MULTIPLE VEHICLE COLLISION WITH FIRE DURING FOG NEAR MILEPOST 118 ON INTERSTATE 40, MENIFEE, ARKANSAS JANUARY 9, 1995

and

SPECIAL INVESTIGATION OF COLLISION WARNING TECHNOLOGY

HIGHWAY ACCIDENT REPORT

Adopted: December 4, 1995
Notation 6530A

National Transportation Safety Board

Washington, DC 20594

ANALYSIS 49

Introduction 49
Accident 49
General 49
Survival Factors 50
Crash/Fire/Rescue 50
Drivers 51
Vehicles 52
Motor Carrier Operations 54
Highway 54
Rear-End Accidents 54
Collision Warning Technology 57
Aviation Collision Warning/Avoidance Systems 57
Railroad Collision Warning/Avoidance Systems 58
Marine Collision Warning/Avoidance Systems 59
General 59
Weatherford, Texas 62
Fairfax, Minnesota 62
Citizens Band Radios 64
Four-way Emergency Flashers 64

CONCLUSIONS 65

PROBABLE CAUSE 66

RECOMMENDATIONS 67

APPENDIXES

Appendix A--Investigation and April 1995 Conference 69
Appendix B--Compilation of Menifee, Arkansas, Accident Photographs 71
Appendix C--Collisions Involving Low Visibility and/or Low Awareness 79
Appendix D--Fifty-State Hazard Flasher Survey 89
Appendix E--Industry Comments from April 1995 Conference 93

CONTENTS

EXECUTIVE SUMMARY vii

INTRODUCTION 1

INVESTIGATION 1

Accident 1
Collision Sequence 3
Injuries 6
Drivers 6
- Driver 1 6
- Driver 2 7
- Driver 3 7
- Driver 4 8
- Driver 5 8
- Driver 6 9
- Driver 7 9
- Driver 8 10
- Driver 9 11

Vehicle Information 12
- Vehicle 1 13
- Vehicle 2 13
- Vehicle 3 13
- Vehicle 4 14
- Vehicle 5 14
- Vehicle 6 14
- Vehicle 7 14
- Vehicle 8 14
- Vehicle 9 14

Motor Carrier Information 15
- Motor Carrier 1 15
- Motor Carrier 2 15
- Motor Carrier 3 15
- Motor Carrier 4 15
- Motor Carrier 5 16
- Motor Carrier 6 16
- Motor Carrier 8 16
- Motor Carrier 9 16

Highway Information 16
General 16
Postaccident Physical Evidence 16
Postaccident Traffic Control 17
Accident History and Traffic Count 17
Meteorological Information 18
Medical, Pathological, and Toxicological Information 18
Emergency Response 19

OTHER INFORMATION 20

Other Safety Board Highway Accident Investigations 20
New Jersey Turnpike 21
Special Study of Reduced Visibility (Fog) Accidents 21
San Bernardino, California 22
Calhoun, Tennessee 23
Bakersfield, California 26
Weatherford, Texas 27
Fairfax, Minnesota 27
Mobile, Alabama 27
Investigative Conference and Related Research 27
Rear-End Accidents 28
Low-Visibility Accidents 29
Darkness 30
Fog 30
Snow 33
Rain 33
Low-Awareness Accidents 34
Enhanced Driver Detection of Obstacles 35
Retroreflective Tape and Paint 35
Vehicle Lighting 36
Citizens Band Radios 38
Forward Looking Sensor Technologies 39
Laser-Based Sensors 39
Intelligent Cruise Control Systems 40
Headway Detection System Technology 40
System A 41
System B 44
System C 44
May 1993 Technology Study 44
Federal Communications Commission Frequency Allocation Rulemaking 47

EXECUTIVE SUMMARY

About 1:50 a.m. on Monday, January 9, 1995, a multiple-vehicle rear-end collision occurred during localized fog at milepost 118 on Interstate 40 near Menifee, Arkansas. The collision sequence initiated when an uninvolved vehicle and the accident lead vehicle entered dense fog. As the lead vehicle reportedly slowed from 65 miles per hour (mph) to between 35 and 40 mph, it was struck in the rear. Subsequent collisions occurred as vehicles drove into the wreckage area at speeds varying from 15 to 60 mph. The accident eventually involved eight loaded truck tractor semitrailer combinations and one light-duty delivery van. Eight vehicles were occupied by a driver only, and one vehicle had a driver and a codriver. Three truckdrivers, the codriver, and the van driver were killed. One truckdriver received a minor injury, and four truckdrivers were not injured.

The National Transportation Safety Board determines that the probable cause of the accident was that many of the drivers entered the area of dense fog at speeds that precluded successful evasive action to avoid the preceding or the stopped vehicles.

The major safety issues discussed in this report are collision warning technology use during low visibility driving conditions, the emergency channel 9 override feature for citizens band radios, and the nonuniformity in State laws governing four-way emergency hazard flasher operation.

As a result of this accident investigation and the related special investigation of collision warning technology, the Safety Board makes recommendations to the Secretary of Transportation; the National Highway Traffic Safety Administration; the Federal Communications Commission; the 50 States, the District of Columbia, the Commonwealth of Puerto Rico, the Virgin Islands, and the Territories; the Telecommunications Industry Association; the Intelligent Transportation Society of America; and the American Association of Motor Vehicle Administrators.

INTRODUCTION

This report presents the results of the National Transportation Safety Board investigation of a multiple-vehicle collision, involving eight truck tractor/semitrailers and one light-duty cargo van, in Menifee, Arkansas. Sections of the report provide information on the sequence of collision events, the drivers, the vehicles, and the motor carriers. The drivers' experience, training, and precollision hours of service, as well as highway information, meteorological conditions, and emergency response, are detailed. Medical, pathological, and toxicological information is also included, where appropriate.

Additionally, this report describes various collision-warning technologies that may prevent or mitigate the consequences of some rear-end collisions occurring in low-visibility conditions. The report also discusses the potential benefits of these technologies in accidents that involve low awareness, including distracted, fatigued, or impaired drivers. A history of Safety Board investigations, public hearings, and conferences in the report illustrates both the recurring nature of these accidents and the Safety Board's continuing recommendations for the prevention of similar accidents.

Finally, the report analyzes the circumstances common to many rear-end collisions with the application of electronic collision warning technologies. The collision in Menifee, as well as past Safety Board-investigated collisions, are examined to determine whether the circumstances may have been mitigated by the application of technological solutions.

INVESTIGATION

Accident

At 1:50 a.m. on Monday, January 9, 1995, a multiple-vehicle rear-end collision with fire occurred during localized fog at westbound milepost (MP) 118 on Interstate 40 (I-40) near Menifee. The accident, about 8 miles northwest of Conway, Arkansas, involved eight loaded truck tractor semitrailer combinations and one local telephone company van. Eight vehicles were occupied by a driver only, and one vehicle had a driver and a codriver. Three truckdrivers, the codriver, and the van driver were killed. One truckdriver received a minor injury, and four truckdrivers were not injured.

The lead combination was struck twice, sustaining extensive damage to the rear of its trailer. The second and third combinations both struck the rear of the first combination, and the fourth combination struck the rear of the third combination. The fifth combination braked to a stop and was struck from behind by the sixth combination. The van either struck the rear of the sixth combination or was pushed into it when the seventh combination collided with the rear of the van. The eighth combination struck the side of the seventh combination, the rear of the van, and the sixth combination, and a fire ensued.

The rear of the fifth combination unit had heavy impact and fire damage. The sixth, seventh, and eighth combinations and the van were destroyed by impact and fire. (See figure 1.)

The drivers of the first five combinations reported they were wearing seatbelts. Restraint use could not be determined for the fatally injured occupants of vehicles six, seven, eight, and nine because evidence of restraint use was destroyed in the collisions and ensuing fire.

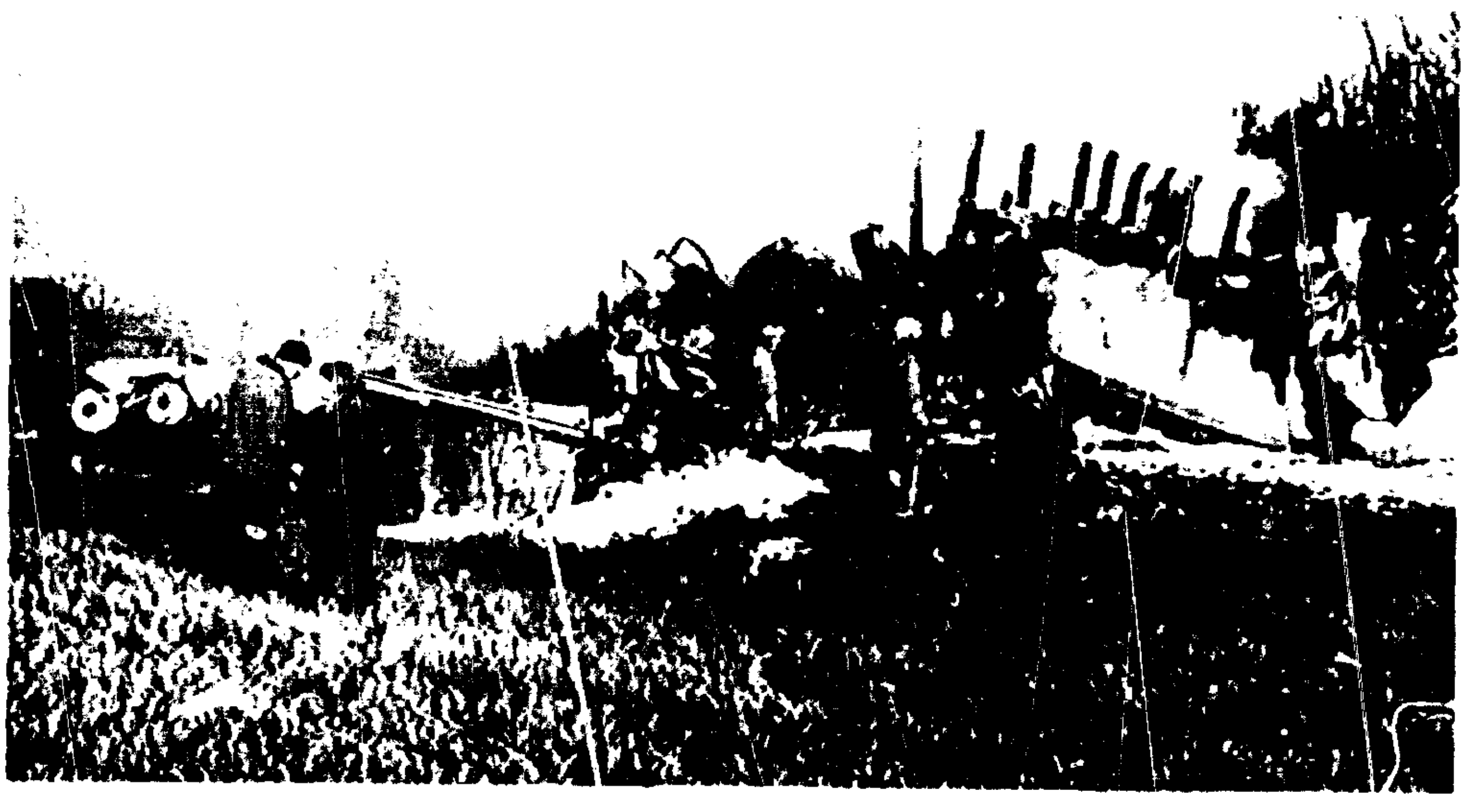

Figure 1. -- Remains of vehicles after impact and fire.

A listing of the vehicles in collision order follows:

Vehicle	Year	Tractor Manufacturer	Operator	Cargo
1*	1995	Peterbilt	West and Weaver Trucking	Cattle
2*	1992	Freightliner	Brady Higgins Trucking	Cattle
3*	1995	Kenworth	Hanna Manufacturing	Rail Ties
4*	1992	Freightliner	Hanna Manufacturing	Rail Ties
5*	1995	Kenworth	Mann Trucking	Scrap Metal
6*	1995	International	Builders' Transport	Paint/Hardware
7	1992	Chevrolet Van	Southwestern Bell	Supplies
8	1995	International	Advocate Services, Inc.	Water Heaters
9*	1992	Freightliner	Werner Enterprises	Newsprint Paper Rolls

*Equipped with citizens band (CB) radios.

Collision Sequence

The collision sequence was initiated when an uninvolved cattle transporter and vehicle 1, traveling westbound, together slowed as the two vehicles entered an area of dense fog. Their drivers had been talking on the CB and had been warned over the radio about a dense patch of fog by truckdrivers traveling east on I-40. The driver of vehicle 1 reported that he had slowed from 65 miles per hour (mph) to between 35 and 40 mph. He stated that his vehicle was struck in the rear, damaging the axles and causing the loss of braking. He kept the vehicle straight in the right lane and continued to slow when his vehicle was struck again. He said that he "stayed in his truck for a couple of minutes and then the explosion behind him occurred after he exited his truck." (See figure 2.)

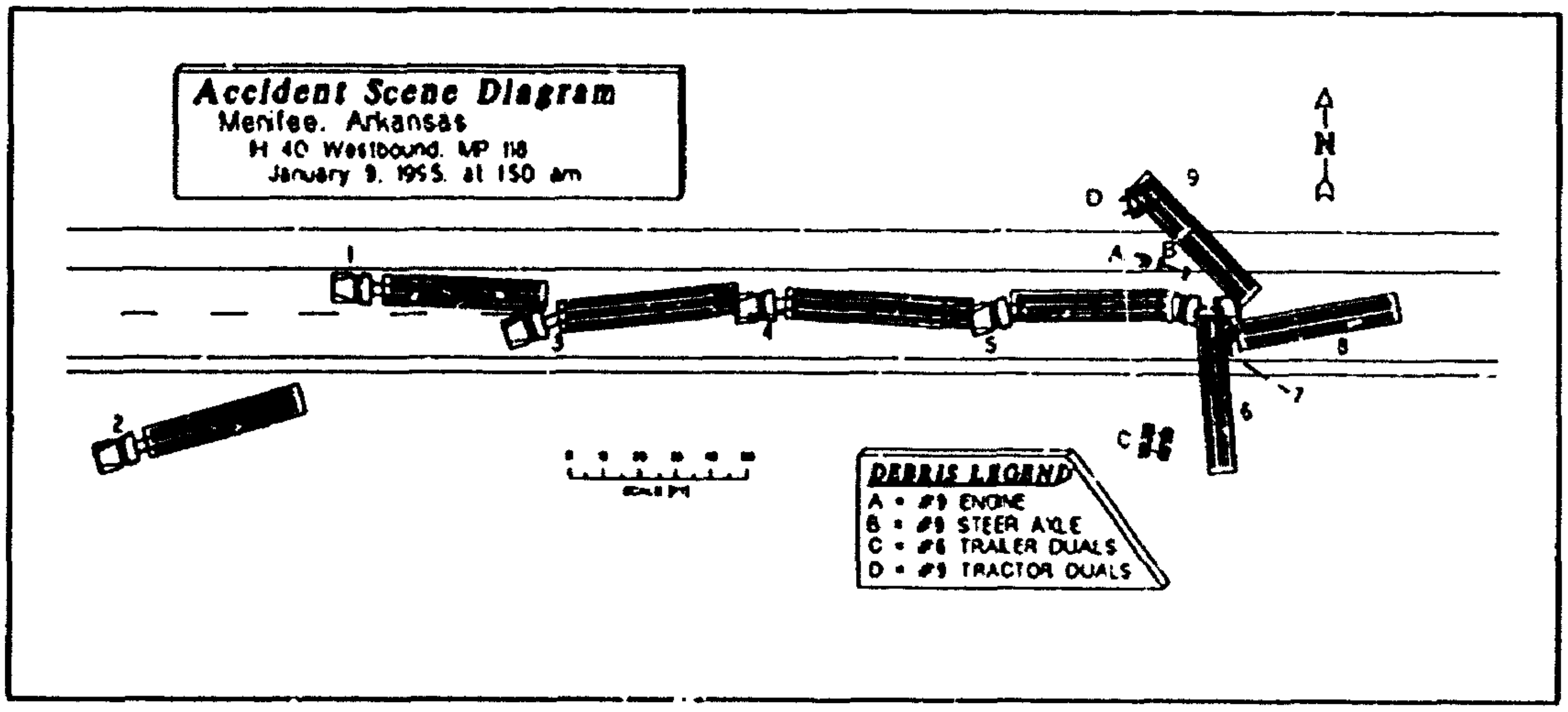

Figure 2. -- Postaccident scene diagram showing position of vehicles.

The driver of vehicle 2 reported that he slowed from 65 to 60 mph when he heard the CB reports about a patch of fog ahead at the bottom of a hill. He began to slow further when he saw the fog and entered the dense fog traveling about 55 mph. Then, he braked harder, slowing to between 40 and 45 mph. He indicated the forward visibility was only 5 feet, but he knew traffic was approaching from behind and was afraid to slow more. Next, he heard someone he thought was the driver of the cattle transporter, which was ahead of vehicle 1, stating on the CB, "I can't see a thing in here." At that time, he came upon vehicle 1 and collided into its left rear. He stated that the vehicle ahead of him was traveling very slowly. Vehicle 2 veered to the left, coming to rest in the center median, after it struck vehicle 1.

After the collision, the driver of vehicle 2 said he jumped from his vehicle and ran toward the vehicle that he had struck to check on its driver. However, he then remembered his truck was still running and returned to shut down its engine. By the time he reached vehicle 1, it had already been struck in the rear by vehicle 3. Then several events occurred nearly simultaneously. The driver of vehicle 2 stood on the steps of vehicle 1 to check on its driver's injuries. At the same time, the driver of vehicle 3 came running up to also check on that driver's injuries, and then vehicle 4 struck the rear of vehicle 3. The driver of vehicle 2 said that he was knocked to the ground by the impact and that he thought vehicle 4 had actually stopped before striking anything, but it was pushed into vehicle 3 by vehicle 5. He added that he was unsure about the time intervals between impacts, but he thought that he was in the fog less than 30 seconds before he struck vehicle 1 and that 30 seconds elapsed between when he was knocked from vehicle 1 and when the fire and explosion behind him occurred.

The driver of vehicle 3 stated that he crested a hill and saw a tractor semitrailer disappearing into heavy fog at the bottom of the hill. As the vehicle ahead of him disappeared into the fog, he saw its brake lights come on, so he reduced his speed to approximately 30 mph. He continued to slow, swerved to the left, and braked when he saw the vehicle ahead of him stopped in the road. He said that the left rear tandem axles of that vehicle had been knocked askew and were partly off the semitrailer into the left lane. After the impact, he ran back to vehicle 4 behind him to check on his coworker, who had gotten out his truck. They were looking at the damage on the grill of the coworker's truck when vehicle 5 struck or was pushed into the rear of that truck.

The driver of vehicle 4 stated that he and the driver of vehicle 3 had been talking on CB radio channel 21 before coming to the fog patch at the bottom of the hill. He was three to four truck lengths behind the unit that was ahead of him, but he lost sight of its preceding taillights as soon as they penetrated the fog. He stated that his coworker came on the radio and said, "Man it's foggy in here." The driver of vehicle 4 then slowed to about 25 mph and continued to slow. Moments later he saw that his coworker's truck was stopped, and he struck the rear of it. He estimated that he was traveling 10 to 15 mph when he collided into the rear of vehicle 3. After the impact, he turned on his flashers and climbed out of his truck, where he met his coworker from vehicle 3. They looked at the damage to his grill, and moments later his truck was struck in the rear by vehicle 5. He was unsure whether vehicle 5 had slid into his truck or was pushed into it by the truck that had struck the rear of vehicle 5.

The driver of vehicle 5 stated that he slowed from 68 to 57 mph when he heard the CB radio reports of fog on the west side of Conway. When he heard more reports of heavy fog and saw the heavy fog at the bottom of the hill, he slowed to 45 mph. He then slowed to between 15 and 20 mph when he had trouble seeing. He stated that when he saw the stopped combination with its flashers on ahead in his lane, he braked and was able to stop approximately 5 feet from the rear of it. Next, he activated his flashers and used his CB radio to warn the drivers approaching from his rear that vehicles were stopped in the inside lane. Also, he remembered the drivers of two trucks that he had been behind since El Dorado, Arkansas, had been talking on channel 21. He attempted to call them but received no answer. Then, the rear of his vehicle was struck very hard, and after the impact, he unbuckled his seatbelt and climbed down. By the time he reached the pavement, another combination had struck the wreckage of his truck and vehicle 6. Additional collisions and fire, in which the drivers of vehicles 6, 7, 8, and 9 were killed, followed shortly thereafter.

An eyewitness truckdriver reported that he was traveling about 65 mph in the right lane between 75 and 100 yards behind vehicle 9. He indicated that he first observed the fog in the head lights of the vehicle ahead and that then, he observed its taillights disappear. At that time, he pulled into the left lane and began slowing his vehicle. He stated that he then saw a fireball, applied his brakes, and skidded into the median. When asked about the speed of vehicle 9, he stated that his truck was slightly gaining on vehicle 9 and that he estimated vehicle 9 was traveling about 60 mph when it entered the fog.

Injuries**

Type	Drivers	Codriver	Total
Fatal	4	1	5
Minor	1	0	1
None	4	0	4
Total	9	1	10

**Based on the injury criteria[1] of the International Civil Aviation Organization, which the Safety Board uses in accident reports for all transportation modes.

Drivers

Driver 1 -- The 52-year-old driver of vehicle 1 had been a truckdriver for 30 years. He had worked for his current employer, West and Weaver Trucking, for the 15 years preceding the accident. During this period, he hauled both milk in a tank truck and cattle. He was very familiar with the accident route and stated that he had never before seen heavy fog in the accident area.

Driver 1 had a current Tennessee-issued Commercial Driver's License (CDL). His driving record showed a speeding conviction in 1993 and in 1990 as well as a fatal accident in 1989 that resulted after another vehicle crossed the center line and struck his truck.

He was off duty on the Friday and Saturday preceding the accident. On Saturday, he went to bed between 9 and 10 p.m. and awoke about 6 a.m. on Sunday. He washed his truck and loaded cattle between noon and 4 p.m., conducted a pretrip truck inspection at 4 p.m., and left Woodbury, Tennessee, at 4:15 p.m. By the time the accident occurred, driver 1 had been awake for 19 hours 50 minutes and on duty for 9 hours 50 minutes. He had in his most recent sleep period about 9 hours of sleep and 4 hours 10 minutes of sleep in the last 24 hours.

The driver had a current medical certificate and indicated that he was in good health on the day of the accident. He reported that he was not taking any medications and that he does not drink alcohol.

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[1]Title 49 Code of Federal Regulations (CFR) 830.2 defines fatal injury as "Any injury which results in death within 30 days of the accident" and serious injury as an injury that " (1) Requires hospitalization for more than 48 hours, commencing within 7 days from the date the injury was received; (2) results in a fracture of any bone (except simple fractures of fingers, toes, or nose); (3) causes severe hemorrhages, nerve, muscle, or tendon damage; (4) involves any internal organ; or (5) involves second or third degree burns, or any burn affecting more than 5 percent of the body surface."

Driver 2 -- The 46-year-old driver of vehicle 2 had been a self-employed small dairy farmer for 20 years. During that time, he often worked part-time hauling various agricultural commodities and drove different sizes and types of trucks. His heavy truck combination experience began in 1969, and he had been driving a tractor trailer part-time for Higgins Trucking of Woodbury, Tennessee, since June 1994. He reported that he was very familiar with his travel route on the night of the accident, that he had never before experienced fog in the accident area, and that he had not ever experienced fog as thick anywhere.

He possessed a current Tennessee-issued CDL. His driving record revealed one property damage accident in April 1990.

Driver 2 usually made one delivery per week for Higgins Trucking. It most often began on Sunday and ended on Wednesday; however, due to the holiday season, Higgins Trucking was essentially closed between December 2?, 1994, and January 5, 1995, and driver 2 did not work during that time.

On Friday, January 6, driver 2 worked for the trucking company from 5 p.m. to 6 a.m. delivering a load of cattle. He went to bed on Saturday between 10 and 10:30 p.m. after being off duty on Saturday. On Sunday, he awoke at 9:30 a.m., took a nap from noon to 3 p.m., reported to work at 4:30 p.m., loaded cattle, and left Woodbury at 5 p.m. en route to Medford, Oklahoma. At the time of the accident, driver 2 had been awake 10 hours 50 minutes and on duty 9 hours 20 minutes. He had 11.5 hours of night sleep and a 3-hour afternoon nap before the accident and 10 hours 40 minutes sleep in the last 24 hours.

Driver 2 had a current medical certificate, was in good health on the day of the accident, and had not taken any medications. He had not consumed an alcoholic beverage in more than a year.

Driver 3 -- The 26-year-old driver of vehicle 3 had been driving heavy truck combinations for 3.5 years and had worked for his current employer, Hanna Manufacturing, since October 1994. He had also attended a truck driver training class.

Driver 3 had a current Louisiana-issued CDL. His driving record showed no accidents or violations.

He was off duty on the Friday and Saturday preceding the accident and reported to work at 6 p.m. on Sunday, January 8. He had a load of lumber to be delivered to Russellville, Arkansas, approximately 30 miles beyond the accident site. He stopped once during the trip about 9 p.m. for a 30-minute break. At the time of the accident, he had been on duty for 7 hours 50 minutes. (After providing preliminary information, driver 3 declined to be of further assistance; therefore, additional information about his background and recent activities was unavailable.)

Driver 3 had a current medical certificate, was in good health, and took no medications on the day of the accident.

Driver 4 – The 37-year-old driver of vehicle 4 had been driving heavy truck combinations for 10 years and had hauled lumber products for the last 4.5 years. His current employer was Hanna Manufacturing. He was very familiar with the route and said that he had experienced fog along it previously. However, he could not recall having experienced fog at the accident site.

Driver 4 had a current Louisiana-issued CDL. His driving record revealed a single property damage accident in April 1993.

His schedule was variable, but he usually worked at night during the week with Saturday off. The week before the accident, he was off duty on Friday and Saturday. He went to bed Saturday about 9 p.m. and awoke between 9:30 and 10 a.m. on Sunday. Later he took a nap between 2 and 2.5 hours long until about 5 p.m. and went to work as usual at 6 p.m. He had been awake about 8 hours 50 minutes and on duty 7 hours 50 minutes at the time of the accident. He had 12.5 hours of sleep on the night before the accident and an afternoon nap on Sunday. He had 10 hours 40 minutes of sleep in the last 24 hours.

Driver 4 had a current medical certificate. He took a prescription medication for an ulcer and reported that he was not ill on the day of the accident. He had not had an alcoholic beverage during the week preceding the accident.

Driver 5 – The 38-year-old driver of vehicle 5 had been a truckdriver for 16 years. He had been working for his current employer, Mann Trucking Company, since August 1993. He was familiar with the accident route as during the last 18 months he had traveled it two or three times a month. He said he had encountered fog on this route previously but not at the accident site.

Driver 5 had a current Mississippi-issued CDL. His driving record revealed two accidents in 1993 while driving an automobile and a speeding ticket in 1992 while driving a truck.

He typically worked irregular hours Monday through Friday and had the weekends off. He finished his work week at 2 p.m. on Friday and was off duty on Saturday. He retired between 1:30 a.m. and 2 a.m. on Sunday and awoke in time to attend a church service at 11 a.m. He then remained at home and reported for work at 10 p.m. At the time of the accident, driver 5 had been awake about 14 hours 50 minutes and on duty for 3 hours 50 minutes. His most recent sleep period totaled about 8.5 hours, and he had 8 hours 10 minutes sleep in the last 24 hours.

Driver 5 possessed a medical certificate that expired on April 7, 1994. He reported that he was in good health on the day of the accident and not taking any medication and that he last consumed alcohol on Saturday evening.

Driver 6 -- The 48-year-old driver of vehicle 6 had been a truckdriver about 17 years and worked the last 5 years for Builders Transport. Driver 6 received 3 days of training when he began working for the company in 1989. Builders Transport approved him in August 1994 as a driver trainer, and he completed a 2-day instructional class for trainers in October 1994. He also received topic training at quarterly safety meetings. During the fall 1993 meeting, he was instructed about winter driving that included the fog instruction to reduce speed sufficiently to bring the vehicle to a controlled stop in the distance visible. He had transported assorted commodities to stores across the country and had no regular route.

Driver 6 held an Arkansas-issued CDL, and his driving record showed one speeding conviction in 1988 and th[illegible] 1987.

His work week began on Sunday night and ended on Friday night or Saturday morning. He was usually away from home for the entire week. On Friday, January 6, he called his wife to tell her that he was tired and would finish his trip on the next day. He arrived home about noon on Saturday, remained at home, and retired at 9:30 p.m. On Sunday, he woke at 7:30 a.m., attended church services, remained home during the day, napping between 2 and 3:30 p.m., and departed for work at 6:30 p.m. He drove 2 hours, approximately 100 miles, from his home to the terminal where he picked up his truck. At the time of the accident, driver 6 had been awake 10 hours 20 minutes. His on-duty time is unknown because his log book was destroyed in the accident. He had 10 hours sleep the night before the accident and a 1.5 hour nap on Sunday afternoon. He had 9 hours 10 minutes sleep in the last 24 hours.

Driver 6 had a medical certificate. He had a thyroid condition that was treated with daily medication. His wife reported that he did not drink alcoholic beverages and that he was feeling well over the weekend.

Driver 7 -- The 34-year-old driver of vehicle 7 had been an employee of Southwestern Bell for 14 years, transporting company mail and equipment for the last 5 years. Driver 7 had completed a defensive driving class given by his employer and had 5 years experience driving the type of van he was operating when the accident occurred. He was familiar with the accident route because he had often made deliveries between Little Rock and Fort Smith, Arkansas.

Driver 7 possessed an Arkansas-issued driver's license. His driving record revealed an accident in 1994 and one speeding ticket in 1993.

He worked 5 days a week, making deliveries 3 days and working 2 days in a North Little Rock, Arkansas, warehouse. His regular schedule was the night shift from midnight to 8:30 a.m., and he had worked that shift for the preceding 18 months. His work week began midnight Sunday and ended Friday morning. He normally departed for work at 11 p.m., arrived home by 9:30 a.m., and then slept until 4 or 4:30 p.m. His schedule for the week before the accident followed that basic pattern; although, he had an extra day off on Friday. He was off duty on Saturday, retiring at 9 p.m., and awoke on Sunday between 8 and 8:30 a.m. He reported for work just before midnight and last talked to his supervisor at 12:25 a.m. on Monday. He made three deliveries before the accident. He had been awake between 17 hours 20 minutes and 17 hours 50 minutes and on duty for 1 hour 50 minutes at the time of the accident. His most recent sleep period totaled 11.5 hours, and he had 6 hours 40 minutes sleep in the last 24 hours.

Driver 7 suffered from hypertension that was treated with prescription medication. His wife reported he was not ill on Sunday when he went to work.

Driver 8 -- The 54-year-old driver of vehicle 8 had been operating heavy trucks for 28 years. He had worked for his current employer, Advocate Services, for 6 months as part of a two-man driving team (sleeper berth operation) with his 39-year-old nephew. The team was familiar with the accident route because their regular schedule routing took them over it several times each week. Whether driver 8 had experienced fog along the route before the accident is not known, but his wife stated that he was very experienced driving in fog. They had lived and driven trucks together for 20 years near Fresno, California, where they encountered tule fog,[2] a dense fog common to that California area. The wife said that her husband would normally slow to between 30 and 40 mph when he entered dense fog.

Driver 8 had a current Arkansas-issued CDL. His driving record showed one conviction for speeding in 1994 and another one in 1992. His wife reported that he had been involved in one car accident in 1969 but had never been involved in an accident with a truck.

The two-man driving team made three trips each week and alternated 5 hours driving with 5 hours in the sleeper berth. Their work week began at 10 p.m. Saturday when they left Fort Smith and drove to Charleston, Illinois. The return trip usually had them arrive in Fort Smith on Sunday between 7 and 9 p.m. Their second trip of the week began at 3 a.m. on Monday, and they travelled from Fort Smith to Charleston to Longview, Texas. They usually returned to Fort Smith about 10 a.m. on Tuesday. The third trip, repeating the route of the second, began at 3 a.m. on Wednesday and ended by 10 a.m. on Thursday. The driving team was then off duty from 10 a.m. on Thursday until 10 p.m. on Saturday.

On the trip that began at 10 p.m. on Saturday, January 7, the codriver drove first. The truck broke down about midnight near Russellville, Arkansas, and after notifying the company, the driving team slept in the truck until a replacement tractor arrived between 5 and 6 a.m. The breakdown set the trip 5 to 6 hours behind schedule; additional delay was caused by snow and ice in Illinois. As a result of the delays, little or no break came between the end of their first trip and the beginning of their second. The driver contacted his wife on Sunday and told her that he would not have time to come home between trips and that he planned to shower and change clothes at the company terminal in Fort Smith. He asked her to bring additional clothing to the terminal at 3 a.m.

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[2]Technically known as radiation fog, it is the fog that is produced over a land area when radiation cooling reduces the air temperature to or below its dew point.

Vehicle 1 -- Vehicle 1 was a 1995 Peterbilt tractor in combination with a 50-foot, split level Barrett livestock semitrailer that was loaded with cattle. The combination weighed approximately 78,000 pounds. The undamaged tractor was released to its driver at the scene before Safety Board investigators arrived, and drivers 1 and 2 returned to Tennessee in it. Therefore, no pre- or postcollision vehicle information is available on the tractor. Thirty-four inches of contact damage began on the left rear and extended toward the center of the semitrailer. The rear axles were displaced sideways to the left, and 17 feet of metal siding was displaced on the left side. (See photograph 1 in appendix B.) A visual examination of the semitrailer brakes showed that no parts were broken, missing, or excessively worn. No grease contamination was present, the drums were free from irregularities, and the brake linings met minimum required thickness standards. The trailer was equipped with automatic slack adjusters.

Vehicle 2 -- Vehicle 2 was a 1992 Freightliner tractor in combination with a 1987 Barrett, 48-foot split level livestock semitrailer that was loaded with cattle. The combination weighed 78,100 pounds. Thirty-one inches of contact damage was on the tractor front bumper, grill, and fenders, extending from the right side toward the center. The front structure was shifted 11 inches to the right, and the right side wheelbase was reduced 18 inches. The front structure of the semitrailer had substantial damage. (See photographs 2 and 3 in appendix B.)

A functional inspection of the brakes on the tractor of vehicle 2 showed that all were adjusted properly. No defects were noted on the tires, suspension, or steering components. Additionally, defects were not noted on the semitrailer, but the pushrod stroke could not be measured because the tow truck operator had backed off the brakes when removing the vehicle from the scene.

Vehicle 3 -- Vehicle 3 was a 1995 Kenworth truck tractor in combination with a 1990 Fruehauf, 48-foot flatbed semitrailer that was loaded with railroad ties. The estimated weight of the combination was 79,000 pounds. The right front of the tractor had 34 inches of contact damage, beginning at the right edge and extending in toward the center. The right front wheel was turned outward 75 degrees; the right front airbrake hose was separated from its frame connection. The forward headwall of the right side fuel tank was punctured, allowing fuel to leak out. The rear of the semitrailer had 48 inches of moderate contact damage that extended from the left side toward the center. The cargo of wood ties moved forward 90 inches at impact, and the shifting cargo pushed down and fractured the front headerboard.[4] The rear of the sleeper cab was pushed inward approximately 24 inches. (See photographs 4, 5, and 6 in appendix B.)

A functional brake test was performed on the tractor and semitrailer. Pushrod stroke measurements showed that all brakes, except the right forward axle semitrailer brake, met the required minimum adjustment standards. That brake had a 2-inch pushrod stroke adjustment and was not considered defective, but a readjustment would be required.

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[4]A protection device, installed behind the tractor cab or mounted on the front of a trailer, to prevent forward-shifting cargo from crushing or penetrating the driver's compartment.

Vehicle 4 -- Vehicle 4 was a 1992 Freightliner tractor in combination with a 1994 Utility, 48-foot flatbed semitrailer loaded with wood railroad ties. The estimated weight of the combination was 80,000 pounds. The front of the tractor had radiator damage, and the semitrailer had 38 inches of contact damage on the left rear, extending from the left edge toward the center. Also, the headerboard on the front of the semitrailer was fractured similarly to the vehicle 3 semitrailer when its load shifted forward at impact. (See photographs 7 and 8 in appendix B.)

Vehicle 5 -- Vehicle 5 was a 1995 Kenworth truck tractor in combination with a 1984 Utility, 45-foot semitrailer loaded with scrap metal. The combination weighed 78,460 pounds. The tractor sustained substantial damage on its front, and the semitrailer had extensive rear impact and fire damage. The steel bed was pushed inward 11 inches, and the axles were destroyed by the postcrash fire. (See photographs 9 and 10 in appendix B.)

An examination of the tires, suspension, and steering indicated no precrash defects. A functional test of the brakes showed that all tractor brakes were properly adjusted. Impact and fire damage prevented a comprehensive inspection of the trailer.

Vehicle 6 -- Vehicle 6 was a 1995 International truck tractor in combination with a 1985 Fruehauf, 48 foot van semitrailer loaded with general hardware, paint, and other combustibles. The impact and postcrash fire destroyed the combination, and no mechanical examination was possible. (See photograph 11 in appendix B.)

Vehicle 7 -- Vehicle 7 was a 1992 Chevrolet utility (cube) van. The impact forces and the postcrash fire destroyed the van. In addition, the cleanup crew crushed and compacted the wreckage during the removal process from the highway. (See photograph 12 in appendix B.) No mechanical inspections were performed on the limited wreckage.

Vehicle 8 -- Vehicle 8 was a 1995 International tractor in combination with a 1992 Strick, 53-foot van semitrailer loaded with hot water heaters. The impact force and fire destroyed most of the combination. The tractor frame, engine and driveline, and a 25-foot section of the rear of the semitrailer were all that remained of the combination unit. The rear of the semitrailer was undamaged. (See photographs 10 and 13 in appendix B.) The estimated weight of the semitrailer cargo was 39,043 pounds. No mechanical inspections were performed on the remains of the tractor. The right side of the tractor had a deep bow in the frame that is characteristic of a severe impact. The brakes of the semitrailer were undamaged, but the tow truck operator changed the evidence of adjustment by backing off the brakes to facilitate vehicle removal.

Vehicle 9 -- Vehicle 9 was a 1992 Freightliner tractor in combination with a 1994 Wabash, 53-foot van semitrailer loaded with rolled paper for newsprint. Impact forces and the postcrash fire destroyed the combination (see photo 13 in appendix B), and no mechanical inspections were performed on the limited wreckage.

on Monday. At 12:15 a.m., he called her again and said that snow and ice would cause him to arrive at the terminal around 4 a.m. During the telephone conversation, she learned that her husband was driving the final portion of the trip. As it was his turn to drive, he resumed driving at their usual switch point, which was the Missouri-Arkansas State line. Because of his schedule, the most recent sleep period of driver 8 is estimated to be 5 hours.

The log book covering the on-duty time period of driver 8 was destroyed in the accident fire. Information on the events of the last trip was obtained from his wife.

Driver 8 had a current medical certificate. His wife said that he was in good health and that he did not report any illness during his Sunday or Monday telephone calls.

Driver 9 – The 31-year-old driver of vehicle 9 had worked as a mechanic in a family garage and as a farm hand since high school until he was age 30. He attended a truckdriver training school in October and November 1993, after which in January 1994, he went to work for a large trucking company headquartered in Salt Lake City, Utah. He received another 3 days of training with that company and was employed there until July 1994 when he was employed by Werner Enterprises, Inc. He received another 2.5 days of training at Werner that included some instruction for driving in fog. He was taught to slow his vehicle to compensate for the reduced visibility. Driver 9 did not have a regular route, and his familiarity with the accident route is not known.

He had a Texas-issued CDL with a hazardous materials endorsement. His Texas driving record indicated no accidents or traffic convictions.

Driver 9 traveled throughout the country and stayed wherever the deliveries took him. He maintained an address at his parents' Texas home and normally visited it for 3 days every 30 days. He was last home between December 23 and 25, 1994, and spoke to his parents by telephone on December 31.

On Thursday, January 5, driver 9 was in Florida and recorded sleeper-berth time from 6:30 p.m. until Friday, January 6, at 2:45 a.m. (8.25 hours). He then made several deliveries on Friday in Florida. He reported additional sleeper-berth time between them from 7:15 a.m. to 12:45 p.m. (5.5 hours), from 3:30 to 6 p.m. (2.5 hours), and from 8:45 p.m. to 9:15 a.m. on Saturday, January 7, (12.5 hours). Later on Saturday, he drove to Alabama and recorded sleeper-berth time from 6 p.m. until 7:30 a.m. on Sunday, January 8, (13.5 hours). After driving to Mississippi, he returned to his sleeper berth at 1:30 until 10 p.m. (8.5 hours). Whether the sleeper-berth time of driver 9 directly corresponds to his amount of sleep cannot be determined. However, based on his sleeper-berth time, driver 9 had been awake and on duty for 3 hours 50 minutes at the time of the accident. He also had 8.5 hours of sleep in his most recent sleep period and 14 hours 10 minutes sleep in the last 24 hours.

The January log book of driver 9 was destroyed in the postcrash fire; however, other company documents provided some of his activities. A computer printout from his on-board satellite system, shipping papers, loading receipts, and weight tickets indicated that he was in compliance with the hours-of-service regulations. His sleeper-berth time was also obtained from company documents.

Driver 9 had a current medical certificate. He suffered from hypertension that was controlled with a prescription medication.

Vehicle Information

The wreckage of the accident vehicles was inspected over a 3-day period at tow yards in Morrilton and Conway, Arkansas. Examinations, where possible, of the tires, steering components, suspension, and brakes were conducted. A functional test to determine the pushrod stroke was performed on those vehicles not damaged too severely. The last three combination units and the van were almost completely destroyed by the impact forces, postcrash fire, and highway cleanup; consequently, a mechanical inspection of these vehicles was limited. The ignition source of the fire could not be determined due to the lack of evidence remaining after the intense postcrash fire and the wreckage removal operations.

The semitrailer of vehicle 8 was not completely destroyed, but the brake pushrod strokes could not be measured because the tow truck operator had backed off the brakes to facilitate removal of the wreckage.[3] This situation also occurred on the semitrailer of vehicle 2. When the tow truck operator caged the spring brakes with a caging bolt on the semitrailer of vehicle 1, the evidence of adjustment was preserved. However, the pushrod stroke could not be measured because the displaced axles of this unit were used to brace other parts of the wreckage and movement could have resulted in turning the semitrailer over in the tow yard. Considering vehicle 1 had the lead position in the collision sequence, its brake adjustments could not have contributed to the accident.

The tail lamp assemblies on the semitrailers of vehicles 1, 3, 4, and 5 were removed and examined at the Safety Board laboratory to determine whether they were incandescent when struck. The lab test showed that the only filament with any appreciable stretching (under certain circumstances may indicate incandescence) was the left outside tail lamp filament of vehicle 1. The lamp filament from vehicle 5 was burned too severely to make any determinations. No filaments could be found in the wreckage of the remaining vehicles.

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[3]When air is lost in an airbrake system, a safety feature results in the mechanical application of spring brakes installed on certain air chambers. The vehicle is immovable until the brake is released by recompression of the spring or a readjustment of the slack adjuster stroke is accomplished. Readjustment of the slack adjuster, commonly known as "backing off" the brakes, destroys evidence of precrash adjustment. Recompression of the spring can be accomplished by either reapplying air (if the system will hold pressure) or mechanically compressing the spring by use of a "caging" bolt. When used, the caging bolt is inserted through the rear of the spring brake chamber housing and then turned to compress the spring.

Motor Carrier Information

Motor Carrier 1 – West and Weaver Trucking of Woodbury, Tennessee, operated vehicle 1. The company was a private interstate operation, which began in 1994, and retained only this vehicle and its driver. The carrier was not registered with the U.S. Department of Transportation (DOT), as required by 49 CFR Part 390.21, and no safety compliance review had ever been performed by the Federal Highway Administration (FHWA) Office of Motor Carriers (OMC).[5] After the accident, Safety Board investigators reviewed 30 days of the driver's logbooks, fuel receipts, trip tickets, and shipping papers No hours-of-service violations were noted in the review.

Motor Carrier 2 – Brady Higgins of Woodbury, Tennessee, operated vehicle 2. The motor carrier was a private interstate carrier with DOT Census No. 389190. The company operated three combination units and employed three truckdrivers. It received a safety compliance audit from the OMC on January 20, 1993, and obtained a satisfactory safety performance rating. A review of the qualification file of driver 2 showed that he had not been administered a preemployment drug screen as required.

Motor Carrier 3 – Hanna Manufacturing of Winnfield, Louisiana, an interstate for-hire motor carrier with 48-State operating authority, operated under Interstate Commerce Commission (ICC) No. 262144. The company operated two tractors, one of which was vehicle 3, and employed two drivers. The primary cargo was lumber, logs, poles, and beams.

Records from OMC disclosed that it audited the motor carrier on February 24, 1994, and assigned a conditional rating. Follow-up compliance inspections by the OMC indicated that all observed deficiencies had been corrected, but the conditional rating had not yet been upgraded to satisfactory.

Motor Carrier 4 – Hanna Manufacturing, which operated vehicle 3, additionally operated vehicle 4.

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[5]The OMC began assigning safety ratings to motor carriers in the 1960's through examinations called safety management audits. In 1985, the examination process was reorganized into two separate inspection levels: safety reviews and compliance reviews. Either level of examination could result in a safety rating of satisfactory, conditional, or unsatisfactory. Beginning in 1995, the OMC delegated safety reviews to the States but continued performing compliance reviews as the sole means of assigning safety ratings. Currently, compliance reviews are conducted in response to written complaints that are found to have merit.

At the end of 1993, the most recent fiscal year for which data have been compiled, 41.2 percent of the active interstate motor carriers had been assigned safety ratings. Of that 41.2 percent, 60.4 percent were rated satisfactory, 32.4 percent were rated conditional, and 7.2 percent were rated unsatisfactory.

If the OMC conducts an audit that results in an unsatisfactory rating or an enforcement action against a motor carrier, the OMC would return 4 to 6 months after the case was settled to conduct a reaudit. Although the OMC intent is to manage conditional ratings under the same guidelines, the staff is generally not available to fulfill that goal.

Motor Carrier 5 -- Mann Trucking Company of Greenville, Mississippi, operated vehicle 5. The carrier was registered under DOT Census No. 179474 and ICC Nos. 154006 and 183598. It was an authorized for-hire general freight interstate carrier, which operated 16 tractors with 37 trailers and employed 24 drivers. The OMC performed a safety compliance review of the company on January 15, 1985, and assigned a satisfactory rating.

Motor Carrier 6 -- Builders' Transport of Camden, South Carolina, operated vehicle 6. The carrier operated a fleet of 2,738 truck tractors with 5,761 semitrailers and employed 2,981 drivers. It received a satisfactory compliance rating after an OMC safety compliance review on May 2, 1994.

Motor Carrier 8 -- Advocate Services, Inc., of Butler, Pennsylvania, operated vehicle 8. The carrier operated 139 tractors with 268 semitrailers and employed 162 drivers. It received a satisfactory rating from the OMC on November 9, 1987.

Motor Carrier 9 -- Werner Enterprises of Omaha, Nebraska, operated vehicle 9. The carrier operated a fleet of 2,709 tractors with 6,170 semitrailers and employed 3,078 drivers. After a compliance review on October 8, 1992, by the OMC, Werner received a satisfactory safety rating.

Highway Information

General -- I-40 is a four-lane, east-west, limited access highway that runs through the north central portion of Arkansas from the eastern border with Tennessee to the western border with Oklahoma. The accident occurred near MP 118, about .5 mile east of the Menifee interchange (8 miles north of Conway) and about 35 miles northwest of Little Rock. The speed limit was 65 mph for both passenger vehicles and trucks.

Approaching the accident site, the westbound lanes had a 900-foot vertical curve (hillcrest) transitioning to a 3-percent downhill grade. (See photograph 14 in appendix B.) The crest of the hill was about .5 mile east of the accident site.

The road had a portland cement concrete surface with asphalt shoulders and was dry at the time of the accident. The cross section consisted of two 12-foot-wide lanes with an 11-foot right and a 4-foot left shoulder in each direction. A 58-foot-wide median separated the eastbound and westbound lanes. The lane markings were 12-foot-long, painted, white stripes at 28-foot intervals. These lane markings and the standard 4-inch solid yellow and white edge lines were all visible.

Postaccident Physical Evidence -- As a result of the collisions, the road surface was covered with fuel and debris. A large portion of the road surface, approximately 20 feet by 40 feet, was burned and scorched. (See photographs 15 and 16 in appendix B.) A significant amount of physical evidence on the road was destroyed by the fire, the rescue and vehicle recovery equipment, and the postaccident traffic before Safety Board investigators arrived.

Some of the physical evidence that was not destroyed consisted of tire marks about 340 feet long in the left lane leading to the impact area. Tire marks continued in the left lane and veered left across the left shoulder into the center median. Tire furrows advanced approximately 35 feet to the middle of the median. (See photograph 16 in appendix B.) Scrape and gouge marks were on the right and left lanes about 2,100 feet from the crest of the hill. Additional scrape and gouge marks proceeded beyond this point approximately 200 feet to the site of the first impact.

The postaccident location of vehicles, cargo, and occupants was reconstructed from police reports and the driver and witness statements. The wreckage was spread over a 400-foot-long area. Vehicle 2 came to a final position in the median, and vehicle 1 was stopped in the right-hand lane with the right side of the tractor from vehicle 3 in contact with the left side of the semitrailer. The tractor and forward portion of the semitrailer from vehicle 3 extended across both westbound lanes. Vehicle 4 stopped at the rear of vehicle 3 with its tractor wedged into the vehicle 3 rear. Vehicle 5 remained in contact with the rear of vehicle 4, and the vehicle 5 tractor was cocked to the left, extending into the left-hand westbound lane.

The remains of three tractor/semitrailers and the delivery van were at the rear of vehicle 5 and extended rearward for a distance of 59 feet. All victims were within 15 feet of the rear of vehicle 5. The vehicle 6 semitrailer was perpendicular to the rear of the vehicle 5 semitrailer and extended approximately 20 feet into the median. The vehicle 9 semitrailer was also perpendicular to the rear of vehicle 5 and extended about 35 feet onto the north roadside.

Postaccident Traffic Control – After the accident, traffic control was set up by the Arkansas State Police (ASP) and the Conway police department. Eastbound traffic was routed off I-40 to U.S. 64 (US-64) at the Menifee exit 117; westbound traffic was routed to US-64 from the Conway exit 125. ASP contacted the highway department for assistance with traffic control. Highway department crews responded and installed flashing lights, barricades, and an arrow board at the above locations.

Accident History and Traffic Count – The 5-year accident history for log miles 116 through 118 on I-40 revealed one fog-related accident in 1991 that involved four vehicles: a motor home, a van, a passenger car, and a truck tractor semitrailer. No fatalities resulted in that accident.

The average daily traffic count in 1993 on I-40 in the accident area was 24,130. The 1993 classification counts indicated that about 29 percent of the vehicles were trucks with five or more axles.

Meteorological Information

The closest weather reporting facilities to the accident area were Adams Field in Little Rock and Little Rock Air Force Base in Jacksonville, Arkansas, 31 and 36 miles southeast of the accident area, respectively. Neither station forecast fog on the night of the accident. The only stations in Arkansas reporting reduced visibility from fog around the accident time were in the northern part of the State.

On the night before the accident, the National Weather Service public zone forecasts for Conway and Faulkner Counties were: "Tonight. . .fair and cold low near 30. Northwest wind 5-10 miles an hour." No fog was forecasted.

Also, an infrared satellite image for the nominal time of 2:31 a.m. was obtained through the MAN computer Interactive Data Access System (McDAS) at the University of Wisconsin. The infrared data resolution was 4 kilometers. Mostly clear conditions existed over the southern half of the State, and no apparent areas of fog were documented by the imagery.

About 20 minutes before the accident occurred, a local ambulance traveled by MP 118, and the occupants later reported that no fog had been present at the accident site. Responding Menifee fire department personnel stated that the fog was localized over a .5- to 1-mile area that began on the downslope of the hill where the accident occurred and extended to the west. Additionally, police and fire personnel stated that the fog moved in and out of the area several times over a period of hours during the rescue process.

Arkansas Highway and Transportation Department (AHTD) personnel familiar with the area stated that fog was not common in any particular area of I-40. The AHTD employees who responded to the accident stated that at their arrival, the fog at the accident site was thick, not stirring, and confined to the low area between the crest of the hill and the Menifee exit. AHTD personnel stated that they did not have a policy requiring the placement of signs to warn motorists of fog. They indicated that their experience with fog in the State did not warrant warning signs.

Medical, Pathological, and Toxicological Information

The drivers of vehicles 6, 7, 8, and 9 and the codriver in vehicle 8 were killed. The Arkansas State Medical Examiner's Office reported that driver 9 died from multiple blunt force injuries and that the remaining fatalities died from smoke inhalation and carbon monoxide poisoning. The drivers of vehicle 6, 7, and 8 and the vehicle 8 codriver had blood carbon monoxide levels of 60, 24.2, 32.4, and 38.2 percent, respectively. An interpretive guide to toxicological findings[6] indicates that a 15- to 30-percent concentration of carbon monoxide is considered toxic and that any concentration over 30 percent is generally regarded as a fatal dose.

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[6] *Human Toxicology* (1983), Volume 3, pp. 437-464.

Since 1967, the Safety Board has investigated numerous catastrophic accidents involving multiple vehicles in conditions of low visibility and/or low awareness. (See appendix C.) The two common themes in many of those investigations are that drivers enter conditions of low visibility at widely varying speeds and that drivers fail to perceive vehicles moving slowly or stopped in the travel lanes forward of them. Some representative investigations of collisions occurring in low-visibility conditions and the resulting safety recommendations are discussed below.

New Jersey Turnpike -- At 7:45 a.m. on November 29, 1969, in a southbound lane of the New Jersey Turnpike, a 1969 Mercury entered sudden dense fog at 45 mph. The driver slowed to about 30 mph but was rapidly overrun by a tractor tank/semitrailer with a combined vehicle weight of 76,340 pounds and loaded with 9,257 gallons of propane. After striking the Mercury, the tank semitrailer overturned, blocking both southbound lanes and the shoulders.

Ten vehicles entered the area just north of the blocked lanes in rapid succession, and multiple collisions between them and the semitrailer occurred. Fire started near one of the passenger vehicles. Twenty-nine vehicles were eventually involved in 12 to 15 primary collisions due to the initial road blockage. Twelve vehicles were destroyed, and most of the others were damaged. Six fatalities and 3 serious and 15 less serious injuries resulted.[9]

The Safety Board determined that the probable cause of the accident was penetration by vehicles into an area of dense fog where the visibility was 20 to 50 feet, together with the varying speeds that prevented evasive actions. As a result, the Safety Board asked the National Highway Traffic Safety Administration (NHTSA) to:

> Initiate (through an appropriate demonstration project) a program and procedures for minimizing the likelihood of catastrophic chain-reaction collisions on high-speed, multilane highways in adverse weather or visibility conditions; such a program to consider, among others: (1) the use of four-way flashers by all vehicles, (2) prohibit stopping on the traveled portion of highways (unless conditions will not permit otherwise), and (3) evacuate vehicles under certain conditions. (H-71-017)

In a letter dated August 17, 1983, the Safety Board acknowledged that NHTSA had taken action consistent with the intent of the recommendation and subsequently classified Safety Recommendation H-71-017 "Closed--Acceptable Alternate Action."

Special Study of Reduced Visibility (Fog) Accidents -- After the investigation of several fog-related accidents, the Safety Board initiated a special study concerning the issues of limited-

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[9] Highway Accident Report--*Multiple Vehicle Collisions Under Fog Conditions and Fire, New Jersey Turnpike, November 29, 1969* (NTSB/HAR-71/3).

visibility driving conditions.[10] This study looked into the facts and circumstances of the New Jersey Turnpike accident, as well as accidents in Joliet, Illinois, in August 1967 and in Petersburg, Indiana, in November 1969. The Safety Board also convened a special Highway Fog Symposium in August 1971. (See appendix C.)

As a result of the special study and related symposium, the Safety Board found:

(1) The most significant driver-related problem is overdriving one's visual range; this results from the inability and failure of the driver to assess his visual range in fog and to relate that distance to the stopping capability of the vehicle.

(2) There is no national agreement among educators and experts as to specific steps to be taken when drivers enter and operate in a dense fog zone. A need exists to resolve the present controversy over the conflicting advice currently being disseminated concerning driving procedures in fog.

The special study recommendations primarily addressed driver training issues that were eventually incorporated into the NHTSA response to recommendations issued from the following investigation.

San Bernardino, California -- At 7:25 a.m. on November 10, 1980, southbound traffic on I-15 suddenly encountered dense fog north of the Highland Avenue off ramp that reduced visibility to between 0 and 50 feet. Drivers, whose vehicles were traveling 55 mph on the well-maintained eight-lane divided highway, said that the visibility obscurement was immediate and unexpected. Some drivers slowed their vehicles partially as they entered the fog bank and others did not. A tractor-trailer combination vehicle braked suddenly to avoid a small car that changed lanes in front of it, and a pickup truck struck the trailer from the rear. This initiated a chain-reaction collision that involved at least 24 vehicles within 5 to 10 minutes over a 450-foot distance. Nine of the vehicles were tractor-semitrailer units, 2 were full-size pickup trucks, and 13 were passenger cars; all vehicles were extensively damaged. The collisions resulted in 7 fatalities, 2 of whom were struck by a heavy truck outside of their vehicles, and 17 injuries.[11]

The Safety Board determined that the probable cause of the accident was the failure of the drivers of many of the vehicles involved to reduce speed as necessary to be able to stop in distances compatible with visibility severely restricted by dense fog. Contributing to the severity of the consequences was the extremely varied sizes and weights of the vehicles in the collisions.

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[10]Special Study--*Reduced Visibility (Fog) Accidents on Limited-Access Highways, November 15, 1972* (NTSB/HSS-72/04).

[11]Highway Accident Report--*Multiple Vehicle Collisions and Fire in Fog, San Bernardino, California, November 10, 1980* (NTSB/HAR-81/2).

The Arkansas State Crime Laboratory, Medical Examiner Division, conducted postaccident toxicological testing on specimens obtained from the five fatalities. All tests were negative for alcohol except for driver 9, and no drugs were detected except in the codriver's specimen. The blood specimen of driver 9 was found to contain 0.02 percent of ethanol W/V; however, a vitreous humor sample from the same driver was negative for alcohol. This difference indicated, and the Arkansas Medical Examiner also stated, that the alcohol in the blood was of postmortem production. The bacteriological growth in the blood caused it to produce its own ethanol, and the driver had not consumed alcohol. Additionally, the urine specimen from the codriver of vehicle 8 contained cannabinoids (marijuana metabolite); however, no drugs were found in the codriver's blood sample. A positive urine test and a negative blood test indicate no impairment but rather the use of marijuana in the recent past (within about 2 weeks). The codriver's employer had preemployment and random drug testing programs. (The random testing covered 50 percent of the employees each year.) The codriver passed a preemployment drug test, but he had not been tested under the random program in the 10 months he worked for the company.

None of the surviving drivers were required to submit specimens for postaccident toxicological testing. (Though not required, driver 5 was given a postaccident urine test, which he passed.) The FHWA regulations in effect at the time of the accident required toxicological testing of only those drivers from motor carriers with 50 employees or more. The five surviving drivers worked for smaller motor carriers, which will be subject to postaccident testing rules beginning January 1, 1996. These surviving drivers were interviewed by the on-scene police, who found no reason to suspect alcohol or other drug use and, thus, did not have the probable cause necessary to order testing under Arkansas law.

Emergency Response

The accident site was in rural Conway County, where fire protection was provided by 12 volunteer fire departments (VFDs). The county had a disaster plan, and a drill was conducted in November 1994 that concentrated on large numbers of causalities needing transportation and treatment. The disaster plan, however, was not activated because this accident did not fit the definition of a major disaster. The local hospital was placed on alert but was not needed.

An attendant at a local truck stop about 1/4 mile north of the accident site was monitoring channel 9 on the CB radio about 1:50 a.m. He heard calls from the truckdrivers at the scene requesting someone to notify the police and fire departments. The attendant notified the local sheriff's department, and by 1:54 a.m., the dispatcher had notified the State police dispatcher and the Menifee VFD, as well as a private ambulance service in Morrilton. The Menifee VFD was about 1 mile from the accident scene and arrived on scene by 2 a.m. The chief immediately notified the fire dispatcher that several heavy trucks were engulfed in flames and requested mutual aid of fire equipment and personnel from surrounding jurisdictions. The mutual aid first-alarm response consisted of the Hill Creek Fire Department and the Sardis Fire Department. About 10 minutes later, the Hill Creek fire chief, a paid firefighter with the city of Little Rock, assumed command and established an incident command post directly across from the wreckage on I-40 eastbound.

An ASP unit was dispatched at 1:54 a.m. and arrived at 2:06 a.m. Additional police units from the Conway police department and the State police closed a 13-mile section of I-40 between Conway and Plumerville about 10 hours so that traffic could be rerouted onto US-64.

The incident commander stated that an estimated 1,500 gallons of diesel fuel, 100 truck tires, and a truck load of hardware supplies including spray paints, paint thinner, plastic bottles, and other combustible material were involved in the fire. He stated that he immediately requested foam to control the fuel oil and tire fires. About 2500 gallons of foam suppressant, generated from 150 gallons of foam concentrate, were used attempting to control the flames. He later issued a second mutual aid call for additional foam and water tankers. The Springfield, Opello, Overcup, Birdtown, Morrilton, and the city of Conway fire departments responded. The incident commander stated that 50 firefighters responded to the accident scene.

The fire was under control and put out by 4 and 6:30 a.m., respectively. The eastbound lanes of I-40 and one westbound lane were reopened to traffic by 12:30 p.m. Next, an environmental cleanup company began spreading clean soil at the accident site to absorb fuel and other contaminants. The contaminated soil was then removed to an approved hazardous material storage facility. The cleanup and wreckage removal continued until the following day.

OTHER INFORMATION

Other Safety Board Highway Accident Investigations

As part of its mission, the Safety Board routinely investigates nonmajor accidents involving commercial vehicles, school buses, multiple fatalities, and accidents where the road or environment had an effect. It has examined the circumstances of several accidents including either low visibility[7] or low awareness.[8] The Safety Board has found that the same types of low-visibility and low-awareness collisions occur today much as they did 30 years ago and result in similar damage and injuries.

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[7]Low visibility includes fog, rain, snow, smoke, darkness, and other conditions where the driver's ability to see the road environment is somehow compromised.

[8]Low awareness includes those conditions of driver impairment, such as fatigue, where the driver's ability to perceive the road environment is somehow compromised.

As a result, the Safety Board reiterated Safety Recommendation H-71-017 to NHTSA, which was made after the investigation of the 1969 New Jersey Turnpike accident. At the time, the recommendation was classified "Open--Acceptable Action." In addition, the Safety Board also urged NHTSA to:

> Consider the circumstances of this and other similar limited-visibility accidents and develop a strategy. . .to inform motorists faced with adverse, limited-visibility driving conditions about the safest actions to take to protect themselves from injury. (H-81-26)

Safety Recommendation H-81-26 was classified "Closed--Acceptable Alternate Action" in 1983, when NHTSA referred most of the Safety Board recommendations to the States. The recommendation concerning the uniform use of hazard flashers was forwarded to the Operations Subcommittee of the National Committee on Uniform Traffic Laws and Ordinances. It was considered on March 13, 1974, and the subcommittee decided that this was a matter of State responsibility and was not a subject for inclusion in the Uniform Vehicle Code (UVC).

Calhoun, Tennessee -- About 9:10 a.m. on December 11, 1990, a tractor-semitrailer in the southbound lanes of I-75 struck the rear of another tractor-semitrailer that had slowed because of fog. The uninjured truckdrivers exited their vehicles and attempted to check for damage. After the initial collision, an automobile struck the rear of the second truck and was in turn struck in the rear by another tractor-semitrailer. Fire ensued and consumed two trucks and the automobile. Meanwhile, an automobile in the northbound lanes of I-75 struck the rear of another automobile that had slowed because of fog. A pickup and two other automobiles then became involved in a chain-reaction rear-end collision. Subsequently, 99 vehicles in the northbound and southbound lanes were in the collision that killed 12 people and injured 42 others. The accident involved 24 tractor-semitrailer combinations, 6 straight body trucks, 16 pickup trucks, 3 motor homes, 8 vans or special use vehicles, and 42 passenger cars.[12]

The Safety Board determined that the probable cause of the accident was drivers responding to the sudden loss of visibility by operating their vehicles at significantly varying speeds. As a result of the Calhoun investigation, the Safety Board concluded that nonuniform driver response (varying reduction in speed) to sudden limited-visibility situations was a recurring problem. In the absence of specific behavioral guidance, drivers perceived risks differently in sudden limited-visibility conditions. Based upon its investigations and research, the Safety Board determined that accidents during limited visibility are primarily due to varying vehicle speeds in the traffic stream. The Safety Board stated that to prevent multiple-vehicle collisions during such conditions, countermeasures were needed to ensure that drivers proceed through limited-visibility conditions at uniform reduced speeds.

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[12]Highway Accident Report--*Multiple-Vehicle Collisions and Fire During Limited Visibility (Fog), Interstate Highway 75, Calhoun, Tennessee, December 11, 1990* (NTSB/HAR-92/02).

The Calhoun investigation and numerous other past investigations of collisions in low-visibility-driving conditions demonstrated a recurring transportation safety problem of great concern to the Safety Board. As a result in April 1991, the Safety Board convened a special public hearing[13] in Knoxville, Tennessee, concerning fog accidents on limited-access highways to determine how the United States and other countries respond to fog. Sixteen U.S. and European experts discussed countermeasures for fog on highways, driver perception and reaction to fog, and state-of-the art fog sensing and highway-user system warning devices.

After consideration of the public hearing discussions as well as other appropriate research, the Safety Board concluded (in part) that:

> 1. Based on the European limited-visibility countermeasure system experience, a comprehensive U.S. system should include a combination of visibility sensors and traffic flow detectors that automatically activate traffic control devices when hazardous conditions occur or traffic slows.
>
> 2. Weather forecasting is not sufficiently accurate, comprehensive, or timely to predict that fog will form in a specific area.
>
> 3. Based on the accidents discussed in that report, motorists are not provided with sufficient specific behavioral guidance on responding to limited-visibility situations.

As a result of the Calhoun accident and the subsequent public hearing, on October 20, 1992, the Safety Board asked the DOT to:

> Incorporate fog and other limited-visibility condition countermeasures in demonstration projects of the Intelligent Vehicle Highway System [IVHS] program. (H-92-86)

In a letter to the Safety Board dated May 24, 1993, the DOT enclosed a copy of its December 1992 IVHS strategic plan report to the U.S. Congress. In that report, the DOT supports the development of IVHS products and technologies that may prove useful in both urban and rural environments. The FHWA has also approved projects for Georgia and Utah to study adverse visibility warning systems.

In its letter dated June 25, 1993, the Safety Board acknowledged that the FHWA had produced functional specifications for sensing fog and other visual restrictions and that it was about

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[13] *Proceedings, Special Public Hearing - Fog Accidents on Limited Access Highways,* 1992 (NTSB/RP-92/01).

to test an array of commercially available sensors. Pending further response from the DOT, Safety Recommendation H-92-86 is classified "Open--Acceptable Response."

Additionally, the Safety Board made several recommendations to the appropriate agencies to review and update remedial training material to ensure that guidance for driving in limited-visibility conditions is uniform and complete. These recommendations are discussed in the following text.

The Safety Board urged the FHWA, NHTSA, the American Association of Motor Vehicle Administrators (AAMVA), the American Automobile Association (AAA), and the American Driver and Traffic Safety Education Association in Safety Recommendations H-92-88 and -89, H-92-94, and H-92-96 and -97, respectively, to:

> In cooperation, review and update driver license, educational, and remedial training materials to ensure that guidance for driving during limited-visibility conditions is uniform and complete and is included in commercial driver license materials.

On February 6, 1995, Safety Board staff met with the AAA director of highway transportation. The AAA has taken the lead to review and update driver license, educational, and remedial training materials for driving during limited-visibility conditions. In the latest edition of its manual *How To Drive*, the AAA gives specific instructions and questions on adverse driving conditions and emergencies. Additionally, the AAA Foundation for Traffic Safety, in coordination with industry groups, has developed the video *Driving in Bad Weather*. Using the setting of a television newscast, this video dramatizes the blinding effects of fog, dust, smoke, rain, snow, and ice. It stresses the need either to slow down to maintain control or to get off the road safely in adverse conditions. Based on the information provided by the AAA, Safety Recommendations H-92-88 and -89, H-92-94, and H-92-96 and -97, were classified "Closed--Acceptable Action."

The Safety Board also asked that NHTSA and the AAMVA, respectively,:

> In cooperation with the American Association of Motor Vehicle Administrators, develop model test questions for licensing examinations on driving during limited-visibility conditions. (H-92-90)

> In cooperation with the National Highway Traffic Safety Administration, develop model test questions for licensing examinations on driving during limited-visibility conditions. Provide this infoımation to your members for inclusion in driver manuals. (H-92-95)

On May 24, 1995, Safety Board staff met with AAMVA members. All State driver's manuals, to date, contain the sections "Special Driving Situations" that emphasize driving in rain or fog, and expressway, night, winter, and emergency driving. Model test questions for licensing examinations have also been developed. For commercial drivers, the newly revised CDL manual (version 2.0) and the CDL license tests (version 2.0) contain information and test questions on driving during limited-visibility conditions. Based on this information, Safety Recommendations H-92-90 and -95 have been classified "Closed--Acceptable Action."

The Safety Board urged the FHWA to:

> Following completion of the National Cooperative Highway Research Program Project 20-5, Topic 23-12, "Reduced Visibility on the Highway," ensure the continued development of effective fog and other limited-visibility countermeasures and make information about these countermeasures available to States on a timely basis. (H-92-87)

In a letter dated March 29, 1993, the FHWA indicated that it was working with the National Cooperative Highway Research Program in assessing the applicability of fog countermeasures to other factors contributing to reduced visibility.

The Safety Board noted in its June 11, 1993, letter that a comprehensive system of limited-visibility countermeasures should be based on detecting traffic flow disruption and providing drivers with specific behavioral guidance. A program of engineering, education, and enforcement is needed to cope with the limited-visibility problem. Pending further response from the FHWA, Safety Recommendation H-92-87 is classified "Open--Acceptable Response."

Other recommendations that resulted from the Calhoun investigation and public hearing addressed the development of road-based countermeasures. Those countermeasures are designed primarily for situations where fog occurrence is somewhat predictable and not necessarily for situations of randomly appearing fogs of short duration in rural areas. Because the Menifee investigation involved the latter type of fog occurrence, another lengthy discussion of road-based countermeasures would not contribute to this report. The issue of vehicle-based countermeasures was briefly discussed during the 1991 public hearing.[14] Since that time, significant progress has been made in the development of this mobile collision warning technology.

Bakersfield, California. -- On July 27, 1993, a tractor-semitrailer crashed into traffic that was slowing or stopped near a construction work zone. According to witnesses and from physical evidence, the truckdriver did not attempt to slow his truck or take other evasive actions. Subsequently, seven vehicles were involved in the chain-reaction collision, and a fire ensued. Nine people were fatally injured, and nine others received minor injuries.

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[14]For a complete discussion of road-based low-visibility collision countermeasures, see *Multiple-Vehicle Collisions and Fire During Limited Visibility (Fog) on Interstate 75 Near Calhoun, Tennessee, December 11, 1990* (NTSB/HAR-92/02) and *Proceedings, Special Public Hearing, Fog Accidents on Limited Access Highways*, (NTSB/RP-92/01).

Weatherford, Texas -- On July 3, 1994, a tractor-semitrailer ran into the rear of a slow moving van. A fire subsequently ensued, and 14 van passengers were fatally injured. The Safety Board found that the truckdriver was fatigued at the time of the crash.

Fairfax, Minnesota -- On December 23, 1994, a tractor-semitrailer, traveling in heavy fog at an estimated 55 mph, was unable to stop for a school bus loading children at the side of the road. The tractor jackknifed and struck three children of whom one was fatally injured and two received serious injuries. The school bus had flashing lights and a top-mounted strobe light activated at the time of the accident.

Mobile, Alabama -- On March 20, 1995, a series of multiple-vehicle collisions occurred in heavy fog on the bayway of I-10 near Mobile. Of the 169 vehicles involved, 17 were tractor-semitrailer combinations and the remaining vehicles were straight trucks, passenger cars, vans, and pickups. One fatality and 71 injuries of varying severity resulted. A 40-vehicle collision had also occurred at this location in October 1992.

In each of the four accidents described above, the driver's responsiveness to the preceding vehicles was affected by either low visibility due to fog or low awareness due to either fatigue or distraction.

Investigative Conference and Related Research

As a result of the Menifee accident and similar accidents investigated over the last 30 years, the Safety Board researched available and future technologies that might be effective in preventing or otherwise reducing the severity of rear-end collisions. The Safety Board sponsored the investigative conference Mobile Collision Warning Technology for Low Visibility/Low Awareness Collisions on April 4 and 5, 1995, in Arlington, Virginia. (See appendix A for agenda.) Representatives from Government, academia, and the transportation industry participated.[15]

This conference focused on vehicle-mounted technologies that could alert vision-restricted or inattentive drivers to impending hazards. The technologies discussed ranged from low-tech improvements in lighting and reflective tape to high-tech radar and laser collision warning systems. A foundation for the discussion of the effectiveness of these technologies was provided by lectures in the areas of human performance and perception, as well as the physical nature of fog, rain, and other atmospheric conditions that affect driver perception and performance.

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[15]A copy of the conference transcript may be obtained from Capital Hill Reporting, 1825 K Street, NW, Washington, DC 20006; telephone: (202) 466-9500.

The information presented in the following sections of this report is summarized from materials presented at the conference and related research. Supplementary information, provided from other sources, is footnoted.

Rear-End Accidents – Statistical evidence indicates that the vast majority of rear-end accidents occur during conditions of daylight, clear weather, and dry roads and can most often be attributed to low driver awareness (inattention or following too closely). Research,[16] conducted by NHTSA using 1990 data, summarizes the problem of rear-end accidents as follows:

Approximately 1.5 million rear-end crashes with 2,084 fatalities and 844,000 injuries, of which 68,000 were serious or incapacitating, were reported by police.

The lead vehicle was stopped (LVS) and the lead vehicle was moving (LVM) in 70 and 30 percent of these crashes, respectively.

Rear-end crashes constitute about 23.4 percent of all police-reported crashes as well as about 4.7 percent of all fatalities.

Eighteen of every 100 vehicles on U.S. highways will be involved in a rear-end crash during their operational life.

A truck tractor, operating as a combination unit, is more than three times as likely to be involved in a rear-end collision during its operational lifetime than a passenger vehicle is.

A rear-end accident that involves a combination unit as a striking vehicle is 12 times more likely to result in a fatal injury than a rear-end accident that involves only passenger vehicles.

A rear-end accident that involves a combination unit as a struck vehicle is 31 times more likely to result in a fatal injury than a rear-end accident that involves only passenger vehicles.

Nonpolice reported rear-end crashes are an estimated 1.76 million per year.

Rear-end crashes result in about 144 million vehicle hours of delay annually and are responsible for about a third of all crash-caused highway delays.

The most common causal factors in rear-end collisions were driver inattention and following too closely, representing 93 percent of the clinical sample.

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[16]Two-volume report released in May 1993: *Rear End Crashes: Problem Size Assessment and Statistical Description* (DOT HS807 994) and *Assessment of IVHS Countermeasures for Collision Avoidance: Rear End Collisions* (DOT HS807 995).

Catastrophic fog-related accidents often involve a number of passenger vehicles, multiple fatalities, and heavy trucks; however, fog-related accidents are a relatively small portion of the rear-end accident problem.

Fog-related fatal crashes constitute about 0.5 percent of all rear-end crashes and about 1.5 percent of all rear-end fatal crashes.

Most fog-related crashes are single vehicle, followed by angle collisions and rear-end crashes.

Thirty-four percent of all fog-related crashes occur between midnight and 6 a.m.

Fifty-six percent of all fog-related accidents occur on roads with speed limits in excess of 40 mph.

More fog-related crashes occur on wet roads than on dry roads. Not only is visibility limited, but stopping distance is increased.

Large trucks involved in fog-related crashes are more often the struck vehicle than the striking vehicle.

Low-Visibility Accidents[17] -- Few rear-end accidents occur under conditions where a fully attentive driver is operating his vehicle in conditions of limited visibility, and that limited visibility becomes a primary factor in the accident sequence. From a human performance perspective, a driver involved in such a limited-visibility accident is often described as traveling too fast for conditions by overdriving his effective visual range of the road ahead.

> What happens to the driver in this limited visibility? It's good and bad news. The good news is that stress goes up. For long duration that's bad, but for short duration, high stress is good. The amount of attention that we allocate to the task goes up and therefore reaction time is faster. The bad part is that vision is impaired. Drivers know that they see less. The question is how much do they think they see less relative to how much they are actually seeing less.[18]

To operate a vehicle safely in conditions of limited visibility, the driver is expected to (1) accurately estimate both his effective visual range and the distance necessary to stop his vehicle under the prevailing frictional capabilities of the road and (2) slow his vehicle to a speed that would

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[17]This section contains summarized testimony of David Shinar, Ph.D., and Raymond Lee, Ph.D., taken at the April 1995 conference.

[18]David Shinar, Ph.D.

allow him ample time to react and initiate steering response or stop before striking a hazard that may appear in his path.

However, in conditions of limited visibility, drivers actually react somewhat differently. They (1) tend to focus on the road edges as guideposts, paying less attention to determining a clear headway; (2) may not be intuitively capable of making accurate visual range estimates and stopping-distance calculations; and (3) tend to reduce their speed only incrementally.

Therefore, electronic collision warning technology, namely forward looking radar, can serve an important function not only by increasing the situational awareness of a distracted or inattentive driver but also by alerting a fully attentive driver to hazards hidden from his visual range due to low-visibility conditions. The use of certain types of low-tech countermeasures, such as increased vehicle lighting and retroreflective material, in reduced-visibility situations may also increase driver visual range under adverse conditions.

To discuss the effectiveness of various collision avoidance technologies in dealing with conditions of limited visibility, those conditions that create limited visibility must be defined. Limited-visibility conditions will most often take place in one of the following categories: darkness, fog, heavy snow, or rain. The discussion will include a general description of the physical properties of each medium and the manner in which those properties affect human perception.

Darkness -- All road vehicles are generally required to be operated with lights between 1/2 hour after sunset and 1/2 hour before sunrise. Under clear weather conditions, the average driver will generally be able to perceive other lighted vehicles with ample opportunity to react to any hazard presented. Therefore, all night time accidents under clear weather conditions do not necessarily involve an element of reduced visibility. However, the visibility of vehicles during the hours of darkness may become a factor in an accident sequence when 1) the hazard vehicle is unlit or inadequately lit, 2) disguised by similar background lighting, or 3) not lit in a manner to allow pattern recognition on the part of an approaching driver, or 4) the approaching driver has visual deficiencies in night vision, color vision, and/or depth perception.

Fog -- For surface transportation, fog may be defined as a cloud in contact with the ground. The water droplet radii in that cloud may range from 10 to 100 micrometers (1,000 micrometers is a millimeter). These are very small water droplets. Per the international definition, haze or mist becomes fog when visibility is reduced to less than 1 kilometer (.621 mile). However, fog may not become a ground transportation problem until visibility is reduced to within 500 to 1,000 feet, depending upon highway speeds and vehicle stopping and handling characteristics.

Fog results like other clouds from either mixing air with different temperatures and relative humidities or cooling air to its dewpoint. The kinds of fogs most inhibiting to surface transportation visibility are those fogs that form in valleys, very often where cool air flows down from higher elevations. When that cool air reduces the temperatures below the dewpoint temperature, reaching 100-percent relative humidity, fog is created.

How does fog affect incident illumination, whether daylight, headlights, or fixed lighting? Figure 3 illustrates light interaction with a single water droplet. Molecules and particles of any kind will scatter light waves or photons, changing their direction of travel. Larger particles will scatter more light. Scattering by a single water droplet, such as those that constitute fog, will peak in the forward direction (away from the light source). Most light energy is scattered in the forward direction away from the light source with a significant few scattered off to the side in a rainbow effect as well as back toward the light source.

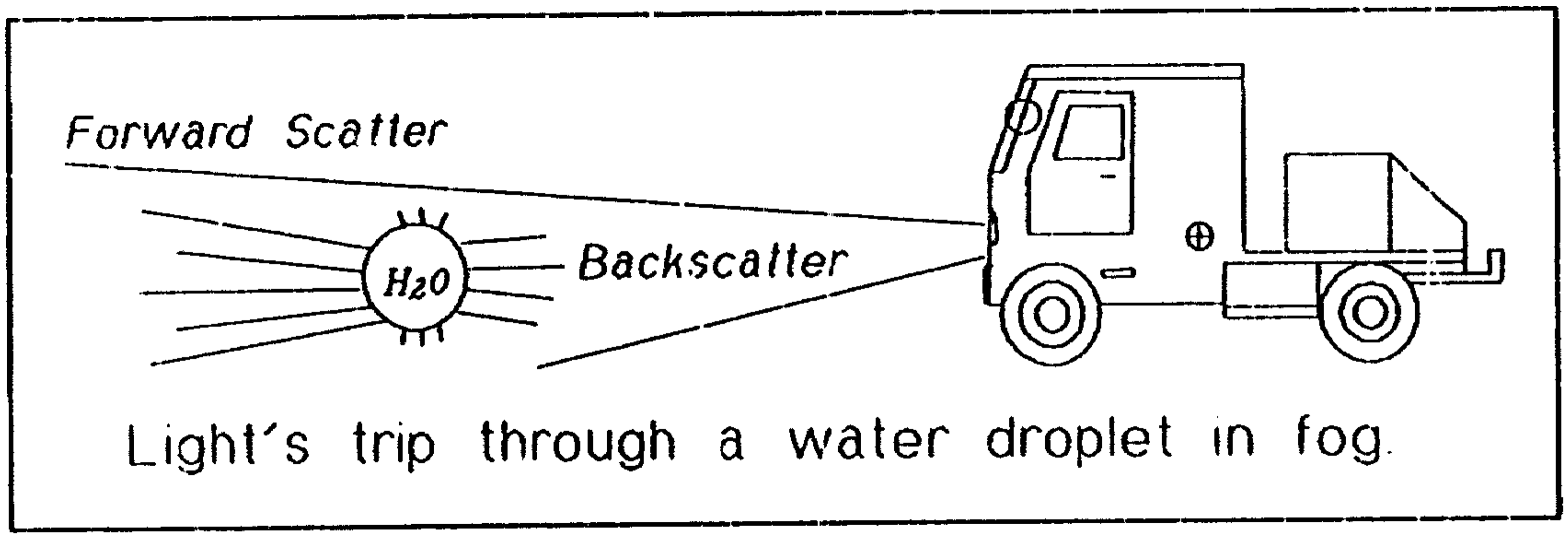


Figure 3. -- Water droplet effect on light transmission.

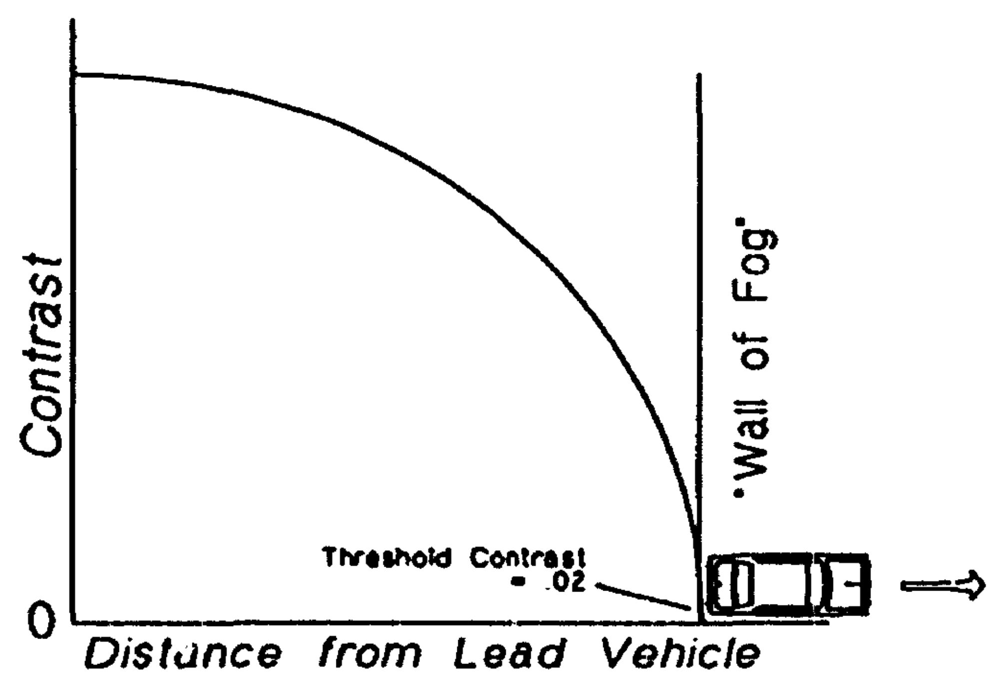
Smaller drops scatter more in the backward direction proportionally compared with larger drops; hence, fog with smaller drops restricts driver visibility more at night because more of the headlight luminance is scattered back towards the driver. The trip of each photon through a fog bank involves many collisions and reflections. Referred to as multiple scattering, it will eliminate any spectral selectivity or rainbow effect due to single scattering. So the effect is: when you put white light in, you get white light out; when you put red light in, you get red light out. The color of the light does not affect its ability to penetrate fog.

Drivers are close to headlights, angularly speaking, and, thus, see the backward scattering peak of light striking water droplets, which is the consequence of single scattering. Therefore, low beam lights aimed down at the road are preferable to high beam lights in heavy fog. Driver perception can be enhanced by raising the driver's eye to the greatest height possible above the headlight source. Therefore, fog lights mounted at road level may provide additional visual range when compared with headlights mounted normally. Drivers of large trucks have an advantage because they sit high above the road and the lights of their own vehicle, as well as the lights of approaching vehicles. Conversely, small sports cars can be severely "fog challenged," according to Dr. Raymond Lee.

Multiple light scattering reduces transmission of the headlight beam and, thus, the ability to illuminate objects effectively. However, it is not the absolute level of light on an object that matters. It is the conspicuity or contrast of that object with its surroundings. Multiple scattering by fog increases the luminance of objects within the light beam and the luminance of their surroundings. Such increased luminance might sound as if it would aid visibility, but because visual detection depends upon some distinct luminance difference between an object and its surroundings, the contrast is actually reduced, particularly in daylight.

The least dense fog, in which visual range equals 1 kilometer, extinguishes light 50 times as rapidly as clear atmosphere. The fogs that cause accidents, in which nominal visibility is 500 feet or less, impose a severe penalty on headlight or taillight luminance transmission through the atmosphere.

Light transmission through fog of a given density is reduced exponentially with distance from the light source. (See figure 4.) Therefore, the driver may perceive that the visual range created by his headlights suddenly hits a "wall of fog" ahead when the fog is of relatively uniform



Contrast in daylight fog is reduced exponentially with distance, giving an impression that a vehicle suddenly appears from a 'wall of fog.'

Figure 4. -- Illustration of the "wall of fog" effect.

density. Likewise, as its contrast with surroundings becomes suddenly perceptible, an object hidden by the fog may often seem to suddenly appear from nowhere. Fog may also significantly affect driver depth or distance perception. Objects that appear hazy under normal conditions can be interpreted as far away. Therefore, the presence of fog may either cause drivers to misjudge following distances and closing speeds or cause delayed reactions to the perceived threat of a road hazard.

Snow -- Heavy snow can often reduce visibility to less than 500 feet, particularly under conditions of strong winds and blowing surface snow. Anecdotal evidence suggests that accidents involving limited visibility in snow are often associated with one vehicle passing another, such as a snow plow or heavy truck, where surface snow is thrown into the visual field of the passing driver.

Headlight use during heavy snow at night can create a blinding glare. White-out conditions, whether from snow or fog, create a homogenous visual field. When driving under white-out conditions with little or no external stimuli, the world outside the windshield starts to fade even should something be there to be seen. Eliminating moving contours from the visual field may also eliminate perception of both form and color; colored lights become invisible.

Rain -- Driver visibility during rain depends primarily on the rainfall rates and type, which determine the number and sizes of raindrops within a driver's line of sight. Scattering by rain and the fog often found with rain can reduce contrast and degrade visual range.

Windshield blurring also affects driver visibility. In moderate to heavy rainfall, the smooth outer surface of the windshield changes to an irregular wavy one. This change causes the driver to look through a water-distorted lens, which is only partially ameliorated by the windshield wiper action.

Another problem associated with driver visibility in rain is reflectivity. Because forward scattering is increased during rain, reflectivity of the road and its surroundings is reduced. On an absorbing surface such as asphalt, or to a lesser extent concrete, the projected light bounces off the surface at an angle in a mirror-like effect and not back at the driver; thus, the road surface becomes less visible.

Furthermore, retroreflective paints are seriously degraded in wet weather conditions because the tiny glass beads imbedded in the paint are immersed in a thin film of water. This phenomenon is similar to seeing a clear drinking glass in a sink filled with clear water, which is significantly more difficult than seeing the same glass on the counter. The refractive index of glass and water is closer than the refractive index of glass and air.

Backscattering by raindrops reduces contrast. Headlight luminance transmitted in any direction is reduced by raindrop scattering, meaning that the total amount of light reaching objects is less (see figure 3). Specular or mirror-like reflections from the road will increase markedly, which increases the glare and driver distraction.

Rain may provide some limited benefit because some light is reflected forward by the mirror-like road surface, thus providing greater illumination to objects and pedestrians on or near the road. However, the moderate increase in illumination to objects and pedestrians is more than offset by the sudden appearance of very bright glare from street lights and oncoming vehicles, an effect absent in dry pavement conditions.

Low-Awareness Accidents -- The mobile collision warning conference addressed some of the factors that affect a driver's ability to easily see or notice an object or highway hazard. These factors, including size, color, motion, pattern, illumination, contrast, and location within a driver's field of vision, differentiate an object from its background. The measure of the tendency for an object to be easily seen, or be conspicuous, is conspicuity.

However, conspicuity does not refer simply to the physical state of an object or hazard but has another component. For the hazard to be perceived, it must be filtered through the senses and past experiences of the driver. Conference speaker Dr. David Shinar reported, "Conspicuity is not a true physical measure. It's a psycho-physical measure because it relates physical parameters to a psychological phenomenon. There is a tremendously big cognitive component in conspicuity."

That cognitive component includes perception and interpretation of information as well as a decision on how to react to it. These three actions occur in sequence. If perception is lacking, an interpretation and a decision cannot take place. Similarly, for perception to occur, attention must be attracted first. A driver can begin the process that leads to addressing a hazard only when that individual attends to sensory input.

Inadequate sleep can reduce or eliminate sensory input, thereby precluding both attention and the factors noted above that enhance conspicuity. The Safety Board described the effects of sleep in its analysis of crew fatigue in the AIA Guantanamo Bay aviation accident report (NTSB/AAR-94/04). The report stated that:

> sleep is a vital physiological need. When an individual is deprived of food and water, the brain provides specific signals - hunger and thirst - to drive the individual to meet these basic physiological needs. Similarly, when deprived of sleep, the physiological response is sleepiness. . . . Eventually, when deprived of sleep (acutely or chronically), the human brain can spontaneously, in an uncontrolled fashion, shift from wakefulness to sleep in order to meet its physiological need for sleep. The sleepier the person, the more rapid and frequent are the intrusions of sleep into wakefulness. These spontaneous sleep episodes can be very short (i.e., microsleeps lasting only seconds) or extended (i.e., lasting minutes). At the onset of sleep, an individual disengages perceptually from the external environment, essentially ceasing to integrate outside information. . . . A microsleep can be associated with a significant performance lapse when an individual does not receive or respond to external information. With sleep loss, these uncontrolled sleep

episodes can occur while standing, operating machinery, and even in situations that would put an individual at risk, such as driving a car.

Another previous Safety Board report (NTSB/RAR-89/02) noted that "just before and just after [a microsleep], the person will perform quite well: during [a microsleep], he does not perform at all and will not respond to external stimuli unless they are massively sensory in nature, very unusual, or particularly meaningful."

Electronic collision warning technology can serve an important function in focusing driver awareness on those obstacles that are already fully visible and in encouraging drivers to follow at a safe distance. The driver may then take effective evasive action, if necessary.

Enhanced Driver Detection of Obstacles[19]

Retroreflective Tape and Paint – Retroreflective tape and paint treatments are required on all trailers manufactured after December 1, 1993, and are designed to (1) make the trailer conspicuous at night and (2) provide a pattern of reflection that suggests the size and shape of the vehicle. These aspects of enhanced visibility and pattern recognition help drivers judge their speed and distance on approach. Regulations were created with attention to making installation of this particular treatment inexpensive, using as little material as possible while still accomplishing the goals of accident reduction.

An important characteristic of retroreflective tape and paint permits portions of a headlight beam to reflect directly back toward the source of the light, thus allowing the driver to see the obstacle more clearly. Therefore, even a large angle between the light source and the plane of the retroreflective material on the truck will still let an approaching motorist perceive the hazard.

Tests of retroreflective material on the clothing of pedestrians demonstrate the value of pattern recognition. Test subjects wearing retroreflective tape outlining the skeletal frame, such as shoulders, arms, and joints, were more quickly and effectively recognized than those wearing clothing simply adorned with retroreflective tape in no particular pattern. Drivers recognized the human form as a potential hazard and were able to judge distance and closing speed more easily as a result of the relative size of the form.

This same principal works, according to Dr. David Shinar, when applying retroreflective tape and paint to vehicles. Installation of this treatment on a box trailer is comparatively simple. As a minimum, the rear of the trailer must be marked at the bottom and corners. Studies have shown

[19] The following section contains testimony of Pat Boyd, David Shinar, Ph.D., and Raymond Lee, Ph.D., taken at the April conference.

such treatment to be effective in enabling drivers to judge distance just as well as the more expensive treatment of surrounding the whole rear profile with this material.

Other types of trailers, including tankers and flatbeds, require greater flexibility in placement. The Federal regulations were written to allow a common sense implementation on any kind of trailer.

NHTSA pilot studies, tracking the 2-year accident experience of treated vehicles, have concluded that retroreflective treatment can reduce side accidents by 15 percent and rear-end accidents by 15 to 25 percent. NHTSA is unaware of any studies evaluating the use of retroreflective materials in fog, snow, or other adverse conditions. Even though the effectiveness of retroreflective treatment would be degraded in fog, some additional margin of safety should be provided compared with a nontreated surface.

Vehicle Lighting -- The increased luminance of hazard flashers increases visibility about 50 percent over taillight use alone. The low beams of an oncoming vehicle can be seen at more than twice the distance of mere taillights. As the fog bank density increases, nominal visibility decreases and the visibility of various vehicle lights decreases proportionately.

The use of fog lamps on the rear of trailers has been discussed in some NHTSA reports of the late 1970's. However, the idea apparently did not gain any momentum. The Society of Automotive Engineers (SAE) rear fog lamp specifications were precisely the same photometrically as specifications for stop lamps. Also, the turn signal and hazard signal have the same brightness specification as both stop lamps and rear fog lamps.[20]

The use of hazard flashers on vehicles in fog could have as beneficial an effect for hazard perception as separate fog lamps on the rear of vehicles, which might mask brake lights. However, a 50-State Safety Board telephone survey (see appendix D) found that although 4 States require hazard flasher use in low-visibility conditions, at least 6 States prohibit their use on moving vehicles.

Many States restrict hazard light use to situations such as heavy trucks ascending hills, traveling below minimum speeds on interstate or secondary highways, or being stopped or disabled along the shoulder of the highway. Most States do not address the use of hazard flashers in low-visibility conditions. The 1992 edition of the Uniform Vehicle Code[21] section 12-215 suggests the following:

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[20]Title 49 CFR 571.108 specifies that stop and red turn-signal lamps, in single lighted sections, must emit no less than 80 and no more than 300 candlepower. Tail lamps are required to emit between 2 and 18 candlepower.

[21]The *Uniform Vehicle Code* is a specimen set of motor vehicle laws that is designed and advanced as a comprehensive guide or standard for State motor vehicle and traffic laws. It reflects the need for uniformity in traffic regulation throughout the United States and, to this end, serves as a reliable, contemporary guide for use by State legislatures.

(f) The driver of any vehicle equipped with vehicular hazard warning lights may activate such lights whenever necessary to warn the operators of following vehicles of the presence of a traffic hazard ahead of the signaling vehicle, or to warn the operators of other vehicles that the signaling vehicle may itself constitute a traffic hazard. (NEW, 1986)

(g) The driver of a truck, bus, or truck tractor pulling a trailer or trailers, equipped with vehicular hazard warning lights may activate such lights when that vehicle is proceeding up a grade, or under other conditions requiring it to be operated at a speed less than the prevailing speed of traffic. (NEW, 1986)

Representatives of Motor Coach Industries[22] (MCI) indicate that some consideration might be given to wiring the overhead rear brake light on their buses into the four-way emergency flasher system. This modification was suggested to provide the driver who was overtaking with additional warning and some size concept of the vehicle that was being overtaken.[23] The Safety Board found no records of past research in this area.

Strobe lights of approximately 200 candela have been mounted on the top and rear of some school buses around the country and are activated when the vehicle is moving. Similarly, strobe lights have been used on rail locomotives. During a visibility test[24] for conspicuity on locomotives, test subjects reported the strobe lights to be "readily visible and attention getting." A 1980 study[25] with three railroads indicated fewer accidents for the strobe-equipped locomotives; however, the limited sampling and operating environment precluded national inferences. The value of such lights is also uncertain in highway transportation applications. The Safety Board knows of no conclusive studies about the effectiveness of these lights in clear weather or in fog and other limited-visibility conditions.

High-intensity forward-facing fog lamps or high-intensity narrow-beam head lamps have been discussed as a possible low-tech solution. However, the reflective nature of fog suggests that even greater backscatter would result, providing more glare to the driver, as when high beams are currently used in a fog bank. Furthermore, the forward projection of the high-intensity beam would

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[22]Manufacturers of the MCI motor coaches.

[23]April 1995 mobile collision warning technology conference, Norm Littler, MCI.

[24]D.B. Devoe and C.N. Abernathy, *Field Evaluation of Locomotive Conspicuity Lights.* Prepared for Federal Railroad Administration, U.S.D.O.T. by RSPA/TSC, U.S.D.O.T., Final Report, Report No. FRA-OR&D-75-54, May 1975.

[25]J. B. Hopkins, *Operational Testing of Locomotive-Mounted Strobe Lights*, Prepared for the Federal Railroad Administration, U.S.D.O.T. by RSPA/TSC, U.S.D.O.T., Interim Report., Report No. DOT-TSC-FRA-80-48, June 1980.

render little additional headway visibility because of the fog "wall affect." A more practical solution to seek, according to Dr. Raymond Lee, is one in which the lead vehicle transmits a higher intensity light rearward, traveling only one way to the receiver, rather than attempting to project a high-intensity beam from the following vehicle that must be reflected and returned to the following driver.

Citizens Band Radios -- According to trucking industry sources, approximately 97 percent of all heavy trucks traveling interstate highways are equipped with CB radios. Many truckdrivers routinely use their CB radio to receive and transmit information concerning hazards that might lay ahead, and channel 19 is primarily used for vehicle-to-vehicle communications. Many emergency services providers also routinely monitor the CB channels, and channel 9 is reserved for emergency communication. On flat land, with the legally permissible 5 watts of power, a range of 5 miles or more is normally expected. Seven of the eight truck tractors in the Menifee accident were equipped with CB radios.

Trucking industry representatives at the Safety Board's April conference supported enhanced driver communication as an effective means to warn drivers of local fog and other visibility-related issues. However, truckdrivers have found that the common CB channel airwaves are often overcrowded, thus reducing the effectiveness of the CB radio to warn other truckers and motorists of road hazards ahead.[26]

Some CB radios currently in production have an override switch that when activated, causes any transmission made on emergency channel 9 to automatically override reception of other channels. This feature has been made available to police and emergency response providers; however, no information is available about the number of CB radios currently in operation that have this feature.[27]

A Federal Communications Commission (FCC) official indicated that the FCC sees some merit in encouraging a channel 9 override as standard equipment on CB radios to enhance highway safety. The FHWA is currently considering a number of frequencies for Intelligent Transportation System (ITS) technology, some of which could be used more effectively for emergency communication on the highways than the current CB frequencies.[28]

The Safety Board reviewed literature to identify IVHS products, prototypes, and experimental collision warning systems that can be mounted onboard vehicles. Probably the most

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[26]Information provided by trucking industry speakers at the mobile collision warning technology conference.

[27]Information provided on June 19, 1995, during discussions with Mac Slayton, Manager of Regulatory Affairs for the Tandy Corporation.

[28]Information provided on June 19, 1995, during a telephone discussion with Dr. Mike Marcus of the FCC.

complete discussion of the developing technologies was found in a 1994 DOT-sponsored study[29] that categorized and briefly described countermeasure technologies for many crash types (not just rear-end crashes). Many similar products were presented in chart form for easy review and comparison.

Forward Looking Sensor Technologies -- FLSs operate in a wide range of frequencies:

Laser Radar
Near-Infrared (NIR) = 0.753 - 3 mm

Wave Radar
Microwave (m-wave) = 1 - 30 GHz
Millimeter-wave (mm-wave) = 30 - 300 GHz

Wave Radar-Based
Radar sensors, operating in various modes of transmission, include:

- -pulse,
- -pulse doppler,
- -frequency modulated continuous wave (FM-CW),
- -binary phase modulation using maximal-length pseudonoise (PN) code sequences, and
- -pulse frequency modulation (PFM).

Manufacturer field testing found that side lobes of a 50 GHz FM-CW radar beam would often sense roadside objects. Rainfall did not significantly decrease the effectiveness of sensors. Some missed targets occurred at the beginning and end of a vertical curve in the road.

Laser-Based Sensors -- Laser sensors (optical radar) filter out false alarms using honeycomb and infrared (IR) filters. A sensitivity time control circuit filters out fog and road surface reflections in the near field below the sensitivity of the laser receiver. Detection performance is degraded due to dirt on the receiver, heavy rain, thick fog, and car exhaust. One tested unit sustained a 30-percent decrease in range because of rain in the atmosphere and on various surfaces, including the reflectorized surfaces of the lead vehicle. Other field tests indicated that a narrow beam FLS laser lost track of targets over 60 meters due to vehicle pitch and roll.

Laser systems using passive transponders (tagging) on the rear of vehicles display some advantages. Transponder-mounted vehicles were detected at a range up to 150 meters. However, vehicles with damaged transponders and nonequipped obstacles can not be detected.

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[29] Wassim G. Najim, Ph.D., *A Review of IVHS Crash Avoidance Technologies*, Volpe National Transportation Systems Center, Cambridge, Massachusetts, March 1994.

Intelligent Cruise Control Systems -- The discussed radar-based technologies can be used to monitor and to maintain a safe following distance behind a lead vehicle or to maintain a predetermined cruise control speed when no vehicles or obstacles are detected in the path of the equipped vehicle. Four ICC systems, three using laser and one using wave radar technology, can be operated in an automatic mode that provides direct vehicle control through both the throttle and braking or in an informative mode that provides only information and recommendations to the driver.

Headway Detection System Technology -- The DOT concluded, low-tech measures aside, that the most applicable rear-end collision countermeasure concept was a headway detection (HD) system.[30] HD systems electronically monitor the dynamic relationship, including relative distance and velocity, between equipped vehicles and other vehicles or objects in their forward paths of travel as well as provide audio and visual warning to the driver when a potential hazard is detected.[31]

Current HD systems use one of two primary competing technologies, either radar or laser, to detect obstacles in a vehicle's path. The older of the two technologies, radar is more correctly described as microwave/millimeter wave radar. The newer laser technology is actually active laser radar and functions using a highly concentrated light frequency.

The leading HD technologies are radar and laser; however, other HD system technologies have been developed. Ultrasonic and infrared systems offer low cost but have lessened degrees of target discrimination and of effective range. Also under development, video technologies are deficient in weather and darkness penetration capabilities and are high in cost.

Both radar and laser HD systems include a transmitter on the following vehicle that emits electromagnetic energy in the direction of the lead vehicle. A portion of this energy is reflected from the lead vehicle and intercepted by a receiver on the following vehicle. The receiver measures the two-way transit time between vehicles to determine the between-vehicle range or distance as well as the frequency shift (Doppler shift) in the reflected beam to determine the relative velocity between vehicles.

The optimal HD system technology depends on the details of the particular safety application. The range and performance characteristics of both radar and laser technologies under clear weather conditions are very similar. However, wave radar has the advantage of being able to

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[30] *Assessment of IVHS Countermeasures for Collision Avoidance: Rear End Collisions* (DOT HS807 995) May 1993.

[31] An electronic collision warning system, as used in this report, is designed to warn the driver of an impending collision if action is not taken. An HD system is a collision warning system specific to the forward path of the vehicle and not inclusive of systems that would warn of lane change or backing hazards. An electronic collision avoidance system, as used in this report, would not only detect a possible hazard and warn the driver, but it would initiate automatic steering or braking to avoid the obstacle.

penetrate fog, smoke, and precipitation to provide even the alert driver with advance collision or hazard warning of objects that could not be visually detected. Laser beam frequencies are more readily reflected by atmospheric particulate such as fog, smoke, and precipitation, and these frequencies are therefore ineffective to provide the driver with warning beyond that provided by his own visual sense. A dirty sensor will likewise severely affect the laser system operation. False warnings may also be created by sunlight shining directly into the laser receiver at sunrise and sunset or being reflected from shiny surfaces.

The negative effects of atmospheric reflectivity on laser beam transmissibility may be offset by a limited-visibility warning. When the laser beam fails to penetrate the atmosphere sufficiently to allow for an adequate collision warning, a low-visibility warning can be issued directing the driver to reduce his speed to an acceptable level at which the laser could detect a hazard in sufficient time for the vehicle to avoid the collision. Proponents of laser technology point out that this type of laser warning system may in some circumstances be more effective in heavy fog than wave radar. Because the driver would not be as inclined to over drive his visual senses through compensatory risk taking behavior, any collisions that do occur would hopefully be at a much lower speed than a vehicle not so equipped.

Laser technology may have some advantage over radar technology, particularly in the early stages of production, as radar beam technology may be more expensive to produce than laser-based systems. However, radar manufacturers claim that market penetration and large-scale production will make radar technology cost competitive with laser technology.

Three HD systems either under development or in production (specified as A, B, and C) are discussed below.

System A -- This radar-based system, currently under production, is designed for use in commercial vehicles and includes a transmitter that emits microwave energy (24.725 GHz) along the headway of the vehicle. A portion of this energy is reflected from road obstacles and intercepted by an antennae mounted behind the grill or on the front of the vehicle. The frequencies received are analyzed by a central processing unit generally mounted in the cab of the vehicle.

Visual and audible warnings are issued to the driver when an obstacle is sensed in the driver's travel path. The visual warnings are communicated through a light display mounted on the vehicle dashboard. During the original manufacturing of the vehicle, in-dash mounting of the light display can be installed.

Large obstacles in the road, such as the rear of a trailer or other full size vehicle, may be detected at 600 feet or more, at which time a yellow detection light is displayed as a nonintrusive driver advisory. Depending upon the system software specified by the purchaser, a visual and/or audible alarm may be sounded at a following or closing distance of 1 to 5 seconds, which is computed at the speed of the equipped vehicle. The visual and audible alarms, using yellow to red lights and different audible tones, respectively, may be progressive at following/closing intervals of 1 second.

The system software can be easily updated by inserting a preprogrammed electronic card about the size of a thick credit card into the central processing unit. The hardware/software package can be designed to allow the driver to set the comfortable alarm/following distance settings.

An option to the standard system includes side beam radar sensors that detect obstacles in the blind spots to the left or right of the equipped vehicle. When a turn signal is activated, a vehicle in an adjacent lane would be sensed, and a visual and audible alarm sounded, which warns the driver not to change lanes.

As an option, the central processing unit can also record a driving history of the vehicle to include speeds driven and alarms sounded during a driver's shift. In the event of a collision, the last 10 minutes of driving activity can be stored and reproduced in graph form on a second-by-second basis. The graph history can include vehicle speed, steering, and braking as well as indicate radar-detected obstacles in front of and to the side of the vehicle. This information can be valuable in reconstructing traffic accidents and in assessing driver activity for review by company officials.

Previous models of this radar-based system have been in production and in commercial vehicle use, including coach buses and heavy trucks, since 1992. One commercial carrier[32] installed the system, containing both options described above, in about 1,500 vehicles and operated the units for approximately 2 years. Many drivers for the carrier praised the system and believed that it provided safety benefits, especially in periods of adverse weather conditions. However, although accident reduction was noted during system use, system operation was discontinued for various economical and operational reasons.

Manufacturer representatives of the HD system indicated that factors leading to the discontinued use of system A by the commercial carrier included:

1) This pioneer system used the only practical FCC-approved radar frequency available at the time, which was 24.125 GHz. Unfortunately, that frequency was also used by police radar. The vehicle radar did not interfere with police radar, and police radar did not interfere with the vehicle radar, however, the vehicle radar could set off police radar detectors in adjacent vehicles. Those vehicle drivers would then believe they were under surveillance by police radar, which sometimes led to unpredictable driver behavior, such as pulling in front of the commercial vehicle and braking suddenly, thus causing the commercial vehicle to brake. The current system A model uses a newly authorized frequency of 24.725 GHz that does not interfere with radar detectors. However, conversion to the new frequency would have been quite an expense for the commercial carrier because a major section of each system would have required replacement.

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[32]Greyhound Bus Lines, Inc.

2) Some drivers were displeased with the software algorithms employed for the alarms. All driver controls were inactivated at the direction of the commercial carrier, and the driver had no control of the system. The alarm algorithms did not always fit the driving situation, and with no driver adjustment control available, drivers believed that sometimes excessive alarms were generated. The software-controlled alarms could have been changed, although this adjustment would have resulted in some additional costs.

3) Some drivers were not comfortable with the system recording capabilities. The system could record driver and vehicle performance for management purposes and for accident reconstruction. The appearance of a "big brother" type driving monitor disturbed some drivers. In addition, drivers were held financially responsible for the replacement of individual driver memory cards that were lost or damaged.

Testimony of drivers for another commercial carrier indicated that its drivers overwhelmingly liked the system. However, this system software package differed from the one above in two primary respects: 1) the following distance alarm was set at 3 seconds and not 5, and 2) the management controls/driver recording systems were not installed. Drivers found the system user friendly, having a minimum of false or nuisance alarms. The system was also not perceived as a mechanism for management accountability by which the drivers might suffer some adverse job action.[33]

System A is currently designed as an after market add-on to heavy vehicles only. The full system, including lateral detection, accident reconstruction, and driver monitoring systems, was installed in the above-described 1,500-unit fleet for approximately $2,500 per vehicle. The HD system can be purchased alone for significantly less, depending on customer needs and the custom design of the software package. System A manufacturers believe that by delivering large numbers of HD systems to original equipment manufacturers, competitive marketing with generally less expensive laser technology is possible.

Prototype models of this system have also been matched with an "intelligent" cruise control. An equipped vehicle traveling at a preset cruise speed would automatically slow when overtaking a slower vehicle. The cruise control can slow vehicle speed through 1) release of the throttle, 2) active and progressively harder braking, 3) automatic transmission downshift, or 4) use of an engine compression brake in commercial vehicles.

Passenger vehicle models of this HD system are currently under development. The 6- by 8-inch antennae needed for the commercial vehicle model is an impractical size for retrofitting on passenger cars. Pending FCC approval, the radar frequency can be easily increased from 24 GHz to 48 GHz or 77 GHz, thus allowing a 3- by 4-inch downsized antennae, which could be installed behind the front grill or plastic fascia of a passenger vehicle during original manufacture.

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[33]Information provided by Preston Trucking representative Don Hansen at the mobile collision warning technology conference.

Vehicle manufacturers have expressed concern over the potential for litigation should an intelligent cruise control/automatic braking system be accused of failure to avoid a rear-end accident. Such concerns may deter or delay mass production of currently available ICC technologies, particularly those with automatic braking, until legal obstacles can be adequately addressed.

System B -- Currently under development,[34] this system uses a laser-based scanning mechanism as opposed to a fixed beam. Within microseconds, beams are scanned forward seven intervals wide and five intervals high, thus creating a pin cushion effect that allows the software to identify objects and rule out spurious returns from reflections. The individual beam is only 3 feet wide at a 1,000-foot distance. Using near-infrared technology that reduces threat to the human eye, targets can be detected up to 480 feet or up to 1,000 feet if striking a reflective taillight assembly. The laser can be configured behind the rear view mirror in a 2-square-inch space. Sensor contamination from road dirt, a problem with externally mounted lasers, can then be eliminated. This laser system also offers side- and rear-hazard detection options. No prototype vehicles were available at the time of this writing. The manufacturer advised that one "Big Three" domestic automaker was to take delivery of its sensors during the summer 1995 to be offered as an option on new vehicles. The target market of the manufacturer is automobiles, and adapting the system to heavy trucks and buses has not yet been considered.

System C -- This laser system is currently under development and incorporates many attributes described above for system B. Some vehicle hazard sensors are being field tested on school buses to eliminate problems associated with loading and unloading accidents in which children are often hidden by the hood of the vehicle or fall beneath the wheels to the side and rear. The manufacturer is also incorporating a cruise control system similar to the one previously described.

May 1993 Technology Study

As noted previously in this text, the DOT issued the comprehensive report Assessment of IVHS Countermeasures for Collision Avoidance: Rear End Collisions in May 1993. This DOT report analyzed the effectiveness of a theoretical HD system (neither wave radar nor laser specific) to a small clinical sample of 74 reported real-world accidents and a large nationally representative General Estimates System (GES) sample. Countermeasures computer modeling involved postulating realistic design functional parameters for the hypothetical HD system and then predicting how drivers and vehicles would perform to avoid crashes given the aid of the proposed system. This study was specific to the performance characteristics of passenger vehicles only and did not include heavy vehicle modeling.

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[34] Information provided by Laser Atlanta Automotive Sensor Systems.

The modeling of these accidents included four possible HD system ranges (150, 200, 250, and 300 feet). The greater the system range, the greater was the possibility of nuisance alarms. However, this forward looking radar system would be theoretically designed to adjust the warning distance commensurate with the time and distance needed by the driver to avoid an obstacle at the varying speeds of the vehicle. Various algorithms were developed to define the operational characteristics of the hypothetical HD system. The warning distance is defined as the critical separation at a given speed at which the HD system would sound a warning if a crash threat were detected upon overtaking either a slower vehicle or a stationary object in the road. The dynamic warning distance refers to a mathematical equation for warning distance as a function of vehicle speed.

The lower the sensitivity of the HD system, the stronger the reflected signal must be to be detected, and the shorter the range at which the HD system will issue a warning. With low sensitivity, nuisance warnings are minimized, but a warning, when issued, may not afford sufficient time and distance for the driver to implement an effective evasive tactic. Conversely, the higher the sensitivity, the weaker the reflected signal that can be detected, and the longer the effective range of the HD system. Longer range, however, increases the likelihood that nonthreats will be reported as nuisance alarms. (See figure 5.) For instance, a 3-degree-wide beam will be largely confined to the 12-foot travel lane of the equipped vehicle at a 300-foot range. Still, at 500 feet or more, the beam will be striking objects outside the travel lane of the vehicle. (See figure 6.)

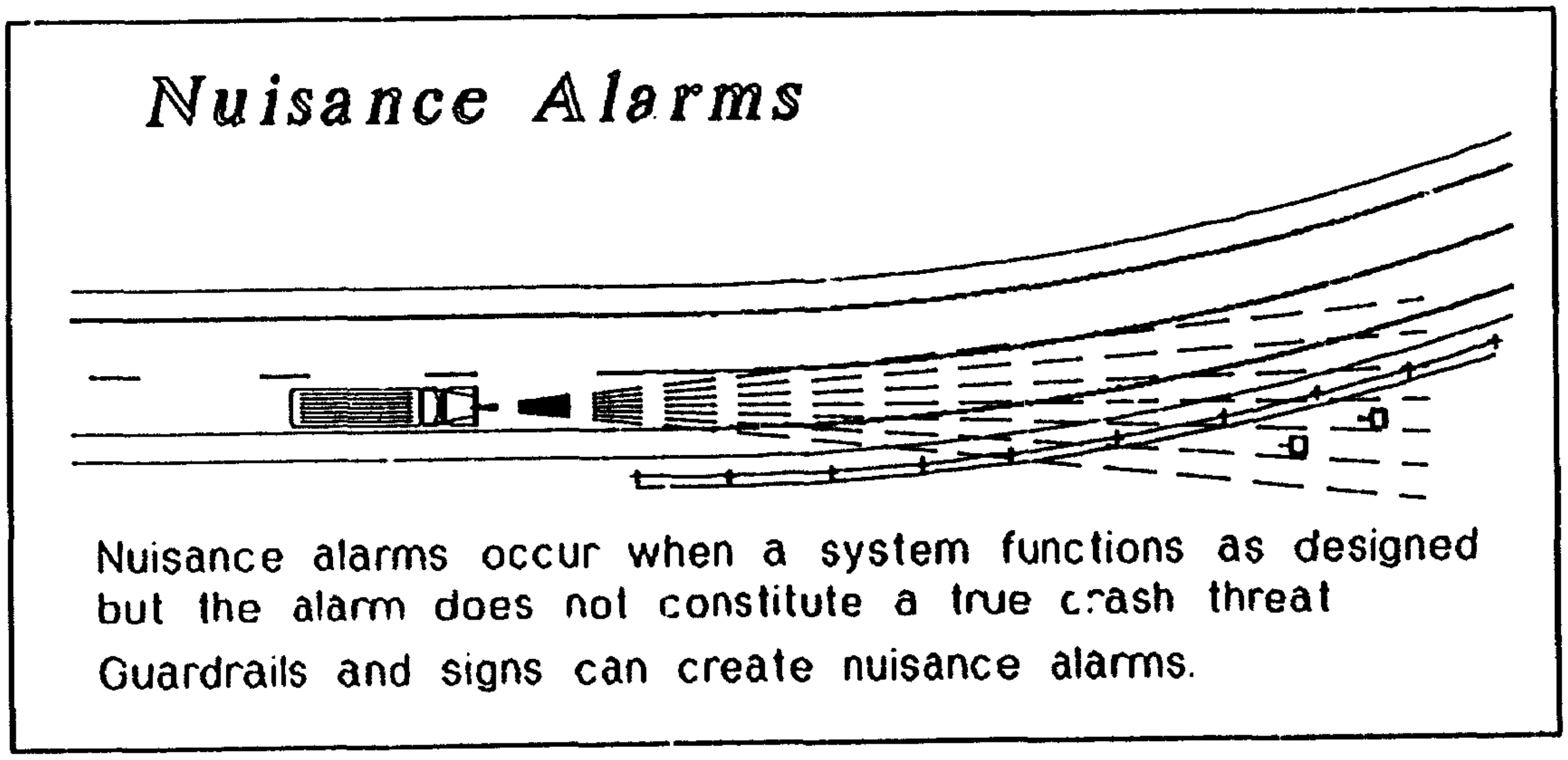
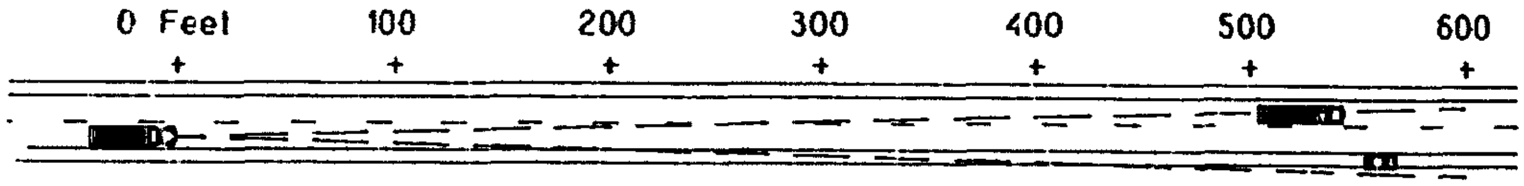


Figure 5. -- Illustration of nuisance alarm occurrences.

Effective Range of a 3-Degree Beam



At 300 feet, the beam is limited to the travel lane of the HD-equipped vehicle.

But at 500 feet, the beam is covering the shoulder and the adjacent lane.

Figure 6. -- Beam range increase effectiveness.

These are complex research problems, complicated by the fact that driver skills, reaction times, and vehicle handling and stopping capabilities vary greatly. A nuisance alarm for a skilled and attentive driver of a sports car may be a true crash threat either for an elderly or distracted driver or for the operator of a heavy truck.

One approach to nuisance alarm problems is to operate sensors with the lowest sensitivity consistent with an acceptable probability of detection of the desired target and to use signal processing logic to further filter out nonthreats. Scanning HD systems are currently under development in which narrow beams are sequentially transmitted in a pin cushion effect forward of the vehicle. Signal processing logic will allow the HD system to determine the size and location of the hazard and, thus, to ignore small objects, such as poles and signs, or those objects outside the projected 12-foot lane in front of the equipped vehicle.

The DOT report cites research that found driver surprise reaction time to a visual stimulus of an obstacle in the vehicle path had a mean equal to 1.1 seconds. However, a range of two standard deviations produced a reaction time variance between .81 and 1.76 seconds to include perception, decision, and braking response time. Other studies further suggested that driver brake reaction times were log normal, positively skewed on the upper end due to physical limitations on the lower end of the distribution. A skewed distribution of reaction times was used in the Monte Carlo computer simulations[35] evaluating the potential benefits of HD systems.

[35]Monte Carlo methods are computer-assisted simulation techniques for obtaining probabilistic approximations to the solutions of problems in mathematics, science, and operations research by the use of random sampling. In traffic accident simulation, probabilities are assigned to a range of key input parameters, such as driver reaction time, lead vehicle deceleration rate, following vehicle deceleration rate, and vehicle speeds, which in turn create outputs that predict the probability of certain outcomes within a given population of accidents.

The DOT report discussed concerns regarding compensatory risk taking by drivers in HD system equipped vehicles. Farber (1991) concluded that a driver aided by an HD system will almost certainly be even more reliable than will a driver alone even should some degree of risk compensation occur. However, earlier researchers in 1976 and 1982 concluded that compensatory risk taking would negate the beneficial effects of an HD system. The critical element seems to be reducing the actual risk of collision to a greater degree than the reduction in the driver's perceived risk of collision.[36]

The DOT report concluded that 37 to 74 percent of all 1.5 million police-reported rear-end accidents involving passenger vehicles were theoretically preventable, depending upon specific crash subtypes. A Monte Carlo-style simulation of about .5 million theoretical accidents concluded that 77 percent of all inattention/following too closely rear-end collisions could have been prevented by HD systems. In those collisions not prevented, significant severity reductions could be expected. Additional benefits may be derived from the prevention of "disguised" rear-end collisions in which vehicles, attempting to avoid contact, swerve off the road or into oncoming lanes of travel.

However, real world restraints may tend to significantly reduce the projected benefits of universal availability of HD systems. An unacceptable level of nuisance warnings could be experienced at the detection ranges used in the simulations, which could substantially reduce the effectiveness of the driver/system interface, thus reducing the optimistic estimates provided about total crash reduction. The number of nuisance alarms a driver will tolerate before ignoring or disabling the system is not known.

A fundamental assumption that is made in modeling the HD system countermeasure is the driver would respond appropriately to the warning signal; the driver would not disable, ignore, or be confused by the system and would respond with hard braking immediately after the onset of the warning signal. However, an unknown level of driver/system interface failure could be expected.

The DOT study offered no conclusion as to HD system effectiveness specific to limited atmospheric visibility conditions and/or heavy trucks. Heavy trucks were said to comprise about 2 percent of the striking vehicles in the total rear-end accidents.

Federal Communications Commission Frequency Allocation Rulemaking

The FCC is currently considering industry requests for the allocation of general use frequencies that would enhance the development of HD systems and other vehicle guidance

[36]Little empirical data on compensatory risk taking are available. Driver education would be critical to reducing compensatory risk taking for the operators of heavy trucks.

technologies.[37] These requests are from Japanese and U.S. automakers as well as the manufacturer of an after market HD system (system A) previously described.[38]

The manufacturer of the after market HD system has requested a frequency of 47.3 GHz, an almost twofold increase from the present operating range of 24 GHz. This increase would allow its current system to shrink the commercial vehicle antennae from 6 by 8 inches for use in passenger vehicles to 3 by 4 inches. The FCC noted no conflicts with this greater frequency.

Japanese automakers have requested a frequency allocation of 60 GHz, which is consistent with the current regulations of Japan. However, the FCC has already reserved 60 GHz for other activities.

The U.S. automobile manufacturers have requested a primary frequency of 76.5 GHz, providing uniformity with current regulations in effect in Europe. The third harmonic of this frequency (about 229 GHz) is assigned to radio astronomy; therefore, frequency integrity would have to be closely maintained to eliminate interference, and that technology could be somewhat expensive. U.S. automakers have also requested 95.2 GHz and 139.5 GHz for future development. The higher the frequency and the shorter the wavelength are, the tighter the manufacturing tolerances also are; therefore, effective use of higher frequencies will require continued technological development.

Although the drivers and passengers of the equipped vehicle will be adequately shielded, the FCC is concerned about the health risks of microwave energy emitted by these systems. An increased radar frequency results in an increase of the energy absorbed by water droplets in the atmosphere, which decreases the system effectiveness, especially in fog, and may require greater power generation than lower frequencies. The FCC believes that a vehicle speed dependent power modulation system might be the solution. When the vehicle is stopped or moving slowly, power and range would be decreased proportionately to minimize microwave exposure to pedestrians and to occupants of nearby vehicles. When highway speeds are reached, power could then be increased to maximize the effective range of the system without unnecessarily exposing humans to unacceptable levels of radiation.

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[37]FCC Rulemaking Docket 94-124 for applications >40 GHz, released November 8, 1994. Comments due March 1, 1995.

[38]Information provided through an interview with Dr. Michael Marcus of the FCC on June 15, 1995.

ANALYSIS

Introduction

In the Menifee, Arkansas, investigation, the Safety Board examined the performance of the drivers and their vehicles, the highway element, and the survival factors influenced by the crash, the fire, and the rescue response. Because vehicles were removed from the scene before Safety Board investigators arrived, remarkable accident evidence on the road was absent and a complete reconstruction of the collision events was not possible.

The investigation found no operational issues with the motor carriers or drivers that are believed to have contributed to the accident. Although deficiencies were noted, including the one toxicological indication of past drug use, none were related to the drivers' operation in the dense fog. All drivers appeared to be reasonably rested without evidence of fatigue. Additionally, no maintenance deficiencies were found that contributed to this accident. Of the 32 brake adjustments measured, only one was at the manufacturer-recommended adjustment limit. This compares with the Safety Board sampling taken in the early 1990's that found approximately 25 percent of five-axle truck brakes to be at or beyond the adjustment limit.

The analysis will discuss those issues explored during the Menifee investigation as well as similar issues identified in previous Safety Board investigations. The Safety Board has investigated or examined the circumstances of several accidents involving either low visibility or low awareness and found that low-visibility and low-awareness collisions occur today with similar damage and injuries resulting much as they did 30 years ago. This report will analyze some of those investigations with the results of a special investigative conference that considered countermeasures for these type of accidents and will address the development and applicability of collision countermeasures. The types of mobile collision warning technologies that may prevent or mitigate the severity of low-visibility and low-awareness collisions specifically will be analyzed.

Accident

General – This accident involved nine vehicles that entered an area of dense fog at widely varying speeds. According to driver and witness statements, vehicles entered the fog-affected area at speeds between 30 mph and 60 mph. The four vehicles involved in the initial series of collisions were subjected to relatively low-collision forces. When vehicles 6, 8, and 9 entered into the crash, the catastrophic damage, injuries, and fire resulted. The speed vehicle 7, the cargo van, entered into the crash is unknown, but this vehicle was eventually overrun and destroyed by following vehicles. The investigation revealed that a minimum of four separate collisions were involved; however, as many as eight could well have occurred. The collisions probably happened within 2 minutes or more.

Official surface weather observations reported around the State did not reflect any widespread fog areas during the early hours of the accident morning. However, the mostly clear skies, light surface winds, and narrow temperature/dew point spread that were shown on the observations indicate the environmental conditions were favorable for fog formation in low-lying areas.

Once in the fog and as it increased in density, the drivers of the leading five vehicles reduced their speeds of between 30 and 60 mph to as slow as between 10 and 15 mph for vehicle 5. Following the collisions that involved vehicles 1 through 4, wreckage blocked the right lane of the two westbound lanes. After vehicle 6 became involved in the collision sequence, its trailer rotated clockwise toward the median and completely blocked the road. The distance that the trailer rotated, combined with the damage apparent to the vehicle 5 rear, indicates that this collision involved greater speed than the initial collision series. The vehicle 6 tractor was destroyed by the damage and the fire that ensued later. An examination of vehicles 8 and 9 and the vehicle 9 distance of postimpact travel also indicate severe impact forces. A witness described the speed of vehicle 9 entering the impact area as slightly slower than his own speed of 65 mph. From the witness statements and collision damage, vehicles 6, 8, and 9 entered the collision area at faster speeds than vehicles 1, 2, 3, 4, and 5. Additionally, the drivers of vehicles 2, 3, and 4 did not reduce their speed appropriate to their closing velocities with the preceding vehicles. The precrash driving strategy of driver 7 is unknown.

Survival Factors -- According to the Arkansas medical examiner's autopsy report, the three drivers and the codriver died from carbon monoxide poisoning. Driver nine sustained contact injuries that would have caused rapid death; no evidence was present that he was alive in the fire. The seriousness of some individual fatalities could not be determined because of the fire damage to both the vehicles and the bodies. All fatalities sustained extensive thermal burns. Because probably no time to escape existed before ignition, trapping smoke and super heated gases caused the four deaths. Due to the relatively high speed impacts involving vehicles 6, 7, 8, and 9, as well as the rapidly ensuing fire, the use or nonuse of restraints was not a factor in the sustained injuries.

Crash/Fire/Rescue -- The Safety Board investigation found that the initial notification of the emergency units was timely and efficient and that the response of the fire department and rescue personnel was prompt and well coordinated. An incident command post was established and mutual aid assistance requested. The intensity of the fire, which was fueled by diesel fuel, gasoline, flammable cargo, and truck tires, prevented any rescue of the trapped drivers and codriver.

The choice of foam used as suppressant was proper for fire control. The request for additional foam and for tankers in the water shuttle operation was initiated early in the incident, allowing for response and set-up time. The large fire fuel load of flammable liquids and rubber tires required great amounts of water for control and extinguishment, and the time required was consistent for the size and difficulty of the operation. The all-volunteer firefighters were well trained, responded in appropriate strength, and operated well-equipped apparatus. The Safety Board concludes that the emergency response personnel of Conway County and its neighboring jurisdictions reacted promptly and in appropriate strength to the emergency.

Drivers -- The drivers involved in this accident were all properly licensed to operate their vehicles and met CDL requirements. The driver violations and the accident history were not found to be issues.

The investigation reviewed the experience, sleep/wake cycle, and health of the drivers to determine whether those factors affected the accident. Each truckdriver had considerable driving experience. The average experience was 15 years; the most-experienced driver had 30 years, and the least-experienced driver had 1 year. The latter driver's trucking experience, however, was augmented by graduation from a truck-driving school and 12 years as a vehicle mechanic and as a farm hand who operated farming equipment.

At least seven of the drivers were familiar with I-40 and the general area of the accident. For six of the nine drivers, the accident location was on their regular routes. A seventh driver had been over the route several times since October 1994. The familiarity of the other two drivers is unknown. Four of the regular I-40 route drivers said that they had experienced fog at various locations on the 135-mile road from Little Rock to Fort Smith, but not at the accident site.

As a result of Safety Board recommendations from the Calhoun, Tennessee, investigation, the AAA published its 1993 *How to Drive* guidelines for drivers operating in low-visibility and fog conditions. Drivers are advised to turn on low-beam headlights, slow to a speed appropriate to the visibility conditions, and turn on their emergency flashers, where allowed. The guidelines also caution that when necessary for drivers to leave the road, they should turn off their headlights and turn on their emergency flashers. In the Menifee accident, the Safety Board determined that the sudden nature of the fog prevented the drivers from considering alternative driving strategies and that familiarity with the AAA guidelines was probably not relevant.

No evidence suggests that physical impairment affected events leading to the accident. Most of the drivers had DOT physicals and current medical certificates; although, driver 5 had let his medical certification lapse during the previous year. Driver 7 was not required to have a DOT physical. None of the surviving drivers (1 through 5) reported suffering any illness on the day of the accident. Relatives of drivers 6, 7, and 8 reported these drivers were not ill. No one was available to provide such information about driver 9, but the autopsy revealed no medical problem that could have impacted the accident. One surviving driver and three deceased drivers routinely took prescribed medications; however, whether two of the deceased drivers had taken their medications on the accident day is not known. The medications, in any case, have no side effects or rare side effects and are not believed to have impacted the drivers' behavior. In addition, a thorough examination of the available driver log books revealed no indications of excessive hours of service.

After assessing the driver data available in this investigation, the Safety Board concludes that neither driver fatigue, inexperience, qualification, nor physical impairment were causal factors in this accident.

No indication was present that illicit drugs or alcohol were in the system of any driver in the accident. Various specimens were obtained from the four deceased drivers for testing that exhibited negative results for drugs and for alcohol, respectively, for all four and for three of the four. The blood specimen test of driver 9 indicated a blood alcohol level of .02 percent gm; however, a similar test of the vitreous fluid of the same driver was negative. If alcohol had been consumed by driver 9, his vitreous fluid would be expected to have a slightly higher alcohol concentration than his blood. That it had none is an indication of postaccident putrefaction, which coincides with the opinion of the Arkansas State Crime Laboratory chief toxicologist, who conducted the testing.

Vehicles -- The investigation analyzed the mechanical condition of the vehicles to determine whether any defects were causal or contributing to the accident. No defects were found in the tires, suspensions, or steering systems of the accident vehicles. A comprehensive inspection of the brakes was performed on tractor 2, combination units 3 and 4, and tractor 5. One deficiency was found in the forward right side trailer axle brake on semitrailer 4. It was at the adjustment limit and had a pushrod stroke of 2 inches, which was not an out-of-service condition and would only result in a slight increase in stopping distance on the combination unit. This deficiency was ruled out as a contributing factor in the accident because no other brake deficiencies were present on this combination unit and because the vehicle braked from a slow speed when maximum performance stopping is not needed.

Mechanical defects may be the single, most underreported factor in motor vehicle collisions. In commercial vehicle accidents, evidence of mechanical deficiencies or failures is many times hidden or destroyed because of the extreme crash forces involved. Other times, the investigators responsible for determining crash factors are not adequately trained in the mechanical components common to commercial vehicles.

The figure has been projected from government data bases over the past several years that mechanical factors are causal in only 2 to 3 percent of heavy truck accidents. However, a 1990 NHTSA study found that up to a third of heavy vehicle accidents may have contributing mechanical factors.[39] The Safety Board 1992 study that examined the performance of heavy vehicle air-brake systems found in a random sample that approximately 56 percent of five-axle truck combinations have brake system deficiencies serious enough to be placed out of service until repairs can be made. Therefore, thorough inspections of crash-involved vehicles would probably uncover more brake system deficiencies than are commonly noted in police accident reports and, eventually, in the government data bases.

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[39] *Improved Brake Systems for Commercial Motor Vehicles*, U.S. Department of Transportation, (NHTSA Report No. DOT HS807 706), 1991.

The Safety Board study also found that the practice of routinely backing off the airbrake adjustments to facilitate wreckage removal contributes to the incomplete data available. The study suggested other methods of stabilizing collision-damaged airbrake systems that would allow evidence to be preserved until trained inspectors could have access to the wreckage. As a result, the Safety Board urged the 50 States, the District of Columbia, the Commonwealth of Puerto Rico, the Virgin Islands, and the Territories:

> In order to preserve evidence from accident investigations, require towing companies during wreckage removal to employ methods of releasing locked airbrakes that do not alter brake adjustment. (H-92-62)

The Safety Board furthermore asked in Safety Recommendation H-92-63 that the Interstate Towing Association (ITA) and the Towing and Recovery Association of America: "Encourage members to voluntarily discontinue the practice of 'backing off' the airbrakes on commercial vehicles during wreckage removal operations." The ITA, acting as the lead agency, responded and expressed its willingness to comply with the intent of the recommendation in a July 16, 1992, letter. However, a management change delayed compliance until 1995 when the ITA published in the July/August newsletter to its members an extensive account of findings and recommendations from the Safety Board report (NTSB/SS-92/01). Consequently, the Safety Board classified Safety Recommendation H-92-63 "Closed--Acceptable Action."

As a subsequent action to Safety Recommendation H-92-62, the Safety Board again contacted each of the recipients and found many unwilling to legislate prohibitions to the practice of "backing off" airbrake adjustments. Because of the legislative reluctance to enact new mandates and the ITA comprehensive effort to discontinue the "backing off" practice, the Safety Board now classifies Safety Recommendation H-92-62 "Closed--Reconsidered."

The investigation also noted that headerboards on the semitrailers of vehicles 3 and 4 failed to completely contain the loads carried, and the cargo on vehicle 3 penetrated the tractor cab from the rear. In the absence of crash-force reconstruction, however, the Safety Board was unable to determine whether load forces resulting from the collisions exceeded those of the headerboard design standards. The adequacy of precrash load securements could not be assessed due to wreckage recovery methods. Consequently, no conclusion regarding the adequacy of the headerboards can be determined in this investigation.

Several of the saddle fuel tanks on the combination units burned in the postcrash fire, which increased the severity of this accident. Fuel system integrity standards 49 CFR 571.103, also known as Federal Motor Vehicle Safety Standard (FMVSS) 301, apply to passenger cars, trucks, and buses that have a gross vehicle weight rating (GVWR) of 10,000 pounds or less and to school buses that have a GVWR greater than 10,000 pounds. Neither this standard nor any other FMVSS applies to fuel system integrity on truck tractors.

One hundred and eighty-two fatal collisions were reviewed in a Safety Board truckdriver fatality study published in 1990. Nine percent or 16 of the 182 collisions involved fire. Fatal Accident Reporting System (FARS) records indicate that approximately 16 percent of the 700 to 800 truckdriver fatality accidents that occur each year are fire-related. Less than 1 percent of fatality accidents involving passenger cars are fire-related.

Some type of system integrity requirement would probably be useful in mitigating the seriousness of heavy truck accidents that typically result in fuel tank damage and fire. However, the Safety Board can not draw specific conclusions in this investigation regarding the adequacy of heavy truck fuel system design because relevant evidence had been destroyed.

Motor Carrier Operations -- Although some minor problems were uncovered, such as the lack of a current medical certificate, no operational issues were discovered that contributed to this accident. The Safety Board concludes that the carriers generally met applicable State and Federal requirements and did not contribute to either the cause or severity of these collisions.

Highway -- About 1\2 mile east of the accident site, the westbound lanes have a straight 900-foot vertical curve (hillcrest) that transitions to a 3-percent downhill grade. At highway speeds of 65 mph, vehicles cresting the hill would have had approximately 30 seconds or less before encountering the dense fog. Once the collision sequence began, the subsequent time to identify and to recognize the road hazards in the fog would have been reduced.

AHTD representatives said that when they arrived, the fog was thick, not stirring, and confined to the low area between the hillcrest and the Menifee exit. Other witnesses and rescue personnel added that the fog was of varying intensities throughout the night. AHTD representatives explained that fog was not common in any particular area of I-40 and that the infrequency of fog would not warrant the installation of warning signs and/or fog monitoring devices.

The 5-year accident history for log miles 116 through 118 reveals that the only other fog-related accident occurred in 1991; involved four vehicles: a motor home, van, passenger car, and truck tractor semitrailer; and resulted in two incapacitating injuries. The Safety Board has found that specific types of fog-warning signage are effective when fog is frequent and predictable, such as in the Calhoun, Tennessee, accident area. The Menifee site, however, has no history of a high frequency of fog or low-visibility accidents. Consequently, the Safety Board concludes that fog signing was not warranted in the accident area.

Rear-End Accidents

Most rear-end accidents are attributed to driver inattention, which is the result of a conscious, unimpaired driver who does not properly perceive, comprehend, and/or react to a crash threat. In the Indiana University *Tri-level Study of the Causes of Traffic Accidents,*[40] extensive analyses of 57 rear-end crashes were conducted to determine causal factors. The study disclosed driver inattention and other forms of delayed recognition as the primary causes of rear-end accidents.

In the 1993 NHTSA report *Rear-end Crashes: Problem Size Assessment and Statistical Description,* rear-end accidents during 1990 were 1.5 million or 23 percent of the nearly 7.5 million accidents reported. The NHTSA publication *Assessment of IVHS Countermeasures for Collision Avoidance: Rear-end Crashes* evaluates rear-end crashes primarily on the clinical analysis of case reports from the National Accident Sampling System (NASS) Crashworthiness Data System (CDS). After reviewing 74 CDS cases in depth, the most common causal factor associated with rear-end crashes was identified as driver inattention to the driving task. The second and overlapping causal factor was following too closely. These two factors together were associated with 93 percent of the clinical sample.

Besides the conscious, unimpaired driver who does not respond appropriately, fatigued drivers also do not respond appropriately. In a study involving 182 heavy truck accidents that were fatal to the truckdriver, the Safety Board found 31 percent of the accidents were fatigue-related. A portion of those accidents were rear-end, but the study suggests that fatigue has a significant role in accident causation. In addition, the Safety Board finds fatigued drivers continually involved in the individual accidents it investigates.

In the NHTSA review of the 74 CDS cases, the category of driver inattention was subdivided into 12 categories. The largest category, labeled "specific activity unknown," accounted for 40.5 percent of the accidents involving an inattentive driver. The Safety Board contends that within a large subcategory are accidents involving drivers who are fatigued as a result of sleep loss.

A recent Safety Board report[41] discussing the effects of sleep loss pointed out that sleep loss is often dismissed as a minimal nuisance or as easily overcome. However, it can potentially degrade most aspects of human capabilities. Sleep loss can be associated with decrements in judgment, vigilance, reaction time, memory, psychomotor coordination, and information processing. The report stated:

> In the most severe instances, an individual may experience an uncontrolled sleep episode and obviously be unable to perform. However, in many other situations, while the individual may not actually fall asleep, the level of sleepiness can still significantly degrade human performance.

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[40] J.R. Treat, N.S. Tumbas, S.T. McDonald, D. Shinar, R.D. Hume, R.E. Mayer, R.L. Stansifer, and N.J. Catellan, *Tri-level Study of the Causes of Traffic Accidents: Final Report Volume I: Causal Factor Tabulations and Assessments,* Institute for Research in Public Safety, Indiana University, (DOT HS805 085), 1979.

[41] Aviation Accident Report--*Uncontrolled Collision With Terrain, U.S. Naval Air Station Guantanamo Bay, Cuba, August 18, 1993* (NTSB/AAR-94/04).

Sleep loss can result from a number of voluntary actions and some involuntary reasons, including physiological sleep disorders such as sleep apnea. Because apnea sufferers obtain very light sleep at night, interrupted by short duration arousals, they wake up tired and have bouts of sleepiness during their waking hours. Regardless of the sleep loss cause, fatigued drivers are a likely causal subset of rear-end accidents for which collision warning systems may be particularly helpful.

The review of the sleep/wake cycles of the drivers in the Menifee collisions indicated adequate sleep for most before the accident. The adequacy of sleep was marginal for the rest of the drivers. However, the accident events show the marginally rested drivers' actions were likely appropriate, suggesting a weak correlation between inadequate sleep and accident causation for those drivers. Fatigue therefore has no relevance to the Menifee accident, but the Safety Board remains concerned about fatigue as a common problem.

The amount of sleep that driver 8 received was slightly less than the average sleep for fatigue-related accident drivers. In addition, his sleep time was split because he shared driving duties with the codriver. They made three trips per week, and each trip was 24 to 30 hours in duration. Because they routinely switched driving and sleeping every 5 hours, driver 8 is likely to have had a maximum sleep period of 5 hours in his last rest period before the accident. However, other factors should be considered in assessing the impact on driver 8 of limited sleep and of a split sleep schedule. He had 28 years of driving experience, and 20 of those years were in California where he often encountered heavy localized "tule" fog. His wife, who used to drive with him, said he would typically reduce his speed between 30 and 40 mph when entering fog. He may have been fully alert and reduced his speed as his wife suggested was his usual practice, but he was confronted by vehicle 6, which was perpendicular to and blocked both travel lanes. He apparently turned hard to the right to avoid a collision, jackknifed the tractor trailer in the process, and was then struck by vehicle 9. Although the Safety Board remains concerned about the potential for fatigue from split sleep periods, it found that the greatly reduced visibility is more likely critical to the accident events than the potential for driver 8 to have been fatigued.

Driver 3 declined any further assistance in the Safety Board investigation after he completed a brief initial interview. The amount of sleep that he obtained in his last sleep period before the accident therefore remains unknown. However, he was off duty and at home for the 2 days before the accident, and nothing indicates that he did not get full and restful nights of sleep during that time.

The amount of sleep obtained in the last 24 hours for drivers involved and for those not involved in a fatigue-related accident has been found to average 6.9 hours and 9.3 hours, respectively. Applying that criteria, drivers 1, 7, and 5 had less than the average 6.9 hours.

The limited sleep of driver 1, however, does not appear to have impacted the accident events. He acted with reasonable caution, slowed his vehicle based on the limited visibility from between 60 and 65 mph to between 35 and 40 mph, and did not run into the truck in front of him.

When vehicle 2 struck his vehicle from behind, his trailer was disabled and incapable of being moved out of the road. Subsequently, he was struck a second time by vehicle 3.

Driver 7 had 6.6 hours of sleep in the previous 24 hours. His supervisor noted no indications of fatigue during their last contact that was 1 hour 25 minutes before the accident. The nearly complete destruction of vehicle 7 by the fire and the impacts of vehicles 8 and 9, however, renders speculation about the role of any influencing factors on his actions unproductive.

Collision Warning Technology

The Safety Board has had a long-standing interest in the technology for mitigating collisions in all modes of the U.S. transportation system. In the early 1960's, the Safety Board became involved in the assessment of collision avoidance technology through the investigation of aircraft mid-air and near mid-air collisions. It has more recently developed recommendations concerning collision warning and avoidance technology for applications in the railroad and the marine transportation industries. The Safety Board recognizes that the technology may be different for the various transportation modes and that each modal system may have specific limitations in collision prevention applications. However, the overall goal of the modal technology development must be the same: to prevent transportation accidents or to mitigate accident-resulting damage and injury.

Aviation Collision Warning/Avoidance Systems -- In early aviation development, aircraft were, of necessity, operated on a see-and-be-seen basis. Federal regulations designed specifically to augment the "see and avoid" concept and to minimize the mid-air collision potential were first issued in 1926 by the Secretary of Commerce. However, doubts about the utility of the "see and avoid" concept continued to rise over the coming decades with the increases in aircraft performance and the increasing air traffic. Many changes in operational rules brought increased safety, but the limitations of "see and avoid" continued to be apparent. The aviation industry began work by 1960 on collision avoidance systems (CAS).

In the 10-year period of 1959 through 1968, U.S. registered aircraft were in 223 mid-air collisions. One hundred and nine of these accidents were fatal and resulted in 528 fatalities. Initially, the problem of mid-air collisions appeared to be predominantly one of general aviation aircraft because 98 percent of those accidents involved that segment of aviation. Examination disclosed, however, that although air carrier aircraft were involved in only 6.7 percent of those accidents, the occupants of those aircraft accounted for 66 percent of the fatalities.

The mid-air collision between an Allegheny Airlines DC-9 and the Forth Corporation PA-28 near Indianapolis, Indiana, was the 19th of 1969 and increased the fatalities to 115 from this type accident that year. This accident prompted the Safety Board to review the entire mid-air collision problem to determine its magnitude, the actions being taken to solve the problem, the additional research required, and the state-of-the-art in collision avoidance systems.

The Safety Board convened a public hearing on November 4, 1969, to inquire into the cause and prevention of mid-air collisions. Twenty-six witnesses including representatives of the U.S. Government and the aviation industry as well as members of the public testified. Written statements from 12 organizations and individuals were also received into the record. The Safety Board adopted its report of the proceedings on November 12, 1970.[42]

At the same time, the Safety Board was conducting a special study of mid-air collisions. The report of this special study was adopted on June 7, 1972.[43] The introduction to the special study noted, "It is conceivable that in the future, a single mid-air collision could result in the loss of a thousand lives."

As a result of its proceedings and special studies on the mid-air collision problem as well as specific accident investigations of mid-air collisions, the Safety Board issued safety improvement recommendations to:

Support the expeditious development of low-cost collision avoidance systems for all civil aircraft (68/14).

Encourage the expeditious development of a collision avoidance system for installation in air carrier and larger general aviation aircraft (69/3).

Make funds available for the ground equipment necessary for support of CAS systems (69/4).

Sponsor developmental contracts for a pilot warning indicator (PWI) system utilizing various technological methods in order to evaluate the practicality of each (69/5).

Develop regulations to require the installation of CWS and PWI systems when they become available (69/6).

Direct an extensive effort toward development of an airborne collision avoidance system, with cockpit displays, as a prime solution to the near mid-air collision problem (69/19).

Beginning in 1993, technology had advanced to the level that these systems are now required on air carriers.

Railroad Collision Warning/Avoidance Systems -- The Safety Board has long advocated state-of-the-art technology to avoid collisions in the rail industry. This technology in the form of advanced train control systems can provide positive train separation (PTS) and automatically intercede in the operation of a train.

About 80 percent of the Safety Board railroad investigations in the last decade have human error as the root cause. Although train crewmembers have extensive training in operating rules and

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[42] *Report of Proceedings of the National Transportation Safety Board into the Mid-Air Collision Problem* (NTSB/AAS-70/2).

[43] Special Study--*Mid-Air Collisions in U.S. Civil Aviation* (NTSB/AAS-72/6).

procedures, they are still subject to errors in human performance or from fatigue. PTS is a technological backup to assist the engineer in controlling the train.

The Safety Board has investigated a number of recent accidents that could have been prevented had PTS been in place. In addition, the Safety Board investigated accidents in 1969, 1986, and 1990 in which recommendations were made to the Federal Railroad Administration (FRA) to "study the feasibility, install and operate, and expand such efforts" relative to PTS. The FRA response has been acceptable to date.

Two separate technologies have been used for the field-tested PTS systems. One approach used the Global Positioning Satellite network in conjunction with train on-board computers to determine train-to-train relative positions; the other approach used land-based transponders. The testing of such systems continues on high-risk routes, and the experience to date has been positive.

Marine Collision Warning/Avoidance Systems -- Collision avoidance for ships has traditionally depended on determining the visual aspect of an approaching ship, which has been facilitated by the particular placement of red and green sidelights, white masthead, and stern lights with specific arcs of visibility. The situation and applicable maneuvering rules can then be identified. Radar also provides the means for detecting and warning of impending collisions as well as for selecting appropriate avoidance maneuvers. Because radar only provides the present range and bearing of the radar echo, any collision avoidance conclusions must be derived from an analysis of changes in these parameters. The electronic computer Automatic Radar Plotting Aids (ARPA) extract and analyze the radar data to predict contemplated avoidance maneuvers.

Performance standards and installation requirements for the ARPA have been established in the United States and internationally. In addition, most licensed officers are required to pass U.S Coast Guard-approved radar courses that include collision avoidance techniques.

The Safety Board has investigated numerous ship collisions that resulted from steering and other equipment failures, misunderstood passing agreements, incorrect radar use, and inadequate shiphandling skills. Many safety recommendations, as a consequence of these investigations, have been implemented. In December 1968, the Safety Board adopted the *Study of Collisions of Radar-Equipped Merchant Ships and Preventive Recommendations* to improve radar equipment, training, and testing. The Safety Board also adopted *Collisions Within the Navigable Waters of the United States, Consideration of Alternative Preventive Measures* and *Major Marine Collisions and Effects of Preventive Recommendations* in February 1972 and September 1981, respectively.

General -- The surviving drivers described the fog as "white out" and "very, very thick, the thickest fog ever." Other drivers, who were not involved in the accident, reported being unable to see the end of the hood (perhaps 8 feet) and to observe the lane markings from the truck cab looking straight down (perhaps 10 feet). Their descriptions indicate severely limited visibility.

In addition, the surviving drivers reported slowing their vehicles from the 65-mph speed limit to speeds between 35 and 40 mph, between 40 and 45 mph, below 30 mph, below 25 mph, and between 15 and 20 mph. Some said they slowed first when they heard a CB radio transmission about fog ahead and then again when they actually entered the fog. Each said slowing was the appropriate response. Two drivers had company-sponsored training that had advised to slow for limited visibility. Two drivers turned on their flashers.

The problem in limited visibility is what speed to choose. Should the headway time[44] between your vehicle and the vehicle in front be reduced to less time needed to brake or swerve, the vehicle ahead will be hit. Conversely, should a speed be reduced sufficiently to preclude a following vehicle from reacting, a rear-end collision will occur. One driver believed he could not reduce his speed below 40 to 45 mph because the trucks behind him were closer than trucks in front and, therefore, posed a greater hazard to him. Further complicating the task of choosing an appropriate speed is the sight-distance variability within limited-visibility areas and the divided attention needed to observe lane markings, shoulder edges, and other peripheral cues to remain on the road.

Drivers 1 and 2 chose speeds that were incompatible with each other and too high for the available visibility. Consequently, driver 2 overtook vehicle 1 and the combination of speed and visibility reduced headway sufficiently so that driver 2 struck the corner of vehicle 1 with about 36 inches of overlap before veering off into the median. If the headway between vehicles 1 and 2 had been slightly greater, the steering maneuver of driver 2 may have been sufficient to avoid collision. Instead, vehicle 1 was disabled and could not be moved. Each succeeding driver then encountered a gross speed differential because the vehicle 1 speed was zero. Collisions between vehicles 1 and 3 and between vehicles 3 and 4 resulted from the incompatibility between speed and visibility that produced a headway time without sufficient reaction time for the drivers.

Driver 5 reduced his speed between 15 and 20 mph. He stated that he saw the emergency flashers on the preceding vehicle and managed to stop just short of striking vehicle 4. It is likely his ability to see vehicle 4 and react was enhanced by its hazard flashers. As with the first series of collisions, succeeding drivers behind the stopped vehicle 5 were also faced with a gross speed differential and unable to compensate for the headway resulting from incompatible speed and reduced visibility.

A critical factor in rear-end collisions is the amount of headway time that is maintained between leading and following vehicles. Sufficient headway time is a function of visibility, speed, and reaction time. Reaction time is the time from the onset of a stimulus to the beginning of a response to that stimulus by a simple motor act, such as pressing the brake pedal. A stimulus must be perceived by our senses and transmitted to the brain; a response must be decided, and an action

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[44]The time available for a following vehicle to close from its position to the position of the preceding vehicle.

initiated.[45] Research studies of driver braking reaction time to an unexpected stimulus have identified reaction time about 1.5 seconds for the 75th percentile driver.[46] The time available for drivers to react in this accident, based on the visibility and their speeds, was less.

The introduction of a warning in advance of the initiation of a response serves to increase the time available for reaction. In one study,[47] drivers' response times were measured when they were anticipating a certain stimulus within the next 6 miles. The same drivers were then subjected to an infrequently triggered stimulus having intervals of hours to days. The results revealed that drivers reacted 1.35 times faster to the anticipated stimulus than the unexpected stimulus (0.54 to 0.73 seconds). Another study[48] indicated that a warning signal with an optimal lead time of 200 milliseconds could reduce reaction time about 50 milliseconds. Each of these studies indicates the advantage of a warning before a stimulus and response. The collision warning systems reviewed during the April 1995 Safety Board mobile collision warning technology conference have the potential for avoidance or reduction in severity of low-visibility accidents.

Evidence in the Menifee accident indicates that vehicle 1 was traveling in dense fog at a reduced speed when it was struck in the rear by vehicle 2. Assuming driver 1 had reduced his speed to 20 mph and vehicle 2 was behind traveling about 45 mph, a warning system would have activated with a warning light when the vehicles were still approximately 168 feet apart. Considering an appropriate reaction time (1 1\2 seconds to react and apply brakes in this high-stress situation) and only moderate braking (0.2 g or 6.44 fps/s) by driver 2, his vehicle would slow to 20 mph while closing on the lead vehicle after 160 feet, and 38 feet of following distance would remain at the time a common speed was reached. Had the driver reacted in a similar manner at the activation of a collision warning system detect light, the vehicles could have reached a common speed while still hundreds of feet apart.

The collision warning system in these scenarios could have provided warning sufficient to avoid the initial collision between vehicles 1 and 2, leaving no road obstructions to be struck by the following vehicles. However, had vehicle 2 been traveling at the highway speed of 65 mph and reacted at an initial warning light, he would probably have been able to swerve around the obstructing vehicle or to brake forcefully, reducing the collision severity. Therefore, the Safety Board concludes that collision warning systems have the potential for avoidance or reduction in the severity of low-visibility collision conditions such as fog, snow, rain, or darkness.

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[45] M. Sivak, P.L. Olson, and K.M. Farmer, "Radar Measured Reaction Times of Unalerted Drivers to Brake Signals," *Perceptual and Motor Skills*, 55, 1985.

[46] Twenty-five percent of drivers would have a longer reaction time.
G.T. Taoka, "Brake Reaction Times of Unalerted Drivers," *ITE Journal*, March 1989.

[47] G. Johansson, and K. Rumar, "Drivers Brake Reaction Times," *Human Factors*, Vol. 13, No. 1, 1971.

[48] M.I. Posner, and C.R.R. Snyder, "Facilitation and Inhibition in the Processing of Signals," *Attention and Performance V.*, eds. P.M.A. Rabbitt and S. Dornic (London: Academic Press, 1975).

The Safety Board also analyzed the circumstances of the accidents near Weatherford, Texas,[49] (a low-awareness collision), and Fairfax, Minnesota,[50] (a low-visibility/low-awareness collision) to determine whether collision warning system technology can be applied for the avoidance or reduction in the severity of low-awareness collisions common to fatigued and distracted drivers.

Weatherford, Texas -- Evidence indicates that vehicle 1, a passenger van, was traveling approximately 15 mph when vehicle 2, a tractor/semitrailer combination, traveling about 55 mph, struck it in the rear. The driver of vehicle 2 was found to have been fatigued, thus operating in a state of low awareness. Had a collision warning system been operational in vehicle 2, a detect light would have illuminated when the combination approached 500 to 600 feet of headway, and then a warning light and tone alert would have activated when the combination approached 3 seconds of headway (about 242 feet). If the driver had attempted avoidance by fully applying brakes (assuming 1 1\2 seconds reaction and brake application time), the vehicles would have reached a common speed while still 24 feet apart, and this collision would have been avoided. A driver with the same 3 seconds of warning time could have driven around the van with a steering maneuver to either the right or left. With the prompt 1 1\2-second reaction time, the combination would have avoided the passenger van by approximately 62 feet. The fatigued driver would probably not have reacted as quickly as a nonfatigued driver. With a longer reaction time, the vehicle still should have slowed significantly, due to braking, and the collision warning system probably would have reduced the severity of the collision.

Fairfax, Minnesota -- A school bus was stopped in dense fog to load children when a tractor semitrailer combination approached about 55 mph from the rear. If a collision warning system had been operational in the combination, a detect light would have activated at 500 to 600 feet of headway. Had the driver been highly alert in this stressful driving situation and applied heavy braking, he could have brought the vehicle to a stop in 366 feet and 134 feet from the rear of the bus. Given the conditions of this collision and the detect light at 500 feet, the driver should have been much better prepared to take appropriate avoidance maneuvers when the school bus warning lights became visible. If the school bus warning lights did not become visible to the driver before the first warning light provided by a collision warning system, the driver may still have had sufficient time and distance to avoid the collision with a combination of braking and steering action. The heightened level of alertness provided by a collision warning system should have provided the driver more time to consider other avoidance options. Consequently, the Safety Board concludes that collision warning systems have the potential for avoidance or reduction in the severity of low-awareness collisions common to the fatigued or distracted driver.

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[49]Highway Accident Brief--*Collision of Tractor/Semitrailer and Passenger Van, I-20 near Weatherford, Texas, July 3, 1994* (DCA/94-M/H006).

[50]Highway Accident Brief--*School Bus Loading Zone Accident, S.R. 19 near Fairfax, Minnesota, December 21, 1994* (CRH/95-F/H006).

The collision warning systems currently available or under development will eventually provide measurable accident reduction benefits. These systems in their current state can be demonstrated effective in preventing or mitigating the circumstances of many rear-end collisions, as well as many of the other classes of collisions that occur during attempts to avoid rear-end type collisions. The current system development may be adequate for the basic needs of passenger vehicles, considering their braking and handling characteristics, and may well serve the needs of commercial vehicles operating at lower than interstate speeds. However, the Safety Board concludes that further development of collision warning technology will enhance the ability of these systems to meet the special requirements of commercial vehicles.

The distance required for the driver of a heavy vehicle traveling 65 mph to react and to stop can be 500 or more feet. Thus, a driver would not have time under many conditions to perceive the signal as an impending hazard and then formulate and initiate a response as well as complete a successful braking maneuver. In many similar situations, a steering input combined with braking action would be most optimistic.

Further development is needed to ensure that the system provides a commercial driver with adequate headway for successful evasive or mitigative efforts. Industry officials have indicated that enhanced operation acceptable for commercial vehicles is possible. However, the development process has slowed because industry is uncertain concerning the results of future FCC rulemaking. Further design improvements are dependent upon the FCC allocation of operating frequencies in the higher bands that would permit the development of narrow beam width systems, thus providing greater range without the associated nuisance lights. Higher frequencies would enable the development of smaller radar antennae, likely to be required before the systems become acceptable for widespread passenger vehicle installation, and the development of multiple beam systems that scan forward travel paths, consequently diminishing nuisance alarms and affording flexibility in operating range. Considering the present demonstrable benefits and the future possible enhancements of the collision warning systems, the continued development of this technology should incorporate the needs of both passenger and commercial vehicles. The Safety Board concludes that the FCC should expedite the allocation of frequencies appropriate for the development of enhanced collision warning systems. Therefore, the Safety Board believes that the FCC should expedite rulemaking action on the allocation of frequencies that would enhance the development possibilities of collision warning systems.

The Safety Board understands that new, relatively untested technology cannot be incorporated into day-to-day operations of a business enterprise without significant disruption. The experiences from the early generation of collision warning systems exemplifies the problems encountered when technology precedes user acceptance. Industrywide incorporation of advanced systems must be preceded by intensive practical testing in commercial fleets, extensive demonstration of the system benefits, and comprehensive training of the final operators. These prerequisites can be achieved under the sponsorship of the DOT ITS programs. Therefore, the Safety Board believes that the DOT and the Intelligent Transportation Society of America should, in cooperation, sponsor fleet testing of collision warning technology through partnership projects with the commercial carrier industry. Incorporate testing results into demonstration and training programs to educate the potential end-users of the systems.

Citizens Band Radios -- The use of CB radios has increased tremendously over the past 25 years as technology has developed smaller, more powerful, reliable units. Channel 19 has evolved into the common routine communication channel. However, CB radios can be built with many channel selections, which is a useful feature when a driver is traversing urban areas and the airwaves become full.

As reported, both westbound and eastbound drivers near the Menifee accident area were discussing the dense fog through their CB radios. At least two of the accident-involved drivers, however, had their radios set to a channel other than the normally utilized channel 19. Because of a mechanical breakdown with an assigned vehicle, vehicle 8 was not equipped with a CB radio and not informed of the "wall of fog" in that manner.

The universal CB channel for emergency broadcasts in the United States is channel 9, which is routinely monitored by emergency response personnel, roadside service providers, and police agencies. Some CB monitors used by these agencies and providers are equipped with a feature also available to the public that allows channel 9 broadcasts to automatically override any channel that might be set on individual radios. Consequently, when an emergency transmission is sent over the channel 9 frequency, a person listening to another channel communications will automatically receive the emergency broadcast. Had the drivers in the Menifee collision sequence had the capability to transmit and to receive on a common channel such as 9, they may have possibly been warned of the road blockage. The Safety Board concludes that equipping CB radios with the emergency channel 9 override feature could enhance their contribution to highway safety. Therefore, the Safety Board believes that the Telecommunications Industry Association should encourage its members to include an emergency channel 9 override as a standard feature on all models of CB radios.

Four-way Emergency Flashers -- Both driver 4 and driver 5 stated that emergency flashers were activated on the vehicle 4 semitrailer.

The Safety Board April 1995 investigative conference noted that the tail lamp low luminance of 2-18 candela does not increase the visibility of a vehicle in typical daylight fog conditions. Flasher lamps have a luminance of 80-300 candela. Researchers indicated that in daylight when the nominal visibility range of a vehicle is 300 feet, the use of flasher lamps with a luminance of 80 candela can increase the visibility range to 450 feet. The Safety Board concludes that the use of four-way hazard flashers can increase the visibility of stopped or slow-moving vehicles in fog conditions. The increased visibility allowed driver 5 to see and avoid a collision with the rear of vehicle 4. The Safety Board also concludes that the use of emergency flashers by vehicles 1, 2, or 3 may have allowed the following drivers enough time to have avoided striking preceding vehicles. Therefore, the Safety Board believes that the AAMVA should develop, within 2 years, guidelines for the use of emergency hazard flashers during limited-visibility conditions.

The Safety Board determined in this investigation that currently a patchwork of State laws cover the use of emergency flashers. While 6 States specifically prohibit the use of flashers on moving vehicles, 16 others place various restrictions on their use. Some States require the use of flashers below certain speeds, on certain roads, or under certain driving conditions. (See appendix D.) Consequently, a cross-country driver can not immediately determine whether the use of flashers is legal. The Safety Board concludes that action needs to be taken to ensure the uniformity of laws allowing the use of four-way hazard flashers. The Safety Board believes that all States as well as the District of Columbia, the Commonwealth of Puerto Rico, the Virgin Islands, and the Territories should review and revise, if necessary, existing State law regarding emergency hazard-flasher operation to ensure that guidelines provided by the Uniform Vehicle Code section 12-215 (f) and (g) are followed.

Additional information at the conference suggests safety benefits may be achieved by connecting the center high-mounted stop lamps to the flasher system. This feature would provide an additional sight reference point for the driver following behind. The Safety Board concludes that incorporation of the high-mounted stop lamp into the hazard-flasher system may enhance the visibility of those light systems. Consequently, the Safety Board believes that NHTSA should assess, within 2 years, the possible safety benefits to low-visibility conspicuity provided by incorporation of the high-mounted brake light into the four-way emergency flasher system.

CONCLUSIONS

1. The emergency response personnel of Conway County and its neighboring jurisdictions reacted promptly and in appropriate strength to the emergency.

2. Neither driver fatigue, qualification, inexperience, nor physical impairment were causal factors in this accident.

3. The motor carriers generally met applicable State and Federal requirements and did not contribute to either the cause or severity of these collisions.

4. The low incidence of fog and fog-related accidents did not warrant fog signing in the accident area.

5. Collision warning systems have the potential for avoidance or reduction in the severity of low-visibility condition collisions such as in fog, snow, rain, or darkness.

6. Collision warning systems have the potential for avoidance or reduction in the severity of low-awareness condition collisions common to fatigued or distracted drivers.

7. Further development of collision warning technology will enhance the ability of these systems to meet the special requirements of commercial vehicles.

8. The Federal Communications Commission should expedite the allocation of frequencies appropriate for the development of enhanced collision warning systems.

9. Equipping citizens band radios with an emergency channel 9 override feature could enhance their contribution to highway safety.

10. The use of four-way hazard flashers can increase the visibility of stopped or slow-moving vehicles in fog conditions.

11. The use of emergency flashers by vehicles 1, 2, or 3 may have allowed the following drivers enough time to have avoided striking preceding vehicles.

12. Action needs to be taken to ensure the uniformity of laws allowing the use of four-way hazard flashers.

13. Incorporation of the high-mounted stop lamp into the hazard-flasher system may enhance the visibility of those light systems.

PROBABLE CAUSE

The National Transportation Safety Board determines that the probable cause of this accident was that many of the drivers entered the area of dense fog at speeds that precluded successful evasive action to avoid the preceding or the stopped vehicles.

RECOMMENDATIONS

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

-- to the Secretary of Transportation:

> In cooperation with the Intelligent Transportation Society of America, sponsor fleet testing of collision warning technology through partnership projects with the commercial carrier industry. Incorporate testing results into demonstration and training programs to educate the potential end-users of the systems. (Class II, Priority Action) (H-95-44)

-- to the National Highway Traffic Safety Administration:

> Assess, within 2 years, the possible safety benefits to low-visibility conspicuity provided by incorporation of the high-mounted brake light into the four-way emergency flasher system. (Class II, Priority Action) (H-95-45)

-- to the Federal Communications Commission:

> Expedite rulemaking action on the allocation of frequencies that would enhance the development possibilities of collision warning systems. (Class II, Priority Action) (H-95-46)

-- to the 50 States, the District of Columbia, the Commonwealth of Puerto Rico, the Virgin Islands, and the Territories:

> Review and revise, if necessary, existing State law regarding emergency hazard-flasher operation to ensure that the guidelines provided by the Uniform Vehicle Code section 12-215 (f) and (g) are followed. (Class II, Priority Action) (H-95-47)

-- to the Telecommunications Industry Association:

> Encourage your members to include an emergency channel 9 override as a standard feature on all models of citizens band radios. (Class II, Priority Action) (H-95-48)

-- to the Intelligent Transportation Society of America:

In cooperation with the U. S. Department of Transportation, sponsor fleet testing of collision warning technology through partnership projects with the commercial carrier industry. Incorporate testing results into demonstration and training programs to educate the potential end-users of the systems. (Class II, Priority Action) (H-95-49)

-- to the American Association of Motor Vehicle Administrators:

Develop, within 2 years, guidelines for the use of emergency hazard flashers during limited-visibility conditions. (Class II, Priority Action) (H-95-50)

BY THE NATIONAL TRANSPORTATION SAFETY BOARD

JAMES E. HALL
Chairman

ROBERT T. FRANCIS II
Vice Chairman

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Member

JOHN J. GOGLIA
Member

December 4, 1995

APPENDIXES

APPENDIX A

INVESTIGATION AND APRIL 1995 CONFERENCE

Investigation

The National Transportation Safety Board received accident notification from the news media about 8:30 a.m. on January 9, 1995. Safety Board investigators from the Washington, DC, headquarters and the Arlington, Texas, regional office arrived on scene about 3 p.m. Representatives of the Federal Highway Administration, Office of Motor Carriers; Arkansas State Police; and Arkansas Highway and Transportation Department participated in the investigation.

April 1995 Conference

The Safety Board conducted the Mobile Collision Warning Technology for Low Visibility/Low Awareness Collisions Conference on April 4 and 5, 1995, in Arlington, Virginia. (The 2-day agenda follows.) Experts from the Government, the commercial carrier industry, and private industry, as well as others, spoke on limited-visibility topics, problems associated with rear-end collisions, and new technology to reduce limited-visibility and low-awareness collisions. The technology discussions concentrated on mobile, vehicle-based countermeasures to rear-end collisions. The participants discussed these issues among themselves and with a technical panel of Safety Board investigators and an audience of about 50 interested people.

Tuesday

9 - 9:10 am \\ Introduction
James Arena - Director, Safety Board Office of Surface Transportation Safety

9:10 - 9:20 am \\ Experience with Low-Visibility/Low-Awareness Accident Investigations
Vernon Roberts - Safety Board Report Manager

9:20 - 9:30 am \\ Synopsis of CRH-95-M-H007
Ken Rogers - Safety Board Investigator-In-Charge

9:30 - 10:10 am \\ National Accident Data on Rear-End, Fog, and Driver Inattention/Reduced Visibility-Related Crashes
Ronald Knipling, Ph.D. - National Highway Traffic Safety Administration, Office of Crash Avoidance Research
Jing-Shiarn Wang - Information Management Consultants

10:10 - 11 am \\ Meteorological Optics/Characteristics of Various Light Systems
How Light Penetrates Low-Visibility Conditions
Driver Perception and Reaction to Light Systems
Raymond Lee, Ph.D.

APPENDIX A

11:10 am - 12 pm \\ Driver Vision, Visual Requirements for Driving, and Effects of Atmospheric Transmission on Visibilit y
David Shinar, Ph.D.

1:15 - 2 pm \\ Conspicuity Issues - Taillights, Flashers, Reflective Material, Reaction Studies
Phillip Garvey - PA TRANS Institute, Pennsylvania State University

2 - 2:30 pm \\ Conspicuity Issues - NHTSA Studies and Rulemaking
Pat Boyd - NHTSA and Richard Singer - Federal Highway Administration

2:45 - 3:30 pm \\ Rear-End Collision Countermeasures
August Burgett, Ph.D. - NHTSA

3:30 - 4 pm \\ Motor Coach Manufacturer Perspective
Norm Littler - Motor Coach Industries

4 - 4:30 pm \\ VORAD - Radar-Based Systems
Jerry Woll - VORAD Safety Systems

Wednesday

8:30 - 9:15 am \\ TRW - Forward Looking Radar Program
Dave Grimmer

9:15 - 10 am \\ GM/Delco - Radar-Based Systems
Bob Wragg

10:15 - 11 am \\ Intelligent Transportation Society of America and Collision Warning
Gordon Fink

11 - 11:30 am \\ Motor Coach Industry Perspective on CWS
Carmen Daecher - UBOA

11:30 am - 12 pm \\ Motor Coach Industry Perspective on CWS
Robert Forman - American Bus Association

1 - 1:30 pm \\ System Users
Don Hanson - Preston Trucking

1:30 - 2 pm \\ Motor Carrier Perspective on CWS
Larry Strawhorn - American Trucking Association

2 - 2:30 pm \\ Motor Carrier Perspective on CWS
Todd Spencer - Owner/Operators Independent Drivers

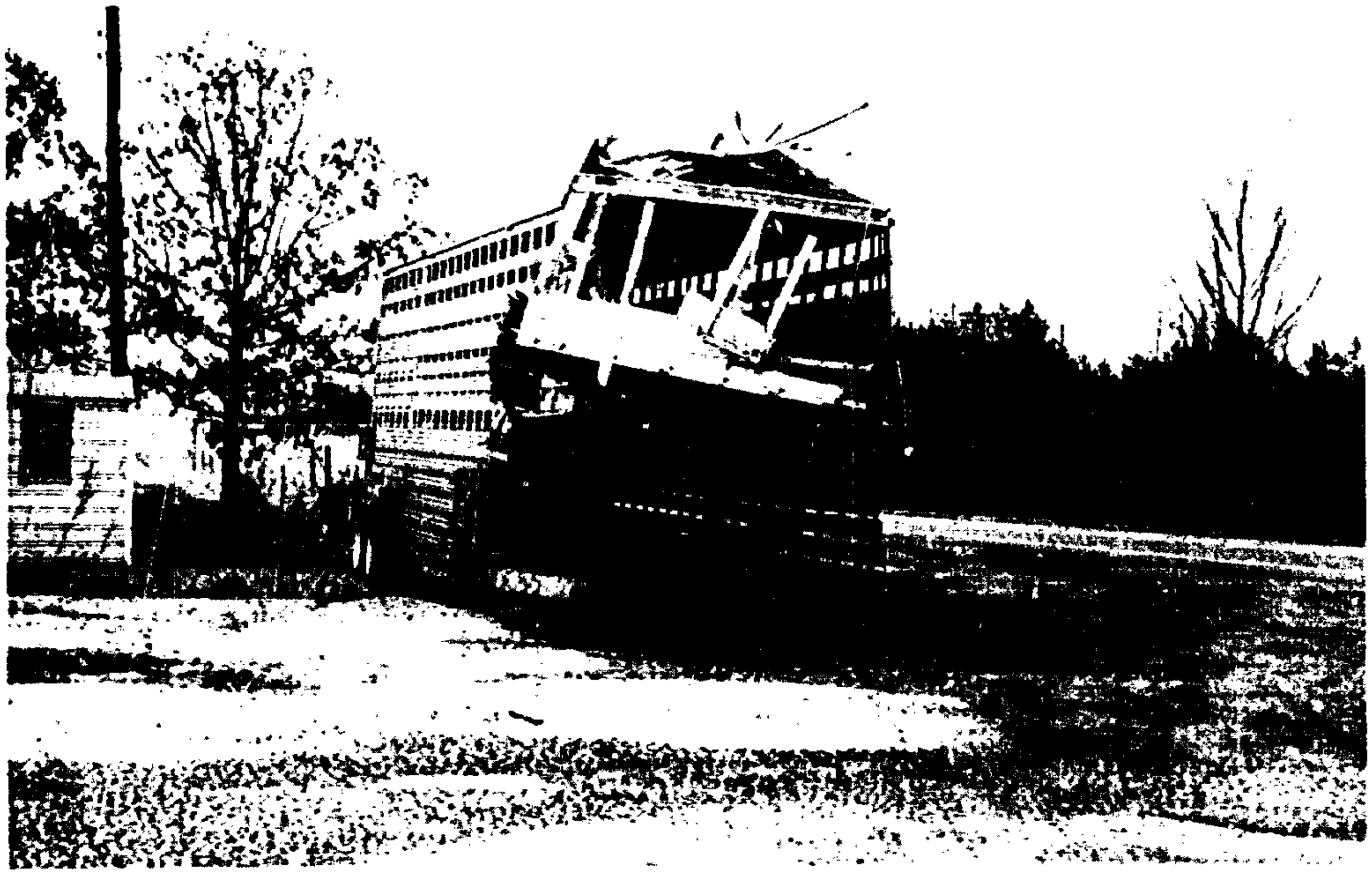
2:30 - 3 pm \\ Motor Carrier Perspective on CWS
Questions and Answers - National Private Truck Council

3:15 - 4 pm \\ Insurance Industry Perspective on CWS
Jack Burkert - Lancer Insurance

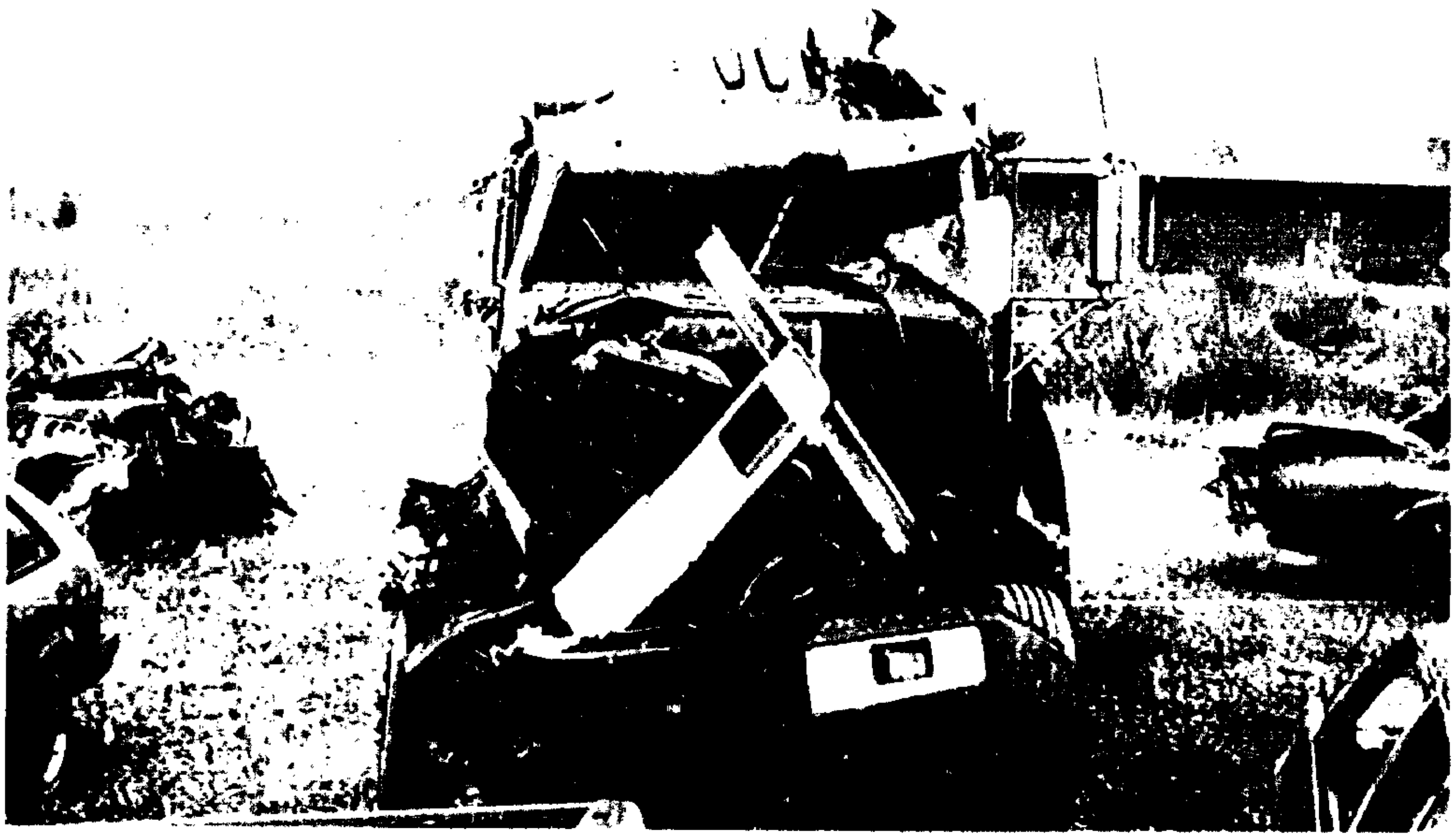
4 - 4:15 pm \\ Safety Board Conference Closing by James Arena

APPENDIX B

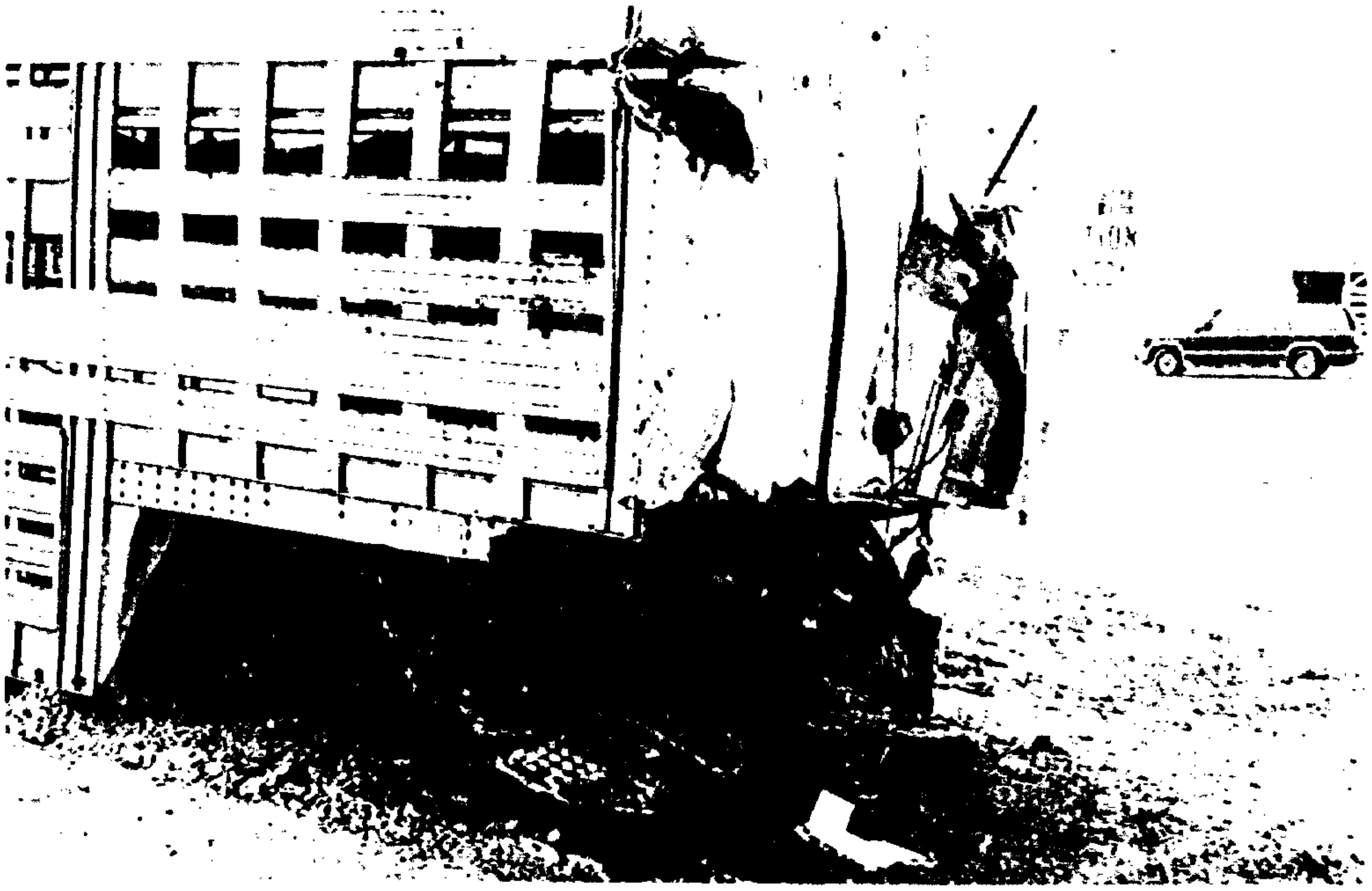
COMPILATION OF MENIFEE, ARKANSAS, ACCIDENT PHOTOGRAPHS



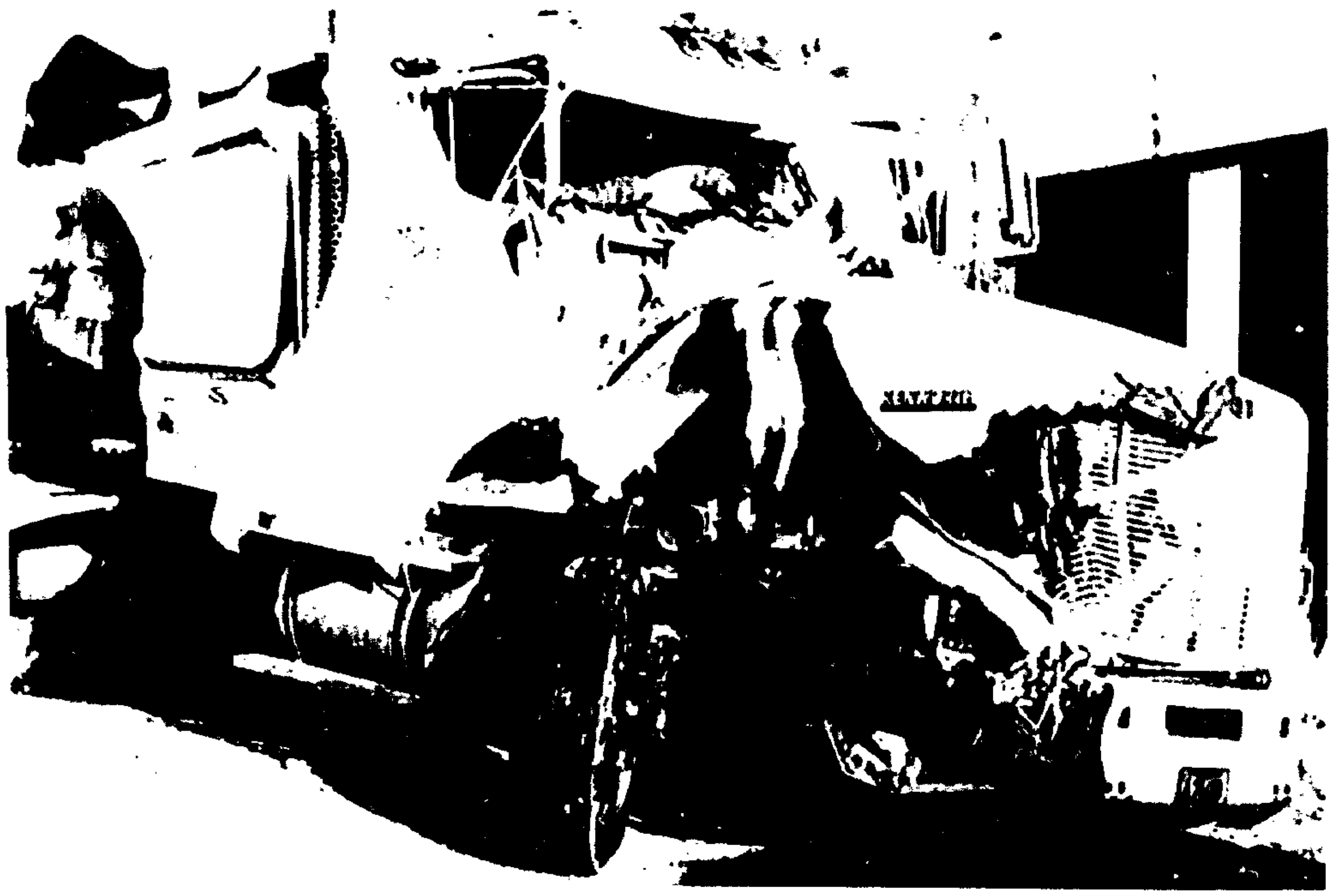
Photograph 1. -- Combination 1 trailer (view from rear toward front).



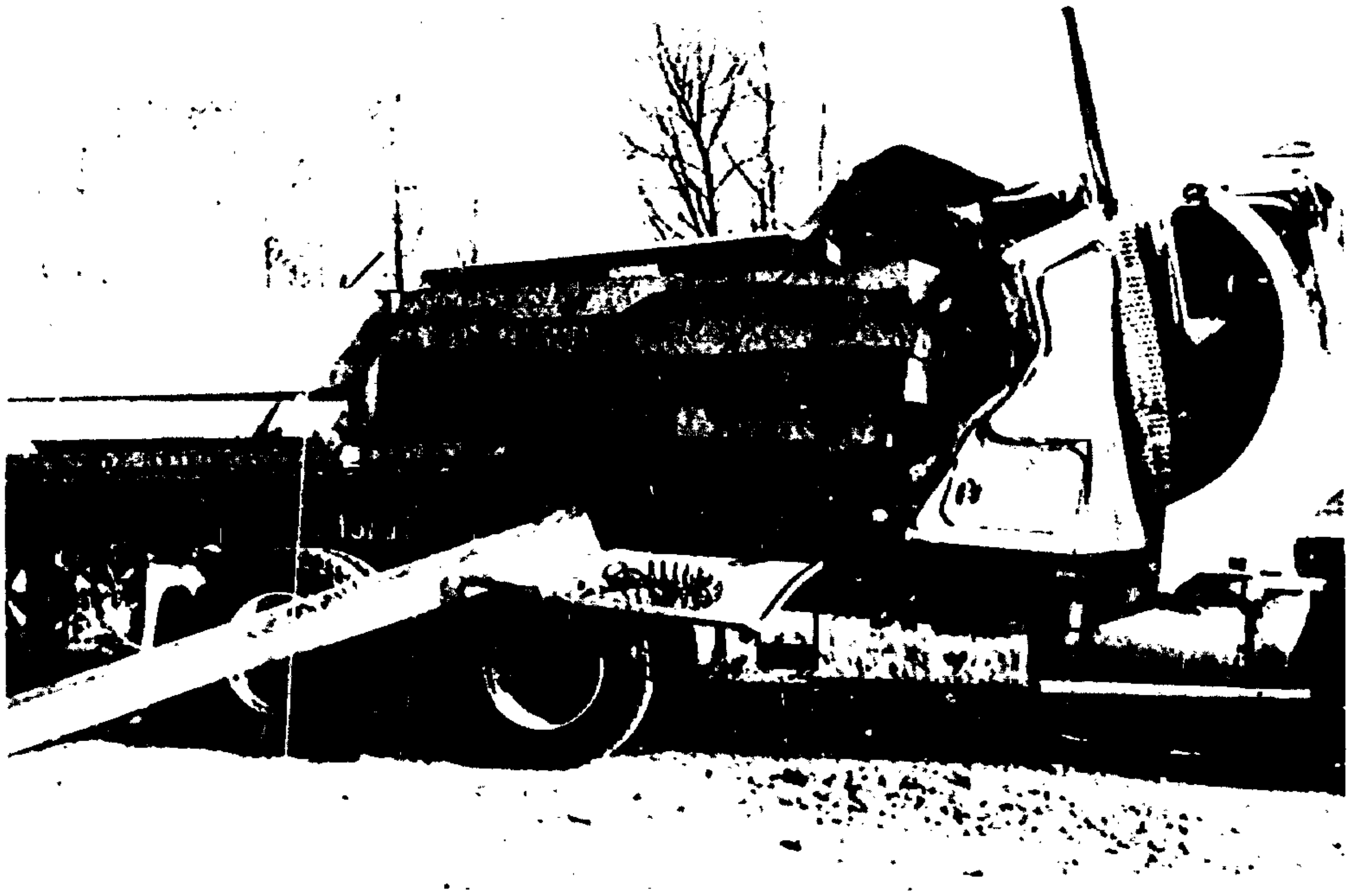
Photograph 2. -- Combination 2 tractor.



Photograph 3. -- Combination 2 trailer (front damage).



Photograph 4. -- Combination 3 tractor.

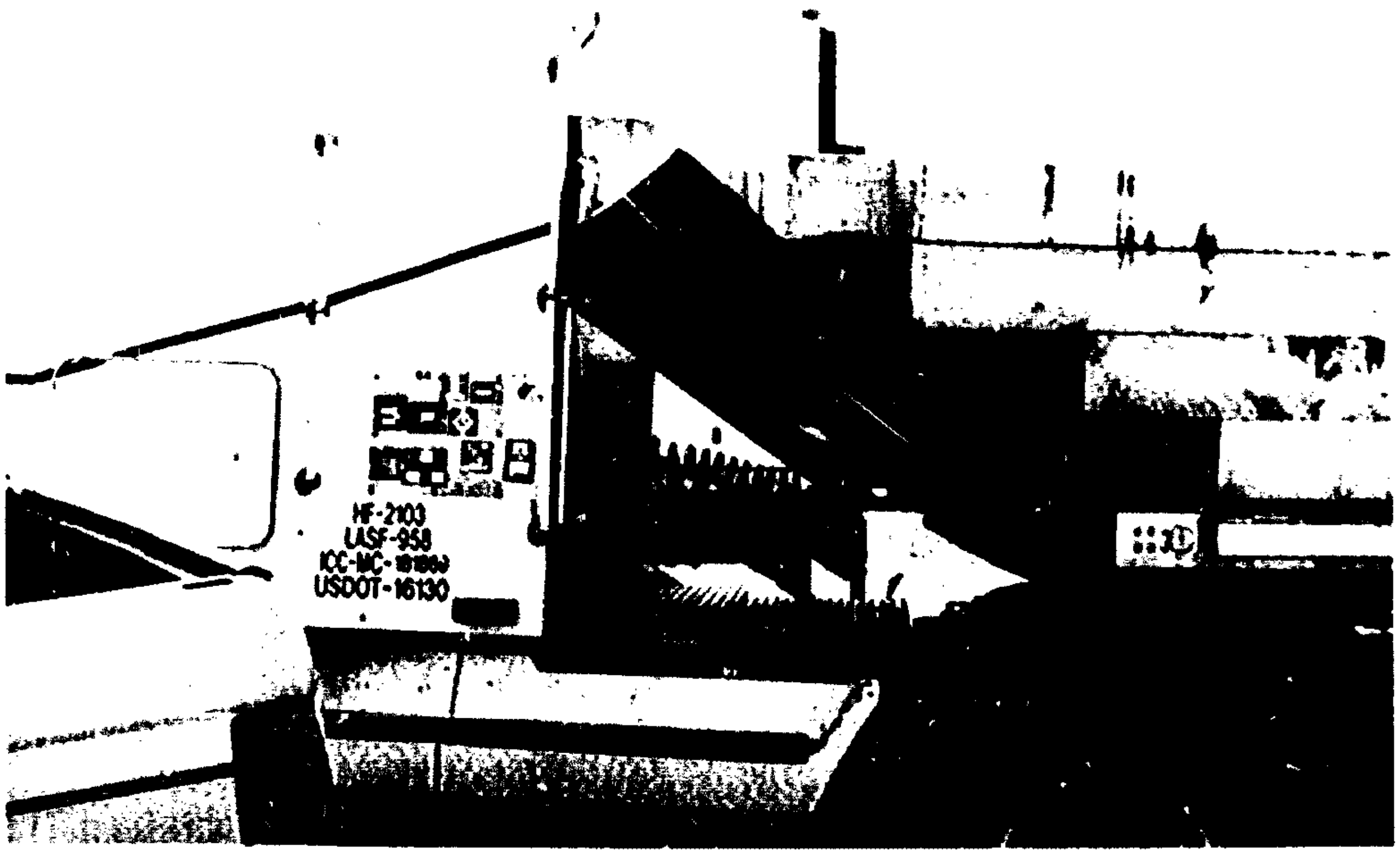


Photograph 5. -- Combination 3 (right side and rear tractor cab damage with headerboard deformation).

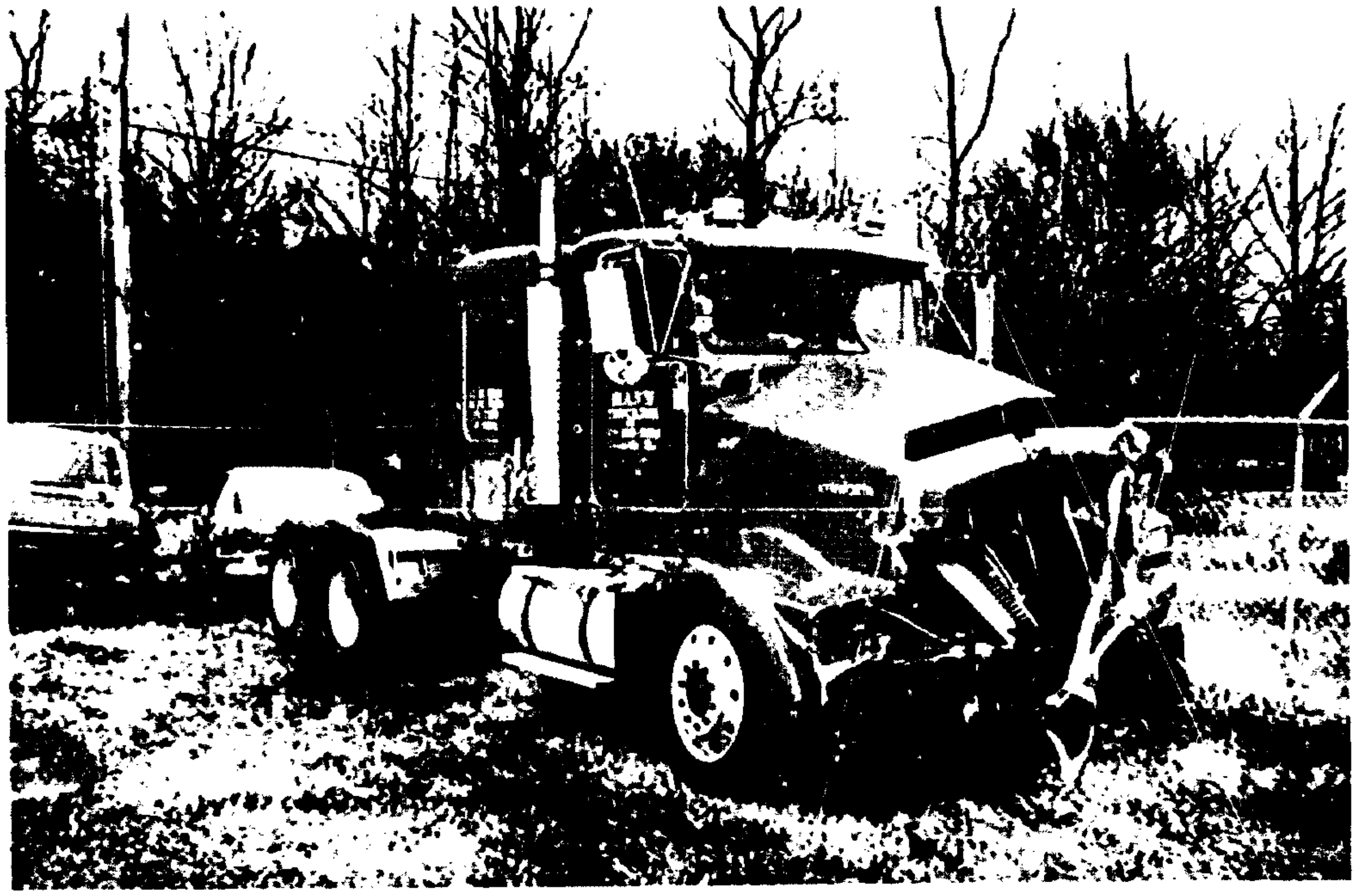
Photograph 6. -- Tractor 3 (front fuel tank damage and puncture).

APPENDIX B

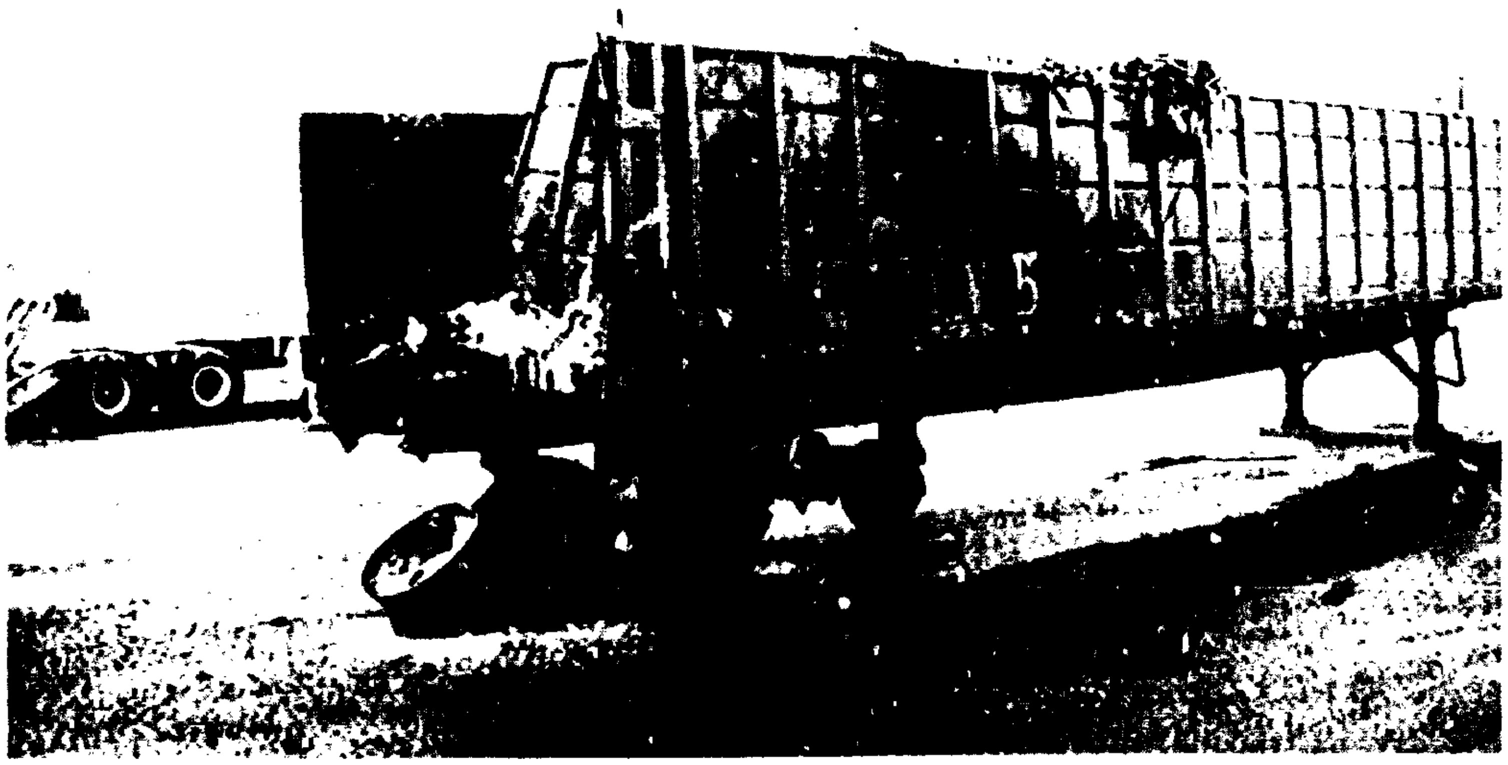
Photograph 7. -- Tractor 4.



Photograph 8. -- Combination 4 (left side tractor/trailer with headerboard deformation).



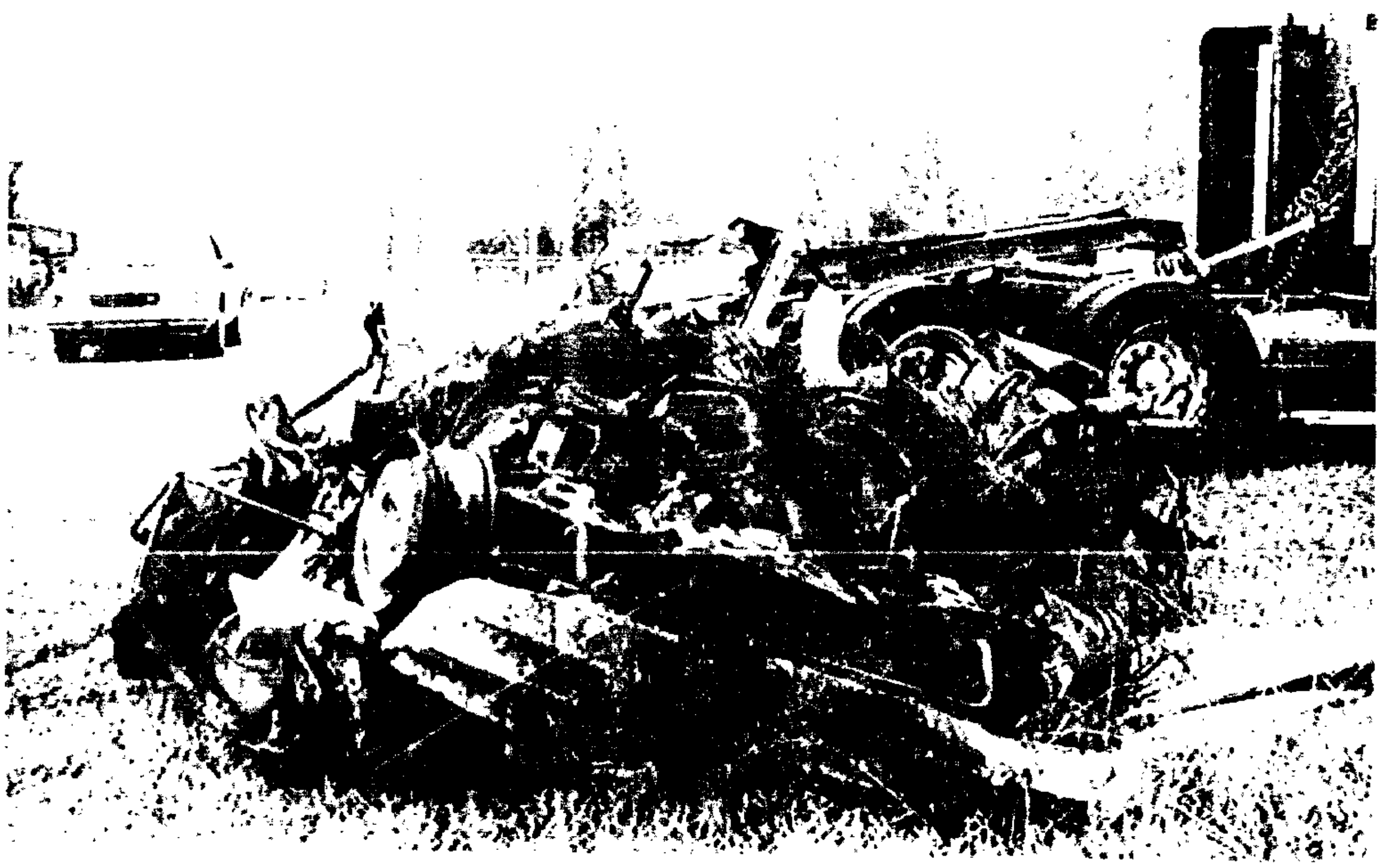
Photograph 9. -- Combination 5 tractor.



Photograph 10. -- Combination 5 trailer (rear impact and fire damage).

APPENDIX B

Photograph 11. -- Combination 6.



Photograph 12. -- Vehicle 7 (crushed van remains).

Photograph 13. -- Combinations 8 and 9 (remains).

Photograph 14. -- Downgrade approaching accident site (viewing back towards east).

APPENDIX B

Photograph 15. -- Accident site (road surface damage).

Photograph 16. -- Accident site (viewing toward west).

APPENDIX C

COLLISIONS INVOLVING LOW VISIBILITY AND/OR LOW AWARENESS

The National Transportation Safety Board has investigated several highway accidents over the last 28 years in which low visibility and/or low awareness was a contributing factor. The low visibility/low awareness accidents usually involve many vehicles and result in multiple fatalities as well as extensive property damage. The following 22 accidents are not necessarily representative of all low visibility/low awareness accidents, but they highlight significant safety issues.

Multiple-Vehicle Collisions -- 08/12/67 -- Joliet, Illinois

In the early morning hours on Interstate 55, a series of collisions involving 11 vehicles occurred in a dense fog. The sequence of events began when an automobile driver heard accident sounds ahead, did not know what to do, decided to pull off, and stopped on the right paved shoulder. A semitrailer driver followed the automobile off the highway and onto the shoulder. Because the automobile did not pull up enough, the semitrailer rear protruded into the lane and was struck by the next approaching vehicle, a tractor combination. Ignition of leaking flammable cargo followed the third collision, resulting in a fire that destroyed six vehicles and caused five fatalities. Twenty-four injuries occurred, and property damage was about $75 thousand. The Safety Board determined that the probable cause of the accident was the failure of the drivers involved to restrict their speeds when operating in a dense fog to permit a safe emergency stop. The catastrophic fire resulted when the improperly packaged cargo of highly flammable paint spilled from one of the vehicles and was ignited either by a flare in use at the accident site or by some other spark source from one of the impacted vehicles.

Bus/Automobile Collision and Rollover -- 11/24/69 -- Petersburg, Indiana

A bus traveling south on two-lane route 57 in dense fog and darkness rounded a right-hand curve on a downgrade. As the busdriver approached an intersection, he saw the headlights of an automobile that he thought was entering the highway from the right and applied his brakes. The bus swerved clockwise, skidded, and struck the automobile broadside, pushing it away from the bus. The automobile had actually been stopped at the intersection. The bus slid sideways and rolled over. The busdriver and passengers were uninjured during impact with the automobile; however, all were injured during the bus rollover. An infant was ejected and fatally injured. The automobile driver was slightly injured. The Safety Board determined that the probable cause of the accident was that the busdriver misjudged the location of the automobile because of the illusion created by the fog. Contributing factors were the excessive speed of the bus in dense fog on wet road and the geometry of the intersection that compounded the illusory effect of the fog.

APPENDIX C

Multiple-Vehicle Collisions and Fires -- 11/29/69 -- New Jersey Turnpike

A 1969 Mercury sedan travelling in a southbound lane about 1/2 mile north of exit 2 entered sudden dense fog at 7:45 a.m. The driver slowed but was rapidly overrun by a tractor and a tank-semitrailer loaded with propane. The tank-semitrailer overturned onto its right side and blocked the southbound lanes and shoulder. In rapid succession, 10 vehicles entered the area just north of the blocked lanes and multiple collisions occurred. Fire started near one passenger vehicle. Twelve to 15 major and numerous minor collisions occurred among the 29 involved vehicles. Six fatalities and 3 serious and 15 less serious injuries occurred. The Safety Board determined that the probable cause of the multiple-vehicle accident was the penetration by vehicles into an area of dense fog where the visibility was 20 to 50 feet, together with the varying rates of speed which prevented appropriate evasive action. Contributing factors were the absence of objective indicators of the density of the fog and the inadequacy of the New Jersey Turnpike speed control system in that it failed to provide timely activation of speed reduction warning signs. (NTSB/HAR-71/3)

Multiple-Vehicle Collisions and Fires -- 08/18/71 -- Ventura, California

A Datsun station wagon towing a small trailer stopped with a flat tire about 4:45 p.m. in the right-hand lane of the two southbound lanes of U.S. 101 about 8 miles northwest of the city limits. The Datsun could not be moved completely onto the highway shoulder because a temporary, 6-foot, wooden-slat fence was about 3 feet off the right edge of the lane. Automobile traffic was able to drive around the stopped Datsun, but a flatbed truck stopped short of the Datsun. The flatbed truck was subsequently struck by a tractor semitrailer that was moving too fast to stop. A second tractor semitrailer approaching the scene also was unable to stop and collided with the stream of vehicles in the left-hand lane, pushing several together. Some cars were inflamed because their fuel tanks ruptured. This truck then struck the first tractor semitrailer and both came to rest in flames off the right side of the highway. Eight people died and 11 were injured in the collisions and fires. The weather was clear and sunny, and visibility was excellent. The Safety Board determined that the probable cause of this series of collisions was the stopping of a vehicle in an unsafe position in a traffic lane, which impeded traffic flow, and the failure of a tractor-semitrailer, moving at posted speed, to reduce its speed sufficiently to avoid collision with stopped and slow-moving vehicles ahead. (NTSB/HAR-72/4)

Multiple-Vehicle Collisions and Fires -- 10/23-24/73 -- New Jersey Turnpike

Between 11:20 p.m. on October 23 and 2:45 a.m. on October 24, a series of nine collisions occurred on the New Jersey Turnpike between gate 15 and U.S. 46. The latter collisions happened under limited visibility conditions that were caused by fog and by smoke from an abandoned, burning garbage dump in the Hackensack meadowlands. Although responsible officials were aware of the hazardous conditions before the collisions, their precautions to ensure the safety of the motorists did not prevent the series of accidents. Sixty-six motor vehicles were involved; 9 people were killed, and 39 others were injured. The Safety Board determined that the probable cause of the series of multiple-vehicle collisions was the penetration of vehicles into areas of severely reduced visibility due to fog and smoke, the latter occasioned by fires adjacent to the Turnpike which had not been promptly extinguished. The delay in closing the affected roads by the New Jersey State Police contributed to the number of accidents.(NTSB/HAR-75/2)

Multiple-Vehicle Collision -- 02/28/75 -- Corona, California

The first of a series of multiple-vehicle collisions occurred in fog at 7:40 a.m. on State 91. The drivers had no advance information to warn them of the fog severity, and a reduced speed limit had not been posted. The California Highway Patrol was escorting some vehicles in convoys through the fog when the collisions occurred. The convey vehicles were not involved in the serious collisions. Fire began when a truck struck an automobile, and the highway was closed about 4 hours. Twenty-three people were injured, 6 of whom were hospitalized. About 60 automobiles and 24 commercial trucks were involved. The Safety Board determined that the probable cause of the collisions was the penetration of vehicles into fog at speeds which were too high for the visibility conditions. (NTSB/HAR-75/7)

Tractor-Semitrailer/School Bus Collision and Overturn -- 03/08/77 -- Rustburg, Virginia

A southbound tractor-semitrailer struck the rear of a stopped school bus on U.S. 29 about 7:50 a.m. Three of the 33 occupants of the school bus died; the other occupants as well as the busdriver sustained bruises and fractures; the truckdriver sustained chest injuries. The Safety Board determined that the probable cause of the accident was the failure of the truckdriver, due to inattention and carelessness, to perceive and avoid the stopped school bus. Contributing to the accident was the stopping of the school bus in the traveled way of the high-speed highway, a practice of the State that was contrary to the provisions of Federal Highway Safety Program Standard No. 17. (NTSB/HAR-78/1)

Tractor-Semitrailer/Multiple-Vehicle Collision -- 06/20/77 -- Atlanta, Georgia

The traffic had backed up and stopped by 3:05 p.m. in the right lane of eastbound Interstate 285, west of a construction zone on connecting southbound Interstate 75. An eastbound tractor-semitrailer approached the standing traffic and collided with and overrode the last automobile in the queue. That automobile was pushed into the vehicle ahead, and two other vehicles to its front were subsequently involved. No fire ensued. Four people in the automobile were killed, one was hospitalized, and a second driver was injured slightly. The Safety Board determined that the probable cause of this accident was the failure of the truckdriver to maintain the proper level of attention to the driving task, to perceive the standing vehicles on the road, and to stop his vehicle short. The driver's inattention to the traffic in front of him may have resulted from fatigue. Contributing to the accident was the failure of the Georgia Department of Transportation to implement existing standards and guidelines for controlling traffic through construction zones, which permitted a 3 1/2-mile backup of slow moving and stopping traffic. (NTSB/HAR-78/5)

Multiple-Vehicle Collisions and Fire -- 11/10/80 -- San Bernardino, California

Southbound traffic on Interstate 15 suddenly encountered dense fog about 7:25 a.m. north of the Highland Avenue off ramp that reduced visibility between 0 and 50 feet. Drivers, whose vehicles were traveling the well-maintained, eight-lane, divided highway, said the visibility obscurement was immediate and unexpected. Some drivers slowed their vehicles partially as they entered the fog bank and others did not. A tractor-trailer braked suddenly to avoid a small car that changed lanes in front, and a pickup truck struck the trailer from the rear. This initiated a chain of collisions that involved at least 24 vehicles within a 450-foot distance and that resulted in 7 fatalities and 17 injuries as well as extensive damage to all vehicles. The Safety Board determined that the probable cause of this multiple-vehicle accident was the failure of the drivers of many of the vehicles involved to reduce speed as necessary to be able to stop in distances compatible with visibility that was severely restricted by dense fog. The initial collision occurred when a tractor-trailer was rear ended after its driver braked abruptly to avoid hitting an unidentified car that changed lanes immediately in front of the truck. Contributing to the severity of the consequences was the extreme varied sizes and weights of the vehicles in the collisions. (NTSB/HAR-81/2)

Multiple-Vehicle Collision and Fire -- 04/20/81 -- Beltsville, Maryland

A scheduled intercity bus with 34 passengers on board was southbound about 5:55 p.m. on Interstate 95. As the bus approached the Interstate 495 interchange, the traffic ahead in the right lane slowed and came to a stop. The bus failed to stop, crashed into the rear of the automobile ahead of it, and precipitated a four-car, front-to-rear-end collision. Two automobiles burst into flames that quickly spread and engulfed the bus after it had been evacuated. Three occupants of the automobile struck by the bus were killed. The drivers of the other three automobiles, the busdriver, and the 34 bus passengers received minor injuries. The Safety Board determined that the probable cause of this accident was the failure of the busdriver to maintain a safe stopping distance between the bus and the automobile ahead as traffic ahead slowed and came to a stop during the peak traffic period. Contributing to the cause and severity of the fires was the separation of the filler pipes from the fuel tanks of two of the automobiles. (NTSB/HAR-81/5)

Multiple-Vehicle Collision and Fires -- 02/28/83 -- Ocala, Florida

A grass fire of an undetermined origin was ignited between 1:30 and 1:55 p.m. in an area between the southbound exit ramp from Interstate 75 onto U.S. 27 and the southbound lanes of Interstate 75. The fire burned rapidly, and a strong south-southwest wind fanned dense smoke across the southbound lanes of Interstate 75. The smoke reduced visibility between 0 and 60 feet for 200 to 300 feet of the road about 2 p.m. Approaching drivers had a clear view of the smoke cloud for over 2 miles before entering the smoke but drove into and through the smoke at varying speeds. At least 22 vehicles, including 3 combination vehicles, entered the smoke and were involved in multiple-vehicle collisions. Vehicle fuel tanks were breached, and a gasoline-fed fire erupted. Eleven vehicles as well as the 3 combination vehicles were burned. Five vehicle occupants were killed, and 36 occupants were injured. At least three rescuers suffered thermal injuries. The Safety Board determined that the probable cause of this accident was the failure of most of the involved drivers to exercise proper judgement and due caution when confronted by a cloud of dense smoke blanketing the highway. Contributing to the accident was the extremely limited visibility within the smoke cloud and the widely varying speeds at which different vehicles entered and were being driven through the smoke cloud. Contributing to the severity of the accident was the breach of fuel system integrity in a number of vehicles and the resultant vehicle fires. (NTSB/HAR-83-04)

Rear-End Collision and Bus Crash Off Bridge -- 11/30/83 -- Livingston, Texas

An intercity bus traveling in the right lane of southbound U.S. 59 about 5:15 a.m. struck the rear of an unloaded tractor-flatbed semitrailer. The bus then veered across the left southbound lane, crashed through a bridge guardrail, and vaulted into a creek bank 26 feet below the bridge deck. The truck had turned right onto southbound U.S. 59 about 927 feet before the accident site. Six bus passengers were killed; five bus passengers and the busdriver sustained moderate to severe injuries during the accident. The truckdriver later reported that he was injured. The Safety Board determined that the probable cause of this accident was the busdriver's lack of alertness, possibly due to fatigue, that 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. (NTSB/HAR-84/04)

School Bus and Tractor Semitrailer Collision -- 04/29/85 -- Tuba City, Arizona

A tractor-semitrailer transporting cattle struck the rear of a school bus on eastbound U.S. 160 about 3:14 p.m. The school bus was stopped with its warning lights flashing in the eastbound lane of the two-lane highway to discharge passengers. Two, 4, 4, 18, and 4 bus passengers sustained fatal, serious, moderate, minor, and no injuries, respectively. The truckdriver and the school busdriver received minor injuries. The Safety Board determined that the probable cause of this accident was the truckdriver's chronic fatigue that adversely affected his ability to avoid a collision with the stationary school bus; his chronic fatigue developed from a loss of sleep due to a combination of excessive duty time and a prolonged irregular duty pattern. Contributing to the accident was the failure of the motor carrier to properly monitor the truckdriver's activities to prevent excessive hours of service. (NTSB/HAR-85/06)

Truck Tractor Semitrailer and Bus Collision -- 07/14/86 -- Brinkley, Arkansas

At 4:15 a.m. a tractor-semitrailer combination was making a U-turn at a highway crossover on Interstate 40 when the semitrailer was struck by an eastbound intercity bus. The truckdriver and his codriver were uninjured. The busdriver and 27 passengers sustained from minor to serious injuries. One passenger was uninjured. The Safety Board determined that the probable cause of this accident was the attempt by the truckdriver to execute an illegal U-turn at a highway crossover. Contributing to the severity of the accident was the operation of the intercity bus at a speed that did not permit adequate time and distance to slow or stop the bus to avoid the collision. (NTSB/HAR-87/05)

Charter Bus/Tractor-Semitrailer Rear-End Collision -- 09/29/86 -- Carney's Point, New Jersey

A charter bus carrying 38 passengers was traveling northbound on the four-lane, divided Interstate 295. After passing three tractor-semitrailers in the left lane, the bus moved into the right lane and struck the rear of another slower moving tractor-semitrailer. The two vehicles continued northbound about 432 feet before coming to a stop. Two, 5, and 31 bus passengers and the busdriver sustained serious, moderate, and minor injuries, respectively. The truckdriver was uninjured. The Safety Board determined that the probable cause of this accident was the busdriver's inattention to his driving task and his misjudgment of the closing speed between the bus and the truck in front of him. Contributing to the accident was the motor carrier's failure to adequately screen the busdriver's qualifications and background. Contributing to the severity of injuries was the high speed of the bus. (NTSB/HAR-87/03)

Multiple Vehicle Collision -- 10/09/86 -- North Bergen, New Jersey

Two charter intercity tour buses carrying European tourists were traveling westbound in the right lane on State route 495 about 7:34 a.m. As the westbound buses approached the Kennedy Boulevard exit, the second bus suddenly veered left into the adjacent lane, struck the left rear of a passenger car in that lane, crossed into the eastbound contra-flow lane, and struck a transit commuter bus. One passenger aboard the transit bus was fatally injured, and 26 other people from both buses sustained serious to minor injuries. The Safety Board determined that the probable cause of the accident was the distraction of the charter busdriver from his driving duties while assisting a bus passenger with a citizens band radio that resulted in his failure to remain within the proper traffic lane while traveling in a construction zone. (NTSB/HAR-87/06)

Amtrak Passenger Train Collision with Tractor-Semitrailer -- 12/19/89 --Stockton, California

Passenger train 708, consisting of one locomotive unit and five passenger cars, struck a tractor-semitrailer at a highway grade crossing about 9:38 a.m. in dense fog. The grade crossing had flashing lights and gates that were functioning at the time of the accident. The collision derailed the locomotive and all five passenger cars. A fire followed the train impact with the truck. The engineer, fireman, and truckdriver were killed in the collision and fire. Three of the seven train crewmembers and 49 of the 150 passengers were injured. The Safety Board determined that the probable cause of this accident was the failure of the truckdriver to operate his vehicle at a speed consistent with the dense fog and to stop at the lowered grade crossing gate. (NTSB/RHR-90/01)

Multiple-Vehicle Collision and Fire -- 12/11/90 -- Calhoun, Tennessee

A tractor-semitrailer in the southbound lanes of Interstate 75 about 9:10 a.m. struck the rear of another tractor-semitrailer that had slowed because of fog. The uninjured truckdrivers exited their vehicles and attempted to check for damage. After the initial collision, an automobile struck the rear of the second truck and was in turn struck in the rear by another tractor-semitrailer. Fire ensued and consumed two trucks and the automobile. Meanwhile, an automobile in the northbound lanes of Interstate 75 struck the rear of another automobile that had slowed because of fog. A pickup truck and two other automobiles then became involved in the chain-reaction rear-end collision. No fatalities, injuries, or fires occurred. Subsequently, 99 vehicles in the northbound and southbound lanes were in multiple-vehicle chain-reaction collisions that killed 12 people and injured 42 others. The Safety Board determined that the probable cause of the multiple-vehicle collisions was drivers responding to the sudden loss of visibility by operating their vehicles at significantly varying speeds. (NTSB/HAR-92/2)

Multiple-Vehicle Collision and Fire -- 07/27/93 -- Bakersfield, California

About 3:50 p.m. a tractor-semitrailer traveling northbound on State 99 crashed into traffic that was slowing near a construction work zone. The accident occurred in an area that was straight and level with good sight distance and visibility. Both of the northbound lanes were open. The work zone was set up substantially in accordance with State requirements. Two changeable message signs south of the construction zone read "Caution, Prepare to Stop" in advance of fixed signs. A State transportation inspector had also been driving the work zone just before the accident to check for traffic backups and to adjust the signing accordingly. Witnesses indicated that the signs were clearly visible and that traffic had slowed. According to the witnesses and the physical evidence, the truckdriver neither attempted to slow his truck nor make any evasive maneuvers to avoid traffic. Seven vehicles became involved in the chain-reaction collision and ensuing fire. Nine people were fatally injured, and nine others received minor injuries. At the time of this report, a probable cause had not been determined. (DCA/93-MH/003)

APPENDIX C

Multiple-Vehicle Collision and Fire -- 07/03/94 -- Weatherford, Texas

A cargo van, which had been converted for recreational use, was traveling at a slow speed in the right lane eastbound on Interstate 20. It was experiencing a mechanical difficulty, and its hazard flashers were activated. The driver, three other adults, and 14 children occupied the van. The driver of the tractor, which was pulling an empty refrigerated semitrailer, took no evasive action before striking the rear of the van. The truckdriver, who was employed by an interstate commercial carrier, stated that he was unsure how the crash occurred because he may have passed out or fallen asleep. Following the initial impact, the van and truck crossed the right shoulder, struck the guard rail, were directed back across the two eastbound lanes, and came to rest in the center median. A fire ignited and consumed the van and the tractor. Fourteen people in the van died, and the other occupants sustained minor-to-severe injuries. The truckdriver received minor injuries. The Safety Board determined that the probable cause of this accident was the truckdriver's failure to attend fully to his driving task due to reduced alertness consistent with falling asleep. Contributing to the accident was the van driver's decision to drive on a travel lane at a slow speed on a high-speed highway. (DCA/94-MH/006)

School Bus/Tractor Semitrailer Collision -- 12/21/94 -- Fairfax, Minnesota

A 77-passenger school bus was stopped on State 19 near Renville County 27 about 9 a.m. to pick up the first students of the day. The pavement was damp with ice-covered shoulders, and a moderate to heavy fog was present. Visibility was between 200 and 400 feet according to police. The school busdriver stopped in the traffic lane and activated the stop arm on the left side of the bus, the rear red flashing lights, and the overhead white flashing strobe light. A student, accompanied by his brothers and his mother, approached the school bus to board. Meanwhile, a 1982 truck tractor/semitrailer combination unit loaded with soybeans was eastbound on State 19. The truckdriver reported that he saw the flashing red light on the rear of the school bus but was unable to stop in time. He was afraid of veering into the opposing traffic lane, so he swerved to the right and began braking. The tractor began jackknifing, struck the three children, traveled approximately 137 feet, and came to rest in a snow bank. The Safety Board determined that the probable cause of this accident was the failure of the truckdriver to respond in time to the stopped school bus. This failure resulted from speed that was excessive for the fog conditions and from a diminished level of alertness or momentary lapse of attention.
(CHR/95-F/H006)

Multiple-Vehicle Collisions -- 03/20/95 -- Mobile, Alabama

A series of collisions involving 169 vehicles with 1 fatality and 71 injuries occurred between 6:30 and 6:50 a.m. in dense fog on the Bayway of Interstate 10. Seventeen of the 169 vehicles were tractor-semitrailer combination units and the remaining vehicles were passenger cars, vans, pickup trucks, and straight trucks. The single collision on the eastbound road involved 110 vehicles, and the 12 collisions on the westbound road involved 59 vehicles. At the time of this report a probable cause had not been determined. (SRH/95-F/H016)

Bayway Fog Detection System Study -- August 1994

In October 1992, a 40-vehicle collision occurred under limited-visibility conditions on the Bayway. A study was commissioned following that incident to explore the feasibility of a fog detection system on the Bayway. The national consulting engineering firm that had designed the fog detection/incident management system on Interstate 75 near Calhoun, Tennessee, completed the Bayway study in August 1994. Its recommended design would mitigate the hazards associated with driving on the Bayway, surrounding bridges, and roads during reduced visibility. After the March 20, 1995, incident, the Bayway study recommendations were implemented the following day.

APPENDIX D

Fifty-State Hazard Flasher Survey

STATE	Flashers Allowed on Moving Vehicle	Flashers Required Below Posted Minimum Speed	Flashers Required in Low-Visibility Conditions	Flashers Required on Disabled Vehicles
AL	Yes	No	No	Yes
AK	No	No	No	Yes
AR	Yes	No	No	Yes
AZ	Yes	No	No	No
CA	Yes	No	No	Yes
CO	Yes[1]	No	Yes[2]	Yes
CT	Yes	Yes[3]	No	No
DE	Yes	No	No	No
FL	No	No	No	Yes
GA	Yes	No	No	No
HI	Yes[4]	No	No	No
IA	Yes	Yes[5]	No	Yes
ID	Yes	No	No	No
IL	No	No	No	No
IN	Yes	No	No	No
KS	Yes	No	No	Yes
KY	Yes[6]	No	No	No
LA	Yes	No	No	Yes

[1]Below 20 miles per hour (mph) on highways.

[2]Less than 1,000 feet.

[3]Below 40 mph on interstates or highways when traffic impeded or blocked.

[4]Towed vehicles only.

[5]Below 40 mph on interstates.

[6]Emergency use only.

APPENDIX D

STATE	Flashers Allowed on Moving Vehicle	Flashers Required Below Posted Minimum Speed	Flashers Required in Low-Visibility Conditions	Flashers Required on Disabled Vehicles
MA	No	No	No	Yes
MD	Yes[7]	Yes	No	Yes[8]
ME	Yes	No	No	No
MI	Yes	No	No	No
MN	Yes	Yes	No	Yes
MO	Yes	No	No	No
MS	Yes	No	No	No
MT	Yes	No	No	No
NC	Yes	No	No	No
ND	Yes	No	Yes	No
NE	No	No	No	Yes[9]
NH	Yes	No	No	No
NJ	Yes	No	No	No
NM	Yes	No	No	Yes
NV	Yes	No	No	No
NY	Yes	Yes[10]	No	No
OH	Yes	No	No	Yes
OK	Yes	No	No	Yes
OR	No[11]	No	No	Yes
PA	Yes[12]	Yes	Yes	Yes

[7] Twenty mph or more below posted 45-mph speed limit.

[8] Disabled commercial vehicles.

[9] Emergency use only on freeways.

[10] Below 40 mph on interstates or throughways.

[11] Slow moving trucks in mountainous areas.

[12] Below posted minimum speed or 25 mph.

STATE	Flashers Allowed on Moving Vehicle	Flashers Required Below Posted Minimum Speed	Flashers Required In Low-Visibility Conditions	Flashers Required on Disabled Vehicles
RI	Yes	No	No	Yes
SC	Yes	No	No	No
SD	Yes	Yes[13]	No	Yes[14]
TN	Yes	No	No	No
TX	Yes	No	No	Yes
UT	Yes	No	No	Yes
VA	Yes[15]	No	No	No
VT	Yes	Yes[16]	No	No
WA	Yes	No	No	No
WI	Yes	Yes[17]	Yes	Yes
WV	Yes[18]	No	No	No
WY	Yes	No	No	Yes[19]

[13]Below posted minimum speed on interstates.

[14]In darkness only.

[15]Below 35 mph on interstates.

[16]Below 40 mph on interstates.

[17]Hazardous situation on Interstate 94.

[18]Slow moving trucks on steep grades.

[19]Commercial vehicles on road or shoulder.

APPENDIX E

INDUSTRY COMMENTS FROM APRIL 1995 CONFERENCE

The National Transportation Safety Board invited selected representatives from private industry to participate in its mobile collision warning technology conference on April 4 and 5, 1995. (Appendix A lists the conference participants.) A summary of comments and concerns about various solutions for the rear-end accident problem follows.

Headway Detection System Manufacturers

* Manufacturers have chosen competing technologies (laser vs. radar) and, therefore, disagree upon their utility. Each specialty is claimed to have overcome the technical problems, such as blinding and cross talk, that plagued earlier systems, and continuing development in both areas shows promise. The merging of their best attributes with infra red or video imaging into one cost effective unit remains a future possibility.

* Manufacturers are competing for different markets: commercial or passenger vehicles or school buses. According to the National Highway Transportation Safety Administration statistics on rear-end accidents, commercial vehicle installation promises the greatest safety return on the investment dollar. Combination units are about two times more likely to be involved in a rear-end collision during their usable life. The rear-end accident, in which a combination unit is the striking vehicle, is approximately 10 times more likely to result in a fatality than the collision involving a passenger vehicle as the striking unit. Therefore, system development for commercial vehicles would appear to promise significant dollar payback to commercial vehicle operators.

However, offering HD systems as an option on original equipment passenger vehicles will provide a much greater market, which spurs the competition, mass production, technological development, and price reduction necessary for such an option to be a reasonable purchase for the consumer. Mating the HD system to intelligent cruise control, with or without automatic braking, could be the convenience factor that causes luxury passenger vehicle customers to purchase the entire package, much the way antilock braking systems and airbags found a foothold in the market before Government mandates.

* Someone suggested that the primary difference between an automotive and a commercial vehicle HD system might be that the commercial vehicle would require more headway than the passenger vehicle; therefore. the system could be manufactured with the necessary sensitivity for a 500-foot range. An automotive system, requiring shorter stopping distances and quicker lane change maneuvers, could be effective at a 330-foot range or 3.7 seconds of headway at 60 miles per hour. Collision warning must be made a viable and accepted technology before the large-scale introduction of automatic braking or automatic steering.

APPENDIX E

* Economy and small size appear to provide an immediate advantage to the introduction of laser-based systems in the passenger vehicle market. The laser also generates a more focused, narrower beam without the side lobes common to radar and may therefore be more target selective. Radar-based manufacturers point out that with a proper allocation of higher frequencies (above 40 GHz) through current Federal Communications Commission rulemaking procedures, their technology could facilitate that the size be reduced, the beam be narrowed, and, therefore, the cost and performance be competitive with lasers, while offering the distinct advantage of fog and precipitation penetrating range. New radar technologies are capable of greater target selectivity, rivaling laser-based systems.

* For HD systems to do a reliable job, we need to address issues relative to the transportation infrastructure that include reflective devices on the roadside allowing the HD system to recognize road curvature and lane lines and on vehicles making them easily recognizable from other road clutter.

* The projected reliability of these systems, which incorporate solid state technology, should be excellent. Original equipment manufacturers (OEM's) are asking for a 10-year/ 100,000-mile durability standard.

* The user/driver must appreciate the worth of these HD systems and, therefore, encourage management to provide this tool. As the drivers accept the collision avoidance technology and its convenience , then management control and driver recording systems may be more feasible.

Motor Coach Industry

* Rear-end accidents are the most costly to the motor coach industry.
* These types of technology are clearly needed.
* False detections must be zero.
* Although supportive of collision warning technology, the industry is doubtful that collision avoidance technology - automatic braking and steering - will ever be practical in commercial vehicles.
* The technology must be nonintrusive and nonobtrusive to drivers to gain acceptance.
* Wiring of the high mounted rear brake lamp to the hazard flashers may be effective in reducing rear-end accidents in fog. Such an improvement would be easily and economically accomplished in production vehicles.
* Motor coaches are generally built to order and could easily include HD systems requested in customer specifications.

Commercial Trucking Industry

* The industry speakers were universally opposed to a Government mandate of HD systems. The failed antilock brake system regulations of the 1970's were cited as an example of the Federal Government legislating before the technology was properly developed.

* An owner/operator has an average of 1.4 trucks, a $96-thousand gross income, and a $28-thousand net income. He can not afford to purchase and maintain a $2-thousand experimental HD system.

* "We're getting into something that a guy with a screwdriver, a wrench, and a hammer can't understand anymore. Technological developments in the area of electronic throttle control, electronic brake activation, antilock braking systems, and now the possibility of HD systems and automatic cruise control, require a total vehicle systems approach. I mean, pretty soon, we've got so many gadgets hung on a truck, we don't have room in the truck to haul cargo anymore."

* All the whistles and bells in the cab of a truck may be leading to driver overload. Does the benefit of the HD system justify the expense?

* Some speakers believed that these systems will provide the driver with a sense of invulnerability and that the driver will not take proper precautions. Others disagreed and believed that a minority of drivers would engage in compensatory risktaking and that the majority would properly regard the system as only a tool.

* The best solutions are usually the simplest solutions. The use of hazard flashers in restricted vision situations should be encouraged, and the laws governing their use should be standardized nationwide. One speaker noted that drivers had received traffic citations for using hazard flashers while in the travel lanes of interstate highways.

* Citizens band radio usage should be encouraged, and licensing should restrict use to crucial situations. The chatter over the main frequencies has become an unreliable source of communication for truckdrivers.

* "About that accident down in Arkansas where fog was sudden. This system (A) which provides about a 300-foot warning distance is not going to keep me from having . . . a wreck at the bottom of the hill. The buzzer is going to be making that noise as I crash into that pile. In the fog, a driver wouldn't know whether to steer left or right."

* The best way to avoid fog-related accidents is to park your vehicle, but truckers seldom have that option.

* Speakers from a trucking company currently using four "system A" units spoke very favorably.

(1) Many drivers reported being alerted to a hazard in time to take evasive action.

(2) False alarms were all but nonexistent. Nuisance alarms occurred on occasion, but the driver was generally able to visually recognize the source, such as signs and guardrails on a curve, and acted appropriately without undue stress. The speed sensitive alarm activates when the vehicle is within 3 seconds of an object in its headway.

(3) Drivers requesting the HD-equipped vehicles and becoming accustomed to the system, reported a lost sense of security when driving a nonequipped vehicle.

(4) No evidence was present that drivers practiced compensatory risktaking.

(5) The HD system does not include driver monitoring technology, and drivers therefore perceived the system as a safety tool and not a threat to job security.

(6) These systems will be successfully utilized when "sold from the bottom up," and the drivers have a demand for the devices.

(7) Due to the almost universal acceptance from drivers, the trucking company now considers equipping all its vehicles with the HD system.

Insurance Industry

The trucking industry and the HD system manufacturer representatives believed that based on projected savings in claims, the insurance industry should reduce premiums to assist carriers in purchasing HD systems. However, an insurance industry representative advised that the industry lacks data about the safety value of HD systems to compute actuarial tables that properly reflect the expected accident reduction cost savings. Until the systems are in use and produce certifiable reductions in accident number and severity, the insurance industry will not offer rebate incentives for HD-equipped vehicles.

The insurance industry representative suggested that the Government undertake a large-scale, long-term controlled study of fleet vehicles, commercial and/or passenger, in which financial incentives are awarded to purchase and install HD systems. Such Government action could serve to accelerate development and acceptance of the system technology in the private market and provide actuarial table information for the insurance industry. The representative also advised that Government mandate may be necessary for HD systems to gain wide usage in the commercial vehicle market. HD systems are currently a sizable expense, and the financial return is uncertain. For a trucking company to finance such a system in all vehicles would require a large expenditure, placing the carrier at a competitive disadvantage to other carriers. Unless the "playing field is leveled" by requiring all commercial trucks to install the HD system, few companies will incur the expense without reasonable expectation of improvement in "the bottom line."

The representative continued that the insurance industry has mixed support for commercial vehicle use of a "black box" type technology, such as the device in aviation and offered as an option on "system A." Although recording vehicle speed and driver action may be an effective management tool, it may also put the commercial vehicle owner at a disadvantage in traffic accident litigation, even after the most minor violation. Although partially credited with a 25-percent accident reduction described earlier for the 1,500-equipped vehicles in the test fleet, the driver monitoring type technology employed by radar "system A" may have also been largely responsible for driver rejection of the entire HD system technology. Driver monitoring devices, as an integral part of an HD system package, can be described as a double-edged sword for both company management and their insurance carriers.