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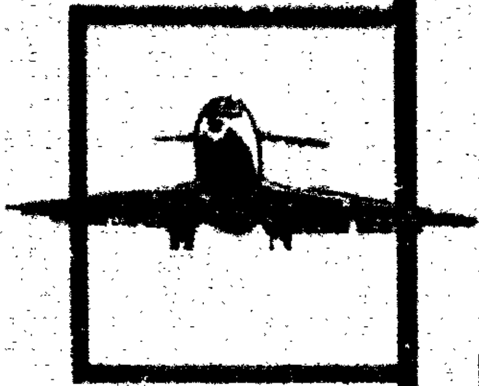

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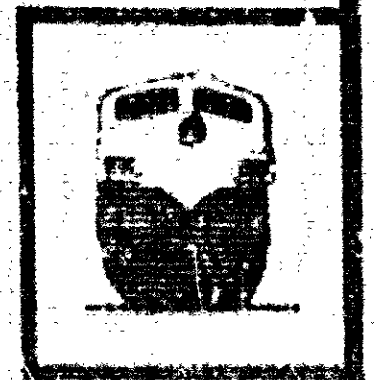

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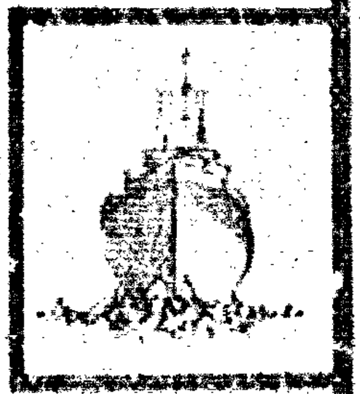
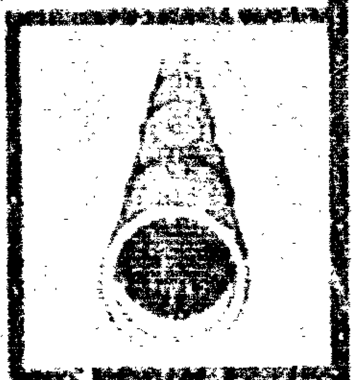
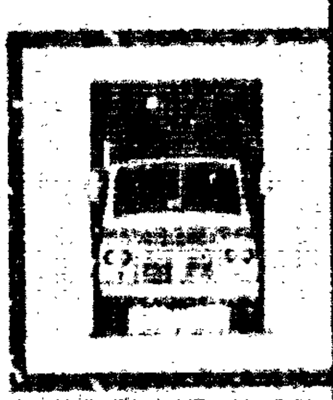


HIGHWAY ACCIDENT REPORT

EAST SIDE CHURCH OF CHRIST
BUS SKID AND OVERTURN
U.S. ROUTE 183,
NEAR LULING, TEXAS
NOVEMBER 16, 1980

NTSB-HAR-81-4





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16. Abstract

About 7:25 a.m., central standard time, on November 16, 1980, an intercity-type bus was traveling south on U.S. Route 183, a two-lane rural highway in south-central Texas. It was raining and the pavement was wet. As the bus approached and attempted to negotiate a curve to the left, the rear tires of the bus lost traction. The bus skidded across the opposing traffic lane and onto the shoulder before it could be steered back onto the highway. As it crossed the highway again, the bus spun 180° and slid into a drainage ditch where it struck the side of the ditch and overturned onto its left side. Two passengers were killed, and the busdriver and 35 passengers were injured.

The National Transportation Safety Board determined that the probable cause of the accident was the low wet cornering capability of the marginal yet "legal" rear bus tires and the low frictional quality of the wet pavement, which combined to produce loss of rear tire traction and vehicle control as the bus was being operated at or near the posted 55 mph speed limit.

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NATIONAL TRANSPORTATION SAFETY BOARD
WASHINGTON, D.C. 20594

HIGHWAY ACCIDENT REPORT

Adopted: July 22, 1981

EAST SIDE CHURCH OF CHRIST BUS SKID AND OVERTURN U. S. ROUTE 183, NEAR LULING, TEXAS NOVEMBER 16, 1980

SYNOPSIS

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INVESTIGATION

The Accident

About 7:25 a.m., c.d.t., on November 16, 1980, an intercity-type bus with 38 occupants was traveling south on U.S. Route 183, a two-lane rural highway in south-central Texas. The bus was en route from Austin, Texas, to Corpus Christi, Texas, and had just passed through the city of Luling. The bus was carrying a church choir from Austin to Corpus Christi to sing at a church gathering. A light rain was falling, and the pavement was wet.

According to the busdriver and bus passengers, the bus was traveling between 40 and 50 mph as it approached a curve to the left. The busdriver said that he had reduced foot pressure on the accelerator as he approached the curve. (See figure 1.) Shortly thereafter, the rear of the bus slid sideways. The busdriver and two passengers reported that the rear of the bus first moved to the left; three other passengers stated that the rear of the bus first moved to the right.

The busdriver reported that after the rear of the bus slid sideways, he took his foot off the accelerator and steered to the left and into the skid to regain control. He said that he seemed to regain control, and he recalled someone saying "you got it, you got it." However, the bus was on the wrong side of the road by that time so he steered to the right. The tires on the left side of the bus left three concentric tire scrub marks on the northbound shoulder from this maneuver. As the bus crossed the highway again, the rear of the bus spun clockwise about 180°, and the bus slid sideways off the road

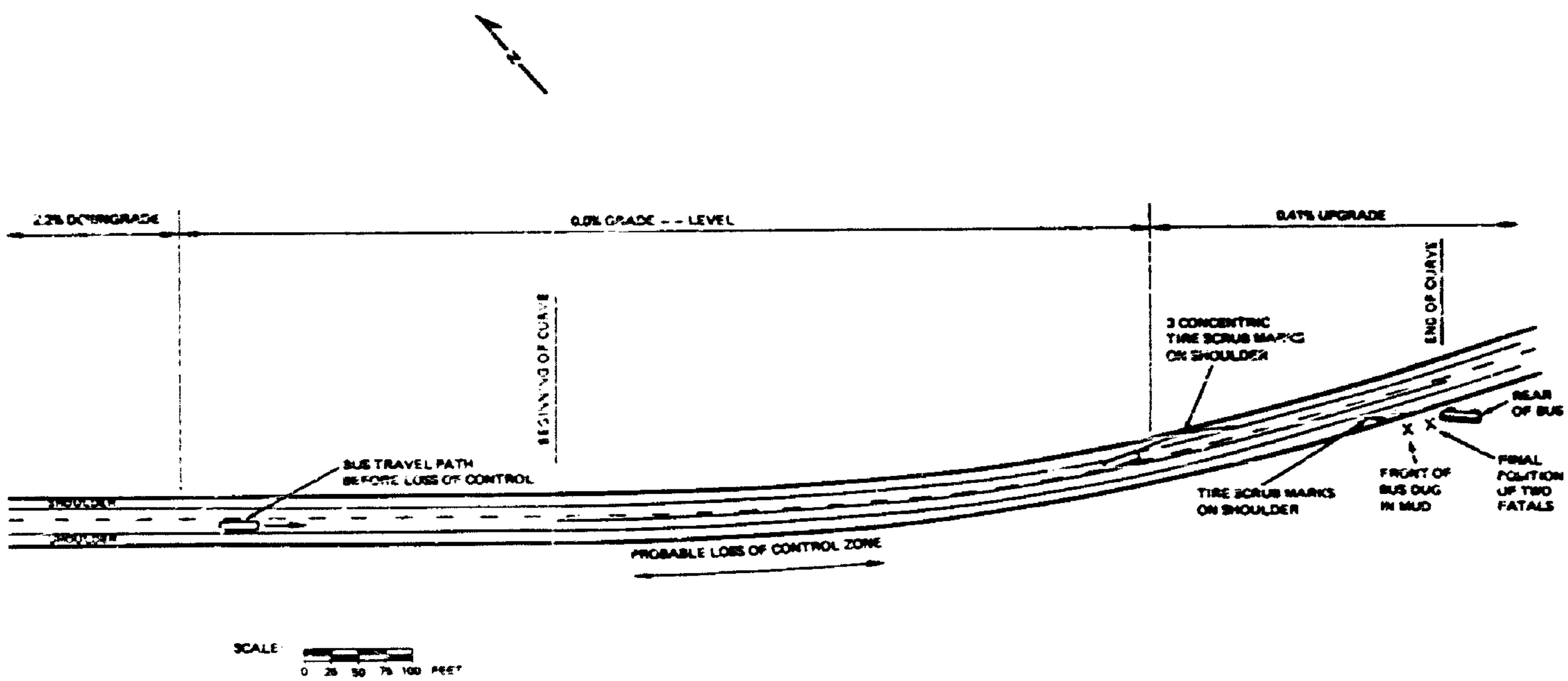


Figure 1.—Accident scene diagram.

and into a shallow drainage ditch. The front wheels of the bus hit mud on the far side of the drainage ditch, the bus' side windows swung open, and the front windshields came out as the rear of the bus continued to rotate and the bus overturned onto its left side.

Bus occupants reported that they seemed to be thrown only sideways as the bus hit the ditch and overturned. Bus passengers originally seated on the right side of the bus were thrown either on top of passengers seated on the left side of the bus or into the left side overhead luggage rack. Two passengers, who had been sitting together in the third seat behind the busdriver, were ejected during impact and were found lying about 6 feet apart in the drainage ditch, forward of the front of the bus. Another passenger was pulled out from a depression underneath the bus. As a result of the accident, the two passengers thrown into the drainage ditch were killed; the remaining 35 passengers and the busdriver were injured.

Injuries to Persons

Injuries	Driver	Passengers	Totals
Fatal	0	2	2
Nonfatal	1	35	36
None	0	0	0
Totals	1	37	38

Vehicle Information

The bus was a 1961 GMC Parlor Coach, VIN PD 4106-218. It was purchased by the East Side Church of Christ in November 1978, and had been driven about 14,000 miles since that time. Since the bus was registered as a private bus, it was subject only to State of Texas motor vehicle regulations. It was equipped with a 586-cubic-inch diesel engine, power steering, a 4-speed manual transmission, two axles, and dual tires on the rear axle. Except for the right front tire, all tires came with the bus when it was purchased by the church. The bus seating capacity was 39, and it weighed about 27,400 pounds at the time of the accident. Its designed maximum in-gear speed was about 63 mph.

State of Texas motor vehicle regulations require that motor vehicles be inspected annually by a licensed garage in that State. This bus was last inspected in November 1979, and was required to be inspected by the end of November 1980, to remain in service. The bus was maintained by a church member in his spare time. He was not employed as a mechanic, but he had about 20 years of experience in repairing and maintaining automobiles and other vehicles in his spare time. He had prepared the bus for this trip and was one of the passengers in the accident.

The lower left front corner and left front wheel of the bus had a large amount of smeared and packed mud. (See figure 2.) The front bumper was pulled forward about 4 inches and the lower body panel between the front bumper and wheel was crushed inward. The front area of the bus forward of the front wheels was distorted about 6 inches to the right while the rear area of the bus behind the rear wheels was distorted about 6 inches to the left. There were two shallow dents about 6 feet apart along the left roofline at the front of the bus and two similar dents about 6 feet apart along the left roofline at the rear of the bus. The window frames of the first and fourth windows on the left side of the bus were distorted and forced outward. The second and third window frames on the left side of the bus were distorted and torn from the top hinge mountings.

The third row of seats behind the driver, where the two persons who were ejected had been sitting, was located at the roof support column between the first and second

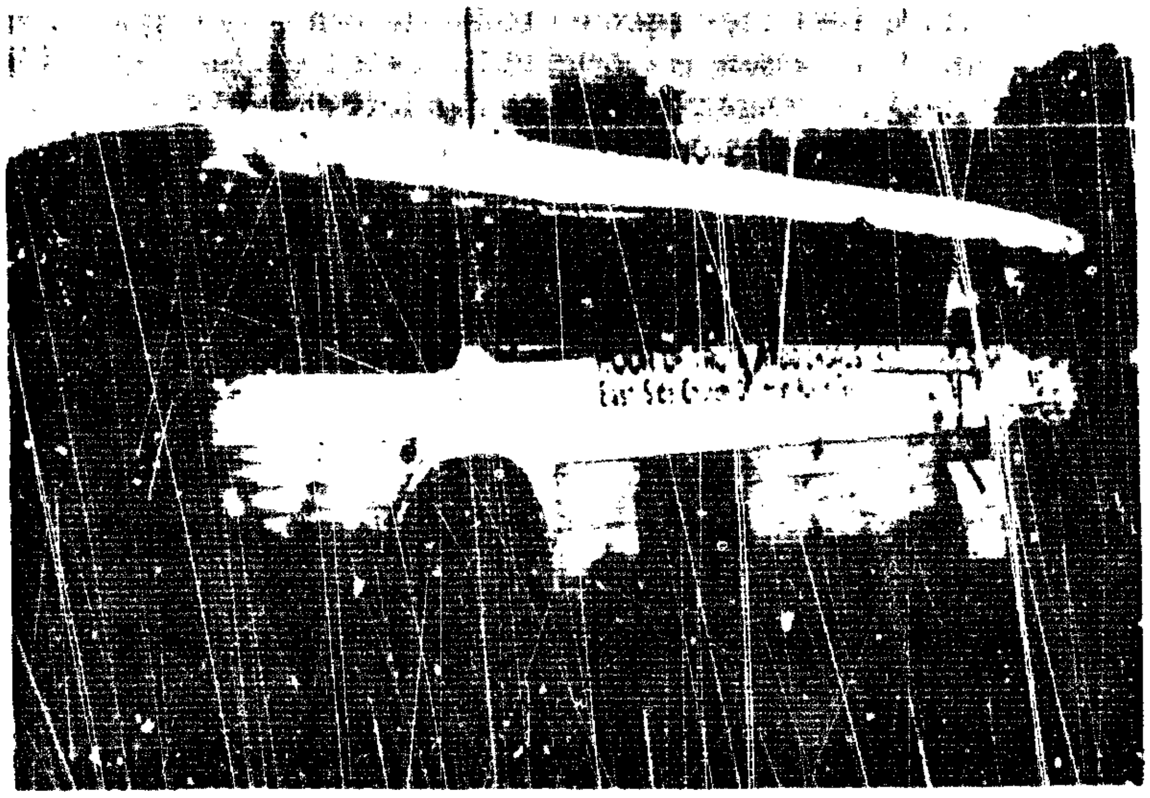


Figure 2.--View of left side of bus.

large side windows. There were no tissue deposits or blood transfers on the inside or outside of the bus near these seats, or any other evidence which may have aided in determining whether they were injured inside or outside the bus. Although blood transfers were found in the area above the busdriver's head, the busdriver did not have any bleeding wounds; this indicated that some passengers were thrown both forward and sideways at impact, perhaps explaining how the two third-row passengers were ejected through the side window of the bus. All seats remained anchored to the floor, and none of the seat frames were damaged. The seatback cushion for the window seat located six rows behind the driver was pushed forward about 11 inches.

No air leaks, broken hardware, component deteriora' on, or malfunctions were noted during a postcrash test of the air-ride suspension system. The steering wheel could be turned a fraction more than 3 inches without front wheel motion; this just exceeded the 3-inch Texas inspection limit for steering lash. 1/ Steering lash is the amount of free play in the steering wheel before positive steering input occurs. It is symptomatic of mechanical wear in steering system components, and horizontal free play in the kingpins probably produced this degree of steering lash. With this condition, there would be a small fraction of a second of time delay in steering response until the free play was bridged, which should not have significantly affected steering control of the bus.

Air leaks were found in the quick-release valve at the accumulator air tank for the front axle brakes and in the air supply line for the right front brake chamber. These leaks did not appear to be a result of the accident. All brake linings were of more than adequate thickness, and there was no evidence of contamination. Push-rod travel for the type-24 brake chambers at the left and right front wheels was 1 3/4 inch and 2 inches,

1/ "Rules and Regulation Manual for Official Vehicle Inspection Stations and Certified Inspectors," Texas Department of Public Safety, October 3, 1979.

respectively; according to the manufacturer, this type of brake should be readjusted when push-rod travel reaches 1 3/4 inches. Push-rod travel for the type-30 brake chambers at the left and right rear wheels were both 2 1/2 inches; this type of brake should be readjusted when push-rod travel reaches 2 inches. When the brakes were applied, the brakeshoes contacted the drums on all wheels and there was no change in air pressure, indicating all brakes would work to some degree in stopping the bus. There are no Texas inspection criteria for directly measuring and evaluating brake push-rod travel; Texas guidelines require that during a road test, a bus must be stopped within 40 feet from a speed of 20 mph.

Tire Information

The left front tire was a 11.5 x 20.5, tube-type, Goodyear Regrooveable Intercity Bus tire with bias-plys. The right front tire and the four rear tires were 12.5 x 22.5, tubeless, Goodyear Regrooveable Intercity Bus, bias-plys. According to Goodyear, the 1981 Tire and Rim Association Yearbook, and the National Highway Traffic Safety Administration, the two front tires were functionally similar and could be used on the same vehicle. Recommended maximum tire pressures were 100 psi for the front tires and 90 psi for the rear tires.

Regrooveable tires are a special class of tire for which the grooves in the tread pattern can be cut deeper (regrooved) after the tire has worn. The rear tires were manufactured so that there were three levels within each groove. (See figure 3.) The lowest level was the bottom of the tread groove. The next level was the top of tread wear indicators that were molded 2/32 inch higher than the bottom of the groove. These tread wear indicators were placed at only six points equidistant around the tire and were about 3/4 inch long. According to Federal Motor Vehicle Safety Standard No. 119, the purpose of tread wear indicators is to "enable a person inspecting the tire to determine visually whether the tire has worn to a tread depth of one-sixteenth (or 2/32) of an inch." 2/ The third level was the top of "fillets" that were molded 6.5/32 inch higher than the bottom of the groove. These fillets were placed at each corner of a tread groove and were about 1/2 inch long. Fillets are used to support or stabilize the sidewalls of the tread groove so that the tire tread does not wobble or squirm while the tire is in use, since such squirming would lead to abnormal tire wear.

When a tire of this design is worn to the top of the fillets, the original tread groove pattern is no longer continuous around the tire, and a "slotted" tread pattern develops. All four rear tires on the accident bus were worn to, or below, the top of the fillets at some part of the tire or across the entire tire. (See figures 4 and 5). When the tire tread is worn to the top of the tread wear indicators, the slots disappear at the six tread wear indicators. If the tire is uniformly worn, narrow horizontal smooth bands appear across the tread of the tire. (See figure 6.)

Air pressure, tread depth, and tire condition for each tire on the bus is shown in Table 1.

The church member who maintained the bus reported that the tires were all in "good condition," and the cuts or missing sections of rubber were the result of the bus' being backed into the curb around the church at various times.

2/ "Motor Vehicle Safety Standard No. 119 -- New Pneumatic Tires for Vehicles Other Than Passenger Cars," National Highway Traffic Safety Administration, November 13, 1973.

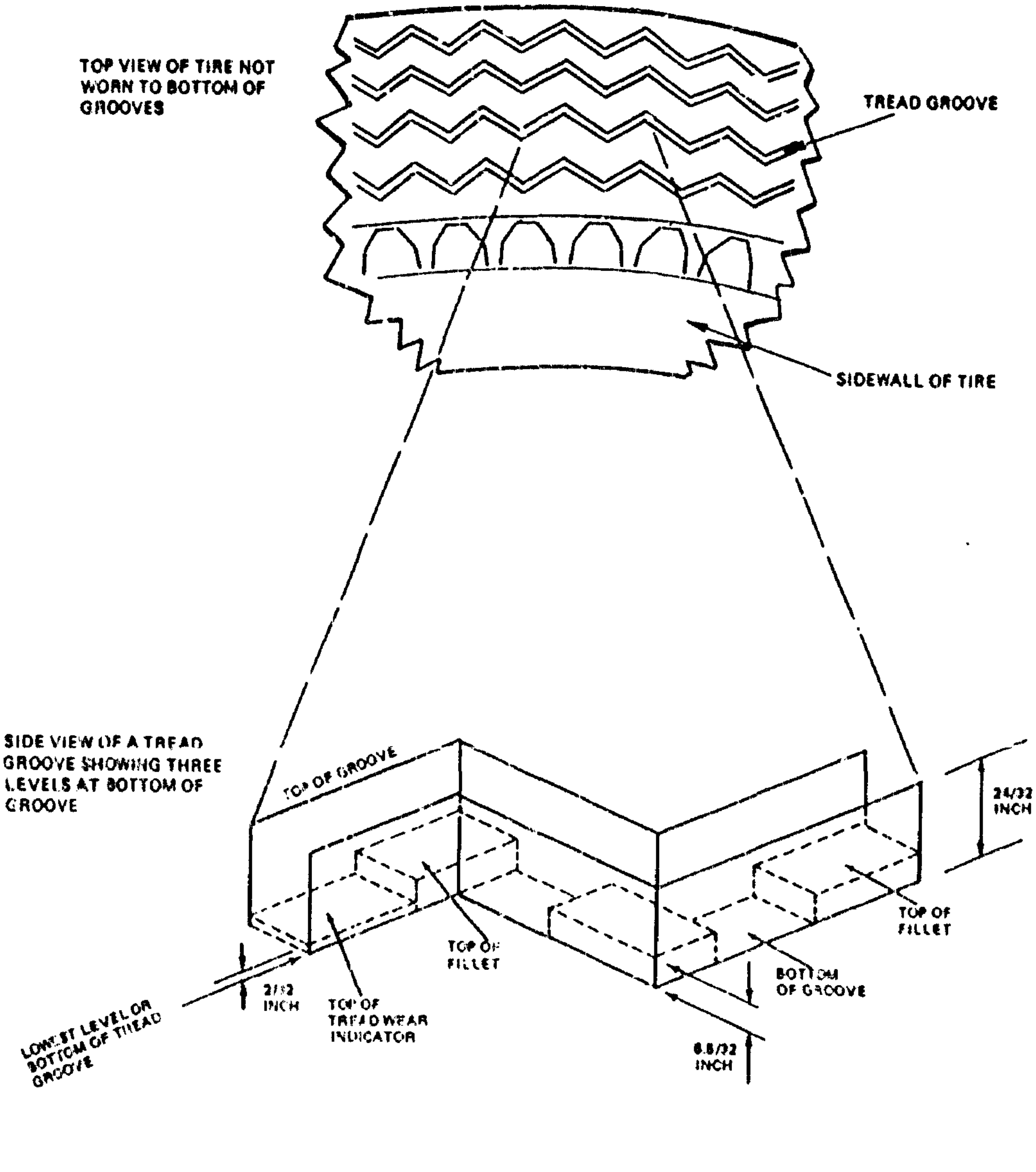


Figure 3.—Tire grooves in the rear tires.

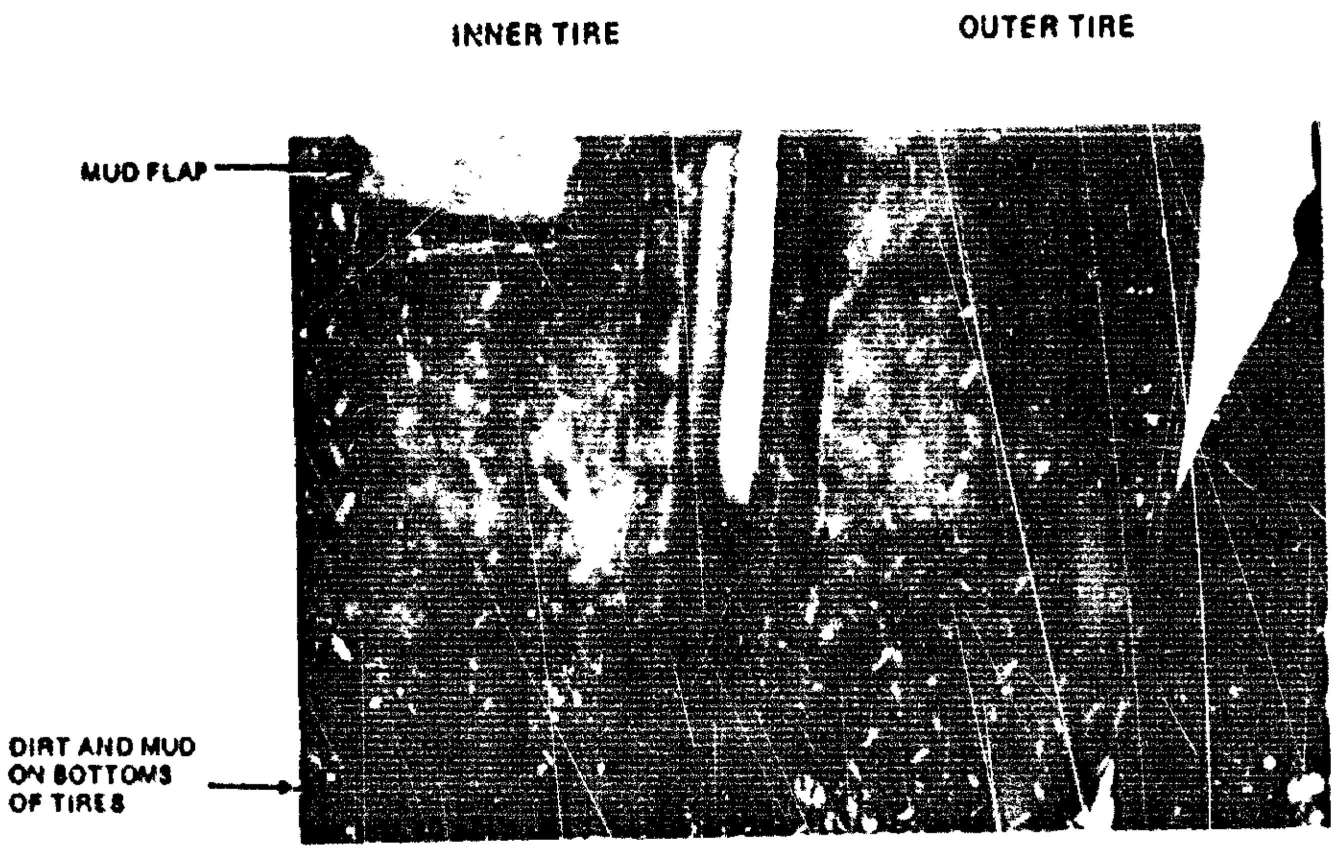


Figure 4.—Right rear tires of bus; note slotted pattern.

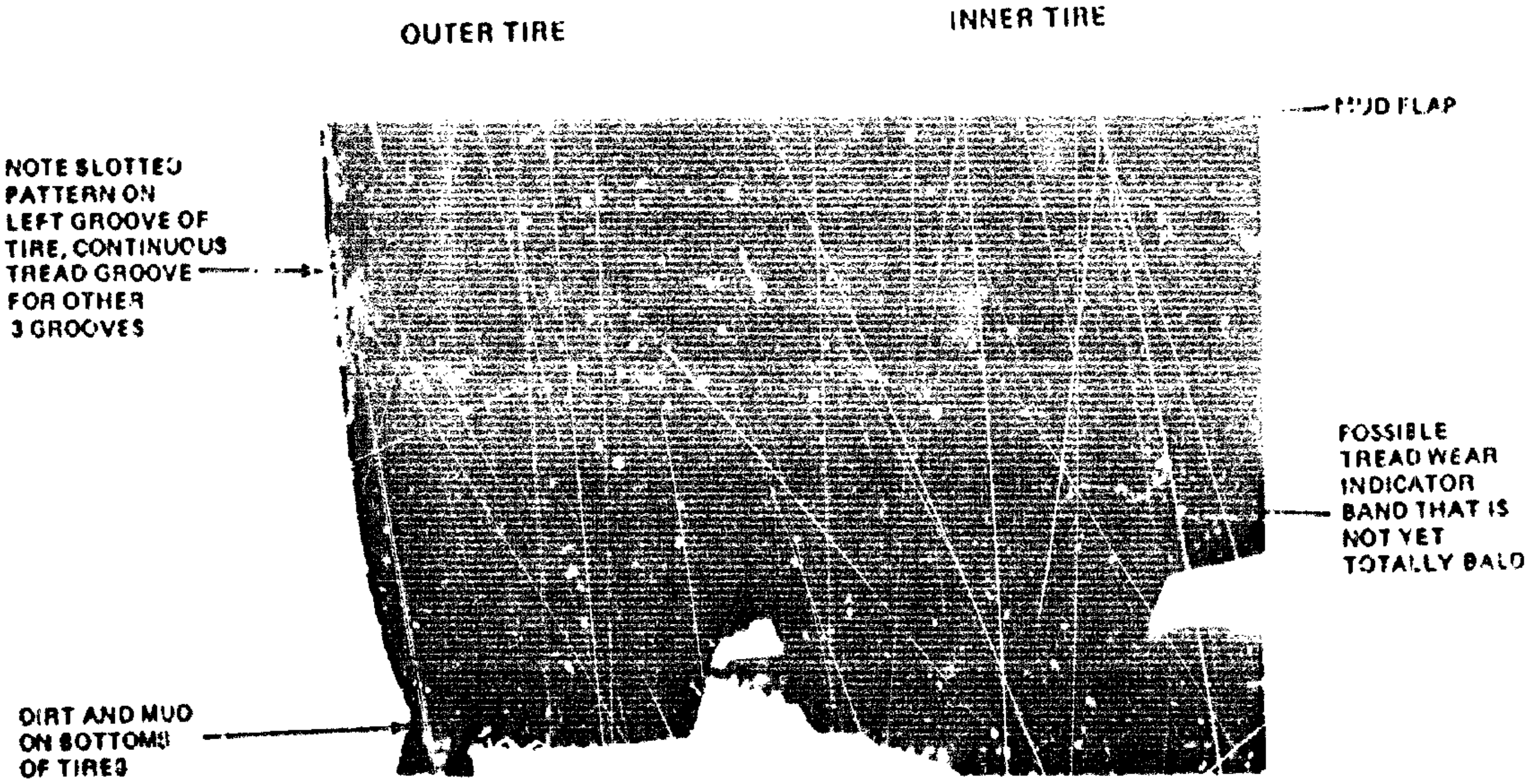


Figure 5.—Left rear tires of bus.

TABLE 1.—Tire Air Pressure, Tread Thickness, and Condition.

Tire Location	Air Pressure (psig)	Minimum Tread Depth (inches)	Condition
Left front	81	11/32 to fillet	• Tread groove continuous. • Inner tread worn lower than outer tread. • Cupping wear evident.
Right front	77	14/32 to fillet	• Tread groove continuous. • No signs of abnormal wear; a new recently installed tire.
Left rear (outer)	67	1/32 in slots of outside shoulder groove	• Tread groove continous in the center and inside shoulder of the tire; tread groove worn below the top of the fillets along the outside shoulder of the tire. Tire may have been partially regrooved. o Sections of rubber missing along inside and outside shoulders of tire -- no tire cords visible.
Left rear (inner)	63+	0/32 in center of tire	• Tread groove worn below the top of the fillets along the outsides of the tire, worn smooth at spots along the center of the tire.
Right rear (outer)	60	4/32 in slots across tire	• Tread groove worn to or below the top of the fillets, more or less uniformly across and around the tire. • According to bus maintenance man, tire had been used as the right front tire, recently switched to rear o Rubber section missing along the outside shoulder of the tire -- no tire cords visible
Right rear (inner)	66+	1/32 in slots of inside shoulder groove	• Tread groove worn to or below the top of the fillets; somewhat more wear to the inside of the tire

Texas has no special guidelines for measuring the tread depth of commercial regrooveable tires. Under the Texas inspection procedure, the following provisions apply to the bus tires:

Inspect for and Reject:

Any tire with tread or sidewall cracks, cuts, or snags (as measured on the outside of the tire) in excess of one inch in any direction and deep enough to expose the body cords.

Any tire with tread wear indicators worn so that the tread wear indicators contact the road in any two adjacent major grooves in the center or middle of the tire. (See figure 6.)

Any tire without tread wear indicators worn so that less than 2/32 (1/16) of an inch of tread design depth remains when measured (with a tread depth gauge) at the lowest points in any two adjacent major grooves in the center or middle of the tire. (See figure 7.)

The tread depth requirement of these regulations shall not apply to more than one tire in each set of dual wheels. The other requirements will apply to the other tire on the dual wheel.

Busdriver Information

The 30-year-old busdriver held a valid general Texas driver's license with no operating restrictions; no special training or license is required to operate a private bus in Texas. He had no traffic violations on his driving record.

He had driven the accident bus and another bus owned by the church for about 1 year and had about 1,500 miles of driving experience with these buses, his only experience with driving large vehicles. There were three other men who served as busdrivers on the bus at the time of the accident; this busdriver was the least experienced of the group. He had been driving since the trip started at 6:30 a.m. and had been driving for about an hour through continuous rain before the accident.

The church group was to sing at the church gathering in Corpus Christi at about 3:00 p.m. The informal trip plan called for driving about half of the 190-mile trip, stopping to eat, and then having another driver take over and complete the trip. There was no scheduled arrival time in Corpus Christi; the busdrivers had estimated that about 3 1/2 to 4 hours would be required one-way.

The busdriver reported that he had no problems with the bus during the trip and had never experienced a loss of traction on the bus before. One of the other busdrivers did recall that the bus had fishtailed or lost traction as he was driving through a curve on an interstate highway during a light rainstorm about a month before the accident. He said that the pavement on which traction was lost was a different color than the pavement he had been traveling on. Since the bus corrected itself once it cleared that section of pavement, the busdriver determined that he had been on a bad spot in the pavement for maintaining traction. No other negative comments were made about bus handling or control.

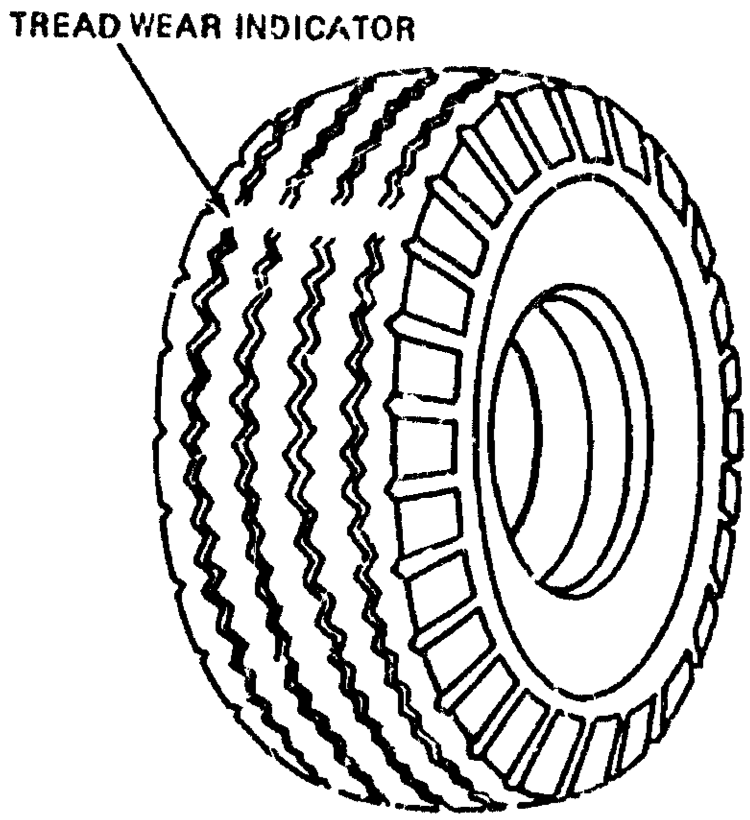


Figure 6. Tire worn to tread wear indicators
(From Texas Inspection Manual)

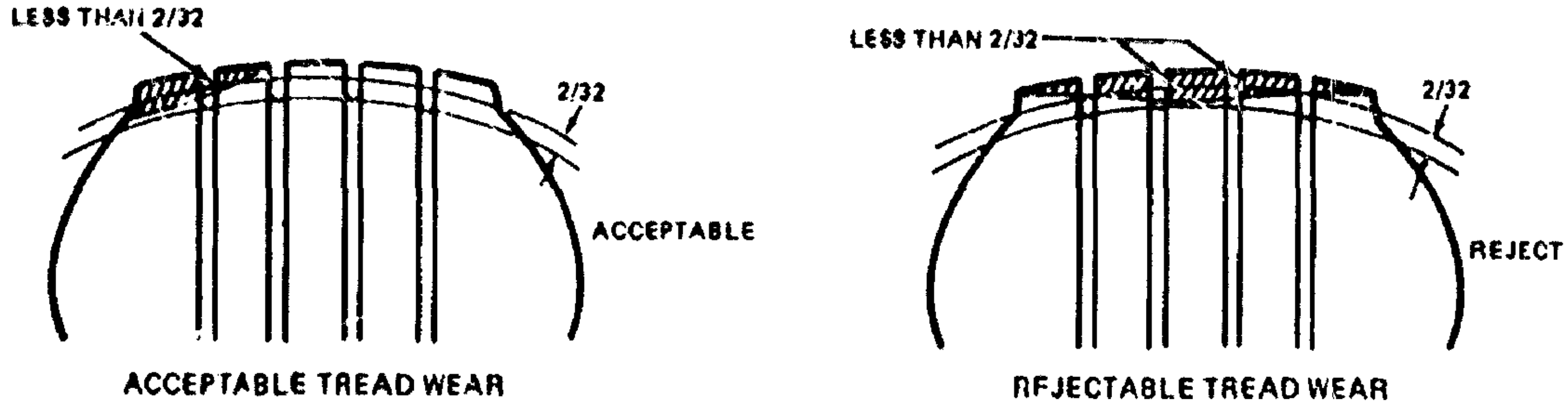


Figure 7.—Acceptable and rejectable tread wear patterns
(From Texas Inspection Manual)

Highway Information

U.S. Route 183 is a north-south, Federal-aid primary highway that runs through central Texas from the Texas-Oklahoma border to Corpus Christi. It passes through Austin and offered a direct route for the bus trip. The accident occurred about 50 miles south of Austin, 1 mile south of Luling. The accident site was in an undeveloped rural area with no defined intersecting roads or driveways within 1/2 mile. (See figures 8a and 8b.) Average daily traffic was about 3,100 vehicles in 1975 (11 percent trucks) and 4,800 in 1979.

At the accident site, U.S. Route 183 is a two-lane asphalt concrete highway, with 13-foot-wide traffic lanes and 10-foot-wide asphalt concrete shoulders. The traffic lane pavement is black while the shoulder pavement is light grey. There are no edgelines to separate the traffic lanes from the shoulders; it is a common practice in this area not to use edgelines. Through traffic occasionally uses the shoulders, a permissible practice according to the local highway patrol. According to the busdriver, he had no problems differentiating between the traffic lane and the shoulder and was operating the bus in the traffic lane.

The posted speed limit is 55 mph. Between traffic lanes, there is a solid yellow centerline for southbound traffic and a broken yellow centerline for northbound traffic. Raised, yellow reflective markers were mounted on the pavement along the centerline, and white reflective delineators were mounted on 4-foot-high posts along the edge of the road and throughout the curve.

Investigation revealed that the southbound approach to the curve consisted of 1,500-foot straight section of roadway on a 2.2-percent downgrade, followed by a 350-foot straight, level section of roadway. The crown, or the amount of side slant in the straight, level section of roadway varied from 0 to 0.008 feet/foot. A value of 0.01 to 0.03 feet/foot is recommended for drainage purposes. 3/ The curve was a 2° left curve (2,865-foot radius) with a design speed of about 60 mph. The grade was level for the first 550 feet of the curve and then changed to a 0.4-percent upgrade in the area where the bus left the scrubmarks on the northbound shoulder. Superelevation, or the amount of side banking in the curve, varied from 0.008 feet/foot at the beginning of the curve to a maximum of 0.028 feet/foot about 250 feet into the curve. About 0.012 feet/foot is average for a superelevation that will meet minimum drainage requirements. 3/ The crown and superelevation values indicated that there was limited side banking available at the beginning of the curve. Side banking aids in resisting centrifugal force, the force that tries to make a vehicle slide sideways while it is turning. Common design practices call for 50 to 100 percent of the maximum superelevation (0.014 to 0.028) to be available at the beginning of the curve. 3/

The highway was built in 1931 as a 20-foot-wide concrete road, 7 inches thick at the centerline and 9 inches thick at the edges, with no base or subbase. The highway was widened to its current width in the 1950's, and an additional 2 1/2 inches of asphalt concrete were added to the traffic lanes. In 1972, a 3/8-inch asphalt chip seal coating was added, the last major update of the pavement.

The pavement was deteriorated at the time of the accident, with lateral cracks visible about every 10 to 15 feet and several patches within 1/2-mile of the accident site. On the approach to the curve and on the curve, contour and rutting bar measurements

3/ "A Policy on Geometric Design of Rural Highways," American Association of State Highway Officials, 1965 edition.

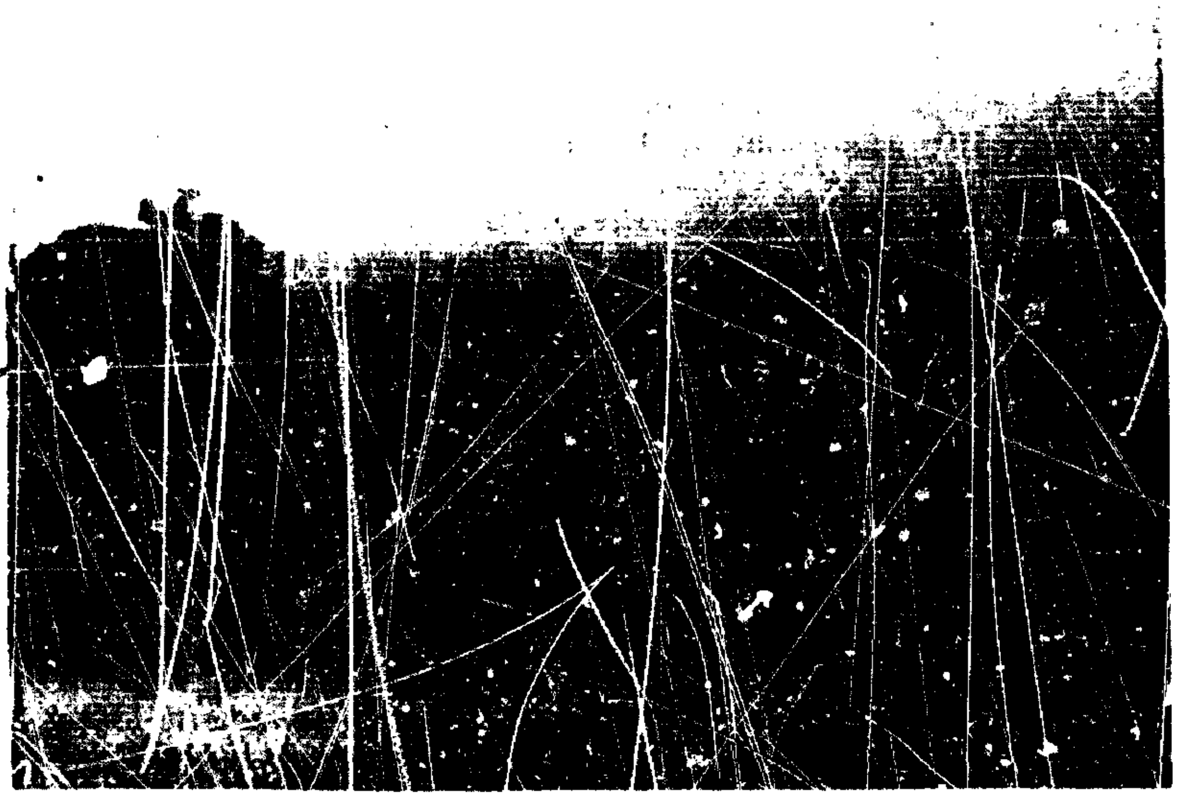


Figure 8a.--Accident site. Photo taken about 100 feet before beginning of curve.

Figure 8b.--Accident site; bus tire scrub marks on opposite shoulder and final position of bus.

revealed a number of shallow points where water could accumulate or drainage would be slow. Six days after the accident and during a light intensity rain, three Safety Board investigators did not observe any serious flooding problems. However, the road surface in the traffic lanes was saturated with water in some areas. Some puddles had formed on the shoulders, but none had formed in the shoulder area where the bus maneuvered. (See figure 8a.)

The ground area beyond the edge of the southbound shoulder had a side slope of 5 feet horizontal to 1 foot vertical, which continued to the bottom of a drainage ditch located about 20 feet from the edge of the shoulder. No guardrails are recommended or required on a side slope as flat as this one, and none were present. 4/

In December 1977, the Texas Department of Highways and Public Transportation (DOT) tested the frictional properties of the pavement about 0.4 mile north and south of the accident site with a locked-wheel skid trailer as part of a routine inventory of the State's road system; no tests were conducted at the accident site. The trailer met the requirements of the American Society of Testing and Materials (ASTM) Standard E 274-70, as revised July 1974.

A locked-wheel skid trailer measures the longitudinal friction coefficient developed between the pavement and a standard test tire that is braked and slides in the direction of travel of the trailer. This locked-wheel braking test simulates and measures the ability of friction between the tires and pavement to stop or slow a vehicle when the brakes lock the wheels. The standard test tire is constructed with automobile tire rubber compounds and has been found to be representative of average automobile tires in terms of frictional quality. However, large truck and bus tires are constructed with harder rubber compounds that wear better but have lower frictional quality than automobile tire compounds. Therefore, trailer tests using a standard test tire obtain higher test values than tests using truck or bus tires. 5/

There is no standard test tire that is equivalent to truck and bus tires in terms of frictional quality, and there are no standard correction factors to translate data from the standard "automobile" test tire to equivalent truck and bus tire values. Therefore, a test result from using the currently available standard test tire may be considered acceptable for automobile tires but may not be acceptable for truck and bus tires.

When standard trailer tests are run to check the relative wet frictional qualities of highways under a periodic inventory program, the left wheelpath of traffic is wetted and measured at a test speed of 40 mph. Test readings of 0.38 and 0.34 were obtained for the two locations 0.4 mile north and south of the accident site in 1977. For comparison purposes, tire-to-pavement friction coefficients of 0.10 to 0.15 would be obtained on an ice-covered surface while values of 0.80 and above would be obtained on a dry, coarse-textured pavement surface that is clear of debris or foreign material -- optimum operating conditions.

Texas DOT has no written guidelines or standards for detecting wet pavement problem locations or for initiating corrective actions resulting from low locked-wheel trailer test results, high accident rates, or any other indication of wet pavement

4/ "Guide for Selecting, Locating, and Designing Traffic Barriers," American Association of State Highway and Transportation Officials, 1977.
5/ "Truck Tire Cornering and Braking Traction Study," Ensco, Inc. for the U.S. Department of Transportation, 1979. NHTSA-9-6227. "Initial Tests on Stopping Distance and Spin-Out Characteristics of Regrooved Tires on Buses" Texas Transportation Institute, 1967.

problems. According to the State traffic engineer, "slippery when wet" signs are placed at locations according to the national Manual on Uniform Traffic Control Devices guideline. This guideline states that such signs are "intended for use to warn of a condition where the highway surface is extraordinarily slippery when wet." 6/ No such signs were in place at or near the accident location before the accident and none were placed after the accident.

The Texas DOT accident records show that three accidents had occurred within a 1/2-mile distance of the accident site in 1977; two of these accidents occurred on dry pavement and one occurred in wet weather. It could not be established whether the road contributed to the wet weather accident from the available information. There were no accidents reported for 1978 and 1979 near the accident site.

Meteorological Information

The accident occurred in daylight with overcast skies; the bus occupants reported a light intensity rain. The official observer for the National Weather Service in Luling, noted a trace of rain and 0.01 inch of rain for the first 2 of the 3 days preceding the accident and 1.33 inches for the 24 hours preceding the accident. This amount of rain over that period of time should have washed the pavement clean of foreign materials.

Of the 10 climate divisions in Texas, the south-central division ranked fourth in the amount of precipitation. Of the 252 counties, Caldwell County, the county in which the accident occurred, ranked 97th with respect to the rate of wet weather injury accidents. This would be a ranking of about fourth on a scale of 10, 7/ indicating that Caldwell County was not experiencing an abnormally high rate of wet weather injury accidents in comparison to other counties with respect to the amount of precipitation. A recent Safety Board study developed an index which related the percentage of fatal accidents on wet pavement to the percentage of time the pavement was wet. 8/ The national wet fatal accident index was 3.54 while the index for Texas was 4.94 -- the second highest index among all of the States.

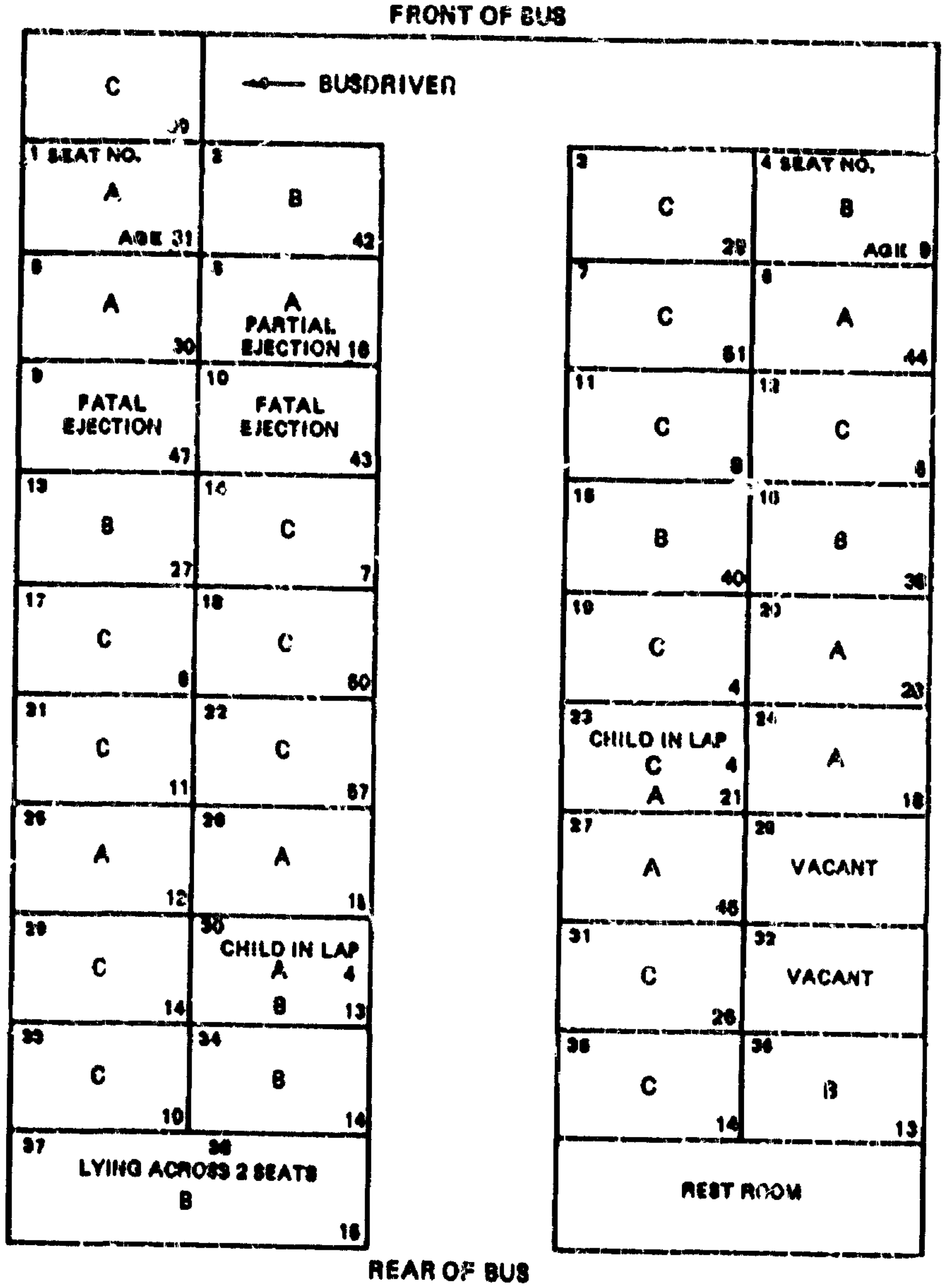
Medical and Pathological Information

No autopsies were performed on the two occupants who were killed; autopsies were neither required nor requested. The investigating officer reported that the passenger in the window seat had a severely crushed chest, and the passenger in the aisle seat had severe injuries to the head and neck. Figure 9 contains the seating position, police-reported level of injury, and age of the bus occupants.

Survival Aspects

Those bus occupants with minor-to-moderate injuries evacuated the bus through the front windshields and rear windows. A rapid exit was not critical to survival. The highway patrol was notified of the accident about 8 minutes after it occurred, and the first unit arrived on-scene about 8 minutes after notification. There were no indications that rescue efforts were unnecessarily delayed or that injuries became more severe because of delayed treatment.

6/ "Manual on Uniform Traffic Control Devices for Streets and Highways," U.S. Department of Transportation, Federal Highway Administration, 1978.
7/ (97/252) 10 = 3.85 or about fourth on a scale of 10.
8/ "Special Study--Fatal Highway Accidents on Wet Pavement--The Magnitude, Location, and Characteristics," February 1980. (NTSB-HSS-80-1)



A Level Injury -- Incapacitating injury
B Level Injury -- Nonincapacitating injury
C Level Injury -- Possible injury

Figure 9.--Bus seating chart with occupant age and injury level.

Tests and Research

In order to determine where the busdriver may have first lost control, the Safety Board "projected back" from the tire scrub marks that the bus left on the northbound shoulder. This projection indicated that control of the bus probably would have been lost near the beginning of the curve. At the request of the Safety Board, the Texas DOT performed sand patch tests and locked-wheel skid trailer tests both outside and within this area on November 20 and 21, 1980. (See figure 10.)

Sand patch tests measure pavement texture depth, an indication of the coarseness and drainage quality of the pavement surface. These tests indicated that the texture depth was considerably reduced on the southbound traffic lane approach to the curve and the traffic lane through the curve, when compared to tests taken on similar new chip seal coatings. Texture in the traffic lanes at the accident site ranged from 0.013 to 0.026 inch deep, while new chip seal coatings provide maximum depths of 0.164 inches. Currently, there are no national standards regarding acceptable or minimum pavement texture depths. However, pavement texture depths in the southbound traffic lane were predominantly below those acceptable or minimum levels recommended by research while the shoulder pavement texture depths met or exceeded all recommended values. (See table 2.) For example, texture in the traffic lanes ranged from 0.013 to 0.026 inch deep, while shoulder texture ranged from 0.038 to 0.068 inch deep. Galloway et al. recommended a minimum pavement texture of 0.040 inches, and Elsenaar et al. 9/ recommended 0.015 to 0.031 inches for pavements with operating speeds between 50 and 75 mph. Research performed by the Texas DOT in 1970 indicated that low pavement surface texture was a significant contributer to wet weather accidents; there was a noticeable increase in the rate of wet weather accidents to vehicle-miles traveled at locations with texture depths of 0.035 inches or less. 10/

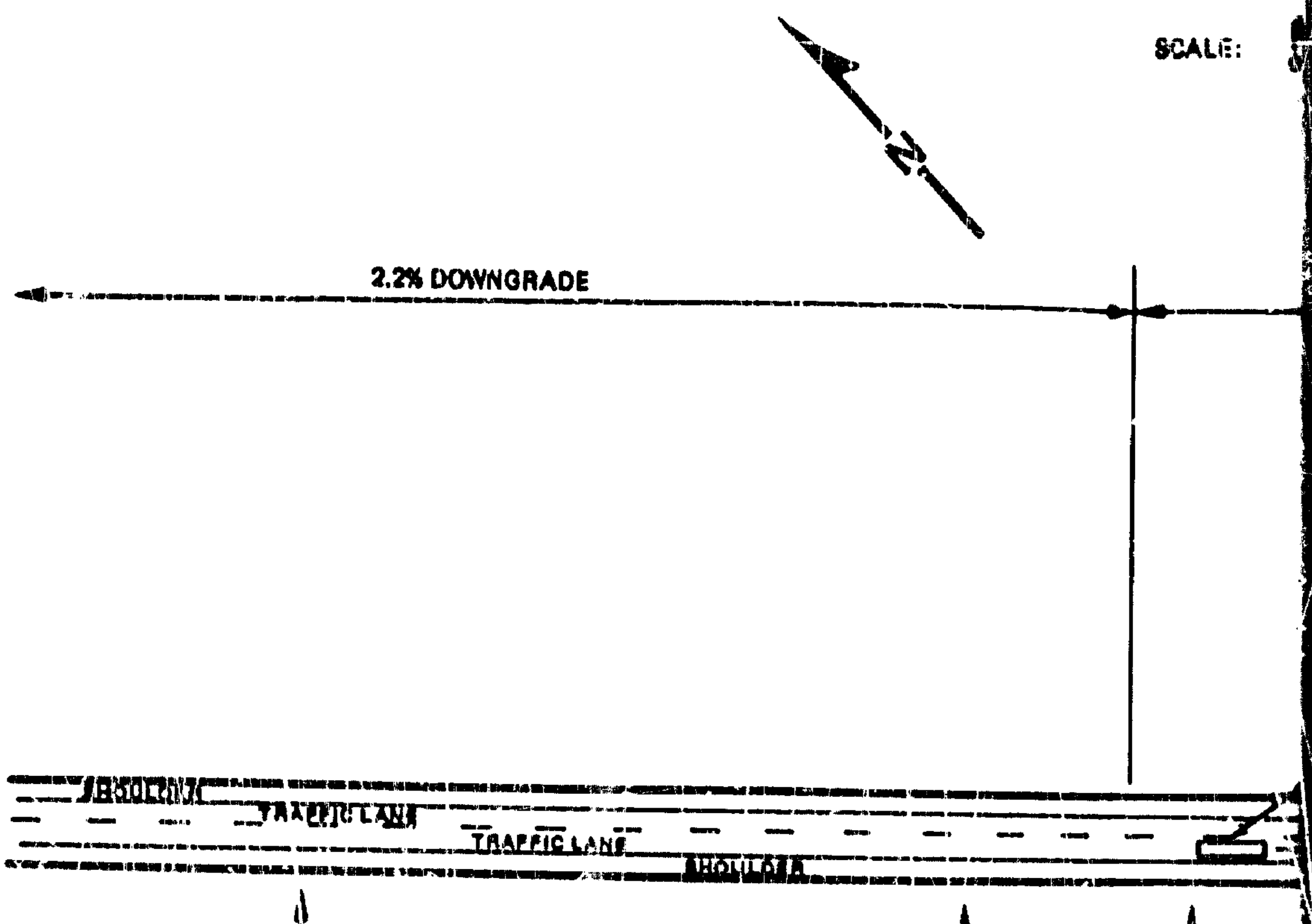
Standard 40-mph locked-wheel skid trailer tests were performed at the accident site that were similar to those performed near the accident site in 1977. (See table 3.) A standard-test-tire-to-pavement friction coefficient of 0.32 was obtained on the southbound straight, level approach, 300 feet before the curve, and 0.26 was obtained 250 feet after the curve began. Friction coefficients obtained on the southbound shoulder at the same locations (0.32 and 0.25) were similar to those obtained in the traffic lanes (0.32 and 0.26).

High-speed, and therefore nonstandard, locked-wheel trailer tests were performed near the posted speed limit. This type of testing has been recommended by the Safety Board to replace the standard 40-mph tests performed during routine inventory testing. 11/ The Safety Board recommended high-speed testing because its investigations have shown that there was a significant loss in tire-to-pavement frictional quality as test speeds were increased at some wet pavement accident sites. The high-speed tests at this bus accident site indicated that tire-to-pavement frictional quality for automobile tires was appreciably degraded at wet-pavement speeds near the posted speed limit in the southbound traffic lane. (See table 4.) Using the standard test tire that is representative

9/ "Pavement Characteristics and Skid Resistance," Elsenaar, Reichert, and Sauterey, French research reported in U.S. Transportation Research Record No. 622, 1976. "Tentative Pavement and Geometric Design Criteria for Minimizing Hydroplaning," Galloway, et al., February 1975, FHWA-RD-75-11.
10/ "The Degree of Influence of Certain Factors Pertaining to the Vehicle and Pavement on Traffic Accidents Under Wet Conditions." Texas Highway Department, Research Report Number 133-3F, September 1970.
11/ "Safety Effectiveness Evaluation--Selected State Highway Skid Resistance Programs," September 29, 1980. (NTSB-SEE-80-6.)

FIGURE 10.

SAND PATCH AND LOCKED-WHEEL
ON NOVEMBER 20 AND 21, 1980, AT
LULING, TEXAS



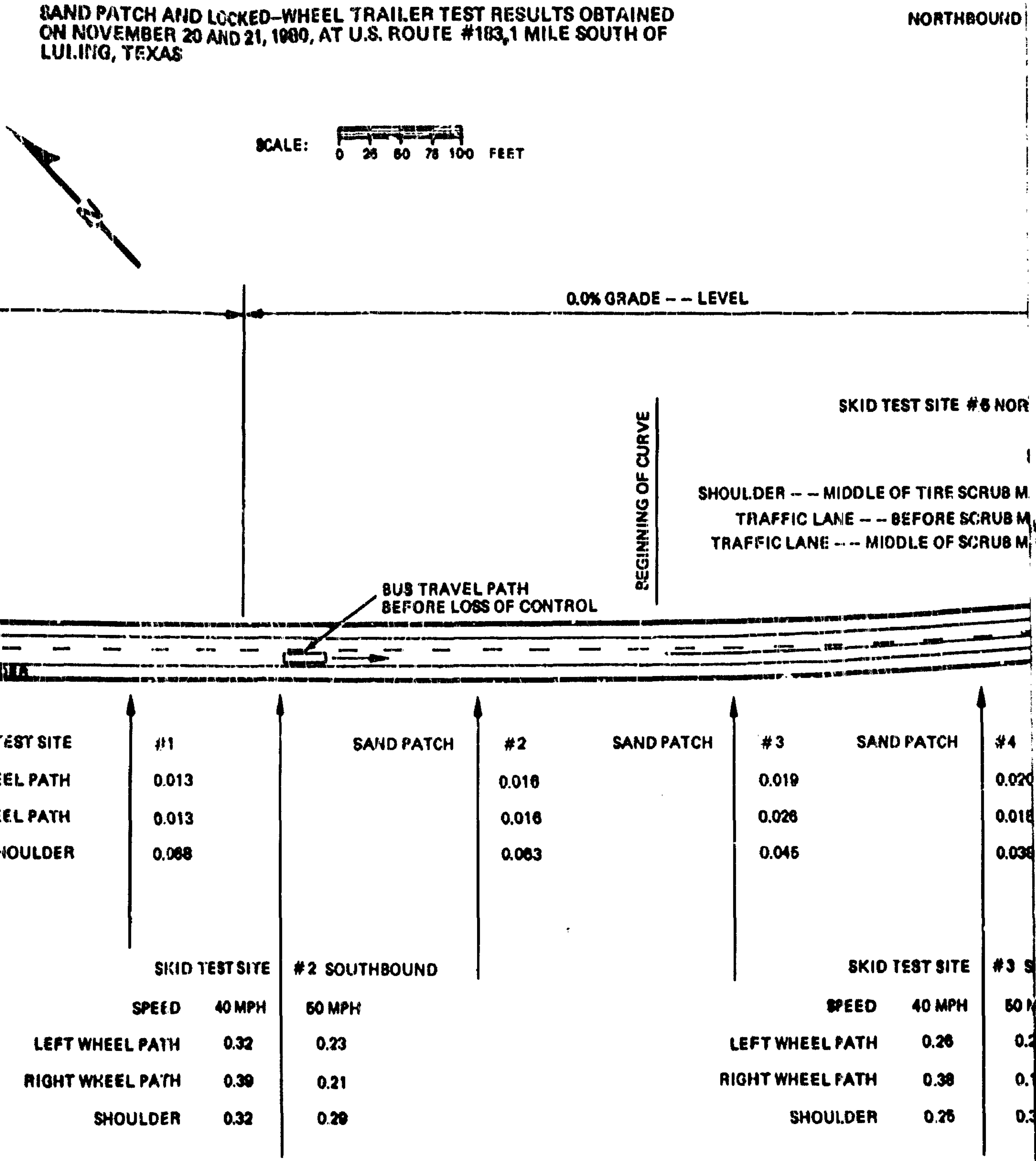
SOUTHBOUND SAND PATCH TEST SITE	#1
LEFT WHEEL PATH	0.013
RIGHT WHEEL PATH	0.013
SHOULDER	0.068

SKID TEST SITE		# 1 SOUTHBOUND
SPEED	40 MPH	50 MPH
LEFT WHEEL PATH	0.30	0.32
RIGHT WHEEL PATH	0.14	0.23
SHOULDER	0.30	0.33

SKID TEST SITE		# 2 SO
SPEED	40 MPH	50 MP
LEFT WHEEL PATH	0.32	0.23
RIGHT WHEEL PATH	0.39	0.21
SHOULDER	0.32	0.2[illegible]

FIGURE 10.

SAND PATCH AND LOCKED–WHEEL TRAILER TEST RESULTS OBTAINED ON NOVEMBER 20 AND 21, 1980, AT U.S. ROUTE #183, 1 MILE SOUTH OF LULING, TEXAS



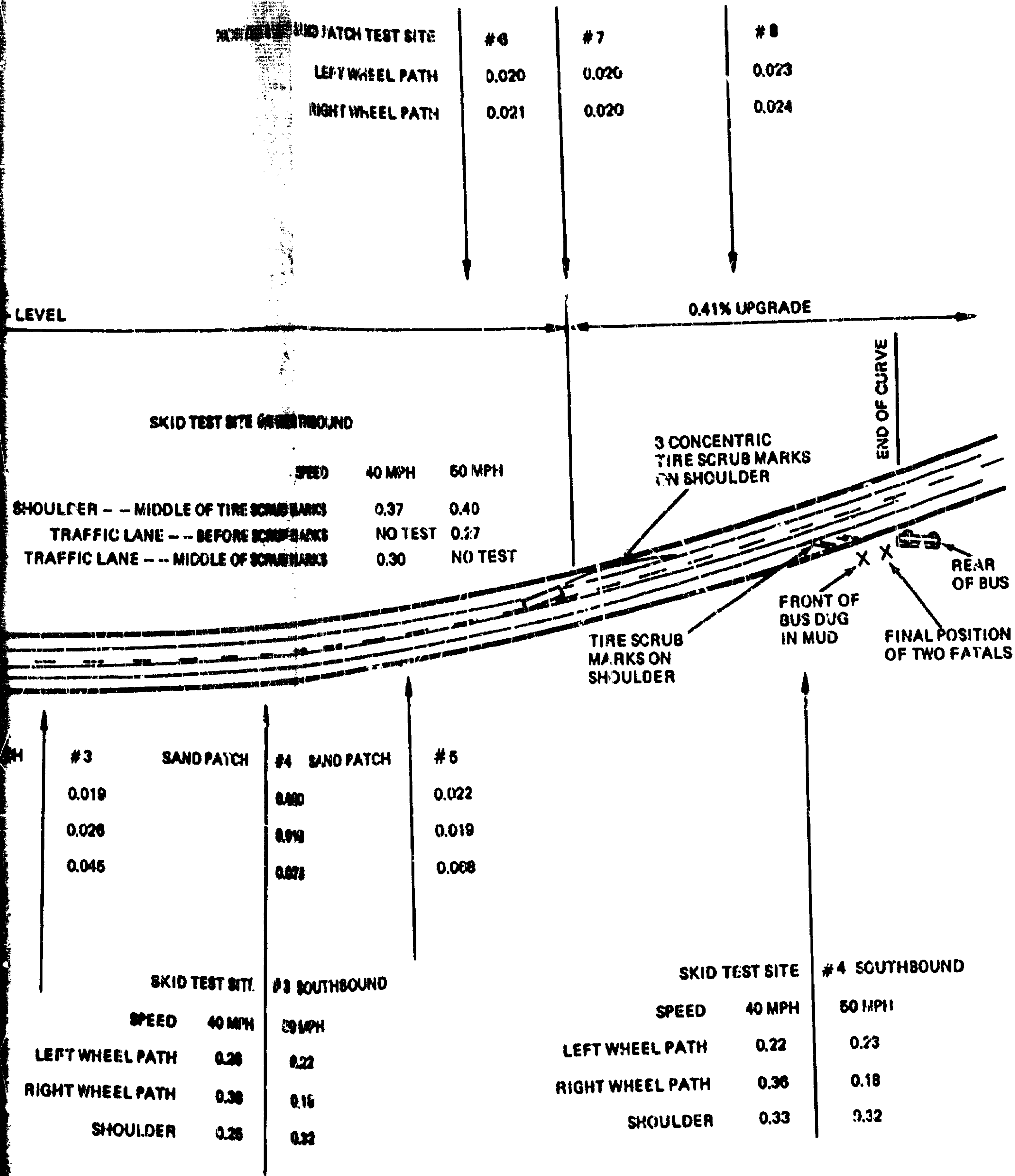

SAND PATCH TEST SITE
#6
#7
#8
LEFT WHEEL PATH
0.020
0.020
0.023
RIGHT WHEEL PATH
0.021
0.020
0.024
LEVEL
0.41% UPGRADE
END OF CURVE
SKID TEST SITE
SPEED
40 MPH
50 MPH
SHOULDER – – MIDDLE OF TIRE SCRUB MARKS
0.37
0.40
TRAFFIC LANE – – BEFORE SCRUB MARKS
NO TEST
0.27
TRAFFIC LANE – – MIDDLE OF SCRUB MARKS
0.30
NO TEST
3 CONCENTRIC TIRE SCRUB MARKS ON SHOULDER
REAR OF BUS
FRONT OF BUS DUG IN MUD
FINAL POSITION OF TWO FATALS
TIRE SCRUB MARKS ON SHOULDER
#3
SAND PATCH
#4
SAND PATCH
#5
0.019
0.022
0.026
0.019
0.045
0.068
SKID TEST SITE
#3 SOUTHBOUND
SPEED
40 MPH
LEFT WHEEL PATH
RIGHT WHEEL PATH
SHOULDER
SKID TEST SITE
#4 SOUTHBOUND
SPEED
40 MPH
50 MPH
LEFT WHEEL PATH
0.22
0.23
RIGHT WHEEL PATH
0.36
0.18
SHOULDER
0.33
0.32

TABLE 2. Comparison of Sand Patch Test Results Obtained at Accident Site on November 20, 1980, with Recommended Values

Southbound Location	Traffic Lane Sand Patch Values (inches)	Comparison to Recommended Values 1/	Shoulder Sand Patch Values (inches)	Comparison to Recommended Values 1/
450 feet before beginning of curve	0.013 left wheelpath	Just Below French Below Galloway	0.068	Above French Above Galloway
	0.013 right wheelpath	Just Below French Below Galloway		
150 feet before beginning of curve	0.016 left wheelpath	Just Within French Below Galloway	0.063	Above French Above Galloway
	0.016 right wheelpath	Just Within French Below Galloway		
50 feet after beginning of curve	0.019 left wheelpath	Within French Below Galloway	0.045	Above French Above Galloway
	0.026 right wheelpath	Within French Below Galloway		
250 feet after beginning of curve	0.020 left wheelpath	Within French Below Galloway	0.038	Above French Just Below Galloway
	0.018 right wheelpath	Within French Below Galloway		

1/ French Research: (Kisenaar, et al)

1. For pavements with texture depths of 0.007 to 0.015 inch —" 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.

2. For pavements with texture depths of 0.015 to 0.031 —" Medium-textured pavements; these are normal pavements for sections on which moderate speeds are encountered, between 80 and 120 Km per hour (50 to 75 mph).

3. For pavements with texture depths of 0.031 to 0.047 —" Coarse-textured pavements; these pavements are to be used for sections on which speeds are normally higher than 120 Kilometers per hour (75 mph)."

Galloway recommends a pavement texture depth of 0.040 inches.

TABLE 3. Locked-Wheel Skid Trailer Tire - To - Pavement Test Results at 40 mph

	Type of Test	Date	Location	Friction Coefficient (Tire-to-Pavement Frictional Quality)
1.	Standard Locked-Wheel Skid Trailer Test (left wheel path of traffic lane @ 40 mph)	1977	0.4 mile south or beyond accident site in southbound direction of travel.	0.34 @ 40 mph
2.	Standard Locked-Wheel Skid Trailer Test (left wheel path of traffic lane @ 40 mph)	1977	0.4 mile north or before accident site in southbound direction of travel.	0.38 @ 40 mph
3.	Standard Locked-Wheel Skid Trailer Test (left wheel path of traffic lane @ 40 mph)	After Accident	Southbound direction of travel in straight, level approach to curve, 300 feet before beginning of curve.	0.32 @ 40 mph
4.	Standard Locked-Wheel Skid Trailer Test (left wheel path of traffic lane @ 40 mph)	After Accident	Southbound direction of travel in curve, 250 feet after beginning of curve.	0.26 @ 40 mph
5.	Non-Standard 1/ Locked-Wheel Skid Trailer Test (left wheel path of shoulder @ 40 mph)	After Accident	Southbound direction of travel in straight, level approach to curve, 300 feet before beginning of curve.	0.32 @ 40 mph
6.	Non-Standard 1/ Locked-Wheel Skid Trailer Test (left wheel path of shoulder @ 40 mph)	After Accident	Southbound direction of travel in curve, 250 feet after beginning of curve.	0.25 @ 40 mph

1/ Test is nonstandard because it was taken on the shoulder rather than the traffic lane.

TABLE 4. Locked-Wheel Skid Trailer and TIRF Machine Simulator Test Results at 50 mph

Type of Test	Date Taken	Location	Friction Coefficient (Tire to Pavement) Frictional Quality
1. Nonstandard 2/ Locked-Wheel Skid Trailer Test (left wheel path of traffic lane at 50 mph)	After Accident	Southbound direction of travel in straight, level approach to curve, 300 feet before beginning of curve.	0.23 @ 50 mph
2. Nonstandard 2/Locked-Wheel Skid Trailer Test (left wheel path of traffic lane @ 50 mph)	After Accident	Southbound direction of travel in curve, 250 feet after beginning of curve.	0.22 @ 50 mph
3. Nonstandard 3/Locked-Wheel Skid Trailer Test (left wheel path of shoulder @ 50 mph)	After Accident	Southbound direction of travel in straight, level approach to curve, 300 feet before beginning of curve.	0.29 @ 50 mph
4. Nonstandard 3/ Locked-Wheel Skid Trailer Test (left wheel path of shoulder @ 50 mph)	After Accident	Southbound directional travel in curve, 250 feet after beginning of curve.	0.32 @ 50 mph
5. Nonstandard 4/ Locked-Wheel TIRF Machine Simulator (right front bus tire @ 50 mph)	After Accident	Test made on surface simulator with a 0.23 coefficient of friction, when standard ASTM test tire was used.	0.15 @ 50 mph
6. Nonstandard 4/ Locked-Wheel TIRF Machine Simulator (right rear outer bus tire @ 50 mph)	After Accident	Same as above	0.[illegible]5 @ 50 mph

2/ Test is nonstandard because it was taken @ 50 mph in the traffic lane rather than 40 mph.

3/ Test is nonstandard because it was taken @ 50 mph on the shoulder rather than 40 mph in the traffic lane.

4/ Test is nonstandard because it was made on a machine simulator and a standard test tire was not used.

of an average automobile tire, tire-to-pavement friction coefficients of 0.23 and 0.22 were obtained at 50 mph for the southbound approach to the curve and the curve traffic lanes, as compared to 0.32 and 0.26 obtained during the 40-mph tests. The 50-mph test values (0.23 and 0.22) were quite close to being equivalent to attempting to stop or slow a vehicle on ice (0.10 to 0.15) in terms of how fast speed can be reduced. While the frictional quality of the southbound traffic lane decreased at the higher test speeds, the frictional quality of the southbound shoulder remained about the same or increased (0.29 and 0.32 at 50 mph as compared with 0.32 and 0.25 at 40 mph).

The right front bus tire and the right rear outer bus tire were selected as being representative of the average condition of the front and rear bus tires and were tested on a TIRF (Tire Research Facility) machine that simulated the wet pavement surface at the accident site. (See figure 11.) The TIRF machine was used because there was no available equipment to test the larger bus tires at the accident curve and it was necessary to establish what the braking and cornering conditions were for the bus tires rather than a standard test tire that has known higher frictional quality. The same type of standard test tire that was used to conduct the locked-wheel skid trailer tests at the accident site was used to develop a simulated TIRF surface that was similar in locked-wheel frictional quality to the pavement surface at the accident site. Under simulated wet pavement conditions that were similar to the accident site tests and at test speeds of 40 and 50 mph, use of the standard test tire on the TIRF machine produced locked-wheel, tire-to-pavement friction coefficients of 0.24 and 0.23 on the simulated surface. These readings were similar to the lowest reading of 0.26 that was obtained during the 40 mph tests and the highest reading of 0.23 that was obtained during the 50-mph tests when the standard test tire was tested at the accident curve. In this manner, the TIRF surface was designed to produce tire-to-pavement frictional quality values that would be representive of actual pavement tests using a standard test tire.

When the bus tires were tested on the TIRF machine surface, there was an even greater loss of tire-to-pavement frictional quality than with the standard test tire. 12/ Friction coefficients of 0.15 and 0.08, respectively, were obtained when the front and rear bus tires were used in locked-wheel braking tests at 40 mph. Friction coefficients of 0.15 and 0.05 were obtained for the two tires at 50 mph. (See table 4.) All of these values are equivalent to attempting to stop or slow a vehicle on ice in terms of how fast speed could be reduced.

In summary, pavement and bus tire tests indicated a progressive deterioration in tire-to-pavement, locked-wheel frictional quality in the southbound traffic lane near the beginning of the curve. Tire-to-pavement frictional quality fell to levels equivalent to attempting to stop or slow on ice as speed increased and the bus tires replaced the standard test tire. This occurred even for the bus front tire with 14/32-inch of tread depth, a depth far above any recommended or required tread depth.

Wet pavement cornering tests on the TIRF machine indicated that the bus rear tire had a much lower resistance to sliding sideways during a turning maneuver than the front tire. (See figure 12.) For example, at a road speed of 55 mph, the posted speed limit at the accident site, and a tire load of 4,700 lbs., approximately the load on each tire of the bus at the time of the accident, the maximum lateral force capability of the front tire to resist sliding sideways was 1,430 lbs. Under the same speed and load, the maximum lateral force capability of the rear tire to resist sliding sideways was 380 lbs. When the

12/ "Results of Force and Moment Measurements For Two 12.5 - 22.5/G Bus Tires Under Wet Cornering and Braking Traction Tests Conducted For the National Transportation Safety Board," Arvin/Calspan Advanced Technology Center, January 1981. (NTSB Public Docket No. HY-353.)

Figure 11.--Arvin/Calspan TIRF tire test equipment.

tire load was decreased to 4,000 lbs., approximately the load on each tire on an empty bus, the maximum lateral force capability of the front and rear tires dropped even further to 1,280 and 320 lbs., respectively.

The TIRF locked-wheel and wet pavement cornering test results for the bus front tire were similar to test results of other research efforts that measured the locked-wheel and lateral force capability of truck and bus tires with 6/32 inch or more tread depth on actual pavement. 13/ This provided supporting evidence that the simulated TIRF tests were realistic. No other study had ever tested tires worn to the level of the bus rear tire. However, there was data to indicate that as tire tread depth was reduced, locked-wheel and lateral force capability was reduced for truck and bus tires. 13/ And, the TIRF tests found such a reduction in locked-wheel and lateral force capability for the worn rear bus tire as compared to the bus front tire with more tread depth.

The TIRF tests did not indicate any significant change in braking traction or lateral force capability for the tires, whether they were tested at the manufacturer's maximum recommended inflation pressure or at the tire pressures measured after the accident.

ANALYSIS

The Accident

According to the busdriver and the passengers, a loss of rear tire traction initiated the accident sequence. These witnesses reported the bus was traveling at 40 to 50 mph and the busdriver did not report any abnormal maneuvers that would have brought about an initial loss of traction. No conditions were found that would have produced an initial

13/ Ibid., p. 13.

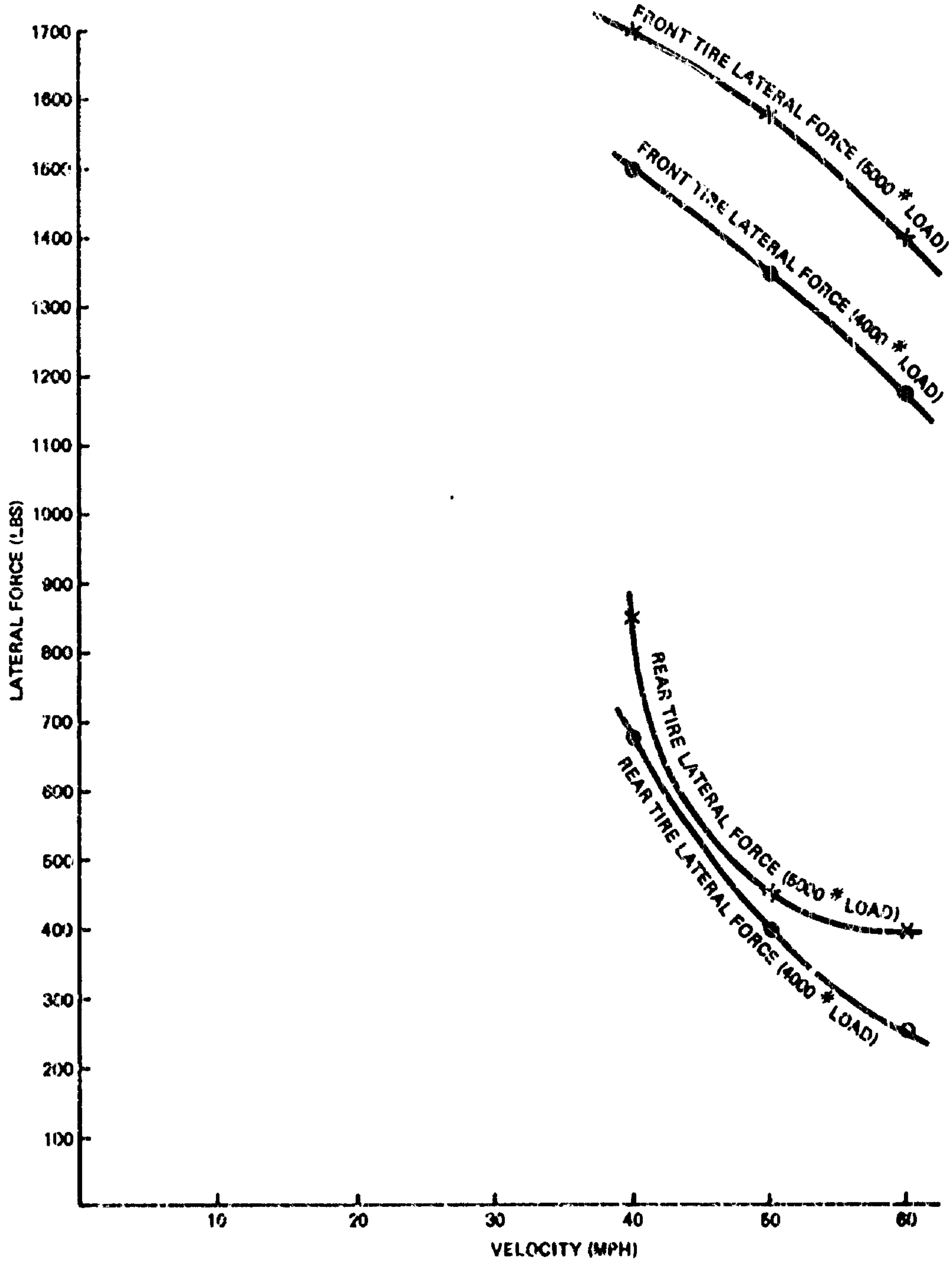


Figure 12.-- Maximum lateral force capability of right front and right rear outer bus tires as a function of vehicle speed on a 0.23 coefficient of friction surface.

loss of traction to the left that some bus occupants described. However, the pavement tests, tire tests, and physical evidence indicate that it was possible for the bus to have lost traction to the right, as other bus occupants described, but not within the reported traveling speed range.

Based on Safety Board calculations, the centrifugal force that would have been produced during a normal steering maneuver through the curve did not exceed the lateral traction capability of the front tire on the low-frictional-quality pavement surface at any speed between 40 to 60 mph. (See figure 13.) On the other hand, the centrifugal force exceeded rear tire traction capability at a speed of about 57 mph, and the rear tires would have lost traction to the right. (See figure 14.) An analysis of the bus tire scrub marks on the northbound shoulder indicated that the bus was probably traveling at or near this speed as its left wheels traveled across the shoulder and its right wheels traveled primarily between the traffic lane wheel paths.

The scrub marks indicated that the busdriver had temporarily regained a high degree of steering control and was steering the bus as sharply to the right as speed would allow, probably to avoid running off the opposite or left side of the road. The Safety Board calculated that the bus had to be traveling about 50 mph in order to produce the marks. Since the busdriver had taken his foot off the accelerator when the rear tires lost traction, and the bus had been skidding sideways for at least some limited distance before he temporarily regained steering control, the bus had to be traveling at a higher speed when traction was first lost because it would have lost some speed due to rolling resistance, engine drag, and side skidding on first level, then uphill ground before it produced the scrub marks. These factors normally reduce speed slightly under conditions of low, wet tire-to-pavement frictional quality and speeds of 50 mph or more. Considering these factors and allowing some margin for the representativeness of various test results, the Safety Board concludes that the bus was probably traveling between 50 and 60 mph, a speed that could result in the loss of rear tire traction.

The absence of any physical evidence until the bus produced the tire scrub marks on the opposite or left shoulder limited the Safety Board's ability to determine exactly how the bus reached the opposite side of the road after the rear of the bus initially lost traction to the right. According to the busdriver, he steered to the left upon initial loss of control; if so, he could conceivably have oriented the bus toward the left side of the road. Such factors as increased superelevation and improved pavement frictional quality were present once the bus was outside of, or beyond, areas of lower superelevation and pavement frictional quality in the traffic lane wheel paths near the beginning of the curve. These factors, in combination with a then-decreasing speed, could have improved lateral traction capability, permitting the busdriver to drift or gradually steer the bus to the left, while avoiding a total counterclockwise spinout or a continuing slide to the right. A counterclockwise spinout or slide to the right can be produced by steering to the left when the rear of a vehicle initially loses traction to the right. The proper maneuver for a loss of rear traction to the right would be to steer to the right, but that maneuver does risk traveling onto the shoulder/off the highway and may not be instinctively performed.

As the bus approached and traveled across the shoulder area on the left side of the road, the primary concern of the busdriver was to avoid going off that side of the road. As a result, based on the tire scrub marks, he began and maintained a sharp steering maneuver to the right that could be performed on the higher frictional quality, well-drained shoulder and traffic lane area. However, that maneuver eventually led to spinout and total loss of control as the bus entered and crossed the lower frictional quality traffic lanes again.

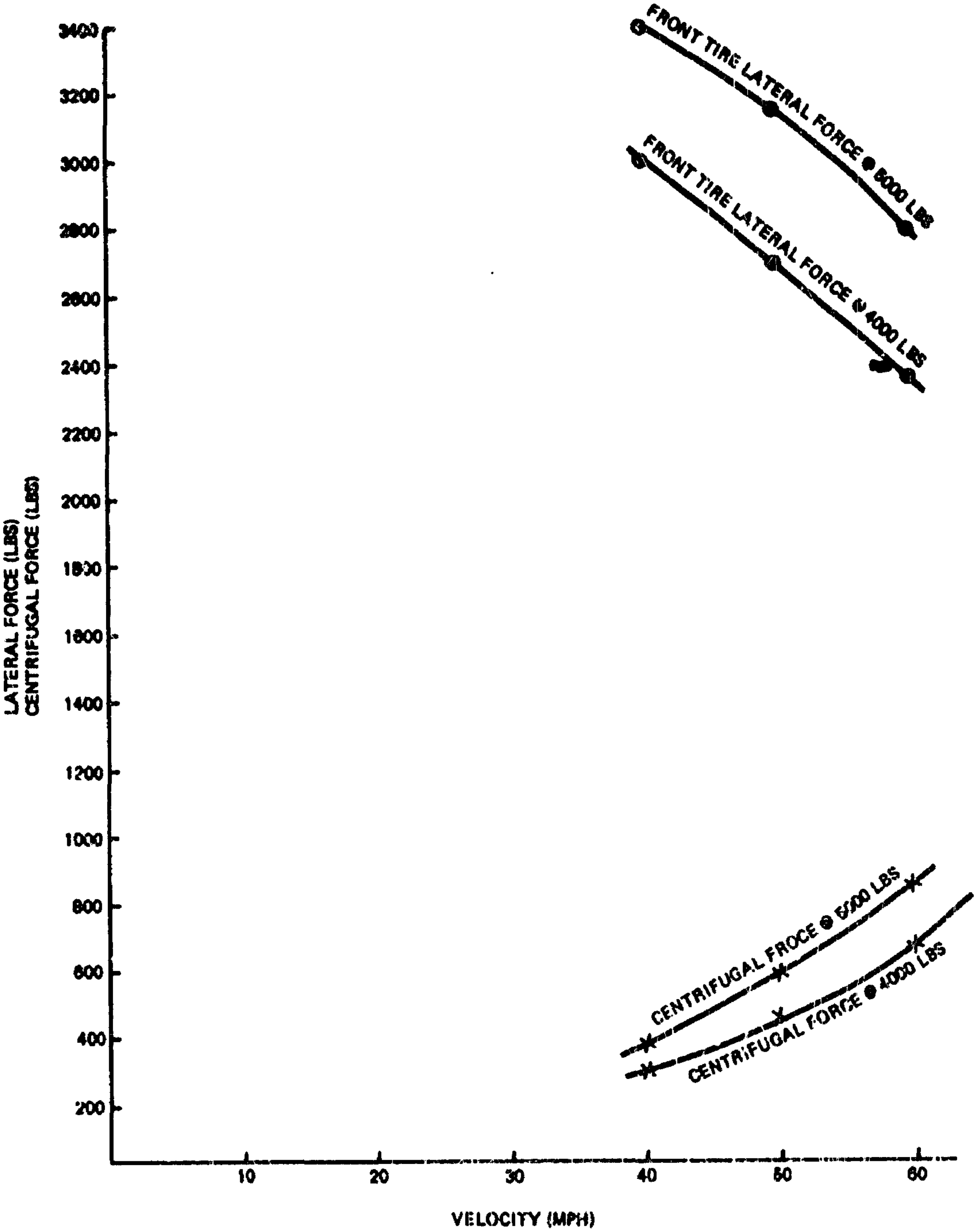


Figure 13.—Maximum lateral force capability of bus front tires and centrifugal force created during turning maneuver on a 2° curve with a 0.23 coefficient of friction as a function of vehicle speed.

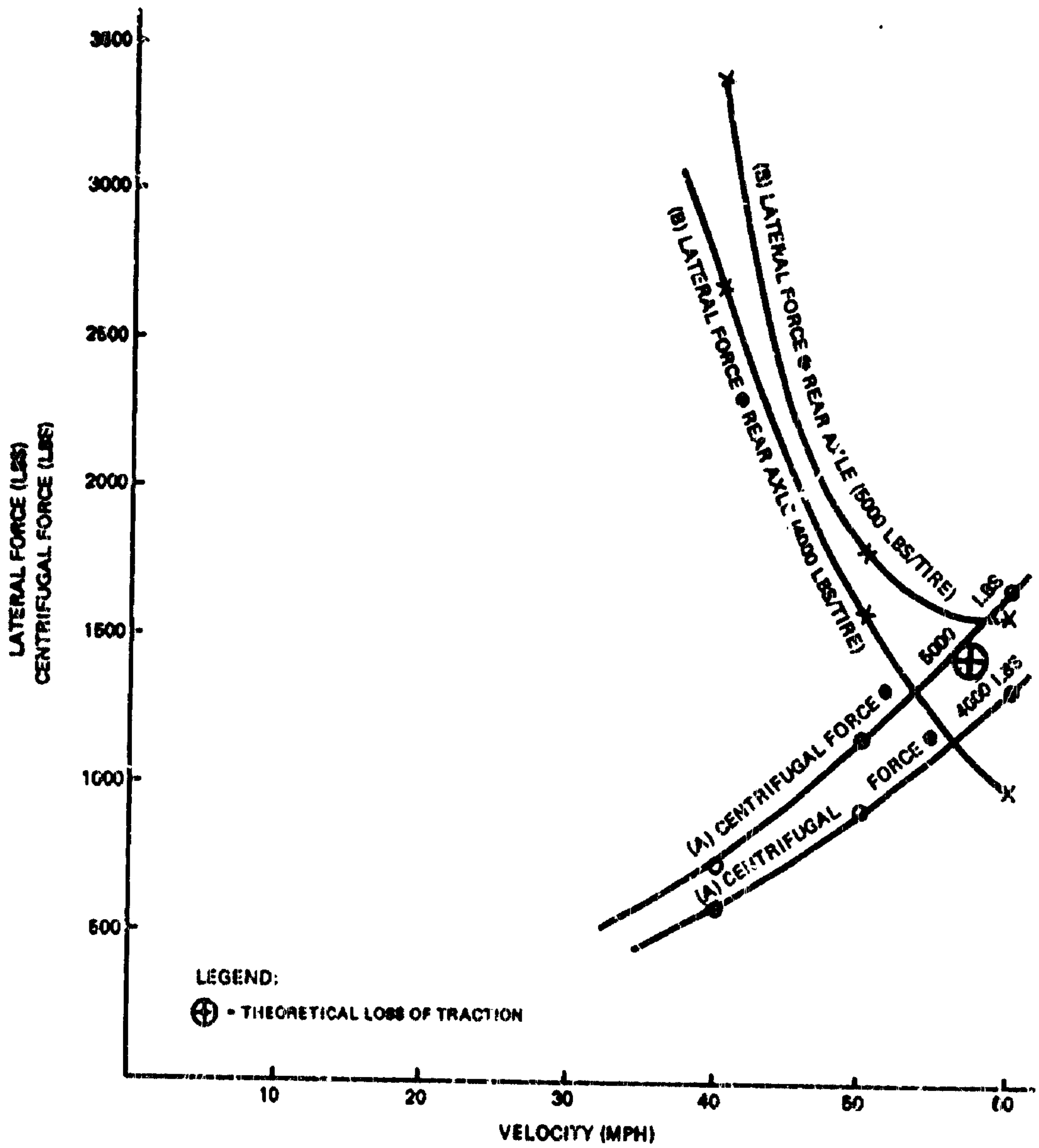


Figure 14.--Maximum lateral force capability of bus rear tires and centrifugal force created during turning maneuver on a 2° curve with a 0.23 coefficient of friction as a function of vehicle speed.

Factors Limiting Bus Rear Tire Lateral Traction Capability

Poor pavement drainage qualities -- rutting, limited crown, and limited superelevation -- allowed water to remain on the traffic lanes during the light rainfall. Total tire hydroplanning, where the tire is fully separated from contact with the road surface by a thin film of water, should not have developed because calculations indicated that the bus would have to be traveling about 80 mph for total hydroplanning to occur. However, the Safety Board believes that the lack of continuous tire tread groove depths and, perhaps, the shallow pavement texture could have hindered water from being channeled through or under the rear tire paths and reduced tire-to-pavement contact, especially at or near the speed limit. This, in turn, severely limited the lateral traction capability of the bus rear tires at that speed and on pavement of already low frictional quality. Further testing and evaluation of worn tires is currently being conducted by the National Highway Traffic Safety Administration (NHTSA) that should provide further evaluation and expansion of the problems identified by the Safety Board in this investigation.

Physical evidence and test data indicated that any small reduction in traveling speed or improvement in tire or pavement condition may have prevented the accident. For example, had the busdriver reduced operating speed to slightly less than 50 mph, he would have compensated for the tire and pavement problems and maneuvered through the curve. If the rear tires had been as good as the front tires or had at least 2/32 inch of continuous tread groove depth, the accident probably would not have occurred. Since the busdriver was able to regain a high degree of steering capability while traveling on the northbound shoulder, the accident may have been prevented if the pavement in the traffic lane wheel paths had drainage and frictional qualities that were closer in character to that of the shoulder area.

The Safety Board examined current State of Texas and Federal programs, policies, and standards to determine their effectiveness in reducing wet weather accidents of this type. Such measures could assist by: (1) reducing high-speed operation in wet weather, (2) providing adequate performance standards for the design of tires, (3) prohibiting the use of marginal or inadequate tires, (4) providing objective methods to detect pavement with low wet frictional quality, (5) providing objective methods to more consistently warn the public of pavement segments with low wet frictional quality, and (6) providing objective methods to determine when pavements with low wet frictional quality should be repaired. However, the Safety Board found that neither Texas nor Federal agencies have adopted standards able to assist in preventing this type of accident. The Safety Board was able to identify standards and policies used by the State of Pennsylvania regarding pavement evaluation that could theoretically assist in preventing this type of accident, but these standards need further evaluation.

Programs and Standards for Operating Speeds in Wet Weather

On March 12, 1980, the Safety Board recommended that the NHTSA "develop a program to alert the public to the component factors and magnitude of the wet-pavement accident problem." 14/ Perhaps such a program would assist in reinforcing the need for reduced travel speeds and for tires to be in appropriate condition for wet weather travel. NHTSA replied that it is currently assessing public "awareness and understanding of the wet pavement accident problem" and "what needs to be done to increase our [NHTSA's] understanding of wet weather driving problems." NHTSA also reported that its public information funds are committed to other priority projects, and consequently, it would be some time before it could introduce any program.

14/ Ibid., p. 14

"Slippery when wet" signs are used nationally to advise drivers to slow down or use caution on pavement with low wet frictional quality, but the national guideline for using the sign is too general or subjective and the sign's effectiveness when used alone is questionable. For example, no objective standards are provided by the national Manual on Uniform Traffic Control Devices (MUTCD) to determine when a highway surface is considered "extraordinarily slippery when wet" and a sign should be posted. Since no trailer tests were made at the accident site during the 1977 Texas DOT inventory and there was no significant accident history near the accident site, there was no reason for the Texas DOT to have been alerted to a potential wet weather problem before the accident and to have posted such signs. However, even though standard trailer test values were found to be low in the curve after the accident (0.22 and 0.26), no signs were placed at the accident site in reaction to the "extraordinarily slippery when wet" guideline, which is used by the Texas DOT to determine when a sign should be posted.

The Pennsylvania Department of Transportation (Penn DOT) has a policy whereby "slippery when wet" signs are posted at all locations with standard trailer test values of 0.34 or less. 15/ The purpose of the Penn DOT policy is to "provide immediate warning to motorists of a possible hazardous condition until permanent corrective action can be taken." Theoretically, the Penn DOT policy has merit in that it would automatically account for such factors as reduced pavement frictional quality above standard skid trailer test speeds and the currently lower fictional quality of truck and bus tires. As this investigation illustrated, these factors can occur and combine with already low frictional quality pavement to produce conditions equivalent to attempting to stop or slow on ice, even for tires with adequate tread depth.

In reaction to the 1977 inventory tests near the accident site, the Penn DOT policy would not have resulted in the posting of a "slippery when wet" sign in advance of the accident site, where the 0.38 reading was obtained, and with the high test value and low accident rate, no sign probably was necessary. However, after the bus accident, the results of the standard trailer test on the approach to the curve (0.30 and 0.32) and the curve (0.26 and 0.22) would have required the posting of "slippery when wet" signs to aid in preventing future accidents under the Penn DOT policy.

Recent Safety Board studies indicate that Penn DOT has one of the better overall programs for attacking the wet pavement accident problem and has one of the lowest rates of fatal accidents in wet weather. 16/ While the Penn DOT policy for consistent placement of "slippery when wet" signs has theoretical merit, it has not been specifically evaluated regarding its influence on Pennsylvania's good wet weather record. And, when "slippery when wet" signs were evaluated at several test sites that were not located in Pennsylvania, use of the signs alone was not found to be effective in reducing traveling speed. 17/ However, when the signs were used with flashing lights at these same locations, they were effective in reducing higher traveling speeds below the critical safe wet pavement speed. It would seem possible that the Penn DOT policy for consistent placement of signs, along with a suitable signing configuration such as the use of flashing lights, would be an effective method of alerting the public to potential hazardous conditions. The Safety Board has recently recommended that the Federal Highway Administration (FHWA) conduct further research to develop more effective signing

15/ State of Pennsylvania Department of Transportation Letter of February 15, 1978, to FHWA Docket No. 77-16 -- Skid Accident Reduction Program; Advanced Notice of Proposed Rulemaking.
16/ Ibid., p. 14 and 16.
17/ "Driver Awareness of Highway Sites with High Skid Accident Potential," Bio-Technology, Inc., for the Federal Highway Administration, July 1974. (DOT-FH-11-7972)

systems to advise motorists of safe speeds on slippery, rutted, or poorly drained wet surfaces. 18/ Since the Penn DOT policy has theoretical merit, it should be considered a candidate for further evaluation by the FHWA in the placement of such signs.

Tire Design and Inspection Standards

Federal Motor Vehicle Safety Standard (FMVSS) No. 119 for new commercial vehicle tires is not specific enough to prohibit tire designs that are similar to the design of the bus rear tires that were involved in this accident. These designs place supporting fillets above the tread wear indicators and noncontinuous tread grooves are produced when the tire is worn to the fillets and before the tire is worn to the tread wear indicators. As this investigation illustrated, this design practice defeats the function of the tread wear indicator in indicating when a tire has worn beyond the point of maximum safe use with respect to tread depth. The NHTSA, the Federal agency responsible for developing and enforcing FMVSS No. 119, should revise the Standard so that it effectively guards against design practices that render safety devices ineffective.

The State of Texas vehicle inspection criteria contain specific guidelines regarding tire cuts, tire tread depth, and tread wear indicators. The bus had been inspected 11 months before the accident and had to be inspected again within 2 weeks in order to remain in service. If the bus had been inspected on the day of the accident, Texas Department of Public Safety inspection officials maintain that the right rear and left rear outer tires of the bus would have been rejected during inspection because of the missing sections of rubber, based on the inspection guidelines. However, the guidelines call for rejection for cuts in excess of 1 inch and deep enough to expose the body cords. On the bus tires, the cuts were not deep enough to expose the body cords. According to inspection officials, the guidelines are interpreted to mean that either condition is cause for rejecting the tires; however, based on a literal interpretation of the guidelines, the tires would not have been rejected.

While there is some question as to whether the rear outer tires would have passed Texas inspection guidelines for cuts, the bus rear tires probably would have passed the guidelines for tread depth. The left rear outer tire of the bus had borderline but sufficient tread depth in the two center grooves to pass the tread depth requirement for that tire. And, since the Texas tread depth requirement applies to only one tire for each set of dual wheels, the limited tread depth of the left rear inside tire (bald in spots) would not have been grounds for rejecting that tire on the basis of tread depth. Since the right rear outer and inner tires were not worn to the tread wear indicators, these tires would have passed inspection for tread depth.

The right rear tires of the bus would have passed Texas inspection because the effect of the Texas requirements is largely negated by the fact that the provisions of FMVSS No. 119 regarding tread wear indicators do not adequately take into consideration the "fillets" used in tire designs. Based on the findings of this accident, the Texas Department of Public Safety should revise its inspection criteria to require tires to be rejected before they are worn to noncontinuous tread groove depths. The left rear tires of the bus would have passed Texas inspection because the tread depth requirement applies to only one tire per dual wheel and allows the passing tire to have less than 2/32 inch of tread depth in the shoulder grooves at the same time. Since the bus lost traction with the tires in this condition, the Department should also reevaluate these inspection criteria to determine whether they provide sufficient lateral traction capability.

18/ Ibid., p. 14.

Although the tires on the bus involved in the accident were not subject to Federal inspection regulations, many vehicles which do fall under these regulations use these same types of tires. Federal Motor Carrier Safety Regulations for inspecting commercial vehicles that operate interstate contain guidelines regarding minimum tread depth requirements (49 CFR Parts 200 to 399). However, these guidelines will not be effective for regrooveable tires or any other tires with a pattern of tread wear indicators and fillets that are similar to the bus rear tires. Section 393.75(b) and (c) of these regulations require 4/32 inch of tread depth for tires mounted on the steering axle and 2/32 inch of tread depth for tires mounted on any other axle. However, these sections further state that the tread depth measurements "shall not be made where the tie bars, humps or fillets are located." Therefore, since there was about 4/32 inch of "tread depth" in the remaining slots of the right rear outer bus tire, that bus tire probably would have passed Federal inspection guidelines for interstate vehicles.

The left rear outer tire and the right rear inner tire of the bus also probably would have passed Federal inspection guidelines. These tires were worn to less than 2/32 inch of tread depth, but only at one shoulder groove. As with the Texas inspection guidelines, Federal guidelines reject a tire only when the tread is worn to less than 2/32 inch in two adjacent major grooves. Therefore, these tires would have passed Federal inspection guidelines.

Under Federal inspection guidelines, the bus would have been placed "out of service," meaning it could not be operated until repaired, because the left rear inner tire was bald in the two adjacent center grooves. Unlike Texas guidelines, Federal guidelines do not limit tread depth requirements to only one tire for each set of dual wheels on buses. However, the Safety Board is not certain that replacing one tire on the rear of the bus would have been sufficient improvement.

It would seem inappropriate to conclude that the bus operators should have changed the rear tires or reduced traveling speed since the tires would have passed a majority of inspection guidelines for tread depth and there were no signs advising of the need for speed reduction at the accident scene. The need for a change in some tires or at least reduced travel speed in general should have been apparent to an experienced busdriver or mechanic. However, an experienced busdriver or mechanic should be aware of inspection requirements and could conclude that if the tires would pass inspection, they would be adequate for use.

The Bureau of Motor Carrier Safety has responsibility for developing and enforcing Federal Motor Carrier Safety Regulations for commercial vehicles operating interstate and the NHTSA has responsibility for developing and seeking the adoption of model State motor vehicle inspection guidelines. The Safety Board believes that these Federal agencies should examine all recommended and existing inspection guidelines for commercial vehicle tires, establish appropriate guidelines, and advise the States of these guidelines. Commercial vehicle owners and operators should also be alerted regarding these guidelines to aid in developing an understanding of the need for compliance with them.

<u>Standards for Detecting and Correcting Highway Locations With Potential Wet Weather Problems</u>

In 1977, the FHWA began a comprehensive review of the wet pavement accident problem, the leading environmental cause of accidents, and encountered much controversy over such items as pavement testing policies for detecting locations with potential wet weather problems and policies for the correction of these locations, once detected. In responding to a request by the FHWA for comments about the use of locked-wheel trailer results, many States commenting opposed the establishment of any firm policies based on these trailer test results, citing such factors as liability, costs, a desire for flexibility, lack of reliable test procedures, and a weak correlation or no correlation between locked-wheel trailer results and accidents or accident rates. 19/ The Texas DOT has no written policies or standards for detecting potential wet weather problem locations that are based on locked-wheel trailer results. According to a 1974 FHWA policy that is currently under review, standard locked-wheel trailer test results of 0.37 or less at locations with a 50-mph traffic speed indicate a pavement surface in need of "analysis for corrective treatment." 20/ Under the FHWA policy, the standard 40-mph left wheel path results obtained after the accident (0.32 and 0.26) would have caused the location to be studied for potential corrective treatment.

As to policies for corrective repair of the pavement surface that are based on locked-wheel trailer results, the FHWA has no specific policy and there is no national policy from other national associations or agencies. The Texas DOT has no written policy of this type. In 1971, the Safety Board first recommended that the FHWA establish a policy in this area, especially a minimum skid number or range of skid numbers whereby the pavement surface would be corrected on a high priority basis, simply because of its accident potential. 21/ The Safety Board continues to recommend this action because that type of policy, in combination with an appropriate tire policy, should at least eliminate tire-to-pavement frictional quality that is equivalent to attempting to slow or stop a vehicle equipped with adequate tread depth tires on ice.

For example, the wet pavement frictional quality at the accident site was already low at standard test speeds (0.32 and 0.26 at 40 mph) and lower at high speeds, (0.22 and 0.23 at 50 mph) when tested with a standard test tire that was equivalent to an average passenger car tire. Use of the bus front tire with more than adequate tread depth further reduced tire-to-pavement frictional quality to a level equivalent to attempting to slow or stop on ice (0.15 at 40 and 50 mph). Pavement frictional quality should not be permitted to drop to a level where any tire with more than adequate tread depth and reasonable frictional quality can produce such low tire-to-pavement frictional qualities. 22/ Additionally, tire frictional quality should be maintained at some minimum level so that minimum standards for pavement frictional quality will not be compromised to dangerous levels. In 1976, the Safety Board recommended that the NHTSA establish minimum frictional quality standards for commercial vehicle tires and NHTSA concurred with the recommendation. 23/ However, to date, no rulemaking action has been taken by NHTSA.

According to the tests and physical evidence in this accident, the establishment of an appropriate minimum pavement skid number policy to eliminate hazardous stopping conditions could also provide enough of an increase in lateral traction capability to even

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19/ Ibid., p. 16.
20/ "Highway Safety Program Manual for Highway Safety Program Standard No. 12," Federal Highway Administration, U.S. Department of Transportation, February 1974.
21/ "Highway Accident Report--Chartered Bus Crash on U.S. Route 22 (Interstate 78), Near New Smithville, Pennsylvania, July 15, 1970." (NTSB-HAR-71-8)
22/ The bus front tire had 14/32 inch of tread depth, which is more than adequate tread depth since 2/32 inch of continuous tread depth is considered adequate for inspection purposes. A 0.23 - 0.15 = 0.08 drop in frictional quality between a standard test tire result and a large truck or bus tire result at 50-mph test speeds is not unusual and is therefore considered reasonable tire frictional quality.
23/ "Highway Accident Report--Metropolitan Coach Corporation Charter Bus Accident, Bethesda, Maryland, October 11, 1975." (NTSB-HAR-76-6)

compensate for some truck and bus tires with marginal tread depth as an additional benefit to safety. A graphic example was the ability of the bus rear tires to follow the front tire path as the busdriver steered sharply on the left shoulder to avoid going off the road. The 75-percent increase in frictional quality of the shoulder pavement (0.40 at 50 mph), as compared with the traffic lanes (0.23 at 50 mph), permitted the busdriver to perform an evasive turning maneuver that was 4 times sharper than the curve he was maneuvering through at a slightly higher speed when lateral traction was first lost. Therefore, the selection of an appropriate minimum skid number policy at some point between the shoulder and traffic lane wheel path test values would seem to have some potential in preventing loss of lateral traction accidents similar to this bus accident.

In keeping with a needed minimum skid number policy that would eliminate hazardous stopping conditions, the Safety Board believes that the pavement at the accident site should be updated on a high priority basis. The deteriorated condition of the pavement and increasing traffic demands provide further support for updating on a high priority basis. In the absence of a national minimum skid number policy, the Safety Board examined other State policies to determine if they could at least serve to alleviate the problems this accident illustrated.

Penn DOT has a pavement correction policy that would require corrective work to be completed "as soon as fiscally possible" for pavements with trailer test results below 0.30 and no significant accident history, the circumstances at this location. 24/ Only locations that have both low frictional quality and a high accident history would take a higher priority. (See figure 15.) Such a policy is consistent with the Safety Board's recommended minimum skid number policy, and the Penn DOT policy should be considered for further evaluation and national application by the FHWA.

CONCLUSIONS

Findings

1. Pavement and tire tests indicated that the worn rear tires of the bus could have lost traction on the wet pavement with low frictional quality if the busdriver was attempting to steer around the slight 2° curve at or near the speed limit.

2. Tire scrub marks that the bus left on the opposite shoulder indicated that the bus was traveling at or near the speed limit.

3. Poor pavement drainage qualities -- rutting, limited crown, and limited superelevation -- allowed water to remain on the roadway during the light intensity rain that was falling at the time of the accident.

4. A lack of continuous tread groove depths on the worn rear tires of the bus and, perhaps, shallow pavement texture could have hindered water on the roadway from being channeled through or under the rear tire paths; this, in turn, severely limited the rear tires' ability to resist sliding sideways on the already low frictional quality pavement at or near the speed limit.

5. Physical evidence and test data indicated that any small reduction in traveling speed or improvement in tire or pavement condition may have prevented this accident.

24/ Ibid., p. 23.

SKID RESISTANCE TEST RESULTS

Federal Instructional Memorandum 21-2-73, with reference to NCHRP Report 37, "establishes a rationale for development of a set of minimum recommended skid numbers (SN) for use in the determination of the need for correction of existing pavement surfaces."

The Pennsylvania policy for corrective work in compliance with IM 21-2-73 will be as follows for various skid numbers:

Category	Skid Number (SN40)	Existing Wet Pavement Accident Problem	Action by Engineering District
A	30 or less	At least 35% of all accidents related to wet pavement	Immediate corrective action must be placed on an approved program within one year of date of notification of test results. Corrective action must be completed within the next year following programming, but in no case shall be greater than two years after the date of notification of test results.
	Also 31 to 34	At least 45% of all accidents related to wet pavement	
B	31 to 34	At least 35% of all accidents related to wet pavement	Corrective work to be completed as soon as fiscally possible.*
C	30 or less	No	Same as "B" above.*
D	31 to 34	No	Maintain accident surveillance and take corrective action as necessary.
E	35 to 40	Yes	Same as "D" above.
F	35 to 40	No	Maintain surveillance for possible future retesting.
G	41 or above	---	No action required.

*- Locations in Category B shall receive priority over those in Category C when taking corrective action due to the presence of an existing wet pavement accident problem.

Figure 15.-- Pennsylvania Department of Transportation Pavement Correction Policy.

6. An examination of current State of Texas and Federal programs, policies, and standards found that neither Texas nor Federal elements of this type were able to assist in preventing this type of accident.

7. The Safety Board was able to identify standards and policies used by the State of Pennsylvania regarding pavement evaluation that could theoretically assist in preventing this type of accident, but these standards need further evaluation.

8. Currently, there are no national programs to alert the public to such factors as the need for reduced travel speeds or for tires to be in appropriate condition for wet weather travel, and none are scheduled in the forseeable future at the Federal level because of other NHTSA priority projects.

9. Since no pavement tests were made at the accident site during the 1977 Texas DOT inventory of this road and there was no significant accident history near the accident site, there was no reason for the Texas DOT to have been alerted to a potential wet weather problem before the accident occurred.

10. The national guideline that is used by the Texas DOT for the posting of "slippery when wet" signs is too general for consistent application, as evidenced by the fact that no signs were placed warning of the low frictional quality pavement after the bus accident occurred, even though objective standard tests revealed low quality pavement.

11. Pennsylvania has a policy that would require "slippery when wet" signs to be posted as a result of the pavement tests made after the accident; its guidelines are theoretically practical and effective and should be further evaluated as a candidate for national application.

12. Federal Motor Vehicle Safety Standard (FMVSS) No. 119 for commercial vehicle tires is not specific enough to reject tire designs that produce noncontinuous tire tread grooves before the tires are worn to the tread wear indicators, rendering the tread wear indicators useless as an indicator of when a tire has exceeded maximum safe use with respect to tread wear.

13. While there is some question as to whether the rear outer tires would have passed Texas inspection guidelines for cuts, because of limits in FMVSS No. 119 and Texas regulations, the bus rear tires probably would have passed Texas guidelines for tread depth on the day of the accident, even though they were worn below continuous tire tread groove depths and less than 2/32 inch of any tread pattern remained in areas on three of the four rear tires.

14. Although not applicable to the bus involved in this accident, Federal Motor Carrier Safety Regulations for inspecting vehicles that operate interstate and use similar tires do not contain appropriate guidelines for rejecting tires that are worn below continuous tire tread groove depths.

15. It would seem inappropriate to conclude that the bus operators should have changed the rear tires or reduced traveling speed since the tires would have passed a majority of inspection guidelines for tread depth and there were no signs advising of the need for a speed reduction at the accident scene.

16. Many States oppose the establishment of any firm policies to detect or correct potential wet weather problem locations based on locked-wheel skid trailer test results, and the Texas DOT has no written policies in this area.

17. According to a 1974 FHWA detection policy that is currently under review, locked-wheel trailer test results made after the bus accident would have identified the accident site as a potential wet weather problem location and would have initiated a study of the accident site for potential corrective treatment.

18. There continues to be no specific national policy that would establish a minimum skid number or range of skid numbers, whereby at least pavement surfaces that produce conditions equivalent to a vehicle's attempting to stop or slow on ice with good tires would be corrected on a high priority basis, simply because of their accident potential.

19. Although the National Highway Traffic Safety Administration concurred with a 1976 Safety Board recommendation to establish minimum frictional quality standards for commercial vehicle tires, no rulemaking activity has been initiated to date.

20. In keeping with its recommended minimum skid number policy, the Safety Board believes that the pavement surface at the accident site should be updated on a high priority basis because of its limited ability to provide adequate tire-to-pavement braking traction on wet pavement; increasing traffic demand and the deteriorated condition of the pavement provide further support for updating on a high priority basis.

21. According to a Pennsylvania policy for correcting the pavement surface that is based on locked-wheel trailer results, corrective repair of the pavement would be completed as soon as fiscally possible; only locations that have both low frictional quality and a high accident history would take a higher priority.

22. Since the Pennsylvania policy would give high priority to correcting pavements with low frictional quality, it should be considered for further evaluation and national application.

Probable Cause

The National Transportation Safety Board determined that the probable cause of the accident was the low wet cornering capability of the marginal yet "legal" rear bus tires and the low frictional quality of the wet pavement, which combined to produce loss of rear tire traction and vehicle control as the bus was being operated at or near the posted 55 mph speed limit.

RECOMMENDATIONS

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

--the National Highway Traffic Safety Administration:

> Accelerate its activity to establish rulemaking action for minimum frictional quality standards for commercial vehicle tires. (Class II, Priority Action) (H-81-33)

Advise State Motor Vehicle Inspection agencies of the problems associated with operating vehicles equipped with tires worn to noncontinuous tread groove depths. (Class II, Priority Action) (H-81-34)

Issue model inspection criteria to prohibit the use of tires worn to noncontinuous tread groove depths. (Class II, Priority Action) (H-81-35)

Reevaluate its Federal Motor Vehicle Safety Standard No. 119 to eliminate tire designs that produce noncontinuous tread grooves before the tire is worn to the tread wear indicators. (Class II, Priority Action) (H-81-36)

--the Federal Highway Administration:

Revise Sections 393.75(b) and (c) of the Federal Motor Carrier Safety Regulations to prohibit the use of tires worn to noncontinuous tread groove depths on any axle of a commercial interstate vehicle. (Class II, Priority Action) (H-81-37)

Issue an On-Guard Bulletin to advise owners, operators, maintenance personnel, and State commercial vehicle inspectors of the problems associated with operating vehicles equipped with tires worn to noncontinuous tread groove depths. (Class II, Priority Action) (H-81-38)

Evaluate Pennsylvania Department of Transportation policies for the placement of "slippery when wet" signs and the detection and correction of potential wet pavement problem locations for national policy purposes. (Class II, Priority Action) (H-81-39)

--the Texas Department of Public Safety:

Revise its tire tread depth inspection criteria to prohibit the use of tires worn to noncontinuous tread groove depths. (Class II, Priority Action) (H-81-40)

Reevaluate its tire tread depth inspection criteria that limits the tread depth criteria to only one tire in each set of dual wheels while permitting that tire to have less than 2/32 inch of tread depth in the shoulder grooves at the same time. (Class II, Priority Action) (H-81-41)

—the Texas Department of Highways and Public Transportation:

Post "slippery when wet" signs with flashing lights at the accident location until the pavement surface is repaired and its skid resistance qualities are improved. (Class II, Priority Action) (H-81-42)

Repair and improve the skid resistance qualities of the pavement surface at the accident location after those locations with high accident histories and low frictional quality are improved. (Class II, Priority Action) (H-81-43)

BY THE NATIONAL TRANSPORTATION SAFETY BOARD:

/s/ ELWOOD T. DRIVER
Vice Chairman

/s/ FRANCIS H. McADAMS
Member

/s/ PATRICIA A. GOLDMAN
Member

/s/ G. H. PATRICK BURSLEY
Member

JAMES B. KING, Chairman, did not participate.

July 22, 1981

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