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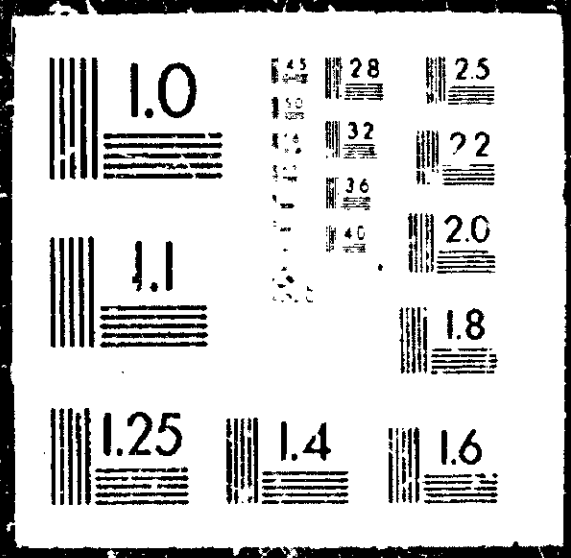


PB92-917002

National Transportation Safety Board Hazardous Materials Special Investigation Report: Cargo Tank Rollover Protection

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

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

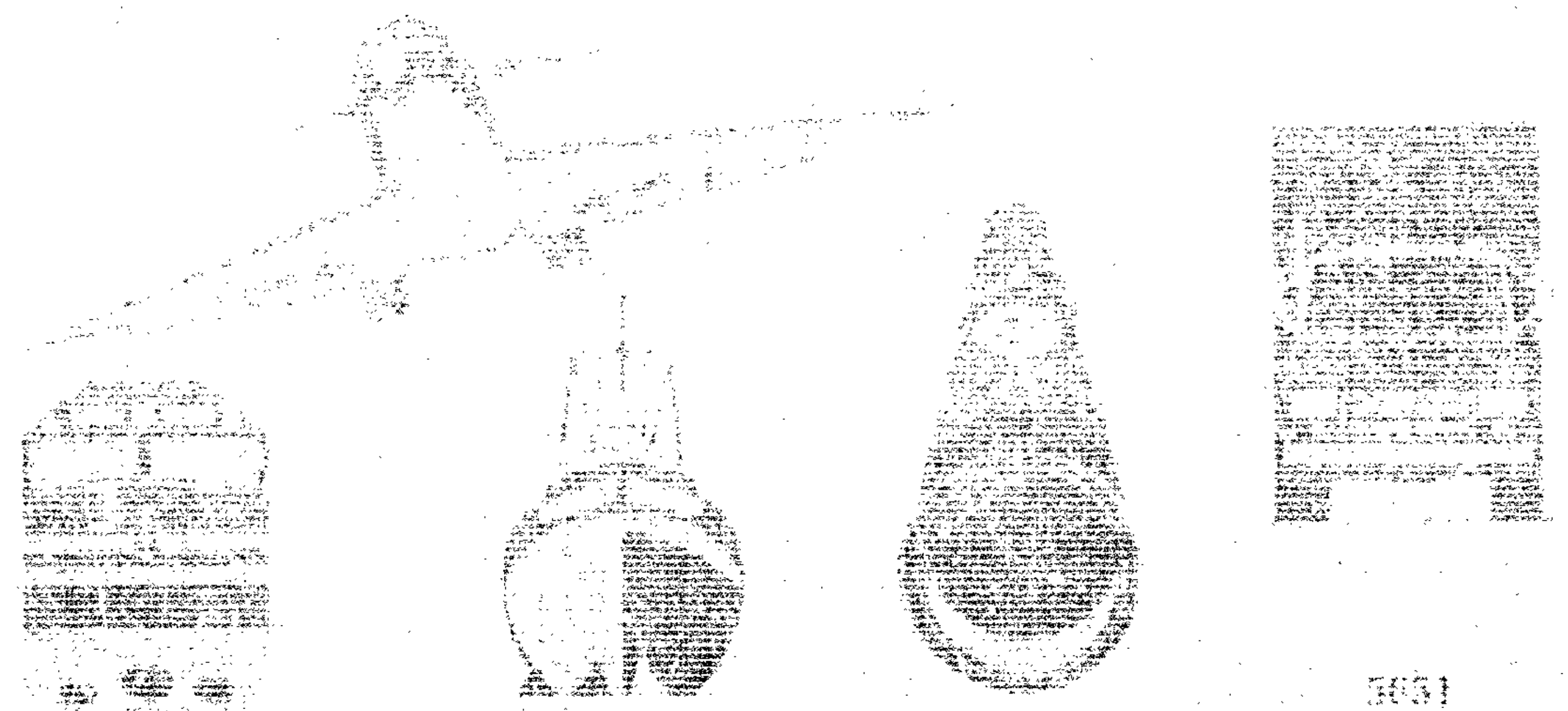
PB92-917002
NTSB/SIR-92/01

NATIONAL TRANSPORTATION SAFETY BOARD

WASHINGTON, D.C. 20594

SPECIAL INVESTIGATION REPORT

CARGO TANK ROLLOVER PROTECTION



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The National Transportation Safety Board is an independent Federal agency dedicated to promoting aviation, railroad, highway, marine, pipeline, and hazardous materials safety. Established in 1967, the agency is mandated by Congress through the Independent Safety Board Act of 1974 to investigate transportation accidents, determine the probable causes of the accidents, issue safety recommendations, study transportation safety issues, and evaluate the safety effectiveness of government agencies involved in transportation. The Safety Board makes public its actions and decisions through accident reports, safety studies, special investigation reports, safety recommendations, and statistical reviews.

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NATIONAL TRANSPORTATION SAFETY BOARD

WASHINGTON, D.C. 20594

HAZARDOUS MATERIALS SPECIAL INVESTIGATION REPORT

CARGO TANK ROLLOVER PROTECTION

Adopted: February 4, 1992
Notation: 5651

Abstract: Between January and May 1991, the National Transportation Safety Board investigated seven highway accidents in which bulk liquid cargo tanks, Department of Transportation (DOT) specification MC 306 or MC 312, overturned and released hazardous materials through damaged closures or fittings on top of the tanks. In three of the accidents, structural failure of the rollover protection devices for the top fittings resulted in impact damage to the fittings and the release of the cargo; in four of the accidents, the design and configuration of the devices were not adequate to protect and shield the top fittings from external objects or from plowing into the ground. As a result of these accidents, the Safety Board conducted a special investigation on cargo tank rollover protection. The safety issues discussed in this report are the adequacy of DOT regulations regarding the design and performance of rollover protection devices installed on bulk liquid cargo tanks; the effectiveness of oversight pertaining to the design and construction of the cargo tanks; and the adequacy of accident reporting to and data collected by the DOT. Recommendations concerning these issues were made to the Research and Special Programs Administration and to the Federal Highway Administration.

CONTENTS

EXECUTIVE SUMMARY

Between January and May 1991, the National Transportation Safety Board investigated seven highway accidents in which cargo tanks overturned and hazardous materials were released through damaged closures or fittings on top of the tanks; none of the cargo tank shells had been breached. The cargo tanks involved in these accidents were U.S. Department of Transportation (DOT) specification MC 306 or MC 312 bulk liquid cargo tanks. Under DOT regulations contained in Title 49, Code of Federal Regulations, Part 178, all of the tanks examined during the investigation were required to have rollover protection for the fittings on the top of the tanks. All of the tanks were also equipped with rails or guards to provide that protection. Because of the damage to the top fittings in these accidents, the Safety Board has, in this report, examined the adequacy of the design and the performance of the rollover protection devices installed on the tanks.

During the course of this special investigation, the Safety Board also assessed the adequacy of the DOT regulations for rollover protection as promulgated by the Research and Special Programs Administration (RSPA) and the effectiveness of the Federal Highway Administration (FHWA) to enforce regulations pertaining to the design and construction of cargo tanks. The Safety Board also reviewed the adequacy of the accident data collected by the FHWA and the RSPA to detect the frequency of rollover accidents and to identify potential problems related to the design and construction of bulk liquid cargo tanks.

The safety issues discussed in this report are:

1. The adequacy of DOT regulations regarding the design and performance of rollover protection devices installed on bulk liquid cargo tanks;

2. The effectiveness of FHWA's oversight pertaining to the design and construction of bulk liquid cargo tarks; and

3. The adequacy of accident reporting to and data collected by the DOT.

Safety recommendations addressing these issues were made to the Research and Special Programs Administration, and the Federal Highway Administration.

NATIONAL TRANSPORTATION SAFETY BOARD
WASHINGTON, D.C. 20594

HAZARDOUS MATERIALS SPECIAL INVESTIGATION REPORT
CARGO TANK ROLLOVER PROTECTION

INTRODUCTION

In January 1991, the National Transportation Safety Board investigated three highway accidents in which cargo tanks overturned and released hazardous materials through damaged closures or fittings on top of the tanks; none of the cargo tank shells had been breached.[1] All three cargo tanks involved in these accidents were equipped with devices intended to provide protection for the closures and fittings on top of the tanks during rollovers. The failure of the devices to provide adequate rollover protection raised concerns about their performance and the adequacy of the minimum safety requirements applicable to the devices. To address these concerns, the Safety Board conducted a special investigation on cargo tank rollover protection.

The Safety Board investigated four additional accidents that occurred between January and May 1991 in which hazardous materials were released through damaged top fittings on cargo tanks that overturned during accidents. The seven accicents included in this special investigation are:

Location	Date	Cargo Tank	Hazardous Materials Cargo
Albuquerque, NM	01/08/91	MC 312[2]	4,900 gallons hydrochloric acid
Hamilton, OH	01/15/91	MC 306	2,100 gallons No. 2 fuel oil
Lantana, FL	01/21/91	MC 306	8,800 gallons gasoline
Ethelsville, AL	04/20/91	MC 306	7,400 gallons diesel fuel
Bronx, NY	04/22/91	MC 306	4,000 gallons gasoline
Edenton, NC	04/22/91	MC 306	7,400 gallons diesel fuel
Columbus, GA	05/02/91	MC 306	8,804 gallons gasoline

Selection criteria for the rollover accidents composing the special investigation were based on observations of damaged top fittings made during the Albuquerque accident investigation. The Safety Board included in the special investigation rollover accidents about which (a) it received notification, (b) initial information indicated that cargo was released through top fittings damaged by external impacts, and (c) evidence relevant to the location of cargo release was not destroyed by fire.

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[1] As used in this report, the term "breach" refers to a puncture, tear, or other unintentional opening.

[2] MC 306 and MC 312 are designations for tanks that are designed and built according to U.S Department of Transportation specifications. Cargo tanks with these designations are typically used for hazardous materials transported as bulk liquids.

The Safety Board attempted to determine the prevalence of rollover accidents involving bulk liquid cargo tanks and the release of cargo through damaged fittings on the top of the cargo tank. There is no existing national accident data base that can provide a direct estimate of the prevalence of cargo tank rollover accidents. However, a 1989 report[3] published by the University of Michigan Transportation Research Institute (UMTRI) estimated that 10,787 accidents occur annually that involve the rollover of a tractor-semitrailer as either the primary or subsequent accident event. According to the report, rollovers of cargo tank semitrailers transporting hazardous and nonhazardous materials account for 1,640 (15 percent) of the total, although tractor-cargo tank semitrailers are projected to account for 6 to 8 percent of the tractor-semitrailer combinations in use. The issues relating to accident data collection are discussed later in this report.

According to information provided by the Truck Trailer Manufacturers Association, the cargo tank industry estimates that 90,000 to 100,000 cargo tanks of Department of Transportation (DOT) specifications MC 306, MC 307, and MC 312 are currently in service.[4] Of this total, about 63 percent are MC 306 cargo tanks, 23 percent are MC 307, and 14 percent are MC 312.

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[3] Campbell, K. L.; Blower, D. 1989. National estimates of the number of truck travel, and accident experience of tractor semitrailers used to transport hazardous materials. UMTRI 89-1. University of Michigan Transportation Research Institute, 2901 Baxter Road, Ann Arbor, MI 48109 '50.

[4] The MC 307 specification cargo tank, although not involved in any of the accidents included in the special investigation, is part of the MC 300 series cargo tanks subject to the federal regulations discussed later in this report.

SUMMARY OF ACCIDENTS

Albuquerque, New Mexico

On January 8, 1991, about 7:50 a.m. local time, a cargo tank loaded with 4,900 gallons of hydrochloric acid[5] overturned in Albuquerque, New Mexico, as the driver attempted a left turn at the bottom of an exit ramp from Interstate 25 (I-25). The driver said that he had accelerated from about 15 to 22 mph just before the accident to avoid a collision with an automobile. The cargo tank rolled about 270° and between 3,000 and 3,900 gallons of hydrochloric acid were released through damaged fittings on top of the tank. There were no injuries or evacuations; however, I-25 and the local roadway were closed for about 7 hours to protect the public from acid vapors (fig. 1).

The cargo tank, a DOT specification MC 312 tank constructed of steel, was manufactured by Acro Trailer Company in 1981. The cargo tank was equipped with three fittings on the top of the tank: a rupture disk[6] mounted on a neck flange, a manhole assembly, and a cargo discharge valve mounted on a flange. To protect the fittings from damage during a rollover accident, square-formed steel tubing was welded to stiffening rings attached to the tank (fig. 2). The steel tubing was installed in front of the rupture disk assembly, and both in front of and behind the manhole assembly and discharge valve. The 2-inch square steel tubing was fabricated from 1/4-inch-thick steel plate. The dimensions of the steel tubing protection varied, depending on the size of adjacent fittings.

During a postaccident inspection of the cargo tank, a Safety Board investigator observed that all of the rollover protection devices (steel tubing attachments) had broken off during the accident. Additionally, the rupture disk assembly, the manhole assembly, and the discharge valve had been damaged, allowing the release of hydrochloric acid (fig. 3).

Hamilton, Ohio

On January 15, 1991, about 8:40 a.m. local time, a straight truck with a 2,100-gallon capacity cargo tank filled with fuel oil overturned in Hamilton, Ohio, after the driver lost control of the vehicle. The speed of the vehicle at the time of the accident is unknown; however, the posted speed limit was 55 mph. The driver was cited for failure to control the vehicle.

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[5] The hydrochloric acid transported was 35.2-percent solution. A 38-percent solution of hydrochloric acid is considered concentrated.

[6] A thin membrane designed to rupture when the pressure difference across the membrane exceeds a designed limit. Rupture disks are commonly used as pressure relief devices on cargo tanks that are used to transport nonflammable and nonvolatile liquids.

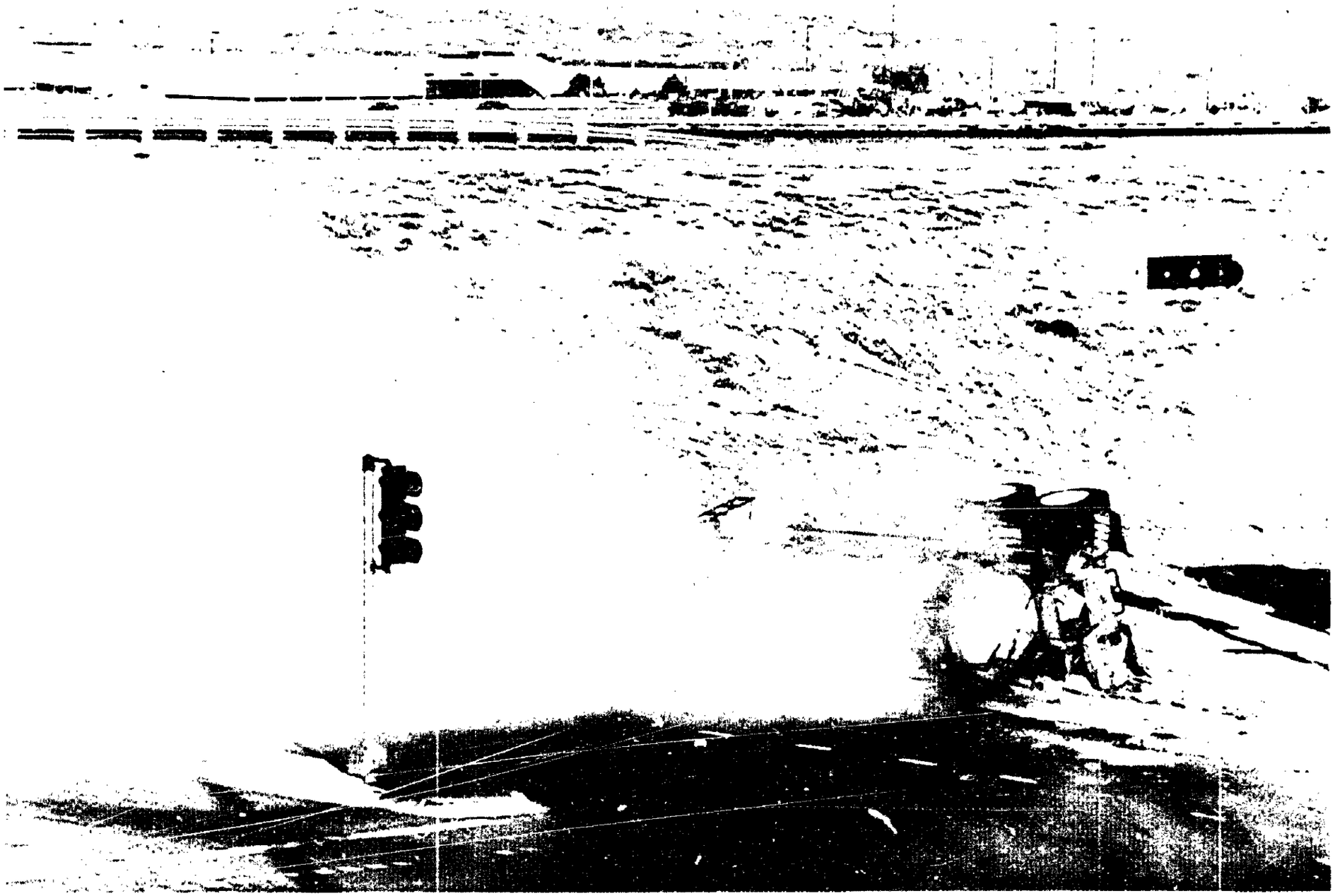

Figure 1.--Overturned tank trailer and a cloud of hydrochloric acid fumes. (Photo courtesy of the Albuquerque Journal.).

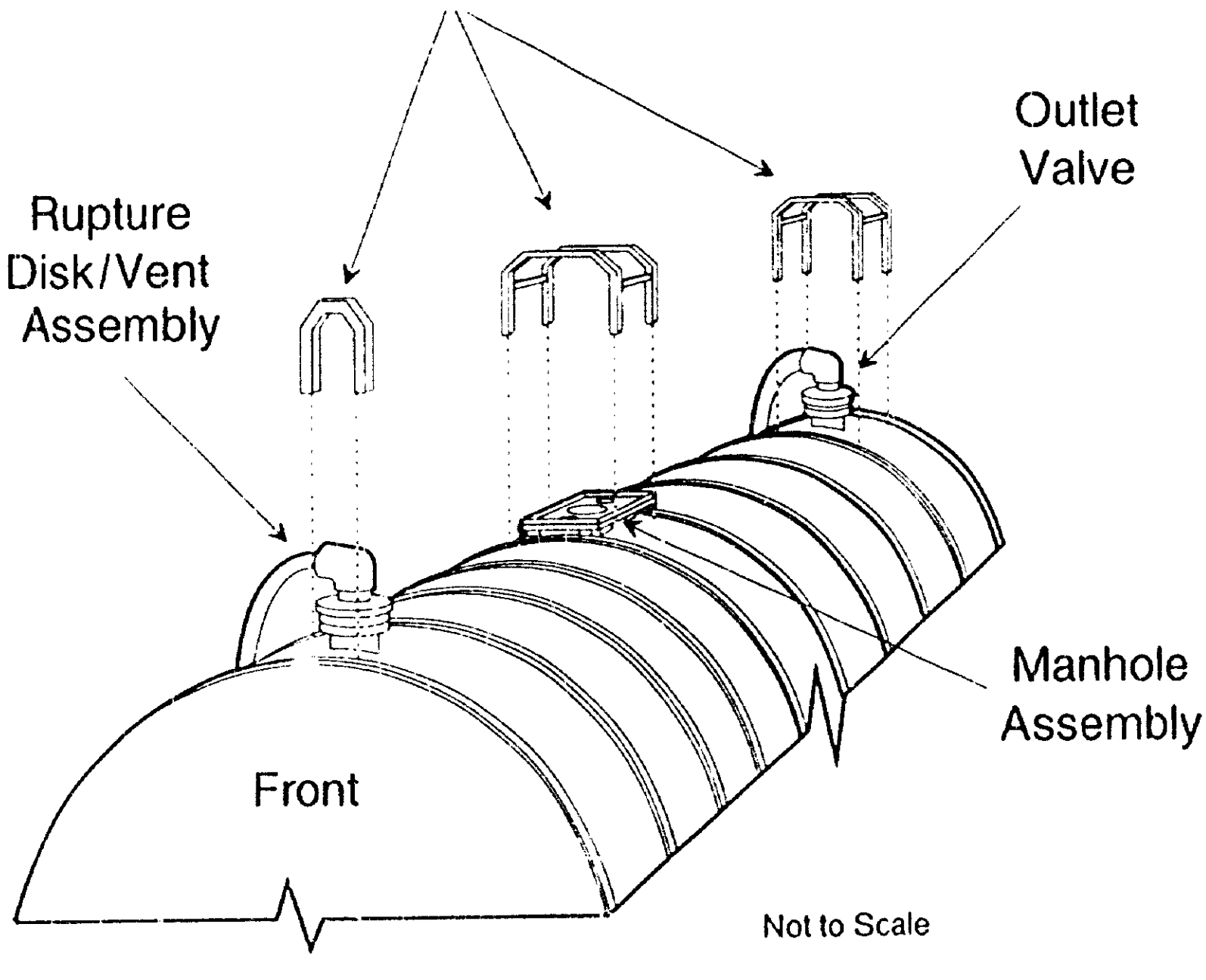

Figure 2.--Rollover protection and fittings on the MC 312 accident cargo tank (Albuquerque, NM) manufactured by Acro Trailer Company.

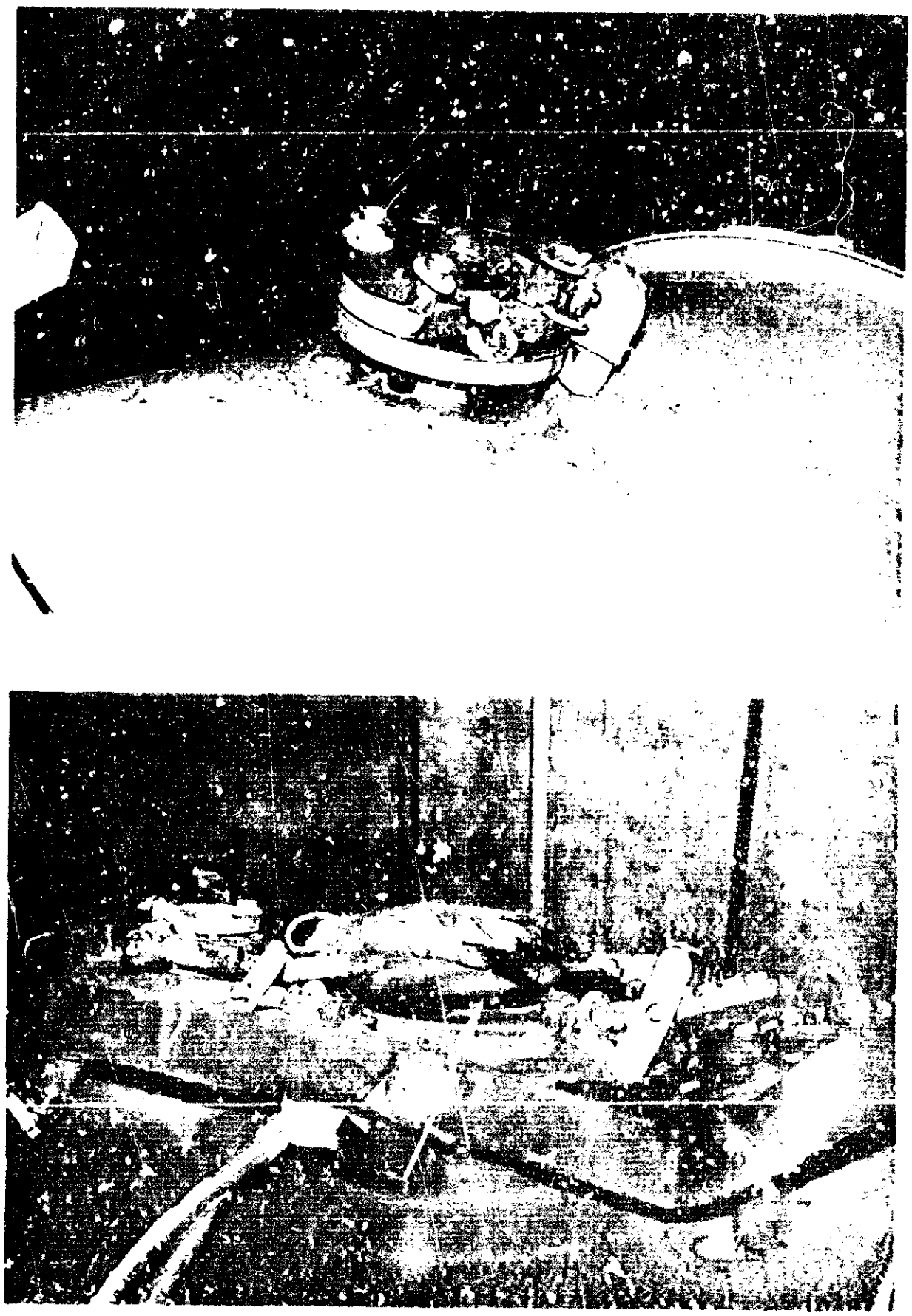

Figure 3.--Damaged top fittings (Albuquerque, NM): rupture disk (top), and manhole assembly (bottom). The arrow points to the damaged manhole cover.

The truck rotated as it slid across the opposite lane of traffic on a two-lane road and struck a highway guardrail. The vehicle then overturned as it crossed over the guardrail and an adjacent fence. The cargo tank separated from the truck and came to rest against several trees at the bottom of an 8-foot embankment. According to the carrier, about 800 gallons of fuel oil were released through two damaged manhole covers located on the top of the tank. A small fire started in the truck after fuel was released from the vehicle's fuel tank. However, the cargo tank was not involved in the fire. The driver sustained serious injuries;[7] there were no other injuries and no evacuations.

The MC 306 cargo tank, which was constructed of steel, was manufactured by Progress Industries, Inc., in 1990. The cargo tank had five compartments, and each compartment was fitted with a top manhole assembly. To protect the fittings from damage during an overturn, two 0.1046-inch-thick steel rails were formed into the sidewall of the tank and extended along the length of the cargo tank on each side (fig. 4). Each rail was reinforced and supported by five 1/4-inch-thick steel plates. There were also 0.1046-inch-thick plates crossing between these rails at each end of the cargo tank. The side rails and end plates extended about 1 1/2 inches above the top of the manhole assemblies.

A postaccident inspection of the cargo tank by the carrier disclosed that the left side of the front plate was bent toward the rear of the tank. Most of the left side rail was crushed inward toward the tank, and the right side rail between the first and second manhole covers was also bent inward. The carrier stated that the manhole covers for compartments 2 and 3 were damaged and opened, resulting in the release of the cargo (fig. 5).

Lantana, Florida

On January 21, 1991, about 2:30 a.m. local time, a cargo tank loaded with 8,800 gallons of gasoline overturned on I-95 in Lantana, Florida, after the vehicle left the right side of the roadway. According to the Florida Highway Patrol, the speed of the tractor-cargo tank semitrailer was about 55 mph at the time of the accident. The cargo tank rolled onto its right side, struck a guardrail, and slid to a stop coming to rest upside down. About 4,000 gallons of gasoline were released through damaged fittings on top of the tank. There were no reported injuries, fires, or evacuations. The northbound lanes of I-95, however, were closed periodically for 12 hours, during emergency response and cleanup operations.

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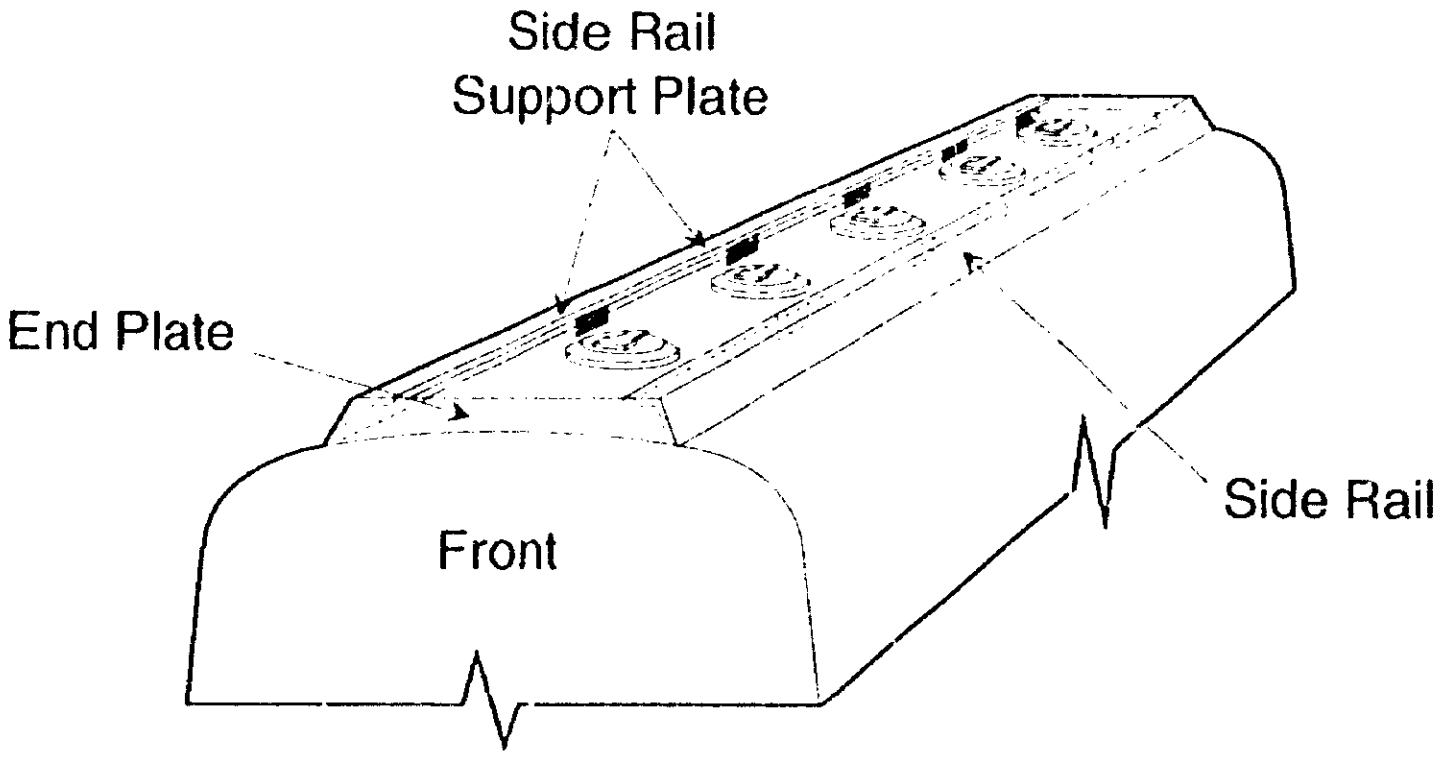
[7] Serious injuries are injuries that (1) require hospitalization for more than 48 hours; (2) result in a fracture of any bone (except simple fractures of the fingers, toes, or nose); (3) cause severe hemorrhages, nerve, muscle or tendon damage; (4) involve any internal organ; or (5) involve second- or third-degree burns, or any burns affecting more than 5 percent of the body. (See 49 CFR 830.2).



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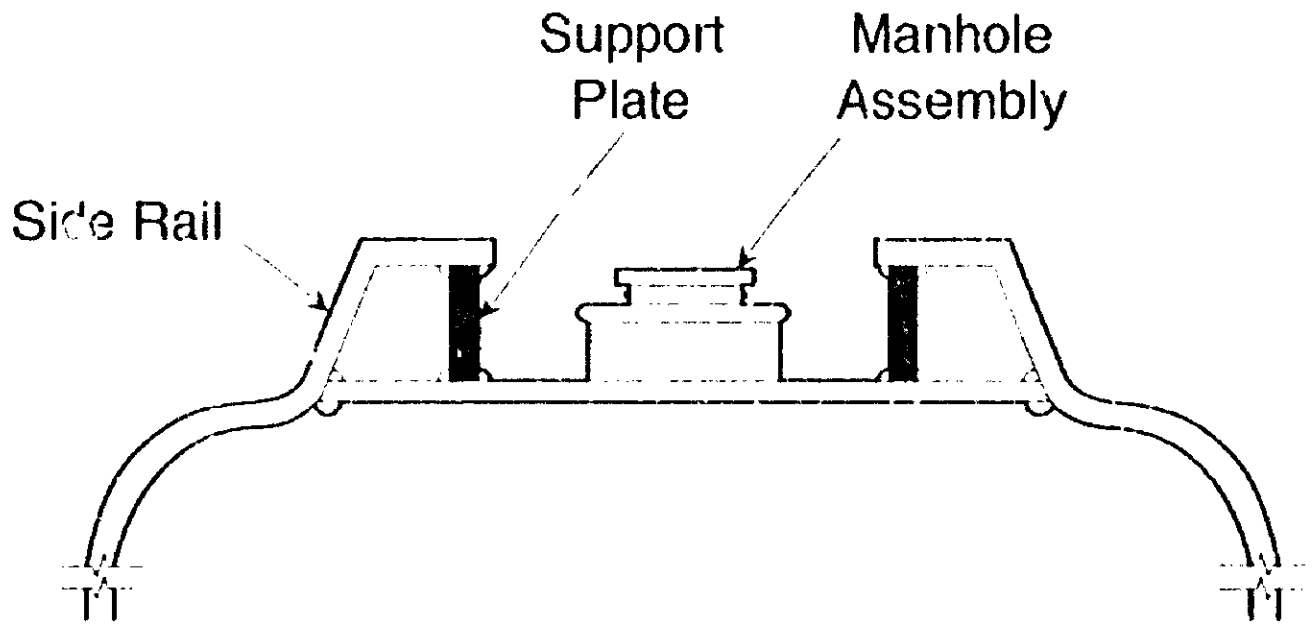


Figure 4.--Rollover protection and fittings on the MC 306 accident cargo tank (Hamilton, OH) manufactured by Progress Industries, Inc.: general configuration (top), and end view cross section (bottom).

Figure 5.--Damaged rollover protection rails (A) and front plate (B) (Hamilton, OH).

The aluminum MC 306 cargo tank was manufactured by Fruehauf Corporation in 1983. The cargo tank was equipped with five compartments, and a manhole was installed in the top of each compartment. Each manhole was equipped with a steel plate manhole cover, and each manhole cover held three fittings: a dome lid, a vapor vent, and a loading probe (fig. 6).

Two 8-inch-high extruded aluminum rails were welded to the top of the cargo tank shell to protect top fittings from damage during a rollover accident. The inverted V-shaped rails were 5/32 to 5/32 inch thick and ran the entire length of the cargo tank. Aluminum plates, 8/32-inch-thick, crossed between the rails at the each end of the cargo tank (fig. 7). These side rails and end plates extended 1 1/4 inches above the dome lids, 1 1/2 inches above the loading probes, and 2 1/4 inches above the vapor vent. The rubber cover for the vapor vent was 1 1/4 inches higher than the side rails and end plates; however, dislodgement of the cover would not cause a release of cargo. During a postaccident inspection of the cargo tank, a Safety Board investigator documented the damage to the rollover protection rails and to the top fittings. The rear half of the right side rail was damaged; the most severe damage occurred between the fourth and fifth compartments. The rail at this location was split at the top of the inverted V, bent toward the centerline of the tank, and compressed down about 1 1/4 inches; however, the rail was not bent below the top of the tallest fitting. The dome lid on the second compartment was distorted and fractured. This dome lid was open and would not reseat on the manway cover. All other dome lids were closed. Additionally, two aluminum loading probes on two manway covers displayed evidence of external strikes and were dislodged from their respective manway covers. A third loading probe was also dislodged but was not located. Each dislodged probe left a 2 1/4-inch-diameter opening through the manhole cover to the cargo compartment (fig. 8). Metallurgical examination of the two recovered probes and the damaged manway cover also determined that a zinc residue from the smears found on the damaged areas of the probes and the manway cover was consistent with a zinc-coated object striking the probes and the manway cover. The highway guardrails at this location were zinc-coated.

Ethelsville, Alabama

On April 20, 1991, about 8:40 a.m. local time, a cargo tank loaded with 7,400 gallons of diesel fuel overturned in Ethelsville, Alabama, after a collision with a pickup truck that had crossed the center line on Highway 82. The Alabama Department of Public Safety estimated the speed of the tractor-semitrailer at 45 mph and the speed of the pickup truck at 55 mph prior to the accident. After impact, the tractor-semitrailer swerved left across the highway, rolled at least one full revolution as it went down an embankment, and came to rest upside down. About 3,509 gallons of diesel fuel were released through a manhole cover that had opened on top of the tank as a result of the accident. The driver of the pickup truck suffered fatal injuries from the collision, and a passenger sustained serious injuries. The driver of the tractor-semitrailer sustained minor injuries. There were no fires or evacuations.

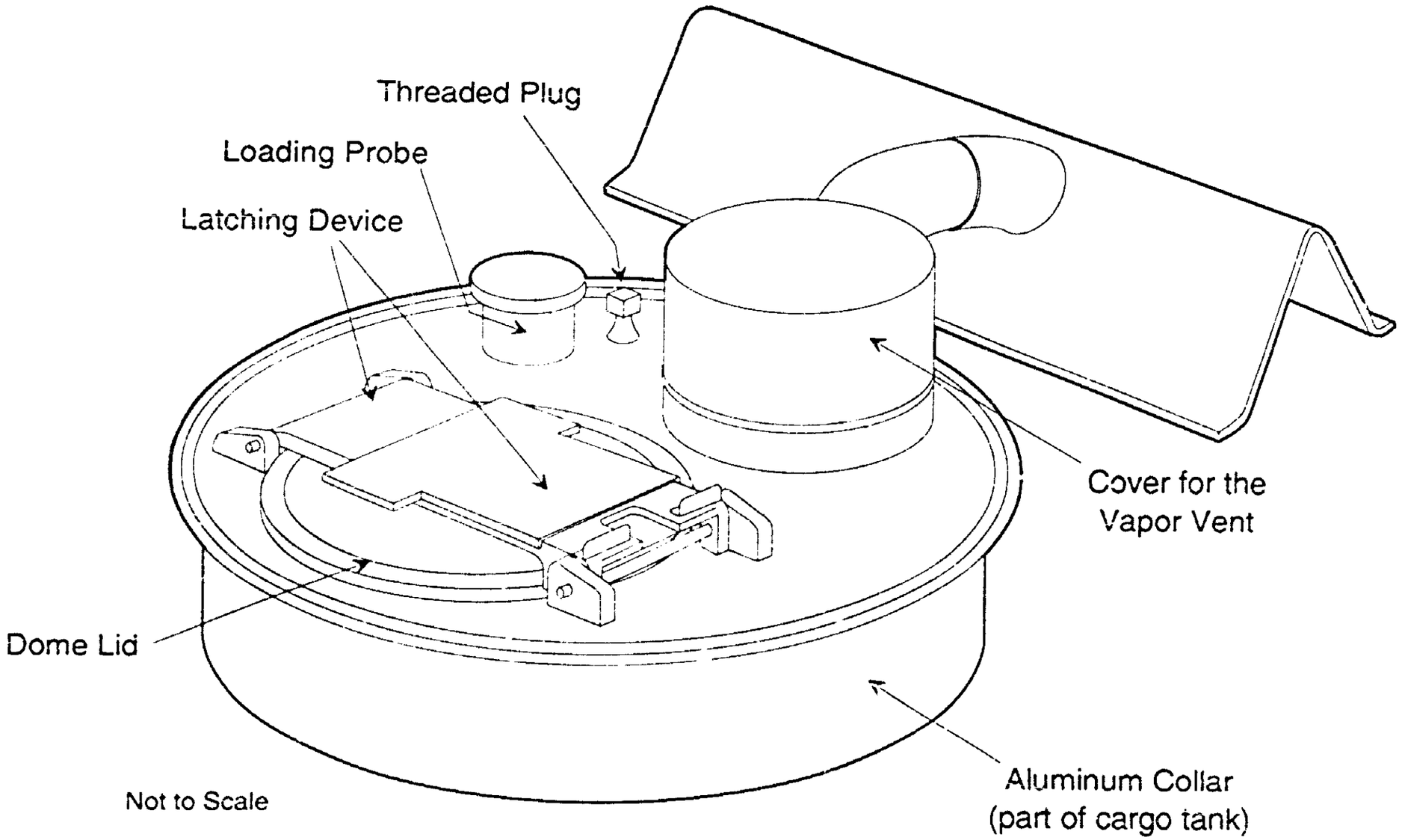
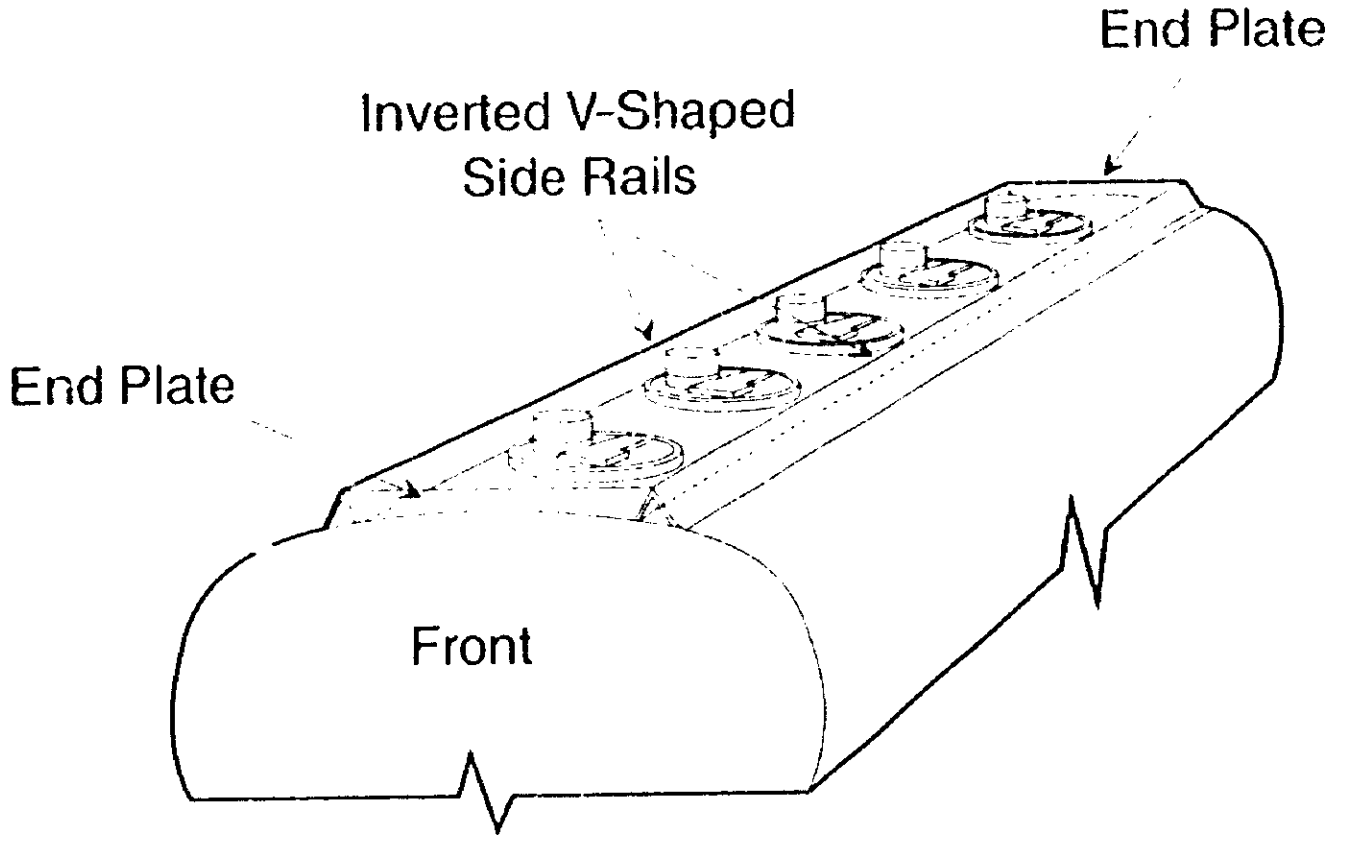


Figure 6.--Manhole assembly on the MC 306 accident cargo tank (Lantana, FL) manufactured by Fruehauf Corporation.



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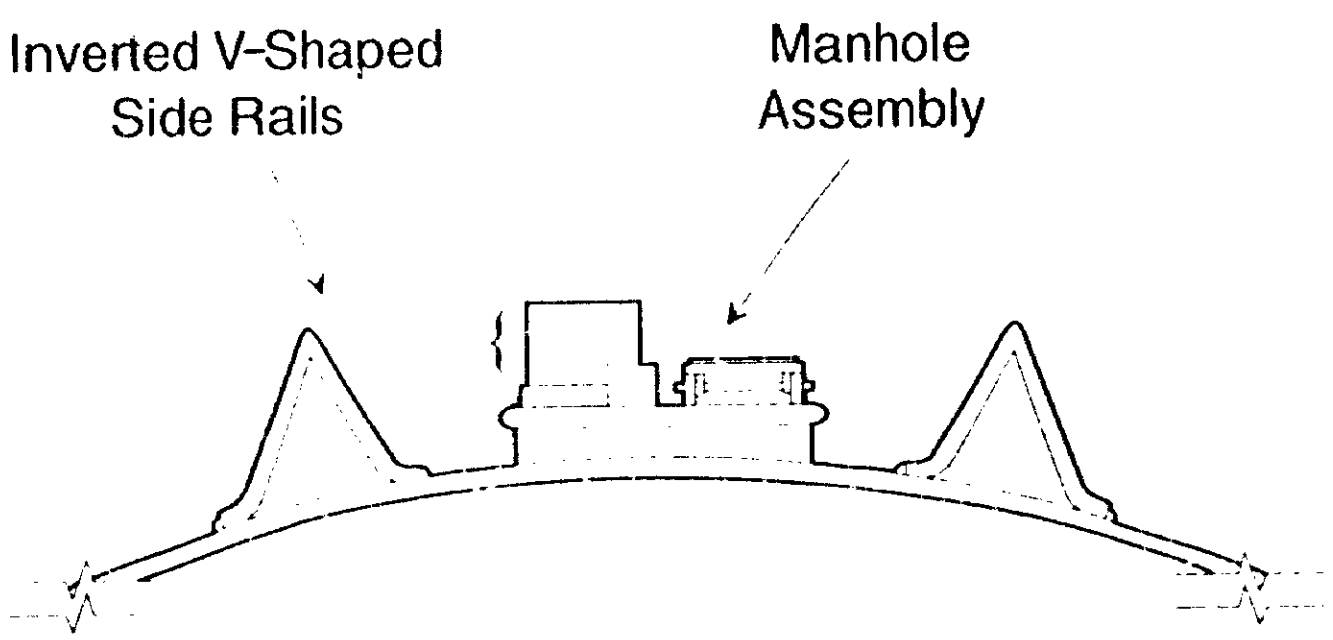

Figure 7.--Rollover protection and representative fittings on the MC 306 cargo tanks manufactured by Fruehauf Corporation and the Heil Company: general configuration (top) and end view cross section (bottom). The tube extending from the cover for the vapor vent (brace) to the side rail is not shown; the tube is depicted in figure 6.

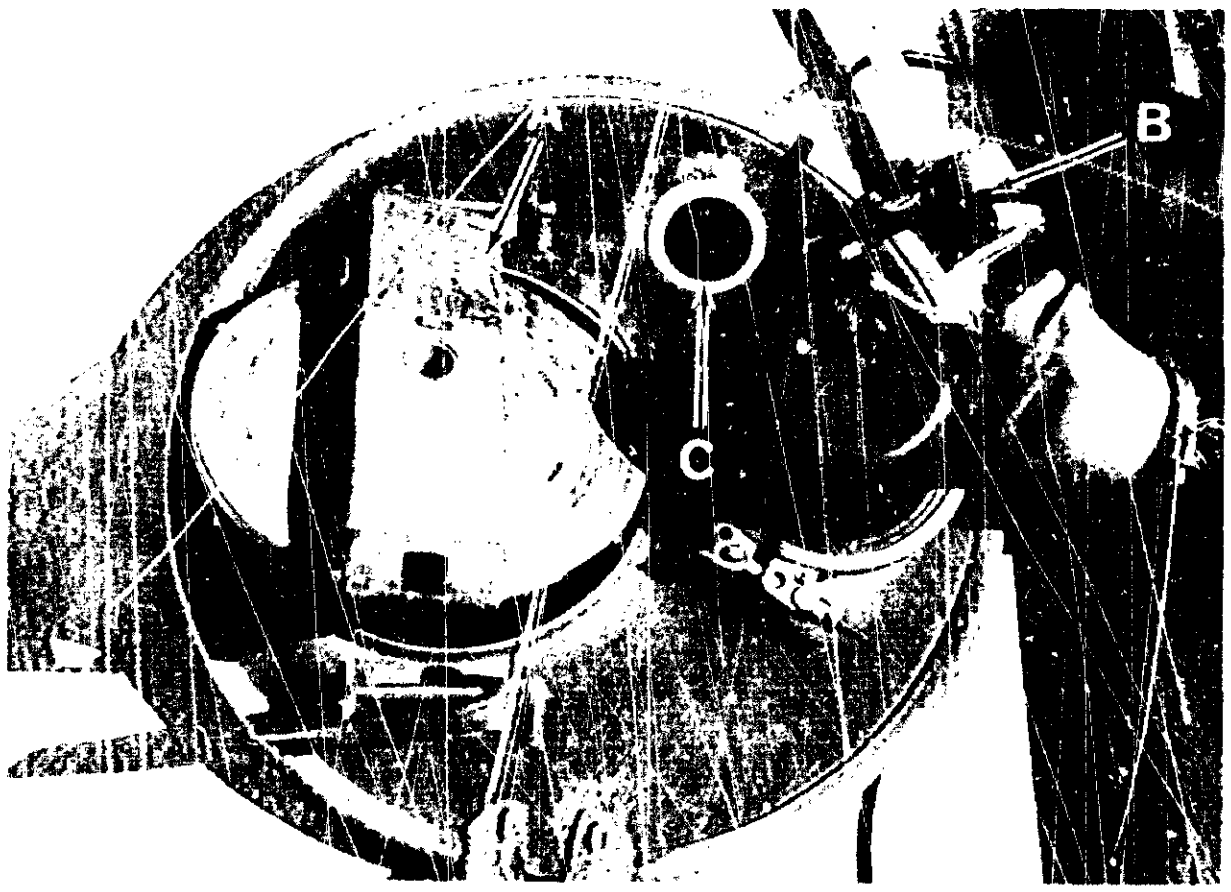

Figure 8.--Damaged manhole assembly on the second compartment (Lantana, FL): distorted and fractured dome lid (A), dislodged loading probe (B), and opening for the loading probe (C).

The aluminum MC 306 cargo tank was manufactured by Fruehauf Corporation in 1985. The cargo tank was equipped with four compartments, and the top of each compartment was equipped with a manhole assembly. Each manhole assembly was fitted with a dome lid, a vapor recovery valve, and a loading probe. Rollover protection for the fittings on the top of the cargo tank consisted of aluminum inverted V-shaped rails and end plates. The side rails and end plates extended 1 inch above the height of manhole covers on this tank.

A postaccident inspection of the cargo tank by the carrier disclosed that the rear quarter of the right side 8-inch-high rail was crushed almost flat against the tank shell, and the left side rail was bent almost 6 inches to the right (fig. 9). The top of the cargo tank was covered with dirt and grass, and the dome lid for the rear compartment was found in the open position. Examination of the latching mechanism for the dome lid revealed that the lid was held in place by overlapping hinged latches. The top latch has a flat, shovel-like area that acts as a handle to permit an operator to lift the top latch to open the dome lid (fig. 10).

Bronx, New York

On April 22, 1991, about 4:07 a.m. local time, the driver of a straight truck fitted with a cargo tank containing about 4,000 gallons of gasoline lost control of the truck on wet pavement and at an undetermined speed after the vehicle crossed the Bronx-Whitestone Bridge in Bronx, New York. As the vehicle approached the toll booths at the end of the bridge, the driver applied the brakes and the truck spun around 360°. The vehicle then overturned and the cargo tank separated from the truck. The cargo tank slid toward the toll booths and into a concrete retaining wall. A concrete curb, installed to separate lanes of traffic at the toll booths, was located along the path that the cargo tank slid. The front manhole cover separated from the tank; gasoline was released and ignited. All 4,000 gallons of gasoline were consumed in the fire, which spread through storm drains up to 1/2 mile away from the accident site. The fire burned for about 4 1/2 hours and the roadway was closed for about 7 hours. The driver sustained minor injuries; there were no other injuries or evacuations.

The steel MC 306 cargo tank was manufactured by Bomar Tank Discharge Systems, Inc., in 1984. The cargo tank was constructed with five compartments, each equipped with five fittings on the top of the tank: a manhole assembly, an adapter for a fill line, two vents, and a connection for the control rod to the internal emergency shut-off valve located at the bottom of the compartment. To protect these fittings from damage during a rollover accident, four curved transverse 3/16-inch-thick steel plates had been welded, evenly spaced, along the top of the tank. The plates were about 3 1/4 inches higher than the manhole cover, but less than 3/4 inch higher than the adapter for the fill line. The plates were joined to two side rails that ran the length of the tank; the primary function of these side rails was to contain cargo spilled during transfer operations. The side rails were 1 inch below the top of the manhole covers and 4 inches below the top of the loading adapter fitting (figs. 11 and 12).

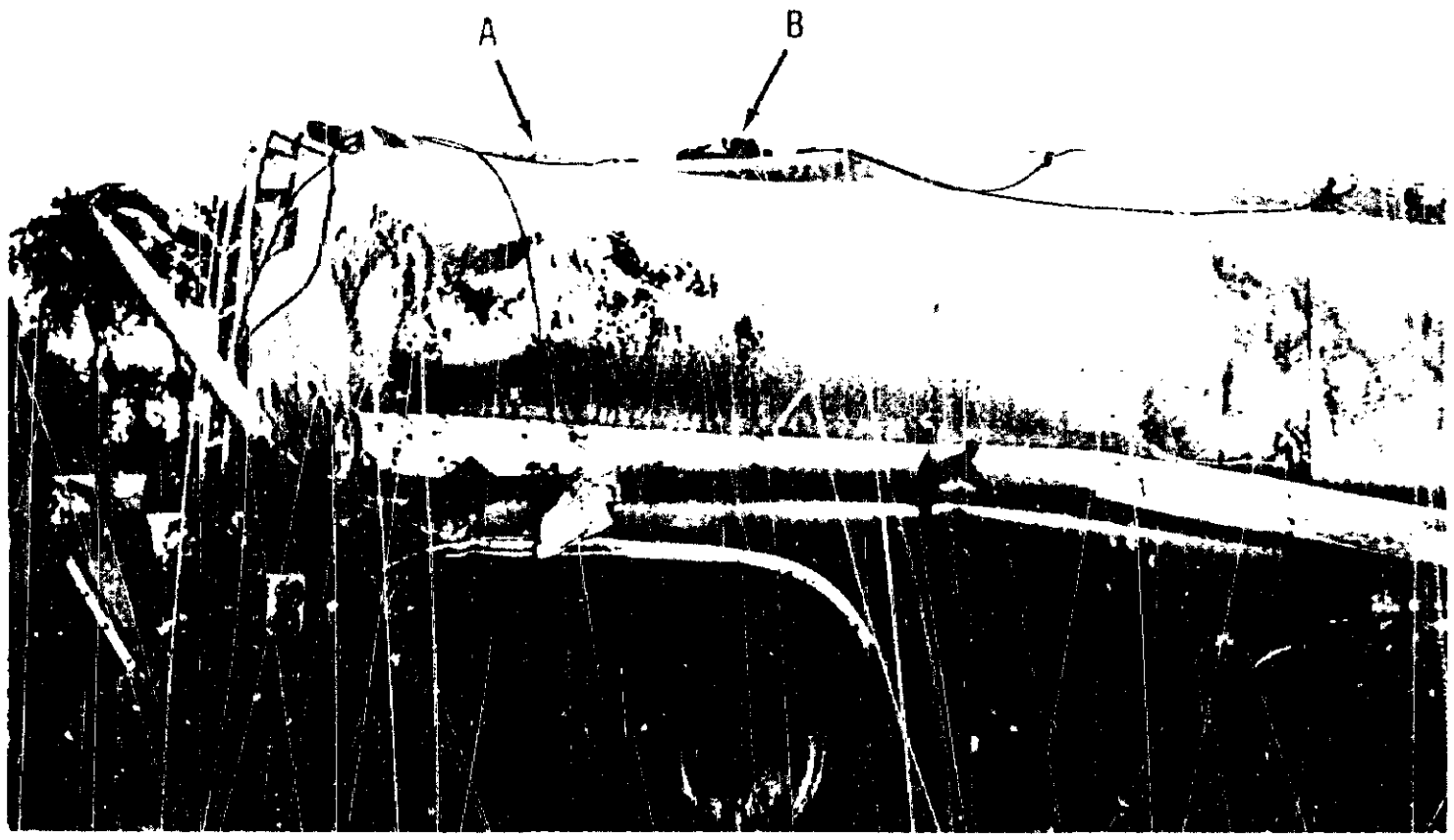

Figure 9.--Partially crushed rollover protection rail (A) and the rear dome lid (B) on the MC 306 accident cargo tank (Ethelsville, AL) manufactured by Fruehauf Corporation.

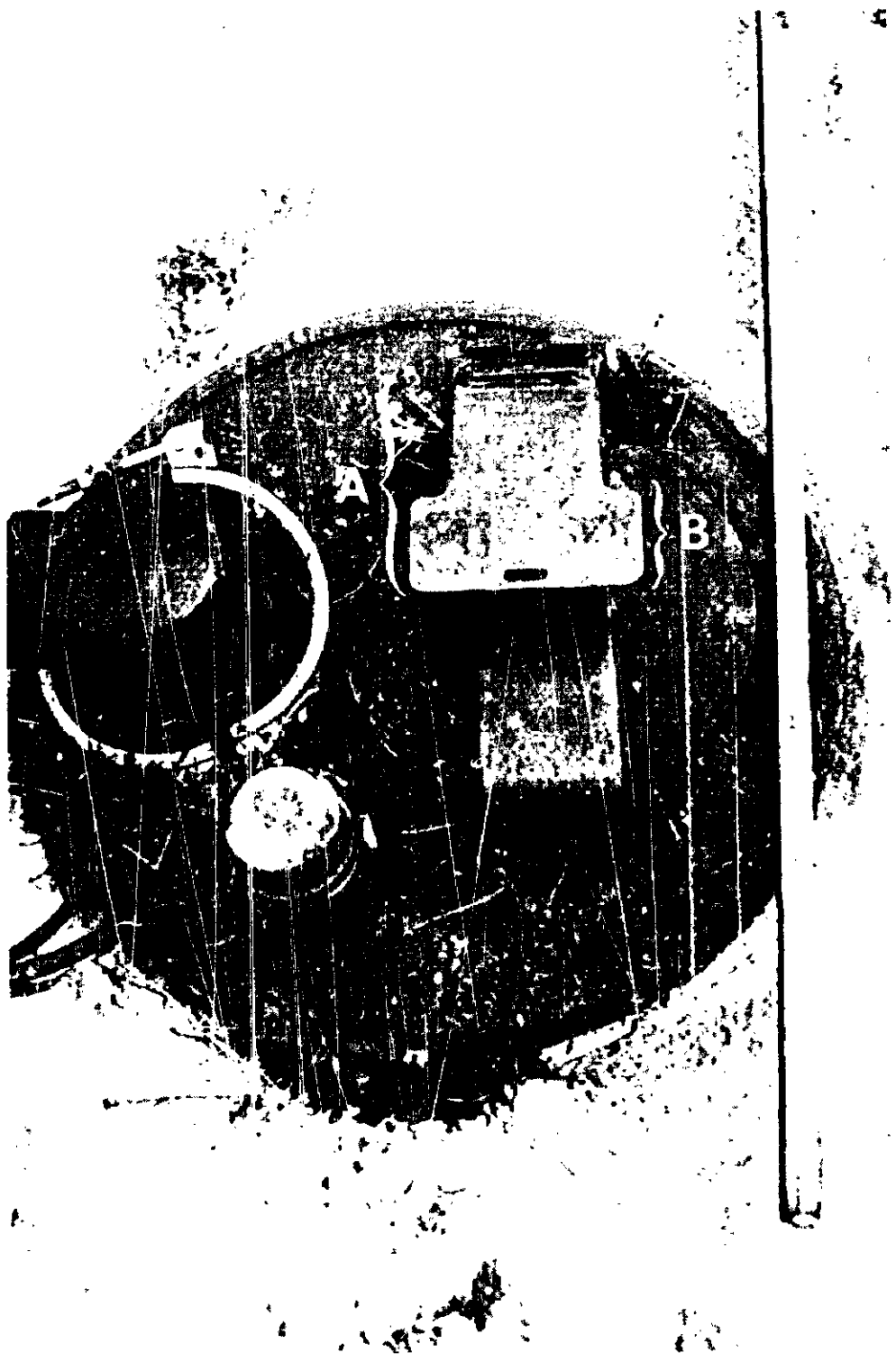

Figure 10.--Grass and dirt around fittings on the manhole assembly, and the slightly bent top arm of the latching mechanism of the dome lid (A). The shovel-like area on the top arm (B) points toward the front of the cargo tank (Ethelsville, AL).

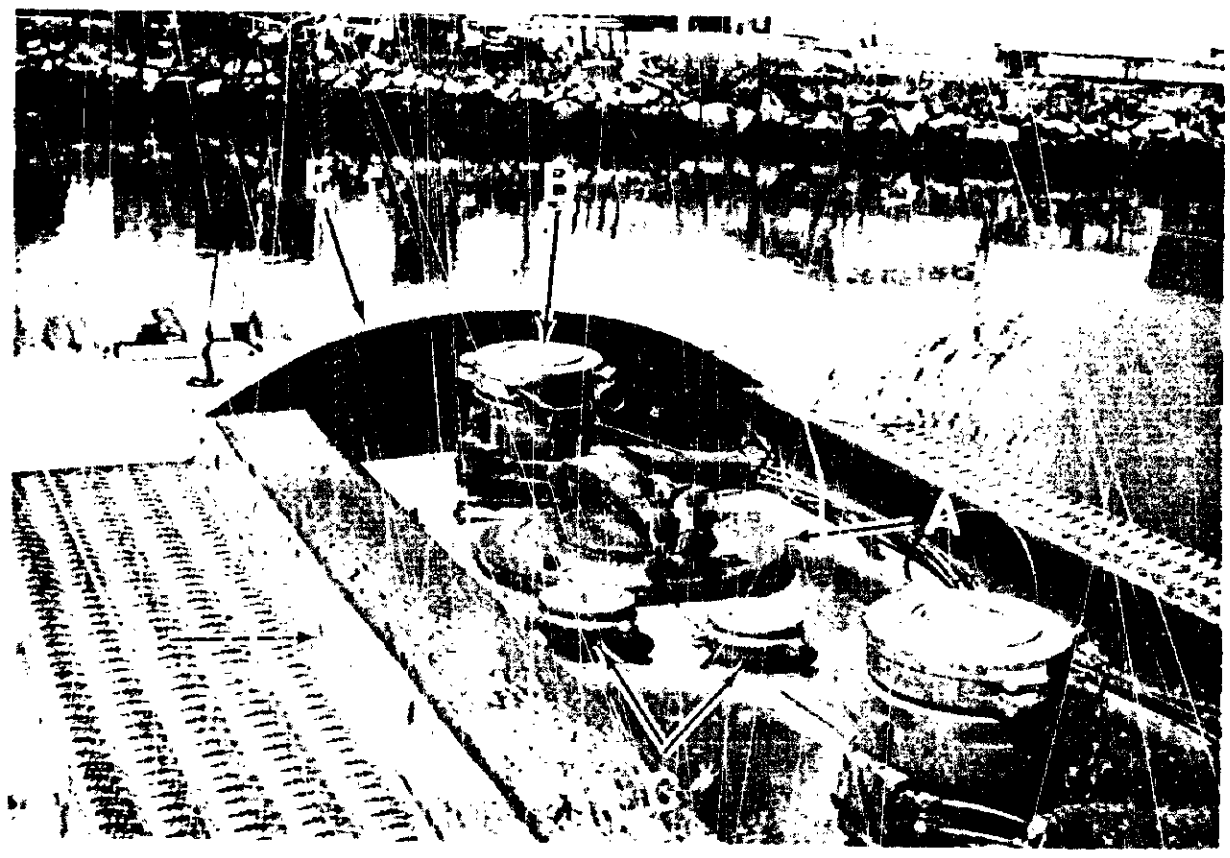

Figure 11.--Rollover protection and fittings for the forward compartment on an MC 306 cargo tank comparable to the accident cargo tank (Bronx, NY) manufactured by Bomar Tank Discharge Systems, Inc.: manhole assembly (A), fill adapter (B), vents (C), side rail (D) and transverse rollover plate (E). A control rod connection for the internal emergency shut-off valve is obscured by the fill adapter of the next compartment.

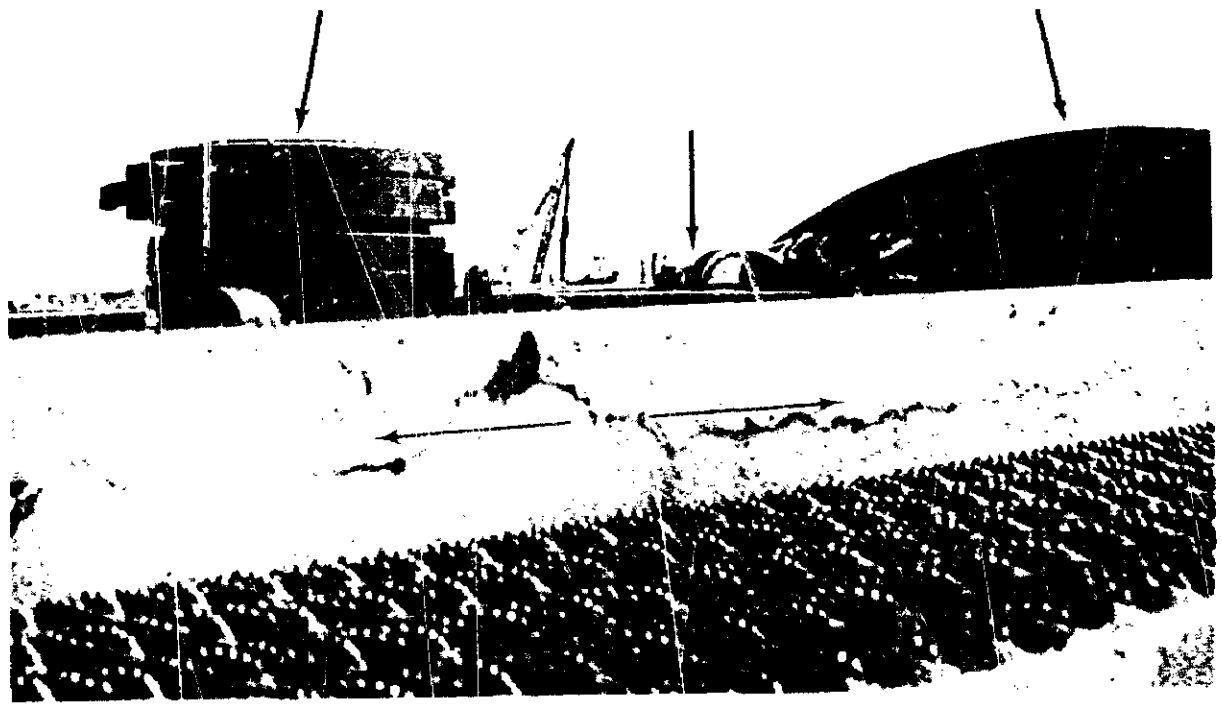

Figure 12.--The fill adapter (A) and manhole cover (B) above the side rail (C) on the accident cargo tank (Bronx, NY). The height of the transverse rollover plate (D) extends 3/4 inch above the fill adapter.

During a postaccident inspection of the cargo tank, a Safety Board investigator observed little damage to the curved rollover protection plates. However, the right side rail was bent inward toward the center of the tank at the forward manhole opening, and the manhole cover for that opening was missing (fig. 13). No other fittings were missing from the top of the tank.

Edenton, North Carolina

On April 22, 1991, about 5:15 a.m. local time, a cargo tank loaded with 7,400 gallons of diesel fuel overturned in Edenton, North Carolina, after crossing the opposite lane and going off the left side of Highway 32. The North Carolina Highway Patrol traffic accident report states that the driver fell asleep and the vehicle left the highway at an estimated speed of 55 mph. The cargo tank rolled onto its left side and came to rest in a large ditch with the top of the cargo tank against a dirt embankment. According to the carrier, about 6,000 gallons of diesel fuel were released through three open manhole covers on the top of the tank. The driver sustained serious injuries, and there were no fires or evacuations.

The aluminum MC 306 cargo tank was manufactured by The Heil Company in 1985. The cargo tank was constructed with five compartments, and each compartment was equipped with three fittings: a dome lid, a vapor recovery valve, and a loading probe. To protect the fittings in a rollover accident, inverted aluminum V-shaped side rails and end plates were welded to the top of the tank, similar to the design used on the Fruehauf cargo tanks (Lantana, FL; Ethelsville, AL; and Columbus, GA). The side rails and end plates extended about 3 inches above the height of manhole covers.

During a postaccident inspection of the cargo tank, the carrier found relatively minor damage to the rollover protection rails and end plates. However, the carrier found that the top of the cargo tank was covered with dirt and grass, and three of the five dome lids opened during the accident. The dome lids had latching mechanisms similar to those installed on the Fruehauf cargo tanks involved in the accidents in Lantana, Florida, and Ethelsville, Alabama. Each dome lid was held in place by two overlapping hinged latches. The top latch had a flat shovel-like area to permit an operator to lift the top latch and to open the dome lid. Dirt and grass were found wedged under the top latch of an unspecified number of the dome lids (fig. 14).

Columbus, Georgia

On May 2, 1991, about 8:30 p.m. local time, a cargo tank loaded with 8,804 gallons of gasoline overturned in Columbus, Georgia, on a ramp from the Columbus/Manchester Expressway to I-185. A tachograph mounted on the tractor indicated that the vehicle was decelerating rapidly from 36 to 29 mph immediately before the overturn. The cargo tank overturned onto a grassy area on the outside of the curve and rolled about 270°. The shipper/carrier estimated that 3,886 gallons of gasoline were released through partially

Figure 13.--The open manhole (A) for the forward compartment and the dented right side rail (B) looking forward from the accident cargo tank (Bronx, NY).

Figure 14.--Grass and dirt around fittings on the manhole assembly on the accident cargo tank (Edenton, NC). The shovel like area (arrow) on the top arm of the latching mechanism of the dome lid points toward the front of the cargo tank. (The horizontal board is used for measuring heights of top fittings.)

opened manhole covers on the top of the tank. The driver sustained serious injuries. Although there were no fires or evacuations, the entrance ramp and the southbound lanes of I-185 were closed for several hours during the cargo recovery process.

The aluminum MC 306 cargo tank was manufactured by Fruehauf Corporation in 1979. The cargo tank was equipped with a top-mounted manhole cover with a dome lid manufactured by CB Corporation, a loading probe, and a vapor recovery valve assembly for each of the tank's five compartments. To provide rollover protection for these fittings, the cargo tank had inverted aluminum V-shaped side rails running the length of the tank and aluminum plates at each end, like those on the Fruehauf cargo tanks involved in the accidents in Lantana, Florida, and Ethelsville, Alabama. The side rails on the tank extended about 1 1/4 inch above the top of the manhole covers.

During a postaccident inspection of the cargo tank, a Safety Board investigator observed little damage to the rollover protection rails, although the front metal plate was bent rearward. The carrier stated that four of the five manhole dome lids were open after the accident. The dome lids, which are designed to lift and automatically reseat to relieve an internal pressure surge, can be mechanically prevented from reseating by rotation of the locking mechanism for the dome lid (fig. 15). Scrape marks were observed on two of the five dome lid closure assemblies. The orientation of the scrape marks was consistent with an impact that could cause a rotating force on the dome lids. Dirt and grass were also wedged between an electrical box and the inside of the rollover protection rail near the third and fourth compartments (fig. 16).

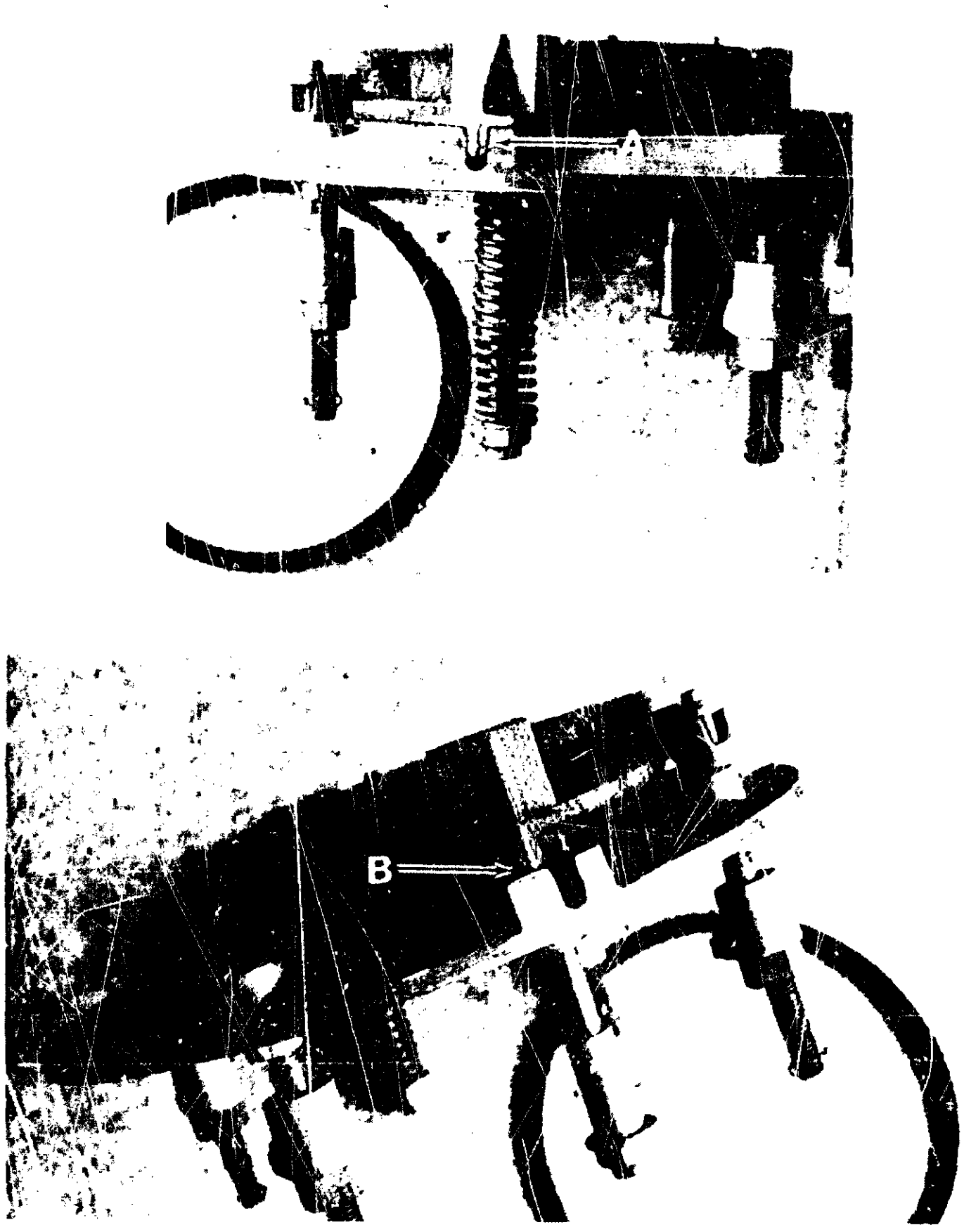

Figure 15.--Dome lid manufactured by CB Corporation representative of the lids on the accident cargo tank (Columbus, GA): spring-loaded locking mechanism seated to the closed position (A), and mechanism prevented from seating to the closed position (B). (The spring has been removed for demonstration).

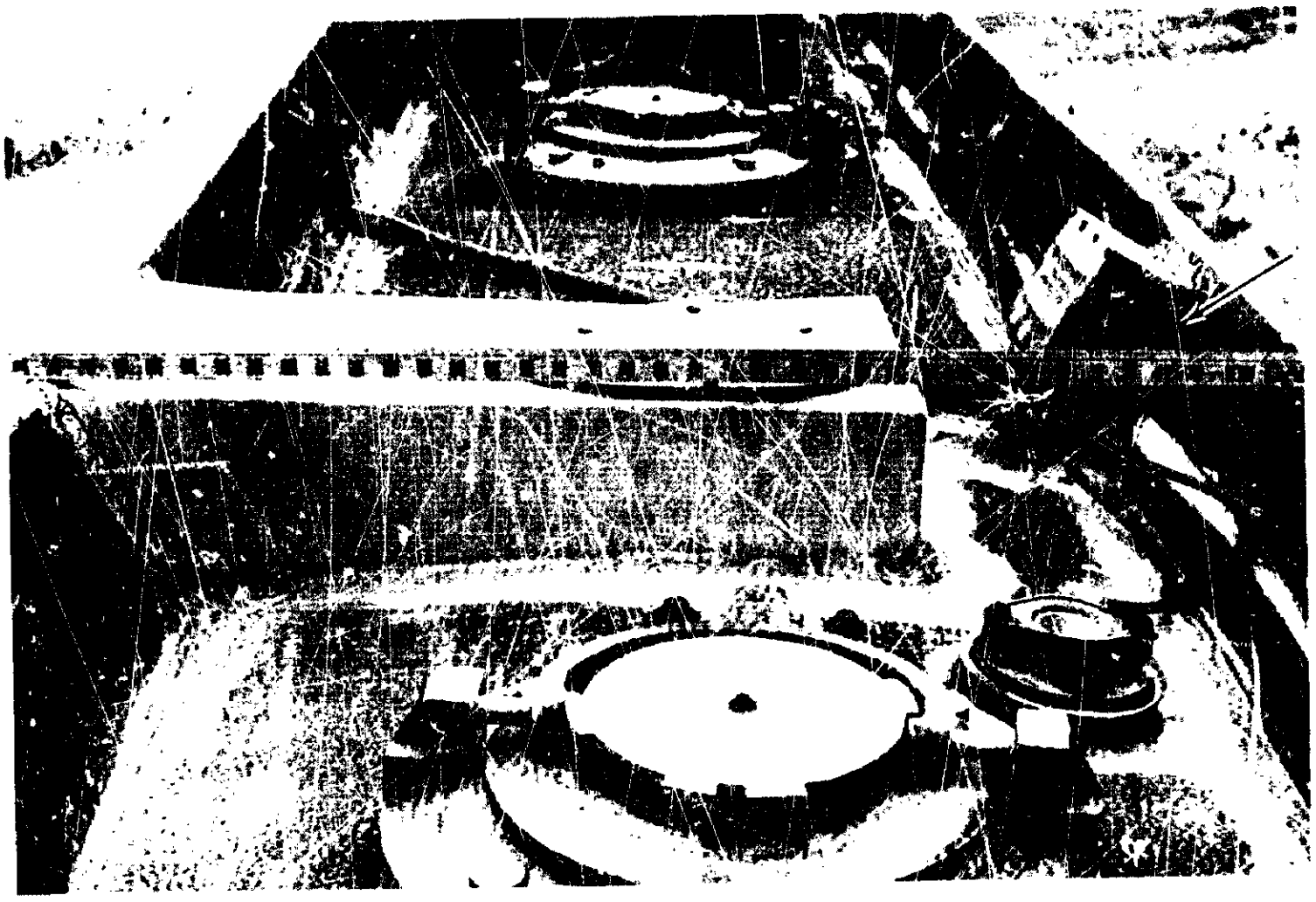

Figure 16.--Grass and dirt wedged between an electrical box and the rollover protection rail (Columbus, GA).

FEDERAL REGULATIONS FOR ROLLOVER PROTECTION

General

With the creation of the Department of Transportation (DOT) in 1966, the Federal Highway Administration (FHWA), an agency within the DOT, became responsible for issuing and enforcing safety regulations for cargo tanks that transport hazardous materials. The FHWA continued to have exclusive responsibility for cargo tank safety until July 1975, when the Secretary of Transportation created the Materials Transportation Bureau (MTB) and designated it as the lead agency for the DOT's hazardous materials transportation safety program. The MTB no longer exists, and its responsibilities have been given to the Research and Special Programs Administration (RSPA) within the DOT. While the MTB was given responsibility for issuing all regulations affecting the transportation of hazardous materials, the responsibility for developing and enforcing regulations applicable to a single mode of transportation was left with the appropriate DOT modal administration, such as the FHWA.

All of the cargo tanks that were involved in the previously summarized accidents were constructed between 1979 and 1991. The applicable DOT design requirements for these tanks and all other specification MC 306, MC 307, and MC 312 bulk liquid cargo tanks were contained in Title 49, Code of Federal Regulations (49 CFR), Sections 178.340 through 178.343. These requirements became effective in 1967.

In June 1989, the RSPA issued comprehensive amendments to the regulations for the design and manufacture of all DOT specification bulk liquid cargo tanks.[8] The amendments included more stringent requirements pertaining to the design, construction, certification, and testing of the cargo tanks, manholes, closure valves, pressure relief devices, and devices for accident damage protection. Because of these extensive changes, cargo tanks constructed under the new regulations given in 49 CFR 178.345 to 178.348 will be designated as specification DOT 406, DOT 407, and DOT 412 cargo tanks, and will supersede the existing MC 306, MC 307, and MC 312 cargo tanks.

The new regulations were scheduled to become effective on December 12, 1989; however, in response to many petitions for reconsideration, the RSPA postponed the effective date of the new regulations and published additional amendments in September 1990.[9] Under the 1990 amendments, the effective date of the 1989 changes and all subsequent amendments became December 31, 1990. Under the September 1990 amendments, the RSPA also authorized a transition period between December 31, 1990, and August 31, 1993, during which new MC 306, MC 307, and MC 312 cargo tanks may continue to be constructed under the provisions of 49 CFR 178.340 through 178.343 that were

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

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

in effect prior to December 31, 1990. After this transition period, all new bulk liquid cargo tanks must be constructed in accordance with the provisions of 49 CFR 178.345 to 178.348.

Rollover Protection

Requirements for accident damage protection, including rollover damage protection for top-mounted closures and fittings, were included under 49 CFR 178.340-8 for specification MC 306, MC 307, and MC 312 cargo tanks. Comparable requirements for the newly designated DOT 406, DOT 407, and DOT 412 cargo tanks are included in 49 CFR 178.345-8.

According to the provisions of 49 CFR 178.340-8(c), all closures for filling, manhole, or inspection openings "shall be protected from damage which will result in leakage of lading in the event of overturning of the vehicle." The regulations authorized cargo tank manufacturers three options to comply with this performance standard: (1) enclose or recess the fittings within the body of the tank; (2) enclose the fittings within a dome that is attached to the tank; or (3) enclose the fittings with guards that are attached to the tank. The regulations further required that if guards were used as rollover protection, they were to be designed and installed to withstand a vertical load of twice the weight of the loaded tank and a horizontal load in any direction equivalent to one-half the weight of the loaded tank. If more than one guard was used, each guard was to carry its proportionate share of the load.

All seven of the cargo tanks involved in the accidents addressed in this report were configured with rollover protection devices attached to the tank rather than with recessed fittings or domes that enclosed the fittings. According to a representative of the Fruehauf Corporation, industry use of recessed fittings and domes was not common for the construction of MC 306, MC 307, and MC 312 cargo tanks.

The 1989 and 1990 amendments also included new design requirements for rollover protection for specification DOT 406, 407, and 412 cargo tanks. According to the general requirements in 49 CFR 178.345-8(a) for accident protection devices, including rollover protection devices, each cargo tank must be designed and constructed to "minimize the potential for the loss of lading due to an accident." Under 49 CFR 178.345-8(a)(3), accident damage protection devices such as rollover protection devices must be designed, constructed, and installed as to maximize the distribution of loads on the tank wall. This section further limits the stresses that can be generated on the wall of the cargo tank when the cargo tank is at its maximum allowable working pressure,[10] and when any accident damage protection device is being subjected to the horizontal and vertical loads addressed by the regulations.

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[10] Maximum allowable working pressure is a design parameter of the cargo tank, and is based on the maximum internal pressure likely to be generated by the commodities carried, or that will occur during the loading and offloading of the tank.

Under 49 CFR 178.345-8(c), rollover protection must be provided for each closure fitting located in the upper two-thirds of the circumference of the cargo tank. The regulations permit one of three configurations to protect these fittings: (1) enclosure or recess of the fitting within the body of the cargo tank; (2) enclosure of the fittings within a rollover damage protection device, or (3) use of a fitting that is 125 percent as strong as the otherwise-required damage protection device.

The regulations in 49 CFR 178.345-8(c)(1) further require that a damage protection device be designed and installed to withstand "a load normal (perpendicular to the tank surface) and tangential from any direction (perpendicular to the normal load) to the tank shell[11] equal to at least twice the weight of the loaded cargo tank motor vehicle."[12] If more than one rollover device is used, each device must be capable of carrying its proportionate share of the required loads, and at least one-fourth of the required total tangential load. Deformation of the protection device is acceptable if the fittings are not damaged. Under these new standards for the DOT 400 series tanks, the tangential loading standard is 4 times that for the MC 300 series tanks. Also, normal and tangential design loads for the DOT 400 series tanks are based on the weight of the loaded cargo tank motor vehicle rather than just the weight of the loaded cargo tank, as previously required for the MC 300 series cargo tanks.

Engineers at the RSPA verbally indicated that the RSPA expects cargo tank manufacturers, as a minimum, to perform "straightforward" stress calculations to determine if rollover protection guards meet the design loads required by the DOT performance standards and that the RSPA does not oppose the use of techniques such as finite element analysis to evaluate cargo tank design.

The RSPA has no written guidance about or interpretations of the factors and assumptions that must be considered for the design of rollover protection devices. Further, the FHWA and the RSPA have not issued any guidance r interpretations that address other details about the design of the guards, such as minimum clearances between the height of the fittings and the guards, or shielding of the fittings from all directions. The specific design of these guards was and is left to the cargo tank manufacturer. The RSPA has indicated that it is not necessary to issue specific guidelines for the design of components on cargo tanks, and that the role of the DOT is to

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[11] Under the superseded standards of 49 CFR 178.340-8(c), design loads were described as "vertical" and "horizontal," whereas the new standards of 178.345-8(c) describe the design loads as "normal" and "tangential" to the tank surface. RSPA representatives verbally indicated that the change in terminology was to clarify the standard.

[12] A cargo tank motor vehicle is defined as a motor vehicle with one or more cargo tanks permanently attached to or forming an integral part of the motor vehicle (see 49 CFR 171.8). The RSPA has indicated that for a tractor-cargo tank semitrailer, the cargo tank motor vehicle consists only of the cargo tank and its semitrailer.

publish performance requirements and allow the industry the flexibility to meet those requirements.

One cargo tank manufacturer, Thompson Tank and Mfg. Co., Inc., has stated that the DOT has:

- never evaluated existing damage protection devices [including but not limited to rollover protection devices] for compliance;
- not determined if compliance was possible;
- refused to provide sample calculations or examples of acceptable design procedures;
- been unable to provide accurate or precise explanations to inquiries concerning compliance; and
- refused to "approve" [evaluate] design calculations and procedures if submitted.

Thompson Tank identified the Truck Trailer Manufacturers Association (TTMA) and seven firms involved in the design and construction of cargo tanks that reportedly experienced similar problems. The Safety Board was able to contact six of these firms and the TTMA to verify this information. All expressed some concern about the reasonableness of the new standards for cargo tanks that were adopted in 1989 and 1990, and the ability of manufacturers and designers to comply with the new standards without some direction or guidance from the DOT (RSPA). Three of the firms further indicated that they had requested the RSPA, as early as 1985 or 1986, to approve submitted calculations or to provide sample calculations pertaining to the design of these cargo tanks. According to these firms, they were advised by the RSPA that the RSPA did not approve such calculations, perform the calculations, or provide sample calculations to the industry. A fourth firm indicated that it needed simple guidelines to ensure that it was complying with the regulations. This firm noted that it was a small company and did not have a large engineering staff to perform the needed calculations. The TTMA also noted that during various meetings with its membership, discussions occurred related to the possibility of requesting sample calculations from the DOT (RSPA); however, the TTMA never made a formal request for any sample calculations.

Basis of Design Load for Rollover Protection Devices

There is no record documenting the basis of the design loads for rollover protection guards or devices for the MC 300 series cargo tanks in the RSPA's "History of Section" files.[13] The RSPA files indicate, however, that the design loads for the MC 300 series tanks were developed during a 1966 conference. According to the RSPA, it has no records that indicate how the design loads for rollover protection devices were derived. According to the TTMA, the design requirements for these tanks were first published in draft form in 1966 by the Interstate Commerce Commission (ICC), which then had the regulatory responsibilities related to safety requirements for cargo tanks that were later transferred to the DOT. The TTMA also indicated that its members did work with the ICC in the development of these standards. An engineer with Fruehauf Corporation, who was involved with the development of these design requirements, does not recall the justification for the design loads. Further, the director of engineering for the Heil Company stated that the design loads were not based on testing and that no one could quantify the type or severity of accident to be protected against.

In its 1985 Notice of Proposed Rulemaking[14] to revise the requirements for cargo tanks, the RSPA noted that the most common highway accident involving loss of cargo tank lading is a rollover. The RSPA also stated in the notice that the top of the cargo tank is one of the "most vulnerable areas" and that "the rollover damage protection system can receive lateral [tangential] loads that equal or exceed the normally applied load." The RSPA, therefore, proposed that the tangential design load for rollover protection devices should be increased to twice the weight of the cargo tank motor vehicle and each device should be capable of supporting at least one-fourth of the load. There is no indication in the notice, however, that the proposed increase in the tangential loading standard was based on testing or on modeling that estimated the dynamic forces acting upon the rollover protection devices during a rollover. A RSPA engineer indicated that the proposed standard for perpendicular loading was derived from the previous specifications in 49 CFR 178.340-8 without additional research.

The RSPA and the FHWA, however, did jointly sponsor tests in the late 1970s and early 1980s to evaluate the forces generated on the cargo tank and the closure fittings during a rollover. According to a 1980 report published by Dynamic Science, Inc.,[15] documenting part of this research,

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[13] These files, kept with the RSPA's dockets on regulatory rulemakings, trace the development of each section of the hazardous materials regulations. The files have not been updated since 1979.

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

[15] Tyndall, L. H.; Leananen, D. H.; 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

three 180° rollover tests were conducted on a test tank. The average peak horizontal acceleration measured was 2.9 g, and the average peak vertical acceleration measured was 7.7 g as the test tank began to roll from its side onto its top. (Because the weight of an object is equivalent to the force generated by gravity or 1 g, an object with acceleration of 7.7 g is subject to forces that are 7.7 times its weight.) Representatives from the FHWA and the TTMA indicated that they were not aware of any additional research about the types and magnitudes of forces generated in a rollover accident, or of any studies that attempted to characterize the most common damage incurred in a rollover accident.

The National Aeronautics and Space Administration (NASA) has used computer programs employing finite element analysis to design cargo tanks to transport rocket fuels and other highly poisonous and reactive materials. Although the NASA-designed cargo tanks are comparable to DOT specification MC 338 cargo tanks that are typically used for cryogenic materials, NASA used the computer models to evaluate the forces and stresses that were likely to be generated during different accident situations, including frontal impacts, side impacts, falls from an overpass onto the tank top, and fire conditions. The RSPA had suggested that NASA consider that the tanks be designed for these accident conditions because of the hazards of the materials being transported and to ensure that the tanks would meet the performance standards that the RSPA believed could later be required.

The rollover protection device on the NASA-designed cargo tank is a tubular frame in the shape of a tripod. A steel plate is welded to the frame to prevent the penetration of objects through the open frame; the plate completes the rollover protection device. One rollover protection device is welded to the tank on the front side of the closure fittings, and a second device on the rear side. A portable hood is also used to shield the sides of the fittings (fig. 17). According to a NASA engineer, the rollover protection devices have not been physically tested, nor have any of the cargo tanks that are equipped with this type of device been involved in a rollover accident. NASA currently has 5 cargo tanks equipped with the device and plans to construct 3 additional tanks; the U.S. Air Force has 16 NASA-designed cargo tanks and is considering 18 additional tanks.

Transportation, Federal Highway Administration, Bureau of Motor Carrier Safety. 2 vol. Available from: National Technical Information Service, 5285 Port Royal Road, Springfield, VA 22161.

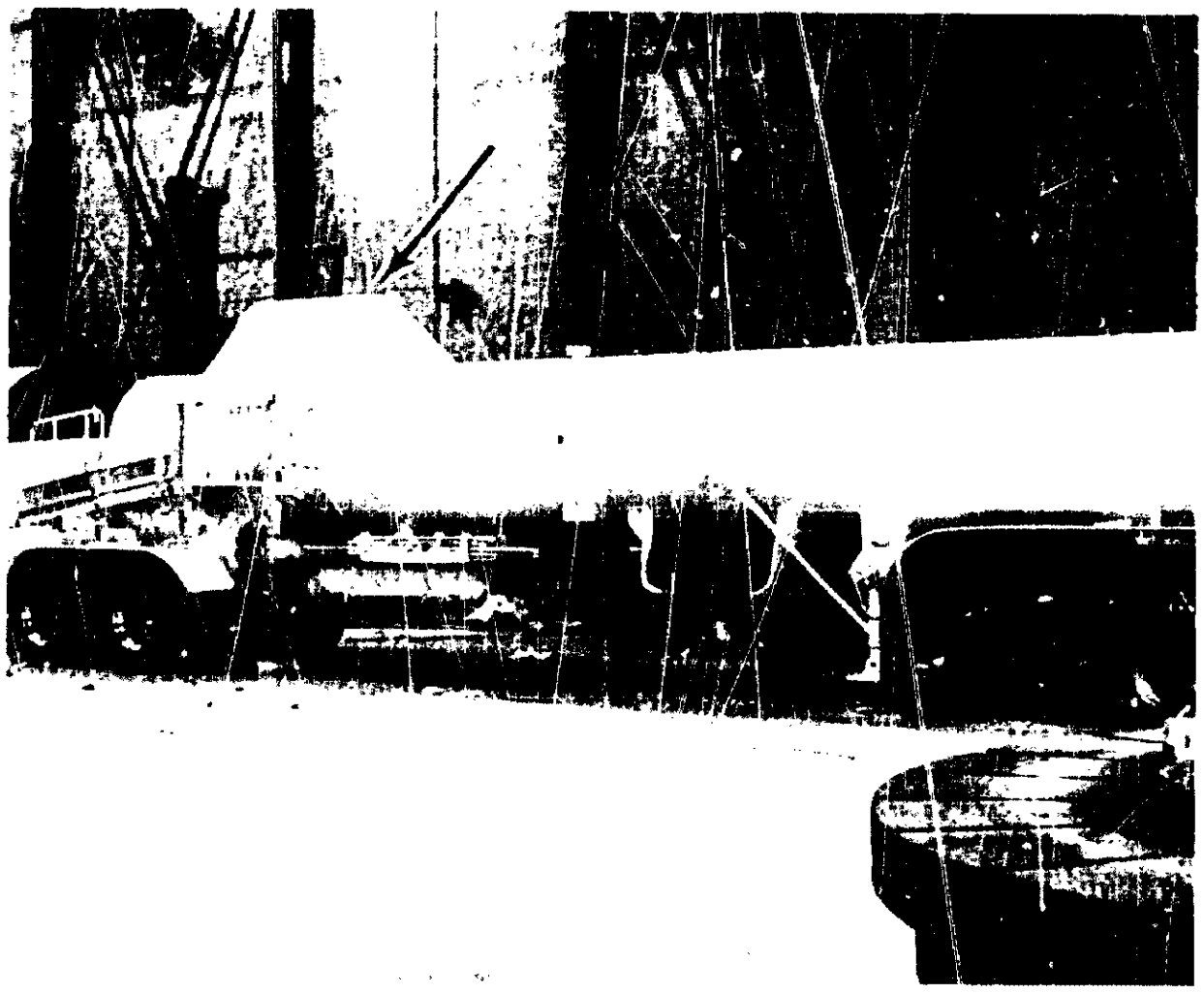

Figure 17.--Rollover protection device (arrow) for the NASA-designed cargo tank. (Photo courtesy of the National Aeronautics and Space Administration.)

FEDERAL OVERSIGHT OF CARGO TANK SAFETY

Cargo Tank Safety Program

FHWA Cargo Tank Enforcement Program.--The FHWA is responsible for the enforcement of the highway cargo tank design and safety standards that are included in the DOT's hazardous materials regulations. The FHWA indicated that its cargo tank enforcement program, which also includes carrier operations, has concentrated on carrier operations rather than cargo tank manufacturers because past inspections of cargo tank manufacturers have not revealed a significant number of violations.

Inspection Program.--Computer records of the FHWA indicate that there were 69 inspections of cargo tank manufacturers from October 1, 1984, through October 1, 1990.[16] The computer records also indicate that three enforcement cases were completed against cargo tank manufacturers between October 1, 1988, and May 31, 1991. Because the FHWA did not begin to maintain computer records of enforcement actions taken against cargo tank manufacturers until October 1988, there is no record that indicates if any enforcement actions were taken between October 1984 and October 1988. Failure to design an adequate rollover protection device was not cited in any of three enforcement actions on record.

The FHWA has not maintained a complete list of cargo tank manufacturers. Based on information provided to the FHWA by the TTMA, the FHWA estimates that there are about 70 cargo tank manufacturers in the United States. Because recent amendments to the hazardous materials regulations now require the registration with the RSPA of all cargo tank manufacturers, repair facilities, and assembly plants, the Safety Board contacted RSPA to try to verify the estimated number of manufacturers. According to the RSPA, about 74 companies had registered as cargo tank manufacturers as of July 24, 1991. The RSPA indicated, however, that this number may be low because during the initial stages of the registration program, the RSPA did not record in its data base whether a registrant was a cargo tank manufacturer, assembly plant, or repair facility.

The FHWA conducts its inspections through its nine regional offices. Each region submits an annual work plan to FHWA headquarters for review and approval. Although each plan identifies the amount of time allocated to hazardous materials inspections, the number of inspections of cargo tank manufacturers is not specified. The FHWA further indicated that inspections of cargo tank manufacturers are performed sporadically--when there is a hazardous materials incident involving a tank manufactured by a company, or when the tank manufacturer is recognized as not having been inspected for an extended period of time. There is no written guidance to the regional

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[16] The FHWA indicated that this number may not be accurate: it may include several inspections on the same company, and may not reflect inspections of manufacturers that are also motor carriers.

offices regarding the frequency of inspections or the circumstances that would initiate an inspection of a cargo tank manufacturer.

When inspections of cargo tank manufacturers are conducted, the FHWA inspectors use written work sheets that are included in an FHWA operations manual. The work sheet used for inspections of cargo tank manufacturers references the design and construction requirements of the regulations, including those provisions for the design of rollover protection guards. For the different regulatory provisions referenced, the FHWA inspector marks the appropriate field to note a violation or no violation.

Compliance of Cargo Tank Manufacturers with DOT Standards.--Inspections of the cargo tank manufacturers are normally performed by a regional FHWA safety investigator, who is not trained to analyze the design of cargo tanks for compliance with the rollover protection requirements. Headquarters representatives of the FHWA indicate that currently no one in the FHWA who is involved with motor carrier safety has the knowledge to review, evaluate, and determine if the cargo tanks comply with the design loading requirements of 49 CFR 178.340-8(c) for the MC 306, MC 307, and MC 312 specification cargo tanks, or 49 CFR 178.345-8(c) for the new specification DOT 406, DOT 407, and DOT 412 cargo tanks. According to the FHWA, detailed reviews of the compliance of these tanks with these requirements would have to be performed by the RSPA. The Safety Board, through a review of the RSPA's files and discussions with the RSPA's staff, found no indication that the RSPA routinely evaluates design calculations to verify that the manufacturers are building their cargo tanks to meet the design loads required in the DOT standards for rollover protection. The RSPA representatives indicated, however, that the RSPA will evaluate design calculations if requested, but that cargo tank manufacturers have not requested the RSPA to verify their design calculations. The RSPA also indicated that the FHWA, as the modal enforcement agency, has the responsibility to ensure that cargo tank manufacturers are meeting DOT design standards.

The FHWA relies on the cargo tank manufacturers to determine that the rollover protection devices satisfy the design loads required in the DOT standards. Under the provisions of 49 CFR 178.340-10 for specification MC 306, 307, and 312 cargo tanks, a "responsible" official of the tank manufacturer was required to provide written certification that the tank was designed, constructed, and tested in accordance with the applicable requirements for the DOT specification tank, and that the tank complied with all DOT requirements.

Under the provisions of 49 CFR 178.320(b) that became effective on December 31, 1990, each cargo tank design type and completed cargo tank must be certified to be in conformance with the specification requirements by a DOT-registered design-certifying engineer and a DOT-registered inspector. The manufacturer must obtain a written and signed certificate from the design-certifying engineer to indicate that the design of the tank is in compliance with the specification requirements. The certifying engineer must sign all sketches, drawings, and calculations used for the certification, and include them with the written certificate of compliance. Under the

requirements of 49 CFR 178.345-15 for DOT 406, 407, and 412 cargo tanks, the manufacturer must also provide to the owner of the tank, at or before the time of delivery, written certificates attesting that the cargo tank has been designed, constructed, and tested in accordance with the DOT specifications and that the tank conforms to DOT specifications. The certificate attesting to the design of the cargo tank must be signed by a "responsible" official of the manufacturer and the design-certifying engineer. The certificate attesting to the construction, testing, and compliance of the tank must also be signed by a responsible official of the manufacturer and a DOT-registered inspector.

A person employed as a design-certifying engineer or as a registered inspector is considered to be registered if the person's employer, such as a cargo tank manufacturer, is registered with the DOT according to 49 CFR 107, Subpart F. A cargo tank manufacturer, repair facility, or assembly plant that is registered with the DOT is not required by the regulations to submit to the DOT the names and qualifications of the individual employees designated as design-certifying engineers or registered inspectors. If a DOT registrant, such as a cargo tank manufacturer, has employees who serve as registered inspectors or design-certifying engineers, the registrant must so indicate to the DOT and further certify that the individual inspectors and engineers meet the required qualifications. If a registrant contracts an outside person or company to perform these functions, the registrant must provide the DOT with the name, address, and DOT registration number of that person or company. A registrant is required to notify the DOT in writing within 30 days if the registrant either begins or stops performing any type of activity that requires certification by a registered inspector or design-certifying engineer.

Under the provisions of 49 CFR 171.8, a registered design-certifying engineer must have the knowledge and ability to perform stress analysis of pressure vessels and to determine if a cargo tank design and its construction meet the applicable DOT specification. A design-certifying engineer must also have an engineering degree and 1 year of work experience in structural or mechanical design. A registered inspector must have the knowledge and ability to determine if a cargo tank conforms to the applicable DOT specification, and have any of the following combinations of education and work experience in the design, construction, inspection, or repair of cargo tanks:

- an engineering degree and 1 year of work experience; or
- an associate degree in engineering and 2 years of work experience; or
- a high school diploma (or General Education Diploma) and 3 years of work experience.

The DOT permitted the limited registration of persons who did not meet the educational requirements for a registered inspector or design-certifying engineer but who had at least 3 years of work experience performing these

functions as of September 1, 1991. Such individuals were required to submit a registration statement to the RSPA by December 31, 1991.

The FHWA believes that the DOT registration program will result in greater compliance of the cargo tank manufacturers with the design requirements for cargo tanks. Although the RSPA is responsible for the implementation of the DOT registration program, the FHWA indicated that its field inspectors will inspect records and files to verify that cargo tank manufacturers are using DOT-registered design-certifying engineers and inspectors. The FHWA is also currently considering the addition of structural engineers to its staff to evaluate cargo tank designs, or the use of contract engineers to perform this function. Although the FHWA has recognized the need to verify that cargo tanks are being designed and built in accordance with the regulations, the FHWA has not made a commitment to take action.

Compliance of Accident Tanks With DOT Standards.--The cargo tank involved in the rollover in Albuquerque, New Mexico, on January 8, 1991, was manufactured by Acro Trailer Company in 1981. This company was inspected in 1985 by a member of the FHWA headquarters hazardous materials staff and an FHWA regional hazardous materials specialist. There were no violations noted concerning design, fabrication, or installation of the rollover protection guards.

After the Albuquerque accident, Acro sent a letter to the FHWA providing the strength calculations for the rollover protection guards on the MC 312 cargo tank involved in the accident. According to Acro's calculations, the guards used for overturn protection had a vertical strength that could support 10 times the weight of the cargo tank and a horizontal strength that could support 5 times the weight of the cargo tank, or 5 times stronger in the vertical direction and 10 times stronger in the horizontal direction than required under 49 CFR 178.340-8.

Because the FHWA did not have an individual on its staff qualified to evaluate Acro's calculations, the FHWA forwarded the calculations to the RSPA. The PSPA determined that the Acro calculations were not sufficiently detailed to make a complete evaluation. The RSPA, however, using a "best case" scenario, determined that the rollover protection devices on the Acro tank did not meet the minimum strength requirement in bending caused by horizontal loading, and the tank, therefore, did not comply with 49 CFR 178.340-8.

Strength calculations were also submitted to the Safety Board by New Progress, Incorporated, for the MC 306 cargo tank involved in the Hamilton, Ohio, accident,[17] and by Fruehauf Corporation for the type of MC 306 cargo tank involved in the Ethelsville, Alabama, accident. Calculations were not obtained for the tanks involved in the remaining accidents because the rollover protection devices on these tanks were not significantly damaged. The calculations submitted by New Progress indicated that the side rails had a vertical strength that could support more than 6 times the weight of the cargo tank and a horizontal strength that could support more than 9 times the weight of the cargo tank. The calculations submitted by Fruehauf indicated that the side rails could support 13 times the weight of the loaded tank vertically, and 3 1/2 times the weight of the loaded tank horizontally.

A Safety Board metallurgical engineer reviewed the calculations submitted by New Progress and Fruehauf to determine, on the basis of the manufacturers' respective calculations, if the rollover protection rails on these tanks met the design loads required under 49 CFR 178.340-8(c). The Safety Board engineer concluded that Fruehauf's calculations reasonably demonstrated that the rollover protection rails for the Fruehauf tank did exceed the design loads required in the standards. The Safety Board engineer concluded that the calculations submitted by New Progress, however, were incomplete and incorrect because (1) horizontal loads were not calculated for the rollover protection rails which extended along the length of the cargo tank; (2) the formulas used to calculate the horizontal loads on the transverse end rails were not correct; and (3) the vertical loads were calculated as horizontal loads applied to the front and rear ends of the rollover protection rails. After these problems were discussed with New Progress, a second set of calculations was submitted. The second set was almost identical to the first set, and did not correct the errors previously noted. The Safety Board engineer then made his own calculations; the results indicate that the side rollover protection rails on the cargo tank involved in the Hamilton accident do not meet the minimum design standards for horizontal loading. The Safety Board engineer also stated that a simple application of the loading formulas was not possible because of the structural complexity of the rollover protection rails. The Safety Board engineer noted, as did some cargo tank manufacturers, that the FHWA and the RSPA had no written guidance or interpretations regarding accepted methods and assumptions for calculating the loads on the rollover protection rails. Consequently, the Safety Board engineer had to make certain assumptions about the application of the design loads.

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[17] The cargo tank was manufactured by Progress Industries, Inc., on October 10, 1990. On October 12, 1990, TSI Holdings, Inc., purchased certain assets of Progress Industries--including real property, machinery, and inventory--and formed New Progress, Incorporated, to manufacture cargo tanks. New Progress hired some of the personnel that had been employed by Progress Industries, and continued to manufacture the same cargo tank models, equipped with the same design rollover protection devices as were installed on Progress Industries cargo tanks. New Progress personnel provided to the Safety Board rollover protection device design calculations for the cargo tank models built at the manufacturing facility.

Acro indicated that the tank involved in the Albuquerque accident was 1 of 12 tanks that were equipped with the tubular rollover protection guards. Acro is in the process of locating the owners of these tanks and advising the owners to install lateral and longitudinal plates on the rollover guards. New Progress has also indicated that it is modifying the design of the rollover protection rails of the type on the tank involved in the Hamilton accident. New Progress intends to install seven diagonal support plates along each side rail: one at each end of the side rail and one at each of the five existing vertical support plates. New Progress stated that all new tanks will have this configuration and that existing tanks will be modified as they are brought in for repairs.

Accident Data Collection

A reportable accident under the FHWA's Motor Carrier Safety Regulations (49 CFR 394.3) is defined as "an occurrence" that involves a commercial motor vehicle engaged in the interstate, foreign, or intrastate operations of an interstate motor carrier, and that results in a fatality, bodily injury requiring medical treatment, property damage of $4,400 or more, or other specified criteria. Under 49 CFR 394.9, a motor carrier must complete and file an FHWA accident report form with the regional office of the FHWA within 30 days after the carrier learns or "should have" learned of the accident. The regional offices forward the accident reports to FHWA headquarters in Washington, D.C., where information from the accident report is entered into the FHWA's computerized accident data base. The FHWA does not screen or verify the information on the written accident reports other than the identity of the motor carrier. The FHWA uses the data base to develop motor carrier profiles, which are used to provide background information for enforcement inspections. An FHWA staff analyst estimated that accidents are underreported by about 50 percent.

A reportable hazardous materials incident under the RSPA's hazardous materials regulations (49 CFR 171.15 and .16) is defined as an incident that involves a commercial motor vehicle engaged in the interstate, foreign, or intrastate operations of an interstate motor carrier, and that (1) results in the unintentional release of a hazardous material; or (2) occurs during the course of transportation in which, as a direct result of the hazardous materials, a person is fatally injured or requires hospitalization, carrier and property damage exceeds $50,000, an evacuation of the public occurs, or other specified criteria are met. Under 49 CFR 171.16, each interstate carrier that transports hazardous materials shall submit a written DOT hazardous materials incident report to the RSPA within 30 days of the discovery of the incident. The RSPA then enters into the computerized data base information from the coded data fields on the incident report. Other than the reported injuries and fatalities, the RSPA does not routinely verify any information on a hazardous materials incident report. The RSPA will also follow up on missing information from incompletely coded data fields.

To determine the frequency of rollover accidents resulting in damage to the top fittings and release of the cargo, the Safety Board compared the

accident data from the RSPA and the FHWA computerized data bases for 1987, 1988, and 1989. The RSPA accident data base indicated there were an average of 89 reported rollover accidents involving a cargo tank and release of cargo annually, whereas the FHWA data base indicated an average of 86 such accidents annually. The FHWA data base further indicated an annual average of 74 reported rollover accidents without a release of cargo for this same time period. The FHWA data base does not identify the mode of failure, such as a puncture of the tank shell or a damaged fitting. The RSPA data base does identify damage to fittings but does not document whether the damage was to top-mounted fittings or to other fittings on a tank. The RSPA introduced a revised hazardous materials incident form on January 1, 1990, that distinguishes damage to top-mounted fittings from other fittings. For 1990, the first complete year the revised report forms were in use, the data base identified 96 accidents that involved the rollover of a cargo tank vehicle and some release of the cargo. The top-mounted fittings were damaged in 37 of these accidents.

Of the seven accidents considered in this report, six accidents met the reporting criteria for the FHWA and the RSPA. (The carrier in the Hamilton, Ohio, accident was not an interstate carrier and therefore was not subject to the FHWA and RSPA reporting requirements.) Accident reports for three of the six accidents (Albuquerque, Lantana, and Bronx) were on file with the FHWA as of December 10, 1991. Incident reports for four of the six accidents (Ethelsville, Albuquerque, Lantana, and Bronx) were on file with the RSPA as of December 10, 1991. The FHWA indicated that any enforcement action that may be taken would occur only if FHWA inspectors discover, during the next inspection of these motor carriers, that the required accident report form was not filed. The RSPA indicated that if any enforcement action is taken, it would most likely be a warning letter to the motor carrier.

As previously noted, a 1989 report published by UMTRI (see footnote 3) provided national estimates of the annual amount of travel and the number of accidents of tractor-cargo tank semitrailers transporting hazardous materials. The report estimated that for 1984 and 1985, about 1,046 accidents per year occurred in which the rollover of a cargo tank semitrailer combination transporting hazardous materials was either the primary or secondary accident event. Hazardous materials were released in 669 of these accidents; the report did not specify, however, the number of accidents in which the release occurred through top-mounted fittings. The UMTRI's estimate is based on a comparison of FHWA accident data for 1984 and 1985 with (a) the National Highway Traffic Safety Administration's (NHTSA) National Accident Sampling System (NASS), which uses a probability-based sampling procedure to estimate all accidents reported to the police, and (b) UMTRI's own data base that documents all truck accidents involving a fatality.

The UMTRI acknowledged that the estimates in its report are of limited statistical reliability because there is no existing national accident file that has the detail and coverage to provide a direct estimate of the number of accidents involving cargo tanks transporting hazardous materials. Specifically, the report noted the following limitations:

- The FHWA does not receive accident reports from intrastate carriers or from carriers exempt from DOT regulations.

- Not all interstate carriers are reporting accidents as required by DOT regulations.

- Because the FHWA accident data base only identifies the primary accident event, rollovers that occur as secondary events are not identified.

- The NASS files use small sample sizes, which causes considerable variation in data from year to year, and the files do not identify trailer body style, or cargo spillage information.

- The UMTRI's data base does not document accidents other than those with a fatality.

The FHWA, with the assistance of the National Governor's Association, is implementing a new database that will collect accident data directly from all the State governments. As of December 1991, 20 States are participating in this effort. This file will have some cargo tank rollover data; however, it will not include information needed to precisely identify the type of damage to the cargo tank.

The Hazardous Materials Transportation Uniform Safety Act, enacted November 16, 1990, requires the DOT to expand the application of its hazardous materials regulations to include intrastate commerce. According to the RSPA and the FHWA, each agency is drafting proposed rulemaking that will address the reporting of hazardous materials accidents and incidents involving intrastate carriers. Because the proposed rulemaking has not yet been released for comments, the Safety Board does not know if all intrastate carriers transporting hazardous materials will be subject to the new requirements.

ANALYSIS

Release of Hazardous Materials in Summarized Accidents

The release of hazardous materials in each of the seven accidents occurred because closure fittings on top of the tanks were either damaged or forced open after striking the ground or objects such as guardrails and curbs along the roadway. The closure fittings were vulnerable to damage because the rollover protection guards structurally failed in three of the accidents (Albuquerque, Hamilton, and Ethelsville), and did not adequately shield the closures from external impacts in the remaining four accidents (Lantana, Edenton, Columbus, and Bronx).

None of the seven accidents involved events that were extremely severe or abnormal in truck transportation. None of the accidents involved a high speed impact against a sharp rigid object, or involved multiple rollovers on exceedingly steep terrain. All of the accidents occurred under conditions and in locations that are common to the transportation environment. Consequently, the Safety Board believes that the seven accidents provide a reasonable measure of the performance of the rollover protection devices on each cargo tank.

Releases Caused by Structural Failure of the Rollover Protection.--In the Albuquerque accident, the rollover protection guards were sheared off during an overturn that occurred at a low speed, between 15 and 22 mph. As a result, all of the fittings on the top of the tank struck the ground or roadway and were severely damaged. If the rollover protection guards had not been sheared off, it is likely that the top-mounted fittings would not have been damaged and the hydrochloric acid would not have been released.

Structural failure of the rollover protection rails also contributed to the release of hazardous materials in the Hamilton and Ethelsville accidents. In the Hamilton accident, fuel oil was released through the damaged manhole covers for compartments 2 and 3 of the cargo tank. The left- and right-side rollover protection rails were also significantly damaged. The left side rail, along most of its length, was crushed inward toward the centerline of the tank; the length of the right side rail between the first and second manhole covers was also bent toward the centerline. The structural failure of the side rollover protection rails left the manholes more exposed to strikes from objects along the roadway and thereby increased the vulnerability of the manhole covers to impact damage. The damage to the manhole covers, therefore, most likely resulted from the structural failure of the rollover protection rails.

In the Ethelsville accident, the last quarter of the right side rail was bent to the right and crushed almost flat against the tank; the protection provided by the rail for the rear manhole cover was lost, allowing release of the diesel fuel. The significant amount of dirt and grass found on top of the tank after the accident indicates that the rear manhole cover slid across the ground before the tank came to rest in an upside down position.

Consequently, the forward-facing shovel-like latch to the dome lid most likely dug into the dirt and opened, resulting in the release of the diesel oil.

Releases Caused by Inadequate Protection.--The cargo tanks involved in the Lantana, Edenton, and Columbus accidents had inverted V-shaped rails and end plates as rollover protection guards that were similar to those on the cargo tank in the Ethelsville accident. Although the cargo tank involved in the Bronx accident had four curved transverse plates that exceeded the height of the fittings on the top of the tank, the height of the side rails that extended along each side of the tank did not exceed the height of the fittings. In each of these four accidents, the rollover protection rails and end plates sustained only minimal to moderate damage and did not structurally fail. In each accident, however, cargo was released through fittings that were either damaged, dislodged, or opened through impact with the ground or objects along the roadway.

In the Lantana accident, although the right side rail was bent to the inside and compressed about 1 1/4 inches between the fourth and fifth compartments, the rail was not crushed below the top of the fittings. The dome lid on the manway cover to the second compartment, however, was distorted and fractured, and three loading probes were dislodged from their manway covers. The two recovered probes and the damaged manway cover had smears of a zinc residue. The damage to the dome lid and the zinc smears left on the probes and the manway cover indicate that these fittings were struck by objects along the highway, most likely a guardrail. As the tank overturned and scraped against the highway guardrail, the guardrail encroached into the area on top of the tank that should have been protected. Consequently, the dome lid was damaged and the probes were dislodged.

The cargo tanks involved in both the Columbus and the Edenton accidents overturned after leaving the roadway and slid in dirt and grass adjacent to the roadway. Although the rollover protection rails on both tanks were virtually undamaged, the dome lids on the two tanks dug into the dirt and grass as the vehicle slid across the ground. Consequently, three of five dome lids on the Edenton tank and four of five dome lids on the Columbus tank were opened, releasing the cargoes.

The marks found on the right side rail of the cargo tank involved in the Bronx accident indicate that the missing manhole cover for the first compartment most likely dislodged after the cover struck an unknown object, possibly a curb at the toll plaza, after the cargo tank had separated from the truck and slid sideways. Because the side rails on the tank did not extend above the top of the manhole covers and the loading adapters, these fittings were not protected or shielded from side impacts. The transverse plates, at best could protect the fittings only from direct front and rear strikes.

Although the rollover protection rails or guards were taller than any of the closure fittings on the tanks, the vertical clearance between the top of the tallest fitting on each tank and the top of the rollover protection rail or guard was only 1 1/4 inches to 3 inches. Further, for the cargo tank

involved in the Bronx accident, the top of the side rails was as much as 4 inches below the top of the tallest fitting. Although the fittings on the tanks in these four accidents were bordered by rollover protection rails or guards, the design and configuration of the rollover protection devices were not adequate to protect and shield the fittings from objects such as curbs, highway guardrails, trees, and shrubs. The rollover protection devices likewise failed to adequately protect the fittings from plowing into the soft ground.

Federal Regulations for Rollover Protection

The failure of the rollover protection rails and guards to protect the closure fittings on the tanks involved in these accidents raises concerns about the adequacy and enforcement of the DOT requirements regarding the structural integrity and the configuration of rollover protection devices on MC 306, MC 307, and MC 312 cargo tanks. Although the 1989 and 1990 amendments to the regulations for the design and construction of cargo tanks are a significant improvement, the Safety Board is also concerned about the adequacy of the performance standards for rollover protection devices on the new DOT 406, DOT 407, and DOT 412 cargo tanks.

Structural Integrity.--Structural failure of the rollover protection guards and rails on the cargo tanks involved in the Albuquerque, Hamilton, and Ethelsville accidents resulted in damage to the top-mounted fittings and release of the cargo.

Although Acro and New Progress provided loading calculations for the rollover protection guards and rails on the tanks involved in the Albuquerque and Hamilton accidents, respectively, evaluation of Acro's calculations by the RSPA and of New Progress' calculations by a Safety Board metallurgical engineer indicates that the rollover protection on both tanks did not comply with the minimum design loads that were required under 49 CFR 178.340-8(c): the RSPA determined that the rollover guards that failed on the cargo tank in the Albuquerque accident did not meet the minimum horizontal strength requirements, and calculations of the Safety Board engineer indicate that the rollover protection side rails on the cargo tank in the Hamilton accident did not meet the minimum horizontal strength requirements. Calculations of the Safety Board engineer demonstrated that the rollover protection rails on the Fruehauf-manufactured cargo tank in the Ethelsville accident did meet the minimum horizontal and vertical strength requirements.

Acro and New Progress failed to provide sufficiently detailed calculations to demonstrate that the rollover protection devices on their tanks satisfied DOT requirements. Acro and New Progress did not consistently interpret the DOT performance standard and did not uniformly apply appropriate formulas to calculate the required loads. Their failure to submit complete and correct calculations may be attributed to one or more factors, including:

- a lack of sufficient guidance from the RSPA about the factors and assumptions that a cargo tank manufacturer must consider when calculating the loads on the rollover protection devices;

- the failure of Acro and New Progress to have a design engineer who knew how to apply and make the calculations; or

- attempts to disguise the inability of the devices to meet the DOT standards.

The second and third factors relate to the Federal oversight of cargo tank manufacturers, which is discussed in a subsequent section of this report. The first factor, however, relates to the effectiveness of the regulatory standard.

A performance standard must be consistently interpreted and uniformly applied to be effective. Therefore, users of a performance standard must have sufficient guidance about the factors and assumptions that should be considered before the user can be expected to interpret and apply the standard in a consistent manner. Several firms involved with the design and construction of cargo tanks have complained about the lack of written guidance from the DOT on how to calculate the loads and how to determine if the rollover protection devices, as designed, meet DOT performance standards. The RSPA also had difficulties in evaluating Acro's calculations because they were not sufficiently detailed. As a result, the RSPA had to make certain assumptions by using a best-case scenario.

Consequently, the Safety Board does not agree with the RSPA that the calculations are necessarily "straightforward" and obvious to all tank manufacturers, or even to the RSPA. Further, the Safety Board concludes that the lack of sufficient guidance from the RSPA about the factors and assumptions that a cargo tank manufacturer must consider when calculating the loads on the rollover protection devices could have contributed to the failure of Acro and New Progress to submit adequate and complete calculations. The Safety Board notes that the Federal Aviation Administration (FAA) publishes advisory circulars that provide specific guidance to the aviation community regarding acceptable methods for complying with certain FAA regulations, and that the RSPA's Office of Pipeline Safety published a guidance manual in 1985 for operators of small gas systems.[18] The Administrator of the RSPA noted in an introductory letter to the manual that the manual was "developed to provide a broad and general overview of your compliance responsibilities." The Administrator further noted that the manual "gives specific details for methods of operations and selection of materials which will meet the pipeline safety standards requirements." The RSPA's Office of Pipeline Safety has also endorsed the American Gas

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18 Research and Special Programs Administration. 1985. Guidance manual for operators of small gas systems. U.S. Department of Transportation, Research and Special Programs Administration, Information Services Division, 400 Seventh St., S.W., Washington, DC 20590. 227 p.

Association's written guide[19] to pipeline operators as being of "significant assistance to gas piping system operators in their efforts to comply" with the Federal regulations for the transportation of natural gas and other gases by pipeline (49 CFR Part 192). The Safety Board therefore believes that the RSPA can and should similarly provide cargo tank manufacturers with specific written guidance about the factors and assumptions that must be considered when calculating the loads on the cargo tank rollover protection devices.

Based on the RSPA evaluation of the rollover protection guards on the Acro cargo tank involved in the Albuquerque accident and the Safety Board engineer's calculations related to the rollover protection rails on the cargo tank involved in the Hamilton accident, the Safety Board concludes that the rollover protection devices on those accident cargo tanks failed to comply with the bending load requirements of 49 CFR 178.340-8(c). The Safety Board is also concerned that other Acro and New Progress tanks may not meet the load requirements of 49 CFR 178.340-8(c). The Safety Board believes that the FHWA should evaluate, with the assistance of the RSPA, all designs of rollover protection devices installed on cargo tanks manufactured by the Acro Trailer Company and by New Progress, Incorporated, to determine if the cargo tanks comply with existing DOT standards; and then require that cargo tanks failing to comply with existing DOT standards be removed from hazardous materials service or be modified to comply with the standards.

Justification of Design Loads.--The rollover protection rails on the cargo tank in the Ethelsville accident most likely met the minimum loading standards. The structural failure of these rails, however, contributed to the release of the cargo. Further, the results of the simulated rollover tests conducted under RSPA and FHWA sponsorship, for purposes other than determining rollover protection standards, indicate that the forces that act upon a tank and its rollover protection devices in a typical rollover accident can easily exceed the design loads that were required under 49 CFR 178.340-8(c) for the MC 306, MC 307, and the MC 312 specification cargo tanks, and that are now required under 49 CFR 178.345-8(c) for the new DOT 406, DOT 407, and DOT 412 specification cargo tanks. Because of the lack of any subsequent research by the cargo tank manufacturing industry or the DOT, there is inadequate information about the forces that can be encountered in a rollover accident and, therefore, about the extent to which cargo tanks can reasonably be designed to withstand these forces.

The Safety Board believes the DOT and the industry should establish reasonable and effective performance standards based on work similar to that done by NASA to model and analyze forces acting upon a cargo tank under different accident conditions. To be effective, the design loads required in the standards for rollover protection devices must be based on the forces that can be expected to act upon them during a rollover accident. The design loads must, therefore, be based on appropriate engineering modeling and analysis of such forces if a tangible safety benefit is to be realized.

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[19] American Gas Association. 1990. Guide for gas transmission and distribution piping systems. American Gas Association, 1515 Wilson Boulevard, Arlington, VA 22209. 351 p.

Because the design loads specified in 49 CFR 178.340-8(c) for the older MC series specification cargo tanks and the standards of 49 CFR 178.345-8(c) for the new DOT specification 406, 407, and 412 cargo tanks have not been determined from engineering modeling and analysis, the design loads for the rollover protection devices may not be sufficient to adequately protect against the structural failure of the devices during a rollover accident.

The Safety Board, therefore, believes that the FHWA and the RSPA should (1) model and analyze the forces that can act upon rollover protection devices on bulk liquid cargo tanks during a rollover accident; (2) promulgate performance standards that are based on the engineering models and analyses of these forces; and (3) establish a program to phase out from hazardous materials service the use of all cargo tanks that fail to meet the new performance standards. Some cargo tanks currently in use may be capable of being modified to meet the new performance standards.

Protection and Shielding.--In the accidents that occurred in Lantana, Bronx, Edenton, and Columbus, the cargoes were released because the fittings on top of the tanks were not adequately protected and shielded from impact with the ground or objects along the roadway. The configuration of the rollover protection devices on these four cargo tanks was inadequate to prevent objects along the roadside from striking fittings on the tops of the tanks and causing the release of cargo. The rollover protection devices provided only 1 to 3 inches of vertical clearance between the top of the tallest fittings and the top of the rollover protection device, but permitted the penetration of shrubs, trees, curbs and other typical roadside objects into the area bordered by the rollover protection devices. On the tank involved in the Bronx accident, the side rails, which were 1 inch below the manhole cover and 4 inches below the loading adapter, provided no protection from side impacts.

The performance standard in 49 CFR 178.340-8(c) for the MC 306, 307, and 312 cargo tanks required that top-mounted closures be protected from damage that would result in leakage, whereas the performance standard in 49 CFR 178.345-8(c) for the new DOT specification 406, 407, and 412 cargo tanks requires the tanks to be designed and constructed to minimize the potential for the loss of lading due to an accident. The Safety Board recognizes that the regulations establish performance standards rather than specific design standards for rollover protection devices. Consequently, the regulations do not address details such as the minimum vertical clearances between the rollover protection guards and the fittings, configurations to prevent the intrusion of roadside objects into the area enclosed by the rollover protection guards, or other methods to shield the top fittings. The Safety Board believes, however, that these performance standards should be supplemented by sufficiently detailed guidance and interpretations about acceptable means to comply with the performance standard. For example, details about configurations that provide an acceptable level of shielding and protection, such as the configuration on the NASA-designed cargo tank, could be included in advisory circulars provided to the cargo tank industry. Consequently, the Safety Board concludes that the lack of written guidance, not only about the calculation of the design loads for the rollover devices but also about the protection and shielding of top-mounted fittings on bulk

liquid cargo tanks, has resulted in designs and configurations of rollover protection devices that fail to provide an adequate level of protection. The Safety Board, therefore, believes that the RSPA should develop detailed written guidance about acceptable means to shield and protect the top-mounted closure fittings on all bulk liquid cargo tanks.

Federal Oversight of Cargo Tank Safety

Inspection of Cargo Tank Manufacturers and Enforcement of Regulations.--The FHWA has the responsibility within the DOT to enforce the DOT regulations that apply to highway transportation, including the standards for the design of cargo tanks that transport hazardous materials. The FHWA indicated that its cargo tank enforcement program has concentrated on carrier operations rather than cargo tank manufacturers because past inspections of cargo tank manufacturers have not revealed a significant number of violations. However, the low number of violations revealed may not be an accurate indication of the actual level of compliance to the DOT standards by cargo tank manufacturers, but rather the result of a low number of inspections (69 from October 1984 through October 1990) and a sporadic inspection policy.

Further, the FHWA inspectors are not trained, qualified, or directed to evaluate loading calculations or to determine if the rollover protection devices on a cargo tank have been designed and built to DOT specifications. Because the FHWA inspectors are not qualified to evaluate the loading calculations for rollover protection devices, it is likely that they are not qualified to technically evaluate other design calculations or features for a cargo tank. The RSPA was able to evaluate the loading calculations for the Acro cargo tank and presumably can evaluate other design calculations. The RSPA indicated, however, that it does not review cargo tank designs unless requested by a manufacturer. Consequently, the extent to which cargo tank manufacturers are complying with the regulations cannot be determined because the FHWA has not inspected or verified that cargo tanks are being designed and built according to DOT requirements. Evidence in two of the seven accidents discussed in this report, however, indicates that the rollover protection on the two tanks involved did not meet the standards set forth in the regulations.

Also, the DOT registration program has established educational and professional qualifications for design-certifying engineers and registered inspectors, which the FHWA believes should improve the level of compliance. Effective oversight, however, will not be attained by simply verifying that a cargo tank manufacturer is utilizing design-certifying engineers and registered inspectors, as suggested by the FHWA. The FHWA must also verify the quality of the work performed by the design-certifying engineers and the registered inspectors. The FHWA may also want to consider having manufacturers submit the appropriate plans and calculations to the FHWA for review and evaluation to ensure that the design of the cargo tank complies with the regulations.

Although the FHWA recognizes that it needs structural engineers to evaluate cargo tank designs, the FHWA has not made a commitment to obtain such expertise. The Safety Board believes that a commitment is needed from the FHWA that it will obtain the expertise necessary for the proper enforcement of the DOT standards for the design and construction of cargo tanks.

Consequently, the Safety Board concludes that the FHWA is not actively and properly exercising its enforcement responsibilities with respect to the design and construction of DOT specification cargo tanks. The Safety Board believes that the FHWA should (a) obtain the technical resources needed to properly evaluate cargo tank designs for compliance with DOT specifications, and (b) implement a program to evaluate the design and construction of cargo tanks for compliance with DOT specifications.

Accident Data Collection and Evaluation.--Another important aspect of effective oversight is the detection of safety problems through the analysis and evaluation of accident data.

The UMTRI report noted the lack of a national accident data base that can provide reliable information about the number of cargo tank rollover accidents. Despite the statistical limitations of the UMTRI's estimate of the number of rollover accidents involving the release of hazardous cargo during 1984 and 1985, the Safety Board is concerned that this estimate, 669 accidents per year, is more than 7 times greater than the average number of accidents reported per year to the FHWA and the RSPA from 1987 through 1989. Of the seven accidents investigated and addressed in this report, six apparently met the reporting requirements of the FHWA and the RSPA; yet reports for only three of the six accidents are on file with the FHWA, and reports for four of the six are on file with the RSPA.

The seventh accident (Hamilton, Ohio) involved an intrastate carrier transporting a DOT specification cargo tank. Intrastate carriers are likely to use DOT specification cargo tanks for the transportation of bulk liquids, particularly gasoline and fuel oil, but such carriers are not subject to the current reporting requirements of the FHWA or the RSPA when transporting these cargoes.

In addition to the underreporting of accidents, inadequately reported and recorded information can also mask trends or a specific pattern of performance. For example, an accident in which a vehicle with a DOT specification cargo tank collides with another vehicle and then overturns may be reported to the FHWA as a collision accident. It may not be identified as a rollover accident in FHWA's data base because the FHWA data base does not identify secondary accident events. Further, if hazardous materials were not released in such an accident, the accident would not have to be filed with the RSPA even though a DOT specification cargo tank was involved. In this example, the cargo tank might have retained its cargo, released a nonhazardous cargo, or might have been empty. The damage to the tank and whether a release of cargo occurred should still be of interest to the RSPA. Consequently, the failure to identify secondary accident events or to record other damage information prevents an accurate evaluation of

accident performance. Because accidents appear to be underreported and current accident data collection and recording procedures can result in the masking of accident trends, the Safety Board concludes that the FHWA and the RSPA cannot rely on their accident data bases to identify important trends and potential problems related to the design and construction of bulk liquid cargo tanks.

The Safety Board believes that the FHWA and the RSPA should implement a program to collect information necessary to identify patterns of cargo tank equipment failures, including the reporting of all accidents involving any DOT specification cargo tank.

CONCLUSIONS

1. In tank truck accidents at Albuquerque, New Mexico; Hamilton, Ohio; and Ethelsville, Alabama, the structural failure of the rollover protection devices resulted in impact damage to the fittings and the release of the hazardous materials from the tanks.

2. In tank truck accidents at Lantana, Florida; Bronx, New York; Edenton, North Carolina; and Columbus, Georgia, the design and configuration of rollover protection devices were not adequate to protect and shield the top-mounted fittings on the cargo tanks from objects external to the cargo tank or from plowing into the ground.

3. The rollover protection devices on the cargo tank in the accident at Albuquerque, manufactured by Acro Trailer Company, and on the cargo tank in the accident at Hamilton, manufactured by Progress Industries, did not meet the applicable DOT performance stardard for rollover protection devices.

4. There is insufficient guidance from the RSPA about (a) the factors and assumptions that a cargo tank manufacturer must consider when calculating the loads on the rollover protection devices, and (b) the protection and shielding of top-mounted fittings on bulk liquid cargo tanks.

5. There is inadequate information about the forces that can be encountered in a rollover accident and the extent to which rollover protection devices for cargo tanks can reasonably be designed to withstand these forces because neither the RSPA, the FHWA, nor the industry has provided engineering modeling or other analysis to determine the magnitude of forces acting upon a cargo tank under different accident conditions.

6. The performance standards for rollover protection devices on MC specification 306, 307, and 312, and DOT specification 406, 407, and 412 cargo tanks may not be sufficient to prevent structural failure during a rollover accident because limited tests conducted under RSPA and FHWA sponsorship, for purposes other than determining rollover protection standards, indicate that forces that act upon a tank and its rollover protection devices in a typical rollover accident can easily exceed the specified loads.

7. FHWA inspectors are not trained, qualified, or directed to evaluate loading calculations or to determine if rollover protection devices on a cargo tank have been designed and built to DOT specifications.

8. The FHWA has not adequately exercised its enforcement responsibilities pertaining to the design and construction of DOT specification cargo tanks.

9. The FHWA and the RSPA accident data bases are not adequate to identify important trends or potential problems related to the design and construction of bulk liquid cargo tanks.

RECOMMENDATIONS

As a result of this special investigation, the National Transportation Safety Board made the following recommendations:

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

Provide cargo tank manufacturers with specific written guidance about (a) the factors and assumptions that must be considered when calculating the loads on cargo tank rollover protection devices in determining compliance with existing Department of Transportation performance standards; and (b) acceptable means to shield and protect the top-mounted closure fittings on all bulk liquid cargo tanks. (Class II, Priority Action) (H-92-1)

Assist the Federal Highway Administration to evaluate the design of the rollover protection devices installed on all cargo tanks manufactured by the Acro Trailer Company and by New Progress, Incorporated, to determine if the cargo tanks comply with existing Department of Transportation standards. (Class II, Priority Action) (H-92-2)

Assist the Federal Highway Administration to improve the performance of the rollover protection devices on bulk liquid cargo tanks by:

- Modeling and analyzing the forces that can act upon rollover protection devices during a rollover accident. (Class III, Longer Term Action) (H-92-3)

- Promulgating performance standards for rollover protection devices that are based on the engineering modeling and analysis conducted in response to Safety Recommendation H-92-3. (Class III, Longer Term Action) (H-92-4)

- Phasing out from hazardous materials service the use of all cargo tanks that fail to meet the new performance standards promulgated in response to Safety Recommendation H-92-4. (Class III, Longer Term Action) (H-92-5)

Implement, in cooperation with the Federal Highway Administration, a program to collect information necessary to identify patterns of cargo tank equipment failures, including the reporting of all accidents involving a Department of Transportation specification cargo tank. (Class III, Longer Term Action) (H-92-6)

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

Evaluate, with the assistance of the Research and Special Programs Administration, designs of rollover protection devices installed on all cargo tanks manufactured by the Acro Trailer Company and by New Progress, Incorporated, to determine if the cargo tanks comply with existing Department of Transportation (DOT) standards; and then require that cargo tanks failing to comply with existing DOT standards be removed from hazardous materials service or be modified to comply with the standards. (Class II, Priority Action) (H-92-7)

Implement a program, including the acquisition of the necessary technical resources, to evaluate the design and construction of cargo tanks for compliance with Department of Transportation specifications. (Class II, Priority Action) (H-92-8)

Implement, in cooperation with the Research and Special Programs Administration, a program to collect information necessary to identify patterns of cargo tank equipment failures, including the reporting of all accidents involving a Department of Transportation specification cargo tank. (Class III, Longer Term Action) (H-92-9)

Improve, with the assistance of the Research and Special Programs Administration, the performance of the rollover protection devices on bulk liquid cargo tanks by:

- Modeling and analyzing the forces that can act upon rollover protection devices during a rollover accident. (Class III, Longer Term Action) (H-92-10)

- Promulgating performance standards for rollover protection devices that are based on the engineering modeling and analysis conducted in response to Safety Recommendation H-92-10. (Class III, Longer Term Action) (H-92-11)

- Phasing out from hazardous materials service the use of all cargo tanks that fail to meet the new performance standards promulgated in response to Safety Recommendation H-92-11. (Class III, Longer Term Action) (H-92-12)

BY THE NATIONAL TRANSPORTATION SAFETY BOARD

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Adopted: February 4, 1992

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