NATIONAL TRANSPORTATION SAFETY BOARD

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HIGHWAY ACCIDENT REPORT
MULTIPLE- VEHICLE COLLISIONS UNDER FOG CONDITIONS, FOLLOWED BY FIRES, NEW JERSEY TURNPIKE, NORTH OF GATE 2 NOVEMBER 29, 1969

NATIONAL TRANSPORTATION SAFETY BOARD
Washington, D. C. 20591

REPORT NUMBER: NTSB-HAR-71-3

SS-H-6

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ADOPTED: JANUARY 20, 1971

NATIONAL TRANSPORTATION SAFETY BOARD
Washington, D. C. 20591
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FOREWORD

The National Transportation Safety Board (NTSB) may, in its discretion, elect to investigate and/or hold public hearings on selected highway accidents.

On December 16, 1969, the Safety Board designated this accident a major highway accident as defined in Section 400.43(b) of the Board's Regulations (14 CFR Part 400). The Board ordered a public hearing and designated a Chairman of the Board of Inquiry on December 17, 1969. Notice was given by the Chairman that a public hearing would be held commencing at 9 a.m., e.s.t., on Tuesday, February 3, 1970, at Cherry Hill, New Jersey.

This report is based on facts obtained from the official report of the New Jersey State Police, from the Bureau of Motor Carrier Safety of the Federal Highway Administration, from a special trauma team of National Highway Traffic Safety Administration, in addition to investigations made by the Highway Safety Division of NTSB's Bureau of Surface Transportation Safety, and testimony at the public hearing held in Cherry Hill, New Jersey, February 3 to 6, 1970.

SS-H-6

NATIONAL TRANSPORTATION SAFETY BOARD
WASHINGTON, D. C. 20591
HIGHWAY ACCIDENT REPORT

Adopted: January 20, 1971

MULTIPLE-VEHICLE COLLISIONS UNDER FOG CONDITIONS, FOLLOWED BY FIRES, NEW JERSEY TURNPIKE, NORTH OF GATE 2, NOVEMBER 29, 1969

I. SYNOPSIS

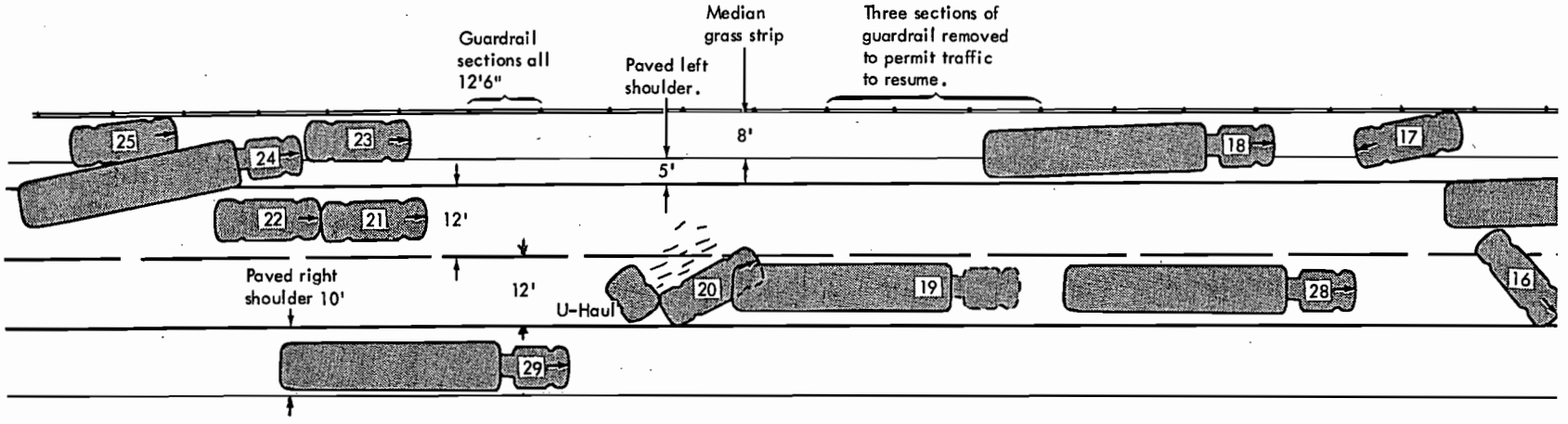
At about 7:45 a.m., November 29, 1969, in a southbound lane of the New Jersey Turnpike, and at a location about one-half mile north of Exit 2, a 1969 Mercury sedan entered sudden dense fog at about 45 miles per hour. The driver slowed to 30, but was rapidly overrun by a tractor and a tank-semitrailer of 76,340 pounds combined vehicle weight, loaded with 9,257 gallons of propane. The tank-semitrailer overturned onto its right side, and blocked both southbound lanes and the shoulder.

In rapid succession, some 10 vehicles entered the area just north of the blocked lanes, with multiple collisions between them and the trailer. Fire started near one of the passenger vehicles.

A loaded tractor-semitrailer of 57,690 pounds entered the area, struck several vehicles and then the overturned tank-semitrailer, causing a hairline crack in the shell of the propane trailer. Fire spread rapidly and destroyed nine vehicles.

Among the 29 vehicles involved, there were 12 to 15 primary collisions, and numerous minor collisions. There were six fatalities, and three serious and 15 less serious injuries. Included were six tractor-semitrailer units, 21 automobiles, and a U-Haul semitrailer. Twelve vehicles were destroyed, and most of the balance suffered damage.

The Safety Board determines that the probable cause of this multiple-vehicle accident was the penetration by vehicles into an area of dense fog where the visibility was 20 to 50 feet, together with the varying rates of speed which prevented appropriate evasive action. Contributing factors were the absence of objective indicators of the density of the fog, and inadequacy of the New Jersey Turnpike speed control system in that it failed to provide timely activation of speed reduction warning signs.



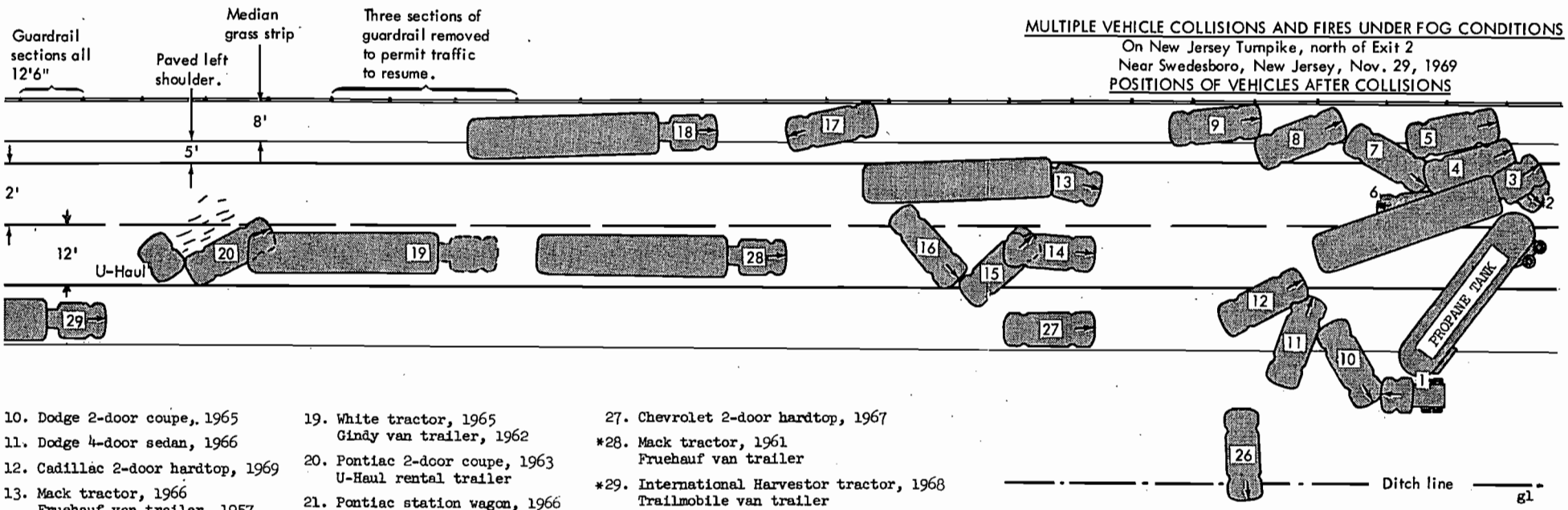
VEHICLES:

1. International Harvester tractor, 1965
   Downingtown MC331 tank trailer, 1965
2. Chevrolet 4-door sedan, 1965
3. International Harvestor tractor, 1965
   Trailmobile van trailer, 1968
4. Chevrolet 4-door sedan, 1963
5. Oldsmobile convertible, 1962
6. Mercury 2-door hardtop, 1966
7. Oldsmobile 4-door hardtop, 1969
8. Dodge 4-door sedan, 1969
9. Oldsmobile 4-door hardtop, 1970
10. Dodge 2-door coupe, 1965
11. Dodge 4-door sedan, 1966
12. Cadillac 2-door hardtop, 1969
13. Mack tractor, 1966
    Fruehauf van trailer, 1957
14. Plymouth 4-door sedan, 1966
15. Jaguar 2-door coupe, 1967
16. Plymouth 2-door hardtop, 1970
17. Mercury 2-door hardtop, 1969
18. GMC tractor, 1966
    Great Dane van trailer, 1966
19. White tractor, 1965
    Gindy van trailer, 1962
20. Pontiac 2-door coupe, 1963
    U-Haul rental trailer
21. Pontiac station wagon, 1966
22. Ford 4-door sedan, 1966
23. Pontiac station wagon, 1969
24. Mack tractor, 1968
    Strick van trailer, 1969
25. Pontiac 4-door sedan, 1968
26. Chevrolet 2-door hardtop, 1968
27. Chevrolet 2-door hardtop, 1967
*28. Mack tractor, 1961
    Fruehauf van trailer
*29. International Harvestor tractor, 1968
    Trailmobile van trailer

* Vehicles 28 and 29 not involved in collisions or fires.

FIGURE 1

MULTIPLE VEHICLE COLLISIONS AND FIRES UNDER FOG CONDITIONS
On New Jersey Turnpike, north of Exit 2
Near Swedesboro, New Jersey, Nov. 29, 1969
POSITIONS OF VEHICLES AFTER COLLISIONS



10. Dodge 2-door coupe, 1965
11. Dodge 4-door sedan, 1966
12. Cadillac 2-door hardtop, 1969
13. Mack tractor, 1966
    Fruehauf van trailer, 1957
14. Plymouth 4-door sedan, 1966
15. Jaguar 2-door coupe, 1967
16. Plymouth 2-door hardtop, 1970
17. Mercury 2-door hardtop, 1969
18. GMC tractor, 1966
    Great Dane van trailer, 1966
19. White tractor, 1965
    Gindy van trailer, 1962
20. Pontiac 2-door coupe, 1963
    U-Haul rental trailer
21. Pontiac station wagon, 1966
22. Ford 4-door sedan, 1966
23. Pontiac station wagon, 1969
24. Mack tractor, 1968
    Strick van trailer, 1969
25. Pontiac 4-door sedan, 1968
26. Chevrolet 2-door hardtop, 1968
27. Chevrolet 2-door hardtop, 1967
*28. Mack tractor, 1961
    Fruehauf van trailer
*29. International Harvestor tractor, 1968
    Trailmobile van trailer

* Vehicles 28 and 29 not involved in collisions or fires.

Scale 1" = 20'

II. FACTS

A. The Accident

1. Time Factors: The series of collisions and fires began at approximately 7:45 a.m., November 29, 1969. A Turnpike employee at Toll Gate No. 2 was notified of the accident shortly before 7:50 a.m. by a passing motorist. The first State Trooper arrived at the scene about 7:55 a.m., and the final event had occurred before that time.

The total event involved some 12 to 15 primary collisions and an indeterminate number of secondary and tertiary collisions, many of which cannot be isolated in terms of the forces involved or the crash results. Available evidence does not permit a detailed chronological accounting of the total event from start to finish, but six main sequences can be identified. Certain of these will be discussed to the extent that they relate to how and why the accident happened, and what safety lessons may be learned therefrom. Detailed descriptions of accident events not covered in this section are included in Appendix F for reference purposes.

In Figure 1, 29 vehicles have been identified and given identifying numbers which are used hereinafter for reference. Figure 1 shows the final positions of the vehicles, after impacts.

2. Phase 1, The Initial Event: [1/]

At approximately 7:45 a.m., a 1969 Mercury two-door hardtop, Vehicle 17, southbound on the New Jersey Turnpike about a half-mile north of Exit 2, encountered a patch of fog described by the driver as sudden and dense. He had been traveling at 45 to 50 miles per hour, from Exit 4, and had experienced intermittent fog. On entering the heavy fog, he slowed to 30. In his rearview mirror, he saw what appeared to be a large truck approaching rapidly from the rear. He started to accelerate but, before his car could respond, he received a severe blow from the rear which shoved the car forward. He was wearing his seatbelt, but not the available shoulder restraint. He did not recall what happened after this impact, until he was afoot on the east shoulder of the northbound lanes, and said he did not know how he got there.

It was established through laboratory examination of paint samples that the vehicle which struck Vehicle 17 from the rear was Vehicle 1, a commercial carrier, carrying propane, owned and operated by Petrolane-Northeast Gas Service, Inc. It was also determined that Vehicle 17 was

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1/ Details of injuries and of vehicle damage will be presented in later sections under appropriate headings.

contacted a second time by Vehicle 1, which partially overran Vehicle 17. Vehicle 17 was found on the median berm and shoulder, having rotated some 180° from its original line of travel in a counterclockwise direction. (See Figure 2.)

Vehicle 1 semitrailer overturned onto its right side, and the fifth wheel was forcibly separated from the tractor frame. The semitrailer slid to a position about 120 feet south of Vehicle 17, with the propane tank approximately at a right angle to the roadway across the two southbound lanes and the paved shoulder. Tractor 1 had rotated approximately 180° clockwise in a jackknifing movement. It came to rest upright, immediately ahead of and partially under the fore-end of the propane tank.

The driver of Vehicle 1 did not survive; his body was found on the sod embankment just north of the front of Tractor 1.

3. Phase 2:

Vehicles entered the scene immediately following the initial event in this approximate order:

Vehicle 10, a white 1965 Dart coupe, with a driver and one occupant, slowed when the driver entered the heavy fog, and stopped about two car lengths north of the propane unit. Both occupants reported seeing a man lying on the ground just ahead of the propane tractor, bleeding badly. Just as they stopped other cars passed to their left, and crashing sounds could be heard.

When Vehicle 4 entered the scene, the driver slowed because of the heavy fog. He saw the propane tank, and stopped, but said he misjudged the distance and bumped hard enough to damage his headlights and grille. When he stopped, there were two cars to his left, later tentatively identified as Vehicles 2 and 5. The front seat occupant of Vehicle 4 saw a man lying on the ground in the "L" formed by the propane tank and the tractor, and a white coupe north of where the man was lying.

Vehicles 2 and 5 had bumped into the propane tank. When the two occupants of Vehicle 4 left their car, they had to go around the rear of these cars, then on the median to the south side of the overturned propane tank. The driver of Vehicle 4 said a man was in the driver's seat of a blue sedan (Vehicle 2 was a blue Chevy II sedan), slumped over the wheel and appearing to be unconscious.

Vehicle 8, a 1969 Dart sedan with four persons, slowed on entering heavy fog, and stopped on the median berm with its left front against the guardrail. Vehicle 9, a 1970 Oldsmobile sedan with a lone occupant,

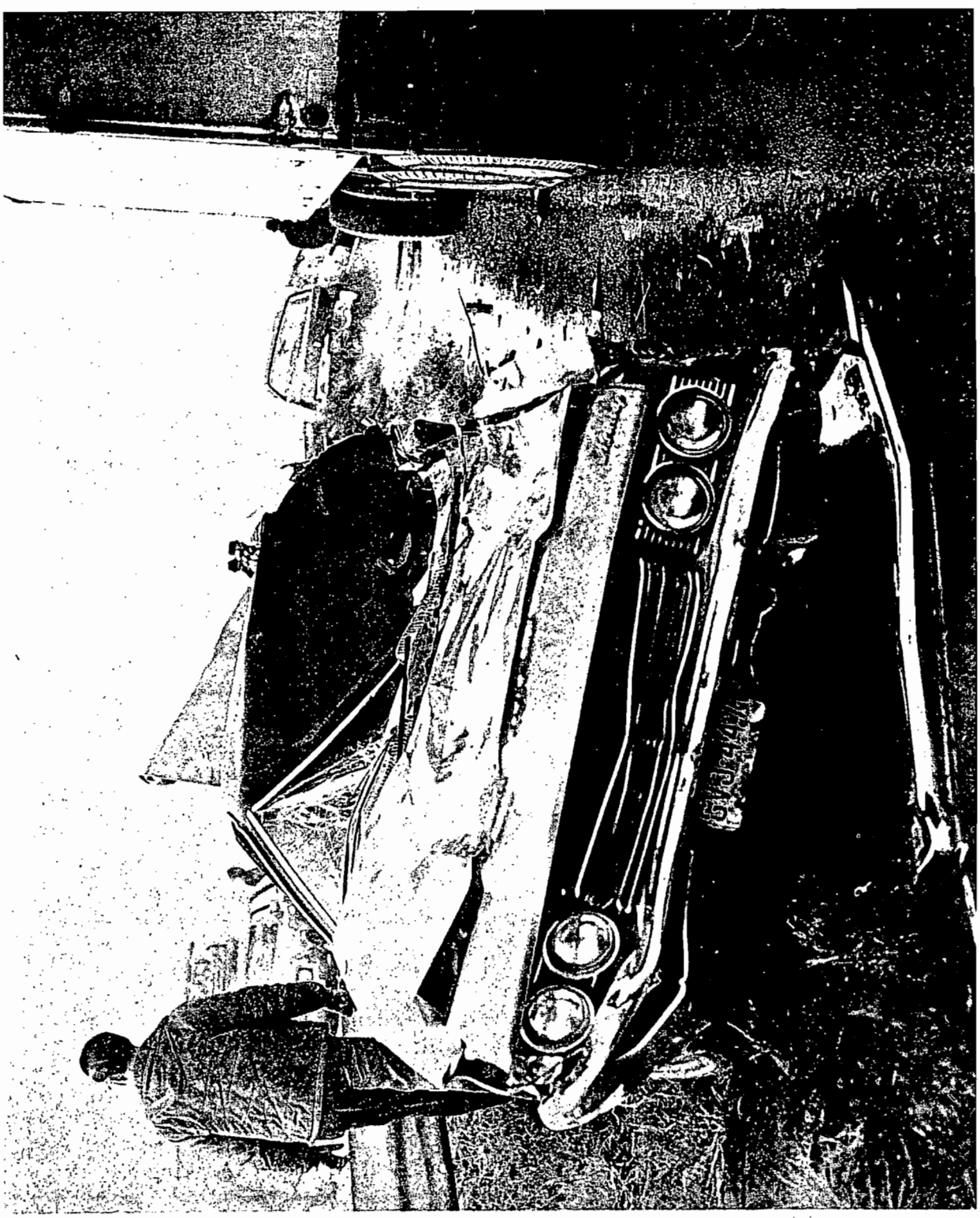

Figure 2. Mercury Monterey (Vehicle 17) facing north alongside median guardrail.

stopped a car length behind Vehicle 8, also on the median berm. All occupants evacuated safely, but a rear-seat occupant of Vehicle 8 had trouble undoing her seatbelt.

Vehicle 6, a 1966 white Mercury two-door hardtop, stopped north of the vehicles which were against the tank, and the driver got out to try to flag down any following cars, while three passengers remained in the car.

This was the scene as observed by a motorist who drive around the propane tractor onto the sod embankment, and continued southward to Exit 2 where he reported the accident to a toll collector. He described the fog at the scene as heavy, with visibility about 20 feet.

4. Phase 3:

Vehicle 13, a tractor and semitrailer private carrier came into the scene in the left lane, and the driver saw stopped cars ahead in the fog. He applied brakes and swerved left. His vehicle crashed into Vehicle 9, which went forward and bumped Vehicle 8. Vehicle 13 stopped about 50 feet north of the overturned propane tank, in the left lane.

By this time, 12 passengers cars, plus a tractor and semitrailer had accumulated in the area just north of the overturned Vehicle 1. Two drivers were in their cars, appearing to be unconscious, and at least five other occupants who could have left their cars had not done so. A fire was observed in progress near the forefront of these cars, and a man appearing to be severely injured, or dead, was lying near the front of Vehicle 1 tractor.

5. Phase 4:

Tractor-semitrailer 3, with a load of three large diesel engines, approached the scene at 45 to 50 miles per hour. The driver suddenly saw the heavy fog, and just as he entered, he observed two red vehicle lights ahead. He said he applied maximum braking, but crashed into vehicles ahead. The driver and an unauthorized passenger were ejected. Injured, they escaped to safety south of the overturned propane semi-trailer.

The fire which had been observed earlier suddenly spread, to engulf most of the vehicles in the area immediately north of the propane tank. The propane tank was rotated clockwise about 30° following the impact by Vehicle 3. Subsequently, a 7 1/2-inch long semicircular hairline crack was found in the top of the propane tank, about one-third of the distance back from the forward end. As the tank lay on its side, the height of this crack above the pavement approximately equalled the height of the trailer bed of Vehicle 3. It was later found that propane was leaking from this crack. (See Figures 3, 4, and 5.)

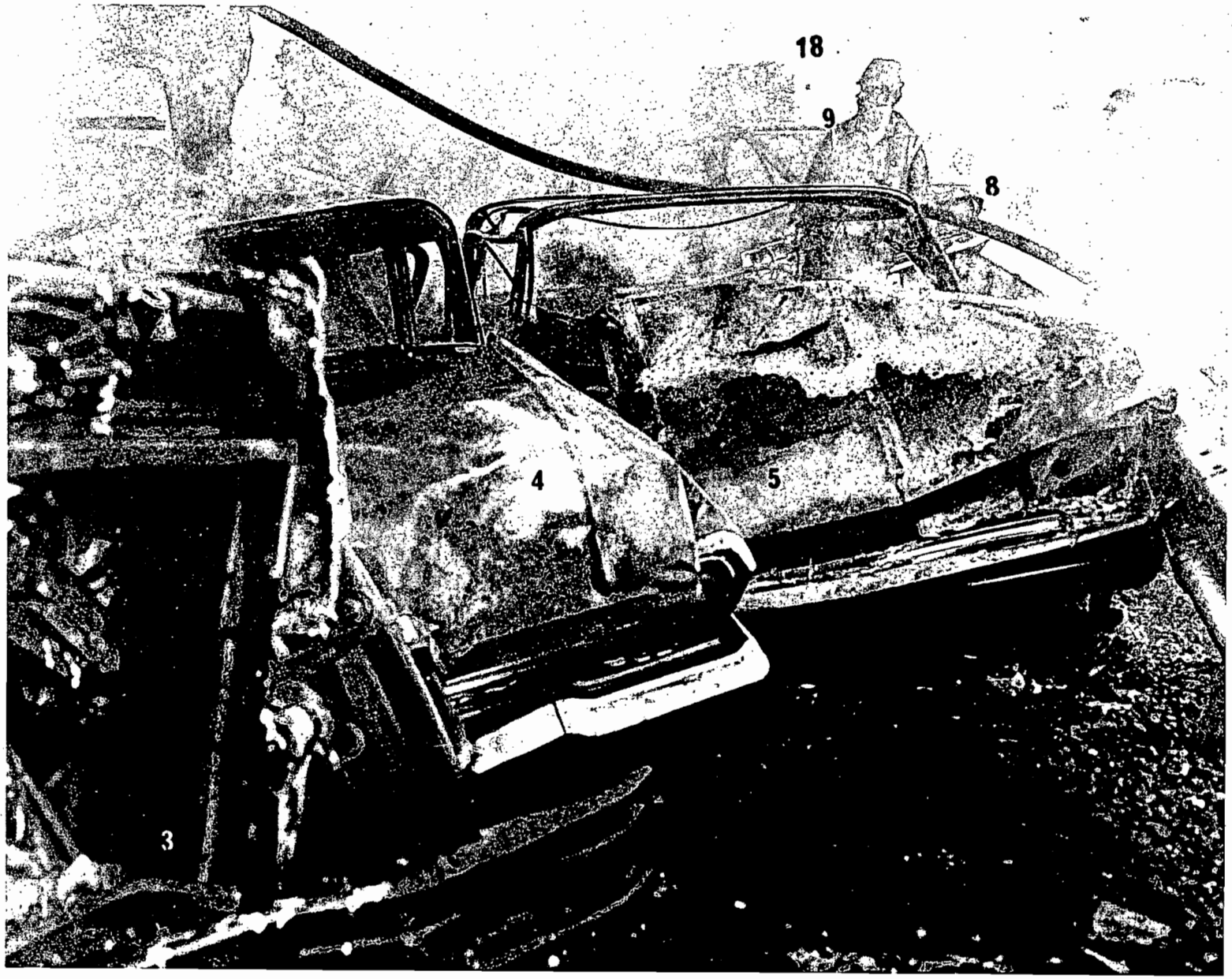

Figure 3. Vehicles 3, 4, and 5, looking north.

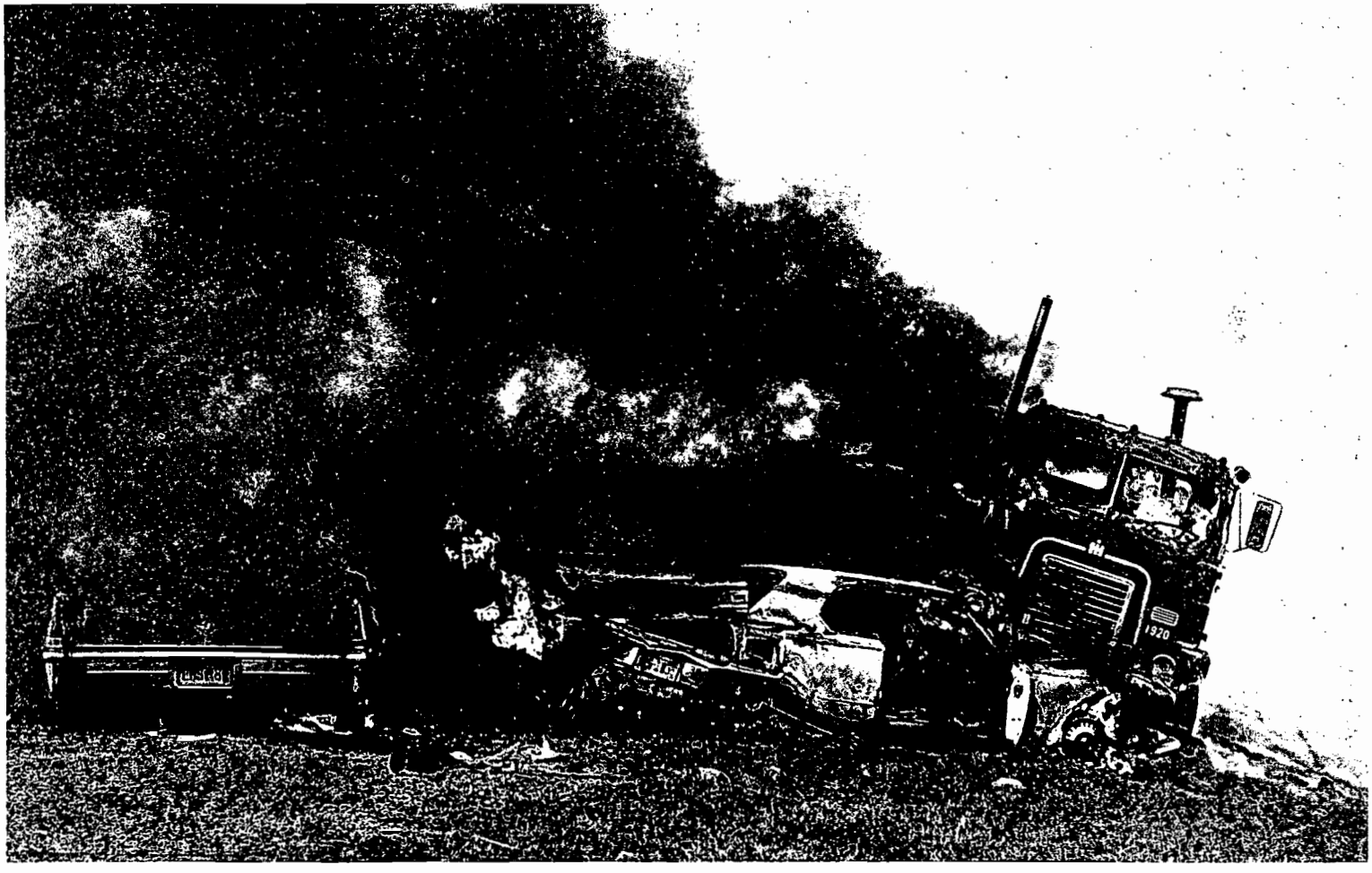

Figure 4. Vehicles 1, 10, 11, and 12, looking south.

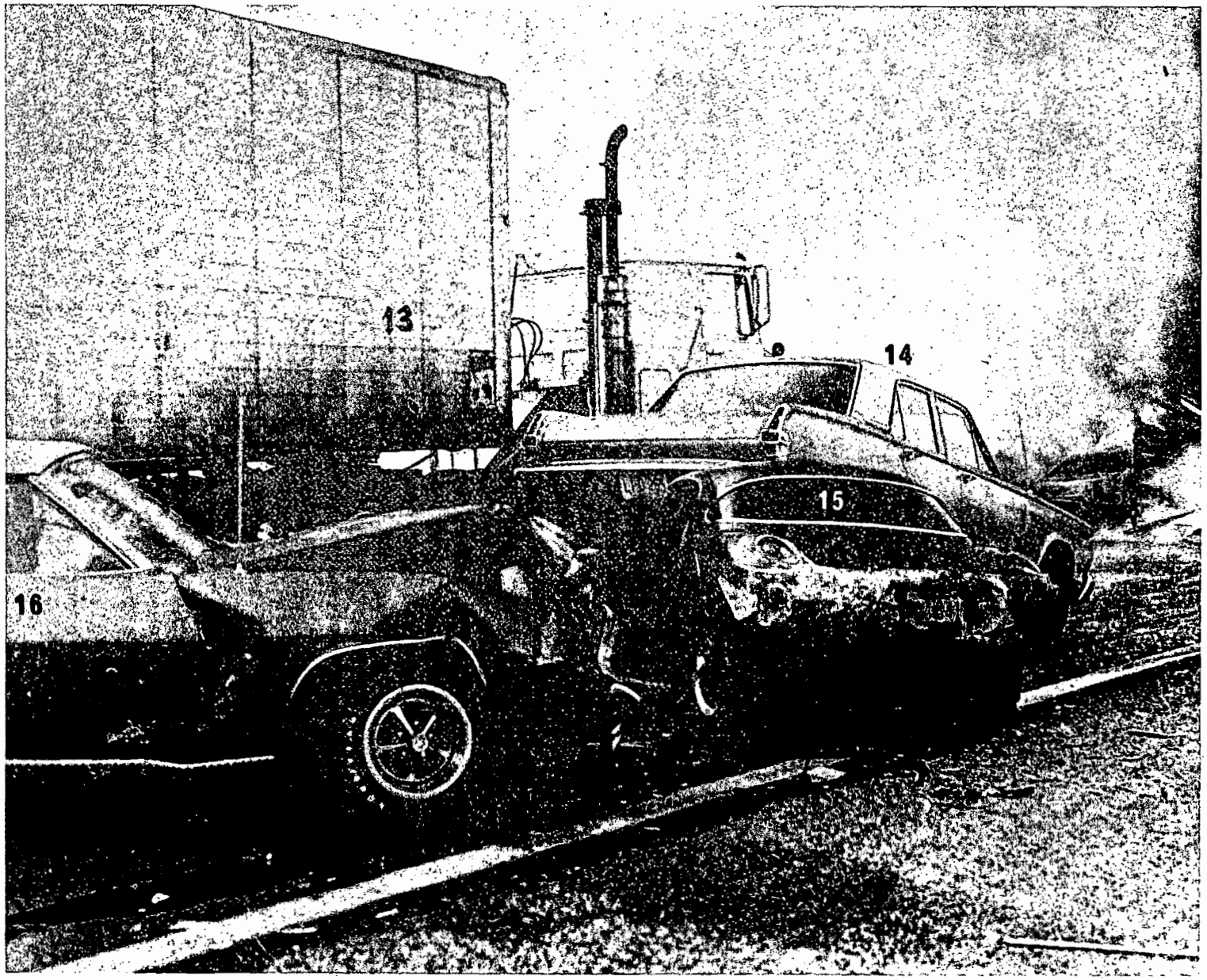

Figure 5. Vehicles 14, 15, and 16, looking south.

6. Phase 5:

Tractor-semitrailer 28 stopped safely a short distance behind Vehicle 16 in the right lane, followed by Tractor-semitrailer 19, which also stopped safely. Also in the right lane, Vehicle 20, a 1963 Pontiac Tempest two-door, towing a small U-Haul trailer with household goods, was seen to stop with its four-way flashers operating behind Vehicle 19. Its two occupants remained in the car, but the drivers of Vehicles 19 and 28 had left their tractors. Close behind Vehicle 20 was a third carrier, Tractor-semitrailer 29, which stopped safely on the paved shoulder area, slightly to the rear of Vehicle 20. (See Figure 6.)

Tractor-semitrailer 18, reportedly traveling at high speed in the right lane, did not stop, and rammed the U-Haul trailer, driving Vehicle 20 partly under the rear end of Semitrailer 19. Tractor-semitrailer 18 swerved left and stopped on the median strip, about 100 feet south of the rear of Vehicle 20.

Almost immediately, Vehicle 20 burst into flames which completely engulfed the vehicle and its two occupants, whose almost completely burned bodies were found in the car. According to witnesses, there were no visible attempts by Vehicle 20 occupants to leave their car before or after the crash.

7. Phase 6:

Vehicle 21, a 1966 Pontiac station wagon, stopped in the left lane. Vehicle 22, a 1966 Ford Fairlane, stopped safely behind Vehicle 21. Vehicle 23, a 1969 Pontiac station wagon, took evasive action to the left onto the median, and grazed the guardrail. Behind it, Vehicle 25, a 1968 Pontiac Bonneville sedan, also stopped on the median.

Tractor-semitrailer 24, in the left lane, unable to stop, slightly bumped the left rear of Vehicle 22, pushing it forward into Vehicle 21. Vehicle 24 then swerved left and pinned Vehicle 25 between its semitrailer and the median guardrail. Of 22 persons in these five vehicles, only two were slightly injured.2/ (See Figure 7.)

B. Description of the Accident Scene

1. The Highway:

This series of collisions and fires occurred in the southbound lanes of the New Jersey Turnpike, near Milepost 13.5, approximately one-half mile northeast of the overpass of State Route 322 which serves Exit 2 of the Turnpike.

2/ A complete roster of all persons involved -- by age, sex, and injury status -- is provided in Appendix A.

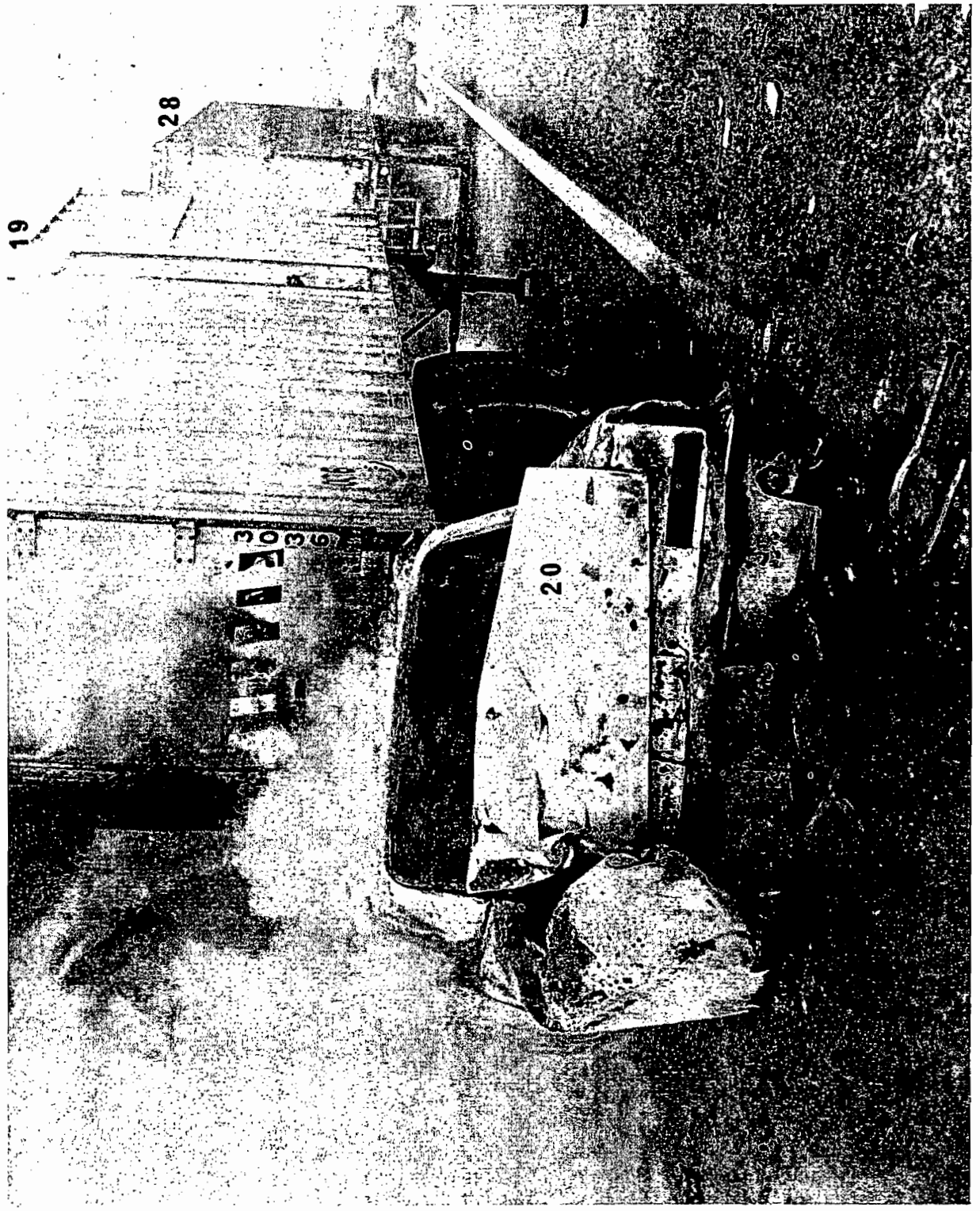

Figure 6. Vehicle 20 in rear of Vehicle 19 Semitrailer.

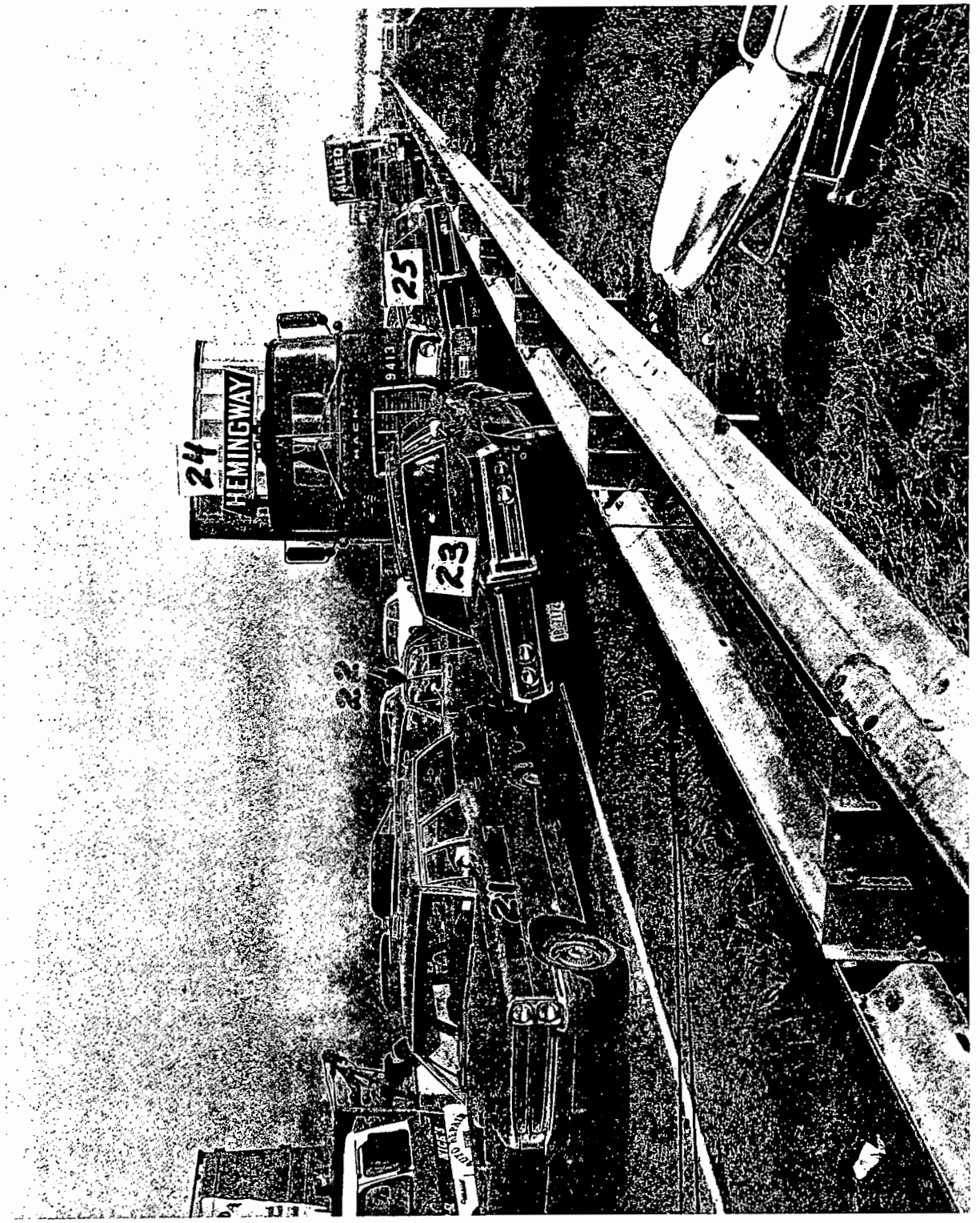

Figure 7. Vehicles 21 through 25, looking north.

The southbound lanes consist of two 12-foot lanes of bituminous concrete, slightly traffic polished, with an estimated skid number of 65, dry.3/ Approaching the scene from the north, the highway is about 1.5 percent upgrade for about a half mile, then levels somewhat to .5 percent upgrade about a quarter-mile north of the scene.

The right shoulder is of coarse-surfaced bituminous concrete 10 feet wide, terminating in a graded, sod embankment which slopes down to the northwest at about 20 to 25 percent. About 25 feet beyond the shoulder, the slope ends in a ditch which drains to the northeast; beyond this ditch the embankment slopes up again and is terminated at a property fence, some 65 feet west of the shoulder's edge. There is no guardrail on the right side at this point.

The left shoulder is of coarse-surfaced bituminous concrete about 5 feet wide, beyond which is a raised grassy berm which rises beyond the shoulder and levels off at a height of about 15 inches above the shoulder. The grass median is about 8 feet wide, from the left shoulder edge to the center of a double median guardrail.

All elements of the highway were in good condition, and either met or exceeded applicable standards of the American Association of State Highway Officials (AASHO), on which Federal standards are based. The raised median berm is a holdover from the original design when the Turnpike was built, in 1949, which did not provide for a median barrier. It does not conflict with AASHO standards.

2. The Environment: The maximum elevation in this area is about 110 feet (mean sea-level datum). Numerous low-lying areas, characterized by marshy ponds and fields, were still soaked from a rainfall a day or two before the accident. Ground temperature was above freezing.

The New Jersey Turnpike Authority receives, under contract, weather forecasts from the Northeast Weather Service at 8:00 a.m. and 4:00 p.m. every day of the year. During adverse weather, reports are automatically received every 4 hours.

3/ The "skid number" is one means to describe the average resistance of a pavement to skidding, with average tires. It is obtained by measuring the horizontal braking force on a given wheel (or wheels) and dividing this by the weight carried by that wheel (or wheels). The factor derived, coefficient of friction, is multiplied by 100 to obtain the skid number. In this accident, no actual skid tests were made by the police or by other investigators. The estimate shown is based on pavement descriptions provided in "Traffic Accident Investigator's Manual for Police," J. S. Baker, et al., Northwestern University Traffic Institute.

On November 29, 1969, at 3:00 a.m., the State Police central control dispatcher requested a weather forecast because of reports of fog at the northern end of the Turnpike. The Northeast Weather Service teletyped back the following weather report:

> "This ground fog will hold over that area (northern sections) until 8:00 a.m., to 8:30 a.m. Further ground fog development is expected elsewhere. Willow Grove in Pennsylvania is now down to 2 miles and clear skies over the remainder of the Turnpike will allow this to form in other places as well. For the rest of the night have patchy ground fog developing, with visibilities dropping to 1/8 to 1/2 mile over short distances over the remaining districts. Improving conditions to non-critical levels will occur 8 - 9 a.m."

The next report from Northeast was received at 8:00 a.m., on November 29, 1969.

Weather reports from nearby airports indicated that conditions were conducive to the formation of ground fog. The Philadelphia Airport (7 miles northeast) recorded the following at 7:55 a.m.:

> "Visibility 1 1/2 miles, temperature 31°F., dew point 26°F., wind 350° 5 knots."

The Greater Wilmington Airport (19 miles west-southwest) recorded the following at 7:56 a.m.:

> "Visibility 1 mile plus, temperature 30°F., relative humidity 93%, wind 300° 6 knots."

Witnesses who used roads near the Turnpike reported variable fog conditions, with extremely limited visibility in places. Persons involved in the early phases of the accident reported light to moderate intermittent fog, with clearer spaces in between, some miles north of the scene. At the scene, fog was described as suddenly becoming "very heavy," or "like a blanket," with visibility ranging from 50 feet to as low as 20 feet in places. Fog density was not constant, and varied with location and time. People involved in later phases of the accident reported less density. The police and other official personnel who arrived afterwards said that visibility was several hundred feet while they were south of the scene.

At the public hearing, experts testified that fog is not predictable to a certainty, but that its likelihood is predictable. When the dewpoint and air temperatures approach each other, fog is

likely to result. It is thus possible to "predict" fog by extrapolating the closure rate at which these two temperatures are changing. Conditions varying along a highway will affect the variability of local fog conditions.

3. Traffic Controls: Traffic controls consisted of the following:

(1) Lane markings and delineators, (2) median guardrail, (3) a system of variable advisory signs at the Turnpike entrance booths, (4) a system of hazard-warning signs, and (5) a system of variable speed-limit signs.

The outer edges of the highway are marked with solid 6-inch white lines. Lanes are separated by an intermittent 6-inch white line with 25-foot segments and 25-foot intervals.

Reflectorized delineator posts, spaced at 150-foot intervals, mark the outer shoulder edge and median guardrail.

A double-band steel guardrail provides a median barrier atop the berm. This guardrail is constructed of standard "W-beam" rails, 12 feet 6 inches long, mounted on 6-inch standoff blocks and supported by 6-inch wide steel I-beam posts embedded about 3 feet 8 inches into the soil. Rails are of 10-gauge galvanized steel. The top edge of the W-beam rail is about 24 to 26 inches above the crest of the berm. When the median barrier was installed (1960-1961) the berm was not regraded, but weather and traffic have somewhat eroded the original sharp upgrade of the outer berm edge. From the face of the barrier to the left traffic lane is slightly over 12 feet.

Following the accident, it was found necessary to replace about 10 sections of median guardrail. Individually damaged sections were directly adjacent to Vehicle 5, a section just ahead of Vehicle 17, several sections approximately 30 to 60 feet north of Vehicle 17, and four continuous sections approximately 100 feet north of Vehicle 17. These four sections had been distorted about 18 to 24 inches eastward, with the posts bent and distorted eastward and slightly southward. No attempt was made to correlate damaged guardrail sections with specific vehicles, and the damaged (replaced) sections were not marked or preserved for study.

Advisory signs at Turnpike entrances consist of a number of condition notices capable of showing the existence of adverse conditions and their location along the Turnpike, controlled by personnel at the entrance booths. These are set in accordance with reports initiating in the field, to agree with specific hazard-warning and speed-limit-reduction signs in trouble spots.

The New Jersey Turnpike Authority maintains an electronically controlled system of hazard-warning and speed-limit signs for the purpose of advising motorists of adverse conditions and speed limits considered appropriate to those conditions. The hazard-warning signs can be activated to display, in red neon, any of the following sets of words: "Drive Slow," "Snow," "Ice," "Fog" or "Accident," "Ahead." The matrix speed limit signs display the normal speed limit of 60 m.p.h. in red neon, and can be set from 55 miles per hour to 30 miles per hour in 5-mile decrements.

There is a combination hazard-warning and speed-limit sign within 1 mile of entry from each interchange and service area, with a maximum spacing of every 5 miles. There is a total of 75 hazard-warning signs and 80 speed-limit signs on the Turnpike system. The last sign north of the scene (for southbound traffic) was about 2.4 miles north -- or 2 1/2 minutes driving time at 60 miles per hour.

These signs are triggered by tone-coded radio signals from New Brunswick, and are activated or deactivated only at the request of the New Jersey State Police who patrol the Turnpike.

At 7:21 a.m., while in the vicinity of milepost 4.5, some 8 miles south of the accident site, Trooper Winkler observed decreasing visibility and requested the activation of all the signs between Toll 1 and Toll 2, located at mileposts 1, 5, 9, northbound, and 4 and 9 southbound. They were activated at 7:23 a.m., 7:25 a.m., 7:26 a.m., 7:28 a.m., and 7:30 a.m., respectively, to read "Drive Slow Fog Ahead" with a reduced speed limit of 50 m.p.h. These changes did not affect southbound traffic north of the accident site. All signs north of Gate 2 showed no hazards, and speed limits were set at 60 miles per hour.

4. Traffic Supervision:

The State Police is the traffic supervision agency on the Turnpike. The determinations of the number of police assigned to an area, and the length of various patrol beats, are arrived at by mutual agreement between the State Police and the Turnpike Authority.

Factors such as traffic volumes, frequency of traffic accidents, requirements of traffic enforcement and services are taken into consideration in the determination of patrol beats. Patrol beats which can be traversed in 30 to 45 minutes are considered optimum on the Turnpike.

The patrol area where the accident occurred extended from Milepost 0 to Milepost 17 -- a 34-mile total beat. The "ideal" patrol time for this beat is said to be 34 minutes. The trooper had passed the accident site at four different times during his tour, the last time about 40 minutes before the accident, and found no fog problem there.

Enforcement Under Adverse Weather Conditions. The basic rule on speed -- prima facie speed limit -- of the State of New Jersey applies on the Turnpike (N.J.S.A. 39:1-1). This rule states essentially that the driver is responsible for controlling the speed of his vehicle in accordance with certain specific hazards, and in accordance with the then existing conditions, for example, of traffic and weather. When adverse conditions are not present, it is prima facie lawful to operate at a speed not exceeding the speed limit designated by the Authority, when appropriate signs giving notice of such speed are erected and posted.

No criteria are established (in New Jersey statutes or in the Uniform Vehicle Code) as to what specific conditions of traffic or weather are necessary to require a speed lower than that posted, and what speed shall be permissable. Thus, a legally "safe" speed is essentially a matter of each individual driver's judgment. Enforcement of such general rules poses problems to law enforcement agencies and the courts.

Of 14,062 moving traffic violations cited by the State Police on the Turnpike in 1969, 424 were for "careless driving," including an estimated 282 citations (2 percent) for driving without due caution in adverse weather conditions. The data do not show breakdowns or analyses which would indicate the specific ranges of "safe" visibility (for example), or the specific acts which comprised "driving without due caution." Typical law enforcement experience is that such general rules are enforced almost entirely as the result of an accident in which no specific violation can be cited, rather than as actions taken by the officer in "on view" enforcement of driving behavior.

Personnel: The Moorestown State Police troop had a total roster of 32 in November, 1969, including five command and supervisory officers and 27 troopers. Personnel assigned to special details are available to augment the regular patrol force when needed.

The State Police employ a Standard Emergency Fog Procedure as a guide for action when hazardous fog conditions materialize. It sets forth procedures to be followed, with criteria for activating the appropriate hazard-warning signs and for reducing speed limits in accordance with the existing visibility. Three fog conditions are defined: Light, Medium to to Heavy, and Dense. Visibility range is defined in terms of the number of reflectorized delineators (spaced 150 feet apart) a trooper can see ahead when patrolling. It is in chart form, and is based on past State Police experience of safe speeds under various fog conditions.

5. Turnpike Maintenance Department -- Emergency Fog Procedure:

The Turnpike Maintenance Department also utilizes an Emergency Fog Procedure as a guide to allocating personnel and assignments when they are notified by the State Police, for example, when adverse fog conditions

require closing of the Turnpike. The Maintenance Department's central control dispatcher is notified by radio from the New Brunswick police dispatcher as to the existence of any of the three fog conditions, and prescribed operating procedures are then invoked.

When the maintenance crew reported to work at the station near the accident site that morning, they had received no notification from the State Police or anyone else relating to the fog conditions, and hence this unit was not operating under Emergency Fog Procedure.

6. Traffic Composition:

Traffic Volumes: The average daily traffic (ADT) volume between Interchanges 2 and 3, from November 1968 to November 1969, was 23,211 vehicles. These volumes were almost equally divided as to northbound (11,082) and southbound (12,129) flow.

In 1968, 65,930,693 passenger vehicles and 12,695,622 commercial vehicles traveled on the New Jersey Turnpike. Vehicles meeting the commercial classifications constituted approximately one-sixth of the total traffic volume. Of this fraction, trucks account for about four-fifths and buses one-fifth.

7. Fog Accident Statistics:

The New Jersey Turnpike records for the year 1968 indicate that there were 2,034 accidents on the Turnpike. Of these, 30, or 1.47 percent, occurred in the fog. Two of these accidents resulted in one death each. The multiple-vehicle accident under discussion resulted in six fatalities.

8. Enforcement Action Resulting from this Accident:

Three traffic violation citations were issued as a result of this accident. The company operating the propane carrier was charged with exceeding gross weight limitations, but found not guilty. The drivers of Vehicle 3 and Vehicle 24 were charged with careless driving -- speed too fast for conditions. Both were found guilty and fined.

C. Vehicle Identification and Damage Description:

Because of the number of vehicles involved in this accident, no attempt is being made to describe, in narrative form, the damage experienced by each vehicle, with the exception of Vehicles 1, 17, and 20. Appendix B identifies each of the 29 vehicles involved in the series of collisions. Appendix C reflects the damage to the vehicles involved, as observed (or reported) after the vehicles had been removed.

The damage sustained by the propane tractor and tank-semitrailer (Vehicle 1), the 1969 Mercury Monterey hard top (Vehicle 17), and the 1963 Pontiac Tempest (Vehicle 20) is described in detail because of the importance of this information in the overall series of collisions and fires. (See Figure 8, front of Petrolane tractor.)

1. Vehicle 1, Tractor-Semitrailer:

Owner: Petrolane-Northeast Gas Service, Wilton, Connecticut

Manufacturers: International Harvester

Model: DCOF-405, cab over engine (COE)

Date Manufactured: March 15, 1965

Engine: 238HP (6175 N-65)

General: 3 axles, adjustable (sliding) 5th wheel

Gross Combination Weight and Center of Gravity:

Cargo:	9,257 gallons propane @4.230 pounds per gallon	39,160	pounds
Vehicle:	Tare weight	37,180	"
	GROSS COMBINATION WEIGHT. . . .	76,340	"
	New Jersey Intrastate weight limit (GCW)	72,000	"
	OVERWEIGHT	4,340	"
Center of gravity:	(Combined factors for semitrailer 1)	84	inches
	Center to Center of Outside Trailer Tires	90	"
	Critical (Static) Overturn Angle (computed)	28	degrees
	Stability Factor (Resistance to Overturn)	.535	

Figure 8. Front of Vehicle 1 tractor. (The three spots on the left front, near the grille, were the points where blue paint chips were found, identified as from Vehicle 17.)

Damage: The cab of Tractor 1 was completely gutted by fire. The windshield had disintegrated, and about nine-tenths of it was missing. The nature of the fractures and absence of mechanical damage to the wipers and centerpost is characteristic of fire damage rather than impact damage. The left door stop had broken and separated.

The fifth wheel subframe crossmembers had separated on the left side and bent upward. The fifth wheel trunnion brackets were spread and the fifth wheel had separated from the tractor in what appeared to be a clockwise twisting motion, as viewed from the rear.

The right side rail was kinked inward and downward at the point where the center fuel-tank bracket is attached to the frame.

The diesel fuel tank mounted on the right side was crushed downward. Its forward head had separated from the tank shell at the bottom, making an opening of some 6 square inches in area. All the diesel fuel had escaped.

White paint was found on the air compressor pulley and cross-tube support, just aft of the cab on the right side of the tractor. This paint appeared to have come from the forward head of the propane tank.

The tank-semitrailer had separated from the tractor, but the air brake jumper hose, from tractor to trailer, was still attached to both units.

The tractor drive shaft was kinked, and the rear drive axle ("bogie") was locked, prohibiting rotation of the wheels.

Tire scuff marks were found on the outside of the right side rail adjacent to the right rear drive tire. The left rear drive axle spring had pulled out of the rear spring bracket, and the spring rebound clips had broken.

The left side of the bumper was pushed rearward into contact with the left front (steering) tire. The outer edge of the left tire tread was mutilated and torn along its outer periphery.

The steering-gear housing was broken above the pitman-arm shaft bearing and the steering mechanism was locked.

Blue paint transfers were found on several places on the Vehicle 1 tractor: (1) left front tractor bumper; (2) front panel behind the bumper on the left side, just below the outer chrome strip, approximately halfway down into the left of the cab center line; and (3) the outside of both front and rear left drive-axle tires. (See Figure 8.)

Samples of these blue paint transfers were identified through laboratory examinations by the New Jersey State Police as having come from the 1969 Mercury, Vehicle 17.

2. The Tank-Semitrailer, Vehicle 1:

Owner: Petrolane-Northeast Gas Service, Wilton, Connecticut

Manufacturer: Downingtown Iron Works, 1965

Type: MC331, National Board 67221

Capacity: 10,330 water gallons 4/

General: Tandem axles

Dents and Abrasions: A dent approximately 1 foot in diameter was located in the forward head in the 10 o'clock position, as viewed from the front. A heavily scuffed continuous abrasion pattern was found along the entire right-hand side of the tank shell. (See Figure 9.) The pattern was located at the outermost right-hand edge of the shell, more pronounced at the rear of the tank, and passed through the position of the recessed liquid level gauge. The level gauge was not damaged. The right-hand mounted ladder, used by the driver to observe the liquid level gauge, had separated from the mounting pads, required by the Department of Transportation (DOT). The tank shell was not damaged at this point.

On the top of the tank, having the appearance of paint transfers, were three parallel scuff marks extending rearward from the area of the semicircular crack. With the trailer on its right side, the lowest mark was blue, the middle mark black, and the uppermost red.

Crack: (See Figure 10, photograph of the crack in the tank)

A semicircular crack approximately 7 1/2 inches long was found in the top of the tank, approximately one-third of the distance back from the forward head. The crack was directly adjacent to an internal baffle circular mounting-clip pad, 5 inches in diameter, and followed the perimeter of the clip pad for about 180° at the toe of the pad-to-shell weld.

The tank shell surrounding the crack was dented (shell out of round) for fore-and-aft distance of 10 feet and transversely about 2 feet. The deepest indentation was three-quarters of an inch at the crack.

4/ During the month of November, 1969, of 124 deliveries made to Petrolane-Northeast Gas Service, 107 deliveries -- 86 percent -- exceeded the New Jersey legally permissible maximum of 72,000 pounds gross combination weight (g.c.w.). The highest g.c.w. recorded was 79,880 pounds -- 7,880 pounds over the limit. (Invoice 024278 dated 11/19/69.)

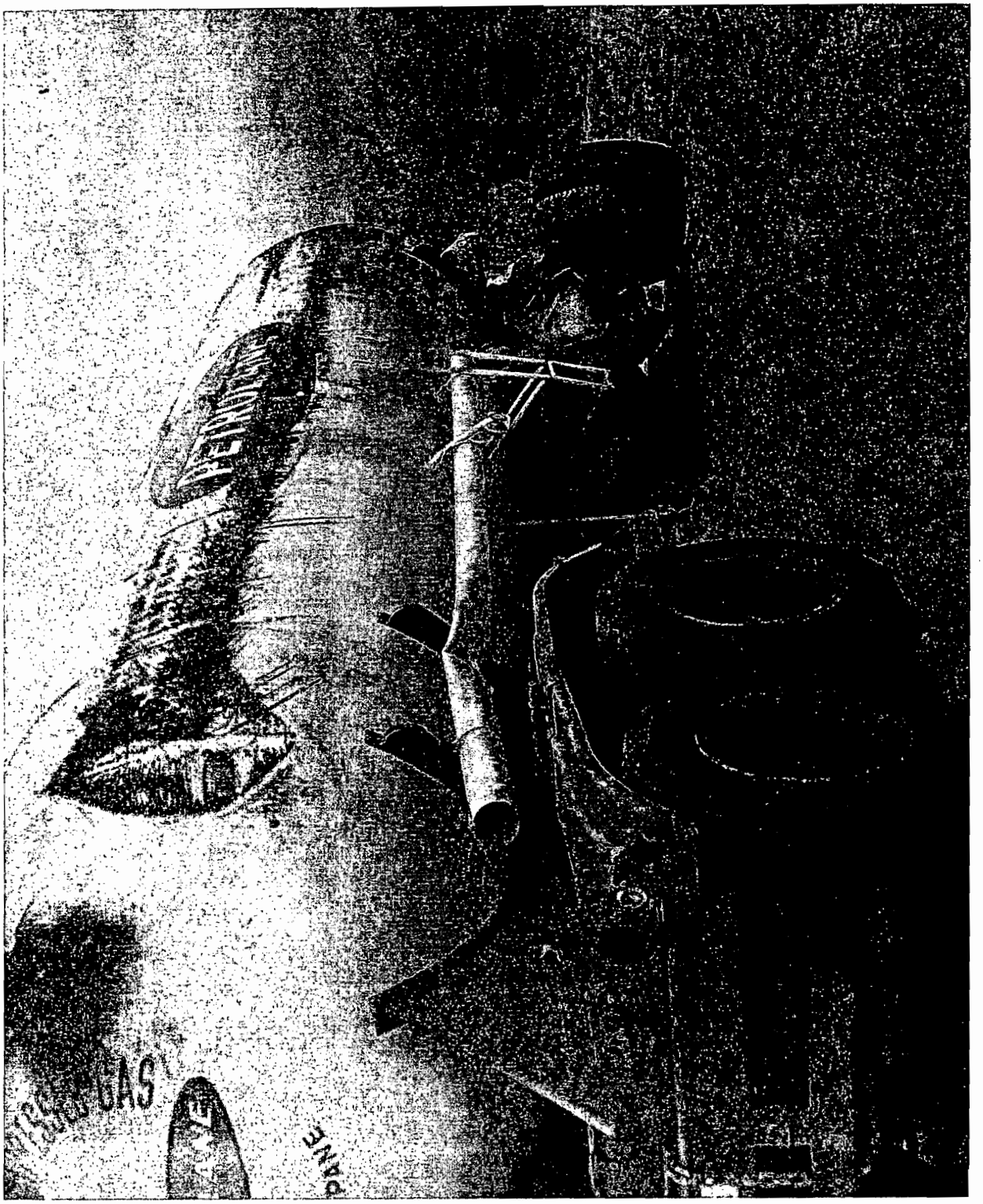

Figure 9. Right side of Vehicle 1 Semitrailer.

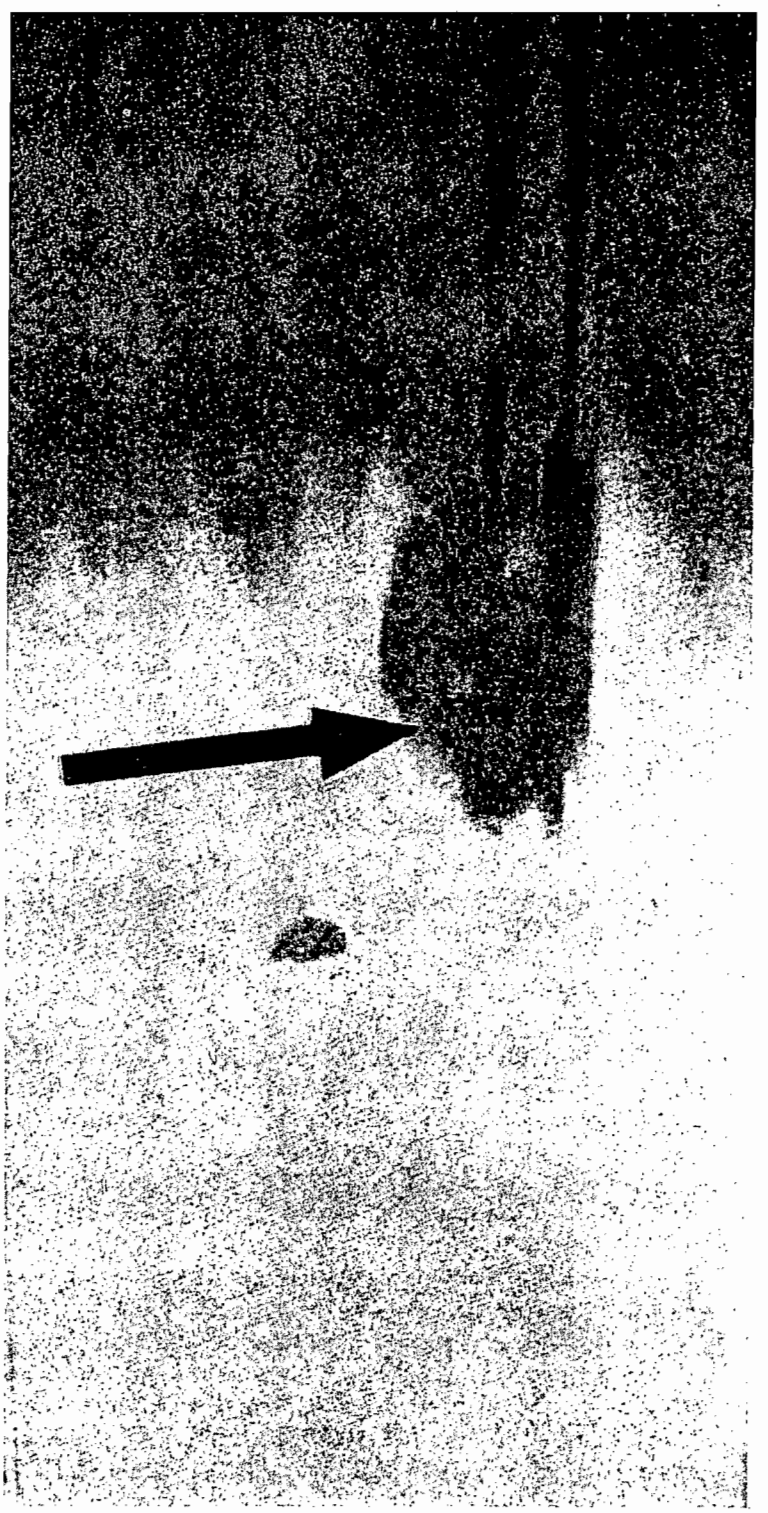

Figure 10. Crack in propane tank, Vehicle 1.

Based on internal baffle distortion (buckling) the tank shell appeared to have been pushed inward more than three quarters of an inch and then sprung back partially to its original configuration.

Other Mechanical Damage: The upper coupler (fifth wheel plate) was bent or bowed slightly at the outer flange edges, right and left, but there was no distortion to the plate itself or to the brackets welded to the tank shell.

The bracket which supports the trailer-mounted fender over the right rear tractor drive wheels was bent rearward.

The hose tube located at the right rear of the trailer was partly crushed and kinked, but not torn loose.

Both the right and left rear fiberglas trailer fenders were damaged.

The vertical structural members from the trailer frame to the rear tank head were bent in a counterclockwise twist, as viewed from the rear.

The suspension on the right side of the trailer was damaged, permitting the right rear tandem wheels to move rearward approximately 1 foot. The forward spring hanger on the right side fractured through the hanger-to-frame weld. The right rear forward shackle pin also broke. The right rear torque rod fractured through the shaft.

There was an inward bend in the right rear outside wheel rim, extending about 2 inches inward at its maximum point.

The support leg (used when the trailer is not hitched to a tractor) on the right side was bent inward and rearward.

Fire Damage: Both the forward and rear tank heads showed surface soot marks on approximately one-half the head, but the paint underneath was not blistered. There was no soot or identifiable fire damage to any part of the main tank body except at the heads. There was no evidence of fire at or near the semicircular crack from which propane had escaped.

Plastic components of the rear signal lamps were partially burned and melted. The wiring to these lamps was also partially burned.

3. 1969 Mercury Monterey, Vehicle 17: The damage to Vehicle 17, a blue two-door hardtop, was as follows: (See Figure 11.)

Rear Body: Severe impact damage the full width of the rear of this vehicle was evident, with the greater forward distortion evident on the left rear. The trunk lid was buckled upward and distorted forward. Rear body components were peeled upward and forward away from the side rails (frame). The rear bumper had been torn off and was missing.

Figure 11. Left side of Vehicle 17. (Two spots on left rear fender, ahead of wheel, mark the places where green paint was found, and which matched paint from Vehicle 1.)

Rear Underside: The left side of the rear axle was distorted forward. The fuel tank mounted forward of the trunk compartment, was partially crushed, severely dented, and perforated. There was a hole about 4 to 6 inches in diameter in the right rear tank wall.

The tank-support mechanism no longer held the tank, and it was held in place only by the fuel-gauge wiring. The right-hand support strap was missing entirely, but neither of its attachments was damaged. The left-hand strap had become unhooked at the rear end, where a T-shaped hook engages a slot in the vehicle body. The tank was found resting on top of the transverse track arm (sway bar). The fuel-tank filler spout, which is assembled by being forced into a rubber-type grommet in the end of the tank, had pulled out of the grommet, leaving an opening in the left end of the tank. The fuel tank had rotated along its lateral axis so that the forward tank wall was at the top.

The right-hand side of the rear axle housing separated from the differential housing at the point of weld.

The right rear coil spring was dislodged from its normal position. The right rear shock absorber had been extended to the point where the two halves had separated. Both side rails had buckled upward and forward where they are curved to go over the rear axle.

Left Side: The left door was missing. The door locking pin which is mounted on the rear door post (B-pillar) was gouged and buckled. Vertical tire scuff marks made by a tire larger than a passenger-car tire were found on the outer face of the left front fender. Two horizontal gouges were on the forward face of the left rear fender, with metal having been displaced rearward. These gouges matched in dimension the top and bottom flanges of a truck bumper. The left B-pillar was bent slightly rearward and inward. Rubberlike deposits were found at the top and bottom of the B-pillar.

Top: On the hood of the vehicle was a swirly deposit (or rotary scuff) of rubber. The left-hand windshield post (A-pillar) was pushed rearward and inboard. The forward and left side of the roof was distorted severely, rearward and downward.

Right Side: The right rear fender had buckled forward, as from an impact from the rear. There was minor rearward buckling of the right front fender. The right door and glass were not damaged, and operated normally.

Front: There was relatively minor damage to the lower half of of the bumper. The grille and headlamps were in almost normal condition. One photograph showed the headlights still on after the accident. The left front suspension (A-frame) was out of alignment.

Drive Shaft: The exposed tubular drive shaft was longitudinally distorted, but had returned almost to its original alignment. There was circumferential scoring and perforation of the shaft tube at a point directly below a seatbelt anchoring bolt which extended through the floor pan into the drive-shaft tunnel. The bolt showed fresh thread damage and a slight bend. (See Figure 12.)

Interior of Vehicle: The dash and instrument panel were distorted downward on the driver's side. The steering column was bent downward and the steering wheel forced down into the horizontal seat cushion. The wheel rim was bent inward. The backrest of the driver's seat was distorted rearward with a permanent displacement to about 30° above the horizontal. Granules of broken glass were observed to be in every seam of the upholstery of the driver's seat and backrest, and in the floor carpeting in that area. The seatbelt of the driver's seat was undamaged. (See Figure 13.)

4. 1963 Pontiac Tempest, Vehicle 20: This vehicle, a two-door sedan, was pulling a U-Haul trailer, van-box type, medium size, with single axle.

Damage: When found, the front end of Vehicle 20 was under the rear of Trailer 19. The entire front end was severely crushed and distorted rearward, back through the windshield. The hood, upper engine components, and right front fender were completely crushed. (A drawing showing the related dimensions of the front of Vehicle 20 and the rear of Trailer 18 is in Appendix D.)

Severe impact damage was found at the left rear fender area, which had been distorted forward and to the right. The trunk was crushed forward, more at the left side than at the right, and the trunk lid was sprung upward and to the right. (See Figure 6.) The left rear frame and bumper were distorted forward and to the right. Both doors appeared to have been jammed. The right door was forcibly removed to extricate the burned bodies of the two occupants.

The U-Haul trailer towed by Vehicle 20 was demolished and its contents spread over a wide area. Its axle had separated from the frame, and the wheels had separated from the axle.

Photographs, taken at the scene before Vehicle 20 was moved, show its fuel tank appearing to be separated from the vehicle, and lying directly below its normal mounted position. After Vehicle 20 was moved, the tank was no longer with the vehicle. A tank believed to be from Vehicle 20 was located. It had been pierced, bent, dented, and was no longer capable of holding liquid.

Eye witnesses said Vehicle 20 was engulfed in a ball of flame when it was struck in the rear and driven forward. All combustible materials -- upholstery, tires, consumable contents, paint, etc. -- had been consumed by fire, and all glass and soft metal components had been destroyed.

Figure 12. Driveshaft and portion of driveshaft tunnel, Vehicle 1.

Figure 13. Driver's seat of Vehicle 17.

Figure 14 shows part of the contents of Vehicle 20's trunk compartment, including a number of aerosol-type containers and a large rectangular can of the type commonly used to carry engine oil. The smaller cans indicated no mechanical damage, and the rectangular can showed signs of distention. Its spout fittings appeared to have been melted away by heat. There was no indication of what any of these containers might have held.

5. Vehicle Pre-Crash Condition:

No conditions were found to indicate pre-crash failure of a safety-related component (brakes, tires, steering, etc.) and no testimony was developed which would lead to a suspicion that a pre-crash failure had precipitated any crash event. However, operational tests were not made of those vehicles which were driven from the scene, and pre-crash operating condition could not be determined for those vehicles severely damaged or destroyed by impact and fire.

6. Summary of Vehicle Damage:

See Appendix C for a brief summary of vehicle damage.

7. Fuel-System Damage -- A Summary:

A number of vehicles suffered damaged fuel tanks, separated filler spouts, or loss of hanger supports -- both crash and fire-induced. For example:

Vehicle 1 -- 100-gallon diesel fuel tank split at bottom, and fuel escaped;

Vehicle 2 -- fuel tank crushed and filler pipe crushed and dislodged;

Vehicle 4 -- fuel tank crushed and filler pipe separated from tank;

Vehicle 6 -- fuel tank damaged and filler pipe separated from tank;

Vehicle 7 -- filler pipe not damaged but separated from tank;

Vehicle 10 -- fuel tank damaged and filler pipe separated from tank;

Vehicle 17 -- fuel tank damaged, hanger straps broken or dislodged, and filler pipe separated from tank (no fire involved);

Figure 14. Part of contents of Vehicle 20, in trunk compartment.

Vehicle 20 -- fuel tank damaged, hanger straps broken or loosened so that tank was not retained on vehicle, and filler pipe separated from tank. (See Figure 15 for examples of fuel-tank and filler-pipe damage.)

Fuel-tank damage to passenger cars involved piercing-type ruptures, rips, and general distortion, in many cases showing marks which appear to have been impressed by, or through, adjacent components such as frame members, sway bars, or differential housings. One common condition was distortion at filler-pipe entrance holes or fittings. A general observation was that fuel-tank material ductility allowed considerable deformation before rupture or puncture occurred.

Filler-pipe damage involved mechanical disengagement from the fuel tank, with considerable crushing appearing to have been transmitted through the component (fender, rear body panel, etc.) adjacent to the filler opening or through which the filler pipe was routed. In some cases, there was melting of the soldered connection without obvious mechanical load applications.

Tank-support damage involved the fracture of support straps and/or the disengagement of strap or strap anchor ends, evident where there had been marked distortion to rear frame members, or trunk floors. Where straps broke, or became slack and disengaged, tanks were no longer restrained.

Miscellaneous damage to fuel systems, such as fuel lines, fuel pumps, and carburetors, could not be identified or catalogued because of extensive destruction from mechanical or fire sources. Many of the impacts were of such nature and force as to suggest spillage of fuel from these various components, but conclusive evidence could not be found.

8. Fire Damage and Sources of Fire:

When seen by the State Police and by fire officials, each burning vehicle could be considered a separate fire. These were in three general areas: one at each side of the highway, southbound in the area just north of the propane carrier, and another some 75 yards upstream (Vehicles 19 and 20).

On the left side of the highway, southbound, were six passenger cars, the tractor and semitrailer of Vehicle 3; on the right side, were three passenger cars and the tractor of Vehicle 1 -- all completely burned except for Vehicle 1 tractor, which was gutted in the cab, and its right front tire and fender were burned away. In the area 75 yards

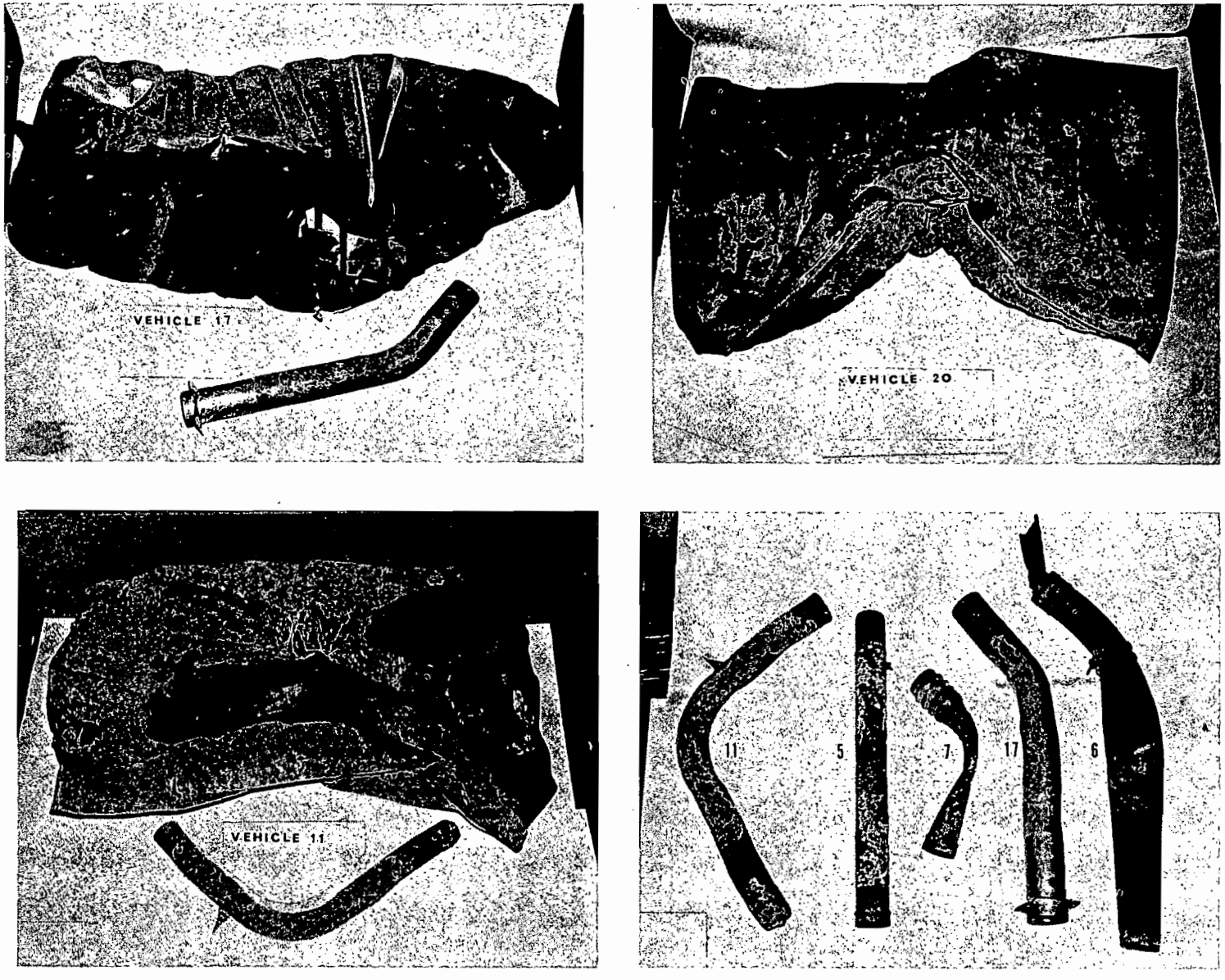

Figure 15. Various fuel tanks and filler spouts.

northward, one passenger car and its U-Haul trailer were completely burned, and the rear of Trailer 19 (and some contents) partially burned. In all, 10 cars -- one semitrailer and one U-Haul trailer -- were completely destroyed, and one semitrailer and one tractor cab were damaged by fire.

Ignition sources for these fires are not known. Several potential ignition sources were available, such as: automotive ignition systems, batteries, and/or electrical circuits; sparks from metal-to-metal, or metal-to-pavement, friction during collision impacts; hot exhaust systems; and static electrical discharge.

There were various fuels available to propagate and to feed the various fires, including the following:

Gasoline: In the area just north of the propane semitrailer, on the left side of the highway, the fuel tanks of four cars were damaged and lost fuel, and in two other undamaged tanks the fuel was burned or boiled away. On the right side, two cars lost fuel in crashes. These cars are estimated to have averaged 10 gallons of gasoline in their tanks at the time of the accident.

In the area 75 yards upstream, one car fuel tank lost its fuel in the crash.

In the initial crash event, Vehicle 17 lost its fuel from a crash-damaged tank, but no fire was involved.

Diesel Fuel: The content of one 100-gallon diesel fuel tank (Vehicle 1) escaped due to tank damage, and the contents of two 80-gallon tanks (Vehicle 3) escaped or burned away.

Propane: When measurement was taken 15 3/4 hours after the accident, it was calculated that 197 gallons of propane had escaped from the propane tank-semitrailer, Vehicle 1. This would represent an average loss rate of about 12.3 gallons (or 440 cubic feet of propane gas) per hour. Some witnesses indicated that what appeared to be ice had formed on the propane tank near the crack, and that liquid was dripping onto the ground below. Material, which may be ice or fire-extinguishing foam, appears in some of the photographs of the tank in the location of the crack.

Other Flammable Materials: In addition to the liquid fuels, other combustible materials were available to contribute to the total fire, such as: automotive plastics and fabrics from car interiors, automotive paints, wiring, lubricants, tires; personal belongings and contents of vehicle trunks containing clothing and luggage; cargo,

shipping materials, and dunnage from one semitrailer. Extensive erosion of the roadway surface where major fires had occurred suggests that some components of the paving materials also contributed to the total fire.

D. Drivers and Occupants

1. Driver Information:

The background information on the drivers of six commercial vehicles involved in this series of collisions is set forth in Appendix 1.

No detailed background data was developed on the private automobile drivers. The driver of Vehicle 17 said he had been involved as a noncontact unit in an accident on the New Jersey Turnpike, similar in some respects to the accident in this report, approximately 14 months earlier. He considered himself to be sensitive to driving in fog conditions as a result of this experience.

No driver had reportedly traveled a distance which would be considered as exhausting. One driver (Vehicle 5) had intended to take the Pennsylvania Turnpike westward, but told interviewers that he had assumed the New Jersey Turnpike terminated into the Pennsylvania Turnpike, and was not looking for turnoff signs. All other drivers interviewed had driven the New Jersey Turnpike before, and the driver of Vehicle 17 was a regular commuter between Exit 4 and Exit 1.

Of the drivers who appeared as witnesses at the public hearing, and who were asked specifically, none reported having received formal driver training, or special instruction for driving on freeways or in fog conditions. According to police reports, all drivers had current driver licenses. Information as to traffic violations, or restrictions on driver licenses, was not obtained. No evidence was presented to suggest that any driver was affected by fatigue, liquor, drugs, or adverse physical conditions at the time of this accident. The investigating State Police officer testified he did not detect alcoholic odors or appearances in any driver interviewed, and no blood-alcohol tests were administered.

2. Significant Driver Observations:

Four of the drivers had entered the Turnpike within a few gates north of the accident, but 25 had come through from the New York/Newark area, or beyond. Of those interviewed, all had observed the variable fog conditions which prevailed throughout the northern areas, with brief patches of variable fog interspaced with stretches

of relatively clear visibility. All interviewed reported that traffic was light and of mixed consistency, moving normally. None reported seeing any of the hazard-warning signs which are said to be displayed at Turnpike entrance gates during adverse driving conditions, and all reported seeing the neon-lighted, speed-limit signs reading "60" at intervals throughout the Turnpike, with no signs indicating a lower limit. This is consistent with State Police reports.

Individual driver estimates varied as to visibility distances, and the degree of hazard presented by the intermittent fog north of the scene. Some drivers commented that 60 miles per hour was "too fast" in the foggy stretches. Traffic generally did slow down in such places, but reportedly some vehicles continued at undiminished speed. All agreed that the fog at the accident scene was the worst encountered. Those who arrived in the earlier sequences of the overall event tended to describe the fog as being more dense than in descriptions furnished by those involved in the latter sequences. The fog reportedly dispersed about 9:30 a.m.

Time estimates by drivers and occupants were not consistent, and some were in conflict with officially established times. Elapsed time estimates were similarly inconsistent, so that time intervals can only be estimated in some instances.

Few drivers could give more than partial descriptions of people, vehicles, or events. However, many were able to recall specific facts which helped to identify or to explain a given sequence. Concurrent with improving visibility in the latter phases of the accident, events and sequences were more fully described.

Three drivers (Vehicles 4, 6, and 9) reported seeing flames before Vehicle 3 arrived on the scene.

One driver commented on the length of time it took the police to respond and that no effort was made to evacuate persons at the scene, other than the injured. He also indicated that he was kept at the scene until 3:30 in the afternoon, and that about 100 people were standing within 100 feet of the tank truck.

E. Post-Crash Activities:

1. Police Service:

The State Police received notice about 7:50 a.m., from Gate 2 toll collector, that there had been an accident and that the highway was blocked. A radio message sent by New Brunswick (headquarters) to Moorestown at 7:51 was overheard by the trooper on patrol. The taped

log shows that at 7:53 he confirmed the call, saying he was at Toll 1 (the southern end of the Turnpike) and was on his way. He reported that he arrived at the scene at 7:55 a.m. The distance from Toll 1 to the scene is 13.5 miles. When the first trooper arrived at the scene, the situation had changed drastically from what it was when reported to the Gate 2 toll collector -- additional crashes had occurred, major fires were in progress, and six persons had died.

Additional State Police personnel were sent from Moorestown, and a call went out for fire services. No police from nearby city or county jurisdictions were requested; in the opinion of the State Police, they were not needed. Direct support to the police was provided by maintenance crews -- in rerouting traffic and providing logistics support -- in accord with standing operating procedures in emergencies. Local police took over the task of handling excess local traffic which had been diverted from the Turnpike.

Surviving participants and onlookers were reportedly cleared from the immediate crash area, because of the recognized hazard posed by the leaking propane tank and the fires, and to provide room for the operations of rescue, firefighting, and wrecker crews.

Little actual investigation was possible during the immediate postcrash period, because of emergency matters requiring priority attention. Partial statements were taken, and gross measurements were made. Identifications of vehicles and occupants were made at the scene to the extent permitted by circumstances. Others were asked to go to the Moorestown station, where additional identifications and statements were obtained, or were contacted at the Underwood Memorial Hospital, in Woodbury. In all, 11 statements were obtained by police from drivers.

Some time after midmorning, a specialist on liquefied petroleum gas (LPG) from the New Jersey State Police headquarters arrived to take charge of righting and removing the propane unit, Vehicle 1.

A freelance photographer[5/] took many photographs which recorded significant facts before vehicles were moved. Later, police photographs recorded many aspects of the scene and the details relating to certain key vehicles. A drawing of the scene was prepared by police showing the identity and positions of all vehicles.

2. Fire Control:

The New Jersey Turnpike has no firefighting units of its own, but

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5/ E. Robert Sweeten, Ft. Royal, New Jersey, took the photographs in Figures 2, 3, 4, 5, and 6.

has contractual arrangements with local firefighting services. At the initial call for fire service, one company responded, arriving approximately a half hour after the first trooper. Other units were called to assist. Driving to the scene was described as hazardous for some units because of dense fog on access roadways near the Turnpike.

On their arrival, fire units were advised by police of the hazard regarding the propane tank, which could result in a sudden release of cargo if it overheated. Thus, the primary fire-control activity was to cool the propane tank. Since the propane tank was not directly immersed in flame, and its initial temperature had been cool, no problem resulted from overheating of the tank.

The fires had progressed to a point where nothing could be done further to save lives and property before firefighting units could arrive. The main fires were brought under control in about an hour (by 9:30 a.m.) through the use of water, chemicals, and foam. Once the main fires were out, salvage efforts began.

3. Rescue Service:

The circumstances surrounding the postcrash situation voided a need for rescue in the literal sense. By the time police arrived, no persons remained in vehicles or in immediately hazardous positions except the dead. All others, including those seriously injured, had found their respective ways to temporary safety through their own efforts or assisted by other persons in the accident. None of the injured was in critical condition, but three were seriously injured and required hospitalization. Ambulance service was provided by five local service units, and supplemental hospital transportation was proved by turnpike maintenance crews. All of those hospitalized and most of those who required emergency medical service were taken to Underwood Memorial Hospital in Woodbury, New Jersey, some 10 miles from the scene by the most direct route. A few others were taken to nearby clinics. Underwood Memorial Hospital is a key unit in an areawide emergency medical aid plan, and the extra load imposed by this accident did not strain its facilities.

As soon as fire control permitted, rescue teams made car-to-car searches for possible victims. The last two bodies were not found until major cleanup operations were under way, and wreckers were able to separate vehicles in the area where Vehicles 2 and 6 were crushed and overrun.

4. Debris Removal and Cleanup:

When the highway was blocked by this series of collisions, hundreds of vehicles were backed up to Exit 3, some 12 miles north of the accident scene. To restore traffic flow as soon as possible, several sections

of median guardrail were removed so that cars could cross into the northbound lanes, and proceed southward some 800 feet to the first "U-Turn" slot. Cars in the rear of the jam turned around and returned to Exit 3.

Ten wreckers from four nearby towing and wrecking companies responded to the scene. First, vehicles were separated for search and possible recovery of victims, and then towed or dragged to off-highway locations pending removal to storage yards. Some of the vehicles were temporarily pushed off the highway by a front-end loader.

Three mobile cranes assisted in untangling the wreckage in the main impact and fire area, and later raised the propane tank semi-trailer to an upright position. An LPG pressure-tank semitrailer was called to the scene early, in the hope that the propane aboard the overturned semitrailer could be transferred, but the transfer could not be made while it was on its side. About 5:30 p.m., the propane tank semitrailer was righted, and by that time nearly all other debris had been removed. The propane unit was hooked up to a tractor unit and taken to a turnpike dump site 3 or 4 miles north of the scene, where the propane transfer to another vessel was completed at 11:30 p.m. Identifiable vehicles were taken to private storage yards. Unidentified wreckage -- parts, burned contents, and miscellaneous debris -- was loaded on dump trucks and taken to the turnpike dump site.

Two sections of highway were damaged where fires had occurred, but traffic was permitted to resume about 7:30 p.m. when all debris had been removed. Highway repairs, including resurfacing of the burned areas and replacement of some 10 sections of guardrail, were effected 2 or 3 days later.

III. ANALYSIS

A. Factors Related to Environment and Controls:

1. The Fog Factor:

Predictability of Fog: The formation of fog is dependent on a number of meteorological factors, such as relative humidity, air temperature, dewpoint, and wind. The density of fog is influenced additionally by local conditions in the susceptible area when the meteorological conditions are "right," such as topography, vegetation, ground moisture, differential cooling, and air pollution. Drivers testified that fog conditions at the scene varied considerably that morning, and thus any prediction as to the location and density of expected fog would necessarily have been general.

The 3 a.m. report teletyped to the New Brunswick dispatcher by Northeast Weather Service, November 29, 1969, predicted fog which would hold over the northern sections of the Turnpike until 8 or 8:30 a.m. The report made reference to "patchy fog conditions" over the remaining sections, and indicated a range of visibilities which could be expected. The report made no reference to times, locations, or expected fog density over the "remaining" sections. The 3 a.m. report also referred to "visibilities ... improving to non-critical levels...," but did not indicate that visibility was critical in the areas affected.

Had a 4-hour reporting period been instituted, it is uncertain whether such a report would have been any more helpful in evaluating the fog conditions which developed at the accident site.

Supplemental weather data from various nearby airports and recording stations are useful only to the extent that the information can be interpreted; the New Brunswick dispatcher, who receives this data, is not qualified to interpret it.

It appears, then, that weather reports are useful on a general basis but cannot provide specific forecasts for field guidance. Only the trooper on patrol, under the present system, can provide the information on which to base operational judgments which affect hazard warnings and appropriate speed limits.

A current project in Oregon, funded by the National Highway Traffic Safety Administration, is studying the effectiveness of automatic fog-sensing devices for detecting and reporting fog. However, results are not yet available as to their feasibility or effectiveness.

Visibility Range and Illusory Effects in Fog: No standards in general use on high-speed, multilane highways relate to the classification of fog density and visibility ranges. The New Jersey Turnpike guidelines appear to be a practical and simple approach; namely, to base the designation of visibility range on the number of delineators which can be seen ahead. This would avoid the question of actual density, and relate visibility (the important factor) to existing conditions of light as well as of fog. No projects are known which seek to provide highway users with criteria for evaluating visibility ranges in adverse weather; such criteria would be an extremely valuable addition to driver-education and driver-training programs. Unless there is a recognizable object in view ahead, the typical driver has no ready means to determine whether the fog is medium, heavy, or dense. Aircraft pilots use wing-tips as a reference, but car drivers are not trained or advised to use available references in the absence of identifiable roadside objects or vehicles ahead. Had the drivers in this accident been so guided, many more might have slowed to an appropriate speed on entering the denser fog which prevailed at the scene.

The need for visibility range criteria is more significant in the light of studies which show that drivers usually over estimate sight distances in fog -- that which can be seen is generally estimated to be farther away than it actually is. This phenomenon may have been demonstrated in the impact of Vehicle 4 with the propane tank -- the driver of Vehicle 4 said he saw the tank and made a normal brake application, but struck the tank lightly because, he said, he misjudged the distance.

Under some conditions, radiation (ground) fog may be very dense close to the ground, but dissipate at say 5 or 8 feet above ground. Such a condition would enable truck drivers to see other trucks (tractor-semitrailers) ahead without being able to see cars which actually were nearer. Driver 18 said he saw Tractor-semitrailer 19, and swerved left to avoid it, but did not see Vehicle 20 which was right behind Vehicle 19, and struck it.

2. Traffic Controls:

Hazard-Warning and Speed-Limit Signing System: The existing hazard-warning and speed-limit signing system on the New Jersey Turnpike is unique. Its purpose is to warn motorists and other highway users of conditions ahead, through a series of variable message signs.

Testimony at the public hearing revealed that delays can and do occur in activation of the signs in adverse weather conditions. The first delay is in detecting the fog, if a trooper leaves an area just ahead of a developing fog condition. By the time he returns to that area, the condition may have become hazardous. Second, a delay of 14 minutes was experienced in this accident in activating the appropriate signs, once the trooper had informed headquarters of conditions at the scene.

Thus, while the mechanical components of the system may operate effectively, activation of the system is dependent on human observation, judgment, and action. In this instance, the system did not prevent the occurrence of a multiple-vehicle, multiple-fatality collision.

Recognizing the application of the basic speed rule, that drivers must regulate their speed in accordance with conditions, none of the drivers approaching the scene that morning from the north had seen any sign denoting speed limit less than 60 miles per hour, or any warning of hazardous conditions ahead. Drivers thus may have tended to rely on the signs, as their observation and evaluation of the relatively light fog patches which they encountered north of the scene did not prepare them for the suddenness and density of the fog at the scene. However, the net effect of this as an accident-causing factor cannot be evaluated, as drivers could not give a "yes" or "no" type answer as to the effect of the 60-miles-per-hour signs on their driving speeds.

The use of such a system, while serving to aid motorists in driving in safety, poses a special kind of responsibility on the Turnpike system to minimize the opportunity for misleading information to be posted which might trap the unwary or the unwise.

Lane Markings as a Control: Both the solid white outer lane lines and the intermittent white lane-divider lines provided adequate guidance to keep vehicles within lanes. Vehicle alignment on the roadway created no apparent problem, as nearly all drivers were well oriented as to their lateral positions on the highway. One driver, Vehicle 12, was not sure if he stopped on the right shoulder or in the right lane.

One person, occupant of Vehicle 11, reported that she recalled being able to see "only two of the center stripes at a time" as their car entered the dense fog area. This was the only reported instance of using the broken lane-divider lines to evaluate visibility range.

The Median Guardrail: The median guardrail served effectively in this accident in its primary function of preventing the encroachment of vehicles into opposing lanes of traffic. Marked distortion of

several sections of guardrail suggest that it absorbed blows of high energy, which absorption may have prevented the rebound of some vehicles back into the path of traffic.

It is difficult, because of the absence of essential data, to evaluate the effect that the guardrail (and raised median berm) may have had on the directional stability of vehicles impacting at varying angles, and in particular on the control of a vehicle such as the propane tractor and semitrailer. The kinematics of the propane carrier (discussed on page 49) strongly suggest that the tractor or the semitrailer, or both might have partially climbed the median guardrail, and that rebound from the rail could have been a significant factor in the overturn of the tank-semitrailer, Vehicle 1.

3. Police Traffic Supervision and Enforcement:

To patrol the beat from Milepost 0 to Milepost 17, in which the accident occurred, in the "ideal" time of 34 minutes, would require a trooper to maintain a 60-mile-per-hour average speed. If the trooper were to stop to aid a motorist or to investigate even a minor incident, the circuit time would be considerably more than 34 minutes. A trooper cannot assess changing weather conditions at one end of the beat while attending to duties at the other. This was the situation on the morning of the accident, and it did not permit the electronically-activated warning system to perform its intended function. While fog was closing in at the accident site, the trooper was at the southern end of his beat, and thus could not observe the deteriorating visibility as a prelude to making a request to activate the signs.

Available accident/enforcement data do not permit an analysis or evaluation of the effectiveness of turnpike traffic law enforcement. However, it would appear to be desirable to reduce the length of individual patrol beats, and thus increase the frequency of patrol passes of a given point, during deteriorating weather conditions. It would seem reasonable, under such conditions, to give a higher priority to maintaining active patrol, and to "on view" enforcement against violators of the basic speed rule than during normal conditions.

There were indications that because of the pressure of other emergency requirements, the police might have permitted nonessential personnel to remain too close to the overturned propane tank throughout the morning. The high risk presented by the overturned and leaking propane tank should have made it imperative to keep such people at a safe range. Had the tank burst, extensive death and injury might have followed. The issuance of orders alone to vacate an area does not absolve the police of responsibility for such a catastrophic aftermath. Specific planning for such events might include the pooling of police services with local jurisdictions so that extra personnel would be available to enforce evacuation and to secure the scene.

The omission of measurements essential to a reasonably accurate reconstruction of the postcrash scene could have been a serious detriment to analysis of the overall event, had not a freelance photographer taken photographs of many vehicles and their relationships to identifiable features of the scene, to enable obtaining a fairly accurate picture. Because they are in total command, police have a responsibility to obtain essential data, including measurements, which permit a better understanding of how and why the accident occurred, as well as the institution of measures to prevent the recurrence of such catastrophes. Police must obtain such perishable data at the only time it is obtainable -- the early postaccident period -- as soon as conditions permit. The availability of outside police assistance might have allowed the State Police to make essential measurements and to identify pertinent marks on the pavement, guardrails, and vehicles, to improve the quality of analyses and reconstruction.

B. FACTORS RELATED TO VEHICLES:

1. Incompatibility of Vehicles:

There were 21 passenger cars and six tractor-semitrailer combinations known to be involved in impacts. Of the passenger cars which struck other vehicles, three are believed to have struck the overturned propane semitrailer, and some five others are believed to have struck other passenger cars in initial impacts. No deaths are believed to have occurred directly as the result of the impacts by passenger cars.

Of the six tractor-semitrailers involved in impacts, five are known to have struck some eight passenger cars directly, plus at least five others in secondary impacts. One semitrailer was struck by a passenger car shoved into it by a tractor-semitrailer. While no deaths can be proven to have occurred directly in the impacts by tractor-semitrailer combinations, five of the six deaths occurred in vehicles struck or overrun by tractors. These vehicles were subsequently consumed by fire.

(a) Differences in Vehicle Weight: Passenger cars involved in this accident ranged in weight from about 3,000 to about 5,000 pounds. Tractor-semitrailer combinations ranged from 25,000 to 76,340 pounds. This would represent a potential range in weight differential from about 5 to 1 as a minimum, to about 25 to 1 as a maximum. Specific examples would be Vehicle 1 impact of Vehicle 17, approximately 19-to-1 ratio; Vehicle 2 overrun by Vehicle 3, about 19-to-1 ratio; and Vehicle 13 impact with Vehicle 9, about 6-to-1 ratio. Weight (or mass) alone does not tell the whole story of impact damage. In this accident, vehicle speeds at impact are indeterminate for the most part, so that impact accelerations or energies cannot be calculated. However, weight differences do parallel the amount of damage suffered by the various vehicles and was a contributing factor to fatalities.

(b) Differences in Stopping Capabilities: Specific stopping distances or braking efficiencies were not determined in this accident, so that it is impossible to relate individual crashes to individual stopping capabilities. In addition, each crash situation was unique in terms of its specifics as to (1) what each driver saw; (2) the speed of each vehicle; (3) each driver's evaluation of the situation and stopping reaction; and (4) the stopping capability of each vehicle as it was loaded.

However, a recapitulation of overall events shows that of the 21 passenger cars involved, 11 made initially safe stops and three had very light impacts with cars ahead. Another was struck from behind while slowing. Thus, only six of the 21 (28 percent) did not stop in time to avoid a major crash -- for whatever reason.

Of the eight tractor-semitrailer combinations involved, three made initially safe stops, one was traveling at a reduced speed but collided with two separate vehicles ahead because it could not stop in time, and four made heavy impacts into vehicles ahead. Thus, five of the eight (63 percent) did not stop in time to avoid a crash.

These differences may reflect the lower stopping capabilities of trucks as compared to passenger cars at give speeds. The Board has attempted to compare passenger-car stopping capabilities with those of trucks and tractor trailer combinations, but can find no results of tests made by a single agency under comparable conditions. Nevertheless, data which has been found shows substantial stopping differences, indicating much longer stopping distances for truck-semitrailer combinations as a class, than for automobiles as a class.

(c) Differences in Vehicle Dimensions: Vehicle dimensional differences as examples of override and underride, are described and illustrated in Appendices D and E. The following specific analyses relate to these dimensional differences:

(1) Vehicle 3 override of Vehicle 2: The bottom of Vehicle 3's tractor bumper would have struck some portion of Vehicle 2 above its bumper, but lower than the top of its trunk lid. The deformation of Vehicle 2 sheet metal during the initial contact could have created a ramp effect, permitting the front wheel(s) of Tractor 3 to ride up onto Vehicle 2.

(2) Vehicle 3 override of Vehicle 6: Vehicle 6 was "bulldozed" towards the left and rotated counterclockwise as Vehicle 3 moved towards its left following initial contact with Vehicles 6 and 4 and Semitrailer 1. During this action, the side of Semitrailer 3 overran Vehicle 6, as indicated by photographic exhibits showing the damage to Vehicle 6. The height of Semitrailer 3's lower side sill was 45 inches, compared with Vehicle 6's hood height of 36 inches and roof height of 55 inches. Extensive damage to the trunk of Vehicle 6 could have resulted from contact with the left rear drive tire or left side trailer support of Vehicle 3.

(3) Vehicle 20 underride of Vehicle 19: When Vehicle 20 with its van-type trailer in tow was struck in the rear by Vehicle 18, it was forced under Semitrailer 19. Photographs and direct examination showed that Vehicle 20 was rotated counterclockwise about 15°. Exhibit D shows that the underride guard of Semitrailer 19 was 7 to 9 inches higher than Vehicle 20's front bumper. The top of Vehicle 20's hood was 2 to 5 inches higher than the rear crossmember of Semitrailer 19. The damage to Vehicle 20 indicates that it was shoved under Semitrailer 19 up to the windshield, jamming both doors.

The override of Vehicles 2 and 6 by the tractor and semitrailer of Vehicle 3 was related to two deaths; the underride of Vehicle 20 into the rear of Semitrailer 19 was also related to two deaths. In another instance of underride between passenger cars (Vehicle 15's underride into Vehicle 14), there were no injuries.

2. Kinematics of Vehicle 17:

There is evidence that Vehicle 17 was struck twice by Vehicle 1. The first impact was from the rear, with Vehicle 17 angled about 10° to the left of the axis of the tractor of Vehicle 1, which was going about 30 miles per hour in the right-hand lane. This impact pushed Vehicle 17 forward probably 100 feet or more, swerving it left into the median guardrail. In impacts between very heavy and light objects, the light object reaches a higher velocity than the heavier one, and is projected forward, depending on the amount of energy absorbed. A damaged guardrail section and the character of damage to Vehicle 17's front bumper suggest such an impact. Vehicle 17 probably stopped briefly at an angle to the roadway, while Vehicle 1 overtook it again, striking Vehicle 17 a second time, with the left front of Tractor 1. The principal force tore off Vehicle 17's left door, and made bumper marks on the left side of Vehicle 17. Vehicle 17 was also rotated counterclockwise and stopped facing northward, about 12 or 15 feet south of the second impact point and on the median berm.

During the second impact, Vehicle 17 was either partially tilted onto its left side, so that the left side tires of Tractor 1 chafed across its hood, windshield, and top, or it was partially overrun by the left drive tires of Tractor 1. However, there was no damage to the front left corner of Vehicle 17 (grille, headlamps) to indicate that Tractor 1 actually climbed up onto Vehicle 17. Rather, it would indicate that Tractor 1 was in a partially tilted position when this raking override occurred, such as might have resulted if the left wheels of Vehicle 1 had been on the high berm and the right wheels on the paved portion of the median.

Speed differential between Vehicles 1 and 17 is estimated to have been 25 to 35 miles per hour, based on evaluation of the damage to the rear of Vehicle 17. Vehicle 17 was reported by the driver to have been going about 30 miles per hour when struck, but it could have been going slower.

Examination of the damage to the drive shaft of Vehicle 17 showed that the drive shaft (not necessarily the vehicle) was virtually stopped when the two vehicles were at the point of maximum engagement in the impact. The severe rear end impact to Vehicle 17 was transmitted through its rear wheels and rear axle assembly to the drive shaft.

The rear universal joint would have permitted the rear end of the drive shaft to flex upward into the tunnel when the rear axle moved forward, but there was additionally some distortion to the shaft. The drive shaft engaged a seatbelt anchoring bolt, which extended into the shaft tunnel, causing the scoring and puncturing described on page 31. Analysis of these marks indicates clearly that the shaft was either stopped or rotating very slowly at the time they were made.

It must be kept in mind that, during the initial impact, the rear body components of Vehicle 17 were crushed forward and would have pressed around and against the rear wheels with great force, tending to lock the wheels momentarily. With the wheels locked simultaneously with the upward distortion of the drive shaft, the shaft would momentarily stop, and thus no conclusions can be drawn as to the speed of Vehicle 17 on impact, based only on evidence of the drive shaft damage.

The kinematics of Vehicle 1 during and after impact suggest an initial speed ranging 50 miles per hour and up. If Vehicle 17 had been at a standstill on impact, it would have sustained much greater damage. The statement of the Vehicle 17 driver that he was going about 30 miles per hour on impact thus tends to be substantiated.

Occupant Kinematics, Vehicle 17: (See Appendix G for pertinent driver and occupant injuries, by vehicle.) When Vehicle 17 was accelerated violently forward, the driver was ejected rearward from under his seatbelt which became slack as the seat back deflected rearward from the inertia of his body. The counterclockwise rotation following initial impact, which halted abruptly when the right rear wheel dug into the raised berm, would have accelerated the driver toward the right side. Thus, he was probably in the right rear seat area when Vehicle 17 was struck the second time, on its left side, and partially overrun. The glass fragments found in all the upholstery seams of the driver's seat would also indicate that the seat was empty when the windshield and door glass were smashed. The compression of the top, dashboard, and steering wheel -- had the driver been in his seat -- would have inflicted injuries considerably more serious than were suffered -- possibly fatal injuries. Injuries to the driver's left side were probably caused by impact against interior vehicle components during the kinematics of the second collision, or by compression of the roof against the left side of his body as his car was partially overrun. He was temporarily dazed or disoriented, but presumably made his own way to safety out the right door which was still operable.

3. Kinematics of Vehicle 1, Tractor and Semitrailer:

When Vehicle 1 struck Vehicle 17 the first time, both vehicles were in the righthand lane of traffic. The second impact occurred

on the median shoulder and berm area. It thus is apparent that Vehicle 1 swerved left after the initial impact. After the second impact, it swerved to the right, jackknifed, and the semitrailer overturned onto its right side, in a clockwise rotation. Had Vehicle 1 overturned in an uncomplicated jackknife to the right, without impact, it should normally have experienced an overturn onto its left side. This leads to the question of what type of force would have been required to cause a rightside overturn of Semitrailer 1.

Right-side overturn could have been caused in one or more of the following manners, which provided the necessary lift to the left side wheels:

1) During the sideswiping and partial override of Vehicle 17;

2) During a possible contacting activity with the median guardrail and the raised median berm (which would explain the substantial leftward displacement of four guardrail sections in the area where Vehicle 1 could have struck the guardrail before impacting Vehicle 17 the second time); or

3) During and resulting from the transverse forces which the tractor semitrailer combination must have experienced as it attempted to maneuver away from a collision and/or rebounded from the median guardrail and berm. The subsequent rightward and leftward oscillations of the tank-semitrailer could have coincided with a natural oscillation period and the sloshing of liquid product in the tank to carry it beyond its 28° (static) upset angle.

As the left trailer wheels raised, and the loaded semitrailer approached its critical angle of 28°, the tractor also would have tipped violently to the right, with its left wheels tending to go up.

The driver could not steer to correct the tipping motion, because the bumper was jammed against the left steering tire and the steering gear had been damaged.

As the entire combination traveled diagonally across the road, from the left shoulder to the right lane, the uncontrollable tractor jackknifed and rotated clockwise. The 60,208-pounds semitrailer attempted to override the tractor and to turn it over onto its left side as the tractor neared an angle of 90° with respect to the trailer. In this sequence, the trailer passed through its critical 28° tipping angle to its right. The vertical forces on the tractor's fifth wheel were such that the subframe crossmembers failed, thereby spreading the cross-shaft trunnion brackets and permitting the fifth wheel to separate from the tractor.

The front end of the tank-semitrailer fell onto the right-hand side rail of the tractor, kinking the side rail inward and downward at the point where the fuel tank was attached. The diesel fuel tank was crushed downward, causing the forward head of the fuel tank to part from the tank shell at the bottom, and permitting diesel fuel to escape. Even though the tractor separated from the semitrailer, the airbrake jumper hose was still attached to both units, indicating that the two components had remained in close proximity throughout the overturn kinematics.

The kink in the right-hand side rail of the tractor was of such magnitude that the tractor drive shaft also kinked, making it doubtful if the drive shaft could rotate; therefore, the tractor drive axle was probably locked.

Distortion to the side rail and to the left rear axle spring assembly, together with the tire marks on the side rail, suggest extreme loading in a clockwise twisting motion, as viewed from the rear.

Center of Gravity Factor, Vehicle 1 Semitrailer: The center of gravity height of the propane semitrailer was calculated to be 84 inches. For an assumed 90-inch-wide track (to the centers of outside tires), this corresponds to a critical overturn angle of 28° which means that if one side is slowly raised so that the axle is beyond 28° above the horizontal, the vehicle will overturn. Calculation also indicated that the overloading would have reduced this angle about one-half degree, making it more susceptible to overturn than if not overloaded. The actual overturn angle will be less than the theoretical angle because flexibility of the tires narrows the lateral base, and the flexibility of the springs allows the load to tip outward. The effect of these factors is unknown as tests to determine at what angle motor vehicles overturn are not made or required by any authoritative agency at this time.

Front Bumper and Steering Gear, Vehicle 1: The vehicle was in motion when the left front bumper end was bent backward, as the outer edge of the tire tread was mutilated severely and torn along its outer periphery by the bumper flange. It is believed that the bumper tip must have engaged something stronger than the flat back or side body components of Vehicle 17, thus reenforcing a belief that the bumper engaged the heavier median guardrail before the second impact with Vehicle 17.

The impact load from the bumper into the tire was in turn transmitted through the steering lever, through the drag link, into the pitman-arm and steering-gear housing, thus accounting for the fracture of the housing.

International Harvester Co., at the Safety Board's request, conducted a series of tests to determine the force necessary to cause this housing to rupture. A steering-gear assembly of the same make and model was used. A turning force equivalent to 624 pounds was applied to the rim of the steering wheel, 20 inches in diameter, causing the wheel hub to fail. A complete examination of the test unit's internal parts and housing showed no indications of failure.

These tests show by elimination that the force which caused the gear housing to fail in Vehicle 1 was transmitted through the tire, as it would be physically impossible for the driver to apply the force necessary to cause the failure.

Vehicle 1 Overload in Relation to Impact and Overturn: From the evidence of repeated overloads by the propane carrier, there would appear to have been almost a total lack of effort, either by the carrier or the shipper, to keep shipments within the New Jersey legal gross combined weight (g.c.w.) limits (72,000 pounds). The carrier had repeated opportunity to observe the overloading pattern when checking invoices for payment. The shipper, incidentally, used the same figure of 4,230 pounds per gallon for every propane delivery, although it is well known in the industry that the commodity weight will vary slightly, as temperature or chemical composition of the product might vary from day to day. Knowing the commodity weight and the tare (empty vehicle) weight at the time of loading, the shipper and the driver could readily compute the amount that could legally be carried at a given time.

An overload of 4,340 pounds above the New Jersey legal weight limit would produce an additional 368,000 foot pounds of kinetic energy at 50 miles per hour. Calculations indicate that this would raise the center of gravity of the semitrailer approximetely 3 inches, reducing its critical overturn angle by more than one-half degree.

While the specific effect of overloading in this instance cannot be established, such an overload would decrease stopping capabilities, increase impact energy, and increase the tendency to overturn.

Kinematics of Vehicle 1's Driver: The driver of Vehicle 1 was fatally injured (see Appendix G for details of injuries). Although using no seat restraints, he probably was retained in his seat when his vehicle first impacted Vehicle 17, as there would have been but slight deceleration of the tractor-semitrailer in that impact. After Vehicle 1 struck the side of (and partially overran) Vehicle 17, and began to overturn, the driver might have

been dislodged to the right, then back to the left as the tractor jackknifed and rotated clockwise. It was not until the tractor had fully jackknifed and separated from the semitrailer, that significant deceleration developed in the tractor, which would have been accompanied by a violent tipping to the left when separation of the fifth wheel occurred.

Windshield damage to the cab of Tractor 1 is characteristic of fire damage rather than impact damage. Because of the absence of a major head-on impact to Vehicle 1, it is fairly conclusive that the driver of Vehicle 1 was not ejected via the windshield.

There is some indication that the left cab door was sprung open, and the driver might then have been ejected. If so, his injuries can be accounted for by his falling under the tractor as it slid over him, without being struck by the wheels or the fore-end of the tank. In a later sequence, his body could have been overrun by one of the other vehicles. Drivers who arrived soon after the initial event saw a man lying near the front of the tractor on the grassy embankment. This could have been the driver of Vehicle 1, whose body was found partially under the front end of Vehicle 10 after the accident, in that area. However, at least one other witness claims he saw a man near the left rear of the tractor, apparently inspecting his vehicle. If this were the driver of Vehicle 1, he could have left his cab voluntarily after the tractor stopped, and could have been struck by some vehicle or vehicles in subsequent collisions. The manner of such collision or the identity of such vehicle(s) has not been established, so the manner in which the driver of Vehicle 1 received his fatal injuries is uncertain.

Performance of the Tank-Semitrailer (MC331), Vehicle 1: The MC331 tank-semitrailer withstood the accident kinematics very well. Some aspects of this satisfactory performance can be attributed to the manufacturer's adherence to DOT regulations for Specification MC331 Tanks. Examples of this were:

1) Separation of the ladder from the required appurtenance pads, with no damage to the tank shell;

2) The high dynamic loading placed on the right front fender bracket, with no noticeable damage to the tank shell; and

3) The recessed liquid level-gauge protection which prevented damage to the gauges or connecting lines, thus providing the intended product-retention integrity during the semitrailer's slide on its right side.

Material ductility of the tank shell was demonstrated, as both forward and rear heads were dented without failure of the basic quenched-and-tempered, high-strength steel or any welded joints.

The semicircular crack in the top of the tank was produced by an indeterminable concentrated impact loading that occurred when Vehicle 3 struck the tank as the semitrailer lay on its side. The impact load was concentrated at a point on the shell where it was stiffened by an internal baffle mounting pad, which limited the spreading of the deflection to adjacent areas of the tank shell, and produced a shear effect. It is believed that the material ductility would have accommodated the loading had it occurred at almost any other location on the tank shell. The increased stiffening offered by the internal baffle was illustrated in the degree of buckle of the baffle.

Had the protection offered by the required appurtenance mounting pads, the recessed level gauge, and the general specifications adhered to by the manufacturer not been present, a massive release of liquid propane could have followed, with catastrophic potential.

4. Kinematics of Vehicle 2:

Vehicle 2 was not observed to have suffered major damage in its impact with the overturned propane tank. Its speed at impact was thus probably not great, but there was apparently sufficient deceleration to disorient or disable the driver, wearing no seat restraints, in the "second collision" with interior vehicle components. He made no known attempt to leave his vehicle, and was observed by two witnesses to be slumped over the steering wheel. When Vehicle 2 was struck and overrun by Tractor 3, Vehicle 2 was totally demolished, and it is assumed that the driver of Vehicle 2 was killed at that time.

Subsequently, fire destroyed what was left of the vehicle, burning the body of the driver to such an extent that it was impossible to determine what vehicle components may have inflicted injury.

5. Kinematics of Vehicle 3:

When the driver of Vehicle 3 saw two red lights in the fog, he applied maximum braking which dissipated some of Vehicle 3's kinetic energy. Impact speed is estimated to have been somewhere in the range of 30 to 35 miles per hour. Vehicles struck directly were probably No. 6, which was pushed off to the left and rotated counterclockwise, No. 4, which was pushed to the left and partially overrun, and No. 2, which was crushed, overrun, and pushed to the left. As Vehicle 3 struck the overturned tank semitrailer, the tractor unit of Vehicle 3 was diverted to the left. Impact with the tank caused the tank to start moving southward and to start rotating clockwise. The crack in the propane pressure tank is believed to have been produced by the right forward corner of the trailer bed after the tractor swerved left.

As Vehicle 3 continued to move left, the propane tank continued to rotate clockwise. Vehicles 2, 4, and 6 were pushed left. Vehicles 4 was pushed against Vehicle 5, which was then pushed left to the median guardrail.

Vehicle 6 continued to rotate counterclockwise and was pushed left by the bed of the semitrailer of Vehicle 3, to the point where it was found during cleanup.

The drive wheels of Tractor 3, or the semitrailer wheels might have caught the left front corner of Vehicle 12, and forced Vehicle 12 to the right into Vehicle 11.

Initial impact deceleration of Vehicle 3 threw both the driver and the occupant, who had no seat restraints, forward and to the right, where they probably struck interior cab components. They were probably ejected through the right cab door, which was torn off and found ahead of Tractor 3 on the edge of the burned area. The occupant of Vehicle 3 was rendered unconscious on ejection, but the driver of Vehicle 3 was able to carry her to safety before flames engulfed the area.

The kinematics of Vehicles 5, 6, 11, 26, and 20 are analyzed in Appendix H.

6. Fuel Systems Damage:

The analysis of fuel systems damage entails a review of components making up the system, as they were affected by this accident environment. Dynamic loadings were not determinable due to lack of essential information on vehicle speeds and kinematics; however, they varied from relatively minor impacts to very high-speed impacts and involved some complete vertical crushing of cars. Some cars were struck several times from different angles, thus complicating analysis. Also, some vehicles trapped next to burning vehicles could have suffered damage to fuel tanks or components which had not been subjected to significant dynamic loadings. And, finally, some unknown fuel tank or component damage could have occurred during rescue or cleanup operations after the accident.

(a) Fuel Tank Support Systems: Vehicles 2, 4, 6, 10, 11, 17, and 20 experienced fuel-tank support system damage. The integrity of fuel-tank support systems of all these vehicles depends upon the structural intergrity of vehicle frame sections, or supporting body components, as well as on support straps and brackets. When the structural integrity of vehicle frame sections was violated by the dynamic crash loadings, some straps were broken or loosened, permitting fuel tanks to escape from their respective vehicles or to be significantly displaced.

Loosened straps permitted the escape of one end of some straps when positive (bolted) anchoring was not provided, as specifically observed in Vehicles 11 and 17. Lateral (side-to-side) mounting straps may tend to fare better in straight rearending impacts, but appear to fare no better than the fore-and-aft mounting when the impact produces diagonal distortion to the supporting framework.

(b) Fuel Tank Filler Pipe: Fuel-tank filler pipes in Vehicles 2, 4, 5, 6, 7, 10, 11, 17 and 20 all separated from their respective fuel tanks from dynamic crash loadings or from heat.

Impact crash loads were applied to the filler pipe, or to its support system, through other components to which they were attached or through which they were routed -- fenders, bumpers, or trunk decks. When such components were displaced with respect to the fuel tank, sufficient loading was apparently applied to the fuel-tank-to-filler-pipe joint to cause separation.

Filler-pipe-to-tank joint separation permitted escaping gasoline to spread or to feed fires. Testimony and observation revealed that some vehicles are equipped with filler-pipe-to-tank connections that are below the top of the tank. With the filler pipe gone, gasoline could flow out the opening, aggravated by any change in the fuel-tank (or vehicle) position which would further lower the position of the opening.

(c) Fuel Tank Materials and Assembly: In all cases, the fuel-tank material and seams exhibited ductility characteristics which permitted general crushing, bending, or twisting to varying degrees, without failure to parent material or to seams. Punctures, rips, and holes found in tanks resulted from highly concentrated loadings in contact with other vehicle components, as found in Vehicles 2, 4, 6, 10, 11, and 17. Rear axles, oil-filler plugs, torque-convertor housings, track (sway) bar swivel bolts on axle housings and trunk floors provided the areas of concentrated impact to puncture fuel-tank shells.

Where there was sufficient heat to melt the soldered filler-pipe-to-tank joints, the fuel released would have been in vapor rather than in liquid state. If liquid gasoline were directly adjacent to (inside) the joint, the liquid would conduct away the heat and prevent melting of the joint solder. As gasoline boils at relatively low temperatures continuing exposure to heat would cause the liquid to boil so that gasoline vapors would be emitted, escaping from the filler cap. If the fuel lines were damaged, the pressure buildup would force liquid gasoline through the line onto the ground or into the engine compartment. Once the gasoline liquid level was below the filler-spout joint, the solder would melt as soon as it reached its melting point -- about 400° F. -- but again only gasoline vapor would be released at the opening.

Whether escaping vapors would burn or merely dissipate into the atmosphere would depend on the proximimity of fire or other ignition source.

Vehicles 5 and 8 did not exhibit serious dynamic distortion in their fuel-tank areas, and withstood the resultant fires without damage to their respective fuel tanks. Both vehicles were gutted by fire, yet their tanks, when water-tested after the accident, were free of leaks. The solder in the filler-pipe-to-tank joint of Vehicle 5 had apparently melted, as the filler pipe subsequently was pulled from its normal position. However, it had earlier passed the water test, which suggests that the clearance between the filler pipe and the tank opening was minimal.

(d) Statistics on Vehicle Fires: Accident statistics show that only about one half of one percent of injury-producing motor vehicle accidents involve fire. But as the crashworthiness of automobiles is improved, thereby enhancing occupant survival, the importance of fuel-system integrity to minimize fatalities by fire becomes more significant.

In this accident, the impact loads which contributed directly to fuel-system damage of passenger cars were admittedly severe by comparison with automobile-to-automobile crashes. Yet the types of fuel-system damage experienced are likely to occur in any accident in which heavy impacts are involved, and thus must be viewed as revealing weaknesses in the system which should be considered for correction.

7. Fire Sources:

The origin of the fires has not been ascertained. Fire was first observed in the area just north of the propane semitrailer, near Vehicle 6, after Vehicle 6 had sustained a second impact which shoved it forward into Vehicles 2 and 4. Ignition could have been from a number of sources, but clearly did not involve propane as a fuel because the crack in the propane tank had not as yet been produced. A description by one witness of "flames licking along the ground . . ." could not apply to propane, and would not be incompatible with gasoline leaking and running slowly. Spilled diesel fuel from Vehicle 1 was in the area, and may well have been the ignition fuel for the first fire observed, although its tendency to vaporize is slight.

The fire(s) in the area north of the propane semitrailer spread rapidly after gasoline was released from damaged fuel tanks, following the massive impact and crushing of some vehicles by Vehicle 3. Some witnesses said that this was the first time they observed fire, so any fire which had started earlier must not have been of great size.

When Vehicle 20 was rear-ended by the truck, its fuel tank was rammed against its torque-convertor housing and rear axle. The ruptured fuel tank released liquid fuel which was ignited, instantaneously engulfing the vehicle and occupants. Flammable-materials type of containers found in Vehicle 20's tank compartment are not believed to have ruptured on impact, and their contents are unknown. Further, possibility of an available ignition source in the trunk compartment would have been minimal.

Regarding the question of whether the propane loss caused damage by fire, it is important to consider the manner in which each of the principal fuels -- gasoline, diesel fuel, and propane -- could have contributed relatively to the fire.

(a) Gasoline: A total of eight cars contributed an estimated lost 10 gallons of gasoline per car, for a total of about 80 gallons in the fire area north of the propane tank. Some of this gasoline was available as an ignition fuel, some of it presumably helped to spread the fire(s), but much of it contributed only as fuel to sustain the fire(s) -- along with other combustibles. It has not been possible to reconstruct the manner (or the quantities of gasoline involved) in which gasoline might have played each of these roles.

Based on an estimated energy release of 130,000 B.t.u. per gallon, gasoline would have provided a total of some 11.7 million B.t.u. to the total conflagration in that area.

(b) Diesel Fuel: The 100-gallon diesel fuel tank of Tractor 1, and the two 80-gallon tanks of Tractor 3 (assuming again that each was half full), contributed a total of 130 gallons of diesel fuel. The fuel from Vehicle 1 was lost somewhere during the violent vehicle kinematics north of where Vehicle 1 came to rest, so it is not known how much of this fuel was released in the forward fire area. Gravity would have carried any liquid fuel generally away from where the fire(s) occurred, and as diesel fuel has low volatility, no vapor-rich air would have been likely to have been blowing into the fire area.

Nonetheless, the first fire observed "licking along the ground" had the characteristics attributed more to diesel fuel than to gasoline.

Based on an estimated 135,000 B.t.u. per gallon, diesel fuel could have contributed an estimated total of 17.2 million B.t.u. to the total conflagration.

(c) Propane: The crack in the propane tank of Vehicle 1 semi-trailer resulted in a loss of approximately 197 gallons of liquid propane. The figure of 197 gallons is subject to very probable errors in the measuring techniques used, both in loading the propane prior to the trip and in its transfer after the accident. Thus, the actual quantity lost could have been somewhat greater or less than the 197 gallons reported.

Propane would have escaped from the hairline crack in the form of propane gas rather than as a liquid. At atmospheric pressure, 197 gallons of liquid propane would represent approximately 7,000 cubic feet of gas.

Testimony indicates that the accident occurred about 7:45 a.m., and Vehicle 1 completed its transfer of propane at 11:30 p.m. -- a total period of 15 3/4 hours during which leaking occurred. The leak rate is assumed to have been fairly constant, affected only by variations in the propane temperature throughout the day. Any frost or icing near the crack orifice, from the cooling effect of rapidly expanding gas, would have been entirely exterior of the tank, and the absence of moisture in the expanding propane gas would have kept a free channel open for the escaping gas. No frost or ice could have formed in the aperture.

Based on this information, the propane leak rate was approximately 440 cubic feet of propane gas per hour. The main fires were extinguished about 9:45 a.m., so approximately 770 cubic feet of gas would have been released while the fire was in progress -- about 1 3/4 hours.

How much of this gas contributed to the fires, or whether the propane contributed in any significant degree, is moot. With a crosswind of some 5 or 6 knots, the gas would not have accumulated. If it had ignited, the flame would have raced back toward the source and burned there, rather than down near roadway level. The nearest object to the crack was the right rear of Vehicle 3 semitrailer, some 12 to 14 feet away. This portion of Vehicle 3 semitrailer was the least burned, which suggests that there was no outside source of fuel feeding the flame in that area. No one testified as to a flame in or near the crack area, although the propane gas could well have mixed with the flames over the fire area and burned there.

Assuming that all the escaping propane did burn, and based on an energy release of 2,322 B.t.u. per cubic foot of gas, the total maximum contribution of the propane gas to the overall fire(s) would have been about 1.8 million B.t.u.

A recapitulation of the maximum estimated contribution of these three fuels shows:

		B.t.u.	Percent
Gasoline:	80 gal. @ 130,000 B.t.u./gal.	11.7 million	38.1
Diesel fuel:	135 gal. @ 135,000 B.t.u./gal.	17.2 "	56.0
Propane gas:	770 cu.ft. @ 2,322 B.t.u./cu.ft.	1.8 "	5.9
	Total B.t.u. Contribution	30.7 Million B.t.u.	100.

This analysis suggests the relative contribution of fuels in the total conflagration, with propane constituting only a relatively minor part of the total. Since propane was not the ignition fuel, the devastating nature of the fires would have been virtually the same if the propane had not been available.

8. Vehicle Rear Lighting and Signaling Systems:

Most of the stopped, or stopping, vehicles exhibited rear lights -- taillights or stoplights -- but only one driver specifically reported seeing such lights ahead as his reason for making an emergency braking application. In that instance, the distance was so short that successful evasive action was not possible.

As discussed earlier, the visibility restrictions and the distorting effect of fog might have combined to nullify the safety effects of rear-signal display. The absence of specific data on individual crashes prevents a detailed analysis of rear lighting or signaling as a factor in this accident.

C. FACTORS RELATED TO DRIVERS AND OCCUPANTS:

Driver behavior in fog, or in any adverse or uncertain environment, is conditioned by many indeterminate factors, among which are specific training, early experience or habits, and the ability to analyze quickly any given set of conditions. No attempt was made to evaluate the drivers in this series of collisions for such factors. However, selected examples of driver behavior relating to use of seatbelts, driving speed, stopping positions, evacuation of cars, and assistance to others will be reviewed to the extent warranted.

1. Use of Seat Restraints:

None of the truck tractors was equipped with seatbelts. Of the passenger cars, only three were known not to be equipped with seatbelts, and in all three there were fatalities or major injuries. The nature of the impacts and examination of driver/occupant kinematics does not indicate that the use of seatbelts would necessarily have prevented these injuries and deaths.

Two other passenger-car deaths and one major injury were in cars equipped with seatbelts which were not being used. In one of these, there was no major impact until after the vehicle was stopped and occupants were evacuating, so the question of seatbelt use is irrelevant.

In only one instance was a seatbelted driver (Vehicle 17) severely injured, and that was as the result of a high-energy rear-end impact followed by a left side impact and partial overrun. The driver stated his belief that had he been wearing the available shoulder restraint, he would not have been ejected into the rear seat, and in all probability would have been killed in the left side impact and overrun of his car.

2. Effect of Visibility on Driving Speeds:

In going through successive fog patches north of the scene,

all of which had been fairly short and light, some drivers may have been lulled into a belief that all of the foggy areas would be the same. Even when visibility dropped in places to two or three car-lengths, some drivers said that cars continued to pass them as though conditions ahead were clear. The existence of the 60 miles-per-hour speed signs could have been a factor in the continuing speed of some vehicles, providing assurance that the fog was not sufficient to require speed reduction. Certainly the signs did not influence drivers to reduce speed.

The density of fog at the scene varied both as to time and place, and the speed of arriving vehicles could have been affected by such variations. All drivers interviewed claimed they reduced their speed, but it appears to have been a matter of degree, depending primarily on how each driver evaluated the density and probable duration and hazard of the foggy area. Some drivers slowed moderately while others slowed considerably, and a few came to a full stop. What to one driver was a prudent act -- namely, to slow down immediately -- brought disaster when the tractor-semitrailer behind him did not slow down.

Two of the earlier arrivals at the blockage created by the overturned propane tanker struck it hard enough to suffer disabling injuries. A third saw the tank and slowed, but said he misjudged the distance and impacted it lightly, while a fourth saw it and stopped well back, out of the line of traffic. It is believed that the white coloring and smooth silhouette of the overturned tank afforded almost no contrast with the foggy environment for these earlier arrivals, whereas later arrivals could see the stopped cars. Even so, some of them were going too fast to avoid collision.

One noteworthy example of safe driving adjustment to conditions was exhibited by one of the truck tractor drivers. He had stopped overnight off the Turnpike because of deteriorating visibility. Approaching the accident scene, he had slowed to 30 miles per hour when visibility became marginal, then to 10 as it became worse. When visibility became hazardous, he had decided to stop, at which time he saw stopped vehicles ahead. He drove his unit as far onto the right shoulder as he dared without risking the soft turf; he stopped, set his flashers, and then took flares to see if he could warn or stop other traffic. Had all drivers judged the conflicting indication in the same way and exercised this degree of caution, there is little likelihood that this series of collisions would have occurred.

3. Stopping Positions of Vehicles:

Variations in selecting a stopping position seemed to parallel the variations in driving speeds; those who slowed safely tended to find normally safe places to stop. In several instances, the stopping position was not voluntarily selected because of panic-type stopping or other evasive action.

Two or three drivers pulled completely off the traffic lanes onto the right shoulder, plus at least one other (who reported the accident) who drove off to the right, around the wreckage, and continued to Exit 2. Several others took to the median area -- wide enough to afford normally safe refuge in many situations, but not under these conditions. And a few stopped where they were, with no apparent effort or recognition of a need to get out of the stream of traffic.

Some who stopped in the traffic lanes might have done so because they were not aware of the collisions ahead. Perhaps to them, traffic had merely come to a halt, and it is not common practice to drive off the highway everytime one encounters a traffic stoppage.

4. Evacuation of Vehicles:

Without exception, all surviving truck drivers dismounted and left the roadway as promptly as possible, but passenger-car drivers and occupants showed no consistency in this. While most said they knew they should get out of their cars and away from the highway, and did so, several left their cars only after rear-end collisions demonstrated the danger of staying there. At least two drivers, stunned or disabled, could not get out in time, and both died in ensuing crashes and fire.

On leaving their cars, most occupants went down the right-hand embankment and then northward away from the scene. Ironically, this presumably "safe" area could have been a death trap if the propane tank had suddenly burst. Other occupants went across the northbound lanes, risking oncoming cars in the fog, to the opposite shoulder, and a number went southward to a point several hundred feet beyond the overturned propane unit.

What motivated the couple in Vehicle 20 to remain in their car is unknown. They were apparently uninjured until their car and its U-Haul trailer were rammed from behind. They could have been unaware of any accident ahead, because of limited visibility and blocking of the roadway by two stopped tractor-semitrailer units. To them, it might have appeared to be a temporary stoppage only, as discussed above.

Prompt action in evacuating cars could have made the difference in reducing the number of deaths by at least three. However, the field of highway safety to the present time has produced no established criteria and no public educational efforts on a broad scale to alert and to guide the driving public in such situations. Further, it appears very difficult to find actions which are suitable for all situations in which such highway stoppages are encountered.

5. Assistance to Others:

Some of the truck-tractor drivers went about lighting and placing highway fusees (burning flares), and several passenger-car drivers tried to warn following traffic about the accident. In some cases, this entailed risks to their own safety in dodging cars which failed to stop. None of these actions was known to be successful in preventing ensuing crashes, possibly because of the minimal visibility and the short time in which drivers could evaluate and react successfully to the warnings. Rescue attempts in two instances were thwarted by the outbreak of fire.

6. Traffic Violations Charged to Drivers:

The police placed charges of careless driving against two of the tractor drivers because of their alleged failure to slow down in foggy conditions. Both were found guilty. The company which operated the propane carrier was charged with overweight violation, but was found not guilty.

It is not clear why careless driving charges were not placed against at least four other drivers for failing to slow sufficiently in the fog which resulted in impacts with vehicles ahead, nor is it clear by what objective indications those charged could have known that slowing was required or by how much. The occurrence of the crashes after the blockage developed was the only indicator that the judgment had been wrong. Inconsistency in the placement of such charges makes it all the more apparent that drivers need substantive criteria -- positive yardsticks -- on which to base decisions to reduce speed and to select the "proper" or "safe" speed, other than on individual opinions and judgment. Opinion and judgment are strongly affected by background. The recent experience of a fog accident by the driver of Vehicle 17 gave him a completely different base for judgment of the situation, as compared to that of the following truck driver. Without such criteria, enforcement would appear to be based on the outcome rather than on specified unlawful behavior.

Worthy of comment was the total absence of alcohol as a factor, with not a single instance of a driver suspected of having been drinking or driving under the influence. There was also nothing to suggest that faulty vehicle condition contributed in any manner to causation of the collisions.

IV. CONCLUSIONS

Analysis of available information and evidence leads to the following conclusions:

1. The weather advisory service subscribed to by the Turnpike Authority can predict the likelihood of weather conditions; but in the case of fog, precise locations or intensity of expected fog cannot be forecast.

2. The density of fog which limited visibility was relatively light and variable north of the accident scene, and was at its densest in the immediate area of the accident during the first events of the collision.

3. The timing of police patrols past a given point was a factor in delaying the activation of the electronic hazard-warning and speed-reduction sign system in the area north of Exit 2. Under conditions of deteriorating visibility, frequency of patrols limits the functioning of the warning system, since the patrol officer initiates action.

4. No hazard-warning or speed-reduction signs were displayed between the New York/Newark area and Exit 2 (north of the scene) during the two hours preceding these crashes, although highway users observed places in which they considered the maintenance of 60 miles per hour speed to be hazardous.

5. The system of speed advisory signs and warnings had official status, was intended to have partially controlling effect on drivers, but as a manageable traffic control system in a changeable weather environment it was incomplete and unreliable. Inadequacies in the information collection portion of this system in changeable weather constituted a system design defect.

6. The highway speed advisory signs were providing incorrect advice, tending to inhibit response to the increase in fog.

7. This series of collisions began when the tractor of Vehicle 1 struck the rear of Vehicle 17, which rotated counterclockwise and was later, in a second collision, sideswiped and partly overrun by the left drive wheels of the tractor.

8. The leaking of propane did not initiate the fire. The actual source of ignition remains unknown, but the earliest fire was probably spread by gasoline or diesel fuel and contributed to by flammable automotive products, vehicle contents, and possibly petroleum components of paving material. The loss of propane had little or no enlarging effect upon these fires.

9. Gasoline and diesel fuel in vehicle fuel tanks escaped as the result of fuel-tank ruptures, punctures, or the dislodging of filler pipes, produced in the main by the striking of passenger cars by tractor-semitrailer units.

10. Cause of death for five of the six fatalities cannot be determined because of the degree of fire destruction of the five bodies in question. However, a review of occupant kinematics indicates that probably four of these five were still alive when fire engulfed their respective cars.

11. Even though the fatalities could not be attributed exclusively to impact effects of the trucks on the passenger cars, the intermixing of passenger cars and trucks in the crash acted to invalidate occupant protection characteristics of passenger cars. The trucks and passenger cars did not operate as a compatible system to reduce occupant fatalities.

12. Vehicle 1 tank semitrailer's overturn resulted from the combined effects of a relatively high center of gravity, a lifting force imparted to the unit by its left side having partially overrun Vehicle 17, by entry of the left wheels upon the raised median berm, and/or possibly striking and partially climbing the median guardrail, and probably the oscillation imparted by successive left and right swerves.

13. The relative proportions of heavy trucks and of passenger cars which could not avoid striking vehicles ahead suggest that the known varying stopping capabilities of different types of vehicles intermixed had an effect in this accident.

14. Specification MC331 propane tank, the semitrailer of Vehicle 1, survived the accident in excellent fashion, considering the impact forces to which it was subjected. The one hairline crack it suffered would probably not have occurred if the concentrated blow had been imparted at almost any other point on the tank shell.

15. The rear-end protection device on Semitrailer 19, which met the provisions of Title 49, Section 393.86 (Motor Carrier Safety Regulations), failed to prevent the underride by Vehicle 20, and the resultant jamming of the front doors of Vehicle 20.

16. Seat restraints, where used, served their intended function in preventing or minimizing personal injury.

17. No pre-crash failures of vehicle safety-related components -- brakes, tires, steering, -- are known to have contributed in any fashion to accident causation.

18. The retentive windshield design, required under Motor Vehicle Standard No. 212, served its intended function in the one affected example, Vehicle 26's impact.

19. Impact against interior vehicle components contributed to the disablement of two drivers who subsequently were killed in later collisions or fires. Had these two vehicles been equipped with the telescoping steering column, now required, and had both drivers been using seat restraints, their chances for survival would have been greatly enhanced.

20. Highway design features -- median strip, median guardrail, wide paved shoulders -- served to reduce crash results by providing areas of refuge and preventing potential crossover into northbound traffic lanes.

21. Current automotive rear-lighting and signalling systems had limited value in warning following vehicles under the heavy fog conditions.

22. The response of police, fire, and other emergency services under the existent conditions was exellent. No aggavation of injury or property loss can be attributed to delay or operating deficiencies of such services.

23. The State police units assigned could have maintained more complete control of the scene, and probably could have been able to spend more time on important investigative matters, had their numbers been augmented by the addition of other units either from the State Police or from nearby police jurisdictions.

24. The resistance of trucks to overturn as influenced by center of gravity height is controllable, but is not presently controlled by any Federal regulation.

25. Significant conflicts in the logic of operation of the highway as a managed system were present; namely, (1) a conflict between the legal theory of the advisory signs and their apparent actual role in the sequence of operations, (2) a conflict between the need for uniform speed of different types of intermixed vehicles to reduce hazardous interaction during smooth flow and a need for differing speeds of the same vehicle types to avoid collisions when interruptions of flow occurs, and (3) a crash design incompatibility of the different types of intermixed vehicles which tended to invalidate the occupant protection characteristics of the passenger cars.

V. PROBABLE CAUSE

The Safety Board determines that the probable cause of this multiple-vehicle accident was the penetration by vehicles into an area of dense fog where the visibility was 20 to 50 feet, together with the varying rates of speed which prevented appropriate evasive action. Contributing factors were the absence of objective indicators of the density of the fog, and inadequacy of the New Jersey Turnpike speed control system in that it failed to provide timely activation of speed reduction warning signs.

VI. RECOMMENDATIONS

The National Transportation Safety Board hereby recommends that:

1. The Federal Highway Administration expedite a study of hazard-warning and speed-limit signing systems, similar in purpose to those used on the New Jersey Turnpike, toward maximizing the effectiveness of a total system, and testing it on selected highways which have accident problems related to adverse weather and visibility conditions, such testing to include expansion of tests of fog-alert devices and methods to improve the communication of pertinent weather information to and from field patrols. (The Board is aware of fog-sensor testing in progress in the State of Oregon, but believes this program is not of the scope needed for total systems design or improvement.)

2. The National Highway Traffic Safety Administration initiate (through an appropriate demonstration project) a program and procedures for minimizing the likelihood of catastrophic chain-reaction collisions on high-speed, multilaned highways in adverse weather or visibility conditions; such program to consider, among others, requirements to: (1) segregate heavy vehicles from light vehicles by assigned use of lanes whenever safe speed is below posted speed; (2) forbid overtaking and passing by heavy vehicles; (3) use of four-way flashers by all vehicles; (4) prohibit stopping on the traveled portion of highways (unless conditions will not permit otherwise); and (5) evacuate stopped vehicles under certain conditions.

3. The National Highway Traffic Safety Administration set a high priority on establishing performance requirements for new buses, trucks, trailers, and combinations in regard to: (1) improved braking capabilities with balanced skid resistance, reduced "fade," and shorter stopping with maximum load; (2) the use of energy-absorbing underride and override barriers to reduce passenger-car impact decelerations through controlled yielding; and (3) minimum limits on stability factors for loaded vehicles. (Stability factor is defined as one-half the tread width between centers of outside tire footprints, divided by the height of the center of gravity of a loaded vehicle.)

4. The Bureau of Motor Carrier Safety, Federal Highway Administration, consider the promulgation of regulations to require improved braking capabilities of regulated vehicles, and inclusion of a numerical statement of the stability factor (value) on the identification plate of all tank trailers which transport hazardous materials, in implementing Recommendation 3, above.

5. That the National Highway Traffic Safety Administration and the Automobile Manufacturers' Association initiate programs leading to the development of automotive fuel-tank systems which will minimize the escape of fuel in collisions, including the prevention of escape of liquid or vaporous fuel into any compartment of the vehicle. These programs should incorporate revisions to existing test methods and standards to more nearly approximate conditions likely to be encountered in collisions, including rear end impacts at substantial speed differentials, with the tested vehicle in a braking attitude, and subjecting pertinent components to varying angles of impact, from straight rear end to 90° right and left.

Test standards should consider exposure of the fuel-tank system to fire without loss of structural integrity or the release of vapors into the vehicle or any of its compartments.

6. The New Jersey Turnpike Authority and the New Jersey State Police take steps to provide more frequent patrols on affected Turnpike sections when fog or other weather conditions are forecast to reduce visibility, so that earliest practical warning may be available when conditions warrant the activation of hazard-warning and reduced speed-limit signs. Increasing patrol frequency should take priority over routine police matters, if necessary, during periods of potentially hazardous weather or visibility conditions.

BY THE NATIONAL TRANSPORTATION SAFETY BOARD:

/s/ JOHN H. REED
Chairman

/s/ OSCAR M. LAUREL
Member

/s/ FRANCIS H. McADAMS
Member

/s/ LOUIS M. THAYER
Member

/s/ ISABEL A. BURGESS
Member

January 20, 1971

VII

APPENDICES

APPENDIX A

ROSTER OF VEHICLE OCCUPANTS -- AGE, SEX, AND INJURY STATUS

(Vehicle Numbers Keyed to Figure 1)

VEHICLE NUMBER	NAME	AGE	SEX	INJURY STATUS
1	John Mullen	31	M	Fatally injured
2	Leo Lussier	56	M	Fatally injured 1/
3	Ralph Nepert	38	M	Treated and released
	Hilda Germick	38	F	Treated and released
4	James Boylan	53	M	No injury reported
	Mrs. James Boylan	50	F	No injury reported
5	James Kleiber	24	M	Hospitalized
6	Anthony LaFauci	23	M	No injury reported
	Mrs. Susan LaFauci	19	F	Fatally injured 1/
	Cosmo LaFauci	65	M	Treated and released
	Mrs. Mary LaFauci	65	F	No injury reported
7	Elijah Dunston	42	M	Treated and released
	Christiana Dunston	49	F	Treated and released
	Henry Dunston	67	M	Treated and released
	Queenie Dunston	67	F	Treated and released
8	Peter Griffin	49	M	No injury reported
	Mrs. Peter Griffin	48	F	No injury reported
	Louis Bartman	--	M	No injury reported
	Mrs. Louis Bartman	--	F	No injury reported
9	Joseph Warrington	53	M	No injury reported
10	Madeline Bogardt	56	F	No injury reported
	George Bogardt	61	M	No injury reported
11	Thomas Kohlweiss	59	M	Fatally injured 1/
	Lily Kohlweiss	22	F	Treated and released
	Nicholas Bayachek	20	M	Treated and released
12	William Bosserman	72	M	Injured slightly
	Mrs. Wm. Bosserman	--	F	Injured slightly
13	Linwood Tull	36	M	No injury reported
14	Robert Green	37	M	No injury reported
	Mrs. Robert Green	--	F	No injury reported
15	David Thompson	48	M	No injury reported
16	William Boone	25	M	Injured slightly
	Mrs. William Boone	23	F	Treated and released
17	Edward Jaffee	35	M	Hospitalized
18	Winford Thompson	26	M	Treated and released
19	John Curley	55	M	No injury reported
20	Gasper Matos	58	M	Fatally injured 1/
	Hilda Matos	47	F	Fatally injured 1/
21	James Buckle Jr.	41	M	No injury reported
	Mrs. James Buckle	40	F	No injury reported
	Buckle child	16	M	No injury reported
	Buckle child	11	M	No injury reported
	Buckle child	6	F	No injury reported
	Buckle child	4	F	No injury reported
22	William Lott	63	M	Injured slightly
	Mrs. William Lott	--	F	No injury reported
23	William Carter	34	M	No injury reported
	Mrs. William Carter	34	F	No injury reported
	Carter child	11	M	No injury reported
	Carter child	7	F	No injury reported
24	Edward Fogler	42	M	Treated and released
25	Edgar McNeil	46	M	No injury reported
	Mrs. Edgar McNeil	43	F	No injury reported
	McNeil child	13	F	No injury reported
	McNeil child	11	M	No injury reported
	McNeil child	9	F	No injury reported
	George Tipton	--	M	No injury reported
	Howard Ellis	--	M	No injury reported
	Mrs. Howard Ellis	--	F	No injury reported
	Ellis child	4	M	No injury reported
26	Ivan Grant	21	M	Injured slightly
	Mrs. Ivan Grant	22	F	Hospitalized
27	Lonnie Blake	25	M	Injured slightly
	Mrs. Lonnie Blake	--	F	No injury reported
	Blake child	4	F	No injury reported
	Blake child	2	M	No injury reported
28	William Eberly	--	M	No injury reported 2/
29	Leonard Chenier	40	M	No injury reported 2/

1/Bodies burned, no autopsy made
2/Vehicle not involved in collision
-- Data not obtained

APPENDIX B

MOTOR VEHICLE IDENTIFICATION

(Keyed to Numbers on Figure 1)

VEHICLE NUMBER	MANUFACTURER	MODEL	YEAR	PLATE NO.	OPERATOR
1-Tractor	I. H. Co.	DCOF-405 3-axle	1965	(NJ) X6H-492	John Mullen
1-Trailer	Downingtown	MC-331 (Tank)	1965	(NJ) TGV-979	
2	Chevrolet	Chevvy II 4-door sed.	1965	(RI) H-479	Leo Lussier
3-Tractor	I. H. Co.	CO-4000-D 2-axle	1968		Ralph Nepert
3-Trailer	Trailmobile	42' closed van	1968	(Md) 7498	
4	Chevrolet	Biscayne 4-door sed.	1963	(NY) JB-318	James Boylan
5	Oldsmobile	88 2-door convert.	1962	(Ill) 281-631	James Kleiber
6	Mercury	Cyclone 2-door HT	1966	(Fla) 10-5588	Anthony LaFauci
7	Oldsmobile	88 4-door HT	1969	(RI) WN-978	Elijah Dunston
8	Dodge	Dart 4-door sedan	1969	(NJ) NJV-470	Peter Griffin
9	Oldsmobile	98 4-door HT	1970	(NY) 7104-WU	Jos. Warrington
10	Dodge	Dart 2-door coupe	1965	(NY) RE-7839	Madeline Bogardt
11	Dodge	Coronet 4-door sedan	1966	(NC) BS-1036	Thos. Kohlweiss
12	Cadillac	DeVille 2-door HT	1969	(NJ) CHB-8	Wm. Bosserman
13-Tractor	Mack	F-373-ST 3-axle	1966	(Md) 9689	Linwood Tull
13-Trailer	Fruehauf	40' produce van	1957	(Md) 7731-GJ	
14	Plymouth	Valiant 4-door sedan	1966	(NJ) LPG-265	Robert Green
15	Jaguar	2-door coupe	1967	(Pa) 8D2-841	David Thompson
16	Plymouth	Barracuda 2-door HT	1970	(NY) SM-9700	William Boone
17	Mercury	Monterey 2-door HT	1969	(NJ) GVJ-447	Edward Jaffee
18-Tractor	G. M. Corp.	DF-7000 3-axle	1966	(Md) 2941	Winford Thompson
18-Trailer	Great Dane	40' refrigerated van	1966	(Md) 4693-GA	
*19-Tractor	White	----------	1965	(Md) C-587	John Curley
19-Trailer	Gindy	40' closed van	1962	(Md) 3036	
20	Pontiac	Tempest 2-door coupe	1963	(NJ) LVM-262	Gasper Matos
20-Trailer	Unknown	U-Haul van, 1 axle	----	---- -------	
21	Pontiac	Station wagon	1966	(Ga) 2A-17162	James Buckle
22	Ford	Fairlane 4-door sed.	1966	(NJ) ECX-885	William Lott
23	Pontiac	Station Wagon	1969	(Md) AB-7172	William Carter
24-Tractor	Mack	F-763-T 2-axle	1968	(Mass) A-7550	James Fogler
24-Trailer	Strick	40' closed van	1969	(RI) 25730	
25	Pontiac	Bonneville 4-door sed	1968	(Ct) 258-294	Edgar McNeil
26	Chevrolet	Camaro 2-door HT	1968	(Md) FW-7958	Ivan Grant
27	Chevrolet	Chevelle 2-door HT	1967	(Md) FX-2924	Lonnie Blake
* 28-Tractor	Mack	B-61 2-axle	1961	(Pa) CH-92987	William Eberly
* 28-Trailer	Fruehauf	40' closed van	----	(Pa) CA 59994	
* 29-Tractor	I. H. Co.	CO-4000-D 2-axle	1968	---- --------	Leonard Chenier
* 29-Trailer	Trailmobile	40' furniture van	----	---- --------	

* Vehicle not involved in collision

---- Data not obtained

APPENDIX C

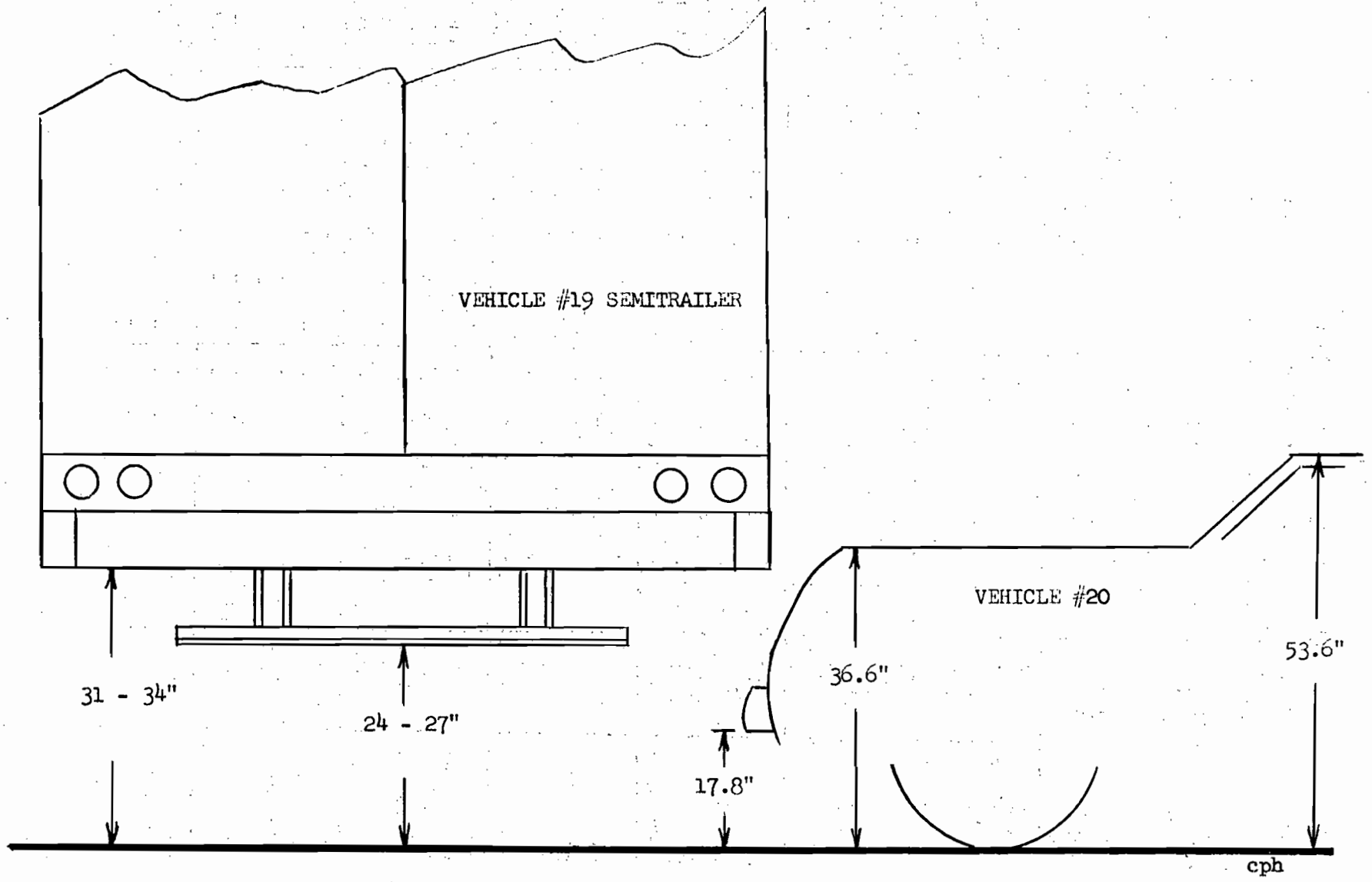
IMPACT AND FIRE DAMAGE TO VEHICLES

Legend: B - Interior or exterior fire damage; E - Extreme damage; (F) - Fatality; R - Repairable.

Vehicle Identification Number (See Figure 1)	Impact Direction (Clock Oriented)	LEFT			RIGHT			Roof	Fuel Tank	Fuel Tank Filler Spout	FIRE DAMAGE		Phase of the Accident	Overall Condition
		Front	Side	Rear	Front	Side	Rear				Interior	Exterior		
1 (F)	11,3	R	R	R	R	E	-	-	E	-	B	-	1	Not R
1-Trailer	3	-	-	R	R	R	R		-	-	-	-	1,4	Repairable
2 (F)	1,5	E	E	E	E	E	E	E	E	E	B	B	2,4	Demolished
3	1,11	E	E	E	E	E	E	E	R	-	B	B	4	Demolished
3-Trailer	1	E	E	E	E	E	E	E	-	-	B	B	4	Demolished
4	1,7	E	E	E	E	E	E	E	E	E	B	B	2,4	Demolished
5	1,4	E	-	-	E	-	-	B	-	-	B	B	2,4	Demolished
6 (F)	6,1,4	E	E	E	E	E	E	E	E	E	B	B	2,4	Demolished
7	2,10	E	E	R	E	E	R	E	-	E	B	B	2,4	Demolished
8	4	R	-	-	-	E	R	-	-	-	B	B	2,4	Demolished
9	5,1	-	-	R	-	-	R	-	-	-	-	-	2,3	Not R
10	5,11	E	-	E	E	E	E	R	E	E	B	B	2,4	Demolished
11 (F)	12,3,7,9	E	E	E	R	E	E	R	E	E	B	B	2,4	Demolished
12	1,11	E	-	-	E	-	-	-	-	-	B	B	2,4	Demolished
13	1,11	R	-	-	R	-	-	-	-	-	-	-	3	Driven Away
13-Trailer	-	-	-	-	-	-	-	-	-	-	-	-	3	No damage
14	6	-	-	R	-	-	R	-	-	-	-	-	5	Repairable
15	7,12	R	-	R	R	-	R	-	-	-	-	-	5	Repairable
16	12	-	-	-	R	-	-	-	-	-	-	-	5	Repairable
17	7,9	R	E	E	R	-	E	E	E	E	-	-	1	Demolished
18	1,12	-	-	-	R	R	-	-	-	-	-	-	6	Repairable
18-Trailer	-	-	-	-	-	-	-	-	-	-	-	-	6	No Damage
19	-	-	-	-	-	-	-	-	-	-	-	-	6	Not Involved
19-Trailer	6	-	-	R	-	-	R	-	-	-	B	B	6	Minor Damage
20 (2F)	6,12	E	R	E	E	E	E	E	E	E	B	B	6	Demolished
20-Trailer	12	E	E	E	E	E	E	E	-	-	B	B	6	Demolished
21	6	-	-	R	-	-	-	-	-	-	-	-	7	Driven Away
22	6,12	R	-	R	R	-	-	-	-	-	-	-	7	Driven Away
23	3,6,12	R	R	R	-	-	R	-	-	-	-	-	7	Driven Away
24	1	R	R	-	-	-	-	-	-	-	-	-	7	Driven Away
24-Trailer	-	-	-	-	-	-	-	-	-	-	-	-	7	Not Involved
25	3,9	-	R	-	-	R	-	-	-	-	-	-	7	Driven Away
26	12	R	R	-	R	-	-	-	-	-	-	-	2	Repairable
27	7	-	-	R	-	-	-	-	-	-	-	-	2	Driven Away
28	-	-	-	-	-	-	-	-	-	-	-	-	6	Not Involved
28-Trailer	-	-	-	-	-	-	-	-	-	-	-	-	6	Not Involved
29	-	-	-	-	-	-	-	-	-	-	-	-	6	Not Involved
29-Trailer	-	-	-	-	-	-	-	-	-	-	-	-	6	Not Involved

APPENDIX D

APPLICABLE UNDERRIDE DIMENSIONS



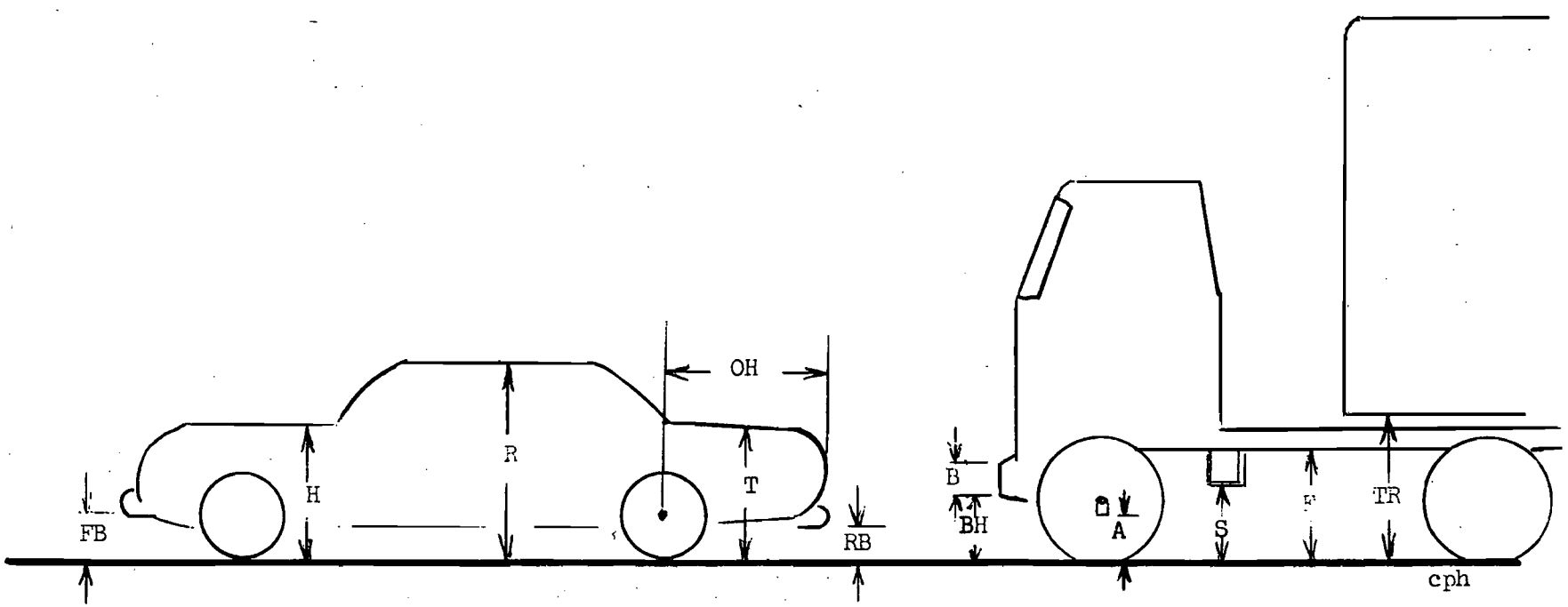
APPENDIX E

APPLICABLE OVERRIDE DIMENSIONS

	FB	H	R	T	RB	OH
Veh. #2	13.4	37.8	55.4	37.8	13.0	45.4
Veh. #4	10.7	36.4	55.0	36.9	10.5	48.1

	BH	B	A	S	F	TR
Veh. #3	24.5	9.0	11.8	16.6	29.0	38.0

(All dimensions in inches.)



APPENDIX F

Movement of Vehicles in the Accident

Only the highlights of the movements of vehicles are included in the Facts portion of this report. Those highlights are taken from the total information obtained concerning the six phases of the accident. The rest of the information is contained herein and is separated into several phases of the accident.

Phase 2:

When Vehicle 7 entered the scene, it reportedly struck another car, but such car has not been identified. All four occupants of Vehicle 7 were injured.

Before the occupants of Vehicle 10 got out, their car was struck from behind by a car described as a Chevrolet with Maryland license plates. These occupants were not injured.

Vehicle 26, a Chevrolet Camaro with Maryland plates, approached the scene in the left lane at some 50 miles per hour. The driver suddenly saw the heavy fog and, at the same time, an unidentified object in his path. He swerved to the right and struck an unidentified car; then his car ran down the right side embankment. It stopped against a concrete ditch drain inlet. He was injured slightly, and his wife was injured severely in the impacts.

Vehicle 27, a 1967 Chevelle hardtop, stopped some 60 feet north of the overturned propane tractor, on the far right of the shoulder. While the driver was assisting his family to safety, an unidentified car brushed against him, slightly nicking the left rear of his car, then continued on and crashed into cars ahead.

Vehicle 11, a 1966 Dodge sedan, in the right lane, entered the scene and crashed into a car or cars ahead. An occupant said visibility had been variable north of the scene, but then got worse so she could see only about "two white lines ahead" -- the intermittent painted lane markers. On impact, this car spun partly counterclockwise and against the rear of another car. The driver was slumped over the wheel after impact, and appeared to be unconscious, but the two occupants received only minor injuries. Just after they impacted, another car struck theirs and partially blocked the left side of their car.

Vehicle 12, a 1970 Cadillac DeVille hardtop, stopped on the right side of the road or shoulder, and the driver and his wife remained in their car. The driver said they had not hit anything, but were later hit and shoved forward, after which they got out.

After the driver of Vehicle 6 had gotten out to try to flag down traffic, Vehicle 6 was bumped and shoved forward by another car. The driver of Vehicle 6 went to get his family out of the car, and while he was doing so, another car struck his car and shoved it into the space between two cars ahead. He assisted his father and mother to the median strip, while his wife remained in the rear seat, right side. When he started to return to her, he saw that a fire had started near the front of his car and crashes were in progress.

The driver of Vehicle 4, after leaving his wife in a safe place south of the propane carrier, returned to the scene to see if he could assist the driver of the blue Chevy II sedan, who appeared to be unconscious. While he was trying to reach this car, he found that cars were still bumping into each other. He also noticed a fire near the middle of the group, with flames licking along the ground, so he decided to leave.

Phase 4:

No witness could describe the kinematics of the vehicles which were involved after Tractor-Semitrailer 3 impacted. The driver of Vehicle 6 saw Vehicle 3 when it was about 15 feet north of his car, but could not describe the action after impact. The final position of vehicles after impact is shown in Figure 1. Vehicle 2 had been moved forward, to the left, and was directly under Tractor 3. Vehicle 4 had also been moved forward and to the left, and was partly under Tractor 3 and jammed between Tractor 3 and the right side of Vehicle 5, which had been moved forward and to the left into the median guardrail. Vehicle 6 had been rotated approximately 180° counterclockwise from its original position, and was in the left lane, partly under the left side of Semitrailer 3. The almost completely burned bodies of the Vehicle 2 driver and Vehicle 6 occupant were later found in their cars. Vehicle 7 was found squeezed between Vehicle 6, on its right, and Vehicles 4 and 5 on its left front. (See Figures 3 and 4.)

On the right (west) side of the highway, Vehicle 12 was found forward of its last position, rotated about 30° counterclockwise, with its right front jammed into the left front of Vehicle 11. Vehicle 11 was at an angle of about 60° counterclockwise from the roadway alignment, its right side jammed into the rear of Vehicle 10, which had been moved farther to the right at an angle of about 45°, and was found with its left front almost touching the front of Tractor 1, and partly over the body of Tractor 1 driver.

It is not clear from their statements whether the two surviving occupants of Vehicle 11 crawled out of the rear of their car before Vehicle 3 impacted or after. Both reported there was fire on the right side of their car when they left. Driver 11 was still at the wheel, appearing to be unconscious; his almost completely burned body was found there later.

Vehicle 14, a 1966 Plymouth sedan, stopped in the right lane when the driver saw fire and wrecked cars ahead. While backing away from the fire, Vehicle 14 was struck in the rear by Vehicle 15, a 1967 Jaguar coupe. Vehicle 16, a 1970 Plymouth Barracuda, traveling in the left lane, swerved to the right to avoid striking Semitrailer 13, but struck Vehicle 15, ramming it forward and partially under Vehicle 14. No one was injured in this sequence. (See Figure 5.)

Semitrailer 19: Minor fire damage was sustained by this vehicle -- to its rear doors and to some of its freight. The DOT-required rear-end protection guard had been distorted several inches forward.

APPENDIX G

SUMMARY OF FATAL AND MAJOR NON-FATAL INJURIES

1. Driver of Vehicle 1 -- male, aged 31, wearing no seat restraints, fatally injured. Autopsy showed basalar skull fracture, compound fracture of left humerus, laceration of scrotum, fracture of fourth and fifth left forward ribs, bilateral fracture of pelvis, fracture of second through sixth ribs right rear, deep lacerations in each lobe of liver, and large "brush burns" on lower abdomen and left thigh. Cause of death: hemorrhagic shock due to lacerated liver and fractured pelvis.

2. Driver of Vehicle 17 -- male, aged 35, seatbelted, sustained fractured left clavicle, fractured left eighth rib, contused left elbow, multiple abrasions and lacerations to left thigh and left ear. Admitted to hospital.

3. Driver of Vehicle 2 -- male, aged 55, using no seat restraints, was fatally injured. Due to complete charring of his body, no autopsy was attempted. Cause of death cannot be specified.

4. Driver of Vehicle 5 -- male, aged 20, using no seat restraints, sustained compound fracture left patella, contusion of right frontal lobe (with partial amnesia), laceration of right eyelid, and contusion of left chest. Admitted to hospital.

5. Occupant of Vehicle 6 -- female, aged 19, not using seatbelt, fatally injured. Due to complete charring of her body, no autopsy was attempted. Cause of death cannot be specified.

6. Driver of Vehicle 11 -- male, aged 59, not wearing seatbelt, fatally injured. Due to complete charring of his body no autopsy was attempted. Cause of death cannot be specified.

7. Driver of Vehicle 3 -- male, aged 38, not wearing seatbelt, sustained 1 1/4-inch laceration to right forehead requiring five sutures. Treated and released.

8. Occupant of Vehicle 3 -- female, aged 38, not wearing seatbelt, sustained 2-inch laceration to scalp, contusions and abrasions to right knee, left ankle, right elbow, right forearm, and right third finger, and fracture of left shoulder blade. Treated and released.

9. Occupant of Vehicle 26 -- female, aged 23, not wearing seatbelt, sustained fractured right tibia and fibula, fractures to both right and left sides of jaw, and multiple lacerations (approximately 4 square inches) to left forehead into hairline. Admitted to hospital.

10. Driver and Occupant of Vehicle 20 -- male, aged 58, female, aged 59, not seatbelted, fatally injured. Extent of burning prevented autopsy. Cause of death cannot be specified for either victim.

APPENDIX H

Brief analyses of the kinematics of Vehicles 5, 6, 11, 20, and 26, and their occupants, are contained in this Appendix.

Kinematics of Vehicle 5:

Vehicle 5 struck the overturned propane tank in much the same fashion, and probably at about the same speed, as did Vehicle 2. Vehicle 5 impacted the tank-semitrailer at approximately the 1 o'clock position, with enough force to cause the injuries noted in Appendix G. From the slight counterclockwise rotational force at impact, the driver's entire unrestrained body went forward so that his right knee probably impacted the instrument panel, and his chest struck the steering wheel. His torso then went up, forward and to the right, so that his head impacted the forward crossmember of the convertible top. His eyeglasses were presumably crushed, thus causing the cut to his eye. The car was later destroyed by fire, but the driver had managed to evacuate it without known help before the fire occurred.

Kinematics of Vehicle 6:

When Vehicle 6 first stopped, without impact, the driver got out, but the three occupants remained in the car. When Vehicle 6 was struck the first time, none of the occupants was injured, but they decided to evacuate. As one of the occupants was in the process of getting out of the left door, Vehicle 6 was bumped again, and the occupant either fell or was thrown to the ground, suffering minor injuries. The other two occupants were not reportedly injured. One of these occupants got out, but the other remained for no reported reason.

This occupant, wearing no seat restraints, was in the right rear seat of Vehicle 6 when it was struck from approximately the 7 or 7:30 o'clock position by Vehicle 3, which would cause her body to be accelerated to the left. As Vehicle 6 rotated counterclockwise, and then accelerated to the left (east) side of the highway, it was partially overrun by the semitrailer of Vehicle 3. In this movement, the occupant would have been accelerated in the direction of the left door, which had been left open. This occupant's body was found partially out the left door after the accident. Because there were no great accelerational forces involved, and because she was in that part of the car least crushed, it is probable that she survived the impacts. However, because of the extent of burning, cause of death could not be specified.

Kinematics of Vehicle 11:

When Vehicle 11 entered the accident scene, the driver braked suddenly, but struck another vehicle. Vehicle 11 spun slightly counterclockwise on impact. The unrestrained driver impacted the steering

wheel, and possibly other interior vehicle components, and was rendered unconscious. The front-seat occupant was thrown forward and to the right, suffering a fractured nose against the dash or cowling. The force of this impact cannot be determined, as the speed of Vehicle 11 was not ascertainable.

Major crushing to the left rear of Vehicle 11 in the 7 o'clock position cannot be identified with any specific impacting vehicle. Its appearance and extent are characteristic of impacts of passenger cars by trucks, but this damage cannot be specifically attributed to Vehicle 3, which was the only likely candidate in the area.

The driver was still seated at the wheel, apparently unconscious, when the two occupants left through the rear window and over the trunk compartment as fire was beginning to engulf the vehicle. Due to the extent of burning, the cause of death of the driver of Vehicle 11 could not be specified.

Kinematics of Vehicle 26:

Vehicle 26 struck another vehicle from the rear, at about 1 o'clock position, while changing lanes from left to right. The driver, wearing no seat restraints, cut his lip on impact with the upper quadrant of the steering wheel. On impact, the occupant's unrestrained upper torso moved forward and slightly leftward, and her forehead impacted the windshield. The windshield bulged outward but was not penetrated. At the same time, her lower torso moved forward and jammed her right foot against the floor pan, putting longitudinal compressive force on the tibia and fibula. Her jaw fractures may have occurred when her head rebounded off the windshield and into the right quadrant of the steering wheel.

The second impact to Vehicle 26 occurred when it stopped against the concrete drain fixture at the bottom of the roadside embankment. The occupant's head went forward a second time and probably produced the second bulge in the windshield, near the right A-pillar. The retention feature of vehicle windshields under Motor Vehicle Safety Standard No. 212 was demonstrated. The occupant might have suffered fatal or severely disfiguring injuries if the windshield had been penetrated by the head in either impact.

Kinematics of Vehicle 20:

Vehicle 20 was accelerated forward from a stopped position when struck from behind by Vehicle 18, then suddenly decelerated when it was jammed under the rear of Trailer 19. It is unlikely that the initial

impact induced critical injury, although whiplash could have occurred. In the deceleration impact with Trailer 19, the driver and occupant, both unrestrained, would have been thrown forward. No determinations could be made as to possible injury to either occupant because of the extent of burning of both bodies. Jamming of both doors and the sudden eruption of fire would have prevented escape if an attempt had been made. Cause of death could not be specified.

APPENDIX I.

Background Information on the Drivers of Six Commercial Vehicles

1. Driver, Vehicle 1: Male, aged 30, married, five children; had been driving tractor-semitrailers for about 9 years, 4 years of which were for the Petrolane Company. During these 4 years, he had had no accidents or driving violations. His driver's license and medical certification were current, and he had no pertinent physical defects. His last logs were destroyed by fire, but he had averaged 7 to 10 hours of driving per day. On the day of the accident, he had completed one delivery of propane in the early morning hours, prior to 4:21 a.m., and left on his second delivery at 5 a.m. From 5 a.m. on, his activities were unknown, as he did not survive the accident.

2. Driver, Vehicle 3: Male, aged 38, married; had been driving tractor-semitrailers for about 22 years, the last 4 years of which were for his current employer. He had had no reported accidents or known driving violations prior to this crash. Both his driver license and medical certification were current. He had driven about 50 hours in the preceding 8 days, and about 4 1/2 hours on the morning of the accident. He had left Rhode Island the night before, en route to Baltimore, Maryland. He had an unauthorized female passenger aboard at the time of the accident. New Jersey State Police charged him with careless driving as a result of this accident. He was tried and found guilty.

3. Driver, Vehicle 13: Male, aged 36, had been driving tractor-semitrailers for about 2 1/2 months, during which time he had no accidents or violations. Both his driver's license and medical certification were current. His medical certificate indicated that he should use glasses while driving, and he was doing so at the time of the accident, but his driver's license showed no such restriction. He had driven some 43 1/2 hours during the preceding 8 days, and had been on duty for 3 1/2 hours at the time of the accident. He was returning to Maryland from a delivery in Newark, New Jersey.

4. Driver, Vehicle 18: Male, aged 26, had been driving tractor-semitrailers for some 4 years, with about 2 years in his current employment. Both his driver's license and medical certification were current. In the preceding 8 days, he had driven about 40 hours. On the morning of the accident, he had been on duty 7 hours, en route from Boston to Federalsburg, Maryland. He had no record of accidents or moving traffic violations in the preceding 4 years.

5. Driver, Vehicle 19: Male, aged 55, had been driving tractor-semitrailers for 25 years, and had been with his present employer 17 years. He had driven 51 1/2 hours in the preceding 8 days, and had been on duty for 3 hours the morning of the accident. His driver's license and medical certification were current. As the result of a fall about 2 years prior, he suffered a 10 percent disability of his right leg and lower back. This limited flexing or bending, but was not noted as affecting the safety of his driving. He had no accidents or violations on record.

6. Driver, Vehicle 24: Male, aged 52, had been driving tractor-semitrailers and trucks for some 30 years, of which the last 20 were for the current employer. His driver's license and medical certification were current. He was restricted to wearing glasses while driving, and reported he was wearing them at the time of the accident. He had been put on record by his employer twice in the preceding 5 months: once for an accident, and once for an unexplained loss of company equipment. After this accident, his employer first notified him of his dismissal. However, it was subsequently learned that the dismissal had been rescinded and changed to a suspension, pending recovery from a leg injury sustained in the accident, at which time final action would be considered. His driving hours were within regulations, and he was en route from Boston to Baltimore.

GPO 906 741