NATIONAL TRANSPORTATION SAFETY BOARD

HIGHWAY ACCIDENT REPORT

MULTIPLE-VEHICLE COLLISION FOLLOWED BY PROPYLENE CARGO-TANK EXPLOSION, NEW JERSEY TURNPIKE, EXIT 8

SEPTEMBER 21, 1972

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15. Supplementary Notes

This report contains Highway Safety Recommendations H-73-37 through H-73-40.

16. Abstract

This report describes and analyzes a series of collisions which occurred in the northbound and southbound lanes of the New Jersey Turnpike on September 21, 1972. A southbound Greyhound bus was sideswiped by an overtaking tractor-semitrailer which was carrying propylene. The tractor-semitrailer then overrode the median guardrail, jackknifed, and overturned in the northbound lanes. Two persons in an automobile which collided with the overturned cargo-tank semitrailer were killed in the collision or in the fire which followed. About 25 minutes after the collisions, the cargo tank exploded; sections of the tank rocketed 1,307 feet northeast and 500 feet southwest of the point of overturn. Twenty-eight persons were injured in the explosion.

The National Transportation Safety Board determines that the probable cause of the initial collision was the evasive steering and skidding of the bus into the path of the overtaking tractor-semitrailer. Override of the median guardrail by and subsequent overturn of the tractor and the semitrailer were caused by the inability of the median guardrail to resist the forces generated by the tractor-semitrailer. In the report, the Board also determines the cause of the initial and secondary fires at the cargo-tank semitrailer as well as the cause of the explosion.

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FOREWORD

The accident described in this report has been designated a major accident by the National Transportation Safety Board under the criteria established in the Safety Board's regulations.

The report is based on facts obtained from an investigation conducted by the Safety Board and on information supplied by the New Jersey State Police, the New Jersey Turnpike Authority, and the Bureau of Motor Carrier Safety of the Federal Highway Administration. The Demonstration Projects Division, Region 15, Federal Highway Administration, performed skid-resistance tests at the accident site at the request of the Safety Board.

The conclusions, the determination of probable cause, and the recommendations herein are those of the Safety Board.

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HIGHWAY ACCIDENT REPORT

Adopted: October 17, 1973

Multiple-Vehicle Collision Followed by Propylene Cargo-Tank Explosion New Jersey Turnpike, Exit 8 September 21, 1972

I. SYNOPSIS

At 8:25 p.m., on September 21, 1972, a tractor-semitrailer (tank) carrying propylene liquid petroleum gas sideswiped a Greyhound bus (carrying no passengers) in the southbound lanes of the New Jersey Turnpike about one mile north of Exit 8. After impact, the bus, while rotating clockwise and sliding across the highway, was struck by a southbound automobile. The tractor-semitrailer scraped, then straddled the turnpike's median guardrail, jackknifed, spun into the northbound lanes, and overturned. Before overturning, the tractor-semitrailer was struck by a northbound automobile.

Fire, which had erupted at the tractor as it scraped the median guardrail, spread to propylene which was leaking from the cargo tank's damaged plumbing. After the fire had burned for about 25 minutes, the cargo tank exploded in a ball of flame; segments of the tank rocketed more than 1,300 feet northeast and 500 feet southwest of the tractor-semitrailer.

As a result of the accident, the driver of the tractor-semitrailer suffered severe burns and multiple fractures; the busdriver received minor injuries. The two occupants of the northbound automobile which struck the semitrailer were killed. Twenty-eight persons, including seven police officers, were injured -- none seriously -- by the explosion of the cargo tank.

The National Transportation Safety Board determines that the probable cause of the initial collision was the evasive steering and skidding of the bus into the path of the overtaking tractor-semitrailer. Override of the median guardrail by and subsequent overturn of the tractor and the semitrailer were caused by the inability of the median guardrail to resist the forces generated by the tractor-semitrailer.

The initial fire was caused by friction sparks when the tractor-semitrailer scraped the median guardrail, which ignited fuel escaping from the tractor's damaged left-side fuel tank. Secondary fire was propagated by propylene which escaped from a rupture(s) in the cargo

tank's external pipes. Contributing to the escape of propylene were (1) the exposed position of the cargo tank's external pipes, (2) the inadequacy of the "plumbing guard" to protect the pipes from impact damage, and (3) the failure of the flow-cutoff system to function as intended by applicable Federal regulations.

Explosion of the cargo tank was caused by extended exposure of a local segment of the tank shell to direct flame and by resultant overheating of that portion of the tank shell, which weakened it below design strength and permitted a break in the tank body. Contributing to the weakening of tank metal was the absence of tank-overheating countermeasures by emergency crews whose arrival was delayed by traffic congestion on a limited-access highway. The number of injuries was increased by lack of understanding of the range of the hazard.

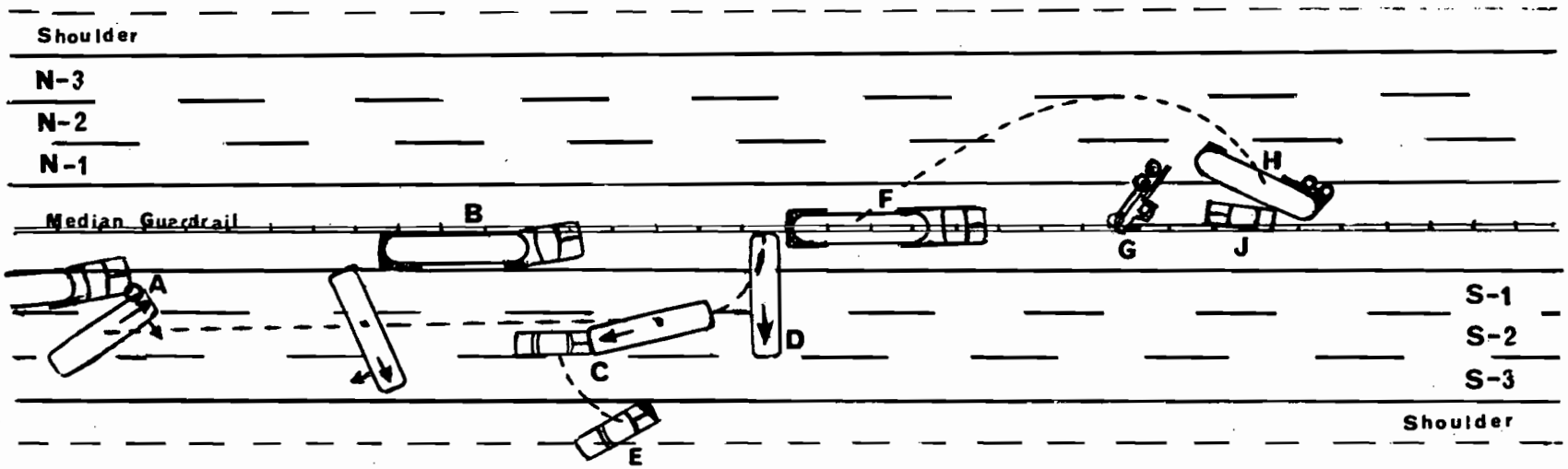
II. FACTS

The Accident

At 8:25 p.m., on September 21, 1972, a Greyhound bus with no passengers was en route from New York to Philadelphia on the New Jersey Turnpike at about 50 m.p.h. in the outermost (right-hand) southbound lane 1/ north of the Hightstown exit (Exit 8) in a light drizzle. The busdriver said that because a car ahead of him suddenly slowed down, he swerved left into lane S-2 to avoid it. A southbound tractor-semitrailer (cargo tank), operated by Matlack, Inc., of Lansdowne, Pa., and carrying propylene, was overtaking and passing the bus when the bus swerved directly into its path, and the truckdriver was unable to avoid a collision. The right front of the tractor struck the left front of the bus just forward of the left front wheel. The tractor scraped the median guardrail, and fire erupted from the damaged left-side fuel tank. The tractor-semitrailer then overrode and flattened about 200 feet of median guardrail. At that time, the truckdriver was apparently thrown from his seat. The tractor-semitrailer jackknifed into the northbound lanes, rotated clockwise about 200°, and was struck by a northbound 1972 Dodge hardtop. The cargo-tank semitrailer overturned onto its left side and came to rest with its rear resting on the raised median and with its front in lane N-1. 2/ (See Figure 1.) The Dodge was jammed between the tank and the median guardrail; its two occupants were killed.

1/ The innermost southbound lane, i.e., the lane nearest the median, is designated in this report as lane S-1, the center southbound lane is lane S-2, and the outermost southbound lane as lane S-3. The corresponding northbound lanes are designated as lanes N-1, N-2, and N-3, respectively.

2/ No measurements or photographs were taken prior to the explosion; positions of vehicles are as described by police and other witnesses.



LEGEND

A Probable point of impact
B Truck scraped guardrail
C Veh. 3 struck bus
D Final position of bus
E " " " veh. 3
F Truck overrode median rail
G Tractor overturned
H Cargo tank "
J Veh. 4

N

0 25 50 75 100

FEET

NEW JERSEY TURNPIKE
NORTH OF EXIT 8
September 21, 1972

Figure 1. Accident site.

The fifth-wheel assembly separated in the overturn. The tractor came to rest on its left side with its rear 6 feet from the cargo-tank semitrailer and with its front across the median guardrail. The truck-driver was rescued via the right cab door; he was not wearing the available seatbelt.

Fire erupted at damaged plumbing at the rear underside of the cargo-tank semitrailer and was concentrated along the rear underbelly of the tank. The fire engulfed the axles, tires, and suspension. Fire which later broke out at the safety relief valves at the top of the tank engulfed the Dodge hardtop and the median guardrails. At times, fire spread across both the northbound and southbound traffic lanes.

After its initial impact with the truck, the bus continued to skid southward for 156 feet. (No skidmarks were found on the wet pavement.) When the bus had rotated about 180°, it was struck head-on by a southbound Chevrolet sedan. The bus came to rest upright across lanes S-1 and S-2, with its rear against the damaged median guardrails. The front wheels were turned about 30° to the right. The busdriver, who had been thrown from his seat, suffered a minor concussion with temporary unconsciousness. The bus, built in 1962, was not equipped with driver seatbelts.

The Chevrolet came to rest about 32 feet northwest of the front of the bus and straddled the edge stripe between the shoulder and lane S-3. (See Figure 1.) Both occupants suffered moderate injuries.

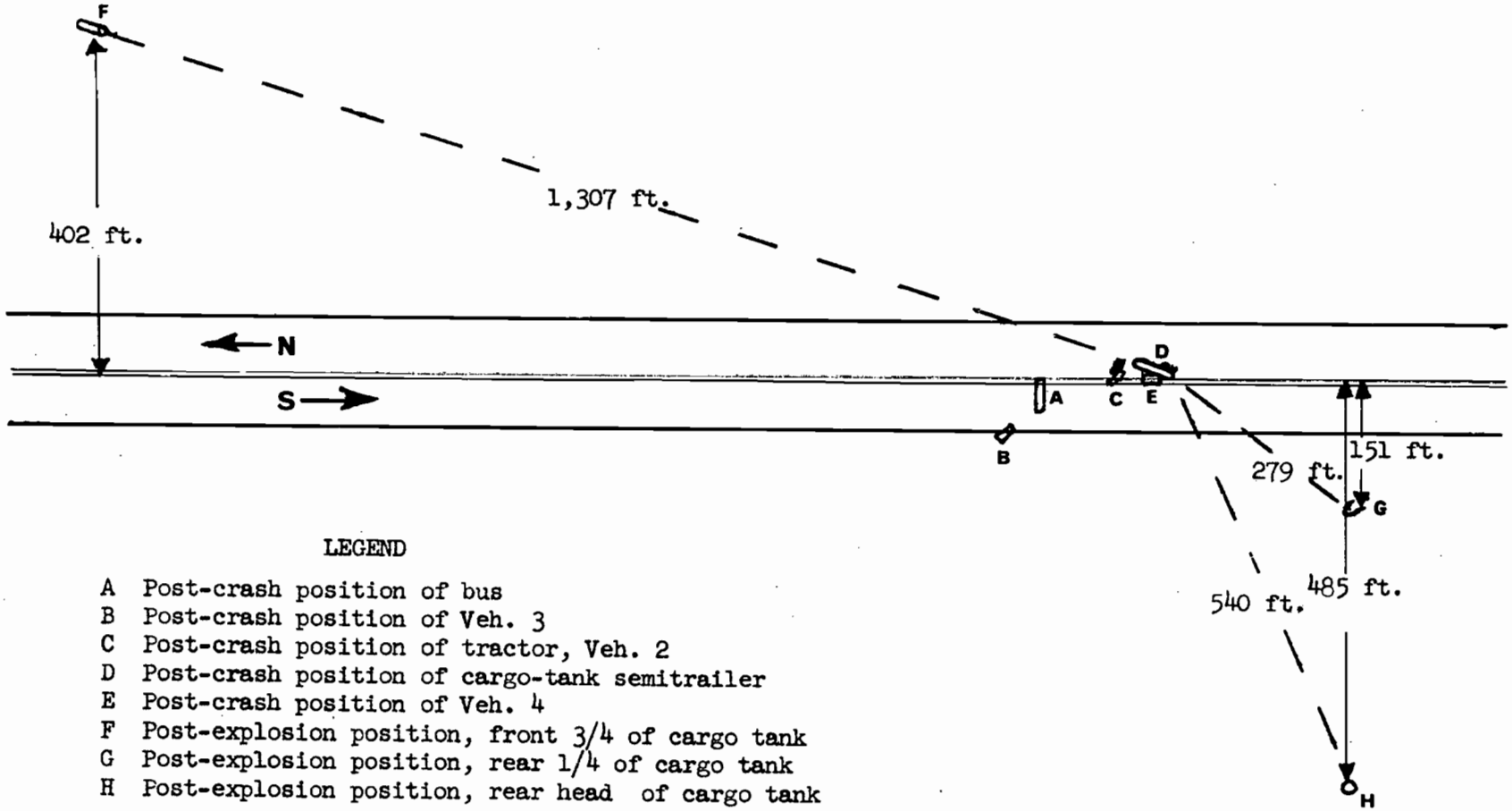
Some cars were driven around the overturned cargo-tank semitrailer, but, as fire increased, traffic stopped in both directions. The three northbound lanes, plus the northbound shoulder and the median, were jammed with cars. Many drivers left their cars and went east or west off the highway.

About 10 or 15 minutes after the crash, two explosions occurred at the cargo tank. Witnesses said that these explosions helped to keep onlookers from crowding closer to the burning vehicle.

About 20 or 25 minutes after the crash, the fire at the cargo tank momentarily subsided and then resumed with a loud hiss and roar. The tank exploded in a huge ball of fire which inflicted burns and other injuries to 28 persons, including 7 police officers and at least one bystander who was 600 feet south of the explosion. However, no one was killed or seriously injured in the explosion. (See Figure 2.)

Postcrash Activities

A southbound State trooper arrived at the scene of the accident at 8:29 p.m. He notified his dispatcher of the fire. The dispatcher sent



LEGEND

A Post-crash position of bus
B Post-crash position of Veh. 3
C Post-crash position of tractor, Veh. 2
D Post-crash position of cargo-tank semitrailer
E Post-crash position of Veh. 4
F Post-explosion position, front 3/4 of cargo tank
G Post-explosion position, rear 1/4 of cargo tank
H Post-explosion position, rear head of cargo tank

SCALE: 1 In. = 200 Ft.

0 200 400

NEW JERSEY TURNPIKE
NORTH OF EXIT 8
September 21, 1972

Figure 2. Distribution of cargo-tank segments after explosion.

additional troopers and notified the Hightstown Volunteer Fire Company. Two fire trucks and one rescue vehicle were dispatched from Hightstown.

A patrolman of the East Windsor Township police also saw the fire and went to the accident scene via a local overpass. Additional local police were dispatched.

The police searched for possible victims, and rendered first aid to the truckdriver, busdriver, and the occupants of the southbound Chevrolet. They then tried to move bystanders north and south away from the burning cargo tank and in back of the right-of-way property lines. The police had no standard distance criteria regarding a danger zone. They had assumed that the cargo tank held propane, and they knew generally of the hazards associated with extended fire near liquid petroleum gas (LPG).

The three Hightstown fire-department vehicles became immobilized in stalled northbound traffic several hundred yards south of the accident scene. Two additional fire vehicles, a 5,000-gallon water-tank unit and a pumper were sent. They approached the scene via the unoccupied southbound lanes north of Exit 8. The pumper unit stopped opposite the burning cargo tank at about the time the fire momentarily subsided. State troopers warned the driver to move to a safer location, north of the bus. As personnel of the pumper unit started to seek survivors in the northbound Dodge, the hiss and roar which preceded the explosion sent them rushing for cover. Their protective clothing was scorched in the blast.

The water-tank unit had been stopped about 100 to 150 yards south of the fire for a minute or two when the explosion occurred. The fire chief, who was in the water-tank unit, said that a flaming mass came directly over his vehicle. The blast scorched the paint and warped some plastic light components and other equipment.

None of the fire units had put out hoses or taken any other direct action to fight the fire or to cool the cargo tank. After the explosion, fire crews controlled the remaining fires, and injured persons were taken to nearby hospitals for examination or treatment.

At the time of the explosion, the approximately 200 onlookers were dispersed along the east and west property lines at distances ranging from 150 to 1,000 feet. One group of spectators had gathered on the median just north of the bus. The total distribution of injured persons could not be firmly established, but the known positions of eight bystanders suggest that there were no concentrated areas in which injuries occurred. (See Figure 3.)

Accident Site

Roadway. The southbound roadway at the accident site consists of three 12-foot-wide traffic lanes, straight and virtually level, of

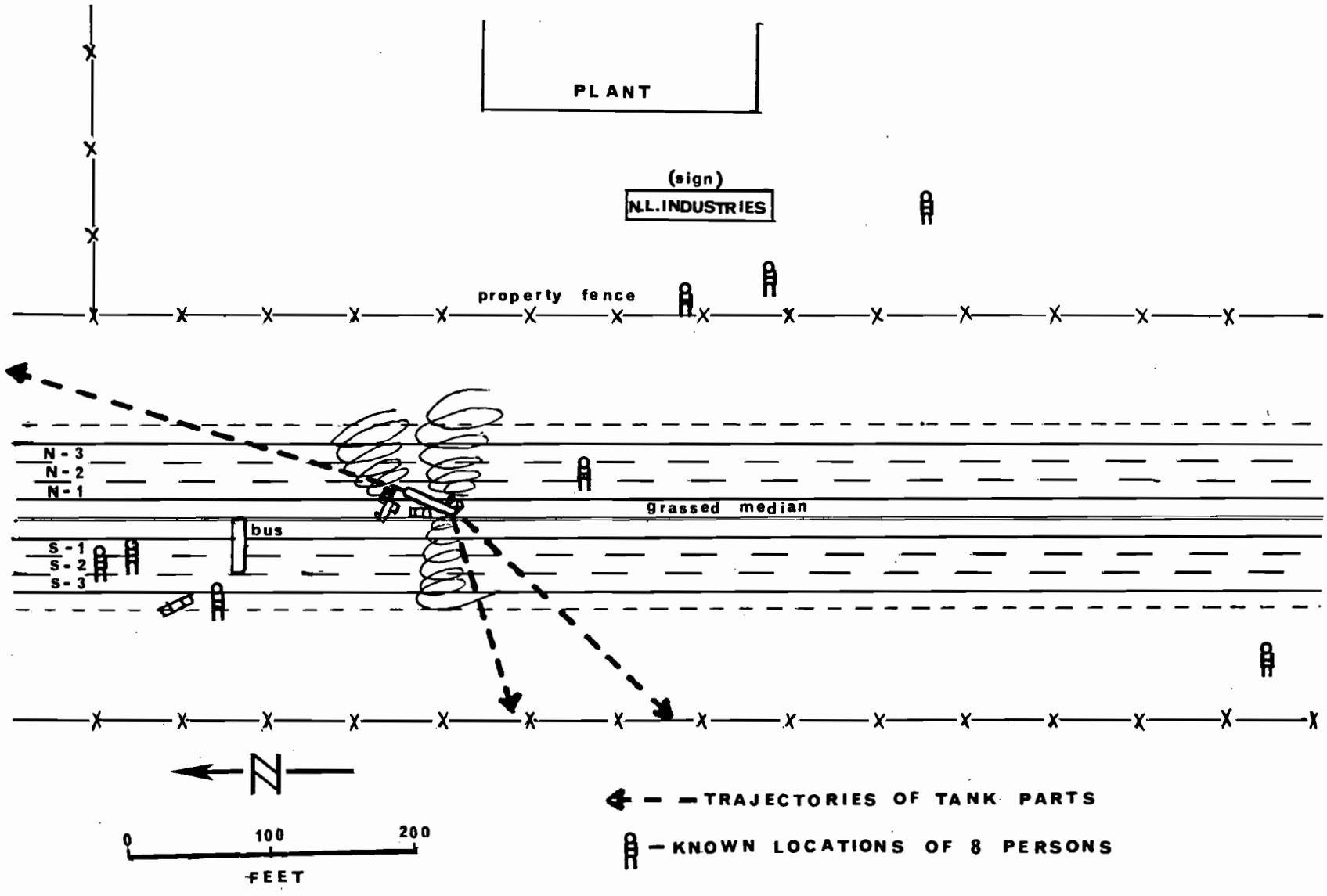


Figure 3. Distribution of persons injured in cargo-tank explosion.

fine-textured asphaltic concrete. It is oriented essentially north and south, bounded on the west by a coarse asphaltic concrete shoulder, 12 feet wide, beyond which is a graded sod embankment. On the east is a 12-foot-wide median, 4 feet of which is asphaltic concrete and the remainder of coarse sod; the center of the median rises about 1 foot above the adjacent roadway. The northbound lanes are of essentially the same configuration.

A double-offset W-beam median guardrail centered on the median is supported by steel I-beam posts on 12-foot-6-inch centers; its top is about 26 inches above the median. The travel lanes in both directions are separated by intermittent white stripes 25 feet long with 25-foot interruptions and are marked on the outer and inner edges by solid white lines.

The roadway was built in 1951; the third lane was added in 1958, and the median barrier was added in 1960. At the time of the accident, the pavement surface was smooth but not polished. Tests conducted by the Federal Highway Administration (FHWA) at the request of the National Transportation Safety Board indicated that the wet "skid number" of lanes S-2 and S-3 was about 55, i.e., a skid-resistance factor of .55, which is well above the minimum recommended skid number. For further details concerning the FHWA tests, see Appendix A.

Traffic controls. The speed limit of 60 m.p.h. was posted in large red neon numerals every few miles. Speed-limit signs on the turnpike can be varied by means of radio controls, but no reduced limit was in effect at the time of this accident. Radio-controlled variable-message "Warning" and "Hazard" signs were not displayed.

North of Exit 4, signs throughout the turnpike noted that lanes S-1 and N-1 were reserved for passenger-car use only. An illuminated 12- by 16-foot sign, "Exit 8 1 mile," with white lettering on a green background, was on the southbound embankment at the accident site. This sign was separated from traffic by a W-beam guardrail.

Environment. The general terrain is undulating, with small farms and isolated industrial plants adjacent to the right-of-way. At the time of the accident, there was no highway lighting, and ambient lighting was relatively low. The temperature was in the low 70's, and a light drizzle had been falling at the accident site and to the north for several hours. Traffic was rated as "light," in a range of 500 to 750 vehicles per lane per hour.

East and west of the highway, property lines are demarked by low wire fences 150 feet from the center of the median. Just east of the highway at the accident site is a paint manufacturing plant, surrounded by patches of woods.

Highway damage. All six lanes of the roadway at the accident site were substantially damaged by fire and required repaving. About 237 feet of median guardrail, including 16 guardrail posts, had to be replaced. The guardrail posts had been bent almost flat in a southerly direction; many rail sections were severely bent, and a number were blue from exposure to excessive heat. (See Figure 4.)

Vehicle Occupants

Bus. The 31-year-old busdriver held a valid license and had no known traffic violations or accidents. He had been trained specifically for busdriving by Greyhound and was duly certificated. His driving logs were current and showed 33-1/2 hours on duty in the preceding 8 days.

The busdriver had been sent from Philadelphia to New York on the day of the accident to pick up and return an empty bus. He departed New York at 7:15 p.m., and entered the turnpike at 7:32. He traveled approximately 45 miles to the accident scene in about 53 minutes, which reflects an average speed of about 52 m.p.h.

According to the busdriver, before the accident a "truck tanker" passed the bus, and the busdriver then passed the "truck tanker" and two cars which had been speeding up and slowing down. As the bus pulled back into lane S-3, the brakelights of the car directly in front of the bus suddenly came on, and the accident sequence began.

As a result of the accident, the busdriver was charged by the New Jersey State Police with two counts of "death by auto" and with "careless driving." The "death by auto" charges were dismissed by a grand jury on December 12, 1972. The "careless driving" charge is pending.

Tractor-semitrailer. The 24-year-old truckdriver held a valid New Jersey driver's license. He had driven straight trucks for 8 years and tractor-semitrailers for 3 years and had begun his current employment on August 2, 1972. The truckdriver was paid a flat amount for each load of propylene which he hauled from Exit 8 to Woodbury (near Exit 3), and he generally made two or three trips each day. He had been on duty a minimum of 60-1/4 hours in the preceding 8 days. Some irregularity was found in his logs.

The truckdriver had taken over the propylene unit just outside Gate 8 at 8 p.m. He had inadvertently turned north on the turnpike and therefore made an exit and reentry at Gate 8-A, about 5-1/2 miles north of Gate 8. He was southbound when the crash occurred.

As a result of the accident, the truckdriver was hospitalized with serious injuries, including wide loss of tissue from burns to the left arm, complete fracture of the left wrist and elbow, compound fracture of the pelvis, rib fractures, and a ruptured spleen. He was also

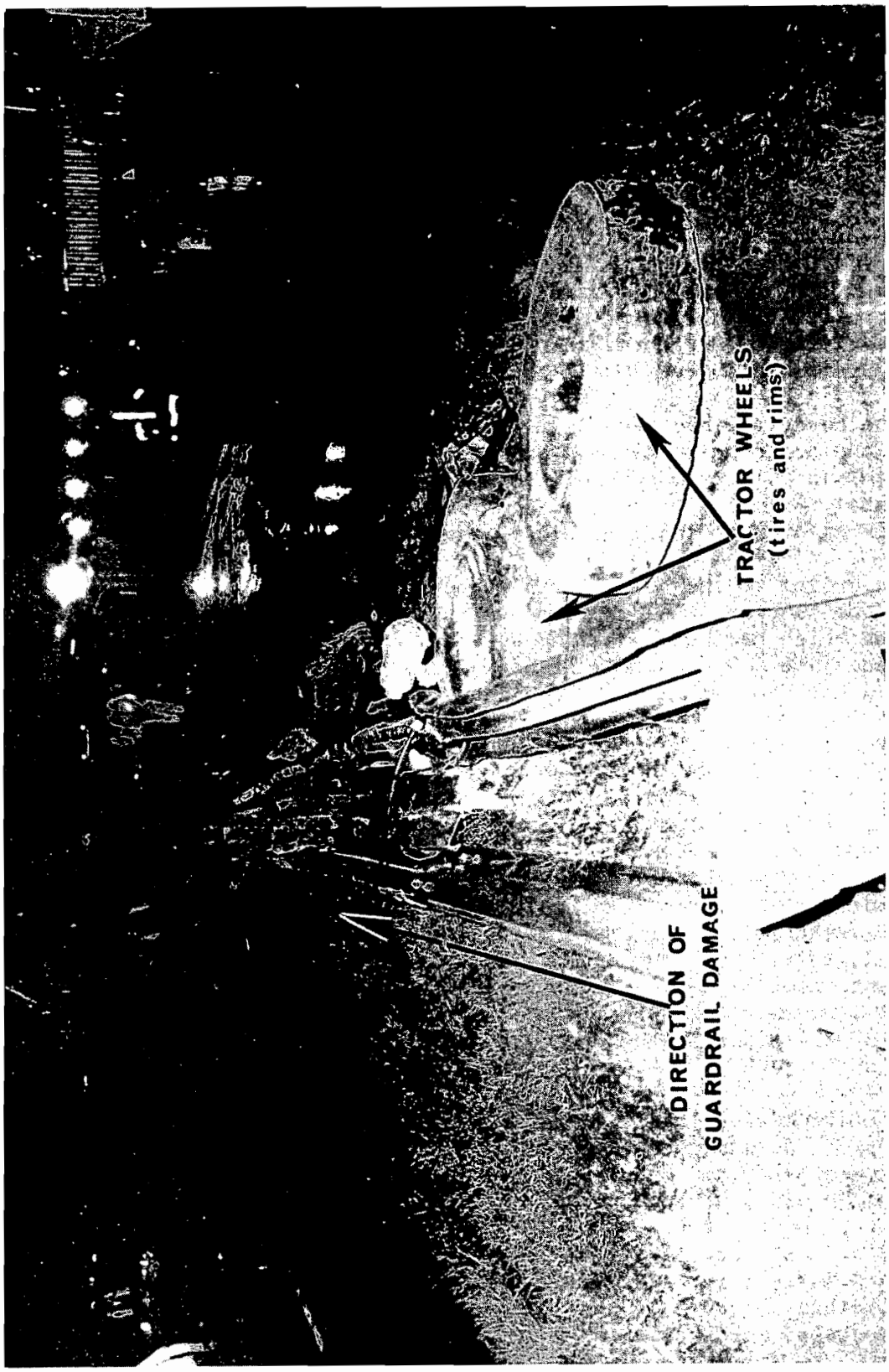


Figure 4. Damaged median guardrail and two front tires and rims of the tractor.

suffering from exposure to propylene and had numerous abrasions and burns on the chest, face, and upper arms.

Chevrolet sedan. The 22-year-old driver of the southbound 1969 Chevrolet sedan was en route from Massachusetts to Florida with a friend. He held a valid Massachusetts driving license, which showed no restrictions. He was treated for contusions and abrasions of the head and was released. The passenger was similarly treated and released.

The driver indicated that while southbound on the turnpike he saw the bus about 50 yards ahead of him. The bus veered to the left, and he then saw flames. He tried to pull off to the right, but his car struck the front of the bus. The passenger saw the bus "drift" to the left, where it seemed to be blocking a truck to its left. The bus then rotated in front of the Chevrolet which hit the bus.

Dodge "Charger." The driver of the northbound 1972 Dodge "Charger" was en route from Philadelphia to New York. She had a valid Pennsylvania driver's license, which showed no restrictions. The occupants of the Dodge, both fatally injured, were known to have left Philadelphia at a time that would have put them on the turnpike at about the time and place of the accident. Causes of death were listed as "extensive charring." The body of the driver showed no blood alcohol, but the passenger had a BA level of .14 percent.

The Bus

The bus, a 1962 General Motors coach model PD-4106, was a 38-passenger interstate bus with single wheels on the front axle and dual wheels on the rear axle. 3/

Accident damage consisted of a dented front bumper and dented body panels, with a residue of white paint in these areas. The lower left-front body in front of the left-front wheel was torn away, with damage extending to air lines, hoses, and wiring. A shallow smudged indentation was on the side panel just behind the driver's window about 6 feet aboveground. The lower left rear of the bus behind the rear wheels was crushed inward. The windshield was loose in its mount but was not cracked; the left A-pillar was deformed about 1 inch away from the glass. At the extreme left-rear top of the bus was a 6-inch indentation, with about 2 inches of localized rightward distortion of the upper body. The driver's window glass was missing, as was the forward pane of the first left-side passenger window. All other left-side windows, except one, had random spiderweb cracks. The left-rear quarter window was missing,

3/ Appendix B presents pertinent details about the four vehicles involved in the collisions.

but the rear window and right-rear quarter window were undamaged. There was no damage to the right side of the bus. (See Figure 5.)

A postcrash examination by Bureau of Motor Carrier Safety and by Greyhound maintenance personnel revealed no safety-related defects which could have contributed to the crash. When the windshield-wiper line was repaired and air was restored, the wipers were operative; the switch was found in the "off" position.

The smudged indentation on the left body was said to have resulted from flying parts of the exploding cargo-tank, as were the indentation and rightward bending at the top rear. Cracking of side windows was believed to have been caused by the concussion of the explosion.

The Tractor-Semitrailer

The tractor-semitrailer consisted of a 1973 Diamond-Reo tractor, with three axles and conventional cab, which was coupled to a 10,000-gallon-capacity cargo-tank semitrailer, type MC-331. The tank contained 7,209 gallons of propylene, which had a vapor pressure of 150 p.s.i. at 65° F and weighed 4.348 pounds per gallon. The gross combined weight of the vehicle was estimated to have been 70,585 pounds. The cargo-tank cylinder wall was 0.468-inch quenched and tempered steel, with head thickness of 0.25-inch. For further details, see Appendix B.

Damage. When both the tractor and cargo-tank semitrailer were inspected on September 20, 1972, no defects were found. A minor leak at one of the flow-regulator valves (not identified) had been corrected on September 18. The mechanical condition of the tractor and cargo tank did not appear to have been a factor in this accident.

Pieces of blue fiberglass from the right and left front fenders of the tractor were found along the median guardrail. Both of the front rims and tires of the tractor had broken away from the spoke-type wheels and were recovered on the west side of the median north of the point of overturn. Neither showed fire damage. Their location after the crash and the severe slashes through the tread areas suggested that separation resulted from impact with the median barrier. The remaining stubs of the lug bolts on the tractor indicated that the rims had been sheared off or had broken off with sufficient force to fracture the bolts.

Witnesses who saw the overturned tractor before the explosion said that the tractor was on its left side. The right cab door was open and undamaged. The front end of the tractor was damaged, but witnesses could recall no further details. There was fire around the chassis of the tractor, which at the time of the explosion was estimated to be about 75 to 100 feet south of the bus and about 6 feet from the north end of the cargo tank.

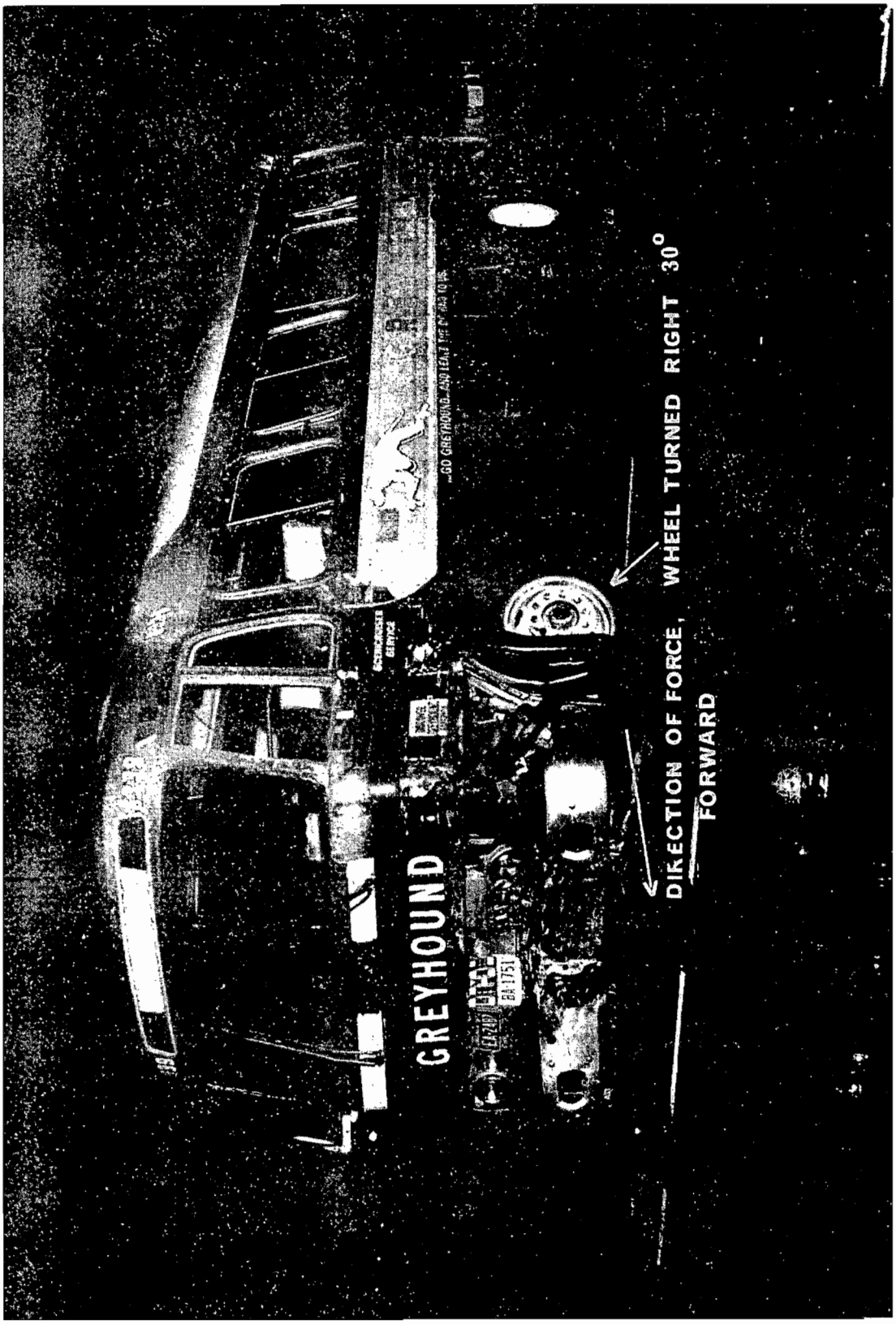


Figure 5. Left side of Greyhound bus.

After the explosion, the tractor, demolished and lying on its top, was found 74 feet from the bus. Witnesses could not say whether the tractor had rotated three-quarters of a turn away from the explosion or one-quarter turn into it. The upper cab was crushed toward the right. Drippings of melted aluminum or pot metal, along with scorched paint and fire damage on the right-side fuel tank, indicated extensive burning while the tractor was in two positions, the first about 100° and the second 160° to the left of its upright position.

The tank shell was recovered in three sections. The front section, about 27 feet long or three-quarters the length of the tank was found 1,307 feet northeast of the explosion point and 402 feet east of the highway center. The rear head was 540 feet southwest, and the rear one-quarter of the cylindrical section was 229 feet southwest of the explosion point. Parts of the trailer suspension and the two axles, with the tires burned off, were found along the eastern embankment of the turnpike. When first seen, the axles and wheels were glowing with heat. Other tank parts or components were found at various points along an 850-foot line generally southeast of the explosion point. The right-front pair of trailer wheels, with tires smudged but still useable, were found about 180 feet southeast of the explosion point. The wheels were attached to a 6-inch stub of box-section trailer axle.

Examination of wreckage. All recovered parts of the tractor-semitrailer (and the other three vehicles) were taken to a turnpike maintenance yard adjacent to Exit 8, where they were examined in detail. A sister cargo-tank semitrailer (and, later, blueprints) was made available by the carrier and was used, together with the blueprints, to identify and locate various damaged components. (See Figure 6.)

The burned suspension, axles, and wheels of the semitrailer were blue from extreme heat, with portions warped or bent. Only shreds of steel wire of the six burned tires remained. The fractured stub of the box-section axle attached to the two unburned wheels was not affected by heat; it showed evidence of a force which had acted rearward on the wheels. (See Figure 7.)

Other than the fifth-wheel separation, no damage could be associated with the overturn of the tractor or semitrailer after the jackknifing. There were no lateral score marks on the cargo-tank body to indicate that it slid on its side, although there were numerous longitudinal and diagonal score marks. Only the mounting pads, with twisted and broken plates or brackets, remained attached to the outside of the tank shell. Three of the four baffle-plate mounts at the fractured open end of the largest tank section had been bent inward or sheared off; considerable loose earth was inside the tank shell. (See Figure 8.)

The line of separation of the tank body into three sections generally paralleled the weld lines, sometimes within the welds but mostly in the

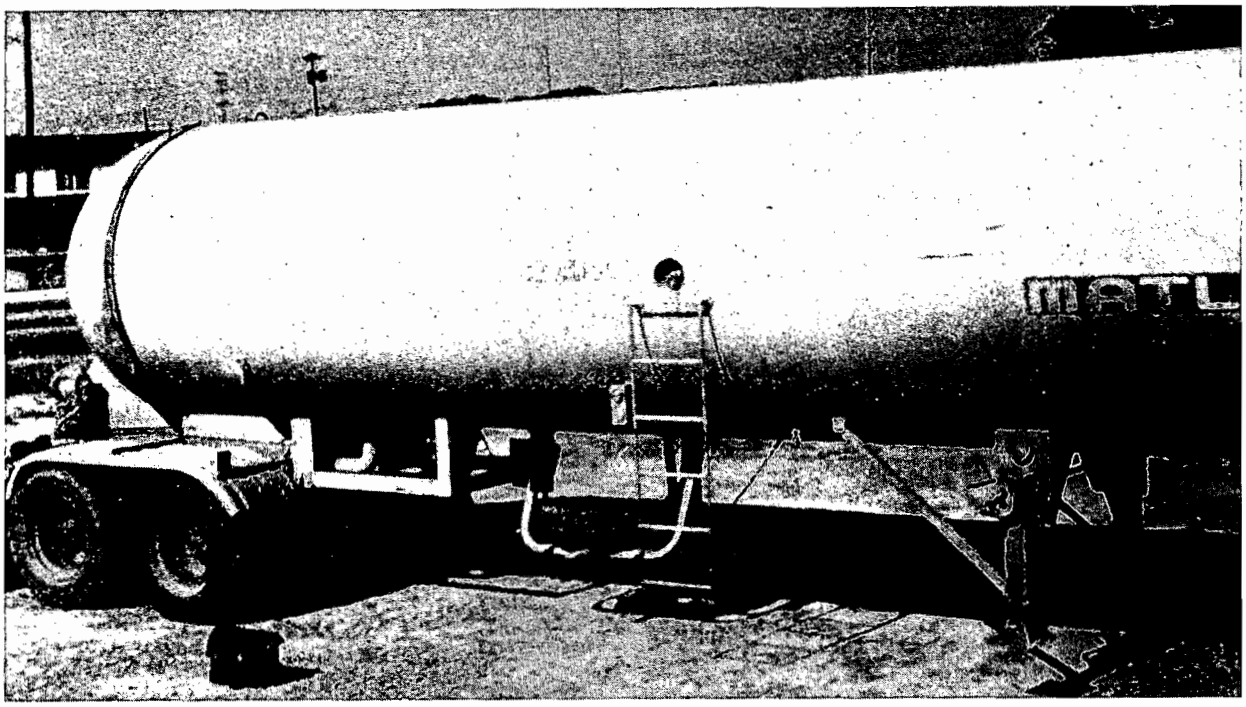


Figure 6. Sister vessel of the wrecked cargo-tank semitrailer.

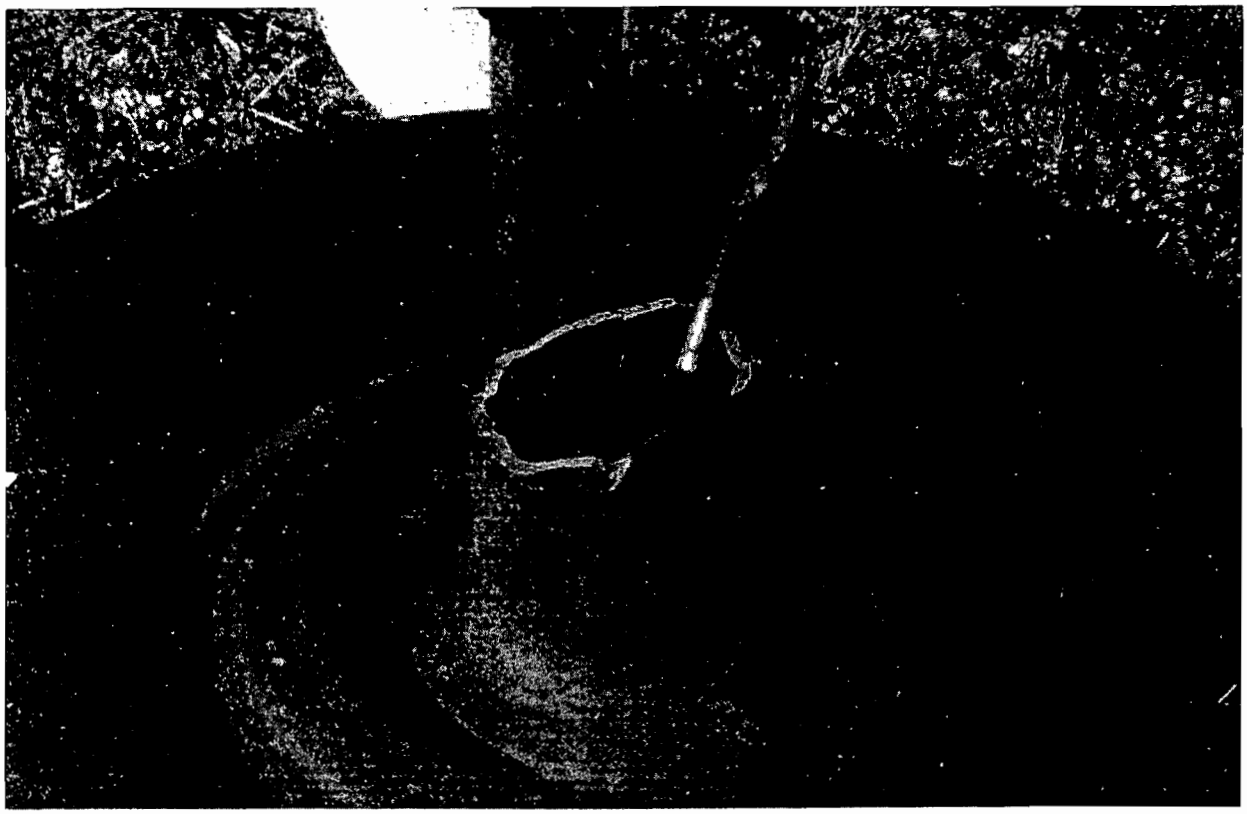


Figure 7. Broken-off right front axle of cargo-tank semitrailer.

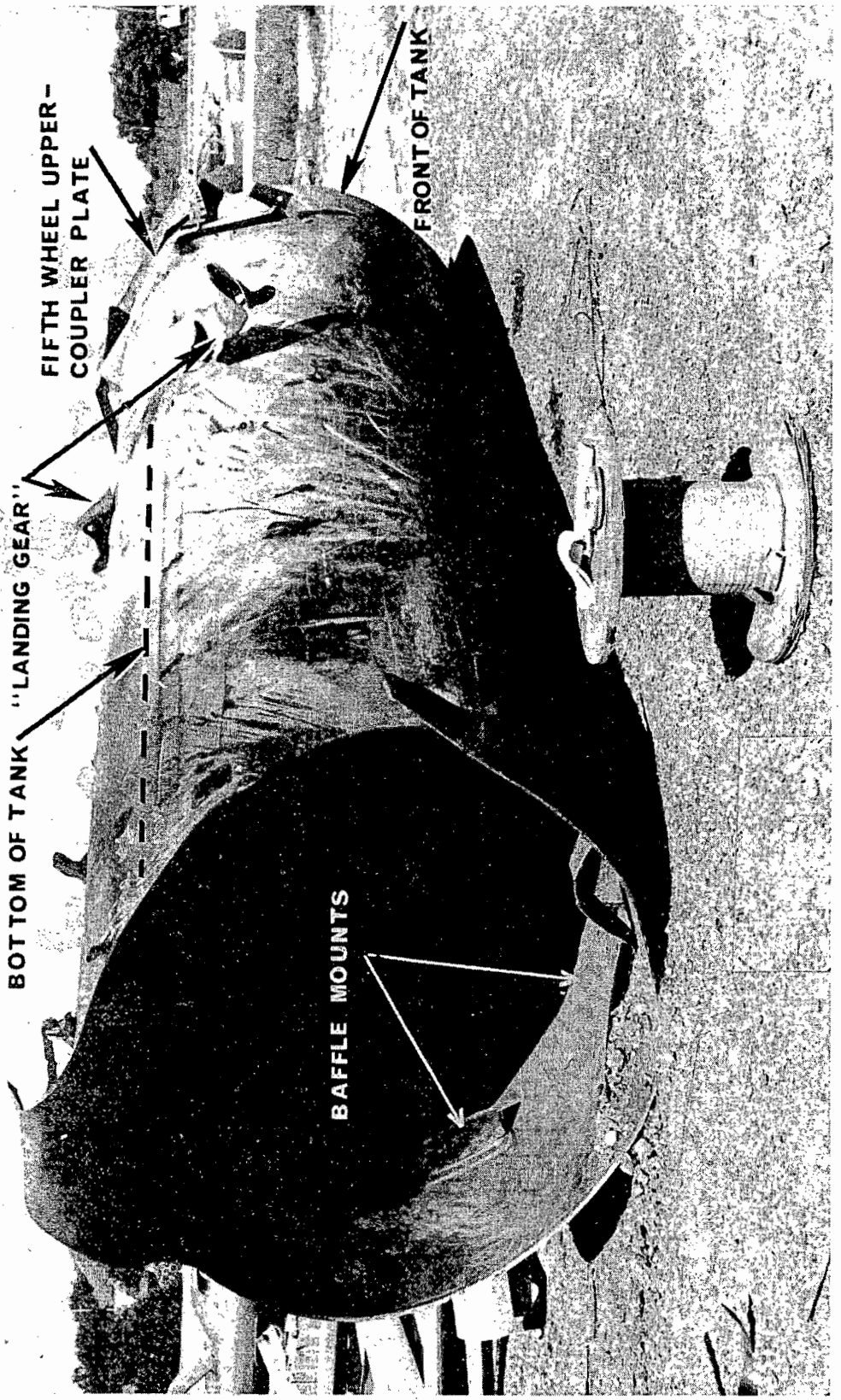


Figure 8. Front portion of the cargo tank.

heat-affected zone adjacent to weld lines. The tear line occasionally crossed the weld lines. At two points along the longitudinal tear at the tank rear belly which began near the withdrawal-valve flange, there was noticeable thinning of the tank body metal, concurrect with discoloration associated with extreme heat. These points were about 25° to 30° to the right of the tank's lower midline. In both areas, the metal had thinned from 0.468 to less than 0.150 inch. Metal samples were taken at several points for testing by the metallurgy laboratory of the Safety Board. Appendix C presents the results of the examination.

The rear tank head had separated from the tank body in a roughly circumferential tear which occurred in the thinner head material and ranged from about 3 inches to about 15 inches from the weld line. (See Figure 9.)

Cargo-tank plumbing. Both the external sprayfill line and the liquid withdrawal line were found in many segments. (See Figure 10 and Appendix D.) It was impossible to determine whether any fractures had occurred before the explosion. The withdrawal shutoff valve, mounted adjacent to the tank body, showed marked rotational distortion and horizontal separation. The aluminum valve body was also partially melted. There was no evidence found to indicate whether damage to the valve body had occurred in the explosion or in the pre-explosion crash, or in both.

None of the plumbing valves could be tested for pre-explosion malfunction. The safety relief valve at the front of the tank was visually and manually checked and was found to be operative, but no operational tests could be made.

The Automobiles

The Chevrolet. The 1969 Chevrolet, a 4-door Impala sedan, was painted off-white. The front end of the car was crushed to the rear by a barrier-like impact of about 20°. The hood was distorted rearward and upward. The left-front wheel was displaced rearward about 2 feet, but the right-front wheel was in its normal position. The windshield was in place, but was cracked and bulged outward in two places. The center and right side of the front-seat backrest was deformed forward about 24 inches. All tires appeared to be in good condition, except for the deflated left-front one, and all four had adequate tread. The car's mechanical condition was not examined.

The Dodge. The 1972 Dodge was identified through the chassis serial number. The vehicle was found in two main portions. The front half, including the engine, front suspension, and body components, was found upright in lane S-2 about 34 feet southwest of the tractor. The rear half was found inverted 56 feet west of the roadway and directly west of the front portion. All combustible materials had been burned.

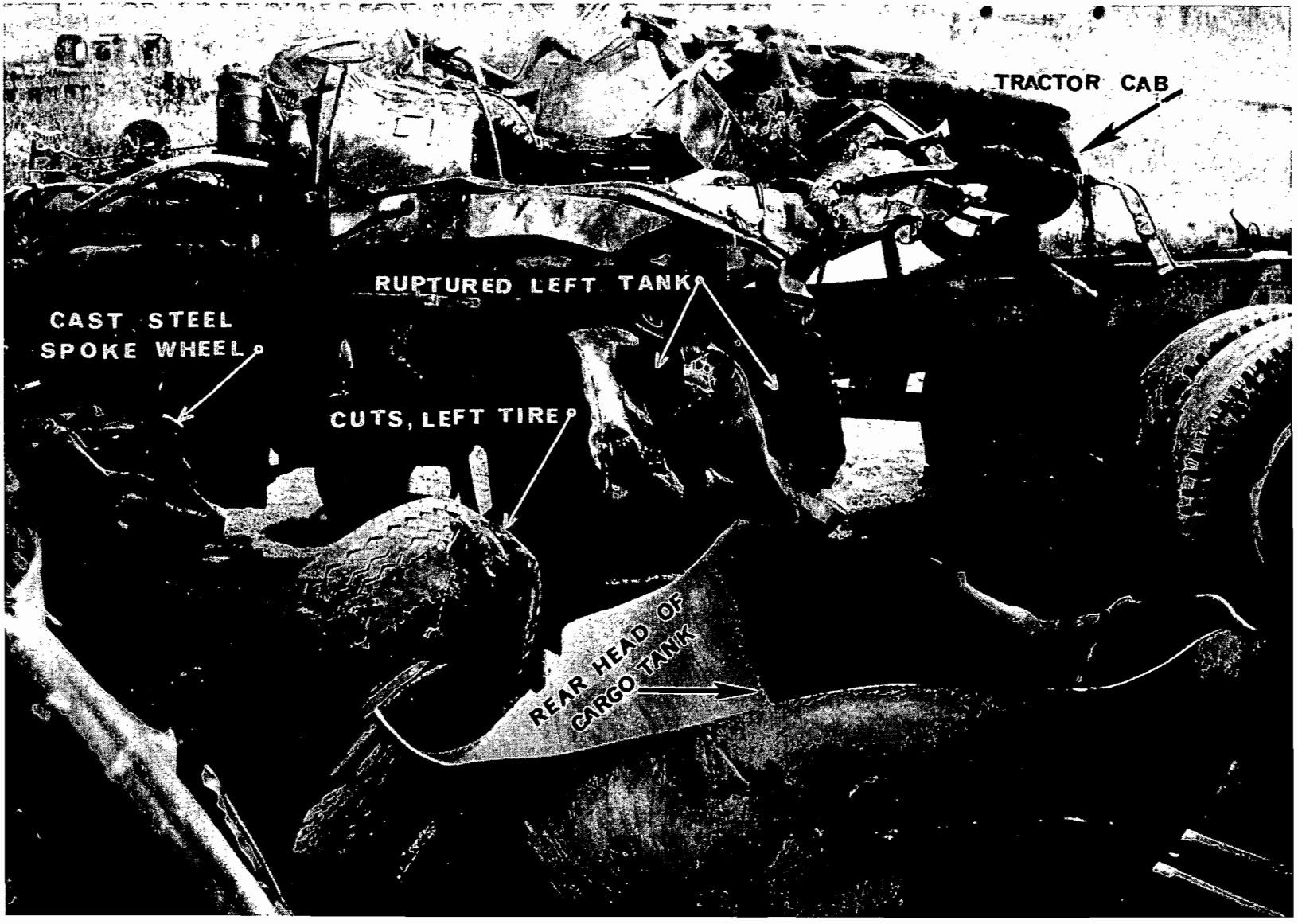


Figure 9. Tractor and rear head of cargo tank.

KEY:

A HOSE COUPLINGS (capped during transit)

B BALL-TYPE FLOW-REGULATOR VALVES, MANUAL

C FLANGES

D CARGO-TANK SHELL (.468-INCH THICK)

E MAIN LIQUID WITHDRAWAL VALVE

E_1 INTERNAL COMPONENTS OF E

F INTERNAL EXCESS-FLOW VALVE IN SPRAYFILL LINE

G SPRAYFILL NOZZLE

H REAR FACE OF SEMITRAILER BUMPER

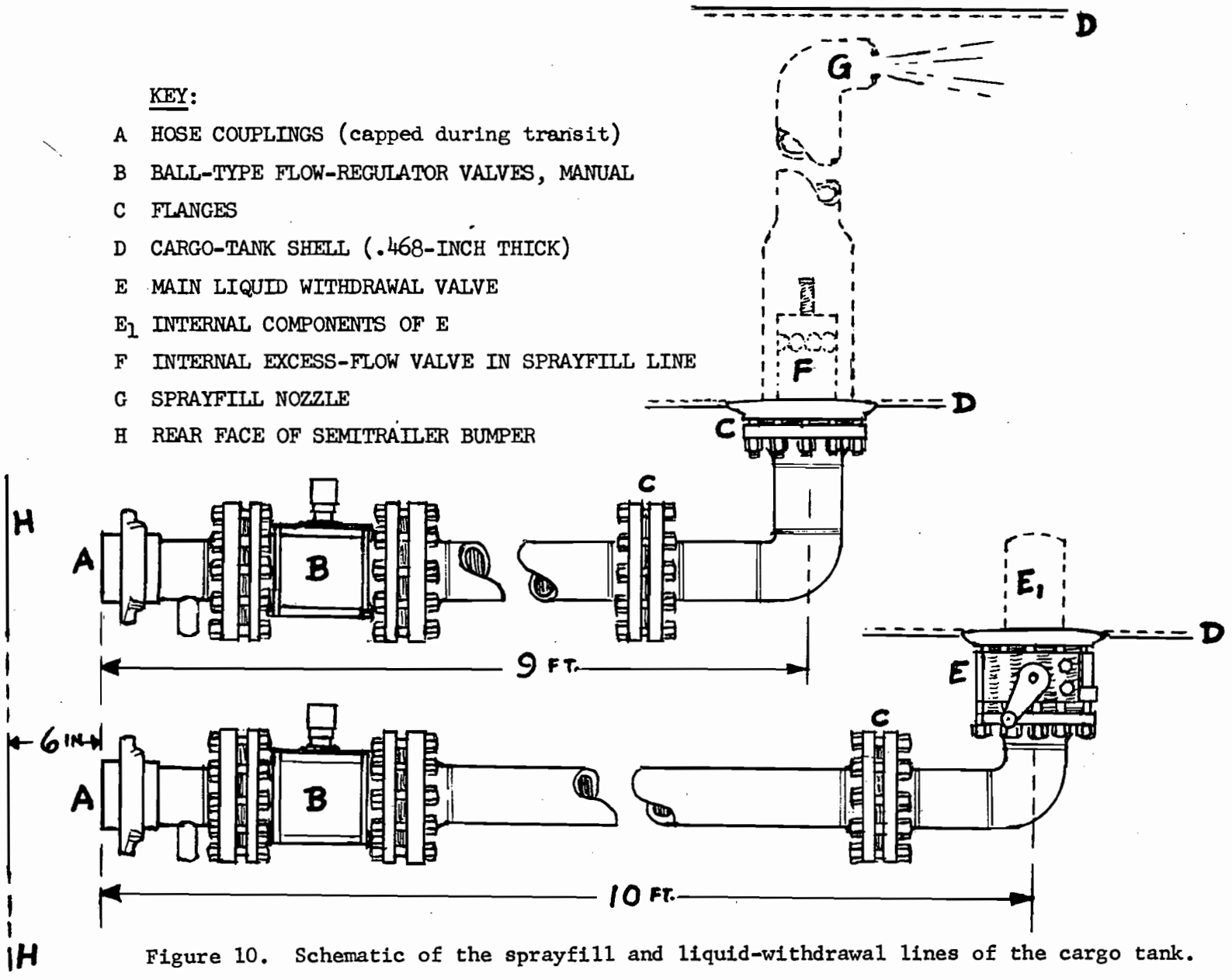


Figure 10. Schematic of the sprayfill and liquid-withdrawal lines of the cargo tank.

All metal parts, except the front bumper, were blackened, crushed, and distorted beyond identification, so that neither the make nor the body type could be recognized. The spare tire and wheel were found undamaged some distance from the other parts.

There was no identifiable evidence of a crash by the Dodge into the tractor-semitrailer or any other object; any such marks would have been obscured by the subsequent damage incurred by fire, explosion, and postexplosion impact with the ground. (See Figure 11.)

When seen by witnesses before the explosion, the Dodge appeared to be wedged between the overturned cargo tank and the median guardrail. No occupants could be seen. Rescue was not attempted because of the severity of fire in that area. The car was described as being "not too badly damaged" at that time, but because of the car's obscured position, witnesses could see no details.

III. ANALYSIS

Crash Kinematics

No evidence was found to support or refute the busdriver's contention that he had applied the bus brakes suddenly, just before the crash, to avoid a car which had suddenly applied brakes in front of him. The swerving and skidding of the bus into lane S-2 are characteristic of an evasive turn combined with brake lockup.

The wet roadway and the resultant absence of visible skidmarks precluded any determination of the speed of the bus or the tractor-semitrailer in any phase of the crash sequence. That the tractor-semitrailer was passing the bus is evidenced by the forward displacement of damaged bus components.

The bus kinematics after the collision with the tractor can be estimated as follows: The right-turn position of the front wheels and the sideswipe impact by the tractor rotated the front of the bus clockwise. The left rear of the bus lightly struck some part of the tractor-semitrailer as the bus rotated. Since paint transfer substantiates a front-to-front collision between the bus and the Chevrolet, the bus had rotated 180° to this point. Such a 180° rotation is typical of a skidding four-wheeled vehicle with all wheels locked. With the driver out of his seat and the brakes released, the bus finally rolled rearward on its wheels in a 90° counterclockwise arc to its point of rest against the median guardrail. The final position of the Chevrolet supports such movement by the bus.

It could not be determined at what point in the crash sequence the front wheel rim lugs of the tractor fractured, but they probably separated when first the left wheel and then the right wheel encountered the

a. Front half.

b. Rear half.

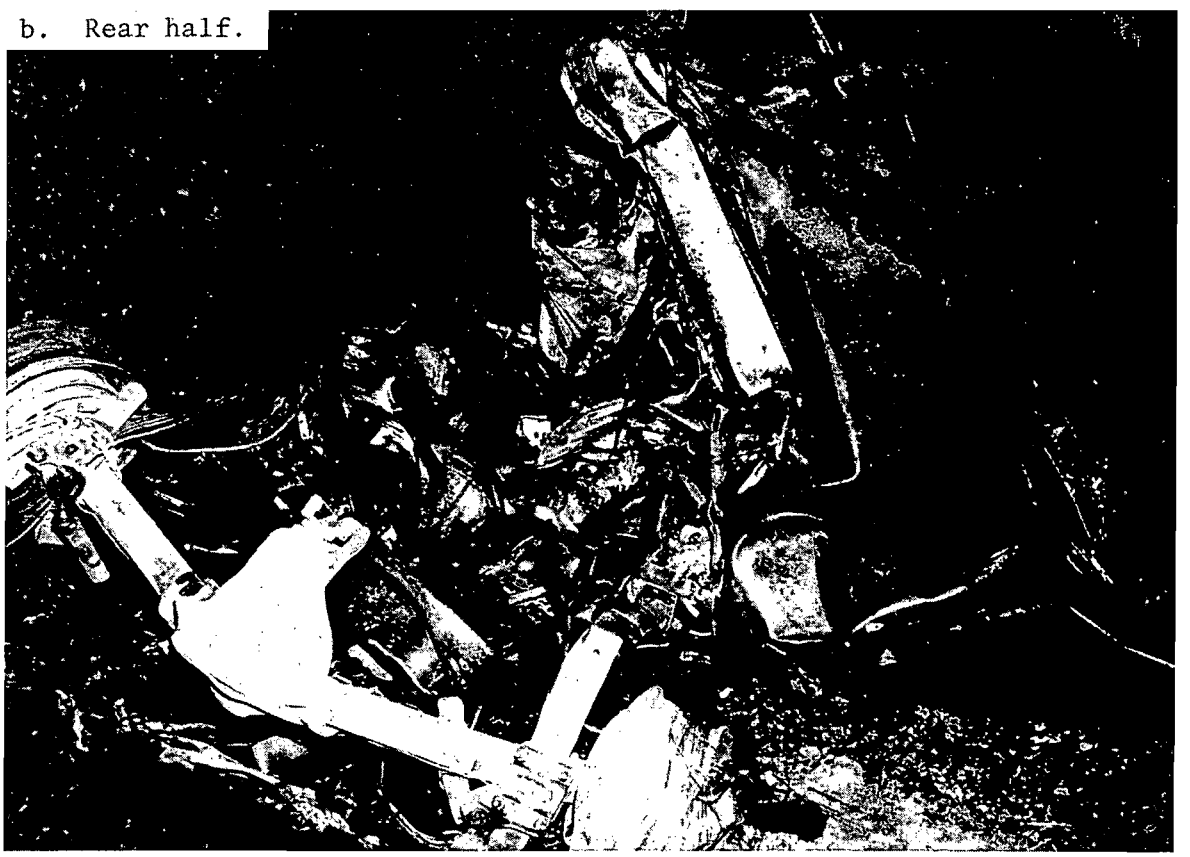


Figure 11. Wreckage of the Dodge Charger.

median guardrail. Similar uncertainty exists as to the forces or impacts which fractured the right-front trailer axle. No analysis could be made on this point because of the speculative nature of pertinent facts.

The tractor-semitrailer jackknifed after the front of the tractor jammed in the median guardrail and the cargo-tank semitrailer was diverted eastward. The heavily loaded semitrailer pushed against the fifth wheel while the tractor was approximately perpendicular to the semitrailer. As the tractor went over onto its left side, the fifth wheel began to fail. As the rear of the semitrailer skidded in a clockwise arc of about 200° around the fifth wheel, the stresses were reversed and the separation was completed.

When the semitrailer's left-side wheels struck the raised median, the high center of gravity of the cargo tank caused the semitrailer to overturn onto its left side. The nature and severity of the impact between the Dodge Charger and the cargo-tank semitrailer could not be established. Underride by the car of the cargo tank, however, was not likely. Such underride would have tended to snag the car on the plumbing guard or other components, so that the car would have been caught under the tank or east of it. When the tank overturned, the car was trapped between the cargo tank and the median guardrail.

Plumbing-System Protection

Specifically which plumbing component was damaged to permit a significant leakage of propylene, or how such damage occurred, could not be determined because of the condition of the recovered parts.

When the tank-semitrailer rode down the median guardrail, and the front tires (and rims) of the tractor broke away, it was possible that loosened median rails or the loose tires either penetrated the plumbing guard or, coming up from below, placed severe rearward or vertical stresses on the plumbing. Furthermore, since the spare tire and hanger were probably raked loose by the median guardrail, the loose spare tire was probably tumbling free beneath the cargo tank. The trailer dual wheels, amputated from the trailer's front axle, could also have come up beneath the plumbing. The wedging of any of these items could have broken the plumbing without sufficient lateral force to separate completely the frangible flange bolts, which would have activated the cutoff feature of either the sprayfill or the liquid withdrawal systems.

Regulations regarding the plumbing guard (49 CFR 178.337-10) do not specify protection from potential impacts on the plumbing from below. In this accident, such an impact probably occurred with sufficient force to fracture the plumbing but without necessarily damaging the plumbing guard.

Because of its design, the external sprayfill pipe contains liquid during transport. A fracture in the external pipe can permit the escape of liquid propylene without necessarily activating the excess-flow valve. The excess-flow valve spring, balanced to hold the valve in an open position when the tank is upright, is no longer in balance when the tank is on its side. Without gravity to assist in closing the valve, a considerably greater outflow is permitted before the valve shuts than would be permitted with the tank upright. This differential in flow was not calculated in this accident because of the absence of pertinent data. It is evident, however, that a flow-check valve, with its spring balanced to hold the valve shut, would work equally effectively with the tank in any position, and would have stopped any outflow from even a minor fracture in the pipe.

The automatic shut-off feature of the liquid withdrawal valve (Fisher C-302A-43) used on the cargo tank would not activate unless there was full breakaway of the external valve body. Thus, a substantial leak could have been caused in the valve body without concurrent fracture of the frangible bolts; as previously stated, a vertical force imposed from below would have permitted this.

Federal regulations (49 CFR 178.337-9) require that "safety relief valves shall be installed to have direct communication with the vapor space in the tank. . ." The vapor space is normally at the top of the tank when the tank is upright. With the tank on its side, the liquid level is above the interior valve openings, but no explicit provision exists in the regulation for venting vapor in all tank positions. The capacity of safety relief valves in a liquid environment depends on a great many variables and cannot be accurately predicted.

The Explosion

When the propylene tank overturned onto its left side, its damaged plumbing was probably leaking and already afire. Torch-like flame was directed against the tank underside and the trailer suspension system.

With the rear of the tank slightly elevated (on the raised median), some of the propylene shifted forward, but a sufficient amount remained at the rear to absorb thermal energy in the area of the tank shell which was directly exposed to the flame and to prevent damaging heat buildup. As the fire continued, the heating of the liquid propylene gradually increased internal pressure. The blowoff pressure of the safety-relief valves was reached, and additional liquid propylene was released laterally into the southbound traffic lanes and was probably ignited by the plumbing-area fire.

As propylene escaped via both the damaged plumbing and the safety-relief valves, the level of liquid of the rear of the tank dropped. Less heat was absorbed by the liquid propylene, which, in turn, reduced the rate of pressure buildup and permitted the relief valves to close. Bystanders and police noted that the fire at the relief valves subsided about a minute or two before the explosion occurred. However, the fire continued at the rupture in the plumbing. As the liquid propylene dropped below the level of the fire, the cooling effect of the boiling liquid on the tank shell was lost, and the tank metal began to overheat. A rough estimate indicated that 2,000 gallons of liquid propylene would have had to escape to lower the liquid level at the rear of the tank sufficiently to permit excessive heat buildup in the tank body metal. Lack of pertinent data precludes a more reliable appraisal of the liquid loss through the safety-relief valves and the plumbing leak.

About 25 minutes after the semitrailer's overturn, the metal in the affected area was hot enough to have been weakened below its design strength; local failure occurred when the temperature exceeded an estimated 1350° F. The local failure produced concentrated stresses in the "vee" of the tear, which ripped longitudinally and circumferentially and invaded unheated metal. Milliseconds after the initial failure, there was a sudden release of internal pressure and a violent expansion of the superheated propylene into the gaseous state. Since the temperature of the propylene was above the boiling point (at amospheric pressure), most of it flashed into vapor instantly. Because of the open-ended configuration produced by the circumferential tear, this expansion produced a rocket-type thrust which completed the separation of the tank body and projected the severed sections in opposite directions. The largest section of the tank flew the longest distance because it held most of the expanding propylene. Because there was no significant amount of oxygen within the cargo tank, even after separation, there was no thrust from burning. 4/ Most of the fireball was produced when the expelled vapor burned in air.

The fact that the opposite sections of the tank did not travel in diametrically opposite directions resulted in part from the fact that the top of the tank was the last to fail and in part from the poor aerodynamic qualities of the two rear portions.

The two lesser explosions which occurred midway in the burning phase were probably the burning tires of the semitrailer. The two fuel tanks and the rear tires of the tractor did not explode.

The violence of the separation in the explosion was sufficient to cause separation of external appendages from the cargo tank, some of which had been already weakened by excessive heating.

4/ Support of the logic in analysis of the explosion is documented in Cornell Aeronautical Laboratory report FRA-RT-71-74, released in 1970.

Failure of the Tractor Wheels and Semitrailer Axle

The Board has never before observed the type of spoke-to-rim failures in truck wheels which occurred to the two front wheels of the tractor, and was unable to determine the cause of such failures or the kinematics involved. Furthermore, the Board was unable to conclude what specific effect (other than generally contributory) the failures might have had on loss of tractor control or on the jackknifing.

Emergency Response

The work of the State and local police was undoubtedly an important factor in minimizing the number of casualties. If the onlookers had been at a "comfortable" range (from a heat standpoint), it is reasonably certain that many more would have been injured or perhaps killed. Nevertheless, the number of casualties was higher than it should have been. If the propylene tank had been oriented only a few degrees counterclockwise from its actual position, the flying sections of tank would have been directed at significant crowds both north and south of the explosion point. It was almost pure chance that the flying suspension parts stopped short of the property fence, and that other components continued over the heads of onlookers into the woods beyond.

There is a lack of objective criteria to guide emergency personnel at the scene of hazardous-materials accidents in determining a potential danger zone. In this instance, the impromptu barricade provided by the bus shielded both vehicles and persons. But a major segment of cargo-tank shell could conceivably have struck the bus, and turned it into a secondary missile, with potentially catastrophic results.

The injury of seven of the eight police officers at the scene attests to their continuing efforts to control the crowd. However, their proximity to the burning cargo tank suggests a lack of awareness of the potential danger. How far the police could or should have gone in requiring evacuation of the area is a question which needs to be examined and resolved by the police profession. In metropolitan corridors like the New Jersey Turnpike, responsible police authorities might be expected to have a working knowledge of the risks, effects, and countermeasures associated with all potentially catastrophic types of highway accidents, so that important field decisions can be made and implemented with minimum delay.

The fire department could have anticipated the entrapment of the three fire-department vehicles in northbound traffic if it had had more extensive knowledge of the situation at the time of dispatch. A delay of a few minutes in order to clarify the situation before vehicles are dispatched can save important time when the vehicles have to travel on a limited-access highway. In this accident, by the time the second units arrived, the fire was already beyond control, since the heating of the

tank underside had already reduced the strength of the tank shell nearly to the failure point. If the cooling of the tank underside had begun 10 or 15 minutes after the fire began, the overheating which preceded failure of the shell might have been prevented.

It must be recognized that any attempt by firemen in the second units to cool the tank when they arrived would have resulted in extreme risk to themselves. Any amount of water available at the accident scene might not have overcome the heat buildup. Although the Safety Board believes that advance planning for a variety of potentially disastrous fires needs to be undertaken, risk to property must always have a lower priority than risk to the lives of the emergency personnel and other bystanders. Recognizing that the fire situation could not be controlled and having determined that rescue was impossible, fire personnel could have assisted the police in urging the withdrawal of onlookers. Such action, however, would have required an understanding of the range of hazard, which so far as the Board can determine, has not adequately been specified for LPG fires in vehicles.

IV. CONCLUSIONS

1. The braking of an unidentified car (or cars) ahead of the bus initiated the multiple-vehicle crash. The reason for braking was not established and the burden for avoiding a collision was on the following driver.

2. Specific precrash actions by the drivers of unidentified cars, the truckdriver, and the busdriver cannot be ascertained.

3. The fire at the left side of the tractor resulted from fuel-tank damage and friction sparks incurred in the shallow-angle collision with the median guardrail. This kind of simple impact can be expected to occur in normal highway operations.

4. Although the aluminum fuel tank of the tractor met applicable Federal regulations, its severe damage resulted in fire. No determination was made whether a steel fuel tank would have resisted damage under the same circumstances.

5. Intrusion of the tractor-semitrailer into the opposing lanes was permitted by the failure of the median barrier to restrain in a shallow-angle collision a type of vehicle which the turnpike regularly accomodates. The intrusion was aggravated by the jackknifing of the tractor-semitrailer, a known design weakness of this class of vehicle which has not been resolved by industry practice or by regulations.

6. The damage to the cargo-tank plumbing, which resulted in leakage of propylene, was probably induced by a vertically applied force from the intrusion of either the dislodged median guardrails or the detached wheels of the vehicle itself.

7. The collision between the cargo-tank semitrailer and the northbound Dodge Charger did not contribute to the upset of the cargo tank or to the damage to the cargo-tank plumbing.

8. The provisions of 49 CFR Part 178.337 for MC-331 compressed-gas cargo tanks, as reflected in widespread current applications of such regulations to existing cargo-tank vehicles, failed to assure the safe performance of the cargo tank in this common highway crash in that:

a) Part 178.337-10 did not state the specific classes of objects for which protection was to be provided;

b) Part 178.337-11 permitted an excess-flow valve to be used which operated with reduced effectiveness when the tank was on its side; and

c) Part 178.337-12, which required a shear section to separate under "undue strain," was vague.

9. The provisions of 49 CFR 178.337-9(a)(6), which required that relief valves be installed to have direct communication with the vapor (gas) space in the tank, did not specify that this condition be met in all attitudes of the tank known to exist in an accident; this resulted in liquid propylene being released when the cargo tank was on its side.

10. In this accident, the opening and subsequent closing of a safety-relief valve while fire was still burning against the LPG cargo tank indicated a cessation of boiling, which was the result of the dropping of liquid level below the fire-application point. This should have indicated to fire officials that heat was being applied to an uncooled part of the tank wall which was subject to heat softening.

11. The performance of the cargo-tank welds met applicable requirements and specifications; partial failure in the welds was a result of unusual pressures and the peculiar sequence of rupture induced by the overheating and softening of the tank body metal.

12. If the propylene cargo tank had been oriented 30° to 45° counterclockwise to its actual position, the rocket thrust could have sent large tank sections into the crowds of onlookers, which would have vastly increased the potential scope of death and injury.

13. The existence of established "danger zone" criteria could have guided appropriate action by the police and other emergency personnel at the accident scene. Based on the observed results of this accident, the radius of the danger zone associated with fire involving an MC-331 cargo tank carrying LPG is at least 1,400 feet.

14. The primary activities of the police in rescuing victims and keeping onlookers away from the fire minimized the incidence of injury to bystanders; however, all persons injured in the explosion were too close to the burning cargo tank.

15. The failure to initiate tank-cooling efforts at an early stage of the fire, contributed to by the complete obstruction of normal traffic approach lanes on the limited-access highway and by the absence of adequate preplanning by fire-department crews, was a significant factor in the overheating and failure of the cargo-tank shell.

16. Implementation of fire countermeasures by fire-department personnel who arrived at the scene after a considerable delay would have exposed such personnel to extreme risk. In retrospect, the public safety would have been better served if fire-department personnel instead had assisted police in moving onlookers away from the immediate scene.

V. PROBABLE CAUSE

The National Transportation Safety Board determines that the probable cause of the initial collision was the evasive steering and skidding of the bus into the path of the overtaking tractor-semitrailer. Override of the median guardrail by and subsequent overturn of the tractor and the semitrailer were caused by the inability of the median guardrail to resist the forces generated by the tractor-semitrailer.

The initial fire was caused by friction sparks when the tractor-semitrailer scraped the median guardrail, which ignited fuel escaping from the tractor's damaged left-side fuel tank. Secondary fire was propagated by propylene which escaped from a rupture(s) in the cargo tank's external pipes. Contributing to the escape of propylene were (1) the exposed position of the cargo tank's external pipes, (2) the inadequacy of the "plumbing guard" to protect the pipes from impact damage, and (3) the failure of the flow-cutoff system to function as intended by applicable Federal regulations.

Explosion of the cargo tank was caused by extended exposure of a local segment of the tank shell to direct flame and by resultant overheating of that portion of the tank shell, which weakened it below design strength and permitted a break in the tank body. Contributing to the weakening of tank metal was the absence of tank-overheating countermeasures by emergency crews whose arrival was delayed by traffic congestion on a limited-access highway. The number of injuries was increased by lack of understanding of the range of the hazard.

VI. RECOMMENDATIONS

The National Transportation Safety Board recommends that:

1. The Bureau of Motor Carrier Safety of the Federal Highway Administration (FHWA) study the existing regulations and requirements in 49 CFR 178.337, regarding LPG cargo tanks, for the purpose of instituting more explicit rulemaking toward reducing the likelihood of leakage and subsequent catastrophic failure of such cargo tanks in a variety of foreseeable types of accident crashes. (Recommendation No. H-73-37)

2. The National Highway Traffic Safety Administration, in cooperation with the Bureau of Motor Carrier Safety and the International Association of Chiefs of Police, Inc., as an addition to the official manual which supplements the Highway Safety Program Standard relating to police traffic services, develop criteria and procedures for the demarkation and evacuation of danger zones at hazardous-materials accidents occurring on highways. (Recommendation No. H-73-38)

3. The Bureau of Motor Carrier Safety and the National LP-Gas Association adopt a tentative distance of 1,400 feet as a danger-zone radius for MC-331 cargo tanks carrying liquefied petroleum gas which are exposed directly to fire. Such a radius should be used pending study and additional experience on which to base a more definitive danger-zone radius. (Recommendation No. H-73-39)

4. The Bureau of Motor Carrier Safety, the National LP-Gas Association, and the National Fire Protection Association jointly consider formally recognizing the fact that, while an LPG cargo tank continues to be directly exposed to fire, the opening and subsequent closing of a safety-relief valve (or valves) signals the dropping of liquid level below the fire-application point, and serves as an indicator of impending failure of the tank from heat softening. This information could then be included in approved safety manuals relating to LPG cargo-tank fires. (Recommendation No. H-73-40)

BY THE NATIONAL TRANSPORTATION SAFETY BOARD:

/s/ JOHN H. REED
Chairman

/s/ FRANCIS H. McADAMS
Member

/s/ LOUIS M. THAYER
Member

/s/ ISABEL A. BURGESS
Member

/s/ WILLIAM R. HALEY
Member

October 17, 1973

APPENDIX A

RESULTS OF FHWA SKID TESTS

FORM SUMMARY DOT FHWA BPR FIELD DATA PAVEMENT SKID RESISTANCE				PAGE 1 of 1 PAGES		
HGY RTE. NO: Southbound Roadway New Jersey Turnpike				DATE: 10/18/72		
LOCATION (PROJECT): National Transportation Safety Bd.				WEATHER: light hazy overcast, occasional southeasterly breeze, cool		
					BEFORE TEST	AFTER TEST
DRIVER: S. Teaster	RCDR. OP: D. Wolf			TIME	9:40 AM	1: PM
NOTEKEEPER: D. Wolf	OBSERVER: G.Larsen,J.R.Watson			RCDR CALIB	15 @ 5 MM	15 @ 5 MM
TOWING BPR VEHICLE:DOT40011	TRAILER: BPR DOT 40075			TIRE	24 PSI	25 PSI
FORCE VERIF DATE: 10/17/72	RCDR ATTN: 10			AIR TEMP	50° F.	50° F.
TEST TIRE NUMBER: 18276-058 A243	WEAR: New, full tread depth			PVMT TEMP	N/R ° F.	N/R °F.
SITE	LANE	SPD MPH	CHART RDG MM	SKID NBR	REMARKS	
MP 68.2	3	40		55		
"	3	40		55		
"	3	40		52		
"	3	40		52		
"	3	30		55		
"	3	30		55		
"	3	50		41		
"	3	50		43		
"	2	40		48		
"	2	40		48		

(Note: tests were conducted in accordance with current FHWA recommended practices and in substantial compliance with the American Society for Testing and Materials Designation E274-70, "Standard Method of Test for Skid Resistance of Paved Surfaces Using a Full-Scale Tire." The FHWA concluded that the section of highway represented by these tests was safe.)

APPENDIX B

IDENTIFICATION OF VEHICLES

Vehicle 1

Operator:	Greyhound Lines, East, Cleveland, Ohio
Certificated Driver:	Donald Johnson, male, age 31
Type Vehicle:	GM Coach, PD-4106, 38-passenger, 1962 model with lavatory
Brakes:	Air; all lining had about 5/8-inch thickness
Steering:	Power
Wheels:	Single wheels on front; duals on single rear drive axle
Tires:	Firestone 11.50 x 22.50, good tread all around
Length:	35 feet
Width:	96 inches
Driver's Seatbelt:	None. (Not required in pre-1965 buses.)
Registration:	Commonwealth of Virginia, tag No. EA-2487 (and others)
Company No.:	6339

Vehicle 2

Tractor:

Operator:	Matlack, Inc., Lansdowne, Pa.
Owner:	Dana Transport, Freehold, New Jersey
Certificated Driver:	John Decowski, male, age 29
Type:	1973 Diamond-Reo, diesel, conventional cab, three-axle
Drive:	Two rear drive axles with dual wheels
Brakes:	Air brakes, drive wheels only
Driver Seatbelts:	Installed, as required by DOT regulations
Registration:	State of New Jersey, tag No. XEJ-644

Cargo-tank semitrailer:

Operator:	Matlack, Inc., Lansdowne, Pa.
Type:	MC-331, Compressed Gas
Manufacturer:	Mississippi Tank Co.; date of mfg., March 1970
Weight empty:	22,740 pounds
Weight of Load:	(7,209 gals. propylene) 31,345 pounds
GVW(both units):	Estimated at 70,585 pounds
Capacity:	10,000 water gallons
Plumbing:	See Appendix E
Shell:	.468-inch quenched-and-tempered steel

Heads:	Hemispherical, .250-inch quenched-and-tempered steel
Operating pressure:	312 psi (setting of safety-relief valves)
Tested pressure:	624 psi
Length of tank:	37 feet, 11½ inches
Length of semi-trailer	38 feet, 9-3/4 inches
Tank diameter:	83 inches, outside diameter
Suspension:	Dual axles, dual wheels (eight wheels in all)

Vehicle 3

Owner:	H. F. Paterson, Redding Shores, Florida
Type:	1969 Chevrolet Impala four-door sedan, V-8 engine
Registration:	State of Florida, tag No. 4W107090

Vehicle 4

Owner:	Richard NMI Rhodes, Philadelphia, Pa.
Type:	1972 Dodge Charger, two-door hardtop, V-8 engine
Registration:	State of Pennsylvania, tag No. 8L-6566

APPENDIX C

EXAMINATION OF FRACTURED PRESSURE-VESSEL SHELL

Date of Examination at Scene: October 2, 1972
Place: Maintenance Yard of New Jersey Turnpike near Exit 8 (Hightstown)
Date of Report: December 14, 1972

The main pressure vessel of the truck fractured into three large pieces. All of the fractures appeared typical of overload separation and no evidence of prior cracking was noted.

Initiation of the breaks appeared to be at areas which were damaged by heat. A metallographic microsection through one of these initiating areas disclosed a fracture profile indicative of failure at elevated temperatures. Hardness measurements and microstructural characteristics of this section indicated that the material was heated above 1350° F.

Hardness results and microstructural characteristics of the one-half inch shell material in another section away from all apparent heat damage were typical of a quenched and tempered steel having a tensile strength of approximately 130 ISI.

(s) MICHAEL L. MARX

Michael L. Marx
Metallurgist, National Transportation Safety Board

APPENDIX D

CARGO-TANK "PLUMBING"

The pipes and valves of cargo tanks are commonly referred to as "plumbing." All LPG cargo-tank plumbing is similar, designed to meet DOT requirements, but there may be minor variations. In the MC-331 tank involved in this accident, which was built expressly for propylene transport, the plumbing presumably met all pertinent DOT requirements, and consisted of the following:

1. The on-loading or "sprayfill" pipe. An external 4-inch steel pipe extends 9 feet from the rear of the trailer. This pipe has a capped hose coupling and Contromatic 300 flanged ball flow-regulator valve at the rear end. Through a 90° elbow, the sprayfill pipe enters the tank vertically, near the bottom of the tank.

Within the tank, the sprayfill pipe extends to the top and bends forward. Product loaded through this pipe rises to the top of the tank and is sprayed forward at very low temperature, thus condensing excess vapor back to liquid and eliminating the need for a vapor line.

At the base of the internal sprayfill pipe is a 4-inch Rego A4500 excess-flow valve, designed to prevent inadvertent reverse flow of liquid. In the event of an inadvertent opening of the manual flow-regulator valve, or of a major leak in the valve or exterior line, this valve is designed to slam shut. This type of valve was used in place of a check valve, which is spring-loaded to prevent any reverse flow, because check valves to meet the requirements were not available in the 4-inch size when this tank was manufactured. 5/

2. The unloading or "liquid withdrawal" line. This is an external pipe with the same dimensions and components as the external sprayfill pipe. At the point where the pipe connects to the bottom of the tank, 10 feet from the rear, is a manual shut-off valve which must be in the "off" position at all times except during actual unloading. This valve (Fisher C-302A-43) is mounted in a cast-aluminum flanged body adjacent to the tank belly. The valve itself is within the tank, activated by an external cam and lever. In the event of a heavy impact, the valve body is designed to break away through shear-type flange bolts; the cam would drop away, releasing the spring-loaded valve and automatically

5/ Some companies are reported to be replacing the 4-inch excess-flow valves with check valves, now available, on a voluntary and intermittent basis.

closing the valve whether the lever was in the "on" or the "off" position at the time of break-away. 6/ (See Figure 10.)

3. Safety relief valves. Separate from the underside plumbing are two 3-inch internal Rego A8436 safety-relief valves in the top of the tank, with a fixed pressure setting of 312 p.s.i.g. One of these valves is 55 inches from the front, and the other 55 inches from the rear of the tank. In compliance with 49 CFR 178.337-9, these valves are required to have direct communication with the vapor space in the tank, and are designed to vent vapor when pressure exceeds the set safety-relief pressure. Design pressure of this tank is 312 p.s.i. at 150° F. 7/

4. Vapor line. This model tank was equipped with a "vapor line" and valve, intended to withdraw vapor from the top of the tank and return it to a storage tank, if necessary. However, because the "sprayfill" principle eliminated the need to vent vapor during filling operations, the vapor line and valve were sealed off and were inoperative.

5. Plumbing guard. To protect the external plumbing from physical impact, a DOT-required "plumbing guard," consisting of a steel framework welded to and suspended below the tank body, was installed. The guard came down to about 35 inches from the ground and surrounded the exposed pipes and valves. This guard provides no protection against localized impacts from below. No known tests have been made to determine the vertical force required to fracture the plumbing.

All pipes terminate at least 6 inches in front of the rear bumper face; they are routed through the rear suspension mounting structure, which provides additional protection from lateral impacts.

6/ The Safety Board has learned that impacts of intermediate or minor severity have been known to permit leakage without break-away of the valve body, through distortion of the valve seat, possibly aggravated by wear.

7/ Safety-relief valve capacity tests are generally based on gas-phase flow (study by Cornell Aeronautical Laboratory: FRA RT-71-74 in 1970). Thus, flow-capacity requirement formulas are applicable only if the relief orifice is communicating with a vapor space. A study of propane venting indicates that a valve sized for gas release will be significantly undersized for liquid release.