to San Antonio from New Orleans (347 miles) and it took them 21 hours, more than twice the time it should have taken.

34/ Allusisi, E. A., Coates, G. D., & Morgan, E. B., Jr., "Effects of Temporal Stressors on Vigilance and Information Processing." Mackie, R. R. (ed.), "Vigilance: Theory, Operational Performance, and Physiological Correlates," New York: Plenum Press, 1977.

The Safety Board believes that there is a possibility that the truckdriver may have suffered from cumulative fatigue due to his irregular work/rest cycle. However, because of the limited data available in this accident, the Safety Board was not able to draw any significant conclusions as to how the irregular work/rest cycle may have affected the truckdriver's judgment and/or performance at the time of the accident.

Toxicological testing indicates that alcohol was not a factor in this accident. However, low levels of marijuana (cannabinoid) metabolites were present in both blood and urine samples. The small quantity suggests that the driver was exposed to marijuana but that there were no psychoactive ingredients evident. Therefore, it is highly unlikely that the drug had any influence on the truckdriver at the time of the accident. The toxicological testing also indicated a low level of diazepam, a drug which has been demonstrated to affect driving. 35/ Although the level of diazepam was enough to have a therapeutic effect, the Safety Board was not able to determine what effect, if any, the low level of diazepam may have had on the truckdriver at the time of the accident. Nor is it known what effects the combined drugs would have had on the truckdriver.

The accident was caused by a combination of physical factors: the rain-slick condition of the highway, the marginal tread depth of the truck tires, and the speed of the truck. Although toxicology results indicate the driver's judgment and motor performance may have been influenced, the Safety Board is unable to determine how this condition contributed to his loss of vehicle control. The Board believes that, in this case, the driver's judgment was faulty, in that he was driving too fast for existing conditions. However, the Board cannot establish that the truckdriver's faulty judgment was attributable to his use of drugs.

Motor Carrier Operations

Hours of Service.--The local motor carrier, GNOM, initially hired the truckdriver to drive locally. Even though the driver met the qualifications for interstate driving and was subject to being sent on interstate trips for GVL, his primary supervision came from New Orleans, which would explain why the driver elected to call GNOM for further instructions throughout the trip. GVL had set up procedures to track interstate drivers and their shipments; however, the procedures apparently were not being complied with by local drivers.

35/ O'Hanlon, J.F., Haak, T. W., Blaauw, G. J., and Riemersma, J. B. J., "Diazepam Impairs Lateral Position Control in Highway Driving," Science, 1982, 217, 79-81; and Smiley, A., and Moskowitz, H., "Effects of Long-term Administration of Buspirone and Diazepam on Driver Steering Control," The American Journal of Medicine, 1986, 80, 22-29.

No records were available at either GVL or GNOM concerning the truckdriver's records of duty status. The fact that GNOM management was aware of the truckdriver's failure to maintain duty status records is distressing. Althcugh the truckdriver was responsible to GVL while on the interstate trip and he was required to turn in records of duty status to GVL, GNOM should have reminded and encouraged the truckdriver to maintain duty status records since this was his first interstate trip after his most recent hiring.

Vehicle Maintenance.--The postaccident inspection of the tractor-semitrailer revealed that the truck was in a state of disrepair with a number of mechanical deficiencies. The discrepancies in the truck brake system--improperly adjusted brakes, contaminated brake linings, and mismatched brake components and marginal tread tires--should have been detected and repaired during routine inspection and maintenance.

An inspection record showed that the accident truck had not been inspected for almost 1 year before the accident. Common safety practices would dictate that a tractor-semitrailer being operated over the road either locally or long distance be inspected much more frequently than once a year. Also, complete maintenance records should be kept wherever the vehicle is housed or maintained, and inspection records should be kept at the branch offices and the GVL office.

The installation of the nonstandard seats and the condition of the lapbelts in the tractor were indicative of total disregard for the safety of the truckdriver and helper. By using equipment in such poor condition, GNOM was not operating in a responsible manner.

GVL advised the Safety Board that since the accident, commercial vehicle truck tires are required to have a minimum of 3/32 tread depth or these vehicles would be put out of service. The Safety Board believes that GVL should set up strict procedures for vehicle inspection and maintenance for all of its commercial operation vehicles. GVL also should maintain complete and accurate records on all equipment used whether owned or leased.

GVL's driver qualification requirements are more stringent than the FMCSR, and the motor carrier puts an effort into disseminating safety information to all of its drivers. GVL also has begun the process of setting up vehicle inspection procedures. Therefore, the Safety Board believes that GVL is attempting to comply with those portions of the FMCSR, not just because it is required, but to ensure that its transportation operations are conducted in a safe manner.

The Safety Board urges GVL to implement and enforce procedures to monitor all truckdrivers, whether they are employed primarily to drive interstate or primarily employed to drive locally and only drive on interstate trips occasionally. This

type of monitoring and enforcement would ensure that the motor carrier responsible for the interstate driver would have direct communication with the interstate driver during the trip.

The OMCS compliance audit highlighted the deficiencies noted during the investigation and rated the motor carrier as being unsatisfactory. A followup compliance review will be conducted on GVL within 12 months of the July 1987 compliance review. The Safety Board agrees with the OMCS and encourages it to monitor GVL practices and procedures so that management and maintenance personnel comply with all applicable FMCSR.

Survival Factors

Bus occupants were subjected to forward acceleration forces during impact with the semitrailer. The floor was torn out of the bus and the first three rows of seats were separated during the collision sequence. During the accident sequence, the occupant space in the right front was taken up by the intrusion of the semitrailer.

The busdriver was massively crushed in his seating area. Bus passengers who sustained fatal injuries were seated in the first three rows on the right side of the bus. They sustained massive crushing injuries to the head and severe lower leg injuries. The front seat passengers were probably struck by the intruding semitrailer causing their severe head injuries. Four of these occupants were ejected through a large opening created at the right front of the bus. These passengers probably sustained their lower limb injuries while being ejected from the bus.

Two surviving bus passengers who sustained serious injuries (a closed head injury and a contused heart) were occupying seats in the fourth and fifth rows. One of these passengers, located in the fourth row, left side, aisle seat, was on the perimeter of the impact area and may have been struck by the intruding semitrailer. The other passenger in the fifth row and all the passengers who sustained moderate and minor injuries probably received their injuries when they struck the seatbacks, sidewalls, armrests, ashtrays, and other surrounding objects. These passengers received contusions, abrasions, lacerations, and some fractured bones. The six passengers who were not injured were seated in rows 6, 7, 9, and 10.

Had lap belts been installed and used by the fatally injured bus occupants, it is unlikely that the injury outcome would have been any different. Because of the reduction in survivable occupant space, it is unlikely that the busdriver or passengers seated in rows one through three would have benefited from the use of lapbelts.

Since some of the seats were ejected during impact, and many of the others were removed by rescue personnel, it is not known which seats in rows four through eight broke loose during the collision and which seats remained intact. Therefore, the Safety Board cannot address the use of seatbelts for these particular occupant positions.

Although the installation and use of seatbelts may have lessened the surviving passengers' injuries in some cases, generally, the level of injury to those passengers who sustained minor or moderate injuries probably would have been the same because they would have sustained similar injuries from contact with the seatbacks, armrests, and sidewalls.

The interior sidewall and roof of the bus were covered by a thermoplastic laminate material about 1/8 inch thick. The material shattered into sharp-edged pieces as the bus structure collapsed. Blood and hair were visible on broken laminate pieces on both sidewalls, showing evidence of occupant contact.

As a result of its investigation of a head-on collision involving an Eagle Coach intercity charter tour bus and a pickup truck in Laredo, Texas, on October 20, 1984, 36/ the Safety Board recommended that the National Highway Traffic Safety Administration (NHTSA):

H-86-62

Develop a standard for intercity-type buses that requires overhead surfaces, which include roof linings, moldings, parcel or luggage shelves, edges, and support hardware, to be designed to reduce or prevent direct contact injuries in rollover and upset accidents, and that such areas resist separation or fracture of a type which would expose occupants to sharp edges.

In a letter to the Safety Board dated January 7, 1987, the NHTSA stated that it believes that the bus industry is capable of coping with the identification and redesign of "unfriendly" interiors. The NHTSA also stated that it has not identified specific significant problem areas of bus interior construction associated with passenger injuries and has no justification for rulemaking action in this area. The Safety Board classified Safety Recommendation H-86-62 as "Closed--Unacceptable Action" on March 12, 1987.

36/ Highway Field Report--"1982 Eagle Charter Coach Head-on Collision with 1983 Pickup Truck, near Laredo, Texas, October 20, 1984" (NTSB-FTW-85-H-FR02).

The Safety Board will continue to supply the NHTSA specific instances of passenger injuries resulting from separations and fractures of interior moldings and sidewalls caused during accidents. Even though Safety Recommendation H-86-62 has been closed, the Safety Board considers this to be a critical issue and will continue to stress its concerns in future pertinent accident investigations and safety issues. Meanwhile, the Safety Board believes that the United Bus Owners of America, the American Bus Association, and all bus manufacturers should be made aware of these accidents and the potential for injuries caused by interior materials breaking apart.

Emergency Response

The emergency response was executed in a timely, orderly, and efficient manner. Emergency response personnel arrived about 3 minutes after the accident and established two triage areas on scene. All injured persons received prompt medical attention and were evacuated from the scene within 45 minutes of the arrival of the first rescue unit.

CONCLUSIONS

Findings

1. Both drivers were qualified as interstate drivers in accordance with the Federal Motor Carrier Safety Regulations.

2. Neither the performance of the busdriver nor the mechanical condition of the bus caused or contributed to the accident.

3. The tractor-semitrailer was in poor mechanical condition: the tires were marginal, the brakes were out of adjustment, and the speedometer was inoperative.

4. The center lane of the highway had a serious bleeding asphalt problem that caused a thin layer of water to remain on the roadway during heavy rain conditions.

5. There are two scenarios that may have precipitated the loss of control of the truck:

   a) The truck may have jackknifed during a slowing manuever initiated on the low friction wet pavement.
   b) The jackknife sequence may have been precipitated by partial hydroplaning of the tractor on a thin film of water over low friction pavement.

6. Considering the heavy rainfall that fell in the area shortly before the accident, the condition of the roadway, and the condition of the truck tires, the Safety Board could not conclusively establish which scenario caused the loss of control.

7. The marginal tread depth of the worn rear tractor tires made the tractor-semitrailer more susceptible to a loss of control or hydroplaning.

8. The partial loss of traction of the rear tractor tires caused the tractor to rotate leftward about the fifth wheel into a jackknife configuration. The rotation was so rapid that the truckdriver was unable to re-direct the alignment of the tractor-semitrailer.

9. The truck was traveling between 57 and 63 mph when the truckdriver lost control of the truck and jackknifed. It later struck the bus in the westbound lanes about 53 mph.

10. The speed of the truck was too great for the highway conditions. The lack of an operative speedometer to advise the driver of the vehicle speed may have contributed to the accident.

11. The bus was traveling between 50 and 55 mph when it was struck by the semitrailer.

12. Although the truckdriver's judgment (with regard to speed and brake application) may have been faulty in this accident, it could not be determined if his faulty judgment was attributable to the diazepam, the THC, or the interaction of these two substances.

13. The truckdriver may have been suffering from cumulative fatigue due to his irregular work/rest cycle. Because of the limited data available, no conclusions can be made.

14. GVL did not adequately supervise and monitor the truckdriver's hours of service.

15. The plastic laminate interior lining of the bus shattered, producing sharp-edged pieces that posed a hazard to the occupants.

16. The overlayed open-graded mix pavement in the center lane may have contributed to the water buildup and the truck loss of control.

17. The use of lapbelts for the busdriver and fatally injured bus passengers would not have saved their lives.

18. Although the installation and use of seatbelts may have lessened the passengers' injuries in some cases, generally, the level of injury to those passengers who sustained minor or moderate injuries would probably have been the same because they would have sustained similar injuries from contact with the seatbacks, armrests, and sidewalls.

19. The emergency response was executed in a timely, orderly, and efficient manner.

Probable Cause

The National Transportation Safety Board determines that the probable cause of this accident was the truckdriver's operation of a tractor-semitrailer at a speed too great for existing weather conditions while traveling on a section of lightly flooded highway pavement. Contributing to the loss of control of the tractor-semitrailer was the inadequate tread depth of the rear tractor tires, the inoperative speedometer, the low surface texture of the pavement, the low friction of the lightly flooded pavement, and the improper corrective maintenance of the highway.

RECOMMENDATIONS

As a result of its investigation of this accident, the National Transportation Safety Board recommends that:

-the Federal Highway Administration:

Revise Sections 393.75(b) and (c) of the Federal Motor Carrier Safety Regulations to prohibit the use of tires worn below 4/32 inch on any axle of a commercial inter-state vehicle. (Class II, Priority Action) (H-88-1)

Issue an On-Guard Bulletin to advise owners, operators, maintenance personnel, and State commercial vehicle inspectors of the problems associated with operating vehicles equipped with tires worn below 4/32-inch tread groove depths. (Class II, Priority Action) (H-88-2)

-the bus manufacturers:

Use material that will minimize potential injury to passengers when lining the interiors of intercity or intracity buses. (Class II, Priority Action) (H-88-3)

-the United Bus Owners of America and the American Bus Association:

> Advise members of the circumstances of the May 4, 1987, accident in Beaumont, Texas, and the potential hazards which exist due to the separation of the interior lining of plastic laminate material. (Class II, Priority Action) (H-88-4)

-the United Bus Owners of America, the American Bus Association, and the American Trucking Association:

> Advise members of the circumstances of the May 4, 1987, accident in Beaumont, Texas, and the potential vehicle handling problems that may be encountered with using tires with marginal tread depth. (Class II, Priority Action) (H-88-5)

-the Graebel Van Lines, Inc.:

> Make certain that all vehicles in commercial operation have operative speedometers. (Class II, Priority Action) (H-88-6)

Also, the Safety Board reiterates Safety Recommendation H-87-2 to the Texas Department of Highways and Public Transportation:

> H-87-2
>
> Develop a statewide comprehensive program for reducing skid accidents on low coefficient of friction roads. Include design and maintenance policy for reducing potential problems associated with bleeding, partial width resurfacing, and differential friction.

BY THE NATIONAL TRANSPORTATION SAFETY BOARD

/s/ JIM BURNETT
Chairman

/s/ PATRICIA A. GOLDMAN
Vice Chairman

/s/ JOHN K. LAUBER
Member

/s/ JOSEPH T. NALL
Member

/s/ JAMES L. KOLSTAD
Member

February 2, 1988

APPENDIXES

APPENDIX A

INVESTIGATION AND HEARING

Investigation

The National Transportation Safety Board was notified of this accident at 4 p.m. on May 4, 1987, by the Beaumont City Police Department. A highway accident investigator was dispatched from the Safety Board's Ft. Worth, Texas, field office and arrived on scene at 11 p.m. Highway accident investigators were dispatched from the Safety Board's Headquarters in Washington, D.C. on May 5, 1987.

Parties participating in the investigation included the Beaumont City Police Department, the Federal Highway Administration, the Texas Department of Highways and Public Transportation, Graebel Van Lines, Inc., and Trailways Lines, Inc.

Depositions and Hearing

There were no depositions taken, and no public hearing was held in conjunction with the investigation of this accident.

APPENDIX B

DRIVERS' LICENSE INFORMATION

Trailways Busdriver--Jesse F. Carroll

Mr. Carroll, 44, held a valid Class D (chauffeur) Louisiana driver's license which was due to expire on June 14, 1987, with no record of any violations. He held a current medical certificate dated March 19, 1987. He had worked as a busdriver for Trailways Lines, Inc., for 17 years. On January 1, 1987, he received a 15-year safe driver award, having driven 900,256 miles without any preventable accidents.

Graebel Van Lines, Inc. Truckdriver--Wallace A. Griffin,Jr.

Mr. Griffin, 45, held a valid Class D (chauffeur) Louisiana driver's license which was due to expire on February 13, 1990. His driving record listed a driving-while-intoxicated conviction in 1983, two speeding convictions in 1986, and a reckless operation conviction in 1987. The record does not include a speeding citation which the driver received in Ft. Worth, Texas, on April 30, 1987, during the accident trip. He had a valid medical certificate dated January 5, 1987.

APPENDIX C

FIELD ACCIDENT INVESTIGATIONS

Decatur, Texas (FTW-85-H-TR38)

On August 13, 1985, a truck-tractor was pulling two semitrailers southbound on U.S. Highway 81, 6 miles south of Decatur, Texas. About 4:15 p.m., the tractor-trailer driver lost control of the unit, and the tractor-trailer unit skidded off the roadway into a drainage ditch and up an embankment. The semitrailer directly behind the tractor remained upright and attached to the tractor; the full trailer overturned on its left side. The truckdriver sustained serious injuries. A light rain was falling at the time, and the pavement was wet.

Witnesses stated that the truck "hit a slick spot" and jackknifed. The concrete roadway was highly polished, and the average skid numbers measured for the right and left traffic lanes were 20 and 33, respectively.

Mineral Wells, Texas (FTW-86-H-TR09)

On April 3, 1986, a tractor-semitrailer was traveling westbound on Interstate 20 near Mineral Wells, Texas, during heavy rainfall. About 2 p.m., the truckdriver lost control of the unit as it traveled over a section of irregular roadway surface. The tractor-semitrailer overturned in the median strip. The truckdriver sustained moderate injuries, and the truck passenger sustained serious injuries.

The roadway consisted of a concrete travel surface with asphalt shoulders; however, the right lane had been overlayed with an asphalt surface in July 1985. The wheelpaths of the right lane were smooth and polished, and the area between the wheelpaths appeared to have good texture with large aggregate exposed. The concrete surface in the left lane was smooth and highly polished.

Dennison, Texas (FTW-86-H-TR11)

About 7:15 a.m. on May 10, 1986, a tractor-semitrailer was traveling northbound on U.S. 69/75 just north of Dennison, Texas. When the truckdriver attempted to brake for traffic which was slowing ahead, the tractor-semitrailer lost traction and began fishtailing. The truck ran off the right side of the roadway and up a dirt embankment and then jackknifed. The truckdriver was not injured. It had been raining earlier in the day and the roadway was still wet.

APPENDIX C

The roadway consisted of a highly polished chip-and-seal asphalt surface with bleeding asphalt in the right lane. The TDHPT had no skid data for this section of roadway. Within the few days preceding this accident, 13 other vehicles ran off the roadway within 2/10 mile of the accident site during wet pavement conditions.

Dennison, Texas (FTW-86-H-TR12)

At 7:45 a.m. on May 10, 1986, a tractor pulling two trailers was traveling northbound on U.S. Highway 69/75, 1 mile north of Dennison, Texas. As the truckdriver attempted to change lanes because of the previous accident, the rearmost trailer began swaying. The trailer separated from the front semitrailer and overturned onto its left side. The truckdriver was not injured.

* U. S. GOVERNMENT PRINTING OFFICE: 1988-201-610:60071