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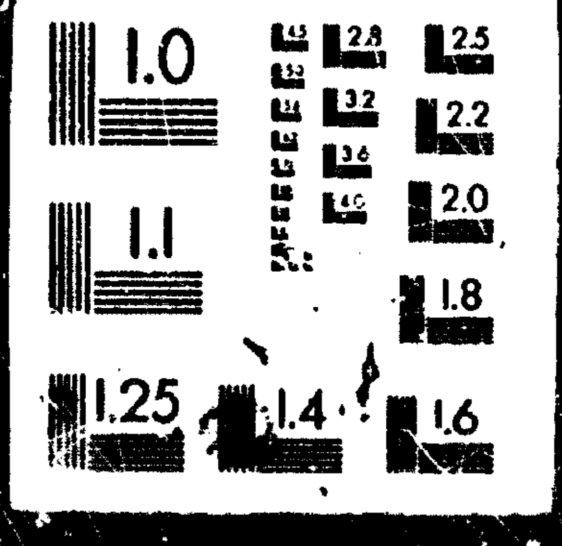

PB91-917004

Hazardous Materials Accident Report - Overturn of a Tractor-Semitrailer (Cargo Tank) with the Release of Automotive Gasoline and Fire, Carmichael, California, February 13, 1991

(U.S.) National Transportation Safety Board, Washington, DC

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U.S. Department of Commerce
National Technical Information Service
NTIS

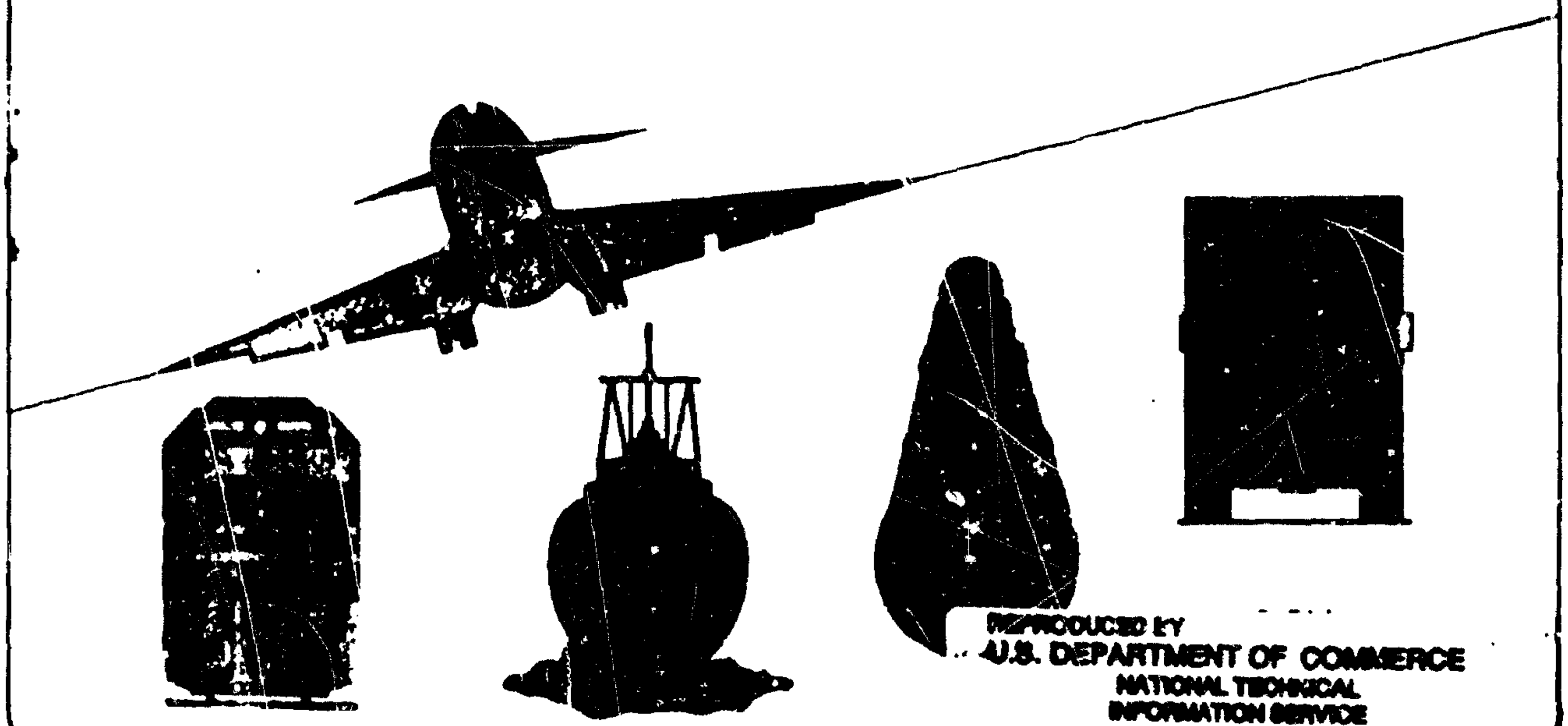
PB91-917004
NTSB/HZM-91/01

NATIONAL TRANSPORTATION SAFETY BOARD

WASHINGTON, D.C. 20594

HAZARDOUS MATERIALS ACCIDENT REPORT

OVERTURN OF A TRACTOR-SEMITRAILER (CARGO TANK) WITH THE RELEASE OF AUTOMOTIVE GASOLINE AND FIRE
CARMICHAEL, CALIFORNIA
FEBRUARY 13, 1991



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CARMICHAEL, CALIFORNIA
FEBRUARY 13, 1991

ADOPTED: September 4, 1991
NOTATION 5471A

Abstract: This report explains the overturn of a tractor-semitrailer (cargo tank) in Carmichael, California, on February 13, 1991, and the subsequent fire that resulted from the release and ignition of automotive gasoline that was being transported in the cargo tank for an intrastate delivery. The safety issues discussed in the report are (a) the lack of U.S. Department of Transportation performance standards for components mounted on manhole covers on motor vehicle tanks transporting bulk hazardous liquids; (b) the adequacy of California standards for highway bulk liquid cargo tanks; (c) the effectiveness of the carrier's evaluation of driver training and performance; and (d) the lack of requirements for postaccident toxicological testing of drivers involved in the intrastate transportation of hazardous materials. Safety recommendations concerning these issues were made to the Research and Special Programs Administration, the Federal Highway Administration, and the National Highway Traffic Safety Administration of the U.S. Department of Transportation; to the State of California; to other States and U.S. Territories; and to the motor vehicle carrier.

CONTENTS

EXECUTIVE SUMMARY

About 3 a.m. Pacific standard time on February 13, 1991, a tractor-semitrailer (cargo tank) overturned as the vehicle was traveling on a main urban roadway in Carmichael, California. The tractor and semitrailer were owned and operated by Calzona Tankways, Inc., of Phoenix, Arizona. At the time of the accident, the truck was being used for the intrastate delivery of gasoline to service stations; the cargo tank contained about 8,800 gallons of automotive gasoline.

The driver lost control of the vehicle in a curve. The vehicle overturned onto its side and struck the embankment of a drainage ditch located in a dirt field beside the road. The cargo tank bounced and came to rest in the dirt field and adjacent to the drainage ditch. The rear end of the cargo tank landed on an unoccupied car parked in the field.

Gasoline from the cargo tank spilled into the drainage ditch, which extended under the roadway and behind private residences nearby. About 15 minutes after the overturn, the gasoline ignited behind a residence. The fire flashed back and engulfed the overturned cargo tank, and the car under the cargo tank. A second unoccupied car parked near the overturned tank truck also caught fire. Gasoline runoff in the drainage ditch entered the underground drainage system and was also ignited.

In addition to the total loss of the tank truck, its cargo, and the two parked cars, four homes and their contents were destroyed or heavily damaged by fire, and the residents from a 2-mile-square area were evacuated. Total property damage and cleanup costs were estimated at nearly $1 million. There were three minor injuries.

The National Transportation Safety Board determines that the probable cause of the accident was the inattention of the driver, for undetermined reasons, which resulted in his operation of the tank truck at excessive speeds leading to its overturn. Contributing to the severity of the accident was the failure of one of the liquid-level sensors mounted on the manhole cover for the forward compartment of the cargo tank to remain secured.

The following safety issues are discussed in this report:

1. The lack of U.S. Department of Transportation performance standards for components mounted on manhole covers on motor vehicle tanks transporting bulk hazardous liquids;

2. The adequacy of California standards for highway bulk liquid cargo tanks;

3. The effectiveness of the carrier's evaluation of driver training and performance; and

4. The lack of requirements for postaccident toxicological testing of drivers involved in the intrastate transportation of hazardous materials.

Safety recommendations concerning these issues were made to the Research and Special Programs Administration, the Federal Highway Administration, and the National Highway Traffic Safety Administration of the U.S. Department of Transportation; to the State of California; to the other States and U.S. Territories; and to the motor vehicle carrier.

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OVERTURN OF A TRACTOR-SEMITRAILER (CARGO TANK)
WITH THE RELEASE OF AUTOMOTIVE GASOLINE AND FIRE
CARMICHAEL, CALIFORNIA
FEBRUARY 13, 1991

INVESTIGATION

The Accident

Events Preceding the Accident.--The accident trip originated at the Atlantic Richfield Corporation (ARCO) terminal in West Sacramento, California, about 14 miles from the accident location (fig. 1). The driver had loaded about 8,800 gallons of unleaded automotive gasoline in the four-compartment cargo tank at the ARCO terminal. According to the driver, he did not check the manways and fittings on top of the cargo tank before departing the ARCO terminal about 2:45 a.m.[1]

The driver's destination was a service station located on Fair Oaks Boulevard (Blvd.) in Carmichael, California, about 1 mile north of the accident location and about 15 miles from the ARCO terminal. In a statement to the California Highway Patrol (CHP), the driver stated that there was virtually no traffic and that he did not have to stop at any stop lights on the accident trip. The driver indicated that he had driven this route on two previous work trips, had passed the accident scene many times in his own car, and was not surprised by the curve.

At the time of the accident, weather conditions were clear, visibility was about 7 miles, winds were calm, and the temperature was about 46 °F. The pavement was dry.

Overturn of the Tank Truck.-- According to the response to written questions submitted by the Safety Board,[2] the driver was not sure of the engine rpm or the transmission gear at the time of the accident. During a telephone interview with the California Highway Patrol (CHP) on February 14, the driver stated that the speed of the truck was about 35 to 40 mph. He also stated that "you get to where you don't even look at the speedometer or the tachometer even," and that he could determine the speed "real close" by listening to the engine. The driver further indicated that he was listening

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[1] (a) All times are Pacific standard time. (b) The cargo tank was loaded through the bottom fittings.

[2] The driver declined to be interviewed by Safety Board investigators upon the advice of his attorney because of possible criminal charges. Safety Board investigators provided a list of written questions to the attorney. The attorney provided a written summary of the driver's answers.

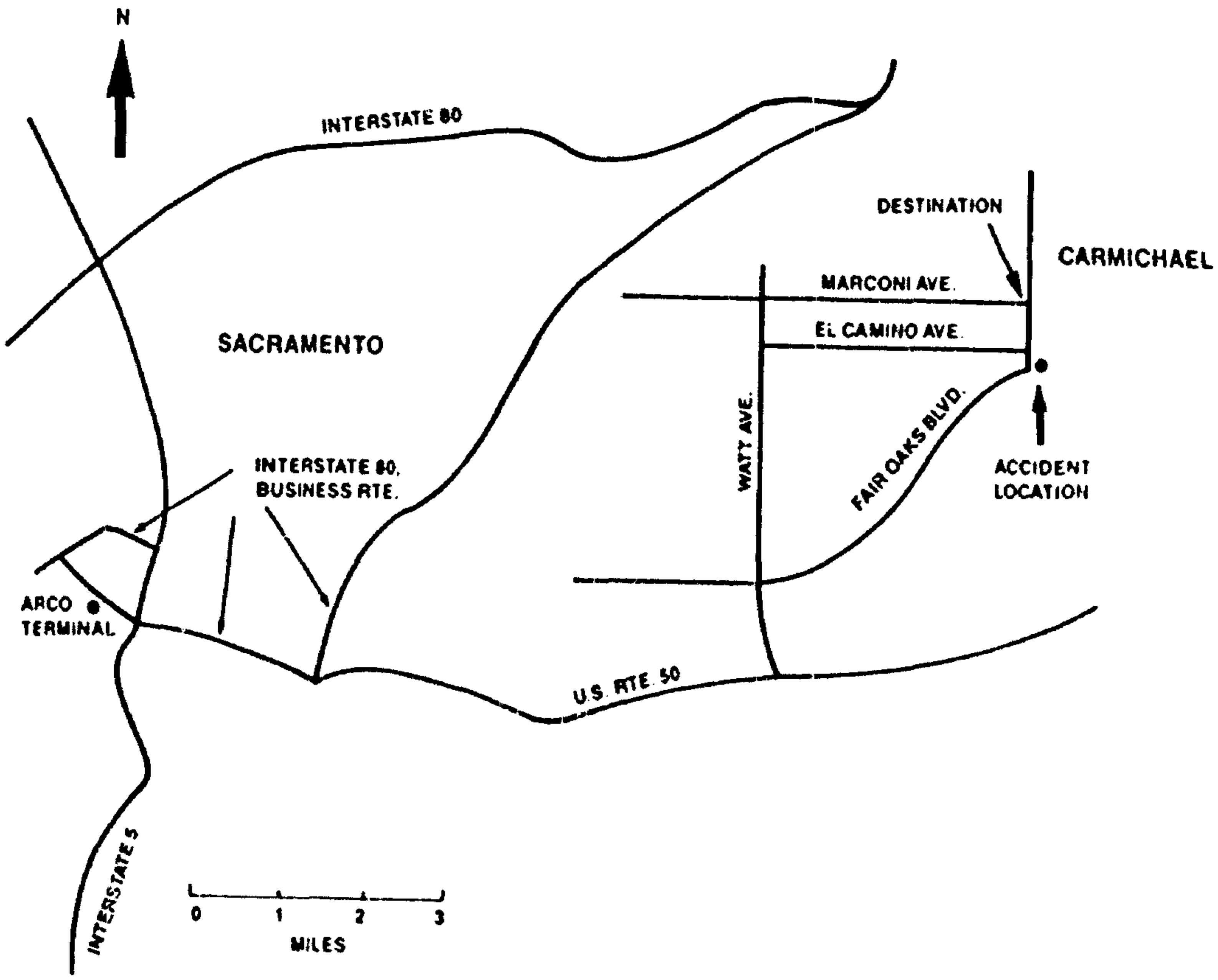

Figure 1.--Accident location and route.

to the radio and may have been singing with music. There were no lights on inside the cab of the tractor, and he was wearing a lapbelt and shoulder harness.

The driver indicated that after the truck had passed through the first curve on Fair Oaks Blvd. [a curve to the right preceding the accident curve to the left], the truck "leaned hard to the right and felt mushy" (fig. 2). He further indicated that he "steered into the lean" and that the truck "felt as if it was coming back," but it "suddenly leaned harder to the right" beyond the point of steering. The driver thought that a right-side tire on the tractor had a blow-out causing the vehicle to overturn.

An employee of the Sacramento Bee newspaper was preparing to deliver newspapers when he saw the accident occur. He stated that he had arrived and parked his car at the corner of Oak Avenue (Ave.) and Boyer Drive about 3 a.m. He was standing next to his car when he heard a loud scraping noise. He turned and saw the tank truck as it began to overturn. According to the employee, the tank truck was in both lanes of northbound Fair Oaks Blvd. and centered in the intersection of Fair Oaks Blvd. and Oak Ave.[3] He saw the truck overturn onto its right side and slide into the dirt field [adjacent to and east of Fair Oaks Blvd.]. The newspaper employee stated that the tank truck hit the drainage ditch [in the field] and bounced, and the cargo tank landed on an unoccupied car parked in the field.

Release of Gasoline.--After the tank truck had overturned and before the newspaper employee saw any indication of a fire, he heard a loud hissing noise and smelled gasoline. He could not see the location on the cargo tank from which gasoline was leaking, although he stated that the top right-hand side of the cargo tank was "crushed and crinkled up." He estimated that he was standing 150 to 200 feet away from the tank truck.

The newspaper employee stated that he saw the driver of the tank truck climb out of the tractor and go to the apartments at 5800 Fair Oaks Blvd. As local residents began to gather outside, the newspaper employee heard someone warning the on-lookers to keep away from the tank truck.

At 3:05 a.m. Sacramento County Fire Dispatch was notified of an accident at 5820 Fair Oaks Blvd. involving an auto and a "gasoline tanker." Engine 9 with a crew of three; Truck 9 with a crew of four; and the Chief, Battalion 4 from Station 9 of the American River Fire District were en route at 3:07 a.m. and arrived about 3:10 a.m. according to fire department dispatch logs. Engine 9 and Truck 9 were positioned on southbound Fair Oaks Blvd. adjacent to the Twin Garden Apartments at 5831 Fair Oaks Blvd. The CHP had also been notified about 3:05 a.m., and two CHP officers in a cruiser arrived between 3:10 a.m. and 3:12 a.m. The cruiser was also positioned on southbound Fair Oaks Blvd., north of the firefighting equipment.

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[3] Preceding the accident curve, Fair Oaks Blvd. follows an east-west direction. In the vicinity of Oak Ave., Fair Oaks Blvd. turns and continues in a north-south direction.

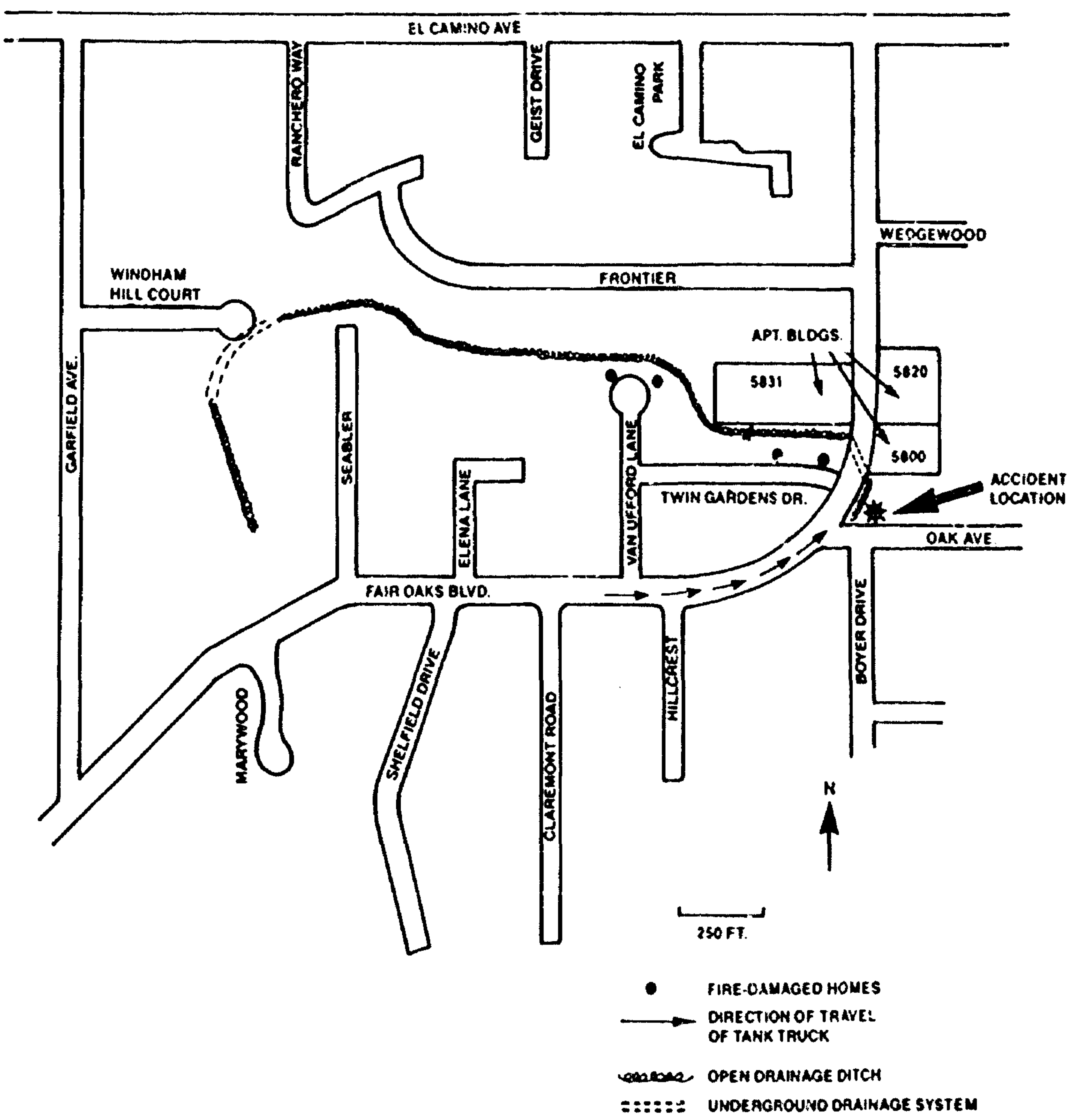

Figure 2.--The accident site and vicinity.

The captain and the engineer from Engine 9 and the captain from Truck 9 all stated they saw gasoline leaking from the tank truck when they first arrived at the scene. The captain from Engine 9 indicated that from his vantage point in the parked fire truck, and with the assistance of a spotlight on the fire truck, he saw product leaking from the top of the tank truck. He did not believe that the leak was located on the side of the cargo tank because the right side of the tank was against the ground and not visible. He stated that the rate of flow was similar to that which would occur from a 4 1/2-inch fire hydrant. He characterized the flow as constant, moderate in rate, and with no pressure.

The engineer from Engine 9 also described product leaking from a single location within 1 foot of the forward head of the tank at what would have been the top of the tank. The engineer initially stated that the leak was through a "puncture" about 4 to 6 inches in diameter. On a second occasion, he stated the leak was through a round opening. The captain from Truck 9 also indicated that product was leaking from a single location toward the front and on top of the cargo tank. He further stated that the flow of product from the tank was not under much pressure. The three firefighters estimated they were 200 to 300 feet from the tank truck.

One CHP officer also stated he saw product "gushing" from a "hole...towards the top, the right side of the truck." He estimated the hole to be 1 to 2 feet in diameter, and described it as a "ruptured" hole. He stated that he did not get very close to the tank truck because he was afraid that the tank would explode. Both CHP officers also noted that the odor of gasoline was very strong when they arrived at the scene.

<u>Ignition and Fire</u>.--Both CHP officers, the captain from Truck 9 and the engineer from Engine 9 all estimated that the ignition of the gasoline and the resulting fire occurred about 5 minutes after their arrival at the accident scene. At the time the fire occurred, firefighting personnel were setting up equipment and attending to the injured driver. The two CHP officers had not been aware that the accident involved a single vehicle, and thought there may have been a second vehicle involved. The officers, upon their arrival, first verified there was not a second vehicle or driver, and then were approaching the injured tank truck driver when the ignition and fire occurred. The communications log contains an entry at 3:18 a.m. that the tank truck had exploded and ignited.

One of the CHP officers stated that he first heard a muffled explosion from the back of a home near 5807 Twin Gardens Drive. He observed flames immediately shoot 60-80 feet in the air. He stated that after the first explosion, the flames spread quickly back toward Fair Oaks Blvd. He stated that a second explosion at 5827 Twin Gardens Drive blew the roof off the house. The fire then advanced across Fair Oaks Blvd. and engulfed the overturned tank truck and the parked car under the cargo tank, which caused a third explosion. A second unoccupied car, parked about 20 feet from where the truck came to rest, also caught fire. The officer estimated that the time between the first and third explosions did not exceed 5 seconds. The second CHP officer also saw the fire come across Fair Oaks Blvd. and recalled that the road was covered in flames. He also described the movement of flames and the explosion of the truck to have been very fast. The engineer from Engine 9 estimated that the time interval between the first explosion and the engulfment of the tank truck was less than 30 seconds. Immediately following the explosions, the firefighters and CHP officers on-scene moved their vehicles and equipment away from the burning tank truck. The CHP officers also began to direct on-lookers away from the tank truck.

Photographs indicate that the fire did not spread beyond the immediate area of the overturned tank truck in the direction from which the truck had come (fig. 3). The drainage ditch at the location of the accident went under Fair Oaks Blvd. and extended west. The fire followed the drainage ditch westward to Windham Hill Court (see fig. 2). Gasoline that entered the underground drainage system in the immediate area was also ignited.

Emergency Response

Emergency Management.--With the ignition of the gasoline, the Sacramento County incident command system[4] was initiated. The Chief of Battalion 4 assumed the responsibility of incident commander, and a command post was established at the intersection of Fair Oaks Blvd. and Frontier Street. Between 3:18 a.m. and 3:57 a.m., five additional alarms were issued. All additional responding units were directed to a staging area established at the southwest corner of Fair Oaks Blvd. and El Camino Ave. where they received their assignments from the incident commander. Ultimately, 18 engines, 6 trucks, 2 hazardous materials units, 1 crash truck, 1 air unit, 1 grass unit, and 141 firefighters from the American River Fire District and five other departments responded to the fire. An additional 44 personnel from six stations were placed on stand-by.

Because of the threat to property and continuing spread of the fire, the incident commander permitted the tank truck to burn and directed his efforts to containing the fire that was spreading through the residential area west of Fair Oaks Blvd. As additional firefighting units arrived, they were directed to various locations on Twin Gardens Drive, Fair Oaks Blvd., Garfield Ave., and Windham Hill Court.

The first patrol unit of the Sacramento County Sheriff's Department arrived at the scene about the same time that the fire started. The incident commander directed the sheriff's personnel to assist firefighters with the evacuation of residents from the 2-mile-square area bounded by Fair Oaks Blvd. to the east and south, El Camino Ave. to the north, and Garfield Ave. to the west. By 3:25 a.m., about 300 residents had been evacuated, including the residents of a nursing home located between Ranchero Way and El Camino Ave. El Camino High School at 4300 El Camino Ave. was opened by 4:10 a.m. to receive evacuees, and Red Cross personnel were present to provide assistance.

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[4] The incident command system establishes procedures for the control and coordination of personnel, facilities, equipment, and communications during all phases of an emergency.

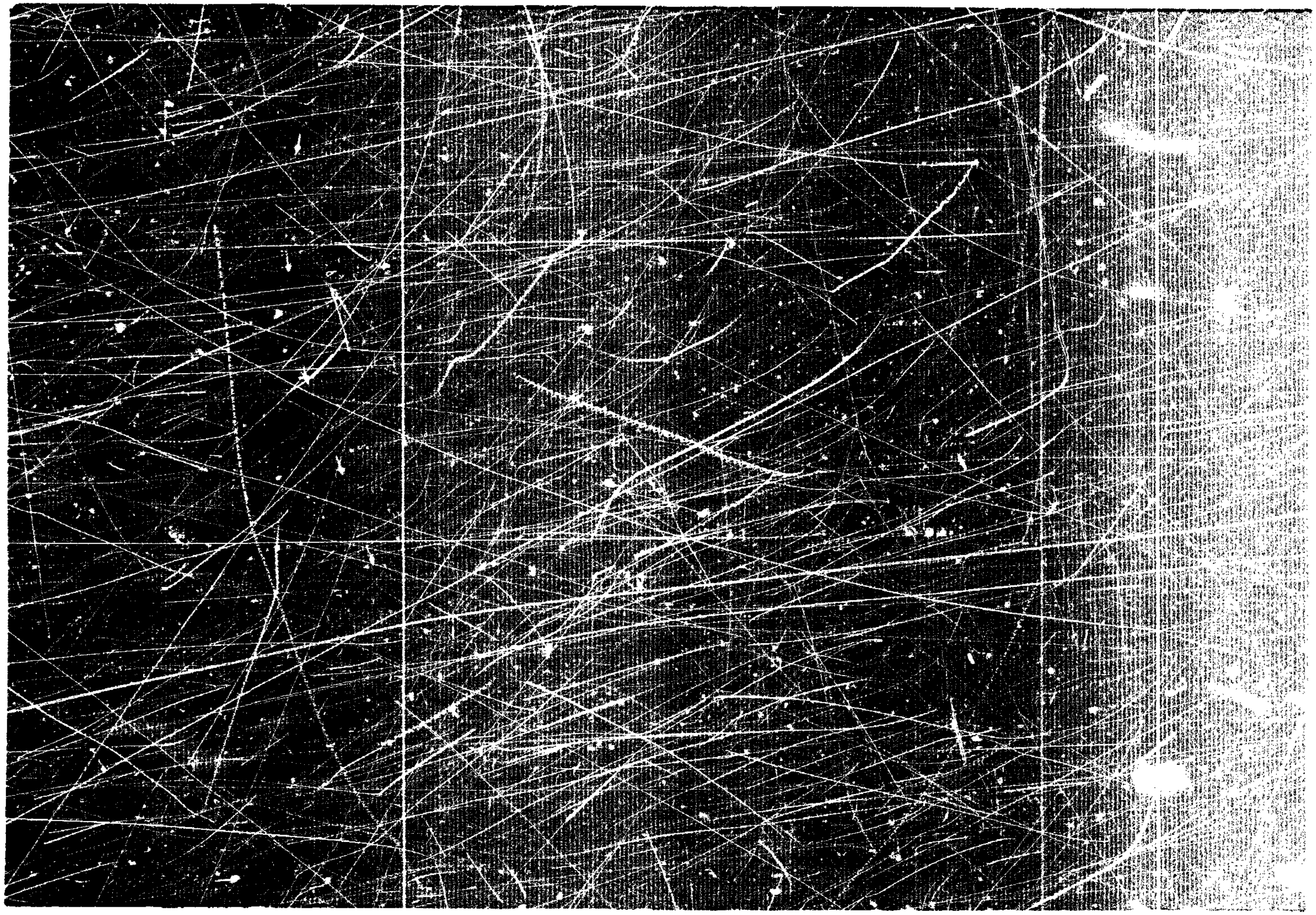

Figure 3.--Aerial view of the accident site. The arrows indicate the direction of travel of the of the tank truck.

Additional CHP patrol units also arrived to assist with the evacuation of residents, to keep traffic and onlookers from entering the evacuated area, and to provide security in the area.

By 4:25 a.m. the fires involving the four private residences at 5821 and 5827 Twin Gardens Drive and 2310 and 2313 Van Ufford Lane were extinguished. By 7 a.m. the fires in the drainage ditches, in the underground drainage system, and at the tank truck were extinguished. Firefighting and hazardous materials units remained on the scene throughout the day to coordinate with various agencies until the remaining gasoline runoff was contained and removed. Residents were permitted to return to their homes about 3:10 p.m., and the command post was disbanded about 7 p.m.

In addition to the response of fire, police, and medical personnel, a total of 217 personnel from other allied agencies--such as the local utility companies, service organizations, and State and local agencies for fish and game, public works, water and irrigation, and environmental protection--also responded and provided support.

Postaccident Debriefing.--At a debriefing held on February 16, 1991, by the American River Fire District, the following conclusions were made:

- The initial description of the accident by the dispatcher that a gasoline tanker was involved allowed firefighters to take precautions as they approached the site.

- Drills conducted prior to the accident with other fire companies in Sacramento and knowledge of their capabilities resulted in effective interaction and communication.

Injuries

Injuries[5]	Resident	Firefighter	Driver	Total
Fatal	0	0	0	0
Serious	0	0	0	0
Minor	1	1	1	3
None	0	0	0	0
Total	1	1	1	3

The driver sustained lacerations on the scalp and arm and abrasions and contusions on the back and face. A firefighter and a resident suffered smoke inhalation.

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[5] Fatal and serious injuries are defined in 49 CFR 830.2.

Damages

The tractor, the cargo tank semitrailer, and two unoccupied automobiles that were parked near the final position of the tractor/semitrailer were completely destroyed by fire. Four houses also sustained structural and thermal damage from the fire.

Calzona Tankways, Inc., owner and operator of the tractor and cargo tank, estimates the damages incurred as follows:

Tractor and semitrailer	$ 120,000
Loss of cargo	5,900
Property (residences and automobiles)	568,000
Environmental clean-up and monitoring	300,000
Total	$ 993,900

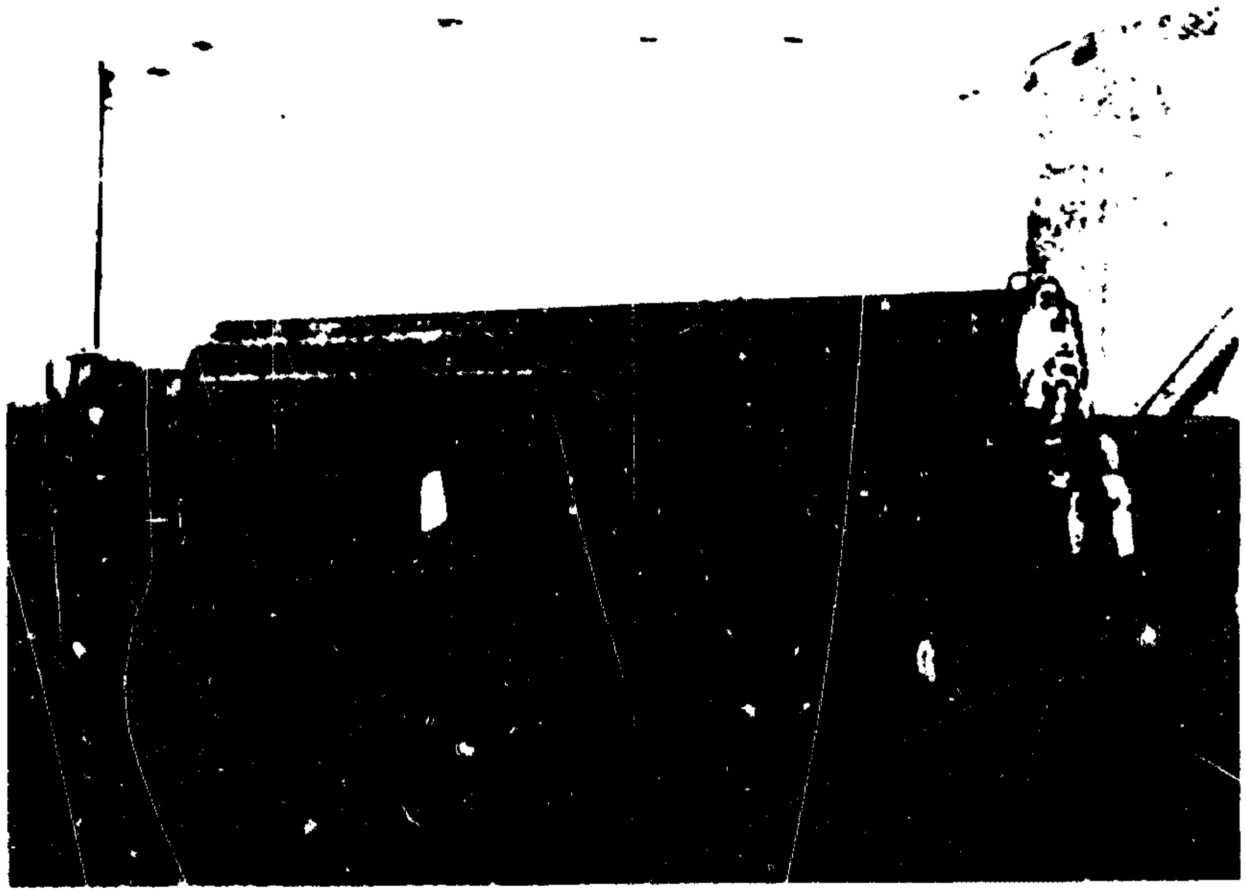
Vehicle Information

General.--The tractor and the cargo tank semitrailer were owned and operated by Calzona Tankways, Inc., of Phoenix, Arizona. The combination vehicle was 56.75 feet long and weighed 79,000 pounds (fig. 4). The vehicle was equipped with air mechanical S-cam service brakes. All wheels were equipped with automatic slack adjusters. The wheels for the tractor's drive axle and the trailer's axle were equipped with spring brakes that served as emergency and parking brakes.

Tractor.--The tractor was a 1989 Kenworth, Model T-400-A conventional. It was equipped with a Cummins L10-300 diesel engine (300 horsepower at 1,900 rpm), Ross power steering, and an Eaton-Fuller nine-speed transmission. The rear drive axle had a 3.70 ratio. According to the manufacturer, the tractor was equipped with radial tires that would travel 516 revolutions per mile. The tractor had a 180-inch wheelbase, an overall length of 23.7 feet, and a weight of 13,775 pounds. Its recorded mileage 2 days before the accident was 211,114 miles. Based on the maximum engine rpm's, transmission ratio, drive axle ratio, and tire revolutions per mile, the maximum attainable speed of the tractor was calculated to have been 59.7 mph.

The truck was equipped with a fully adjustable "air-ride" seat and air conditioning. The driver had no complaints about the environment of the cab.

Cargo Tank.--The cargo tank was a U.S. Department of Transportation (DOT) specification MC 306 aluminum cargo tank manufactured by the Fruehauf Corporation in May 1989. Calzona used the cargo tank to transport various grades of automotive gasoline and, on occasion, diesel fuel. The cargo tank semitrailer was 43 feet 10 inches long, 10 feet 3 1/4 inches high, and 8 feet wide. The design pressure for the tank was 1 psig and the hydrostatic test pressure was 3 psig.



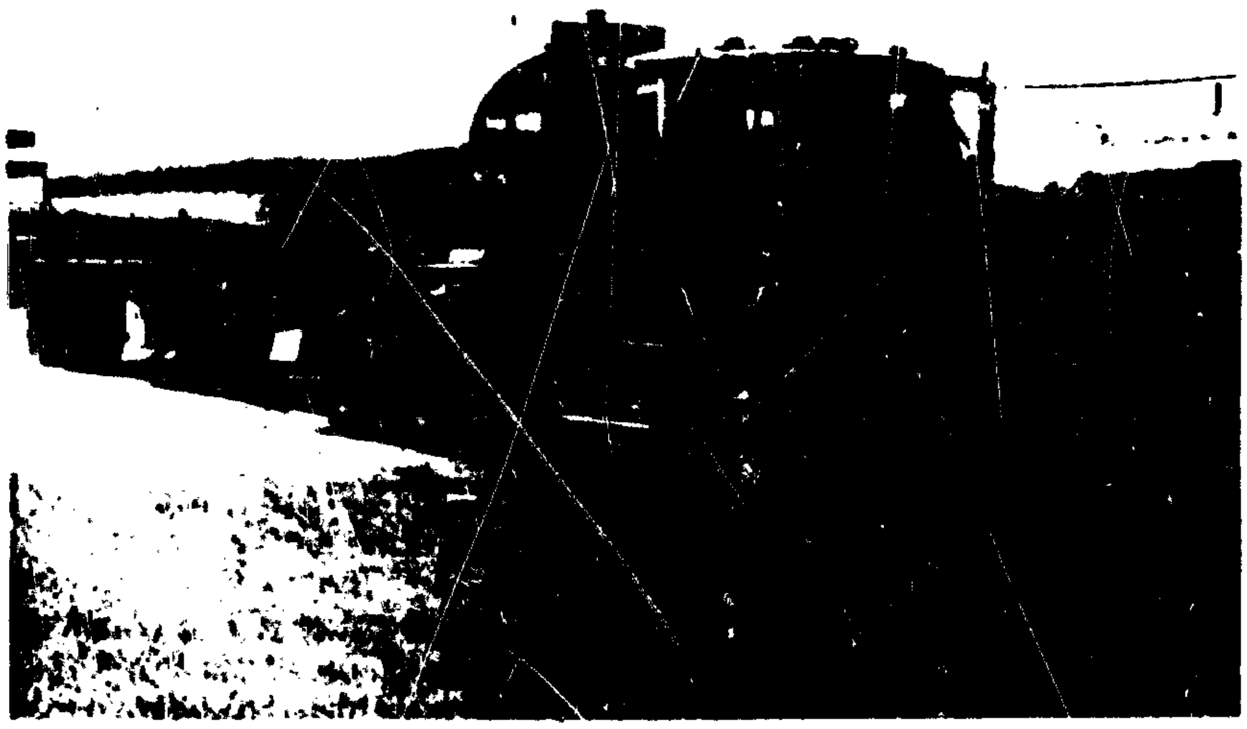


Figure 4.--A tractor and cargo tank semitrailer similar to the vehicle involved in the accident.

The cargo tank had a nominal capacity of 9,500 gallons and was divided into four compartments. The capacity and lading in each compartment at the time of the accident is listed below:

Compartment No. (From front to rear)	Capacity (Gallons)	Lading (Gallons)
1	3,450	3,200
2	1,100	1,000
3	2,150	2,000
4	2,800	2,600

Each compartment was equipped for bottom-loading and discharge through an individual 4-inch aluminum transfer line. The cargo transfer line for each compartment extended from the bottom of the compartment to individual manifolds located at the middle and along the bottom and right side of the cargo tank.

Cargo Tank Manhole and Vapor Return Fittings.--On the top of the tank, each compartment had a manhole opening and a vent opening for a vapor return system[6] (fig. 5). The manhole cover for compartment 1 was the closest fitting to the front of the tank. The vents for compartment 1 and 2 and the manhole cover for compartment 2 were clustered together at the bulkhead separating the two compartments, about 10 feet behind the front of the cargo tank.

Each manhole cover was a 16-inch diameter steel cover manufactured by Betts Industries, Inc., and had an offset 10-inch diameter cast aluminum dome lid for the pressure-actuated fill (PAF) opening (fig. 6). Each cover also had three openings for mounting accessory devices on the cover. On the accident vehicle, two of the three openings were used for mounting liquid-level sensors, and the third opening was closed with a threaded plug. According to Betts, the liquid-level sensors or other accessories are typically secured to the cover by a locking nut on the underside of the manhole cover, a bolted flange, tapered pipe threads, or straight pipe threads. Each manhole cover was seated on an aluminum collar that was welded to the cargo tank, and secured by a bolt-tightened clamp ring.

The dome lid for the PAF opening was spring-loaded and held in place by two hinged steel safety latches. The dome lid assembly for the PAF opening serves as a pressure-actuated emergency vent with a venting capacity of 250,000 cubic feet of free air per hour at a pressure of 5 psig. To vent, the lid for the PAF opening lifts slightly against the force of the spring

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[6] The vapor return system on the cargo tank is connected to a pipeline that discharges into the vapor space of the loading terminal's storage tank for the product being transferred. The displaced vapors from the tank being loaded are thereby directed to the tank being emptied, rather than discharged to the atmosphere.

Figure 5.--Configuration of the manhole covers (M), vents (V), and rollover rails (R) on the top of a cargo tank similar to the cargo tank involved in the accident.

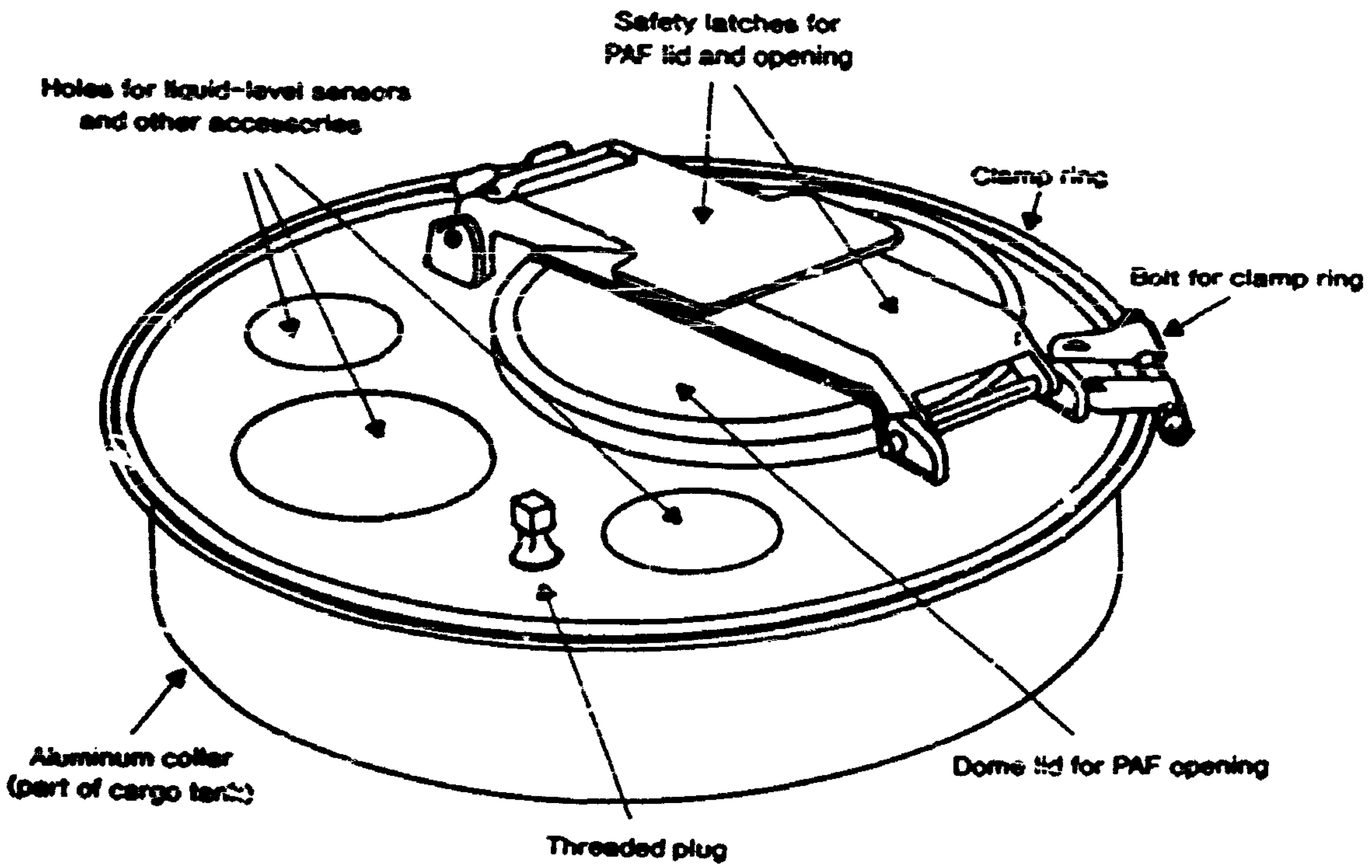

Figure 6.--Schematic of manhole cover.

that normally keeps the lid seated; this breaks the vapor-tight seal and relieves the internal tank pressure. When the force of the spring on the lid exceeds that caused by internal pressure, the dome lid reseats. The latches are designed to prevent the PAF lid from opening and releasing product.

Betts stated that it hydrostatically tests manhole covers to 36 psig in accordance with Truck Trailer Manufacturers Association (TTMA) Recommended Practice No. 61 (RP-61).[7] When a cover is tested, all openings are plugged shut and the 10-inch PAF vent is blocked shut. No accessories are in place during the test. Betts adopted RP-61 in May 1988, and as of May 1991 has not had any cover fail the 36 psig standard. Betts stated that the liquid-level sensors and other accessories are normally installed by the tank manufacturer.

The vent opening to each compartment for the vapor return system was enclosed by a 9 1/2-inch diameter aluminum vapor hood. A 3 1/2-inch diameter hose connected each vapor hood to the right-side rollover rail. The cavity created by the double-leg rail (described in the following paragraph) and the shell of the cargo tank was part of the vapor return system for the cargo tank.

<u>Overturn Protection</u>.--For overturn protection, the cargo tank had two aluminum rails that extended the entire length of the tank and transverse dams at the front and rear of the tank (see fig. 5). Each rail was a double-leg configured as an inverted "V" and protruding vertically from the exterior of the tank shell. The vertical clearances between the top of the rollover rails and the top of the vapor hood and the different devices mounted on the manhole cover were measured on a similar cargo tank, and ranged from 4 1/4 inches for the manhole cover to 5/8 inch for an electronic liquid-level sensor mounted on the manhole cover.

<u>Inspections and Maintenance</u>.--Calzona employs a director of maintenance at a central maintenance facility in Phoenix, Arizona. Most repairs and servicing are done at Calzona's terminal maintenance facilities, although some repair and servicing work is done at dealer facilities. Major repair items, such as an engine overhaul or transmission repair, are done at dealer or other professional facilities.

Under Calzona's preventative maintenance schedule for its tractors and other power units, servicing of different items on the power units is conducted at intervals of 5,000, 15,000, or 60,000 miles. For example, brakes are adjusted every 5,000 miles, the oil and filter are changed every 15,000 miles, and the cooling system is pressure-tested every 60,000 miles. Trailers are completely serviced every 60 days. Brake adjustment is usually done on a weekly or semimonthly basis for those trailers equipped with automatic slack adjusters.

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[7] Additional information about RP-61 is given in the section "Industry-Recommended Practices."

Maintenance records on the tractor and semitrailer dating back to the time of their delivery in June 1989 indicated, with one exception, normal servicing of the brakes, steering, suspension, and tires. On May 11, 1990, Calzona replaced the single-leaf springs on the semitrailer with "four leaf" spring assemblies provided by Fruehauf because of failures with the single-leaf springs. The drivers' pre- and post-trip inspection reports for both the tractor and the semitrailer from January 1 to February 12, 1991, did not identify any operational problems with the vehicles.

A visual inspection of the cargo tank and its compartments, required by DOT, was last conducted on June 14, 1990, by Calzona maintenance personnel. Inspection items included each cargo compartment, manhole cover, manhole lock and gasket, areas of corrosion, dents, welds, piping, valves, and flange connections. No deficiencies were noted.

Calzona's records of scheduled preventive maintenance inspections that were conducted in October, November, and December 1990 and in January 1991 did not note any deficiencies or indicate that any repairs were made to the tank, the manhole covers, the vapor recovery system, or the loading and discharge system.

Postaccident Inspection.--Because the tractor, semitrailer, and the cargo tank were completely destroyed in the fire, postaccident inspection of the tractor and the cargo tank semitrailer was limited (fig. 7).

On the tractor, a partial examination of the transmission, steering, brake system, and suspension was conducted. The steering wheel and shaft were separated from the gear box. The pitman arm and other linkages moved when the input shaft to the steering gearbox was rotated. Because of fire damage, it could not be determined whether the brakes were within the adjustment limits recommended by DOT. All of the spring brake air cans[8] were destroyed in the fire and the springs were displaced. All of the brake linings measured between 3/8 and 11/16 inch. According to inspection standards set by the DOT, the minimum thickness for a truck brake lining is 1/4 inch.

No cracks or other defects were observed in any of the leaf spring assemblies for the axles on the tractor and the semitrailer. The tractor steering axle springs were loose; the rebound pads and spacers that properly position the springs, however, were made of aluminum and were destroyed during the fire.

The tires on the tractor and the semitrailer were destroyed in the fire. The steel belts from the tires were observed on the tire rims on the tractor and semitrailer (see fig. 7).

Most of the shell of the cargo tank had melted. A portion of the rear head and the adjoining tank shell were intact. Small sections of the shell from the bottom of the tank were also intact.

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[8] Protective enclosures for the brake springs.

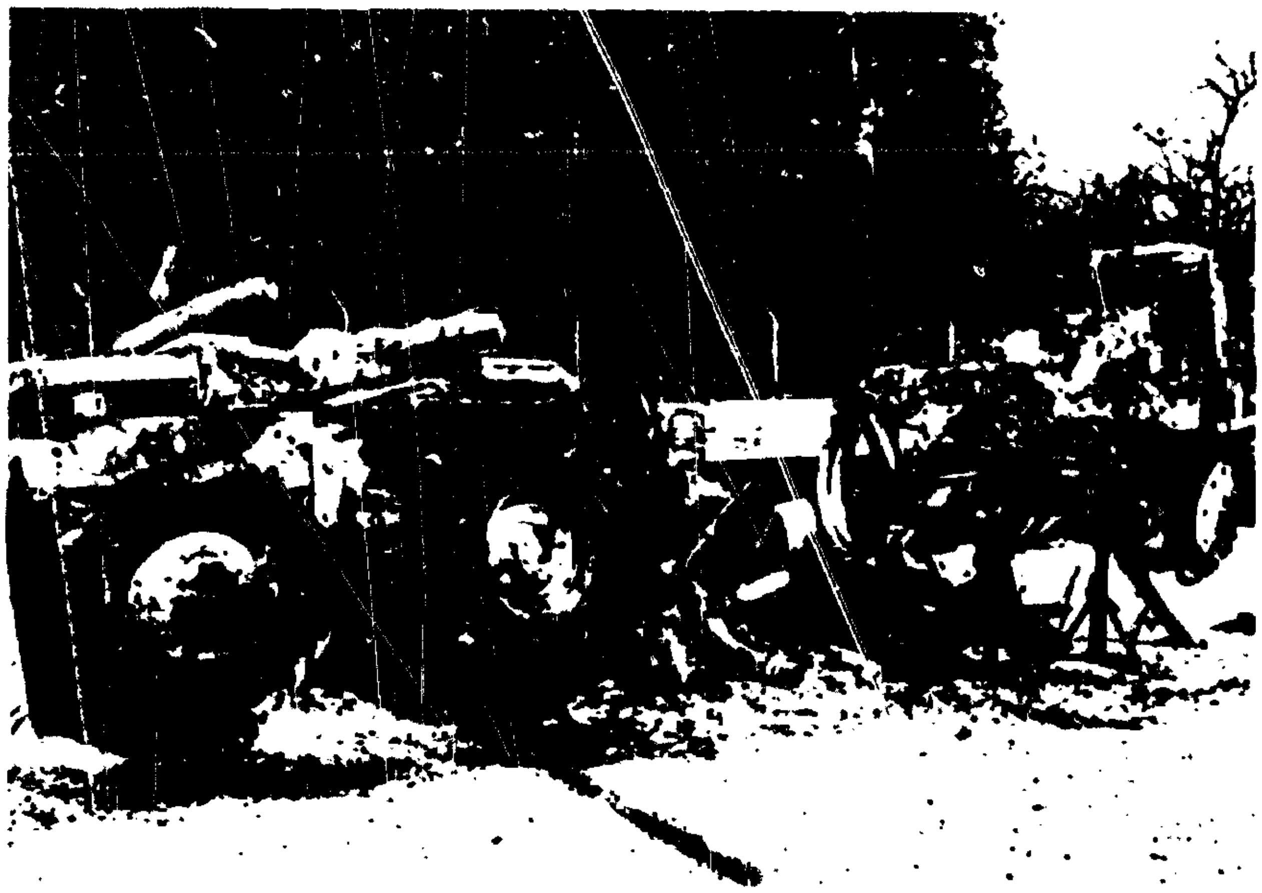

Figure 7.--Accident tractor (top) and cargo tank (bottom).

The manhole covers for all four cargo compartments and the vapor recovery fittings from the top of the tank were recovered from the accident site. The two safety latches for the lid to the PAF opening on one manhole cover were found in the open position. This cover was embedded in molten metal, and the aluminum lid for the PAF opening and the two sensors were missing. Deformation and warping of the manhole cover were also noted when the manhole cover was viewed from the side. The safety latches for the lids to the PAF openings on each of the other three manhole covers were closed.

Roadway Information

Location and Description.--Fair Oaks Blvd. is a Sacramento County road that runs east-west and at the accident curve turns north-south. The accident site was in a residential neighborhood with strip commercial development to the east and north of the intersection with Oak Ave. The single-family dwellings, apartment buildings, and commercial buildings were set back from the street 20-60 feet.

In the area of the accident, Fair Oaks Blvd. was five lanes: two lanes in each direction with a single, two-way left-turn lane in the center (fig. 8). The lane widths varied from 11 to 12 feet, and the paved shoulder widths varied from 3 to 6 feet. The intersection at Oak Ave. was in a 500-foot radius horizontal curve[9] to the left for eastbound traffic with an advisory speed of 35 mph. The posted speed limit on Fair Oaks Blvd. was 40 mph. On the approach to the accident site, there was a regulatory 40-mph speed sign about 1,500 feet in advance of the accident site, a curve warning sign with a 35-mph advisory speed sign about 780 feet in advance, and a turn-warning sign with a 35-mph advisory speed sign 350 feet in advance.

Fair Oaks Blvd. was built on slightly rolling terrain. In advance of the 500-foot radius curve was a 450-foot crest vertical curve (hill) and then a 350-foot-long sag vertical curve (dip). The construction plans indicate that the approach to the accident site was level followed by a +2.48-percent grade for about 350 feet, and then a -2.59-percent grade to the accident site. The construction plans also indicate that the curve had a superelevation of 4 percent. The measured grade and superelevation where the truck overturned were, respectively, -2.83 percent and 3.72 percent.

There was no roadway lighting on Fair Oaks Blvd. from Hillcrest Ave. to Oak Ave. The pavement markings, raised pavement markers, and signs were observed at night and were found to provide adequate delineation and sign message visibility. A side street signal flasher that was located at the northeastern corner of the intersection with Oak Ave. flashed a warning yellow for the traffic going each direction on Fair Oaks Blvd. The device was activated by the presence of traffic on Oak Ave. The stop sign located at the intersection for traffic on Oak Ave. was hit by the vehicle, and the sign post was broken in two. There were no guard rails or other

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[9] The curve of the radius is measured to the center line of the roadway.

obstructions at the intersection with Oak Avenue or in the path of the overturned truck.

A drainage ditch extended along Fair Oaks Blvd. on the east side of the road at an angle of 30 degrees. The 140-foot-long dirt ditch was 9 feet wide at the top of the embankment and 27 to 36 inches deep. The drainage ditch emptied into a drain pipe that extended beneath Fair Oaks Blvd. in a northeasterly direction. On the west side of Fair Oaks Blvd. the drain pipe emptied into an open ditch that extended west behind the residences at 5827 and 5821 Twin Gardens Drive.

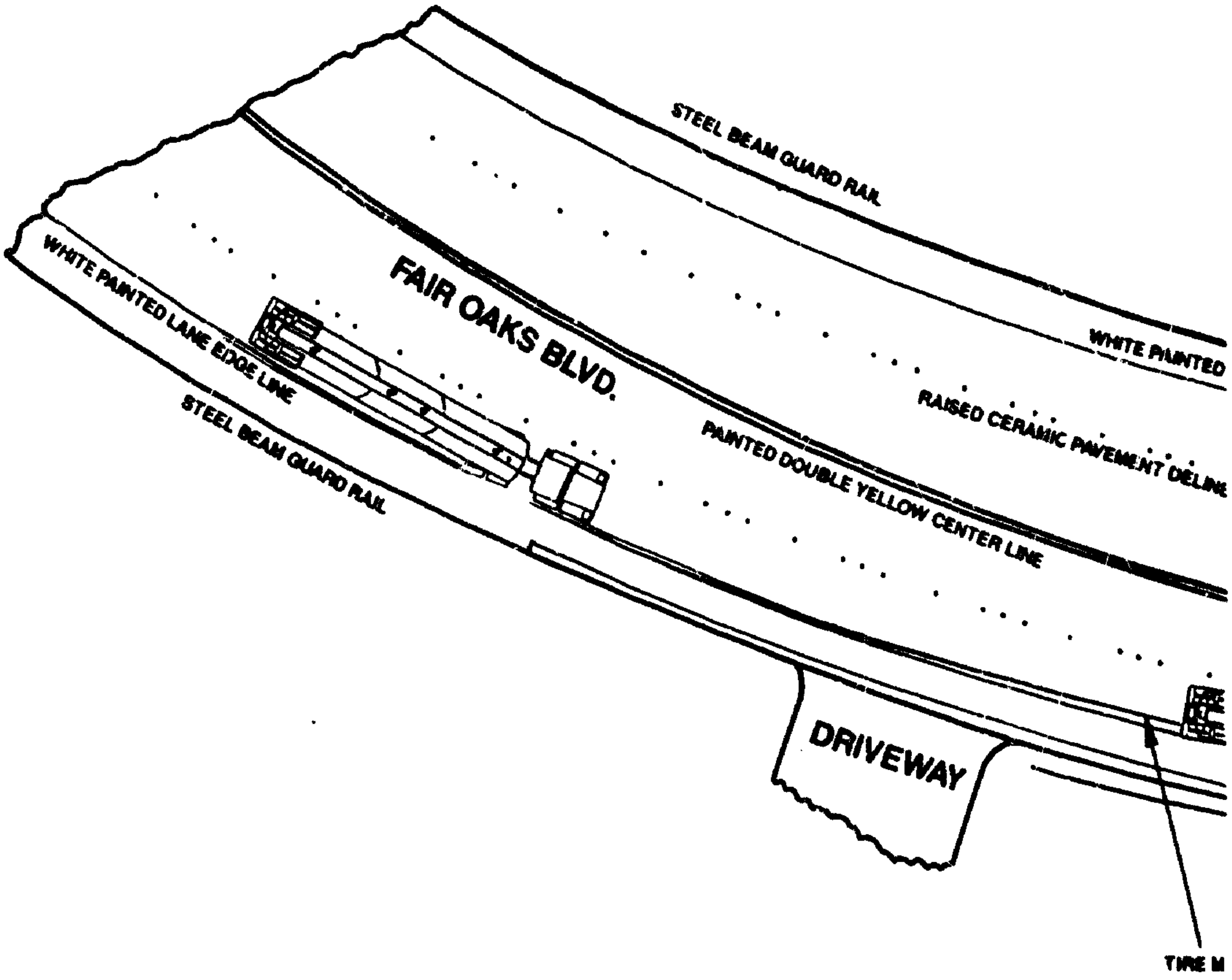
Accident History and Traffic Surveys.--Data prepared by Sacramento County indicate that in the vicinity of the intersection there were 20 accidents from 1988 through 1990. Of this number, 9 accidents were single-vehicle accidents, and 10 involved two vehicles that collided at right angles, during a lane change, or in the approach for a left turn. The remaining accident involved a car striking a pedestrian or bicycle. None of the accidents involved a tank truck that was comparable to the accident vehicle. According to a Sacramento County traffic engineer, the accident history of this intersection cannot be compared to that of other intersections within the county because no other intersections have sufficient similarity to make a meaningful comparison.

According to the most recent traffic count taken on February 21, 1989, the traffic volume over a 24-hour period for southbound traffic on Fair Oaks Blvd. was 11,344 vehicles. A peak hourly volume of 1,371 vehicles occurred between 6 and 7 a.m., compared to 46 vehicles between 3 and 4 a.m. For the northbound direction, the volume over 24 hours was 12,658 vehicles. A peak of 1,321 vehicles occurred between 4 and 5 p.m. compared to 14 vehicles between 3 and 4 a.m.

Radar speed surveys conducted in May and June 1987 on Fair Oaks Blvd. at a location just south of El Camino Ave. indicate that the 85th percentile was 45 mph for the southbound direction and 49 mph for the northbound direction. The average speed was 40 mph for the southbound direction, and 43 mph for the northbound direction.

Physical Evidence.--The CHP documented the location and type of marks and scrapes on the roadway, including the tire marks. From these marks, the CHP developed an accident dynamics diagram (see fig. 8) that depicts the path and orientation of the tank truck from the point the rollover began to its location at final rest. According to the dynamics diagram, the top of the cargo tank was approximately aligned with the drainage ditch when the vehicle struck the embankment of the ditch. The dynamics diagram also indicates that the final location of the cargo tank was at an angle to the ditch, with the front-end of the tank on the embankment and the rear-end of the cargo tank between 10 and 20 feet east of the embankment.

There were about 400 feet of marks on the pavement and dirt of the accident site. Tire marks in the outside traffic lane started about 150 feet into the horizontal curve to the left (see fig. 8). The marks, which were


STEEL BEAM GUARD RAIL
FAIR OAKS BLVD.
WHITE PAINTED
RAISED CERAMIC PAVEMENT DELINE
WHITE PAINTED LANE EDGE LINE
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DRIVEWAY
TIRE M

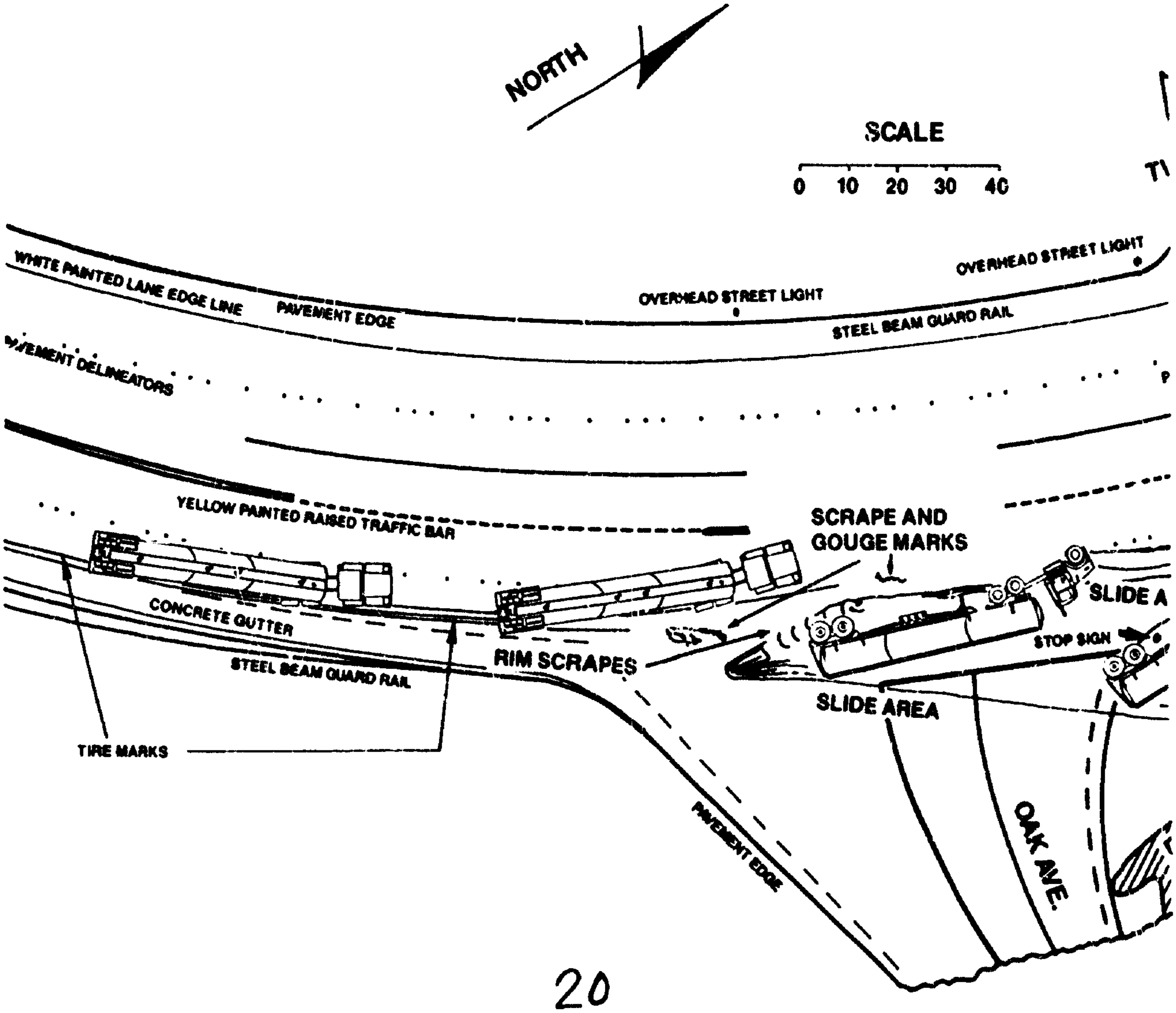
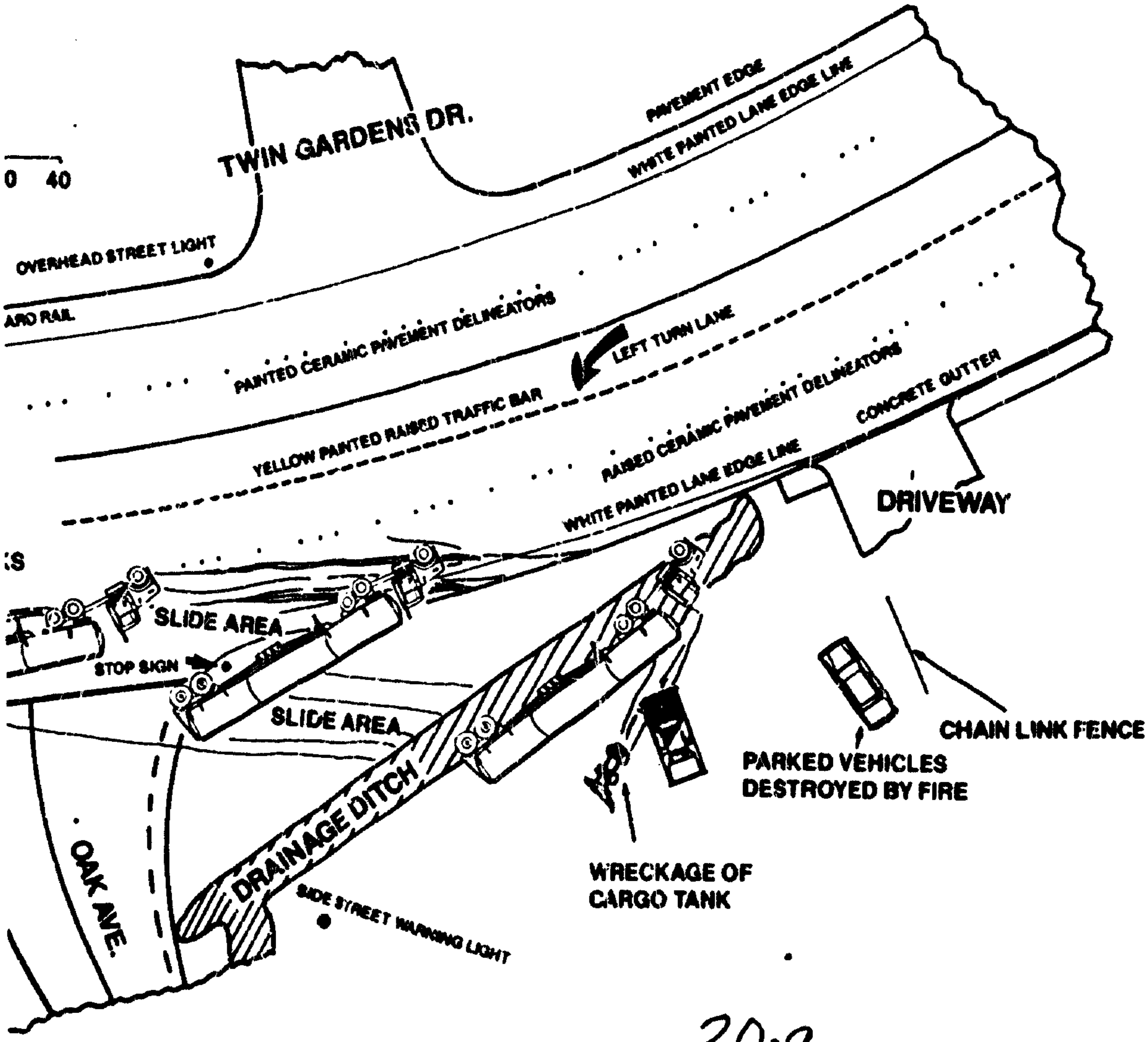


Figure 8. Intersection and accident dynamics diagram. (Courtesy of the California Highway Patrol.)



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smooth and continuous, and not irregular, extended for about 300 feet and led into about 110 feet of scrape and gouge marks on the pavement and dirt to the position of final rest. A radius of 444 feet for the curved tire marks was calculated from the dynamics diagram.

Carrier Information

General.--Calzona Tankways, Inc., is an interstate contract carrier that has been in business since 1985. Although Calzona has the authority to operate in the 48 contiguous States, the company currently transports hazardous liquids, primarily gasoline and diesel oil, in Arizona, California, Nevada, New Mexico, and Oregon. The company was most recently audited by the DOT's Office of Motor Carrier Safety in 1985 and was given a "satisfactory" rating.

Calzona's operation is divided into 3 regions and 18 terminals or bases of operation. The company employs a vice president of safety at the headquarters office in Phoenix and one director of safety for each of the three regions.

The company operates 138 power units: 106 truck tractors and 32 straight trucks with the cargo tanks mounted. The truck tractors have an average age of 2 years, and the straight trucks 4 1/2 years. Calzona also owns 161 trailers which have an average age of 4 years, and 89 of them are 1988 or newer models. Calzona has a total of 360 employees, 320 of whom are drivers.

Calzona incurred 0.55 accidents per million miles traveled for 1990 and 0.75 accidents per million miles for the 3 years preceding this accident. Calzona indicated that the accident rate for 1990 was based on 15 million miles traveled, which corresponds to about eight accidents. Calzona also indicated that the accidents included in the accident rate computation are "on-the-road" accidents in which property damage or injuries were incurred when the vehicle is in motion. The "on-the-road" accidents may or may not have met the DOT's criteria for a reportable accident.[10] During the 3 years preceding this accident, Calzona has had a total of eight DOT-reportable accidents.

The FHWA has indicated to Safety Board staff that the agency does not routinely compute the number of reportable accidents per miles driven by motor carriers because this ratio does not account for (1) the variation of driving conditions such as type of roadway, terrain, and regional traffic volumes; and (2) the tendency of smaller carriers to fail to report accidents to the FHWA. Nevertheless, the director of FHWA's Office of Motor Carrier

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[10] A reportable accident means an occurrence involving a commercial motor vehicle engaged in the interstate, foreign, or intrastate operation of a motor carrier who is subject to the Department of Transportation Act resulting in death or bodily injury, and property damage of $4,400 or more (49 CFR 394.3).

Information Management and Analysis verbally indicated that a recent review of 100,000 records found that the reportable accident rate for motor carriers transporting hazardous materials was about 0.74 reportable accidents per million miles traveled.

Driver Recruitment, Training, and Qualification.--According to Calzona's policy, all new drivers must be at least 25 years of age and have 2 years' experience driving tank trucks transporting liquids in bulk. However, Calzona's vice president of safety indicated that, because of driver retention problems, the company has recruited drivers from truck driving schools; these drivers have less than 2 years' experience driving tank trucks. Prospective drivers must have no record of serious traffic violations (driving under the influence of alcohol or drugs, involuntary manslaughter, hit and run, or reckless driving) within the past 3 years and no more than three traffic convictions for lesser offenses in the past 3 years. Prospective drivers must meet all State and Federal requirements.

Calzona implemented a 10-day training program in 1989 to train newly hired drivers about the safe handling and transportation operation of hazardous liquids and to familiarize drivers with the procedures unique to the carrier and its customers. Each terminal has a designated "driver trainer," who is an experienced, regular company driver and is responsible for training all new drivers at that terminal.

The training program is organized into seven modules that cover Federal and State regulations governing hazardous materials in vehicle and container operations, pre-trip inspections, loading and unloading, special vehicle handling characteristics, documentation and placarding of hazardous materials cargoes, driving and parking rules, and defensive and emergency incident procedures.

The primary methods of instruction include the use of training aids, mock loading/delivery equipment, and visual aids (films and videotapes); the performance of repetitive tasks; and behind-the-wheel exercises.

Instruction about vehicle stability is provided by means of a 30-minute video on truck rollover and handling techniques. The video demonstrates conditions that can lead to a rollover and the situations that a driver should avoid to prevent rollover. The instructor is responsible for teaching new drivers about the special handling characteristics of a cargo tank combination vehicle, vehicle instability, high center of gravity, surge of the liquid load, the effect of curves on stability, the effect of braking on stability, the effect of speed on vehicle control, dangers with evasive or sudden maneuvers, dangers with curves on off-ramps, differences in stability among various configurations of compartment tanks, and the effects of partial loads on basic stability.

At the end of each day's training, the instructor is to write an evaluation of the new driver's performance for the terminal manager. At the end of the training program, each new driver is given a written test on the information in the seven modules. The test, however, does not specifically address the driver's knowledge of rollover. The test, which consists of 60 true/false questions, is corrected and reviewed with the new driver. If the terminal manager is not satisfied with a driver's level of knowledge, the vice president of safety is to be called to discuss the problem. When the terminal manager is satisfied that a new driver understands the material and can perform the job independently, the terminal manager is to complete an evaluation form for the driver's file.

Driver performance is also measured through observational techniques on practice operational runs. A driver is required to correctly perform all of the duties of a delivery, including loading/unloading the product and handling of the documentation.

The driver in this accident completed Calzona's training program on July 25, 1990, according to Calzona's letter dated July 30, 1990, in the driver's file. Although Calzona's procedures required that instructors submit daily evaluations of new drivers and that new drivers pass a written examination, Calzona had no records of the evaluations and test results for the driver. A check of the training records for other drivers also indicated incomplete documentation. According to the responses to written questions submitted by the Safety Board, the driver involved in the Carmichael accident indicated that he did not receive any training about rollovers and overturns from Calzona.

According to Calzona, since the accident, it has advised terminal managers that failure to comply with company safety policies could result in discharge of the managers. Calzona is also reviewing its Driver Training Manual and updating it as necessary. After the accident, the company's training program became a mandatory 2-week period for all new drivers, and will be extended to a 3rd week if the regional director of safety determines it is necessary. The director of safety will also ride with and evaluate each new driver after the driver's first 30 days of employment.

Calzona also indicated that at the time of the accident recurrent training was provided to experienced drivers on an "as-needed" basis, normally following a minor accident or violation of safety procedures. In such cases, the driver would be required to review an appropriate training film and then discuss the accident or safety violation with the terminal manager. Since the accident, Calzona now requires that either the terminal manager, a driver-instructor, or the regional director of safety ride with each driver annually to evaluate the driver's performance. The company is also implementing a training and certification program for the driver instructors.

Inspection and Loading Procedures.--Drivers are to conduct a 14-step inspection at the end of each workday that complies with 49 CFR 396.11. Items to be inspected include the brakes, steering, lights, air and electrical connections, windshield, fuel tanks, frame bends and cracks, wheels, rims, tires, suspension, fifth wheel, landing gear, and cargo securement. At the time of the accident, Calzona did not have a specific policy regarding the inspection of manhole covers on the top of the cargo tank. As a precautionary measure since the accident, Calzona has added manhole covers to the items to be checked in the inspection.

According to Calzona, all loading is accomplished through bottom fittings and is never done through the manhole openings on the top of the tank.

Safety Program.--Since January 1986, Calzona has scheduled monthly or semimonthly safety meetings at each terminal. The driver attended a safety meeting on February 12, the day before the accident. According to the company, Calzona wants drivers to recognize the value of the safety meetings; drivers are not required to attend. The company may, however, withhold a driver's annual bonus if the driver regularly fails to attend the safety meetings. Calzona's vice president of safety also indicated that terminal managers will call in those drivers who have failed to attend the safety meetings to discuss the safety topics covered.

According to the company, each terminal has 12 to 15 training videos and the equipment to view them. Videos are shown at safety meetings, and others are shown as part of Calzona's driver qualification program. Drivers may also take videos home for viewing. The vice president of safety stated that the company will pay the drivers to view the films. For the drivers based in San Jose and Sacramento, where Calzona does not have terminals, the regional director of safety will meet with these drivers and bring the videos for viewing.

Calzona also distributes weekly flyers and monthly letters to the drivers as reminders of safety practices such as defensive driving.

Driver Information

Employment.--The driver, a 35-year-old male, was hired by Calzona in July 1990. Since that time, the driver exclusively drove a tractor-cargo tank semitrailer combination similar to the accident vehicle. The driver initially was based at Calzona's terminal in Stockton, California, and was then based at the ARCO refinery in West Sacramento. The driver made only intrastate deliveries (within California). The driver had not been previously employed as a tank truck driver.

From July 1988 to June 1990, the driver was employed as a relief driver for a courier company in Sacramento. As a relief driver, he used his personal car to make deliveries for local businesses. Between October 1983 and July 1986 the driver was employed as a fleet captain for Movers World Van Lines in Phoenix, Arizona. His responsibilities included driving moving vans and operating forklifts. From June 1982 to October 1983, he drove small trucks to deliver freight.

Training.--In addition to completing Calzona's training program in July 1990, the driver completed, in June 1990, a 13-week, 330-hour course for entry-level drivers at the Truck Driving Academy in Sacramento. The academy, which opened in 1985, is accredited by the National Association of Trade and

Technical Schools, and its curriculum was accredited by the Professional Truck Drivers Institute of America[11] as of October 22, 1989.

The course was designed to train drivers for the Class A commercial driver's license. The course used a combination of classroom instruction and hands-on driving. Training films and videotapes were also shown to supplement the classroom instruction. Of the total course of instruction provided to the drivers, 9 classroom hours addressed jackknifing and rollover, and 10 hours addressed the transportation of hazardous materials. Student performance was measured by written examination on classroom material and by instructor observation of driver tasks performed in the field. There was no testing, however, on the instruction on rollover. Students had to score an average of 70 percent of the total available points to pass. According to the driver's records, he scored 91 percent, which put his performance in the "excellent" category.

License and Driving Records.--At the time of the accident, the driver held a California Class A commercial driver's license that was issued on October 18, 1990. The driver had previously been issued a temporary Class A license on June 21, 1990. The driver also held endorsements for operating tank trucks, double and triple trailers, and for transporting hazardous materials.

California's Department of Motor Vehicles adopted the Federal Commercial Drivers License (CDL) program in January 1989. The program was established by the Federal Highway Administration (FHWA) of the DOT as a result of the Commercial Motor Vehicle Safety Act of 1986. Title 49 Part 383 of the Code of Federal Regulations (CFR) requires that drivers demonstrate that they possess the knowledge, driving skills, and requirements to operate commercial motor vehicles. The regulations also require that drivers pass road and written tests to obtain endorsements on the license for the operation of double/triple trailers, tank vehicles, and passenger-carrying vehicles, and for the transportation of hazardous materials. Under 49 CFR 383, individual States may issue these endorsements and develop knowledge tests based on Federal standards. Proficiency in general driving and handling skills must also be demonstrated to receive the endorsements. All drivers, interstate and intrastate, of commercial motor vehicles are required to pass, by April 1, 1992, the appropriate knowledge and skills tests, including a road test in the type of vehicle that a driver expects to operate.

Under 49 CFR 383.115 and 383.119, which address rollover knowledge, a driver must demonstrate knowledge of (1) handling and stability characteristics including off-tracking, response to steering, sensory feedback, braking, oscillatory sway, rollover in steady turns, and yaw stability in steady turns; (2) differences in cargo surge for liquids of varying product densities; and (3) effects of road grade and curvature on motor vehicle handling with filled, half-filled, and empty tanks.

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[11] A national, nonprofit organization sponsored by the trucking industry for the purpose of advancing truck driver training, proficiency, safety, and professionalism.

California's written tests for endorsements for double/triple trailers and tank vehicles contain questions on stability, surge, and rollover.

The California Department of Motor Vehicles reported it had no record of departmental actions, convictions, failures to appear, or accidents for the driver as of February 15, 1991. A 50-State driver's record check did not identify any violations. On July 6, 1991, the CHP cited the driver for operation of the tank truck at an unsafe speed.

Behavioral Factors.--According to an interview with the CHP, the driver stated that he usually worked 6 days and then had 3 days off. He had worked the night shift, starting at 6 p.m., since his employment with Calzona. He stated that he made as many as five deliveries in the Sacramento area before finishing his deliveries, usually about 4 a.m. Upon finishing his deliveries, he would go home and go to bed about 7 a.m. He stated that after 5 to 6 hours of sleep, he got up and ate before reporting to work; on the day of the accident and until the accident occurred, his activities did not deviate from his normal routine. Also, the driver indicated to the CHP that on his days off he normally went to bed between 3 and 4 a.m. and slept until noon.

Although the driver's trip report and daily log for the accident shift were destroyed in the fire, the driver's work activities prior to the accident were reconstructed from past bills of lading and trip reports. In the week prior to the accident, the driver worked his regular shift and made four deliveries on February 6. The driver was scheduled to be off duty on February 7 through February 10; however, he made one delivery on February 7, and two deliveries on February 9. During his normal shift on February 11, he made five deliveries and drove 268 miles. For his shift on February 12, he was scheduled to make four deliveries. He had completed three deliveries and had driven about 266 miles when the accident occurred en route to the final delivery.

Before his shift, the driver had eaten chicken and dumplings and later had a peanut butter and honey sandwich. During the shift he had eaten popcorn and had drunk coffee.

According to the driver's former supervisors and acquaintances, he was considered to be punctual, reliable, intelligent, and calm under pressure. None of those interviewed knew of any drug or alcohol problems with the driver. The driver stated to the CHP that because he had fallen behind with his bills, he had enrolled in a consumer credit program but was not preoccupied with his finances. The driver was not married and did not have a second job.

Medical Factors.--The driver passed two physical examinations in 1990. The first examination on April 4, 1990, was to fulfill the DOT requirements of 49 CFR 391.41 through 391.49 for his commercial license. He also had a pre-employment examination in July 1990. No special findings or problems were noted during either examination, no medications were prescribed, and no long-term illnesses or conditions were identified. According to the pre-employment physical taken to meet DOT requirements, the driver had normal vision, did not need corrective lenses, had normal color vision, normal horizontal field vision, and showed no evidence of disease or injury in either eye. He was also found to have normal hearing.

The results of the emergency room examination after the accident also indicated that there were no long-term health problems that existed before the accident, nor were there health problems caused by the accident. The attending physician's report stated that the driver was alert, oriented, and did not appear to be intoxicated.

Toxicological Information

Postaccident Testing.--When CHP officers arrived on the accident scene, they did not request that the driver submit a specimen for toxicological tests. According to the CHP officers, they did not have reasonable cause to require that the driver provide a specimen because he appeared coherent, alert, and did not smell of alcohol. When the driver was taken to the American River Hospital for treatment of minor injuries, no blood or urine specimens were taken by hospital staff to perform any diagnostic tests.

A Safety Board investigator contacted Calzona officials on the morning of February 13, after the accident, and requested that Calzona have the driver provide blood and urine samples. Calzona advised the investigator later in the day that the driver, upon the advice of his legal counsel, refused to provide blood and urine samples for toxicological testing.

Carrier Drug Testing Program.--Calzona's drug testing program was implemented in a series of policy letters issued to all employees between May 1987 and March 1990. According to Calzona's policy, all employees are subject to substance testing following an accident that results in property damage or a casualty. Further, under a category of "reasonable cause testing," drivers and mechanics are to be tested "anytime" an incident/accident occurs in which alcohol or drug use "would have been a contributing factor."

Company written policy states that alcohol and drug testing are to comply with applicable DOT standards found in 49 CFR Parts 391 and 394 and with State and local laws. Calzona's written policies state that the company also has provisions to conduct tests for alcohol as part of the company's testing program. Drivers who fail a drug test can be terminated if deemed necessary by the company. Calzona's policies, however, do not address what occurs when a driver refuses to submit to a drug or alcohol test. According to Calzona's terminal manager in Stockton, all new drivers attend a course of instruction on awareness of drug abuse in the workplace and the effects of drug abuse. The terminal manager stated that Calzona's drug testing policies are explained as part of this instruction. Upon completion of the instruction, Calzona requires each driver to sign and date a certificate indicating that the driver received the instruction. A certificate for the driver involved in this accident was signed and dated October 24, 1990.

In April 1991, after the accident, Calzona issued a new operating instruction to its drivers and mechanics regarding alcohol and drug policies. According to this operating instruction, any employee who tests positive to a drug or alcohol test or who refuses to submit to such a test will not be allowed to work and is subject to immediate termination.

DOT Requirements.--The FHWA regulations for controlled substance testing are found in 49 CFR Part 391, Subpart H. This subpart prescribes minimum standards to detect and deter the use of marijuana, cocaine, opiates, amphetamines, and phencyclidine, but does not include alcohol. Under Subpart H, the definition of drug specifically excludes alcohol.

Subpart H applies to "motor carriers and persons" who operate a commercial motor vehicle in interstate commerce and who are subject to the driver qualification requirements of 49 CFR Part 391. Subpart H was last amended in 1988; interpretations and clarifications were issued in 1990.[12] In the 1990 clarifications, FHWA stated that the drug testing program applied to drivers who operate a commercial vehicle in "interstate commerce, i.e., the driver operates the vehicle across a state line, or in some cases, a single-state movement which is the continuation of a through interstate movement." The FHWA further stated in the notice that intrastate drivers were not required to be tested under Subpart H. The FHWA also stated, however, that it would investigate the inclusion of intrastate drivers in a separate rulemaking.

Sections 49 CFR 391.113 and 391.115 address postaccident testing requirements and procedures, respectively. Under the amendment for postaccident testing, a driver is required to provide a urine sample for testing for the use of controlled substances as soon as possible after a reportable accident but in no case later than 32 hours after the accident if the driver of the commercial motor vehicle receives a citation for a moving traffic violation arising from the accident.

In response to these amendments to the testing program, six lawsuits challenging the authority of the testing program were filed in U.S. District Courts in 1989 and were eventually consolidated by the Ninth Circuit Court of Appeals under International Brotherhood of Teamsters, Chauffeurs, Warehousemen and Helpers of America, et. al. v. U.S. Department of Transportation, No. 89-70165. With the filing of the first suit by the Owner-Operators Independent Drivers Association in the U.S. District Court for Northern California, the court issued a preliminary injunction on January 6, 1989, enjoining the FHWA from implementing random and certain mandatory postaccident testing. On November 6, 1989, the FHWA issued a notice[13] to motor carriers that the agency was deferring until further notice implementation of random testing and mandatory postaccident testing

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[12] Federal Register, Vol. 53, No. 224, dated November 21, 1988, page 47134; and Federal Register, Vol. 55, No. 22, dated February 1, 1990, page 3546.

[13] Federal Register, Vol. 54, No. 213, dated November 6, 1989, page 46617.

that was subject to the injunction. The FHWA stated in the notice, however, that the agency would enforce "unenjoined post-accident testing permitted under the terms of the preliminary injunction." Such unenjoined testing was defined as testing "when there is any reasonable suspicion of drug usage, or reasonable cause to believe a driver has been operating a vehicle while under the influence of drugs, or reasonable cause to believe the driver was at fault in the accident and drug usage may have been a factor."

In April 1991, the Ninth Circuit Court of Appeals ruled that FHWA's random, biennial, pre-employment, and postaccident drug testing regulations were constitutional. The FHWA published a notice[14] on August 16, 1991, that reestablishes the requirements for postaccident toxicological testing in reportable interstate accidents. Interstate carriers that employed 50 or more drivers as of December 1989, who were subject to testing, must implement programs for random and postaccident testing by November 14, 1991. All other interstate carriers must implement their programs by January 1, 1992.

State Requirements.--Under Section 23157, Division 11, of the California Motor Vehicle Code, any person who drives a motor vehicle is deemed by the State to have given his or her consent to chemical testing of the driver's breath, blood, or urine for alcohol and drug content if the driver is arrested for driving under the influence of drugs or alcohol. The testing shall be incidental to a lawful arrest and when ordered by a law enforcement officer who has reasonable cause to believe the person was driving under the influence of drugs or alcohol. California does not have mandatory provisions for postaccident toxicological testing of blood or urine of a driver for a commercial motor carrier.

Hazardous Materials Information

At the time of the accident, the cargo tank contained 8,800 gallons of automotive gasoline which is classified as a "flammable liquid" under the DOT's Hazardous Materials Regulations found in 49 CFR Parts 171 through 180. The gasoline had a flash point of -45 °F, flammable limits of 1.3 to 8.2 percent by volume in air, and a vapor pressure of 8 to 15 psia at 100 °F. According to ARCO's Material Safety Data Sheet for the gasoline, vapors can "burn in the open or explode in confined spaces," and may travel "long distances along the ground before reaching a point of ignition and flashing back."

Cargo Tank Standards

State of California.--At the time of the accident, the vehicle was involved with the intrastate transportation of a hazardous material within the State of California. State regulations governing the transportation of

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[14] Federal Register, Vol. 56, No. 159, dated August 16, 1991, page 40806.

hazardous materials are found in Title 13, California Code of Regulations (CCR), Article 3.

Section 1160.2(a) of Article 3 incorporates by reference portions of the DOT's Hazardous Materials Regulations "to the extent specified." This section further stipulates that unless otherwise specified, all references to Title 49 CFR in Article 3 are those DOT regulations that were in effect on October 1, 1988. Exceptions to the DOT regulations are made for certain tanks transporting anhydrous ammonia, tanks that provide an "alternate method of compliance," or tanks that are operating under a special permit or exemption issued by DOT.

Section 1164 of the CCR requires (1) that loading and securement of the load comply with 49 CFR Part 177, Subparts B (Loading and Unloading) and C (Segregation and Separation Chart of Hazardous Materials); (2) that valves shall be tightly closed; and (3) that manhole covers shall be secured on cargo or portable tanks whether loaded or containing residue.

Federal Regulations.--Under the DOT's Hazardous Materials Regulations that were in effect on October 1, 1988, DOT specification MC 306 cargo tanks were authorized containers for the highway transportation of automotive gasoline.

General design and construction standards for DOT specification MC 306 cargo tanks were provided in 49 CFR Part 178. Section 178.341-3 required the manhole and fill-opening covers for each compartment of a cargo tank to be designed and constructed to withstand internal fluid pressures of 9 psig without permanent deformation. During testing of the manhole and fill covers, the safety devices to prevent covers from venting were required. There were no requirements to test the manhole covers with devices such as the liquid-level sensors mounted on the manhole cover, or to test the liquid-level sensors independently.

Revision of Federal Cargo Tank Standards.--In June 1989, the Research and Special Programs Administration (RSPA) of the DOT amended the regulations pertaining to the design, manufacture, operation, and maintenance of all DOT specification highway cargo tanks.[15] RSPA noted in the preamble published with the final rules that the amendments fundamentally changed the design and construction for new bulk liquid cargo tanks. Bulk liquid cargo tanks constructed under the new rules will be designated as specification DOT 406, DOT 407, and DOT 412 and will replace the existing MC 306, MC 307, and MC 312 cargo tank specifications. Consequently, the design and construction standards for the MC 306, 307 and 312 cargo tanks were superseded by the 1989 amendments. In response to petitions for reconsideration filed as a result of the June 1989 amendments, RSPA published a subsequent final rule in September 1990[16] to address these petitions for reconsideration. The 1990

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[15] Federal Register, Vol. 54, No. 111, dated June 12, 1989, page 24982.

[16] Federal Register, Vol. 55, No. 174, dated September 7, 1990, page 37028.

amendments delayed the effective date of the 1989 amendments, which establish standards for the new DOT 400 series cargo tanks, and all subsequent amendments until December 31, 1990. Further, the 1990 amendments, under Section 49 CFR 180.405, provide a transition period during which the continued construction of new MC 306, 307, and 312 cargo tanks is authorized between December 31, 1990, and August 31, 1993; these newly constructed tanks must meet the specifications for the MC 306, 307, and 312 cargo tanks that were in effect just prior to the effective date of the 1989 amendments.

The 1989 amendments included design standards for manhole covers for specification DOT 406, 407 and 412 cargo tanks. Under 49 CFR 178.345-5, each manhole cover must be: (1) capable of withstanding, without leakage or permanent deformation that would affect its structural integrity, a static internal fluid pressure of at least 36 psig, or cargo tank pressure, whichever is greater; (2) fitted with a safety device that prevents the cover from opening fully when internal pressure is present; and (3) secured with fastenings that will prevent opening of the covers as a result of vibration under normal transportation or shock impact during a rollover accident on the roadway when the fill cover is not struck by a substantial obstacle. This section requires that vents on the manhole cover must be blocked when the manhole cover is tested. There is no requirement, however, that manhole covers be tested with accessory devices installed, or that any accessory devices meet any testing standard.

Under these new regulations, manhole covers on all MC 306, 307, 312 and older MC series bulk liquid cargo tanks[17] must be upgraded to meet the 36 psig standard by August 31, 1995. Under 49 CFR 180.405(g), owners of any MC series bulk liquid cargo tank must equip their cargo tanks with manhole covers that conform with 49 CFR 178.345-5.

Industry-Recommended Practices.--Truck Trailer Manufacturers Association (TTMA) Recommended Practice No. 61 (RP-61) is intended to serve as a guide for the design, construction, and testing of manhole and fill-opening covers installed on DOT specification MC 306 cargo tanks. Under RP-61, a manhole cover must withstand a minimum pressure of 36 psig with venting devices blocked. Any leakage "in excess of a drip, such as a steady stream, or permanent deformation that would affect the product retention capability of the manhole and/or fill assembly [cover] shall constitute a failure."

According to RP-61, 1 manhole cover per 100 produced is to be tested, and not less than 1 manhole or fill-opening cover must be tested per quarter of the year during production. If the manhole or fill cover fails, five more covers must be tested. If one of these covers fails, then all covers in the lot from which the tested covers were selected must be tested and pass, or otherwise be rejected for service.

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[17] MC 300, 301, 302, 303, and 305 cargo tanks were the precursors of the MC 306 tanks. MC 310 and 311 cargo tanks were the precursors of the MC 312. Although tanks of these specifications are no longer produced, many may still be in hazardous materials service.

The TTMA selected the design pressure of 36 psig upon review of the rollover studies conducted by the University of Michigan Highway Safety Research Institute and Dynamic Science, Inc., which were completed in the early 1980s. The TTMA stated that 36 psig was selected because these studies showed that significant pressure pulses between 13 and 27 psig were measured during the rollover tests.

Although TTMA acknowledged that RP-61 uses a static load rather than dynamic forces, TTMA contends that a static pressure test is a more severe test than a dynamic pressure test when the dynamic pressure does not exceed the static pressure test value.

TTMA stated that RP-61 prescribes a test for the structural strength of the manhole cover and not for the integrity of the components installed in the manhole cover. According to TTMA, the manufacturer of the manhole cover only tests the cover as it is sold because the manufacturer has no control over the components that may later be installed in the cover.

Other Information

Past Federal Actions.--On May 11, 1976, a tractor-cargo tank semitrailer transporting a partial load of anhydrous ammonia overturned in Houston, Texas. During the crash, the cargo tank ruptured and the ammonia escaped. In its investigation of the accident, the Safety Board determined that excessive speed of the vehicle combined with the lateral surge of the liquid cargo in the tank caused the overturn. The Safety Board consequently recommended (Safety Recommendation H-77-6) that the Bureau of Motor Carrier Safety of the FHWA issue an "On-Guard" bulletin to warn drivers of cargo tank trucks and of tractors hauling cargo tank semitrailers of the hazard of cargo that can experience lateral surge, and to inform the drivers of the correct operating procedures to use whenever the tank is partially loaded. The FHWA satisfied the Safety Board's recommendation by issuing an "On-Guard" bulletin in June 1980 that warned drivers about shifting liquid in partially loaded cargo tanks.

Cargo Tank Rollover Studies.--With the publication of the Notice of Proposed Rulemaking (NPRM) to amend the regulations in Title 49 CFR for cargo tanks[18] (which led to the June 1989 amendment), RSPA cited research studies that had been conducted to evaluate the performance of bulk liquid cargo tanks in accidents: one study was conducted by the University of Michigan's Highway Safety Research Institute under the sponsorship of the Department of State Highways and Transportation for the State of Michigan[19] and one was

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[18] Federal Register, Vol. 50, No. 180, dated September 17, 1985, page 37766.

[19] Ervin, R. D.; Mallikarjunarao, C.; Gillespie, T. D. 1980. Future configuration of tank vehicles hauling flammable liquids in Michigan. UM-HSRI-80-73-1. Lansing, MI: State of Michigan, Department of State Highways and Transportation, State Highways Building, P.O. Box 30050,

conducted by Dynamic Science, Inc., for the Bureau of Motor Carrier Safety in the Federal Highway Administration.[20] These were the same studies reviewed by the TTMA.

In the University of Michigan study, a series of four tests were conducted in which standing stationary cargo tanks filled with water were overturned onto a rigid surface. The pressures and rates of deceleration on the manhole were measured. Deceleration rates of 15 g and peak deceleration rates ranging from 20 g to 44 g were measured. The study predicted that the worst condition expected for simple turnover onto a rigid pavement would result in a 27 psig pressure pulse lasting about 50 milliseconds, with 2-millisecond pulses reaching as high as 60 psig. The study also noted that fluid was sprayed out of the 3-psi vent of each manhole cover, creating a highly diffused mist.

Dynamic Science, Inc., also conducted tests in which a vessel simulating a cargo tank compartment was rolled over 90° or 180° from a standing position. These tests also measured the forces and pressures on manhole assemblies, fill covers, and vents. Results from two series of tests indicated that in a simulation of a 90° overturn, average peak pressures against the manhole were 14.8 psig and 15.6 psig. The study included a recommendation that manhole covers for MC 306 cargo tanks have the structural capability to withstand internal fluid pressures of 13 psig without permanent deformation.

<u>Future Rollover Prevention Research</u>.--In response to the Motor Carrier Safety Act of 1984 (Public Law 998-554, Section 216), the National Highway Traffic Safety Administration (NHTSA) published a study on heavy truck (tractor-trailer combinations) safety.[21] The study, which recommends research in several areas of heavy truck rollover prevention in the human factors area, noted:

- The core portion of the rollover research program would be a carefully planned set of driver/vehicle experiments in which maneuvering conditions approaching rollover are involved.

Lansing, Michigan 48909. 2 vol.

[20] Tyndall, L. M.; Leananen, D. M.; Gauthier, D. (Dynamic Science, Inc.). 1980. Cost-effective methods of reducing leakage occurring in overturns of liquid-carrying cargo tanks--overturn integrity of MC-306-type cargo tanks. DOT-FH-11-9494. Washington, DC: U.S. Department of Transportation, Federal Highway Administration, Bureau of Motor Carrier Safety. 2 vol. Available from: National Technical Information Service, 5285 Port Royal Road, Springfield, VA 22161.

[21] Heavy Truck Safety Study, Prepared in Response to: Section 216: P.L. 98-554 October 30, 1984, Motor Carrier Safety Act of 1984 (DOT HS 807 109 Final Report), March 1987, p. 126.

- One outcome of the planned research would be a better definition of what the driver can and cannot be expected to do in avoiding rollover.

- Another outcome would be the identification of those vehicle properties which are instrumental in providing beneficial feedback to the driver. Such feedback properties could be promoted in improved vehicle design practice or, conceivably, included as a requirement in a safety standard.

As of August 1991, NHTSA has not acted on the recommendations of this study or commenced this research.

Assistance of the California Highway Patrol.--The offices of the North Sacramento Area and the Valley Division Investigative Services Unit of the California Highway Patrol provided Safety Board investigators with photographs, copies of CHP interviews with the driver and other witnesses, documentation of the marks left on the pavement by the accident vehicle, an accident diagram, and other important information about this accident, including the CHP's final report of the accident.

ANALYSIS

General

The design of the roadway was within the design standards--including vertical and horizontal alignment, grade, lane widths, and geometric design--of the American Association of State Highway and Transportation Officials (AASHTO).[22] According to FHWA-endorsed standards[23] for the dimension, size, color, height, lettering, and location of the regulatory and advisory signs, the curve was properly marked and adequate warning was provided by signs and advisory speeds. The approach to the accident was observed at night under similar lighting conditions and no visibility problems were observed. The design, construction, and marking of the road were sufficient. The Safety Board, therefore, concludes that the roadway did not contribute to this accident.

There is no evidence to indicate that the mechanical condition of the tractor and the cargo tank semitrailer contributed to the accident. Because of the severe damage to the tractor and semitrailer by fire, the scope of the vehicle examination was limited. Nevertheless, examination of brakes, suspension, and steering did not uncover any evidence of a mechanical failure. Further, the maintenance and inspection records did not reveal any type of mechanical problem that may have caused the overturn. Although the driver believes that a tire failed, the tire marks on the roadway were not consistent with a tire failure. A ruptured or blown tire would generate an irregular or scalloped-pattern mark on the roadway. There was only one set of tire marks on the roadway--those along the edge of the road in the outside traffic lane. The tire marks were smooth and continuous; such marks are consistent with marks that are made by an overloaded tire resulting from a weight shift of the cargo. Because the truck rolled over to the right, where the smooth tire marks ended and scrapes and gouges indicative of the truck sliding on the pavement began, the Safety Board concludes that overloading of the tires on the right side of the truck, not a flat tire, led to the loss of stability and rollover of the vehicle. The Safety Board therefore concludes that the mechanical condition of the vehicle was not a factor in the accident.

Calzona's accident rates of 0.55 accidents per million miles for 1990 and 0.75 accidents per million miles for the 3 years preceding this accident are below or about equal to FHWA's computed accident rate of 0.74 reportable

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[22] American Association of State Highway and Transportation Officials. 1984. A policy on geometric design of highways and streets. Washington, DC. 1087 p.

[23] (a) U.S. Department of Transportation, Federal Highway Administration. 1988. Manual on uniform traffic control devices for streets and highways. Washington, DC. (Not paged numerically.) (b) The manual is approved by the FHWA Administrator as the national standard in accordance with Title 23, U.S. Code.

accidents per million miles for carriers transporting hazardous materials. Because Calzona included accidents that may not meet the criteria as DOT-reportable accidents, the company's rate of reportable accidents may be lower. Calzona's accident rate, therefore, does not indicate there are significant problems with the company's operation.

Wind was calm and weather conditions were dry and clear; therefore, weather conditions were not a factor in the accident.

The Accident

The tire marks on the road indicated that the truck was traveling in the right (or outside) lane as it approached the curve at Oak Ave. The tire marks left by the truck follow a radius of 444 feet, which is less than the radius of the travel lane into the roadway curve. Thus, the radius of the tire marks indicates that the truck turned into the curve, thereby shortening the turning radius and lowering the rollover threshold. After the vehicle overturned at Oak Ave., it slid on its right side for about 60 feet on the pavement and 50 feet on the dirt until it struck the embankment of the ditch (see fig. 8).

Calculations of the speed of the vehicle when it became unstable were based on the radius of the curve, the radius of the tire marks left by the outside tires of the vehicle, the superelevation of the road, and the center of gravity of the cargo tank as loaded. On the basis of these calculations (appendix B), the Safety Board estimates that the vehicle was traveling between 52 and 59 mph (12 to 19 mph over the posted speed limit of 40 mph and 17 to 22 mph over the advisory speed of 35 mph) when it began to lose stability and started to leave tire marks on the road from the weight shift and centrifugal force. The calculations further estimate that the speed of the vehicle when it overturned was between 48 and 54 mph (8 to 14 mph over the posted speed limit and 13 to 19 mph over the advisory speed). The margins by which the calculated speeds exceed the posted and advisory speed limits clearly indicate that the vehicle was traveling at an excessive speed for the location. Therefore, the Safety Board concludes that the accident was caused by the driver's operation of the vehicle in the curve at an excessive speed, resulting in the overturn of the vehicle.

The CHP performed calculations, similar to those done by the Safety Board, to estimate the rollover speed of the vehicle. The CHP concluded that the vehicle was traveling at minimum speed of 52 mph when it overturned.

Driver Performance, Training, and Qualifications

To determine why the driver was traveling at a speed sufficiently excessive to cause an accident, the Safety Board analyzed the driver's background and personal profile, and his training and qualifications.

Behavioral, Medical, and Personal Factors.--There is no indication from the interviews with acquaintances and former coworkers that behavioral and personal factors had adversely affected the driver's performance and accounted for his operation of the vehicle at an excessive speed. He was described as a quiet, reliable, and dependable individual. Aside from participation in a consumer credit program, which the driver indicated was of no immediate concern to him, there were no known recent significant life events that may have distracted the driver. The driver was familiar with the route, and had a comfortable environment in the tractor while driving. Also, there was no history of reckless performance or excessive speeding in his driving records. Therefore, there is no evidence in his background to suggest that the driver would have deliberately driven the tractor-trailer into this curve at an excessive speed.

Interviews with the driver's acquaintances and former coworkers do not suggest a history of drug or alcohol abuse. Further, according to the observations of the on-scene CHP officers, and the remarks of the attending physician at the emergency room, the driver was not visibly impaired immediately after the accident. However, because the driver refused to submit a specimen for testing in accordance with the company policy, the Safety Board could not determine if drugs or alcohol were a factor in the accident.

Fatigue also does not appear to have been a factor. Even though the driver was at the end of his shift, he had worked the same shift for the 6 months he had been employed by Calzona. According to his statement to the CHP, he maintained the same hours on his days off. The driver had off-duty time and a light to normal workload in the week before the accident. There was no indication of unusual activity in the 72-hour period before the accident that may indicate fatigue as a factor.

The driver's medical records and postaccident examination showed no evidence of a medical condition that would have affected his performance as a driver. Therefore, there is nothing in the driver's behavioral, medical, or personal profile that accounts for his operation of the vehicle in an imprudent manner.

Training and Qualifications.--The curriculum at the Sacramento Truck Driving Academy, at which the driver completed a 330-hour course several months before the accident, was accredited by the Professional Truck Drivers Institute of America. The 330 hours of instruction--which included 9 hours of instruction on jackknifing and rollovers, 5 hours on emergency handling, and 10 hours on hazardous materials transportation--was sufficient to provide an entry-level driver with the basic knowledge and skills to drive a heavy truck. Although students were not tested on much of the instruction, including that on rollover and emergency handling, the driver's overall test score indicates that he had knowledge and an understanding in the subject areas on which he was tested.

Calzona's 10-day qualification program was also well designed and, if implemented as designed, included the necessary elements of instruction and evaluation. Critical driver tasks were identified and taught, and the use of attention for the trainee. The instructor was also able to provide immediate feedback to the trainee about misconceptions or errors. The daily written evaluations and the final written examination were means to assess the capabilities of the student driver.

Calzona, however, was unable to provide copies of the written daily evaluations, a record of the written examination, or other documentation about the accident driver and other drivers despite company policy requiring completion of such documentation. The only documentation in the driver's file was a letter indicating that he had successfully completed the program. According to the responses to the Safety Board's written questions, the driver indicated that he had not received any training on rollover and stability from Calzona. (Rollover training was received from the truck driving academy.) Because Calzona's written evaluations, examination records, and other training documentation were not submitted for the driver, an objective assessment of his knowledge and performance during Calzona's qualification program cannot be made. However, the actions taken by Calzona since the accident to ensure that written evaluations and test records are properly submitted should provide the necessary followup to evaluate the effectiveness of the training program. Additional actions by Calzona--including the certification and evaluation of the driver instructors, evaluation of new drivers after 30 days employment, and the implementation of a mandatory 2-week training program for all new drivers--should also enhance the effectiveness of Calzona's training program.

Despite the lack of testing on some areas of instruction at the truck driving academy and the deficiencies with Calzona's documentation of training, the driver held a valid Class A commercial driver's license with endorsements for hazardous materials transportation and operation of tank trucks. Because the requirements for the Class A license complied with Federal requirements for the commercial driver's license, the driver had to demonstrate his driving skills in a road test of a tank truck and his knowledge through written examinations to receive the license and endorsements. The written examinations for the license and the tank truck endorsement do include questions about stability and rollover.

Therefore, the Safety Board concludes that the driver received sufficient training, including training on stability and rollover, through the truck driving academy and Calzona. Further, the driver, by virtue of his license, had demonstrated he was properly qualified to operate a tank truck and should have had sufficient knowledge about stability and rollover.

Other Factors.--Other factors that may account for the driver's operation of the vehicle at excessive speed are rushing to complete his shift and inattentiveness. In his statements to the CHP, the driver indicated that he had no particular plans when he completed his shift, and that his normal practice was to return home and go to bed. The driver, in the week prior to the accident, had sufficient time off such that he would not have been concerned about violating the requirements for hours-of-service. He therefore had no known reason to rush to complete his shift.

Consequently, the Safety Board believes that the most reasonable explanation for the driver's operation of the vehicle at an excessive speed can be attributed to a lapse of attention by the driver. He indicated that there was no traffic on the accident trip, and that he did not have to stop for a single stop light. The weather conditions, the truck's mechanical condition, and the road condition were also good. Further, the driver's statement that he could tell the speed of the vehicle by the sound of the engine and without looking at the speedometer suggests that he may not have been scanning the instruments in the cab and monitoring his speed before the accident. His singing to the music on the radio is also consistent with a relaxed vigil. The Safety Board therefore believes that the driver most likely was inattentive, for undetermined reasons, to the vehicle's speed.

One method to overcome inattention is to regularly emphasize the conditions that can lead to and the hazards associated with a loss of stability and eventual rollover. Calzona has indicated that it provides to its drivers flyers about safety practices, such as defensive driving. The Safety Board believes this is a good policy; however, the Board also urges Calzona to provide regular reminders to its drivers about the loss of stability and rollover through safety meetings, and the periodic flyers and letters that are now being sent to the drivers. Further, the Safety Board is concerned that drivers of tank trucks for other carriers may also experience lapses of attention that potentially could lead to a rollover. The Safety Board therefore believes that the FHWA should issue periodic "On-Guard" bulletins to remind all carriers and drivers to be attentive and aware of the conditions that can lead to a loss of stability and rollover in a tank truck.

The Safety Board is also concerned that NHTSA has not acted upon the recommendations, of NHTSA's 1987 study, to conduct research of human performance factors that may reduce rollovers of tractor-trailer trucks. The Safety Board believes that NHTSA should proceed with the research as recommended in the study.

Source of Hazardous Materials Release

As the gasoline runoff from the overturned tank truck followed the drainage ditch and reached the rear of the homes on Twin Gardens Drive, gasoline vapors were ignited by an ignition source from one of the homes.

A limited quantity of gasoline was probably released through one or more of the pressure-actuated fill (PAF) openings on each manhole cover when the tank truck overturned and struck the pavement. As documented in the research study conducted by Dynamic Science, Inc., for the Federal Highway Administration, such an occurrence releases only a small quantity of product. Therefore, release of gasoline through the PAF openings cannot account for the quantity of gasoline needed to generate the strong odors noted by the witness and highway patrol officers and to generate the amount of runoff that led to the fires.

Although the driver did not inspect the manhole covers before departing on the accident trip, there is no indication that the four manhole covers and the PAF lids were not properly secured when the accident occurred. The manholes were not routinely opened for loading. Further, the Safety Board believes that an improperly secured manhole would have opened after the tank truck had overturned and before it hit the embankment. However, there was no indication of a spill on the roadway and there was not an immediate ignition of gasoline following the overturn. Therefore, the manholes were most likely properly secured at the time of the accident.

If a substantial release of the gasoline had occurred after the overturn and the impact of the tank truck with the roadway, as the vehicle was sliding across the roadway on its side but before it hit the embankment, gasoline would have covered the roadway and likely would have ignited from the friction of metal. The gasoline, however, did not ignite at that time, and the fire, after it flashed back to the overturned vehicle, did not spread beyond the vehicle along the path of the truck's direction of travel. Further, there was no indication from physical evidence or witness statements that gasoline had spilled on the roadway.

Also, the newspaper employee's descriptions of the impact of the cargo tank with the embankment of the drainage ditch and the damage to the right front of the cargo tank indicate that the forward portion of the cargo tank struck the embankment with a significant force. Consequently, significant release of gasoline probably did not occur until the cargo tank hit the embankment of the drainage ditch.

Witness statements also indicate that a release of gasoline was observed on top of the cargo tank and toward the front of the tank. This release, which was seen by three firefighters and one CHP officer, was consistently reported to be through a hole at the forward end of the cargo tank and on or near the top of the tank. Further, the firefighters' and the CHP officer's comparisons of the flow of the gasoline to the flow from a fire hydrant or through a round opening suggest that the gasoline was being released through a circular-shaped hole.

It is not likely that the release seen by the witnesses was through a tear or gash in the tank shell because such a hole would have been irregularly shaped and would not have caused the type of flow as described. Although flow through a round hole may have resulted from a puncture of the tank shell, a puncture of the cargo tank where the release was observed also appears to have been unlikely. Although the stop sign at the intersection of Fair Oaks Blvd. and Oak Ave. was struck by the vehicle and the wooden post was broken, the sign was struck as the vehicle was on its right side and sliding toward the embankment of the drainage ditch. Because of the orientation of the top of the cargo tank with respect to the broken stop sign post, the top of the cargo tank would not have been susceptible to puncture by the sign post. There were no other known objects along the path of the overturned tank truck that might have punctured the tank in the top right front area of the tank. Therefore, the release seen by the firefighters and the CHP officer was probably at a fitting located at the front end and on top of the tank. Because the topside fitting closest to the front of the cargo tank was the manhole cover for the first cargo compartment, the release most likely occurred at this manhole cover.

One manhole cover was found with the latches for the PAF lid extended open. The postaccident condition of the three other manhole covers was much the same: all appeared to have remained closed and intact with the exception of the non-steel parts and accessory devices that were destroyed in the fire. Because the design of the spring-loaded PAF lid and the safety latches prevents the lid from physically popping open, the latches on the one manhole cover most likely opened after the aluminum lid had melted and the force of the spring on the latches was released. Therefore, the release observed by the firefighters and the CHP officer was not through the PAF opening of the manhole cover for the forward compartment.

The release of gasoline most likely occurred when one of the liquid-level sensors mounted on the manhole cover for the forward compartment dislodged. There were no known objects in the path of the overturned truck that might have struck one of the sensors and caused it to dislodge. Further, the dynamics diagram (fig. 8) indicates that the top of the cargo tank was nearly parallel to the embankment of the drainage ditch when the tank struck the embankment. The angle of the cargo tank, in its final position, suggests that the front right-side of the overturned cargo tank struck the embankment but the rear-end of the tank did not. This would have permitted the tank to pivot at the front end of the cargo tank and attain the angle to the ditch. Consequently, the impact forces on the cargo tank and the forces resulting from the dynamic surge of the gasoline against the top of the tank would have been more intense at the front portion of the cargo tank striking the embankment. Because the manhole cover for the forward compartment is the only manhole opening toward the front of the cargo tank, this manhole cover would have been the most susceptible to the dynamic surge forces of the gasoline. Therefore, the Safety Board concludes that one of the sensors on the manhole cover for the forward compartment most likely dislodged because the sensor was unable to withstand the surge of the gasoline in the overturned cargo tank.

Cargo Tank Performance and Testing

Dynamic Forces on the Forward Manhole.--The tank truck overturned and traveled about 110 feet before hitting the embankment of the drainage ditch (fig. 8). Based on estimated overturn speeds between 48 and 54 mph, and on deceleration calculations for the distance traveled after the overturn, the estimated impact speed of the cargo tank with the embankment was calculated to have been between 28 mph (41 feet per second) and 42 mph (61 feet per second). Calculations are given in appendix C.

NHTSA has indicated that, based on front-end impact testing of new-model passenger cars with a fixed barrier, the elapsed time of the impact forces on a car is typically between 100 and 150 milliseconds (0.1 to 0.15 seconds). Although similar impact tests have not been conducted on commercial tractor-trailer trucks, this range of impact times provides the best available comparison of the cargo tank's impact time with the dirt embankment. Although the dirt embankment of the drainage ditch likely provided some cushion to the cargo tank on impact in this accident (resulting in a longer impact impulse time), the possibility exists that an overturned cargo tank could, in similar circumstances, strike a rigid barrier such as a concrete retaining wall. Therefore, the calculations of the dynamic forces provide a reasonable estimate of the forces that can be generated on the manhole covers. On the basis of the calculated impact speeds of the cargo tank with the dirt embankment, and of the elapsed impact times, the dynamic force per unit area on the forward manhole compartment was calculated to be between 20 and 50 psia. The calculations suggest that had the tank struck a concrete abutment, the manhole cover (and sensors) could have been subjected to pressures consistent with the static design requirements. However, in the case of this accident, the liquid-level sensor may have failed to withstand a dynamic surge pressure significantly below the static design pressure of 36 psig (51 psia).

DOT Standards for Manhole Covers.--The recent revisions of the cargo tank design standards in 49 CFR are a major improvement in the standards. Manhole covers must now be designed to withstand a static pressure of 36 psig rather than 5 psig as previously allowed, and retrofit of the manhole covers on existing bulk liquid cargo tanks must be completed by 1995.

However, the new performance standard that applies to the manhole cover does not specifically address fittings or devices mounted on the manhole cover, and thus these fittings and devices are not required to be (and generally are not) tested for dynamic or static loads. This accident demonstrates that the performance standard for loading should apply to the manhole cover as it will be configured during transportation. If load testing cannot be accomplished with the manhole covers exactly configured, the fittings and devices mounted on the manhole cover should be independently designed and tested to meet the same design loads as the manhole cover itself. If the liquid-level sensors had been required to meet a performance standard comparable to the static loading standard for the manhole cover, the release of gasoline through the manhole cover on the accident vehicle may have been averted, thereby reducing the severity of the accident. The RSPA, therefore, should require that all fittings and devices mounted on a manhole cover of cargo tanks meet the same performance standard to withstand the static internal fluid pressure as that required for the manhole cover.

California Standards.--Because the State has not adopted Federal regulations beyond those in effect as of October 1, 1988, intrastate shipments of all hazardous materials can be made indefinitely in liquid bulk tank trucks that do not meet the improved Federal standards. Consequently, potential improvements in public safety within California will be precluded so long as cargo tanks that fail to meet improved standards remain in intrastate service. There is also an increased likelihood that cargo tanks that fail to meet Federal standards will be removed from interstate service and placed in intrastate service within California. Therefore, the Safety Board believes that the State of California should adopt design standards for bulk liquid cargo tanks that are equivalent to the current standards in 49 CFR Parts 171 through 180.

Toxicological Testing

The driver did not submit or provide urine samples for postaccident toxicological testing upon the advice of his attorney. Because the driver had only made intrastate trips within California, he was not subject to the Federal regulations in 49 CFR Part 391 relating to postaccident testing. Because of the court injunction against the Federal drug testing program that was in effect at the time of the accident, reasonable suspicion of drug use or impairment would have also been required for any postaccident testing under Federal jurisdiction. Further, the CHP officers who were first to arrive at the scene did not order testing because they did not have reasonable cause to believe the driver was impaired by alcohol or drugs. Although a driver may not exhibit visible indications of drug or alcohol impairment after an accident, the absence of alcohol and drug use cannot be conclusively determined without testing.

The Safety Board has, for many years, documented the role of alcohol and other drugs in accident causation throughout the U.S. transportation system. The Board found that alcohol and drug abuse was evident in accidents for all modes of transportation, and that DOT regulations that pertain to the drug and alcohol testing of persons involved in accidents or incidents were inconsistent among modal agencies. To address these concerns, the Safety Board recommended that the DOT:[24]

- Develop regulations for postaccident and postincident testing procedures that are separate from the requirements for pre-employment, random, or reasonable suspicion testing;

- Adopt uniform regulations for all drug and alcohol testing in all transportation modes for private sector employees and DOT employees who are in safety sensitive positions;

- Adopt regulations that provide for the collection of blood and urine samples to test for alcohol and drugs beyond the five that are specified in the Department of Health and Human Services guidelines (marijuana, cocaine, opiates, amphetamines, and phencyclidine).

The Secretary of Transportation responded in August 1990 that DOT-mandated testing was not intended primarily as an accident investigation tool, but as a deterrence of improper conduct by employees performing sensitive safety- and security-related functions. Although the Secretary pledged to work with the Safety Board on a program to determine the role of substance abuse in the causation of transportation accidents and meetings between DOT and Safety Board staffs did take place, no real progress has occurred. The Safety Board remains concerned with the lack of progress to implement these recommendations and again urges the Secretary of

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[24] Safety Recommendations I-89-4 through -12 were issued to the DOT on December 5, 1989.

Transportation to develop the postaccident testing program described by these recommendations.[25]

In 1990, the Safety Board completed a safety study concerning the effect of fatigue, alcohol, and other drugs in fatal accidents involving heavy trucks,[26] which found that drugs of abuse, including alcohol, were present in 33 percent of the fatally injured drivers of heavy trucks. As a result of the study, the Board issued more than 30 safety recommendations concerning drug and alcohol testing and reporting to the DOT, FHWA, other Federal agencies and departments, the States, and associations for the trucking industry.

Of the 13 recommendations issued to each of the States, California has indicated that it has implemented or is considering implementation of several recommendations concerning drug and alcohol testing. The State, however, requires that legislation be enacted before it can implement drug and alcohol testing programs for commercial truck drivers. Legislation that would implement a drug testing program for intrastate drivers and that is equivalent to FHWA's program has recently passed the California Assembly. Action is pending in the California Senate. All 13 recommendations issued to California have been classified as "Open--Await Response."

Because intrastate transportation of hazardous materials may often involve short trips and local deliveries through residential or congested commercial areas, the risk to public safety may be greater than the interstate movement of these materials along interstate or major highways. The FHWA has previously recognized the unique hazards of transporting hazardous materials, and has consequently issued regulations that apply not only to interstate transportation but also to intrastate transportation. For example, under 49 CFR 387.9, the FHWA prescribes minimum levels of financial responsibility for the intrastate transportation of hazardous wastes, hazardous materials, and hazardous substances that are carried in bulk. Section 49 CFR 391.2(d) exempts certain intracity zone drivers from meeting age and certain physical requirements; this section, however, does not exempt intracity zone drivers who operate a vehicle that is used in the transportation of hazardous materials and requires placarding under the Hazardous Materials Transportation Safety Act (49 U.S.C. App. 1801-1813). The FHWA has further recognized these risks by requiring special endorsements on the commercial drivers license for hazardous materials and tank trucks.

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[25] Safety Recommendations I-89-4 through -9, -11, and -12 have been classified as "Open--Unacceptable Response." Safety Recommendation I-89-10, which urged the DOT to provide Safety Board investigators with the toxicological test results for DOT employees in safety-sensitive positions, has been classified as "Closed--No Longer Applicable" because of Congressional action that meets the intent of the recommendation.

[26] National Transportation Safety Board. 1990. Fatigue, alcohol, other drugs, and medical factors in fatal-to-the-driver heavy truck crashes. Safety Study NTSB/SS-90/01. Washington, DC. 181 p. Vol. 1.

Because of the unique and high risks to the public posed by a release of hazardous materials, the Safety Board believes that drivers of all vehicles transporting hazardous materials, particularly in bulk shipments, have an added responsibility to operate these vehicles in a safe manner. The Safety Board concludes that drivers of such vehicles should, therefore, be subject to mandatory postaccident testing for alcohol or drug impairment regardless of whether the shipment is being made by intrastate or interstate transportation.

The FHWA has indicated that it is considering extending the drug testing requirements to intrastate drivers. While the Safety Board believes that FHWA should proceed with such rulemaking, the Board remains concerned that testing for alcohol will continue to be excluded from FHWA's testing program. The Safety Board believes that FHWA should, as a minimum, require postaccident toxicological testing for alcohol and drug impairment of commercial vehicle operators involved with the intrastate transportation of hazardous materials in bulk.

Many States have implemented drug testing programs for intrastate drivers that are similar, in varying degrees, to FHWA's program; other States have no programs in place. The Safety Board therefore believes that each State should likewise require mandatory postaccident testing for alcohol and drug impairment of drivers operating vehicles transporting hazardous materials in bulk within the State.

Emergency Response

Units from the American River Fire District arrived at the accident site within 10 minutes after being dispatched. The local response was timely and effective. The incident command system was implemented, allowing agencies to coordinate their activities with one another after being assigned specific tasks by the incident commander. Communication between the agencies worked well. The coordination between the fire departments, the CHP, and the Sacramento County Sheriff's Department also resulted in a timely evacuation of residents in the immediate area.

The mutual training exercises that were held between the American River Fire District and other fire departments proved to be beneficial. Firefighters were not only familiar with the capabilities of the firefighters at their stations, but also with those of the firefighters from other district stations. This led to an effective firefighting response.

The Sacramento County disaster plan was implemented and was effective in coordinating the activities of all agencies responding to the accident.

CONCLUSIONS

Findings

1. The roadway, the mechanical condition of the vehicle, and the weather were not factors in the accident.

2. The driver had received adequate training and was properly qualified to operate the vehicle.

3. The vehicle was traveling 12 to 19 mph over the posted speed limit for the curve, which caused it to overturn.

4. A lapse of attention, for undetermined reasons, by the driver probably led to the operation of his truck at an excessive speed as he approached and entered the curve on Fair Oaks Blvd.

5. Gasoline was released through an opening in the manhole cover for the front compartment, most likely after a liquid-level sensor was dislodged by a dynamic surge of the gasoline cargo.

6. If the liquid-level sensors had been required to meet a performance standard comparable to the static loading standard for the manhole cover, the release of gasoline through the manhole cover may have been averted, thereby reducing the severity of the accident.

7. Because California has not adopted standards for cargo tanks that are comparable to the most current Federal standards, the public within the State is not receiving the protection provided by the improved cargo tank standards.

8. Drivers of commercial vehicles transporting hazardous materials in bulk in intrastate commerce are not subject to Federal mandatory postaccident testing for drug and alcohol impairment.

9. The emergency response and evacuation of residents were well executed and coordinated.

Probable Cause

The National Transportation Safety Board determines that the probable cause of the accident was the inattention of the driver, for undetermined reasons, which resulted in his operation of the tank truck at excessive speed leading to its overturn. Contributing to the severity of the accident was the failure of one of the liquid-level sensors mounted on the manhole cover for the forward compartment of the cargo tank to remain secured.

RECOMMENDATIONS

--to the Federal Highway Administration, U.S. Department of Transportation:

Require postaccident toxicological testing for alcohol and drug impairment of commercial vehicle operators involved with the intrastate transportation of hazardous materials in bulk. (Class II, Priority Action) (H-91-32)

Issue periodic "On-Guard" bulletins to remind all carriers and drivers to be attentive and aware of the conditions that can lead to a loss of stability and rollover in a tank truck. (Class II, Priority Action) (H-91-33)

--to the Research and Special Programs Administration, U.S. Department of Transportation:

Require that all fittings and devices mounted on a manhole cover of cargo tanks meet the same performance standard to withstand the static internal fluid pressure as that required for the manhole cover. (Class III, Longer Term Action) (H-91-34)

--to the National Highway Traffic Safety Administration, U.S. Department of Transportation:

Proceed with and complete the research of human performance factors that may reduce rollovers in heavy trucks (tractor-semitrailer combinations) as recommended in the 1987 Heavy Truck Safety Study prepared in response to Section 216 of Public Law 98-554. (Class III, Longer Term Action) (H-91-35)

--to the State of California:

Adopt design standards for highway bulk liquid cargo tanks that are at least equivalent to current Federal standards in 49 CFR Part 171 through 180. (Class II, Priority Action) (H-91-36)

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

Require postaccident toxicological testing for alcohol and drug impairment of commercial vehicle operators involved with the intrastate transportation of hazardous materials in bulk. (Class II, Priority Action) (H-91-37)

--to Calzona Tankways, Inc.

Provide regular reminders to company drivers about the loss of stability and rollover through safety meetings, and the periodic flyers and letters sent to the drivers. (Class II, Priority Action) (H-91-38)

BY THE NATIONAL TRANSPORTATION SAFETY BOARD

JAMES L. KOLSTAD
Chairman

SUSAN M. COUGHLIN
Vice Chairman

JOHN K. LAUBER
Member

CHRISTOPHER A. HART
Member

JOHN A. HAMMERSCHMIDT
Member

Adopted: September 4, 1991

APPENDIX A

INVESTIGATION

The National Transportation Safety Board learned of the accident about 9 a.m. eastern standard time on February 13, 1991. An investigative team was dispatched from headquarters in Washington, D.C., and from field offices in Los Angeles, California, and Seattle, Washington. Investigative groups were established for hazardous materials, highway, vehicle, operations, survival factors, and human performance.

Parties to the investigation were the Federal Highway Administration, the Sacramento County Sheriff's Department, the American River Fire District, Calzona Tankways, Inc., Fruehauf Corporation, and Kenworth Truck Company.

The Safety Board did not convene any formal proceedings; interviews and witness statements, however, were obtained.

APPENDIX B

CALCULATIONS FOR THE SPEED OF THE VEHICLE

Calculations for the speed of the vehicle at its loss of stability and rollover are performed using the following formula:

$$V = [\ RG\ ((w/h) + e)\ ]^{1/2}$$

where V = velocity in feet per second, R = radius of the path of the truck's center of mass, G = acceleration of gravity or 32.2 feet per second squared, w/h = the rollover threshold of the truck (1/2 of the track width divided by the height of the center of mass), and e = the superelevation of the roadway.

The following tabulation indicates a range of calculated rollover speeds (converted to speeds in miles per hour, mph, from velocity in feet per second, fps) using the radius of the roadway curve corrected for the track of the center of mass of the truck in the outside lane and the radius of the tire marks left by the outside tires of the truck corrected for the track of the center of mass, the measured superelevation of the roadway at the point of rollover and the maximum superelevation indicated on the design plans, and a range of vehicle rollover thresholds from 0.30 to 0.40.

The manufacturer determined the height of the center of mass of the tractor and tank trailer, loaded as indicated by the carrier, to have been 78 inches above the ground. One half the track width is taken as one half of the distance between the outside walls of the inside tires. Theoretically, if the truck was rigidly suspended, the ratio of w/h would be 36 inches/78 inches = 0.46. The truck was not rigidly suspended but had compliant or flexible tires and suspension. Because the truck was destroyed by the fire, there was no way to determine the stiffness of the suspension system or the tires. The original suspension had been replaced, subsequently the manufacturer was reluctant to estimate the stiffness of the suspension. Therefore, a range of rollover thresholds was used to calculate an estimated rollover speed.

In the early 1980's, the University of Michigan Transportation Research Institute (UMTRI) performed tests and research on truck rollover. A suspension system that is soft or mushy with underinflated tires would have a threshold value near 0.30, and a stiff suspension system with rigid tires would have a threshold value near 0.40. In 1980, Erwin[27] published a

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[27] Erwin, R. D. 1980. Future configuration of tank vehicles hauling flammable liquids in Michigan. UM-HSRI-80-73. Ann Arbor, MI: University of Michigan, Highway Safety Research Institute.

rollover threshold value of 0.34 for an MC 306 tanker, in 1983[28] a value of 0.31, and in 1988[29] a value of 0.35.

	Rollover threshold value	Calculated speed
Rollover:		
R = 444 feet (tiremarks);		
e = 0.372 (at rollover)	w/h = 0.30	s = 48.2 mph
	w/h = 0.34	s = 50.9 mph
	w/h = 0.38[30]	s = 52.7 mph
	w/h = 0.39	s = 54.2 mph
	w/h = 0.40	s = 54.9 mph
Loss of vehicle stability:		
R = 524 feet;		
e = 0.04 (roadway)	w/h = 0.30	s = 52.5 mph
	w/h = 0.40	s = 59.8 mph

The calculated rollover speeds ranged from 48 to 54 mph. The truck traveling in the outside lane entering the curve would have lost stability between 52 and 59 mph. The tire marks left by the truck follow a radius of 444 feet, which is less than the radius of the roadway curve. Thus, the radius of the tire marks indicate that the truck turned into the curve. The calculated rollover speed for the smaller radius curve, left by the truck tires, was 48 to 54 mph. Even the lower speed is well above the 40 mph posted speed limit on Fair Oaks Blvd. and is considerably higher than the 35 mph advisory speed. Although calculated rollover speeds are considered to be estimates and are generally slightly higher than the actual speed at which a vehicle will lose stability and roll over, the margin in this case is sufficient for the Safety Board to conclude that when the accident vehicle overturned, it was traveling 8 to 14 mph over the posted speed limit and 13 to 19 mph over the curve advisory speed.

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28 Ervin, R. D. 1983. The influence of size and weight variables on the roll stability of heavy duty trucks. SAE Paper 831163. Warrendale, PA: Society of Automotive Engineers.

29 Ervin, R.D.; Matthew, A. 1988. Reducing the risk of spillage in the transportation of chemical waste by truck. UMTRI-88-28. Ann Arbor, MI: University of Michigan, Transportation Research Institute.

30 The rollover threshold value used by the California Highway Patrol to estimate the vehicle speed.

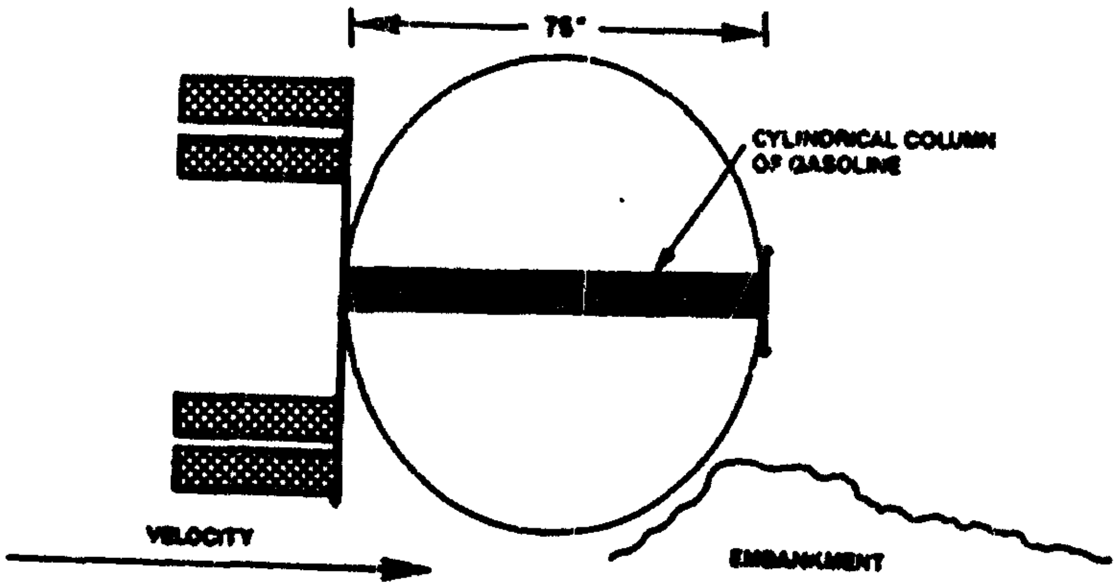
APPENDIX C

CALCULATION OF DYNAMIC FORCES ON THE MANHOLE COVER FOR THE FORWARD COMPARTMENT

Assumptions

1. The cargo tank was 90° from the vertical when it struck the embankment of the drainage ditch.

2. Dynamic surge forces on the manhole cover for compartment 1 at the front of the cargo tank were generated by a cylindrical column of gasoline as shown in the figure below.



REAR-END VIEW OF OVERTURNED CARGO TANK

3. The cargo tank struck the embankment on the right front side of the tank shell, with the force distributed along the length of the front cargo compartment.

4. Based on the dynamics diagram provided by the California Highway Patrol, the tank truck slid about 110 feet after overturning.

5. The coefficient of friction, f, of the truck sliding across the pavement and dirt was f = 0.35 to 0.45. (Ref: National Transportation Safety Board. 1982. Pacific Intermountain Express tractor cargo tank semitrailer Eagle/F.B. Truck Lines, Inc., tractor lowboy semitrailer collision and fire, U.S. Route 50, near Canon City, Colorado, November 14, 1981. Highway Accident Report NTSB-HAR-82-3. Washington, DC. 35 p.)

6. The Safety Board estimated the rollover speed to have been between 48 and 54 mph, or between 70.4 and 79.2 feet per second (fps). Calculations of the California Highway Patrol estimated the rollover speed to have been about 52 mph (76.3 fps). For purposes of calculation, overturn speeds are assumed to range from 48 to 54 mph.

7. The elapsed time of dynamic forces acting on the cargo tank range from 100 to 150 milliseconds, which is typical of the impact time in a front-end collision of a passenger car with a rigid barrier, according to the National Traffic Highway Safety Administration.

Definition of Terms

A cross-sectional area of the manhole cover, in square inches (in^2)

d distance the overturned cargo tank traveled before hitting the embankment of the ditch (110 feet)

dia diameter of the manhole cover (16 inches)

f coefficient of friction

F impact surge force on the manhole cover, in pounds-force (lb_f)

g gravitational acceleration, 32.2 ft/sec^2

l length of cylindrical column of gasoline (75 inches for the maximum depth of the cargo compartment)

m mass of the gasoline in the cylindrical column, in pounds-mass (lb_m)

$(t_2 - t_1)$ the elapsed time interval of the impact of the cargo tank with the embankment of the ditch, in seconds

v_2 0 feet per second, the "at-rest" velocity of the cargo tank

v_1 the impact velocity of the cargo tank with the ditch, in feet per second

V overturn velocity of the vehicle, in feet per second

ρ density of the gasoline, in pounds-mass per cubic foot (46.8 lb_m/ft^3 for gasoline)

Calculation of Impact Velocity with the Embankment of the Ditch

(Ref: Rivers, R.W. 1980. Traffic accident investigators handbook. Springfield, IL.: Charles C. Thomas.)

$$v_1 = \sqrt{V^2 - (2)(f)(g)(d)}$$

Using the above formula for deceleration, estimated impact velocities in feet per second (fps) were calculated as follows:

V (Overturn velocity, fps)	f = 0.35	f = 0.40	f = 0.45
70	49	45	41
76	57	54	50
79	61	58	55

The calculated impact velocities of the cargo tank with the embankment of the ditch range from 41 fps (28 mph) to 61 fps (42 mph). For purposes of calculation, surge forces are computed using impact velocities ranging from 40 fps to 60 fps.

Impact Force

The mass of the cylindrical column of fluid acting on the manhole cover:

$$A = (\pi)\,(\text{dia})^2/4 = \pi\,(16\ \text{in})^2/4 = 201\ \text{in}^2$$

$$m = Al\rho = (201\ \text{in}^2)\,(75\ \text{in})\,(46.8\ \text{lb}_m/\text{ft}^3)\,(1\ \text{ft}^3/1{,}728\ \text{in}^3)$$

$$m = 544.4\ \text{lb}_m \approx 545\ \text{lb}_m$$

Impact force, F, acting on the column of gasoline is estimated by:

$$F = m\,[(v_2 - v_1)\,/\,(t_2 - t_1)]$$

The force on the manhole cover by the gasoline is equal and opposite to the impact force acting on the column of gasoline. Therefore, the estimated impact force/unit area on the manhole cover is:

$$-F/A = -(m)\,[(v_2 - v_1) / (t_2 - t_1)]\,(1/A)\,(1\ lb_f - sec^2 / 32.2\ lb_m - ft)$$

$$= -(545\ lb_m)\,[(v_2 - v_1) / (t_2 - t_1)]\,(1/\ 201\ in^2)\,(1\ lb_f - sec^2 / 32.2\ lb_m - ft)$$

$$-F/A = -(0.08)\,[(v_2 - v_1) / (t_2 - t_1)]\ lb_f/in^2$$

Using the range of impact velocities and time intervals, values of the force per unit area acting on the manhole cover in lb_f/in^2 are as follows:

$(v_2 - v_1)$ fps	$(t_2 - t_1) = 0.10$ sec.	$(t_2 - t_1) = 0.15$ sec.
-40	32	21
-50	40	27
-60	48	32

The dynamic force per unit area exerted on the manhole cover by the surge of a column of gasoline ranges from 21 to 48 lb_f/in^2.

APPENDIX D

Abbreviated Injury Scale (AIS)

Injuries in this accident have been coded according to the revised 1990 Abbreviated Injury Scale (AIS) of the American Association for Automotive Medicine.[31]

Description	AIS Code	Resident	Firefighter	Driver	Total
Maximum injury, virtually unsurvivable	AIS-6	0	0	0	0
Critical	AIS-5	0	0	0	0
Severe	AIS-4	0	0	0	0
Serious	AIS-3	0	0	0	0
Moderate	AIS-2	0	0	0	0
Minor	AIS-1	1	1	1	3
None	AIS-0	0	0	0	0
Unknown	AIS-9	0	0	0	0
Total		1	1	1	3

[31] The AIS is a standardized, universally accepted system of assessing the severity of impact injuries by coding individual injuries. The first scale was published in 1971 under the sponsorship of a joint committee of the American Medical Association, the American Association for Automotive Medicine, and the Society of Automotive Engineers.

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