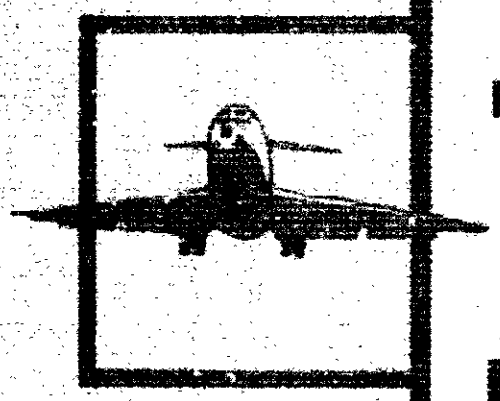

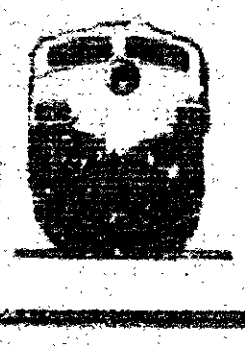

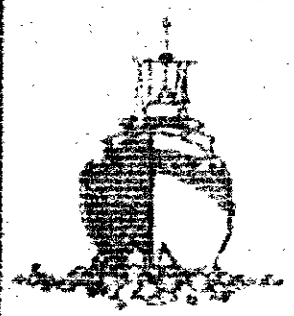

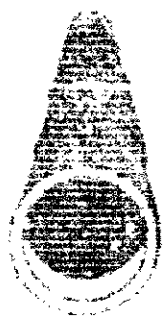

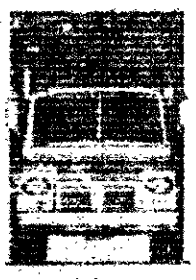

PB84-916204

NATIONAL TRANSPORTATION SAFETY BOARD

WASHINGTON, D.C. 20594

HIGHWAY ACCIDENT REPORT

TRAILWAYS LINES, INC., BUS/
E. A. HOLDER, INC., TRUCK,
REAR END COLLISION AND
BUS RUN-OFF-BRIDGE, U. S. ROUTE 59,
NEAR LIVINGSTON, TEXAS
NOVEMBER 30, 1983

NTSB/HAR-84/04

UNITED STATES GOVERNMENT

TECHNICAL REPORT DOCUMENTATION PAGE

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15. Supplementary Notes

16. Abstract About 5:15 a.m. on November 30, 1983, a Trailways Lines, Inc., intercity bus traveling in the right lane of southbound U.S. 59 about 5 miles north of Livingston, Texas, struck the rear of an unloaded tractor-flatbed semitrailer, operated by E. A. Holder, Inc. The bus then veered across the left southbound lane, crashed through a bridge guardrail, and vaulted to a creekbank 26 feet below the bridge deck. It was dark, the weather was cloudy, and there was no roadside lighting. The pavement of the four-lane, divided highway was dry. The truck had turned right onto southbound U.S. 59 about 927 feet before the accident site and according to postaccident tests had accelerated to about 42 mph when it was struck in the rear by the southbound bus. Six of the 11 bus passengers were killed; 5 bus passengers and the busdriver sustained moderate to severe injuries during the accident. The truckdriver later reported that he was injured.

The National Transportation Safety Board determines that the probable cause of this accident was the busdriver's lack of alertness, possibly due to fatigue, which resulted in his failure to recognize that he was overtaking a slower-moving truck until it was too late to avoid impact. Contributing to the severity of the crash was the excessive speed of the bus.

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CONTENTS

NATIONAL TRANSPORTATION SAFETY BOARD
WASHINGTON, D.C. 20594

HIGHWAY ACCIDENT REPORT

Adopted: July 12, 1984

TRAILWAYS LINES, INC., BUS/E.A. HOLDER, INC., TRUCK REAR END COLLISION AND BUS RUN-OFF-BRIDGE U.S. ROUTE 59 NEAR LIVINGSTON, TEXAS NOVEMBER 30, 1983

SYNOPSIS

About 5:15 a.m. on November 30, 1983, a Trailways Lines, Inc., intercity bus traveling in the right lane of southbound U.S. 59 about 5 miles north of Livingston, Texas, struck the rear of an unloaded tractor-flatbed semitrailer operated by E. A. Holder, Inc. The bus then veered across the left southbound lane, crashed through a bridge guardrail, and vaulted to a creekbank 26 feet below the bridge deck. It was dark, the weather was cloudy, and there was no roadside lighting. The pavement of the four-lane, divided highway was dry. The truck had turned right onto southbound U.S. 59 about 927 feet before the accident site and according to postaccident tests had accelerated to about 42 mph when it was struck in the rear by the southbound bus. Six of the 11 bus passengers were killed; 5 bus passengers and the busdriver sustained moderate to severe injuries during the accident. The truckdriver later reported that he was injured.

The National Transportation Safety Board determines that the probable cause of this accident was the busdriver's lack of alertness, possibly due to fatigue, which resulted in his failure to recognize that he was overtaking a slower-moving truck until it was too late to avoid impact. Contributing to the severity of the crash was the excessive speed of the bus.

INVESTIGATION

The Accident

About 5:15 a.m. on November 30, 1983, a Trailways Lines, Inc., (Trailways) intercity bus traveling in the right lane of southbound U.S. 59 about 5 miles north of Livingston, Texas, struck the rear of an unloaded tractor-flatbed semitrailer operated by E.A. Holder, Inc. The bus then veered across the left southbound lane, crashed through a bridge guardrail, and vaulted to a creekbank 26 feet below the bridge deck where it landed partially on its left side. It was dark, the weather was cloudy, and there was no roadside lighting. The pavement of the four-lane, divided highway was dry. The truckdriver stated that he turned right from State Route Loop 116 (South) 1/ onto southbound U.S. 59 and that he had accelerated to about 35 mph when his truck was struck in the rear by the southbound bus. (See figure 1.) Six of the 11 bus passengers were killed; 5 bus passengers and the busdriver were injured. The truckdriver later reported that he was injured.

According to a witness, the bus had left Lufkin, Texas, between 4:30 a.m. and 4:35 a.m. A timetable supplied by Trailways indicated that the scheduled departure time from Lufkin was 4:25 a.m. and its next scheduled stop was at 5:20 a.m. in Livingston.

1/ Hereafter referred to as Loop 116.

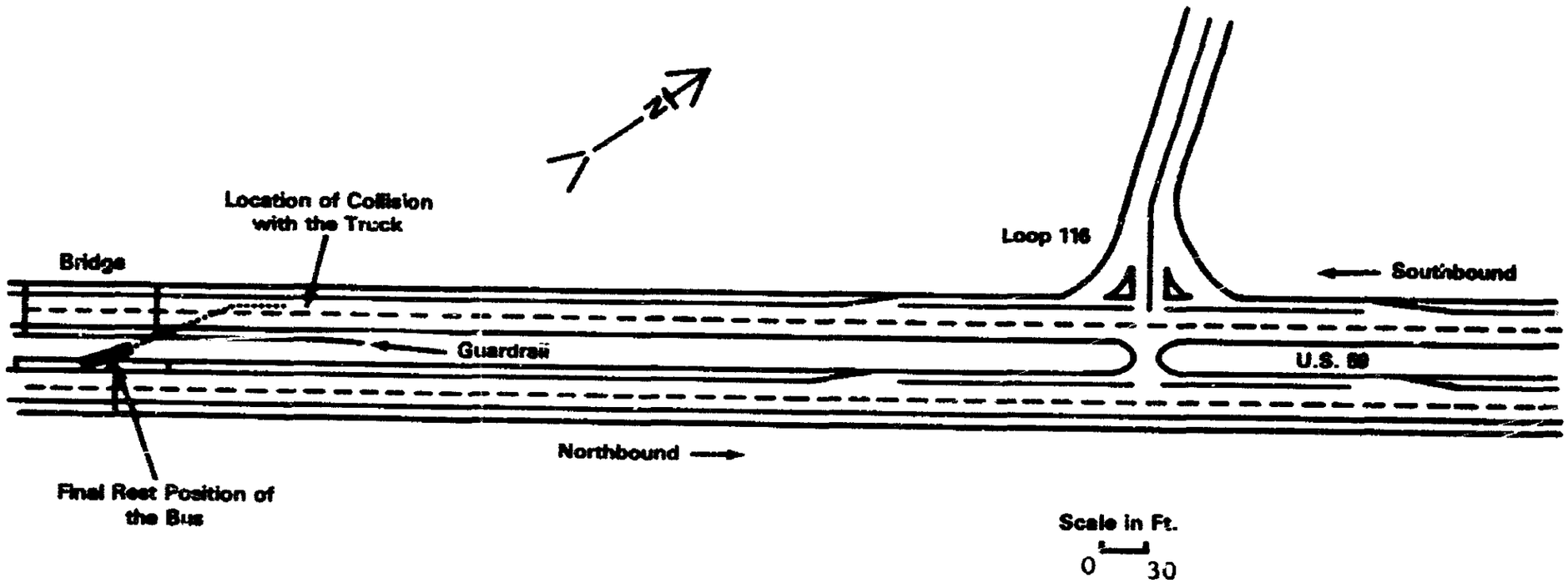


Figure 1.—Accident site.

One of the surviving bus passengers, who stated that he was awake during the trip, reported that he saw the busdriver's head fall or nod about 10 minutes before the accident at the same time the bus drifted onto the shoulder and then returned to the road without stopping.

The busdriver said that he made no stops after leaving Lufkin except a required stop at a railroad grade crossing located about 11 1/2 miles before the accident scene. The busdriver also stated that he deliberately drove onto the shoulder as he approached the railroad crossing to stop in order to reduce the potential for a rear-end collision into the bus. The busdriver stated that the last thing he remembered before the accident was trying to drive farther over into the left (median) lane of the highway to avoid a vehicle operating in the right lane which appeared to be drifting too close to the bus.

The truckdriver stated that on the morning of the accident he left his home, located about three-tenths of a mile from the accident scene, at 5:10 a.m. He said that after he completed his turn onto southbound U.S. 59 and while he was entering the right lane, he was passed by two tractor-semitrailer units. He stated that not more than 10 seconds elapsed between the time he was passed by these two other trucks and the time that his semitrailer was struck in the rear. The truckdriver stated that he did not see any headlights from overtaking vehicles in his rear-view mirrors after the two trucks passed him, and that after the collision he maintained control of his vehicle which he steered onto the right shoulder south of the bridge and stopped.

Injuries to Persons

Injuries	Drivers	Passengers	Others	Total
Fatal	0	6	0	6
Serious	1	5	0	6
Minor/None	1 1/	0	0	1
Total	2	11	0	13

1/ The truckdriver did not appear to be injured after the accident, but did report later that he was injured.

Driver Information

The 43-year-old truckdriver held a current Texas chauffeur's driver license with no operating restrictions and a current medical certificate. He had driven large trucks for 20 years. From December 1978 to November 1981, he received eight tickets which included six speeding violations, failure to use a proper headlight beam, and running a red light. Five of these tickets were received during an 8-month period in 1981. The truckdriver said that he stopped receiving traffic tickets after November 1981 when he stopped hauling shipments that had strict time delivery schedules. No prior accidents were listed on the truckdriver's Texas driving record.

The 38-year-old busdriver held a valid Texas chauffeur's driver license with no operating restrictions and a current medical certificate as required for drivers employed by companies operating in interstate commerce. He had driven buses for 6 years, all for Trailways. According to his Texas driving record, he received five speeding tickets and was involved in two motor vehicle accidents in Texas between March 1979 and September 1982. Due to the driver's physical condition when he was interviewed and because driver records in Texas do not contain information showing if the vehicle being operated was a commercial or a private vehicle, it could not be determined whether the tickets were issued while the driver was driving a bus or his personal vehicle. There were no entries on his driver record beyond September 1982.

The Federal Motor Carrier Safety Regulations (FMCSR) administered by the Bureau of Motor Carrier Safety (BMCS) of the Federal Highway Administration (FHWA), specifically 49 CFR 391.51 (Driver Qualification Files), require that Trailways retain busdriver qualification files which include a statement of motor vehicle traffic violations for the preceding 12 months. On May 10, 1983, the busdriver signed a certificate stating that he had no traffic violations other than parking violations for which he had been convicted or forfeited bond or collateral for the 12 months prior to the date of the certification.

For the 11 months from January 1983 to the time of the accident, the busdriver usually worked 6 days per week from 1:30 a.m. to 7:30 a.m. driving on the same route from Houston, Texas, to Lufkin, and return. The distance is approximately 250 miles round trip. He was driving the return segment of this trip when he collided with the truck. A timetable for this route supplied by Trailways officials listed the scheduled departure time from Lufkin on the return trip as being 4:25 a.m., with a scheduled arrival time in Livingston, a distance of about 48 miles, of 5:20 a.m.

The driver had been on duty for approximately 4 1/4 hours before the accident and was in compliance with the FMCSR's hours of service regulations (49 CFR 395.3) applicable to commercial vehicle drivers operating in interstate or foreign commerce.

The busdriver reported that on the day before the accident he arrived home from work about 8:30 a.m., went to bed around 9:30 a.m. or 10 a.m., and slept until about 2:30 p.m. when his 3-year-old daughter awakened from her nap. The daughter had been put to bed around 1:30 p.m. just before the busdriver's wife went to work. The busdriver was responsible for his daughter's care until his wife returned from work at 10:30 p.m. The daughter was put to bed for the night at some time before the driver took a nap from 9 p.m. until 11 p.m. He left for work at 11:30 p.m. The busdriver's activities on the day before the accident were reported to be typical of his normal work/rest pattern.

During the Safety Board's investigation of this accident, Trailways officials stated that it is a company requirement that all drivers use seatbelts and comply with posted speed limits.

Vehicle Information and Damage

The 46-passenger, 1978 Eagle International intercity bus was operated by Trailways Lines, Inc., of Dallas, Texas. The forward half of the bus was crushed severely and displaced about 3 1/2 feet to the right in the accident. No vehicle deficiencies were reported before the accident, and none was observed after the accident. The damage from contact with the semitrailer began just to the right of the busdriver's seat about floor height and extended across the front of the bus to the rear of the forward entrance door on the right side. The bus headlight switches were found in the "on" and "low beam" positions.

The truck was a 1980 White tractor with a 1981 Hobbs flatbed semitrailer; both units were owned by the truckdriver. The truck was leased to E.A. Holder, Inc., of Kennedale, Texas. The damage from contact with the bus extended from the left rear corner of the semitrailer across a 5-foot-wide area of the rear. The left rear trailer axle spring assembly and rear spring shackle were deformed. The left rear axle wheels had been pushed forward about 2 1/2 inches.

The semitrailer was equipped with lamps and reflectors as required by the FMCSR (49 CFR 393.14). All side-marker, clearance, tail, and identification lamps on the semitrailer were activated by a single switch located in the tractor cab. The three rearward-facing, red identification lamps mounted near the top of the tractor-mounted headerboard 2/ were not functioning after the accident; they are optional equipment and are not required by Federal or State regulations. The seven electric lamps located on the rear of the semitrailer all functioned when switched on after the accident. In addition to the lamps, a red reflector was mounted near each rear corner of the semitrailer. The truckdriver stated that the semitrailer's lamps were on at the time of the collision.

Highway Information

U.S. 59 at the accident site is a four-lane, north/south, divided highway with two 12-foot-wide lanes in each direction separated by a 55-foot-wide median. The highway has 10-foot-wide right shoulders and 3-foot-wide median shoulders. The posted speed limit is 55 mph. The roadway is a slight downgrade for southbound vehicles approaching the accident site. The average daily traffic volume is 13,000 vehicles; about 25 percent of this traffic is large trucks or buses. The southbound lanes of U.S. 59 between the intersection with Loop 116 and the bridge where the bus left the roadway were constructed in 1942. Future construction plans for this section of highway include the addition of 6 inches to the thickness of the pavement surface in late 1985.

U.S. 59 in the southbound direction is relatively straight about 1,500 feet before the intersection with Loop 116. The length of the shoulder acceleration lane for this intersection as indicated by markings on the pavement is 345 feet. The original design plans indicated that a 575-foot-long marked acceleration lane was to be constructed. The guidelines of the American Association of State Highway and Transportation Officials (AASHTO) recommend an acceleration lane length of 900 feet, which is based on passenger vehicle performance. Trucks and buses generally require much longer distances to accelerate to highway speeds.

Although the length of the acceleration lane on the shoulder as indicated by pavement markings was 345 feet, a Texas Statute, Article 6701d, Section 54a, permits driving on an improved shoulder under certain circumstances. The statute states, in part:

> Operation of a vehicle on improved shoulder./(a) a driver may operate a vehicle on an improved shoulder to the right of the main traveled portion of the roadway as long as necessary and when the operation may be done in safety only under the following circumstances. . .(2) to accelerate prior to entering the main traveled lane of traffic.

AASHTO guidelines state that there is a need to provide for overrun at the end of an acceleration lane; "At the far end (of the shoulder acceleration lane) there should be no barrier such as a curb between lane and shoulder which would make it difficult for a driver to continue on the shoulder if the opening in through traffic does not materialize." 3/

2/ A headerboard is a device that is installed behind the tractor cab to protect the driver's compartment from crushing or penetration by forward-shifting cargo.
3/ "A Policy on Geometric Design of Rural Highways," AASHTO, 1965.

The first tire marks attributed to the accident were found in the right southbound lane about 880 feet south of the intersection of U.S. 59 and Loop 116, and 170 feet before the area where the bus crashed through the bridge guardrail. (See figure 2.) South of these tire marks, another tire mark extended from the left passing lane to the edge of the bridge deck at a 21-degree angle to the centerline of the roadway.

The 200 feet of guardrail approaching the bridge consisted of W-beam guardrail mounted on wooden posts. The bridge guardrail consisted of W-beam guardrail mounted on concrete posts, which were spaced 6 1/4 feet apart and which were an integral part of the bridge deck. The bridge guardrail was 40 years old. It was not designed to redirect vehicles of the bus' size and speed. The W-beam bridge guardrail was flattened and the concrete posts were sheared off in the area that was struck by the bus. After crashing through the bridge guardrail, the bus was airborne for a horizontal distance of 106 feet as it dropped to the creekbank 26 feet below the bridge deck.

From January 1980 to September 1983, 12 accidents occurred within 0.2 mile of the intersection with Loop 116. Only three of these accidents involved a southbound vehicle. In two of the three accidents, a southbound vehicle struck another vehicle that was crossing the southbound lanes at the intersection. In the third accident, a southbound vehicle ran off the road and overturned in the median. No accidents occurred that were similar to this bus and truck accident.

Medical and Pathological Information

During the crash, four of the bus passengers were ejected through the windows on the left side of the bus. Two of the ejected passengers died from massive head injuries, and one died of a broken neck. The surviving passenger who was ejected sustained multiple trauma injuries which included rib fractures, a fractured left leg, a chest wall penetration, and a bruised right lung. Inside the bus, three passengers died of massive head injuries, and the four surviving passengers suffered fractures and lacerations. No autopsies were performed. (See figure 3.)

The busdriver sustained a fractured jaw, fractured ribs, chest trauma, multiple lacerations, and abrasions to the eyes. The busdriver stated that he was not wearing his seatbelt. A blood test performed on the busdriver after the accident was negative for alcohol and drugs.

Survival Aspects

After the truckdriver determined that his vehicle had been struck, he stopped his truck, located the bus on the creekbank below the bridge deck, and attempted to flag down traffic traveling in both the south and northbound lanes of U.S. 59. No one offered any assistance. The truckdriver then ran back to his residence, three-tenths of a mile from the accident scene, and asked his wife to telephone the sheriff. The records of the Polk County Sheriff's Office show that this call was received at 5:40 a.m. At 5:44 a.m. a Polk County Sheriff's Deputy arrived at the scene and radioed back to "dispatch everybody available" to the accident scene. Over the next hour, a total of 8 ambulances, 5 rescue vehicles, 1 fire truck, and more than 70 emergency response and law enforcement personnel arrived at the accident scene.

Three male passengers who were not ejected from the bus during the crash escaped through the windows on the left side of the bus. They were assisted up the creekbank by the deputy sheriff and the truckdriver, who had driven back to the accident scene from his residence in another vehicle.

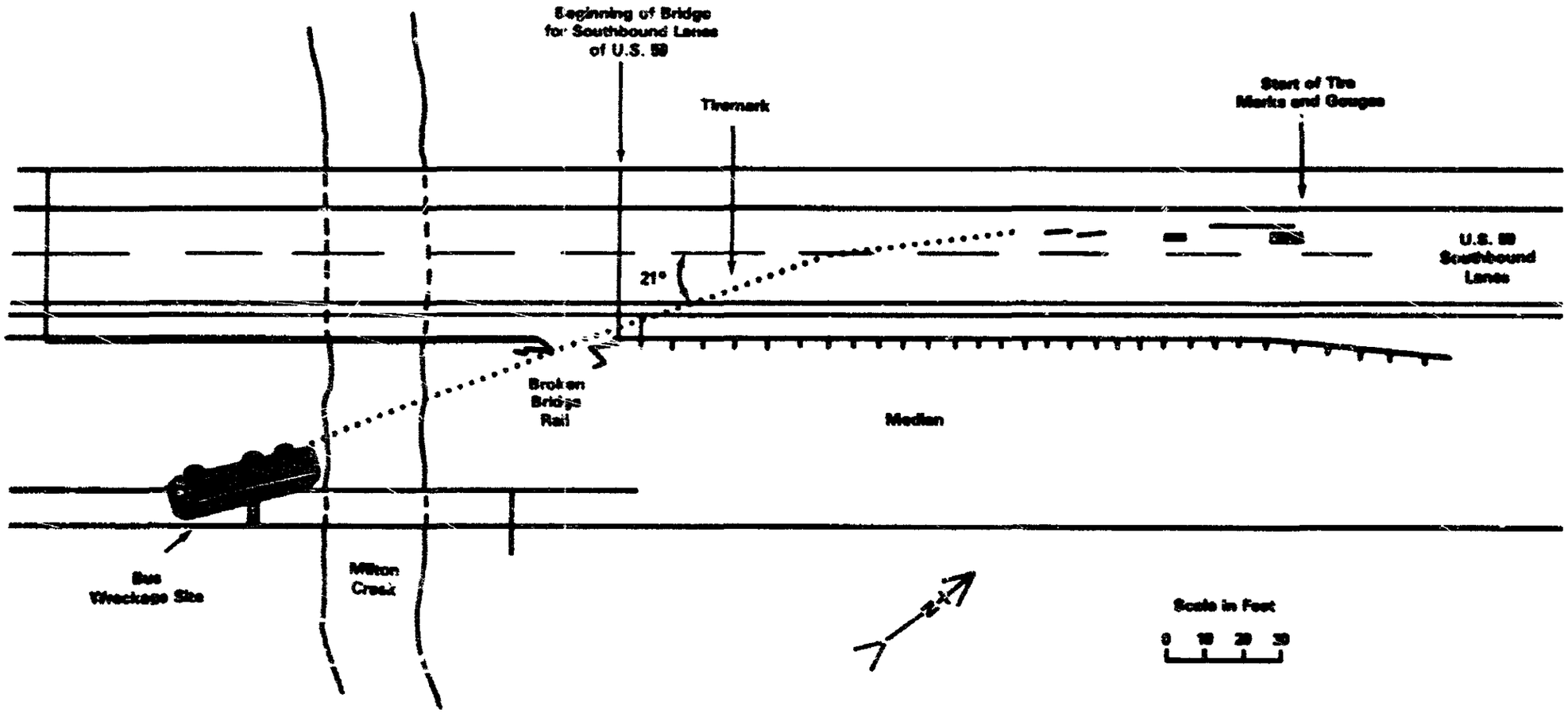
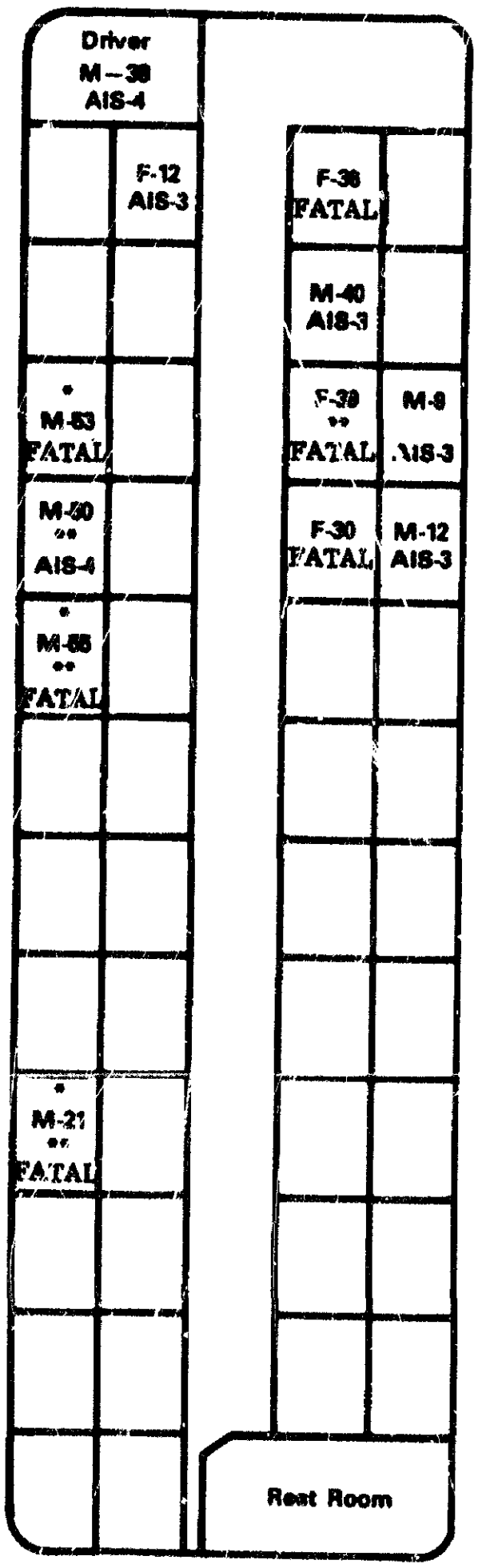


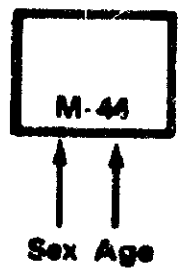
Figure 2.—Physical evidence at the scene.



LEGEND

AIS*	Severity Code
1	Minor
2	Moderate
3	Serious
4	Severe
5	Critical
6	Maximum injury virtually unsurvivable

*American Association for Automotive Medicine: Abbreviated Injury Scale



*Estimated seating position; exact pre-crash position could not be determined with certainty.

**Occupant ejected during crash.

Figure 3.—Bus seat occupancy and injury chart.

The first rescue personnel to enter the bus reported that all occupants who were not ejected were located in a small area at the front and that it was difficult to locate and administer first aid to the survivors because the damage incurred in the secondary collision with the creek bank compressed the front of the bus and left very little room to move around.

While rescue personnel started administering first aid to the survivors, other personnel began cutting a 6-foot by 6-foot opening in the roof near the front of the bus. This opening was used to extricate the dead and injured. As the survivors were removed from the wreckage, they were transported by ambulance to Livingston Hospital. The busdriver, who was the last survivor to be rescued, was taken out of the wreckage at 7:15 a.m. and arrived at the hospital at 7:40 a.m. Three helicopters dispatched to the accident were used at 8:30 a.m. to transport the busdriver and three other seriously injured parsengers from Livingston Hospital to the shock-trauma facility of Hermann Hospital in Houston.

Tests and Research

Three tests were conducted after the accident to determine the speed of the truck at impact. In these tests, the truck was accelerated from a stopped position at the intersection with Loop 116 to the point of impact in 25.7, 26.0, and 25.9 seconds, respectively. Based on the results of these tests, Safety Board investigators determined that the truck was traveling about 25 mph at the end of the acceleration lane and about 42 mph at the point of impact. The acceleration rate was 1.97 feet per second per second.

After the accident, two trips were made from the Lufkin bus terminal to the accident site, a distance of 43.2 miles. On each trip, about 52 minutes were required to complete the trip while operating at or near, but not exceeding, the posted speed limit. If the driver left Lufkin between 4:30 and 4:35 a.m. and the accident occurred at 5:15 a.m. the busdriver made the 43.2-mile trip in between 40 to 45 minutes, with an average speed of between 57 and 64 mph with no stops. Given that the busdriver made at least one stop en route from Lufkin to the accident scene, the bus would had to have been operated at a constant speed at or near 65 mph to maintain an average speed in that range.

The lamp assembly mounted on the left rear of the semitrailer was removed after the accident to examine the bulb filaments. Under certain conditions it is possible to determine by the distortion of the filament if an incandescent lamp was illuminated at the time it was subjected to a shock, such as experienced during a collision. The smaller filament of the dual-filament bulb was distorted into a "V" shape. The larger filament of this bulb was not distorted. Examination indicated and the truckdriver stated that the lamps on the rear of the semitrailer had not been changed or tampered with after the accident and before this examination. The reverse side of the lamp was marked "12 VDC." When the electrical leads of the bulb were connected to a 12-volt, direct current power source, the larger filament burned brighter than the smaller filament.

ANALYSIS

The Accident

The weather at the time of the accident and the mechanical condition of the vehicles were not factors in this accident. Both drivers were experienced in handling their vehicles and held valid Texas driver licenses.

The larger filament of the bulb removed from the semitrailer would burn when the semitrailer's stop, left turn, and/or four-way flasher controls were activated. Since the larger filament showed no distortion, it most probably was not burning at the time of the collision with the bus. The smaller filament would burn when the semitrailer's clearance, tail, sidemarker, and identification lamps were burning. The distortion found on the smaller lamp filament indicated that the rear clearance, tail, and identification lamps were burning at the time of the collision with the bus.

Acceleration tests indicated that the truck was traveling about 25 mph at the end of the acceleration lane from Loop 116 to U.S. 59 and that about 10 to 12 seconds would have elapsed as the truck traveled from the end of the acceleration lane to the point of impact. With no other vehicles between the bus and the truck after the truck entered the right lane, the busdriver probably would have had a clear view of the truck for at least 10 seconds before impact. Even in the darkness, the taillights of the truck, which tests indicated were illuminated at the time, should have been visible to the busdriver for the 1/2-mile, relatively straight section of U.S. 59 leading to the accident site.

The 345-foot-long marked acceleration lane used by the truck was 230 feet shorter than specified by the original road design and 555 feet shorter than the 900 feet recommended by AASHTO guidelines. Since the impact occurred after the front of the truck had traveled about 927 feet from the intersection, the truck probably would have been operating in the right lane even if the marked length of the acceleration lane had met the AASHTO guidelines. The truckdriver was permitted by Texas law to continue driving past the marked end of the acceleration lane on the improved shoulder to accelerate to traffic speed. However, if the acceleration lane had been marked as being 900 feet long as recommended by AASHTO guidelines, the truckdriver might not have driven onto the highway when he did, and as a result he would have had at least an additional 10 seconds in the marked shoulder acceleration lane to see the approaching bus in his left side mirror and gauge the rate of closure of the bus before and while turning into the highway lane.

The tiremarks in the right lane were from the left rear tires of the truck and the right front tire of the bus at the point where the vehicles collided. There were no tiremarks in the right lane prior to this point to indicate that the busdriver applied his brakes before the collision. The damage pattern on the vehicles and the path of the bus toward the guardrail indicated that the busdriver was performing a left steering maneuver just before impact. Since the bus was in the right lane at impact with the truck and then travelled at a 21-degree angle after that impact, the busdriver's steering to the left was probably a quick, last-second maneuver. Therefore, the busdriver probably saw the truck just before impact and steered sharply to the left, but reacted too late to avoid the collision.

The estimated vehicle speeds at impact were calculated based on the truck acceleration tests, the tire marks, the extent of damage to the vehicles and the guardrail, and the distance the bus vaulted from the bridge to the creekbank. From these data, the Safety Board concludes that, when the vehicles collided, the bus was traveling above the 55-mph posted speed limit between 60 and 70 mph and the truck was traveling about 42 mph. Although the busdriver was operating above the speed limit, he would have had sufficient opportunity to change lanes and avoid the truck if he had been alert. At 60 to 70 mph, a bus could have easily been steered into the left lane in about 300 to 350 feet and would have avoided contact with the truck. About 4 to 5 seconds would have been required to perform this maneuver. The facts of the accident indicate, and the Safety Board concludes, that the busdriver was not alert at the time of the accident.

The driver departed Lufkin between 5 and 10 minutes later than his scheduled time for departure. From the road tests, the Safety Board concludes that the busdriver probably was operating his vehicle above the 55-mph posted speed limit at or near 65 mph for most of the trip from Lufkin to the scene of the accident and that the driver may have been speeding to get back on schedule. He was due in Livingston at 5:20 a.m. The schedule established by Trailways requires that the driver drive the approximately 49-mile trip from Lufkin to Livingston in 55 minutes, which requires an average speed slightly in excess of 53 mph.

Trailways should regularly monitor busdriver compliance with posted speed limits and take effective action against drivers who violate speed laws either on their own initiative or to comply with schedules.

Driver Alertness and Time of Day

Research indicates that human performance at certain tasks reaches its lowest level during the early morning hours just preceding dawn. This phenomenon, which is documented in many studies relating to fatigue and human performance during periods of shift work, is attributed to the effects of circadian rhythms--the daily variations in the level of physiological arousal.

The relationship between circadian rhythms and the commercial driving task is best addressed in a research effort initiated by the BMCS in 1975 4/ in which the researchers examined, among other things, work periods that are irregular with respect to the day-night cycle. The research indicates that, on the basis of heart rate measurements, diurnal (daily) variations in the level of physiological arousal occurred in professional truckdrivers who drove during both daytime and nighttime hours, but that a disproportionate number of accidents involving "sleepy or inattentive" drivers occurred between midnight and 0800 when physiological indices of arousal are generally at their lowest levels.

Other laboratory studies of human performance during periods of shift work have corroborated the commonly accepted view that human performance reaches its lowest level during the early morning hours. This period of comparatively poor performance represents the trough of a circadian rhythm in task performance. 5/ The tasks examined in the research included the passive monitoring of a monotonously repetitive environment with the requirement that certain, infrequent signals be reliably recognized, and the active processing of information, including the correct visual identification of various objects. As pointed out in the research, these tasks may be considered to be laboratory representations of two major components of highway driving--monitoring the highway for significant occurrences and correctly identifying those occurrences.

The results of the BMCS research showed that a highly disproportionate percentage of "dozing driver" accidents was found to occur in the hours between midnight and 0600. BMCS field experiments on relay truck driving, sleeper truck driving, and bus driving showed pronounced increases in subjective fatigue, marked changes in physiological state, and earlier degradation of performance of trips that involved driving during these hours.

4/ "A Study of the Relationships Among Fatigue, Hours of Service, and Safety of Operations of Truck and Bus Drivers," U.S. Department of Transportation, Federal Highway Administration, Bureau of Motor Carrier Safety, 1972.

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

The quality of sleep/rest received prior to working irregular hours may help in the control of the circadian rhythm impact. It is noted, however, that those drivers whose schedules end just prior to early morning are perhaps most vulnerable to diurnal variations. This is due to exposure to sleep-disturbing social and environmental stimuli present during daytime hours when these shift workers try to sleep. The cumulative effects of fatigue are felt to be significant for drivers on shift work. Some of the effects of fatigue on operator performance include disruptions in timing, loss of fine motor control, increased variability in performance, and lowering of performance standards. Operational tasks most affected by fatigue are those based upon minute cues in which vigilance and alertness are important. Vigilance appears to be the function most affected by fatigue. 6/

The busdriver in this accident was exposed to several factors which cause fatigue, such as vibration, monotonous monitoring of a dark highway, and physical inactivity resulting from confinement to his seat. A bus passenger reported that, about 10 minutes before the accident, he saw the busdriver's head nod and that the bus drifted onto the shoulder, an indication that the busdriver might have been fatigued or sleepy. In view of the circumstances of the accident, the driving environment, and the 24-hour work/sleep history of the driver, it is possible that the busdriver's lack of alertness to his driving task was related to the early morning hour of the accident and the effects of fatigue.

In 1973, as a result of its investigation of a bus accident in Richmond, Virginia, 7/ the Safety Board issued recommendation H-73-5 that the BMCS:

> Assign high priority to a study of practical methods and means to prevent or to minimize dozing at the wheel by drivers of carriers in interstate commerce, toward the end that appropriate rulemaking will follow.

The FHWA responded to this recommendation by stating:

> In regard to Recommendation H-73-5, there have been numerous "Stay Awake" devices available since 1960 which will warn a driver that he is dozing or is not responding in a normal pattern, implemented by a sensing system on the steering wheel. However, the cost per unit for these devices may be prohibitive. The Bureau of Motor Carrier Safety is of the opinion that these devices can be helpful but are not the answer to the problem. The Bureau believes that proper rest by drivers, sane scheduling of trips, and constant supervision by motor carrier management of drivers can remove the causes that induce drowsiness and instances of drivers falling asleep at the wheel.

Although proper driver rest is essential for the prevention of inattention/fatigue-related accidents, neither the BMCS nor management officials of motor carriers have the means to determine either the amount or the quality of rest obtained during driver "off-duty" periods. Regulations requiring the proper scheduling of trips and driver compliance with hours of service driving and on-duty limitations exist and generally are enforced by the BMCS.

6/ USN Flight Surgeon's Manual, United States Navy, pp. 651-653.
7/ Highway Accident Report--"Runoff and Overturn of Intercity Bus on Interstate 95, Richmond, Virginia, September 3, 1972" (NTSB-HAR-73-2).

The nature of the over-the-road driving task precludes the constant management supervision envisioned by BMCS as being part of the solution to the inattention/fatigue problem. Drivers for the most part are not in contact with management, nor can motor carrier management observe driver performance while a driver is away from management's direct supervision.

In calendar years 1982 and 1983, 64,938 passenger and property carrier accidents were reported to the BMCS as required by the FMCSR (49 CFR Part 394). In 1.6 percent (1,051) of these accidents, the reporting motor carrier stated that the driver dozed at the wheel, while in 97 percent of the accidents the driver was reported to be "apparently normal." Other driver condition categories included "sick," "had been drinking," "medical waiver," and "other." These other categories account for the remaining 1.2 percent of the driver condition data reported to the BMCS. Seven percent (4,726) of all accidents were single-vehicle non-collision accidents which occurred when the reporting carrier's vehicle ran off the roadway. This category of accident accounted for 26 percent (214) of all driver fatalities and 15 percent (2,426) of all driver injuries reported to the BMCS in 1982 and 1983. 8/ In many cases accidents categorized as "ran off roadway" or accidents which involve striking another vehicle in the rear or striking a fixed object can be attributed to driver inattention or fatigue.

The following is a summary of the number of accidents reported to the BMCS by property and passenger carriers, and the numbers and percentages of accidents by driver condition, and the number and percentages of driver fatalities and injuries resulting from single-vehicle ran-off-road accidents for calendar years 1982 and 1983:

	Property carriers		Passenger carriers		Totals
	1982	1983	1982	1983	
Number of accidents reported	31,759	31,613	855	711	64,938
Number and percentage of accidents reporting driver dozed at wheel	511 (1.6%)	537 (1.6%)	2 (<1%)	1 (<1%)	1,051 (1.6%)
Number and percentage of accidents reporting driver apparently normal	30,896 (97%)	30,645 (96%)	851 (99%)	705 (99%)	63,097 (97%)
Number and percentage of accidents reporting driver "had been drinking," "sick," or "other"	352 (1.1%)	431 (1.3%)	2 (<1%)	5 (<1%)	790 (1.2%)
Number and percentage of total accidents occurring when carrier's vehicle ran off roadway	2,268 (7.1%)	2,421 (7.6%)	18 (2.1%)	19 (2.6%)	4,726 (7.2%)

8/ Property carrier accident data for 1982 were obtained from "Accidents of Motor Carriers of Property 1982," U.S. Department of Transportation, Federal Highway Administration, Bureau of Motor Carrier Safety, 1983. Property carrier data for 1983 and passenger carrier data for 1982/1983 are preliminary information obtained from the BMCS.

	Property carriers 1982	Property carriers 1983	Passenger carriers 1982	Passenger carriers 1983	Totals
Number and percentage of all driver fatalities resulting from single-vehicle ran-off-roadway accidents	100 (25%)	114 (28%)	0 (0%)	0 (0%)	214 (26%)
Number and percentage of all driver injuries resulting from single-vehicle ran-off-roadway accidents	1,145 (15%)	1,262 (16%)	10 (10%)	9 (12%)	2,426 (15%)

The Safety Board concludes that the FHWA's response to Recommendation H-73-5 only partially addresses the monitoring and reporting problem, and that driver inattention/fatigue probably remains an underlying, although not clearly identifiable, cause of many commercial vehicle accidents for which the driver's condition is reported to the BMCS as being "apparently normal."

In January 1984, the National Highway Traffic Safety Administration (NHTSA) awarded a contract to investigate the problem of fatigue in driving. The contract effort, "Driver Vehicle Monitoring to Reduce Inattention Related Accidents," reviewed current countermeasure technology, identified other related research projects, and recommended an experimental approach to the problem. As a result of the recommendations of this research, the NHSTA has requested the development of a detailed experimental plan to further study inattention-related accidents. The Safety Board supports the NHTSA's work in this area.

There are several types of devices available on the market designed to alert a driver that fatigue is setting in. Two common devices are readily available to the public. One device is activated when steering wheel adjustments become irregular, and the other, which is worn like a hearing aid, is activated when the driver's head begins to nod. Both of these devices emit a signal to warn the driver.

During the field experiments in the BMCS research, in those instances where devices designed to alert a driver of fatigue setting in were installed in the vehicle, drivers disconnected the devices because they belived the devices were faulty. This occurred because the devices alerted the drivers of changes in the drivers' performance before the drivers themselves were conscious of the changes.

Based on the circumstances of this accident and the frequent occurrence of inettention/fatigue accidents among drivers in interstate commerce, the Safety Board is placing Recommendation H-73-5 in a "Closed-Superseded" status and is issuing a new recommendation that the BMCS initiate a study to determine practical methods and means to prevent or minimize dozing at the wheel by drivers of carriers in interstate commerce, and advise the Safety Board on the findings of this study. In addition, the BMCS should issue an "On-Guard" notice to carriers and drivers advising them of the circumstances of this accident and the findings of the BMCS research on driver alertness and fatigue, and the degradation of driver performance during early morning hours.

Highway Factors

The bus was traveling about 50 to 60 mph when it struck the approach guardrail and then the bridge guardrail at a 21-degree angle. The 40-year-old bridge guardrail was not designed to contain and safely redirect a large vehicle being operated at high speed. Curved, concrete barriers in widespread use today on freeways and interstate highways have contained and safely redirected fully loaded intercity buses traveling at 53 mph when struck at a 16-degree attack angle. However, these barriers are not totally effective in similar impacts by large, loaded trucks, or higher-center-of-gravity schoolbuses. More effective barrier systems are currently under development and field evaluation.

The replacement of the old barrier system at the accident site with a current design is dependent upon the feasibility of integrating the new design into the existing bridge structure, the costs involved, and the priority of other safety projects. There were no accidents at this site for the preceding 3 3/4 years that would have identified the need for improving the existing bridge barrier system. However, the Safety Board understands that this section of highway is scheduled for improvement in 1985. Since the improvement project will raise the pavement surface 6 inches, the existing barrier system unquestionably should be updated. At a minimum the height of the guardrail will have to be raised to meet current standards for conventional, W-beam guardrail. The improvement project would be an ideal opportunity to study the feasibility of providing an advanced barrier system on and approaching the bridge where the accident occurred. It also would be appropriate to extend the marked length of the shoulder acceleration lane from Loop 116 to U.S. 59 to meet existing AASHTO guidelines.

Survival and Rescue Factors

In a bus crash in Alaska in 1981, a 40-passenger tour bus ran off the roadway at a slow speed and rolled to its right down a hillside. 9/ Twenty-five of the 32 occupants were ejected as the bus rolled over 2 1/4 times. Five of the occupants who were ejected were killed. No occupants who remained inside the bus were killed or suffered severe injuries. In its investigation of the accident, the Safety Board concluded that the absence of occupant restraints permitted occupants to be thrown about within the bus and to be ejected from the bus as it rolled, and contributed to the severity of the injuries and to the fatalities.

The bus involved in the Livingston accident probably decelerated only about 2 to 3 mph as it crashed through the bridge guardrail and vaulted onto the creekbank below the bridge deck. Given a high-speed impact of 49 to 57 mph with the creekbank, fatal and serious injuries to the unrestrained occupants were inevitable. The collision with the creekbank resulted in four passengers being ejected through the windows on the left side of the bus. Three of those passengers were killed, and the surviving passenger who was ejected sustained the most serious injuries of any surviving occupant of the bus.

Three of the four passengers sitting next to the aisle on the right side of the bus were fatally injured. One of these passengers was ejected, and the other two were fatally injured when they were thrown forward to the front of the bus. The only surviving passenger who was sitting to the immediate right of the aisle reported that he was awake prior to the crash and that he bent over in his seat and tucked his head down before the impact with the creekbank. Although he sustained serious injuries, this passenger's alert response to the impending crash was probably an important factor in his survival.

9/ Highway Accident Report--"AAR Services Inc., Tour Bus, Denali National Park and Preserve (Mt. McKinley National Park), Alaska, June 15, 1981" (NTSB-HAR-81-7).

The installation and use of seatbelts by the Trailways bus passengers would have prevented the four passengers from being ejected, and may have mitigated the fatal or serious injuries to the passengers who remained inside the bus.

The busdriver was not wearing the available seatbelt. The Safety Board concludes that the busdriver's use of the available seatbelt, as required by the FMCSR (49 CFR 392.16), would not have mitigated his injuries. The major impact area of the bus with the creekbank was at the left front of the bus where the busdriver was seated.

While Safety Board investigators were at the Trailways terminal in Houston for a postaccident examination of the bus involved in this accident, they noted that several Trailways drivers failed to buckle their seatbelts before driving buses from the terminal. Even though the use of a seatbelt would not have prevented the driver in this accident from receiving serious injuries, it is important that all drivers wear the seatbelt that is provided whenever the bus is moving. The ability to maintain control of the bus in an emergency or crash situation is seriously jeopardized if the driver is thrown from the seat. In a 1972 crash in Virginia, 8/ a car ran a stop sign and hit a large schoolbus. The bus ran off the road and partially overturned. All the bus occupants were injured. The Board found that "the second collision of the bus, into the embankment, was caused by loss of driver control; the nonuse of available seatbelts by the driver prevented the regaining of control." Trailways should require its drivers to wear their seatbelts whenever the vehicle is in motion.

The crash damage to the front of the bus and the fact that all occupants who were not ejected were thrown forward to a small area in the front hampered the efforts of rescue personnel who entered the bus to administer first aid to the survivors. The overall rescue effort was performed efficiently.

CONCLUSIONS

Findings

1. The mechanical condition of the vehicles and the experience of the drivers were not factors in this accident.

2. The rear clearance, tail, and identification lamps on the semitrailer were illuminated as the bus overtook and struck the semitrailer.

3. The road was relatively straight for about 1/2 mile before the accident site, and there were no weather- or traffic-related visibility obstructions.

4. The busdriver had about 10 to 12 seconds to view the truck ahead in the right lane after the truck was passed by two other vehicles and before impact.

5. The truck probably would have been operating in the right lane at impact even if the marked length of the shoulder acceleration lane had met existing recommended length standards. However, if the marked length of the acceleration lane had complied with existing American Association of State Highway and Transportation Officials guidelines, the truckdriver might not have entered the roadway as soon as he did. He would have had more time to reach highway speed and observe the approaching bus before and while turning into the right traffic lane.

8/ Highway Accident Report—"Schoolbus-Automobile Collision and Fire Near Reston, Virginia, February 29, 1972" (NTSB-HAR-72-2).

6. The bus was traveling between 60 and 70 mph, and the truck was traveling about 42 mph when the vehicles collided.

7. The busdriver probably was operating his vehicle at or near 65 mph for most of the trip of 43 miles from Lufkin, Texas, to the scene of the accident.

8. The busdriver was not alert at the time of the accident possibly because of the early morning hour and the effects of fatigue.

9. The 40-year-old bridge guardrail was not designed to contain and safely redirect a heavy bus operating at high speed.

10. The installation and use of seatbelts would have prevented the four passengers from being ejected and may have mitigated the fatal or serious injuries suffered by passengers who remained in the bus.

Probable Cause

The National Transportation Safety Board determines that the probable cause of this accident was the busdriver's lack of alertness, possibly due to fatigue, which resulted in his failure to recognize that he was overtaking a slower-moving truck until it was too late to avoid impact. Contributing to the severity of the crash was the excessive speed of the bus.

RECOMMENDATIONS

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

--to the Bureau of Motor Carrier Safety of the Federal Highway Administration:

Issue an "On-Guard" notice to carriers and drivers advising them of the circumstances of the bus accident near Livingston, Texas, on November 30, 1983, and of the research findings of the Bureau of Motor Carrier Safety on fatigue and the degradation of driver performance and alertness during early morning hours. (Class II, Priority Action) (H-84-59)

Determine practical methods and means to prevent or minimize dozing at the wheel by drivers of carriers in interstate commerce, and advise the Safety Board of its findings. (Class III, Longer-term Action) (H-84-60)

--to Trailways Lines, Inc:

Regularly monitor the compliance of Trailways Lines, Inc., busdrivers with posted speed limits, and take corrective action as necessary to enforce the stated policy of the company that all drivers comply with posted speed limits. (Class II, Priority Action) (H-84-61)

Regularly monitor the compliance of Trailways Lines, Inc., busdrivers with seatbelt use requirements, and take corrective action as necessary to enforce the stated policy of the company that all drivers comply with Federal regulations requiring the use of seatbelts. (Class II, Priority Action) (H-84-62)

Determine practical methods and means to prevent or minimize dozing at the wheel by drivers employed by Trailways Lines, Inc., and advise the Safety Board of its findings. (Class II, Priority Action) (H-84-63)

—to the Texas State Department of Highways and Public Transportation:

As part of any major pavement improvement project, provide, wherever feasible, for the lengthening of marked acceleration and deceleration lanes that do not meet recommended design standards of the American Association of State Highway and Transportation Officials. (Class III, Long-Term Action) (H-84-64)

As part of any major pavement improvement project, provide wherever feasible for the installation of advanced barrier systems on and approaching bridges in the State of Texas. (Class III, Longer-Term Action) (H-84-65)

BY THE NATIONAL TRANSPORTATION SAFETY BOARD

/s/ JIM BURNETT
Chairman

/s/ PATRICIA A. GOLDMAN
Vice Chairman

/s/ G.H. PATRICK BURSLEY
Member

/s/ VERNON L. GROSE
Member

VERNON L. GROSE, Member, filed the following concurring and dissenting statement:

The report is thorough and carries my general concurrence. I respectfully dissent, however, on two specific issues. The first involves the adopted probable cause. This objection is substantive and may be based on a philosophic difference with the Board majority.

Four human faults are pinpointed, in the statement adopted by the Board, as collectively constituting a singular probable cause. All four faults--lack of alertness, fatigue, failure to recognize, and avoidance delay (there is physical evidence that the driver instituted last-minute avoidance)--are attributed to a single person. The busdriver bears full blame.

While I acknowledge that the Board has the right to assess blame--the standard adversarial method utilized in litigation, I hold that blame assessment is both unnecessary and counterproductive to the primary Board objective; i.e., attempting to preclude the accident from occurring again. It is unnecessary because preventive measures can be developed and instituted without ever having to point a finger at a person who, with the luxury of hindsight, can be shown to have erred. It is counter-productive because it forces all those parties who, in a blame-free milieu, might openly and willingly offer corrective assistance to consider their own potential culpability before helping the Safety Board in their effort to preclude future accidents.

Even in the extreme case where someone might have deliberately precipitated an accident with malice, it is not the Board's role to establish that person's guilt. That is an issue for the courts. Rather, we must propose changes--physical, economic, social, legal, or environmental--that will either eliminate or mitigate the accident from occurring again. And it is this very point that should force the Safety Board to focus on their purpose in concluding what the causative factors may have been in an accident. Were the Board to possess omniscience about causation and do nothing beyond publishing it, nothing would be accomplished to preclude the next accident. Probable cause statements, though required by Federal statute, cannot make anything safe or safer. It takes action, which emanates from understanding causation, to reduce accident potential. And such action does not require pinning the blame on anyone.

All accidents, with rare exceptions when the forces of nature totally override human endeavor, can be traced to variety of human errors. Accident investigation generally uncovers some—but not all--of those errors. Because it is so easy to "rush to judgment" instead of creatively developing preventive measures for the future, the errors pointed out are frequently those of the last person in that chain of events called an accident.

In this accident, for example, do the findings convince anyone that the busdriver is solely to be blamed? Or even more profoundly, should all corrective actions for the future be focused on him as a person (and in contrast to all busdrivers)? Which of the four faults with which he is charged have never been committed by all those who indict him? Has the Board weighed the additional guilt their decision imposes on a human being who is probably already suffering untold remorse?

For example, what about his company's policy that establishes city-to-city schedules that require an average speed of 53.5 mph, for "on time" arrivals, when the posted speed limit is 55 mph? Does this fact shed any light on an attitude that the company might instill in their drivers toward obeying the law? Interestingly, most recommended corrective actions following an accident consist of revising some law or procedure. Will those new laws be obeyed with this same attitude?

Or take another fact in this accident--that the Texas highway design for the section in which the collision occurred called for a 545-foot acceleration lane, but someone failed to build it according to specifications. So it turned out to be only 345 feet long. Even more significantly, the American Association of State Highway and Transportation Officials (AASHTO) recommended 900 feet--for automobiles which can accelerate much more rapidly than the heavy truck involved in this accident. The end result? The rear-ended truck entered the main highway at less than half the posted speed limit. Even if blame were to be a proper objective, does the busdriver deserve it all? How can blaming a person correct the future?

There must be a better approach--and there is. Instead of focusing on faults, we should concentrate on functions--those tasks, activities, or duties which are required to successfully and safely transport people and material but which, in this accident, were not performed thus. It matters not one whit who failed to carry them out. The Board's obligation is to conceive solutions that, taking into consideration the way in which certain functions failed to be executed in a safe manner, will hopefully mitigate the observed functional deficiency.

Directing attention then on function rather than fault, the following statement on probable causation is offered:

> The National Transportation Safety Board determines that the probable causes of this accident were (a) driving a passenger bus at a speed well in excess of the posted legal limits, (b) high-speed overtake by the bus of a slow-moving truck in the same lane, (c) imperception of a rapid closing velocity between bus and truck, and (d) departure of the bus from the highway roadbed. Contributing to the injury severity was the impact of the bus into a creekbank 26 feet below a highway bridge deck.

Since the Safety Board's mandate does not include the implementation of corrective measures, the end point of our accident investigative work is postulated action or recommendations. Whatever action we recommend should be traceable to or provoked by what we conclude to be causative. However, there are exceptions--because we are not just the National Transportation Accident Investigation Board. Our broader responsibility for transportation safety demands that we take action, whether or not we can trace it to a specific accident. Surely the price for safety would be too high if we had to wait for an accident before we could recommend an obvious safety measure.

My second point of dissent involves the reticence of my colleagues on the Safety Board to propose a recommendation directed at the causative factor of "high-speed overtake of a vehicle in the same lane." Though the majority agreed with me that a call for research or study of methods for alerting an overtaking driver of the closing velocity between him and a vehicle in the same lane was worthwhile, they objected to issuing such a call based on this accident. First of all, the number of rear-end collisions occurring annually establishes this mode of accident as other than rare. Second, there is little question that, in this accident, the factor was causative. Third, the automotive industry has acknowledged the importance of this problem by agreeing to design and install, on future automobiles, a third rear light to indicate braking.

Creative thinking about the "high-speed overtake" factor might include such futuristic and nearly unthinkable solutions as a radar-type device similar to those used on aircraft for collision-avoidance or those used by highway police for measuring velocity. (Motorists of all classes seem willing to invest in technological products like radar detectors and radios to avoid speeding tickets.) More feasible and economic devices or procedures would undoubtedly arise, if the Safety Board were to demonstrate leadership by recommending a study (not regulations) on the subject. Even mundane approaches are now in existence; e.g., the requirement on the Pennsylvania Turnpike for slow-moving vehicles to turn on their emergency flashers below a certain speed on open highway. Should its effectiveness be evaluated, and if judged effective, should its use be expanded?

Though this accident occurred on straight and level roadway, the overtake factor was significant. It becomes even more critical on hills or curves where there is very little time to evaluate the only clue an overtaking driver has available--the rate of expansion of the light pattern displayed on the rear of a vehicle.

July 12, 1984

APPENDIX

INVESTIGATION AND HEARING

Investigation

The National Transportation Safety Board was notified of this accident through the news media at 8 a.m., e.s.t., on November 30, 1983. Highway accident investigators were dispatched from the National Transportation Safety Board's Headquarters in Washington, D.C., and arrived on scene at 5 p.m. on November 30, 1983. Investigators were assisted by representatives of the Texas State Department of Public Safety, the Texas Department of Highways and Public Transportation, the Bureau of Motor Carrier Safety of the Federal Highway Administration, Trailways Lines, Inc., and E.A. Holder, Inc.

Depositions

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

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