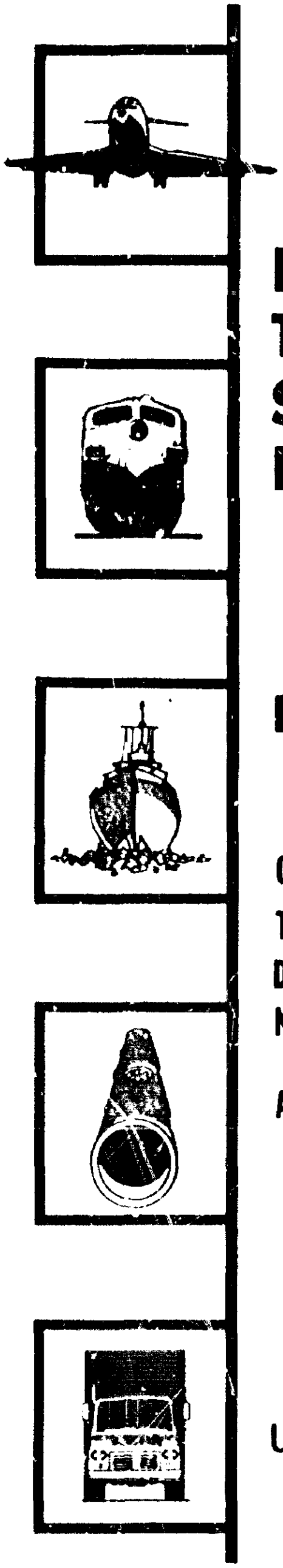
PB 293501



NATIONAL TRANSPORTATION SAFETY BOARD

WASHINGTON, D.C. 20594

HIGHWAY ACCIDENT REPORT

OSTERKAMP TRUCKING, INC.,
TRUCK/FULL TRAILER AND
DODGE VAN COLLISION, U.S. 91
NEAR SCIPIO, UTAH

AUGUST 26, 1977

UNITED STATES GOVERNMENT

TECHNICAL REPORT DOCUMENTATION PAGE

1. Report No. NTSB-HAR-79-1	2. Government Accession No.	3. Recipient's Catalog No. PB293501
4. Title and Subtitle Highway Accident Report - Oaterkamp Trucking Inc., Truck/Full Trailer and Dodge Van Collision, U.S. 91, near Scipio, Utah, August 26, 1977		5. Report Date February 22, 1979
		6. Performing Organization Code
7. Author(s)		8. Performing Organization Report No.
9. Performing Organization Name and Address National Transportation Safety Board Bureau of Accident Investigation Washington, D. C. 20594		10. Work Unit No. 2222B
		11. Contract or Grant No.
12. Sponsoring Agency Name and Address NATIONAL TRANSPORTATION SAFETY BOARD Washington, D. C. 20594		13. Type of Report and Period Covered Highway Accident Report August 26, 1977
		14. Sponsoring Agency Code
15. Supplementary Notes		

16. Abstract

At 4:15 p.m., on August 26, 1977, a 1973 Dodge van and a 1977 Peterbilt truck, pulling an empty 1977 Reliance full trailer, collied head-on during a moderate-to-heavy rainstorm on U.S. 91, 8 miles north of Scipio, Utah. The eight occupants of the van were killed and the truckdriver was injured.

The National Transportation Safety Board determines that the probable cause of this accident was that either or both drivers failed to maintain their vehicle in the proper traffic lane for reasons that could not be determined.

17. Key Words Head-on; wet weather; loss of control; carrier interstate; freight; fatal; skid resistance; crown; asphalt; drainage; upgrade; truck; full trailer; van; tires; brakes; FMVSS 121; HSPS 12; pavement tests; pavement design; interstate highway connecting link.		18. Distribution Statement This document is available to the public through the National Technical Information Service, Springfield, Virginia 22151	
19. Security Classification (of this report) UNCLASSIFIED	20. Security Classification (of this page) UNCLASSIFIED	21. No. of Pages 38	22. Price PC A03/MF A01

NTSB Form 1765.2 (Rev. 9/74)

CONTENTS

NATIONAL TRANSPORTATION SAFETY BOARD
WASHINGTON, D.C. 20594

HIGHWAY ACCIDENT REPORT

Adopted: February 22, 1979

OSTERKAMP TRUCKING, INC.
TRUCK/FULL TRAILER AND DODGE VAN COLLISION
U.S. 91 NEAR SCIPIO, UTAH
AUGUST 26, 1977

SYNOPSIS

At 4:15 p.m. on August 26, 1977, a 1973 Dodge van and a 1977 Peterbilt truck, pulling an empty 1977 Reliance full trailer, collided head-on during a moderate-to-heavy rainstorm on U.S. 91, 8 miles north of Scipio, Utah. The eight occupants of the van were killed and the truckdriver was injured.

The National Transportation Safety Board determines that the probable cause of this accident was that either or both drivers failed to maintain their vehicle in the proper traffic lane for reasons that could not be determined.

INVESTIGATION

The Accident

At 4:15 p.m., on August 26, 1977, a northbound van collided head-on with a southbound truck/full trailer on U.S. Route 91 about 8 miles north of Scipio, Utah. All eight occupants of the van were killed and the truckdriver was injured. The van was en route from Newbury Park, California, to Bountiful, Utah, and had traveled about 200 miles that day. The truck was en route from Idaho Falls, Idaho, to Fillmore, Utah, and had traveled about 300 miles, the last 30 to 40 miles in a spotty, moderate-to-heavy rain. Both the truck and the trailer did not have any cargo.

Traffic was light at the time of the accident, and there were no other vehicles within viewing distance of the accident. The truckdriver was the only surviving witness to the accident and he provided the following explanation of the accident. He stated that he did not know the speed at which he was traveling. He said that he did not have any problem with traction until he began to climb a 2- to 3-percent grade approaching the point of collision, where he saw "a lot of water on the road" and where it "was just like driving on ice." He said that he saw the van approaching in the opposite direction, that it appeared to be on

the proper side of the road, but that it then began to drift toward his side of the road. He said that when the vehicles were quite close and he believed the van driver was "not doing anything at all to get back," he thought he had to do something to reduce speed and give the van driver "time to straighten out." He said he rapidly and firmly applied the brakes on both the truck and the trailer, and the combination began to skid. He said he saw the dropoff beyond the left shoulder of the road, and tried to get the vehicle under control, but that it didn't seem to respond. As he was trying to steer out of the skid, he stated that he attempted to engage the "jake brake," a device which increases the engine's braking capability but is intended for energy absorption during downhill operations. He could not relate additional details concerning his evasive maneuvers.

The physical evidence (gouge marks on the pavement matched to undercarriage damage to the two vehicles and a match-up of damaged components between the two vehicles) indicated that both vehicles were straddling the centerline at impact; the truck/full trailer was almost fully on the van's side of the road, while the van was just across the centerline. (See figure 1.) After impact, the truck/full trailer rotated clockwise while continuing forward. Upon impact, the van immediately rotated counterclockwise and then rotated clockwise with the truck while traveling rearward and to its left. The truck/full trailer stopped on the east side of the road. The van came to rest on the west side of the road.

Injuries to Persons

Injuries	Drivers	Passengers	Other
Fatal	1	7	0
Nonfatal	1	0	0
None	0	0	0

Damage to Vehicles

Major impact damage was to the left front corner of the truck (see figure 2) and front of the van (see figure 3).

Roadway Information

U.S. 91 was being used as a two-lane, 38-mile connecting link between two completed sections of Interstate 15. Since August 1976, 15 other persons had been killed on this connecting link. Nine of these deaths had occurred since July 5, 1977, in three separate accidents involving large trucks. The average daily traffic was 3,500 vehicles. Twenty percent of the vehicles were light trucks and 21 percent were heavy trucks.

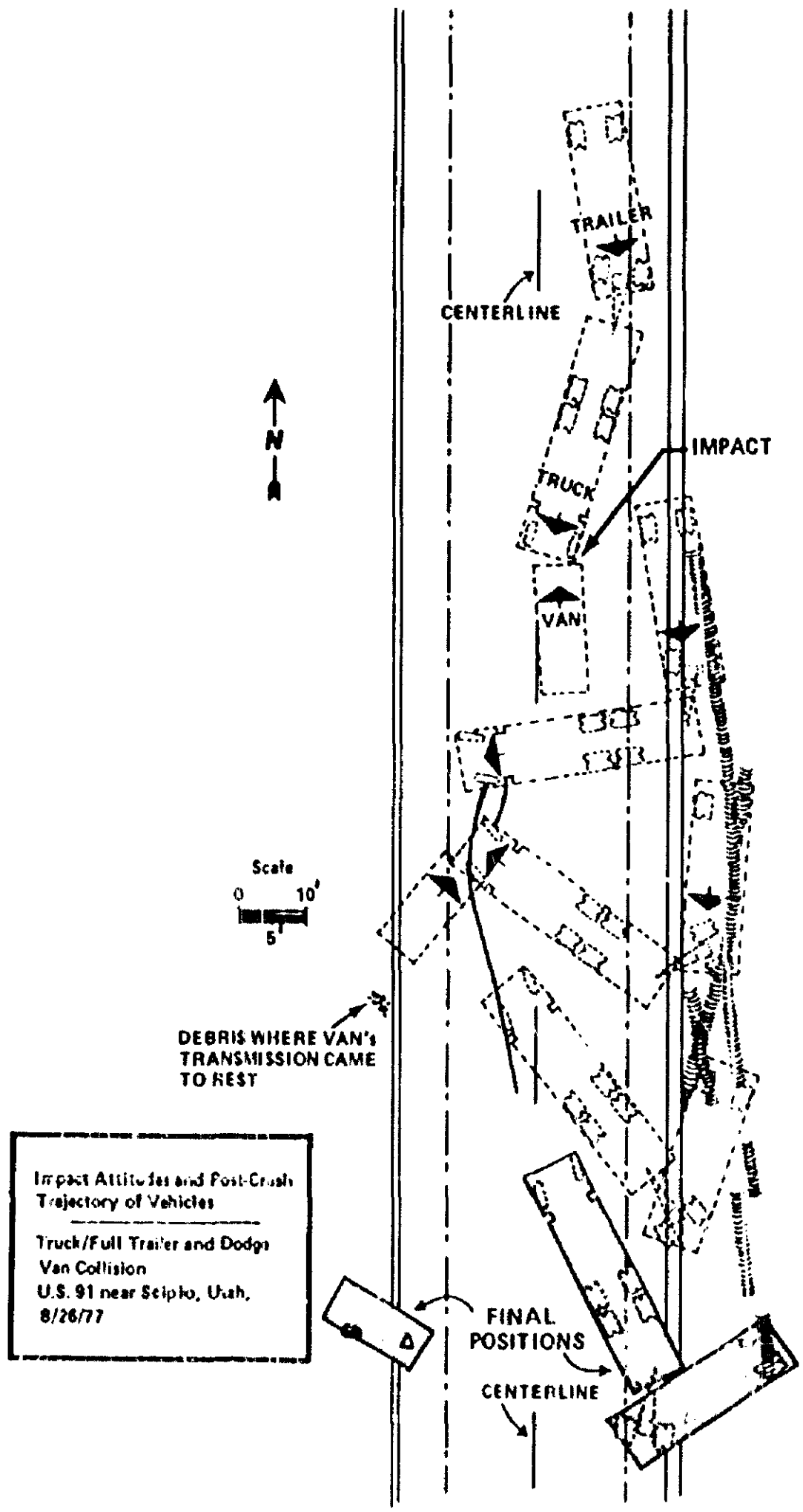


Figure 1. Impact attitude and post-impact trajectory of vehicles.

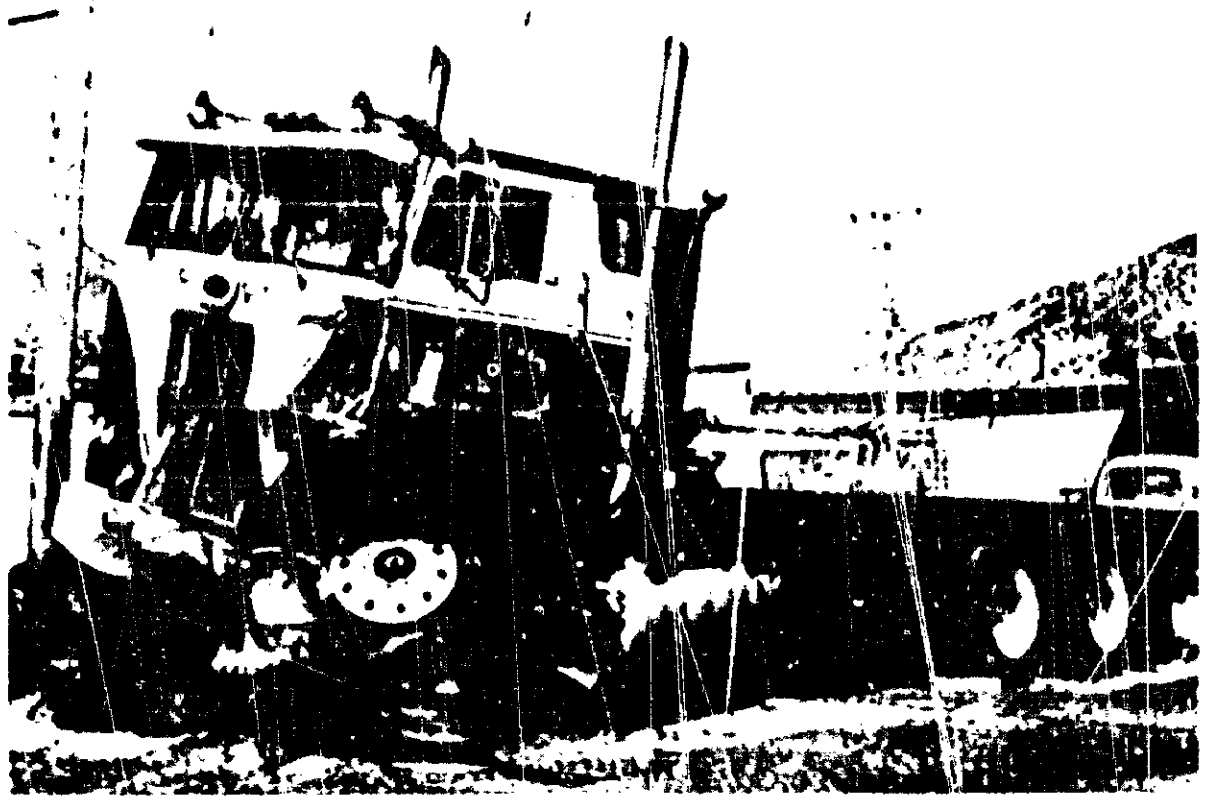


Figure 2. Damage to the truck.

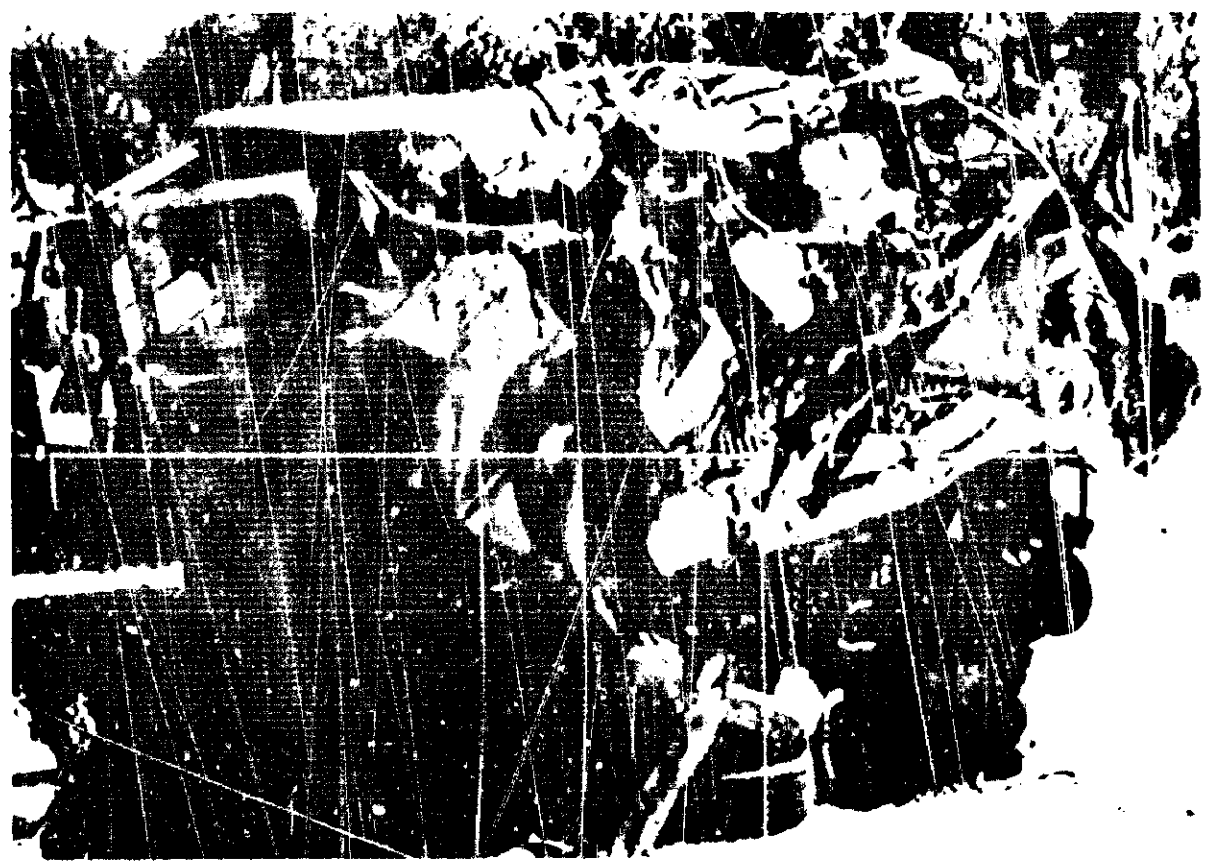


Figure 3. Damage to the van.

A 17-mile section of the connecting link had been resurfaced with a 1 1/2-inch asphalt overlay between June 20, 1977, and July 29, 1977. This accident, one other fatal accident, and three property-damage accidents occurred on this 17-mile section after it was resurfaced. This accident was the only accident that occurred on wet pavement. The State of Utah funded and controlled all activities related to the resurfacing project, which was done primarily because the pavement surface was structurally deficient.

The accident rate was 0.46 accidents per 100,000 vehicle miles for the completed section of Interstate 15 north of the connecting link and 0.69 for the completed section of Interstate 15 south of the connecting link. The accident rate for the connecting link was 1.46 accidents per 100,000 vehicle miles. This same relationship--a lower accident rate for completed sections of interstate highway (1.07) as compared to connecting links (1.41)--was noted statewide. According to accepted highway practices, the accident rate on the connecting link was not high enough to warrant special attention before the recent increase in fatal accidents.

The 55-mph speed limit was not posted. The Utah Highway Patrol had conducted a special traffic law enforcement program between August 7 and 11, 1977, on the U.S. 91 connecting link. Some 408 citations, or 98 percent of the "hazardous" citations 1/ issued, were for exceeding the 55-mph speed limit.

At the accident location, U.S. 91 was a two-lane, two-way, asphalt highway with 12-foot-wide travel lanes and 5- to 8-foot-wide asphalt shoulders. (See figure 4.) The roadway was straight with a 1- to 3.7-percent grade, uphill for the truck/full trailer and downhill for the van. The steepest point of the grade was at the accident site. Impact occurred about 4,200 feet from the bottom of the 2-mile-long grade. Pavement markings were new and in good condition, and conformed to standards established by the Manual on Uniform Traffic Control Devices.

The circumstances of the accident, the truckdriver's testimony, and on-scene observations indicated that a thorough evaluation of the pavement surface was required. Appendix A details this evaluation. Utah Department of Transportation (DOT) Mu Meter and Federal Highway Administration (FHWA) ASTM-E274 locked-wheel skid trailer tests were performed on August 30, 1977, and October 18, 1977, to determine the frictional characteristics of the pavement surface. These tests revealed that the frictional quality of the southbound pavement surface in the truck/full trailer's direction of travel had been deteriorating at the accident site. The wet frictional coefficient of the newly paved surface was found to be progressively lower approaching the point of impact. At 40-mph test speeds, the southbound outside wheel path of traffic had a lower average

1/ Hazardous citations included speeding, impeding traffic, improper turns, and driving under the influence of alcohol.

Figure 4. View of accident site looking north.

frictional coefficient than the inside wheel path. Mathematical projections indicated that the average wet coefficient of friction of the outside wheel path probably was below that recommended for wet pavement surfaces at the time of the accident. Accordingly, southbound vehicles were operating on a split coefficient of friction surface where the tires on one side of the vehicle were traveling on a more slippery surface. At 60-mph test speeds, the southbound inside and outside wheel paths were found to have an alternating pattern of a wide departure in friction values followed by a merging of these values beginning about 1,000 feet before impact. (See figure 5.) This finding indicated that the split coefficient of friction effect was more pronounced at higher operating speeds.

These pavement surface conditions were not discovered through standard pavement inventory procedures commonly used by the Utah DOT, the FHWA, and many other States. Utah DOT standard procedures classified the southbound pavement surface as marginally acceptable shortly after the accident (August 30, 1977). Mathematical projections indicated that FHWA tests probably would have also classified the pavement surface as marginally acceptable if these tests had been made shortly after the accident. Even in its later, more deteriorated condition (October 18, 1977), Utah DOT procedures classified the pavement surface as "marginal," with "further monitoring suggested." FHWA procedures indicated a pavement surface in need of "analysis for corrective treatment."

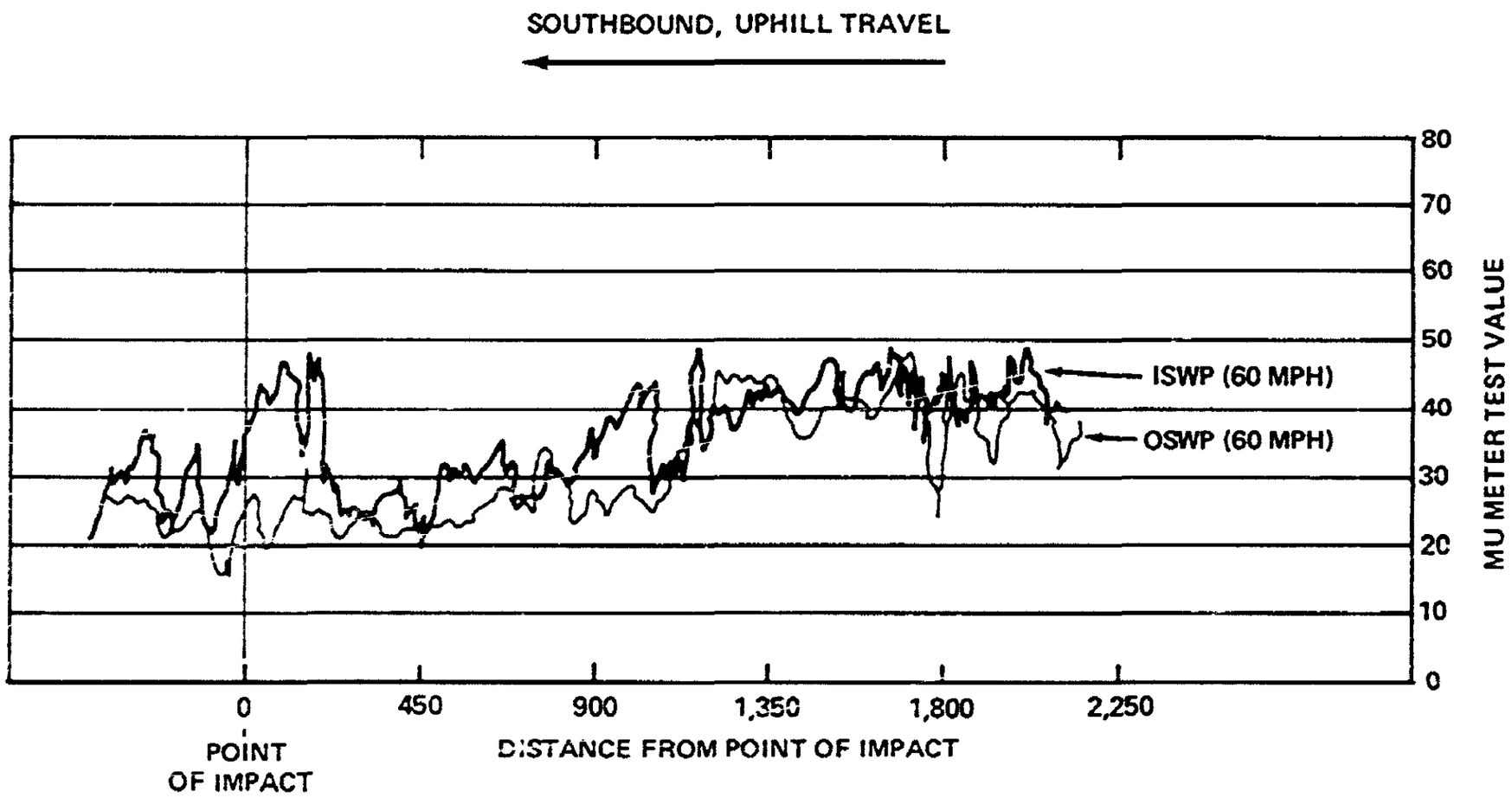


Figure 5. Mu Meter skid numbers for the inside and outside wheel paths of the southbound lane as measured on October 18, 1977.

Similar skid tests conducted in the northbound traffic lane indicated that pavement frictional characteristics were marginal with respect to recommended values, but that a progressively lower, split coefficient of friction surface did not exist there.

A topographic survey indicated that in an area 50 to 100 feet before impact, there was a lateral "flat spot" in the crown on the southbound side of the road. A larger-than-normal amount of water could have accumulated in this area in the southbound traffic lane. Over an approach distance of 500 feet up to the point of impact, the crown on the southbound side of the road varied more significantly than on the northbound approach. FHWA outflow meter 2/ tests indicated that the pavement surface texture/drainage was noticeably not as good in the southbound lane wheel paths as it was in the northbound lane wheel paths. Sand patch tests indicated that surface texture depth in both traffic lanes was below recommended minimums developed by two independent researchers. 3/ In the southbound lane, surface texture depth over an area 75 feet before impact to 75 feet after impact was of such fine texture that, according to one researcher, 4/ its use should be prohibited.

Pavement core samples, the pavement mix design, construction practices, and test results were examined to determine whether any design or construction practices may have contributed to the poor pavement surface produced. Pavement drainage characteristics, low surface texture depth, smooth or polished aggregate, and bleeding or flushing asphalt were all identified as possible candidates for contributing to the low frictional quality of the pavement. Pavement design and construction practices favored the production of a pavement surface with a higher-than-ideal percentage of finer aggregate, which could have tended to reduce surface texture depth and an already low pavement mix design air void content. Low air void content, a higher-than-ideal percentage of finer aggregate, a large aggregate that was suspected to have been susceptible to traffic polishing, and high, heavy-vehicle traffic loads and traction requirements on a continuously steepening grade may have accelerated compaction, flushing, and polishing of the southbound pavement surface at the accident site.

The Utah DOT reported that it had no previous problems using mixes with design and aggregate specifications similar to those in the mix used for the resurfacing project at the accident site. In November 1977, the Utah DOT used a heater planer treatment, scarified the pavement

---

2/ National Cooperative Research Program Report No. 14, "Skid Resistance," (1972), pg. 26.

3/ "Tentative Pavement and Geometric Design Criteria for Minimizing Hydroplaning," Galloway, et al, February 1975, (FHWA RD-75-11).
"Pavement Characteristics and Skid Resistance," Elsenaar, Reichert, and Sauterey, Transportation Research Record No. 622, 1976.

4/ Ibid.

surface, and added more aggregate as an interim measure to improve skid resistance along a 0.6-mile segment of U.S. 91 which included the accident site. The Utah DOT reported that the degree of flame observed during the heater planer treatment was not consistent with the degree of flame that would be seen when burning a surface containing a large amount of excessive asphalt. After the surface treatment was completed, trailer tests indicated the roadway was marginally above acceptable limits. (See appendix A.)

The Utah DOT reported that as a result of other research, which began before this accident occurred, the air void content design specifications for mixes of this type was increased. The findings of this accident investigation indicated that this change may improve the frictional characteristics of future pavements produced.

Driver Information

The 30-year-old truckdriver was a resident of California. He held a valid California driver's license, but had an out-of-date Medical Examiner's Certificate dated July 8, 1976. He maintained a driver's daily logbook. Since the truck was being operated in interstate commerce, the medical certificate and logbook were required under Federal Motor Carrier Safety Regulations. The State of California driver license records indicated that the truckdriver had no major convictions, failures to appear, or accidents. Information provided by the Osterkamp Trucking Company, the truckdriver's employer, indicated the driver had 12 traffic violations in California between November 1973 and the date of the accident. These 12 non-major violations included four for an "overweight vehicle," one for "excessive hours of service," one for "speeding," one for "failure to obey traffic signs," and five for minor State or municipal rule violations.

In addition to California, the truckdriver also normally drove in the States of Arizona, Idaho, Utah, Nevada, Oregon, and Montana. None of these States had any records of major convictions, failures to appear, or accidents for this truckdriver. The truckdriver reported that he was involved in one minor accident in which an automobile struck his truck. Insurance records indicated he was not involved in any accidents.

He had been the only driver of this vehicle since it was purchased new in November 1976, and he had driven this route several times before the accident.

The 34-year-old van driver was a resident of California. He held a valid California driver's license and had no record of previous accidents or violations. He and his family had stopped at a motel in St. George, Utah, at about 3:30 a.m. on the day of the accident. According to the desk clerk, the driver was upset about not making better time when he checked in, and the family checked out about 10:00 a.m. That morning, two prescriptions for one of the children were picked up in a drugstore in St. George.

The driver had borrowed the van from his father-in-law and had driven it "many times." He was a defensive driving instructor and had no history of major medical problems.

Vehicle Information

The truck -- The truck was a 1977 Peterbilt three-axle truck, Vehicle Identification Number 85765P, with a Reliance flatbed body. The odometer reading was 81,528 miles. It was equipped with a Fuller RTO-12513 transmission and a KT 450 Cummins engine. All three axles of the truck were equipped with Michelin XZZ tires, airbrakes, and Eaton antilock brake systems. The antilock system was being used to meet the performance requirements of Federal Motor Vehicle Safety Standard (FMVSS) 121. After the accident, the truck was removed from the scene and stored in an open area before a detailed examination could be initiated. Therefore, control system positions such as the transmission and "jake brake" settings could not be determined.

The tires, steering system, foundation brake system, and the antilock systems were inspected and tested. Appendix B contains the results of this examination. No previous damage, missing components, foreign materials, or irregularities were noted, and all units appeared to be mechanically functional. Tire tread depths, tire inflation pressures, brake slack adjustments, and brake lining thicknesses were all within acceptable levels. Crash damage to both front-axle brake chamber assemblies suggested that the front brakes were applied at impact. This finding indicated that there had not been a system-wide air loss that prevented brake application before impact.

No evidence of a malfunctioning truck antilock system was found. The truckdriver stated that he believed his antilock braking system was functional before the accident, and he had no problems with, or complaints about, the antilock system. A jumper wire was found in the truck antilock warning light circuit. The jumper wire would not have affected the operation of the antilock system. However, the jumper wire altered the circuitry in such a manner that the warning light would not light until both the front and forward bogie-axle antilock electronics had failed. The warning light was designed to light if the antilock system at any single truck axle malfunctioned.

As a result of this accident investigation, Peterbilt examined other trucks and found that some trucks equipped with front-axle antilock control also had been inadvertently equipped with the jumper wire. Therefore, Peterbilt initiated a recall of all trucks built after April 1976 and equipped with front-axle antilock control to inspect for and remove any jumper wires in those vehicles.

The trailer -- The Reliance two-axle full trailer, Vehicle Identification Number RRS-76-808, was equipped with Michelin XZZ tires, and both

axles of the flatbed trailer were equipped with airbrakes and B. F. Goodrich antilock brake systems. (See figure 6.) Appendix C contains the results of examinations of these systems. Tire tread depths, tire inflation pressures, brake slack adjustments, and brake lining thicknesses were all within acceptable levels. No damage was visible to, and no components were missing from, the conventional braking system. Small, laterally-oriented heatchecking cracks were noted along the wear surface of the trailer brake drums. These cracks would not have adversely affected braking performance. No other foreign materials or irregularities were noted on the drums, linings, or associated components, and all pneumatic systems functioned properly.

The initial phase of examining the braking and antilock systems involved road-testing the trailer on various dry pavement surfaces. During these tests, the front wheels of the trailer repeatedly cycled (locked/unlocked) as intended under a full brake application; however, the rear wheels locked and remained locked until the full brake application was removed. These tests indicated a loss of rear-axle antilock capability; however, the rear foundation brakes were working, which met the fail-safe requirements of FMVSS 121 for airbrake systems. During the road tests, the rear of the trailer rotated toward the right while under full brake application; the degree of rotation increased at higher road speeds and as the slope of the road crown to the right increased.

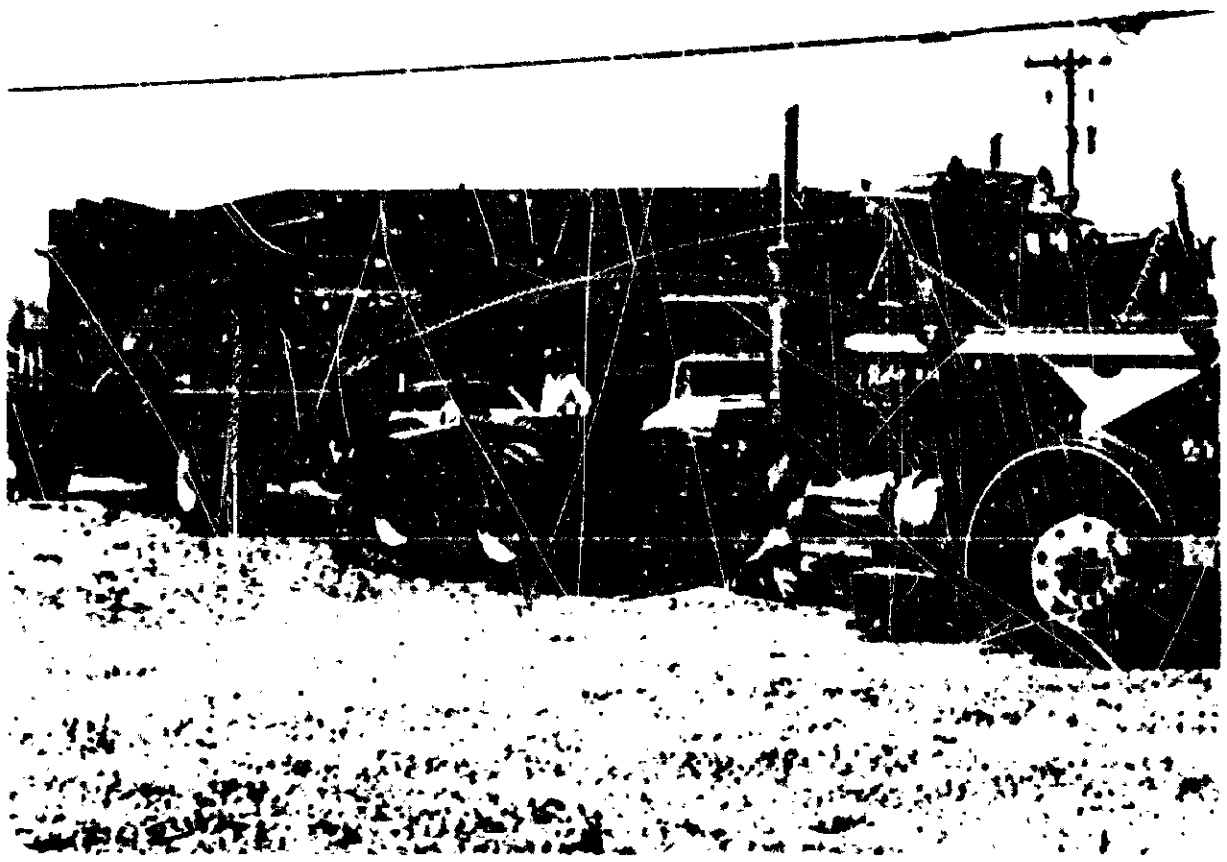


Figure 6. Accident trailer attached to test tractor.

Two deficiencies were noted during the postcrash examination of the components of the trailer antilock systems. There was a kink in one of the two wires leading from the front-axle modulator assembly to the left-front wheel speed sensor. (See figure 7.) This kink probably resulted from improper assembly or reassembly procedures. At the kink, the metal wire conductor was exposed. The wire insulation was scorched where the conductor was exposed. This condition was symptomatic of an electrical short circuit that could have produced intermittent loss of antilock capability at the front axle of the trailer but none was observed during the trailer road tests. No unusual conditions were noted for the two wires leading to the right-front wheel sensor. The wires to both front-axle sensors had not been twisted together. (See figure 8.)

The two wires leading to both rear-axle wheel speed sensors were found twisted tightly together in the direction of forward rotation of the rear wheels. (See figures 9 and 10.) The metal female electrical connectors at the end of the wires leading to the right-rear wheel speed sensor were found to be in contact with each other. An electrical short due to this connector contact accounted for the loss of trailer rear-axle antilock capability which had been observed during the road tests. This connector contact was produced as a result of the wire twisting. The wire twisting resulted from the base of the wheel speed sensor rotating within the tubular axle. There was a noticeable lack of adhesive sealant which was intended to prevent rotation of the sensor within the tubular axle.

A trailer antilock warning light system was found mounted on the left longitudinal frame rail forward of the rear axle and underneath the bed of the trailer. This trailer warning light system was not required by FMVSS 121. Due to its design and location, this system would not have readily served to warn of the antilock system deficiencies discovered during this investigation.

The results of the trailer antilock system examination were made available to the National Highway Traffic Safety Administration (NHTSA) in September 1977. Goodrich advised the Safety Board that the twisted wires on the trailer were "the result of the sensor rotating due to an insufficient amount of adhesive applied during installation." Goodrich further advised NHTSA that it had repaired or replaced 58 sensors that had twisted wires and which had caused disconnection. The NHTSA advised Goodrich in a March 1978 letter that: "It appears that even when properly installed, the in-axle wheel speed sensor has a tendency to twist and disconnect....Incorrect or loss of signal coming from the in-axle sensor is a safety-related defect." The NHTSA reminded Goodrich of the statutory requirements pertaining to safety defects and urged Goodrich to issue a notification and remedy order to correct the problem. In July 1978, a tentative agreement was reached whereby Goodrich would issue a service bulletin to advise assembly and maintenance personnel of the need to insure that sufficient adhesive sealant was applied during assembly of the unit, and the NHTSA would monitor the effectiveness of this approach. Goodrich distributed this service bulletin in September 1978.

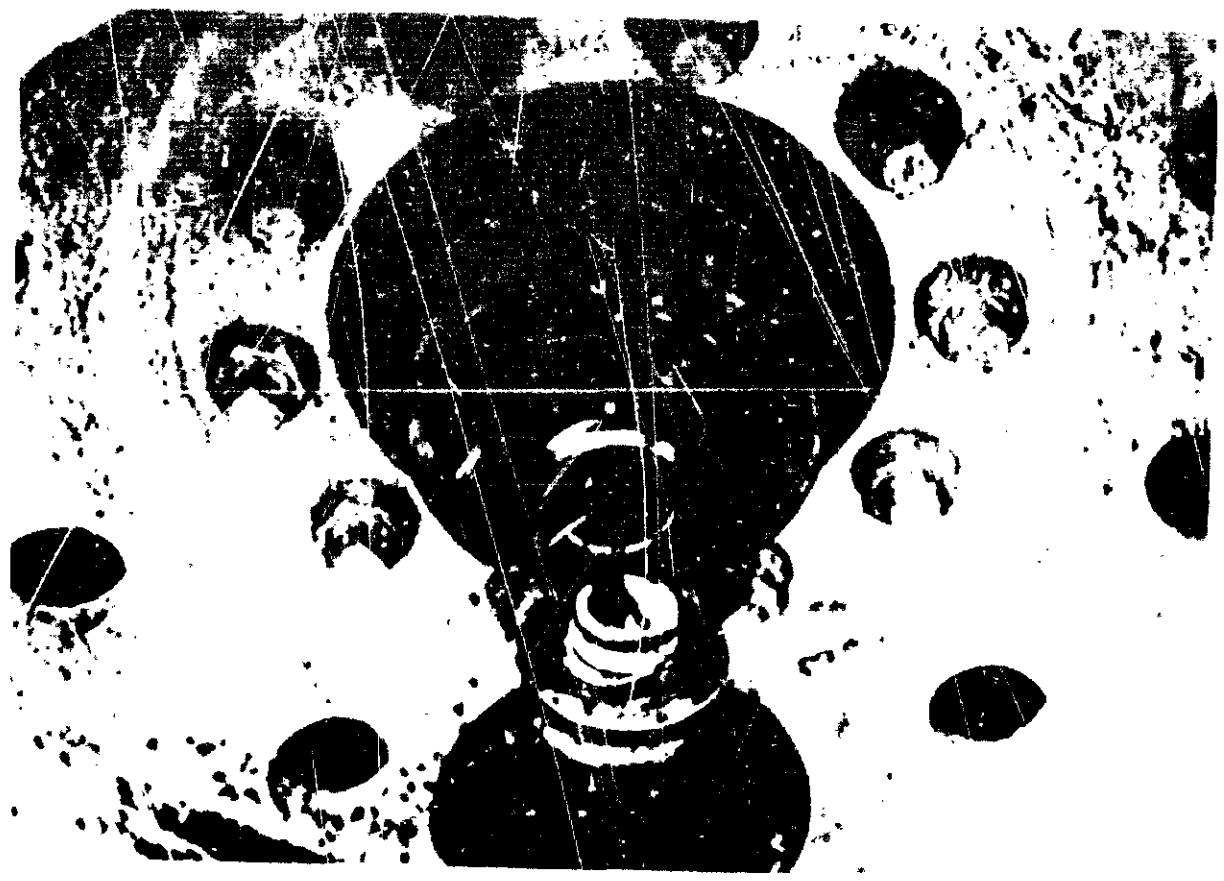


Figure 7. Left front wheel speed sensor. Note disconnected wire and scorched insulation on that wire.

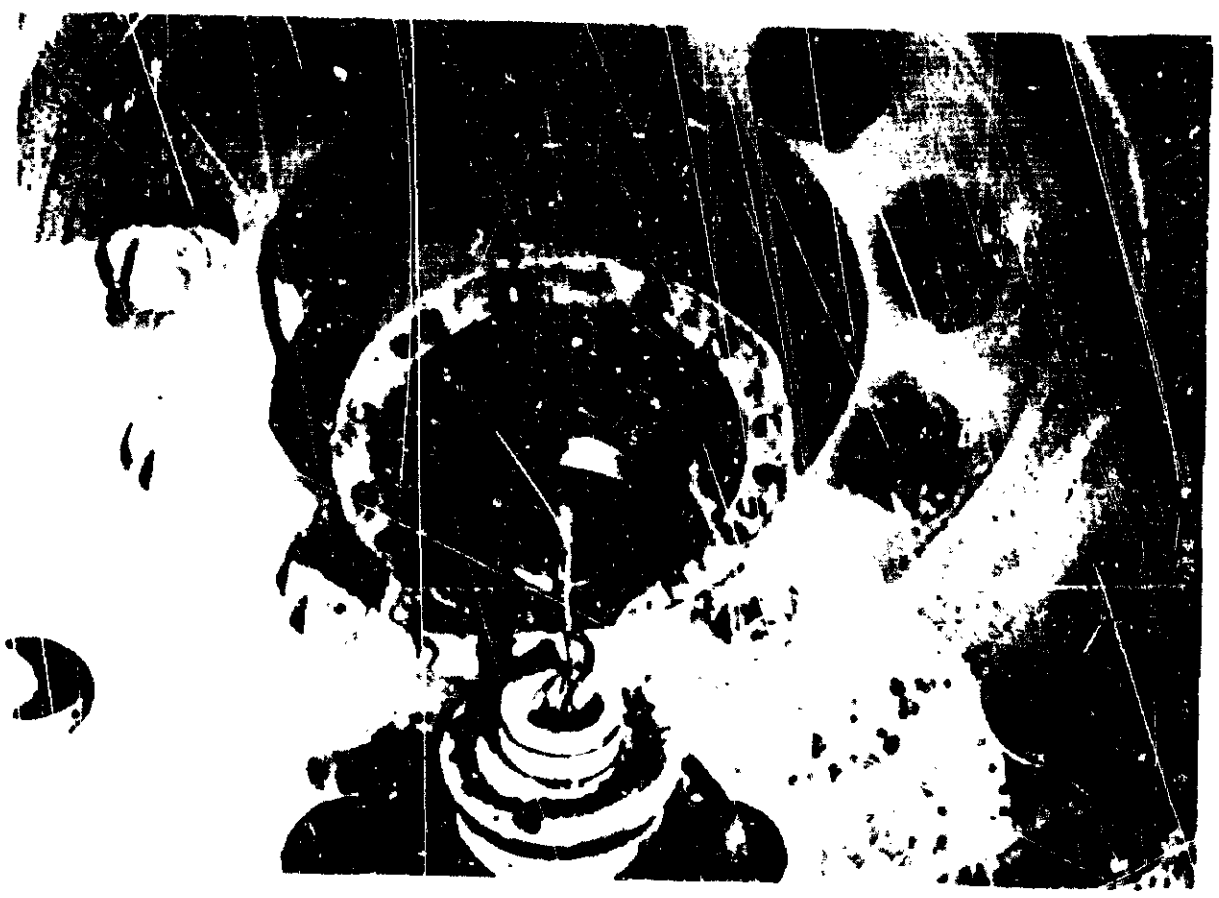


Figure 8. Right front wheel speed sensor.

Figure 9. Left rear wheel speed sensor. Note twisted wires.

Figure 10. Right rear wheel, end of axle. Note metal parts of female connectors in contact with each other.

The van -- The van was a 1973 Model 200 Dodge Tradesman. No damage was visible to and no components were missing from the braking system at the front or rear wheels of the van. No foreign materials or irregularities were noted on the brake pads or discs of the front wheels. No foreign materials or irregularities were noted on the drum, linings, or internal components at the right-rear wheel. The linings for the left-rear wheel were covered with grease and a leaking left-rear grease seal was found. This condition would have caused uneven braking when the brakes were applied, which would have caused the vehicle to rotate. The brake linings for both the left- and right-rear wheels were about 1/8-inch thick; this thickness was above minimum requirements of 1/16 inch. Damage to the brake hydraulic system prevented further testing.

All tires on the van were in almost new condition; tire tread depths were all between 9/32 and 12/32 inch. Normal new tire tread depth is 12/32 to 13/32 inch. The front tires were cut and deflated by crash damage. The rear tires had been deflated by the towing service and, therefore, readings could not be determined. No unusual wear patterns were noted on the tires and, except for crash damage, no unusual conditions were noted at the steering and suspension systems.

Meteorological Information

The accident occurred in daylight with overcast skies and falling rain. The truckdriver described the intensity of the rain as moderate to heavy while witnesses that arrived at the scene within a minute or so after the accident described the rainfall as moderately light to moderate. A Safety Board weather analysis indicated the rainfall intensity was between 0.1 to 0.5 inch per hour -- moderate to heavy. The temperature was 52° F at 5:00 p.m. in Nephi, Utah, about 31 miles north of the accident site. Witnesses said that there was no wind. According to the weather records at Nephi, it had rained several times in the month before the accident, reducing the probability that a build-up of foreign material could have made the pavement surface unusually slippery.

Medical and Pathological Information

No autopsies were performed on the van occupants. Injuries were characterized as massive and severe by rescue personnel. No van occupant was wearing a seat or shoulder belt. The Utah Highway Patrol requested that a blood sample be taken from the van driver, but the blood sample was not obtained by the mortician. The truckdriver's injuries were minor and included shock; lacerations and abrasions to the right hand, knees, and shins; and a sore left elbow. He said he was wearing the available seat belt. Blood tests were made only for the presence of alcohol; results were negative.

Survival Aspects

The character of van occupant injuries, van crash damage, and the severity of the collision indicated that the accident probably was not survivable for the van occupants even if they had been wearing seat or shoulder belts.

Tests and Research

At the request and under the supervision of the Safety Board, the NHTSA conducted a limited series of stopping tests with a similar truck/full trailer combination at the Aberdeen Proving Grounds on October 3, 1977. These tests were conducted on a wet pavement surface with a crown of about 1 percent sloping downward toward the right and an average frictional quality below that measured at the accident site. Emergency stops were made from speeds between 25 and 40 mph, with and without an operating trailer rear-axle antilock unit, and with and without driver steering input after brake application. In all tests, the truck combination was in alignment before brake application and the driver applied the brakes continuously.

These tests indicated that as long as the vehicle was in alignment before braking and the driver maintained continuous braking application, and made no steering input, the vehicle would spin counterclockwise but would not establish a trajectory to the left, as claimed by the truckdriver. The spinning condition developed with all antilock systems working, with all but the rear-axle antilock system working, and with all antilock systems disconnected to simulate a non-antilock-equipped vehicle. With the trailer rear-axle antilock unit not working, the test driver could prevent the truck from entering the lane to his left through corrective steering, but was not able to prevent the trailer from entering the lane to his right at higher speeds.

ANALYSIS

The physical evidence permitted the Safety Board to establish the point of impact, relative positions of the vehicles at impact, principal directions of motion before impact, speeds at impact, vehicle trajectories after the crash, and final points of rest. However, this evidence did not provide enough information for the Safety Board to independently determine the movements of either vehicle before impact. Limits in this evidence and research data prevented the Safety Board from confirming or denying that the truckdriver's alleged evasive actions were necessary, that they took place, or that they would have produced his described loss of control.

Concerning whether his evasive actions were necessary, the truckdriver reported that the van was drifting toward the wrong side of the road and the vehicles were quite close to each other when he applied the brakes. However, at impact, the truck/full trailer was almost fully on the van's

side of the road while the front of the van was just across the centerline. If the truckdriver's description was accurate and complete, the van would not have been across the centerline when he applied the brakes, and he had only to remain in his traffic lane to avoid impact. However, the van could have been drifting toward the centerline, the van driver realized this and could have been correcting to his right as the truckdriver applied the brakes and lost control. The van driver then could have begun an evasive maneuver to the left and was struck by the truck. Therefore, it was not possible to determine whether the truckdriver's alleged evasive actions were necessary.

There were no skidmarks before the point of impact to indicate that the truckdriver had applied his brakes at some point consistent with reacting to the drifting van. However, it is not unusual for even locked-wheel brake applications to be made on wet pavement without leaving skidmarks. The absence of skidmarks from the sliding vehicles after impact indicated that this could have been possible at this location. Therefore, it was not possible to determine whether the truckdriver's evasive action took place.

The Safety Board did not find any conclusive evidence to indicate that a malfunction of the antilock brake systems on the truck or the trailer contributed to this accident. Two antilock deficiencies were found on the trailer which resulted in a loss of the trailer's rear-axle antilock capability. However, the rear foundation brakes were operative, which met the failsafe requirements of FMVSS 121, and the NHTSA antilock braking tests conducted for the Safety Board indicated that even with the loss of trailer rear-axle antilock capability, a rapid, hard brake application alone would not have predictably produced the vehicle's alleged trajectory to the left. Some other undetected, unaccounted for, or currently unmeasured factor -- additional truckdriver corrective or emergency maneuvers, vehicle instability before brake application, or widely fluctuating pavement quality -- may have been present that produced or assisted in producing the described loss of control and trajectory. Therefore, it was not possible to determine whether the truckdriver's alleged evasive action would have resulted in the loss of control that he described.

The Safety Board considered other possible situations that fit the collision sequence indicated by the physical evidence. Among these were the possibilities that the truck/full trailer was operating on the wrong side of the road or that the truck lost operating stability because of speed and environmental conditions, without the van being an influence. Limited available evidence and research data again prevented a full evaluation of these possibilities.

In developing and evaluating the evidence, the Safety Board did become aware of a lack of research data in two significant areas. The Safety Board was unable to find data that would indicate how commercial vehicle tires perform at various speed levels, when loaded at 15 to 25

percent of their capacity, which was the condition that existed in this accident. Also, the full potential effect of a fluctuating split coefficent and progressively lower pavement frictional quality on a continuously steepening grade could not be determined. Additional research could assist future accident investigations and be significant in establishing or assessing performance standards in these safety areas.

The Safety Board was also concerned about the failure of standard pavement inventory procedures to detect the pavement problems discovered at this accident location. Before the recent series of fatal accidents, U.S. 91 in the vicinity of this accident did not have a significant accident rate or history that would have warranted special attention by the Utah DOT. Only nonstandard tests revealed that the southbound pavement surface approaching the accident site had a progressively lower and widely fluctuating wet frictional quality, and an average wet frictional quality that was below recommended values of the FHWA and the Utah DOT. Further effort in developing better pavement evaluation techniques and criteria for pavement inventory programs is necessary.

This investigation also illustrated the importance of a systematic method for monitoring the frictional quality produced by various pavement mix designs. The Safety Board's findings demonstrated that a rapid deterioration in frictional quality was possible even though the Utah DOT presumably had not experienced poor results previously with this mix design. The FHWA Highway Safety Program Standard No. 12 and Federal-Aid Highway Program Manual describe a pavement inventory and pavement mix design evaluation program. The FHWA is currently involved in a comprehensive program to evaluate the information and guidelines offered to the States.

Previous Safety Board highway accident investigations have identified a need to identify and document types of pavement design, surface mixes and quality control practices used by the States that provide inferior pavement surfaces under varying environment and weather conditions. One of the Safety Board's current safety objectives is a skid resistance program. Using data to be collected through the investigation of a sampling of wet-weather skidding accidents and State program reviews, inferior highway surfaces will be identified and described, surface skid resistance characteristics will be documented and textures measured, and tire/road conditions will be recorded. The purpose of the study is to determine conditions faced by motorists under adverse conditions and to accumulate sufficient data to support corrective safety recommendations at the Federal and State levels.

CONCLUSIONS

Findings

1. The available physical evidence, research data, and the truckdriver's testimony did not permit the Safety Board to confirm or deny that the truckdriver's described evasive actions were necessary, took place, or would have produced his described loss of control.

2. The available physical evidence and research data also prevented the Safety Board from fully evaluating other possible situations that fit the collision sequence indicated by the physical evidence.

3. In evaluating the accident, the Safety Board discovered a significant lack of research data on the performance of lightly loaded truck tires, and the potential effect of varying pavement frictional quality.

4. Before the recent series of fatal accidents, U.S. 91 in the vicinity of this accident did not have a significant accident rate or history that would have warranted special attention by the Utah DOT.

5. The southbound pavement surface approaching the accident site was found to have a progressively lower and widely fluctuating wet frictional quality and an average wet frictional quality that was below recommended values of the FHWA and the Utah DOT; these conditions may have existed at the time of the accident.

6. Standard pavement inventory test procedures used by the Utah DOT, the FHWA, and many States would not have detected the pavement problems at the accident site.

7. There is a need for further effort to develop better pavement evaluation techniques for pavement inventory programs.

Probable Cause

The National Transportation Safety Board determines that the probable cause of this accident was that either or both drivers failed to maintain their vehicle in the proper traffic lane for reasons that could not be determined.

RECOMMENDATIONS

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

-- to the National Highway Traffic Safety Administration:

"Accelerate efforts to identify the frictional properties of commercial vehicle tires at all degrees of tire yaw, under loading conditions ranging from 15 to 100 percent of rated load capacity. (Class II, Priority Action) (H-79-5)

"Examine the full potential effect of fluctuating and progressively lower pavement frictional quality on vehicle performance. (Class II, Priority Action) (H-79-6)"

-- to the Federal Highway Administration:

"Evaluate the procedures used in the Safety Board's investigation of this accident for possible inclusion in FHWA guidelines for determining the frictional quality of pavements during pavement inventory programs. (Class II, Priority Action) (H-79-7)"

BY THE NATIONAL TRANSPORTATION SAFETY BOARD

/s/ JAMES B. KING
Chairman

/s/ FRANCIS H. McADAMS
Member

/s/ PHILIP A HOGUE
Member

ELWOOD T. DRIVER, Vice Chairman, did not participate.

February 22, 1979

APPENDIX A

EVALUATION OF PAVEMENT SURFACE -- U.S. 91 NEAR MILEPOST 225

At the request of the Safety Board, the Utah DOT conducted wet pavement friction tests at the accident site on August 30, 1977, using a "Mu Meter" trailer. The Mu Meter trailer was the device used by the Utah DOT to inventory the wet pavement frictional quality of Utah's highways. This trailer measured the friction coefficient developed between the pavement and two rolling pneumatic tires with a 15° yaw angle between the tires. The "Mu number," or friction coefficient, is a measure of the relative slipperiness between a tire and pavement surface. The higher the Mu number, the more friction there is between the tire and pavement surface for stopping, accelerating, and steering. The lower the Mu number, the less friction there is, eventually increasing the chance for skidding. For comparison purposes, Mu numbers of 10 to 15 would be obtained on ice-covered surfaces while numbers of 80 and above could be obtained on clear, dry, rough-textured surfaces, which are optimum operating conditions.

At test speeds of 40 mph, an average wet Mu number of 62 and a low Mu number of 57 were obtained from a standard test of the inside wheel path of traffic along a 3-mile segment of the southbound lane which included the accident site. According to Utah DOT criteria for evaluating the Mu numbers measured, the 3-mile segment was an "operational, normal roadway"; Mu number values of 60 to 100 fell within this classification. Mu numbers at the accident site, however, averaged 58 with a low of 57, indicating that the roadway in that area was "marginal" with "further monitoring suggested," according to Utah DOT criteria.

The truckdriver, the investigating Highway Patrol Officer, and other travelers who arrived after the accident said that the pavement surface was "very slippery" at the accident site, and the investigating officer noted an oily film on the wet surface. The pavement was discolored at the accident site. The two vehicles lost a considerable amount of anti-freeze, oil, and transmission fluid as a result of the accident, which could have contributed to the presence of the oily film and some of the discoloration and slipperiness. However, the surface of the pavement was discolored along the entire length of the grade only in the traffic wheel paths in the southbound lane while the truck came to rest in the northbound lane. If the discoloration was from the vehicles, some continuous discoloration also should have been noted in the northbound lane from deposits left by the truck. It appeared more that asphalt was flushing or bleeding to the surface in the southbound wheel paths. There appeared to be a high percentage of fine and smooth aggregate and asphalt at the surface. The pavement crown varied from 1 to 3 inches in 12 feet which had the potential for affecting water runoff. Therefore, a detailed topographic survey and further pavement tests were performed.

On October 18, 1977, the Utah DOT again conducted wet-pavement friction tests with the Mu Meter trailer. Similar tests were also conducted on that day using an FHWA locked-wheel skid trailer that met the requirements of the American Society of Testing and Materials (ASTM) Standard E274-70 (as revised July 1974). The locked-wheel trailer measured the longitudinal friction coefficient developed between the pavement and a tire on a locked wheel that slid in the direction of travel of the trailer.

Standard Mu Meter tests indicated that the skid resistance of the southbound pavement surface at the accident site had deteriorated since the first test. At standard test speeds of 40 mph, an average wet Mu number of 45.5 and a low Mu number of 36 were obtained for the inside wheel path of traffic at the accident site. However, according to Utah DOT criteria, the accident site was still classified "marginal" with "further monitoring suggested." The State of Utah, FHWA, and many other States conduct their pavement friction tests on the inside wheel path of traffic as standard procedure. A nonstandard test was conducted on the southbound outside wheel path at 40 mph, and an average Mu number of 33 with a low Mu number of 26 were obtained. According to Utah DOT criteria, the accident site was "critical" with "slipperiness failure indicated." Further, the difference in frictional values between the inside and outside wheel paths indicated that a split coefficient of friction surface had developed. This meant that southbound vehicles were operating on a surface where the tires on one side were traveling on a slipperier surface than the tires on the other side.

The results of Mu Meter and locked-wheel skid trailer tests that had actually been conducted on August 30, 1977, and October 18, 1977, were mathematically projected to determine the results that probably would have been obtained if the outside wheel path had been measured on August 30, 1977. This projection assumed that the outside wheel path had deteriorated at the same rate as the inside wheel path. These calculations indicated that an average Mu number of 42 and a locked-wheel value of 31 probably would have been obtained for the outside wheel path. According to Utah DOT criteria, the Mu number of 42 would have classified the roadway surface as "critical" with "slipperiness failure indicated." According to FHWA criteria, this result was below the recommended minimum value of 37.0 and indicated a pavement surface in need of "analysis for corrective treatment." 5/ This mathematical projection indicated that the average wet frictional quality for the outside wheel path probably was below that recommended for wet pavement surfaces near the time of the accident.

5/ "Highway Safety Program Manual for Highway Safety Program Standard Number 12," Federal Highway Administration, U.S. Department of Transportation. February, 1974.

Nonstandard Mu meter tests were also conducted on the southbound inside and outside wheel paths at test speeds of 60 mph. A continuous Mu number record for these tests (see figure 5, page 7) demonstrated that the frictional quality became progressively lower as the Mu meter trailer climbed the grade. Also, an alternating pattern of a wide departure in friction values between the two wheel paths followed by a merging of these values began about 1,000 feet before impact. This progressively decreasing and split coefficient of friction condition was suspected to have even more capability to impair vehicle stability. Theoretically, as a result of this pattern, the tires of a vehicle on the outside wheel path could alternately lose and regain traction in relation to the tires along the inside wheel path. However, this possibility could not be fully evaluated through an examination of existing research.

Utah DOT and FHWA trailers, test results, and evaluation criteria were compared to determine whether FHWA procedures would have more readily detected the pavement problems found at the accident site. The results of Mu Meter tests that had actually been conducted on August 30, 1977, were converted to locked-wheel equivalent values that may have been obtained if locked-wheel tests also had been conducted on that date. The locked-wheel equivalent values indicated that a locked-wheel trailer would probably have measured a skid number of 38.2 on August 30, 1977, if such a test had been conducted at 40 mph on the southbound inside wheel path of traffic. According to FHWA criteria 6/ a standard locked-wheel skid trailer test also would have classified the accident site as acceptable.

The FHWA skid tests in the inside wheel path of the southbound lane on October 18, 1977, measured a skid number of 32.4. This was below the FHWA-recommended minimum value of 37.0 and indicated a pavement surface in need of "analysis for corrective treatment." According to Utah DOT test results and evaluation criteria for the inside wheel path on that date, the accident site was "marginal" with "further monitoring suggested." This comparison indicated that if Utah DOT had used standard FHWA test procedures and evaluation criteria in developing its inventory figures, its highway department personnel may have at least been alerted to the existence of a problem at an earlier time.

Mu Meter and locked-wheel trailer tests were conducted at similar levels of detail in the northbound traffic lane. These tests indicated that while pavement frictional qualities were marginal with respect to recommended values, a progressively lower split coefficient of friction surface did not exist in the northbound traffic lane. For example, by projecting the October 18, 1977, locked-wheel skid test results, it was calculated that on August 30, 1977, 60 mph skid tests results in the northbound lane would have been 38.0 for the inside wheel path and 37 for the outside wheel path.

6/ Ibid.

Outflow meter and sand patch tests were conducted in the northbound and southbound wheel paths on October 18, 1977. The basic equipment used in an outflow meter test consisted of a tube with a flanged end that sat on a rubber ring placed on the pavement. The assembly was weighted down to press the ring against the irregularities of the surface. The tube was filled with water, and the time required for the water level to drop a standard measured distance was recorded. At the time of this report, correlation between outflow times and such factors as pavement texture and drainage were being developed. The outflow meter drainage times were 24 minutes 21 seconds and 4 minutes 26 seconds in two separate tests made in the southbound outside wheel path and 1 minute 27 seconds in the southbound inside wheel path; the drainage time was 16 seconds in the northbound outside wheel path. As a minimum, these test results indicated that texture/drainage was noticeably not as good in the southbound wheel paths as it was in the northbound wheel paths.

A topographic survey indicated that in an area from 50 to 100 feet north of the point of impact, the crown was level in the southbound lane from the centerline to 5 feet west of the centerline, which would encompass the inside wheel path of traffic. This lateral "flat spot" increased the distance water had to flow parallel to the centerline before it began to drain laterally to the side of the road. A larger-than-normal amount of water could begin to accumulate in the southbound traffic lane in an area between 100 to 200 feet before impact. No other "flat spots" were noted in the northbound and southbound lanes for an approach distance of 500 feet before impact. The crown was relatively consistent in the northbound lane over this 500-foot approach distance, ranging from a 0.06- to 0.09-foot drop at points 5 feet east of the centerline, and ranging from 0.14 to 0.22 feet at points 10 feet east of the centerline. In the southbound lane over a similar 500-foot-long approach distance, the crown varied more significantly ranging from 0.0 to 0.09 at points 5 feet west of the centerline and from 0.02 to 0.21 at points 10 feet west of the centerline.

Sand patch tests measure pavement texture depth and are an indicator of the roughness and drainage quality of the pavement surface. Tests conducted indicated that texture depths ranged from 0.011 to 0.013 inch up to about 175 feet before impact in the southbound inside and outside wheel paths. At 75 feet before impact, texture depth in the southbound wheel paths dropped to between 0.007 and 0.008 inch, and remained there until 75 feet after impact. Texture depth in the northbound wheel paths was between 0.012 and 0.013 inch at 65 feet before impact.

At the time of this accident, there were no Federal regulations or guidelines regarding minimum pavement texture depths. In 1975, Gallaway recommended a minimum surface texture of 0.040 inch. 7/ In 1976,

7/ "Tentative Pavement and Geometric Design Criteria for Minimizing Hydroplaning," Gallaway et al, February 1975, FHWA-RD-75-11.

research conducted in France developed five categories of asphalt and concrete pavements based on the sand patch test. 8/ For pavements with texture depths of 0.007 inch or less, this research noted: "Very fine-textured pavements; these pavements are to be prohibited." For pavements with texture depths of 0.007 to 0.015 inch, this research noted: "Fine-textured pavements; these pavements are to be reserved for sections on which vehicle speeds are only occasionally capable of exceeding 80 kilometers per hour (50 mph), e.g. in urban areas."

During resurfacing of the 17 miles of the connecting link, samples of the asphalt mix had been tested daily by the Utah DOT. On October 18, 1977, pavement core samples were taken at the accident site. These were analyzed by the FHWA and Utah DOT. Table 1 contains these test results, target designs, and mix tolerances. In grading the aggregate in a mix by size, the aggregate is sifted through screens with openings that are progressively smaller in size. For this mix, a set of screens ranging from the largest with 1/2 inch openings down to the smallest with 0.0029-inch openings (No. 200) were used for design and quality control purposes.

All aggregate target design values were acceptable within Utah DOT tolerances. The target values were higher than ideal gradation values for the Nos. 16 and 50 screens. In addition, the target values for the Nos. 16 and 200 screens were permitted to further increase during the period when the pavement was laid at the accident site. The target value was increased from 34 to 38 and from 6 to 7 for the No. 16 and No. 200 screens, respectively. Utah mix-sample and core-sample test results indicated that the mix in place met all target values. FHWA core-sample test results for the southbound outside wheel path indicated that the amount of material passing the No. 200 screen exceeded the target and acceptable tolerance values. These findings related to gradation indicated that design and construction practices favored producing a pavement surface with a higher-than-ideal percentage of finer aggregate and that the percentage of very fine aggregate may have exceeded acceptable tolerances at some locations. Utah standards noted that when acceptable tolerance values were exceeded, "the engineer may order the removal of any or all of the bituminous mix in the lot." 9/ The presence of a relatively high percentage of finer aggregate would tend to reduce surface texture depth such as that found in the southbound lane approaching the accident site.

The Utah DOT used the "Marshall" method for designing the asphalt pavement used in this resurfacing project. Utah DOT standard specifications called for a stability value of 1,200, a flow value of 8 to 18, and 1.5 to

8/ "Pavement Characteristics and Skid Resistance," Elsenaar, Reichert, and Sauterey, Transportation Research Record No. 622, 1976.

9/ "State of Utah Standard Specifications for Road and Bridge Construction," 1970 Edition.

TABLE I - Utah Design, Target, and Mix Tolerances;
Utah/FHWA Core Test Results

Physical Properties	Design, Target and/or Mix Tolerances	Utah Mix Samples July 5, 1977			Core Sample Analysis-Accident Site		
					Utah Southbound Wheel Paths 3 Cores New Surface Overlay	FHWA Outside Wheel Path 3 Cores New Surface Overlay	FHWA Inside Wheel Path 1 Core New Surface Overlay
		25	26	27			
Aggregate Gradation Total Passing	Ideal (Tolerance) Target						
1 inch					100	100	100
3/4 inch					98.1	98	96
1/2 inch	100 (92.3 to 100) 100	100	100	100			
					90.3	90	89
3/8 inch					60.0	61	58
No. 4	70 (48 to 92) 59	60.3	58.2	59.0	42.0	44	43
No. 8					33.8	34	34
No. 16	31 (18.6 to 43.4) 34	34.9	34.9	34.0			
						27	28
No. 30						21	22
No. 50	15 (4.5 to 25.5) 21	19.9	20.3	20.0	19.4		
						16	14
No. 100						12	10.3
No. 200	6 (1.5 to 10.5) 6	6.1	6.6	6.1	7.1		
A.C. % Mix Basis	6.6	7.0	7.0	6.5	6.03	4.72	5.81
Bulk Density (P.C.F.)	139	134.94			144.7	143.1	147.1
Bulk Specific Gravity					2.319	2.293	2.358
Max. Theoretical Density	2.30					2.332	2.369
Air Voids %	2.17 @ 6.17 1.32 @ 7.0				1.72 @ 6.03	1.7 @ 4.72	0.5 @ 5.81

Type Asphalt AC-10, Stability 1600, Flow 8
Wear L. A. Abrasion- 26%, Soundness SO_4 - 6.8% Liquid Limit 18, Not Plastic Fractured Face Count - 40
Core Samples were taken from the southbound lane, 25 feet from impact.

3 percent air voids. 10/ The Utah DOT reported it had no previous problems in using mixes within these design and aggregate specifications. Its design for this pavement used AC-10 asphalt and produced a mix with a stability value of 1,600, a flow value of 8, and air voids of 2.17 percent at an asphalt content of 6.5 percent and air voids of 1.32 percent at an asphalt content of 7.0 percent. The Asphalt Institute recommends a minimum stability value of 500, a flow value of 8 to 20, and 3 to 5 percent air voids when using the Marshall method. 11/ Utah DOT standard specifications and the design used for this pavement both used lower air void values than that recommended by the Asphalt Institute.

Asphalt content values from the Utah DOT and FHWA core samples were lower than target design and mix sample values. Therefore, it was not likely that a higher-than-planned asphalt content was present and could have contributed to the bleeding or flushing of asphalt that was observed in the southbound wheel paths. Air voids in relation to asphalt content values from the core samples were lower than target design values which, in turn, were lower than Asphalt Institute-recommended values.

The faces of the larger surface aggregate were generally aligned parallel to the pavement surface, seemed to be on a similar plane as the finer material in some cases, and seemed to be more smooth than rough to the touch. Traffic polishing was evident on some large aggregate, while other large aggregate had a naturally smooth character. L. A. Abrasion test values for wear were 26 percent, the aggregate was not plastic, and the Fractured Face Count was 40. These tests that were made during the design of the mix were more indicators of the stability of the mix and durability of the pavement. As noted by the Asphalt Institute, the L. A. Abrasion test "does not necessarily have any relationship to polishing of aggregate under traffic wear." 12/ Tests directly related to smoothness or polishing resistance (e.g., British Polish Stone Test, Acid Insoluble Test, and Petrographic Analysis) had not been made by the Utah DOT.

Previous research 13/ indicated that "low (air) void content may result in instability or flushing after the pavement has been exposed to traffic for a period of time because of reorientation of particles and additional compacting. It may also result in insufficient void space for the amount of asphalt required for high durability even though stability is satisfactory. Degradation of the aggregate under the action of traffic may also lead to instability and flushing if the void content of the mix is not sufficient.

10/ Ibid.

11/ "Mix Design Methods for Asphalt Concrete and Other Hot-Mix Types," The Asphalt Institute, 1974.

12/ "The Asphalt Handbook" MS-4, The Asphalt Institute, 1970, pg. 37.

13/ "National Cooperative Highway Research Project Report #14, Skid Resistance," Transportation Research Board, 1972.

"Traffic tends to compact any flexible pavement in the wheel tracks. Compaction tends to bring more binder material to the surface and hence into contact with the tires. This invariably decreases the overall microtexture of the surface. Compacting also reduces macrotexture; thus, it is detrimental to good skid resistance at all speeds.

"In pavements in which compaction occurs, the aggregate particles are not necessarily just pushed downward while the binder moves upward. The larger aggregate particles may also be reoriented. This causes their large faces to become aligned with the surface. If the aggregate is susceptible to polishing this can lead to rapid degrading of the skid resistance."

The denser mix observed in the core samples could have been an indication that compaction had occurred. The high percentage of large trucks would have tended to accelerate compaction. Southbound traffic was traveling up a grade that continuously increased in steepness. In order to maintain velocity, more power would have to be applied to the drive wheels and traction requirements would have been greater. This action may have accelerated compaction, flushing, and smoothing of the pavement surface.

In November 1977, the Utah DOT used a heater planer treatment, scarified the pavement surface, and added more aggregate as an interim measure to improve the skid resistance along a 0.6-mile segment of U.S. 91 where skid test numbers were lowest. This 0.6-mile segment included the accident site. After the surface treatment was completed, Mu Meter tests conducted at 40 mph produced Mu numbers in the low to mid 60's.

APPENDIX B

INSPECTION OF 1977 PETERBILT TRUCK (VIN 85765P)

The truck was equipped with Michelin XZZ radial tires. Truck tire tread depth and inflation pressure readings were:

	Outside Tire		Inside Tire	
	Depth (inches)	Pressure (psi)	Depth (inches)	Pressure (psi)
Left front	11/32	flat (crash damage)	(none)	
Left forward rear	6/32	98	6/32	99
Left rear	5/32	95	6/32	96
Right front	10/32	105	(none)	
Right forward rear	7/32	99.5	6/32	93
Right rear	6/32	93	6/32	100

There was less tread depth at the shoulder edges of all truck tires. This condition is usually produced by operating with underinflated or overloaded tires. Recommended air pressure was 100 psi (front). Except for crash damage, no unusual conditions were noted at the steering and suspension systems.

All three axles of the truck were equipped with airbrakes and Eaton antilock brake systems. The antilock system was being used to meet the performance requirements of FMVSS 121. Basically, antilock systems monitor wheel speed to detect locked-wheel skid conditions. Upon detection, the antilock system is designed to first relieve brake pressure to eliminate the locked-wheel condition, and then to reapply brake pressure until full brake pressure is restored. Should another skid condition be detected, the cycle would begin again. Brake slack adjustments under air pressure were:

	Left side	Right side
Front axle	damaged	damaged
Forward rear axle	3/4 in.	11/16 in.
Rear axle	1 1/6 in.	1 1/16 in.

These values were within acceptable adjustment limits.

Damage to both brake chamber assemblies on the front axle suggested that the front brakes and, therefore, all brakes on the combination vehicle had been applied by the truckdriver, at least at the time of impact. The longitudinal flange of the left brake chamber bracket had a fore-and-aft scrape mark that could have been made only by the push rod-to-slack adjuster clevis pin striking the bracket when the brakes were on and the push rod was fully extended. Inspection of the right chamber indicated that the push rod was bent in such a way that the push rod could not return to the released (or off) position following the impact and ultimate release of chamber air pressure.

No other damage was visible to and no components were missing from the foundation brake system (drums, linings, etc.) at any of the truck wheels. No foreign materials or irregularities were noted on the drums, linings, or internal components. The brake linings were original equipment and averaged 11/16 inch at all wheels. Normal new lining thickness is about 12/16 inch. There was no current mechanical reason for the limited lining wear in 81,000 miles of travel. All air-mechanical brake system components on the rear axles functioned under pressure test; it was not possible to pressure test the front-axle brake components because of accident-induced damage.

The Eaton antilock wheel speed sensors were inspected visually; no missing components were noted, and the units appeared to be mechanically functional. Air and electrical lines for the front axle had been severed in the crash. The antilock axle modulator assembly for the front axle had been broken and displaced in the crash and was found hanging below and behind the front bumper. The regulating valve, which controlled the amount of air pressure apportioned to the front brakes, had broken loose and was found at the scene of the accident.

No unusual tire wobble (runout) was observed when the wheels at each rear axle were raised off the ground and the tires were rotated by hand. Voltage readings measured from the wheel speed sensors were:

	Left side	Right side
Forward rear axle	0.75 V	0.6 V
Rear axle	0.8 to 0.9 V	0.9 V

Eaton specifications called for a voltage reading of between 0.3 and 0.9 V. The covers of the axle modulator assemblies for the rear axles of the truck were removed and the inside components were found to be clean and dry. Road testing of the truck was not possible due to accident damage.

To test the electrical system, crash-damaged electrical components at the front of the truck were by-passed and an outside electrical source was connected to the antilock system at each axle. Proper feedback

voltage was received from each axle modulator assembly for the truck antilock warning light system in the cab of the truck. A jumper wire was found in the warning light circuit that would have required both the front-axle and the forward rear-axle antilock systems to malfunction simultaneously before the warning light would illuminate. The wire circumvented the design intent that the warning light illuminate if the antilock system at any one axle malfunctioned.

APPENDIX C

INSPECTION OF 1977 RELIANCE FULL TRAILER (VIN RRS-76-808)

The trailer was equipped with Michelin XZZ radial tires. Tire tread depth was:

	Outside tire Depth (inches)	Inside Tire Depth (inches)
Left front	11/32	8/32
Left rear	9/32	9/32
Right front	10/32	9/32
Right rear	9/32	10/32

There was less tread depth at the shoulder edges of all trailer tires. Tire inflation pressures varied between 90 to 100 psi for the trailer tires.

Brake slack adjustments under air pressure were:

	Left side	Right side
Front axle	1 in.	7/8 in.
Rear axle	1 1/4 in.	1 1/4 in.

These values were within acceptable adjustment levels.

No damage was visible to and no components were missing from the conventional braking system at any of the trailer wheels. Small, laterally-oriented heatchecking cracks were noted along the wear surface of the trailer brake drums. These cracks would not have adversely affected braking performance. No other foreign materials or irregularities were noted on the drums, linings, or associated components, and all pneumatic systems functioned properly under a pressure test. Lining thickness measurements averaged 9/16 inch for the front wheels and 8/16 inch for the rear wheels. Normal new lining thickness is about 12/16 inch. Linings less than 1/16 inch in thickness are not considered acceptable for inspection purposes.

The initial phase of examining the braking and antilock system involved road-testing the trailer by towing it behind two different power units; one unit was a 1977 Peterbilt truck similar to that involved in the accident. Road tests were conducted on various dry pavement surfaces. The front wheels of the trailer repeatedly cycled (locked/unlocked) under a full brake application, but the rear wheels locked and remained locked until full brake application was removed.

These tests indicated a loss of rear-axle antilock capability; however, the rear foundation brakes were working, which met the fail-safe requirement of FMVSS 121 for airbrake systems. During testing, the rear of the trailer moved to the driver's right during braking; the degree of movement increased at higher road speeds and as the road crown to the right increased. No unusual tire runout was seen.

A trailer antilock failure warning light system was found mounted on the left longitudinal frame rail forward of the rear axle and underneath the bed of the trailer. This warning light remained illuminated and would not go out when the trailer was standing still and the brakes were applied. However, when the trailer was stopped under full brake application during the road tests, the warning light for the rear axle would go out. According to design, when the warning light for an axle was out, either the bulb was burned out, electrical power was not available, or there was a loss of antilock capability.

Electrical tests conducted before the antilock wheel speed sensors at each wheel were removed indicated that there was an electrical short between the rear axle modulator assembly and the right rear wheel speed sensor. Satisfactory test signals were received for the sensors at the other wheels of the trailer. During removal of the sensors, it was noted that there was no significant guarantee against rotation of the base of the antilock wheel speed sensor within the tubular axle at any of the four wheels of the trailer. The base of each unit was easily rotated or pulled by hand, and removal felt like breaking a relatively smooth frictional fit rather than an adhesive bond. Goodrich advised that screwdrivers or some similar equipment should have been needed to pry the unit loose during removal from the axle. The unit's design called for an adhesive sealant to be used between the base of the sensor and the inside of the axle to insure that the sensor assembly would not turn within the axle. Adhesive sealant was found to be firmly attached around the outside circumference and flange of the plastic base of each sensor. A nominal amount of sealant was attached to the inside wall and end of the axle tube at the left front wheel. No sealant of any significance was attached to the inside wall and end of the axle tube at the other three wheels.

There were two wires leading from the axle modulator assembly through the axle tube to each wheel speed sensor. At the left front wheel, the female electrical connector at the end of one of these wires was found to be disconnected from its male counterpart within the hollow base of the sensor. This was discovered when the left front sensor was being slowly pulled out of the axle and after the base of the sensor had just cleared the end of the axle. This disconnection probably occurred as the sensor was being pulled from the axle, because the front axle brakes had cycled during the stopping tests and satisfactory electrical test signals were received before the sensor was pulled from the axle for examination. There was a hole in the wire insulation at a kink in

the disconnected wire. The metal wire conductor was exposed, and the wire insulation was scorched around the edge of the hole. This condition was symptomatic of an electrical short circuit that could have produced intermittent loss of antilock capability at the front axle of the trailer, but none was observed during the trailer road tests.

The two wires leading from the rear-axle modulator assembly to the left rear wheel sensor were found twisted tightly together in the direction of forward rotation of the wheel (counterclockwise). The female electrical connectors were both connected to their male counterparts, and the metal parts of the female connectors were not found in contact with each other.

No unusual conditions were noted for the two wires leading to the right front wheel sensor. The wires to both front-axle sensors had not been twisted together.

The two wires leading to the right rear sensor were found twisted tightly together in the direction of forward rotation of the wheel (clockwise). The female electrical connectors at the ends of these wires were found disconnected from their male counterparts after the base of the sensor just cleared the end of the axle. It was not certain whether the wires had been totally disconnected by the wire twisting or as the sensor was being pulled from the axle, especially given the disconnect experience at the left-front wheel and the wire twisting without disconnection at the left-rear wheel. The metal female electrical connectors were found in contact with each other. This condition alone could have accounted for the electrical short monitored during the electrical tests. Satisfactory test signals were received at the modulator assembly after the wires were untwisted and connected to the sensor. Goodrich advised that since the electrical short was not to ground, the trailer antilock failure warning light would not have gone out when the trailer was standing still and the brakes were applied. However, when the trailer was in motion to any degree and any type of stop was made, the short would have been monitored and the warning light would have gone out.

According to Goodrich, four recall bulletins had been issued since the introduction of its antilock equipment. Components on this vehicle were examined to determine if repair or replacement was necessary and performed. A new ratio relay valve control spring had been installed, and a plastic drive arm was installed in place of the recalled metal drive arm. Two 1800-2 axle modulator assemblies had been installed to replace recalled 1800-1 units. The recall on a potentially defective capacitor did not apply as the units with this potential problem had lower serial numbers. The capacitors were tested and functioned properly.

There was evidence of chisel-type damage to the outer lock nut which secured the left-rear wheel bearing assembly to the rear axle, and there were roughened edges on the face of the outer lock nut at the

right rear wheel. Company maintenance records indicated that an inside wheel seal at the left rear wheel had been replaced on January 19, 1977. Repair of the wheel seal would have required removal of the wheel speed sensor. The mechanic who performed this maintenance had left the company and could not be contacted.