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National Transportation Safety Board Safety Study
Locomotive Fuel Tank Integrity

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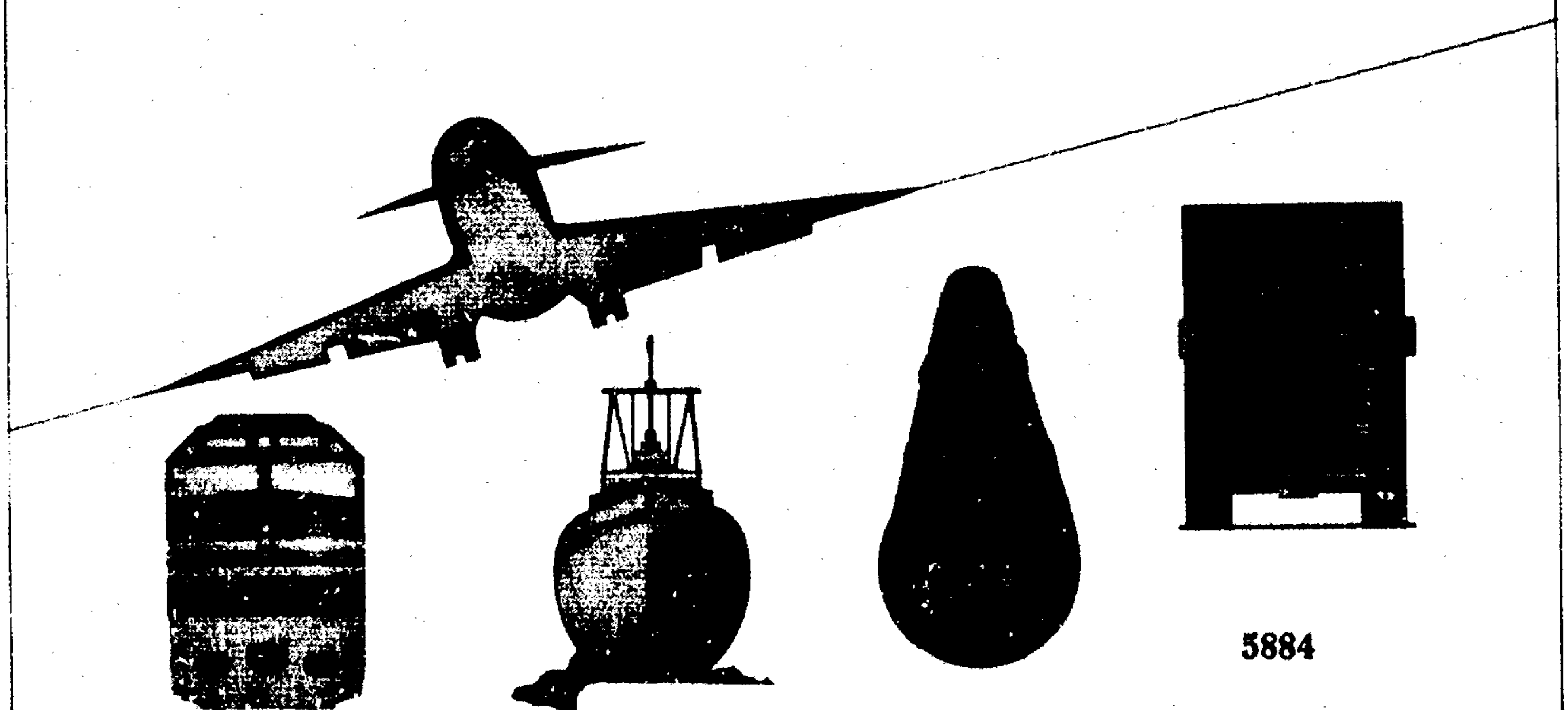
NATIONAL TRANSPORTATION SAFETY BOARD

WASHINGTON, D.C. 20594

SAFETY STUDY

LOCOMOTIVE FUEL TANK INTEGRITY



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This study addresses the concern about the potential for diesel fuel fires in railroad accidents to fatally injure trapped crewmembers, consume cargo, contribute to hazardous materials fires in the train, and endanger nonrailroad property near the accident site. The specific issues discussed in this study are: the adequacy of the current design of the locomotive fuel tank, the factors that affect the current design of locomotive fuel tanks, and the sufficiency of research to improve the integrity of fuel tanks or to improve fuel containment. Recommendations concerning these issues were made to the Federal Railroad Administration, the Association of American Railroads, General Electric, and the Electro-Motive Division of General Motors.

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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LOCOMOTIVE FUEL TANK INTEGRITY

Safety Study

Safety Study NTSB/SS-92/04
Notation 5884

National Transportation
Safety Board

Washington, D.C.
October 1992

Contents

Acronyms of Railroads

Amtrak	National Railroad Passenger Corporation
ATSF	Atchison, Topeka & Santa Fe Railway Company
BN	Burlington Northern Railroad Company
CR	Consolidated Rail Corporation (Conrail)
CSX	CSX Transportation, Inc.
DRGW	Denver and Rio Grande Western Railroad Company
GWWR	Gateway Western Railway
IC	Illinois Central Railroad Company
KCS	Kansas City Southern Railway
LIRR	Long Island Rail Road
MBTA	Massachusetts Bay Transit Authority
METRA	Chicago Commuter Rail Service Board [Metropolitan Transit Authority]
NS	Norfolk Southern Corporation
SOO	Soo Line Railroad Company
SP	Southern Pacific Transportation Company
UP	Union Pacific Railroad Company

Executive Summary

In 1990, the Safety Board investigated three major accidents involving collisions and derailments of locomotives that resulted in diesel fuel fires from ruptured locomotive fuel tanks. Seven crewmembers fatally injured in these accidents suffered extensive burns and smoke inhalation. These accidents heightened the Safety Board's concern about the potential for diesel fuel fires in railroad accidents to fatally injure trapped crewmembers, consume cargo, contribute to hazardous materials fires in the train, and endanger nonrailroad property near the accident site. Because of this heightened concern, the Safety Board initiated a study of this subject.

The safety issues discussed in this study are:

- the adequacy of the current design of the locomotive fuel tank;
- the factors that affect the current design of locomotive fuel tanks; and
- the sufficiency of research to improve the integrity of fuel tanks or to improve fuel containment.

As a result of this study, recommendations were issued to the Federal Railroad Administration of the U.S. Department of Transportation, the Association of American Railroads, General Electric, and the Electro-Motive Division of General Motors.

Introduction

In 1990, the Safety Board investigated three major accidents involving collisions and derailments of locomotives that resulted in diesel fuel fires from ruptured locomotive fuel tanks.[1] Seven crewmembers were fatally injured in the first two of these accidents, all of whom suffered extensive thermal burns and smoke inhalation.[2] The investigation of the third major accident,[3] involving a passenger train in a tunnel, revealed that diesel fuel spilled from a ruptured locomotive fuel tank. The fuel ignited and the resulting smoke and fumes increased the level of hazard in the postcrash phase of the accident, hindering emergency response and rescue activity. Seven rescue personnel were treated for smoke inhalation and many passengers complained of smoke conditions.

These accidents heightened the Safety Board's concern about the potential for diesel fuel fires in railroad accidents to fatally injure trapped crewmembers, consume cargo, contribute to hazardous materials fires in the train, and endanger nonrailroad property near the accident site. Because of this heightened concern, the Safety Board initiated a study of this issue.

As part of the study, the Board reviewed data from its investigations of 29 railroad accidents involving locomotive derailments that occurred in 1991.[4] For most of the accidents, the investigators were able to obtain basic information on fuel tank damage and fuel spill from a review of photographs and other documentation obtained during the course of the investigations. The Safety Board recognizes that its data are limited and biased toward the more severe accidents.

The Board also investigated three locomotive derailment accidents in 1992 to document in detail the sequence of events associated with fuel tank damages and diesel fuel spills. A fuel tank information form was developed to obtain precise information concerning the events in which the fuel tanks were damaged, the type of damage sustained, and what caused the damage. This form was used during the review of the 1991 accident investigations and for the investigations of the 1992 accidents. Also, a metallurgical examination was conducted of the locomotive fuel tanks involved in two of the three 1992 locomotive derailment accidents to determine the general condition of the fuel tank and the cause of the fuel tank failures (overstress, fatigue, or corrosion).

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[1] (a) National Transportation Safety Board. 1991. Atchison, Topeka and Santa Fe Railway Company (ATSF) freight trains ATSF 818 and ATSF 891 on the ATSF Railway, Corona, California, November 7, 1990. Railroad Accident Report NTSB/RAR-91/03. Washington, DC. (b) National Transportation Safety Board. 1991. Collision and derailment of Norfolk Southern train 188 with Norfolk Southern train G-38 at Sugar Valley, Georgia, August 9, 1990. Railroad Accident Report NTSB/RAR-91/02. Washington, DC.

[2] The cause of death of two of the fatalities was attributed to severe trauma.

[3] National Transportation Safety Board. 1992. Derailment and collision of Amtrak passenger train 66 with Massachusetts Bay Transit Authority commuter train 906 at Back Bay Station, Boston, Massachusetts, December 12, 1990. Railroad Accident Report NTSB/RAR-92/01. Washington, DC.

[4] Substantial forces are involved in a locomotive derailment, which may result in fuel tank breach. In addition, the fuel tank is located close to the track, where it is vulnerable to being punctured by the rail or other debris when the locomotive derails. Consequently, the review was limited to accidents in which one or more of the locomotives involved derailed.

The first section of this report provides an overview of the three major 1990 accidents. The second section highlights existing data, from sources other than the Safety Board, on diesel fuel spills and locomotive derailments. The third section provides the results of the Safety Board's review of the 1991 accident investigations and details of the 1992 accident investigations. The fourth section provides background information on the Nation's locomotive fleet, fuel tank size and design, Federal regulations and industry standards regarding locomotive fuel tanks, industry initiatives to improve the integrity of locomotive fuel tanks, and diesel oil fuel properties. The relevant issues, in the Safety Board's view, regarding the integrity of the locomotive fuel tank as a result of a locomotive derailment are discussed in the final section.

Overview of Three 1990 Accidents Involving Rupture of Locomotive Fuel Tanks

In 1990, the Safety Board investigated three major accidents involving collisions and derailments of locomotives that resulted in ruptured locomotive fuel tanks and diesel fuel fires. There were seven fatalities and several reported cases of smoke inhalation in these accidents, which occurred at Sugar Valley, Georgia; Corona, California; and Boston, Massachusetts.

Sugar Valley, Georgia

About 3:13 a.m. eastern daylight time on August 9, 1990, northbound Norfolk Southern (NS) freight train 188, traveling about 25 mph, collided with southbound NS local freight train G-38, traveling about 50 mph, near Sugar Valley, Georgia. The postaccident investigation determined that the engineer of train 188 failed to stop the train at a stop signal at the north end of a siding because he was either asleep, distracted, or inattentive. Train 188 continued through the turnout at the north end of the siding, striking train G-38 nearly head-on.

The lead locomotive unit of train 188 derailed and came to rest about 90 feet to the west of and at a 90° angle to the track. Both locomotive trucks were separated from the unit, and the unit's fuel tank was dented and ruptured. The leaking diesel fuel ignited, and the resulting fire damaged the short hood and the part of the long hood that was over the fuel tank (fig. 1). The interior of the cab was extensively damaged by heat. The lead locomotive unit of train G-38 derailed to the east of the main track; it lay on its right side with the long hood pointed south. The locomotive was off its trucks, and its fuel tank was torn off (fig. 2). The leaking diesel fuel ignited and

Figure 1.—Damage to lead unit, NS 8641, of train 188 at Sugar Valley, Georgia.

Figure 2.—Damage to lead unit, NS 2799, of train G-38 at Sugar Valley, Georgia. (Unit was uprighted after accident.)

the resulting fire caused extensive thermal damage to the cab interior; there was no apparent structural damage as a result of the derailment. The second locomotive unit of G-38 derailed and came to rest on its right side. It sustained structural and thermal damage; the fuel tank was punctured and the leaking fuel ignited. Equipment damage was estimated at $1,260,680.

The conductor on train 188 and the conductor and engineer on train G-38 were fatally injured. These three crewmembers, who were riding on the lead unit of their respective locomotives, suffered smoke inhalation, burns, and massive injuries.

Corona, California

On Wednesday, November 7, 1990, about 4:11 a.m. Pacific standard time, two Atchison, Topeka & Santa Fe Railway Company (ATSF) freight trains collided head-on at milepost (MP) 25.6 in Corona, California. The westbound ATSF freight train 818, which was traveling from Barstow, California, to Hobart yard, City of Commerce, California, was on the Corona siding. The train passed the stop signal, and the lead locomotive unit reentered the main track, blocking all movement on the main track as the train came to a stop. Eastbound ATSF freight train 891, which was traveling about 29 mph on the main track from Hobart yard to Chicago, Illinois, collided with train 818. The left front corner end sill area of the lead locomotive unit of train 818 collided with the left front corner end sill area of the lead unit of train 891. All three locomotive units and five rail cars of train 891 derailed. Four units of the five-unit locomotive consist of train 818 and three rail cars of that train derailed. The total damage was estimated to be $4,400,000.

Each train had three-person crews. The entire crew of ATSF 818 and the brakeman of train 891 were killed.

A postcollision fire enveloped both equipment and personnel. The fire was fed by diesel fuel that spilled from two ruptured locomotive fuel tanks. The postaccident investigation of this collision revealed that the fuel tanks on both the first and third locomotives of train 891 (fig. 3) were ruptured and their contents released. During the collision, one tank was punctured by a set of wheel trucks, and the other was ruptured either by debris or by the impact of landing on top of the lead locomotive of train 818. Some of the fuel was sprayed into the air, making it highly combustible.

According to the coroner's office, the three crewmembers on train 818 died from smoke inhalation and thermal burns. The brakeman on train 891 was killed and suffered traumatic injuries and extensive thermal burns.

Boston, Massachusetts

At 8:23 a.m. eastern standard time on December 12, 1990, National Railroad Passenger Corporation (Amtrak) passenger train 66, consisting of a two-unit locomotive, two material handling cars, five passenger cars, one dining car, and two baggage cars, derailed and struck Massachusetts Bay Transit Authority (MBTA) commuter train 906, consisting of one locomotive, six passenger cars, and one control car, as both trains entered Back Bay station in Boston, Massachusetts.

Operated by an apprentice engineer, Amtrak train 66 was traveling 76 mph, within a 30-mph speed restriction, on a 9°30′ curve when it derailed and struck MBTA train 906, moving about 5 to 10 mph, on the adjacent track. A fire ignited after the collision. On Amtrak train 66, 7 crewmembers and 43 passengers sustained injuries; on MBTA train 906, 5 crewmembers and 391 passengers were injured; 7 firefighters also sustained injuries and many passengers complained of smoke conditions in the tunnel. Estimated damage exceeded $12.5 million.

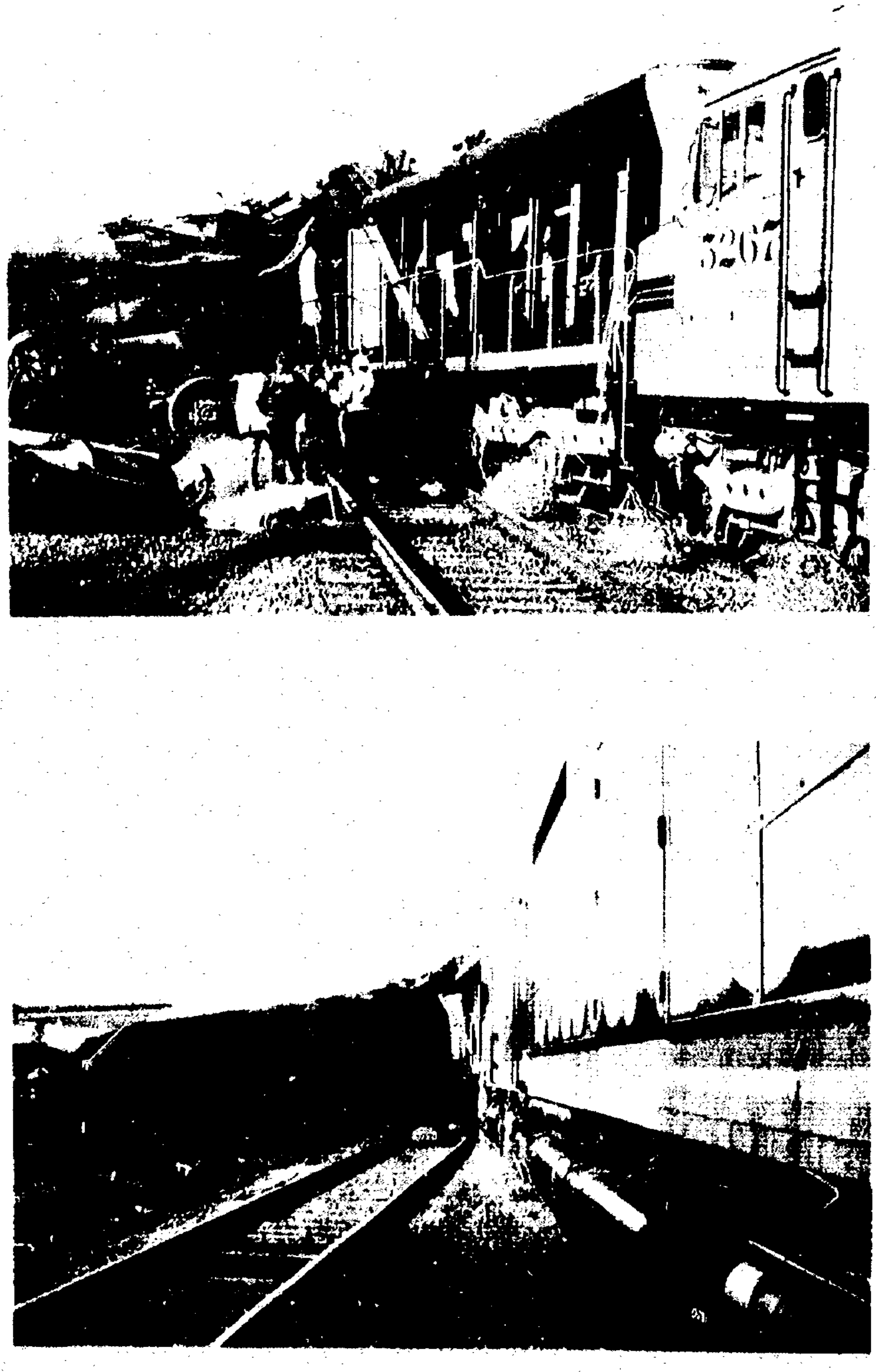

Figure 3.—Damage to fuel tank on third locomotive unit of train 891 at Corona, California.

Existing Data on Locomotive Derailments and Diesel Fuel Spills

The 1990 accidents involving locomotive fuel tank fires discussed in the previous chapter prompted the Safety Board to review available accident data to determine the prevalence of fuel-tank-induced fires in rail collisions. The Safety Board concluded in its report of the 1990 accident at Corona, California, that "neither research nor accident data exist about the effect of ruptured or leaking locomotive fuel tanks in railroad accidents in which postcrash fires occurred." The Federal Railroad Administration (FRA) does not record data on locomotive fuel tank breaches, diesel fuel spills, or diesel fuel fires. The Safety Board, therefore, recommended that the FRA take the following action:

> *R-91-40*
>
> To enhance current accident data collection and analysis, require the recording of data pertaining to postcrash fires involving locomotive fuel tank rupture and spillage, as well as types of locomotive units involved.

The safety recommendation was issued to the FRA on August 23, 1991. On January 8, 1992, the FRA responded to the recommendation, stating:

> The FRA is currently reviewing and revising its accident/incident forms and reporting procedures. Information on the performance of locomotive fuel tanks and the types of locomotive will be included in the new reporting procedures. In the interim, we will instruct the railroads to include this information in the narrative portion of the report form. The information will then be included in our accident/incident data base and available for our joint use in accident analysis.

In a letter of April 1, 1992, the Safety Board acknowledged FRA's response and classified Safety Recommendation R-91-40 as "Open—Acceptable Response," pending a progress report on FRA's activity in this area. On May 18, 1992, Safety Board and FRA staff met to discuss several safety recommendations that were being held in an "open" status, including R-91-40. At the meeting, the FRA indicated that the review of report forms and reporting procedures was continuing. A further meeting between FRA and Safety Board staff was to be scheduled to provide guidance in developing the data forms. On September 30, 1992, the FRA provided Safety Board staff draft copies of revisions to accident/incident data reporting forms that address fuel tank damage and fuel spills.

Data exist on locomotive derailments. According to the FRA, in 1991, there were 237 accidents/incidents involving locomotive derailments; a total of 494 locomotives were derailed in these accidents.[5] As a result of these accidents, 7 onboard locomotive crewmembers were killed and 214 received various degrees of injuries. Table 1 highlights FRA data related to the 1991 accidents involving derailed locomotives that resulted in the fatal injuries to seven crewmembers.

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[5] Railroads are required to file monthly accident/incident reports with the FRA's Office of Safety in accordance with Title 49 Code of Federal Regulations (CFR) Part 225. The reporting threshold that determines which accidents must be reported is adjusted to reflect the effect of inflation on damage costs. The reporting threshold in 1991 was $6,300. According to the FRA, there were 2,658 train accidents reported in 1991. See appendix A for FRA's definitions of train accident, train incident, and nontrain incident.

Table 1.–FRA data on 1991 accidents involving derailed locomotives that resulted in fatal injuries to crewmembers

Date	RR	Location[a]	Ambient temp.	Locomotive speed	Type of accident	Crewmembers	
						Injuries	Fatalities
6/19/91	BN	Convers, WY [Bill, WY]	56	63	Rear-end collision	0	1
8/30/91	BN	Flower, MT [Ledger, MT]	97	E44[b] W50	Head-on collision	3 2	1 2
9/17/91	NW	Knox, IN	58	E26 W25	Head-on collision	3 2	0 1
9/30/91	DRG W	Cliff, CO [Pinecliffe, CO]	60	27	Struck landslide	2	2

[a] The location designated in Safety Board files is indicated in brackets.
[b] E = eastbound; W = westbound.

According to the FRA, in 1991, there were 22 fatalities among employees on duty involving the movement of railroad on-track equipment. The 7 fatalities to crewmembers onboard locomotives that derailed represents about 30 percent of the 22 fatalities. The remaining 15 fatalities primarily involved employees on duty who were struck by moving equipment. The FRA data also indicate that in 1991, there were 13 additional fatalities among employees on duty: 12 from nontrain incidents and 1 from a motor vehicle accident at a highway grade crossing.

The Clean Water Act[6] requires that diesel fuel spills be reported to the Environmental Protection Agency through the National Response Center (NRC).[7] NRC data indicated that 182 reports of diesel fuel spills were made by the railroad industry in 1991.[8] Of these reports, 32 corresponded to accidents reported to the FRA involving derailed locomotives. An additional 80 to 90 of the reports made to the NRC involved locomotive fuel tank rupture or puncture as a result of derailments or the tank striking objects on or near the roadbed. However, the damage may not have met the FRA reporting threshold (the NRC reports did not indicate the amount of damage). Other causes of fuel tank spills according to the NRC reports included leaking gaskets, malfunctioning fuel pumps and fuel sensors, and overfill due to operator error. In several instances, the cause of the diesel fuel spill was listed as unknown.

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6 The Federal Water Pollution Control Act of 1974, as amended, 33 U.S.C. 1251 et seq., is also known as the Clean Water Act.

7 The National Response Center, located in U.S. Coast Guard Headquarters in Washington, D.C., is a continuously staffed communications center that receives telephonic notification of major pollution incidents and transportation accidents, and relays that information to the appropriate Federal agency.

8 According to the Association of American Railroads (AAR), because of the intricacies of the reporting requirements, member railroads have been instructed to report all diesel fuel spills.

Description of the Nature of 1991-1992 Railroad Accidents Involving Locomotive Fuel Tank Breaches and Fuel Fires

Summary of 1991 Accidents

In support of this study, the Safety Board reviewed the data it had collected in its investigations of railroad accidents in 1991 that involved a locomotive derailment (as previously mentioned, there were 237 locomotive derailment accidents/incidents in 1991, according to FRA data).[9] The purpose of the review was to document, to the extent possible, fuel tank damage, fuel spillage, fuel fires, and crewmember injuries in these derailments.

The location, the date, and the railroads involved in the 29 accidents investigated by the Board in 1991 that involved a locomotive derailment are listed in table 2. The derailments resulted from various types of accidents, including head-on collisions with standing trains or cars; rear-end collisions with standing trains or cars; head-on collisions involving two moving trains; sideswipes into standing or moving consists; collisions with track maintenance-of-way equipment; grade crossing collisions; track conditions; debris on the track structure; and washouts.

The number of locomotive units on the accident trains varied from 1 locomotive unit to 10 units. A total of 123 locomotive units were on the trains involved in the 29 accidents, of which 83 units derailed and 23 did not derail.[10] (See appendix B, table 3.) For the remaining 17 units, it could not be determined if the units derailed. In some instances, the locomotives were removed before Safety Board investigators arrived on scene, and the position of some locomotives involved in the accident had not been documented.

The Safety Board examined various factors with respect to the derailed locomotives, including tank damage, fuel spillage, and fire. Of the 83 locomotive units that derailed, the fuel tanks on 55 of these locomotives (66 percent) sustained various degrees of damage.[11] (The fuel tank on only 1 of the 23 locomotive units that did not derail was also documented as damaged.) The fuel tanks on 12 of the 83 locomotive units that derailed were known not to have sustained damage. The condition of the fuel tanks on the remaining 16 locomotives that derailed was not known. (See figure 5.) Again, in some instances, the locomotive was removed from the scene

[9] The Safety Board investigated a total of 100 railroad accidents in 1991, 29 of which involved the derailment of one or more locomotives. The Board's criteria to investigate railroad accidents is based primarily on safety issues. Further, the Safety Board tends to investigate the more severe accidents in which crewmember injuries and fatalities are likely to occur.

[10] Of the existing locomotive fleet, about 75 percent are manufactured by General Motors (GM) and 25 percent by General Electric (GE). (See discussion in the section "Background Information on Locomotive Fleet Size, Fuel Tanks, and Diesel Fuel.") Of the 83 units that derailed, 20 (24 percent) were manufactured by GE, 47 (57 percent) by GM, and 3 by other manufacturers. The make of 13 units was not recorded.

[11] Of the tanks damaged, 15 (27 percent) were manufactured by GE, 37 (67 percent) by GM, and 1 by another manufacturer. The manufacturer of two damaged tanks was not recorded.

Table 2.—Location and date of the 1991 accidents involving locomotive derailments reviewed by the National Transportation Safety Board during its safety study on locomotive fuel tank integrity

Event number	Location of accident	Date of accident	Railroad	NTSB accident number
1	Roebuck, SC	01/19/91	BN	NYC91FR004
2	Northbrook, IL	02/27/91	METRA	CHI91FR018
3	Waterfall, WY	03/04/91	UP	CHI91FR019
4	Lompoc, CA	03/19/91	SP	LAX91FR007
5	Peotone, IL	03/27/91	AMTRAK	CHI91FR021
6	Gypsum, KS	03/28/91	DRGW	CHI91FR022
7	Melrose, MT	04/04/91	UP	LAX91FR009
8	Sodorus, IL	04/05/91	NS	CHI91FR024
9	Chase, MD	04/12/91	AMTRAK	DCA91FR005
10	Roper, KS	05/28/91	UP	CHI91FR028
11	Frisco, TX	06/16/91	BN	CHI91FR030
12	Bill, WY	06/19/91	BN	LAX91FR011
13	Baltimore, MD	06/28/91	AMTRAK	NYC91FR019
14	Fountain City, WI	07/08/91	BN	CHI91FR033
15	Dunsmuir, CA	07/14/91	SP	LAX91FR013
16	Douglas, WY	07/25/91	BN	LAX91FR014
17	Dobbin, TX	07/30/91	BN	CHI91FR034
18	Sprague, WA	08/18/91	BN	LAX91FR016
19	Ledger, MT	08/30/91	BN	DCA91MR009
20	Knox, IN	09/17/91	NS	DCA91MR010
21	Merrill, OR	09/17/91	SP	LAX91FR018
22	Mountain Home, ID	09/22/91	UP	LAX91FR019
23	Pinecliffe, CO	09/30/91	SP	LAX91FR022
24	Gouverneur, NY	11/10/91	CONRAIL	NYC92FR004
25	Minneapolis, MN	11/22/91	BN	CHI92FR006
26	Harrisburg, OR	11/22/91	SP	LAX92FR003
27	Belen, NM	12/05/91	ATSF	LAX92FR004
28	Palatka, FL	12/17/91	CSX	DCA92MR001
29	Cottondale, FL	12/20/91	CSX	NYC92FR005

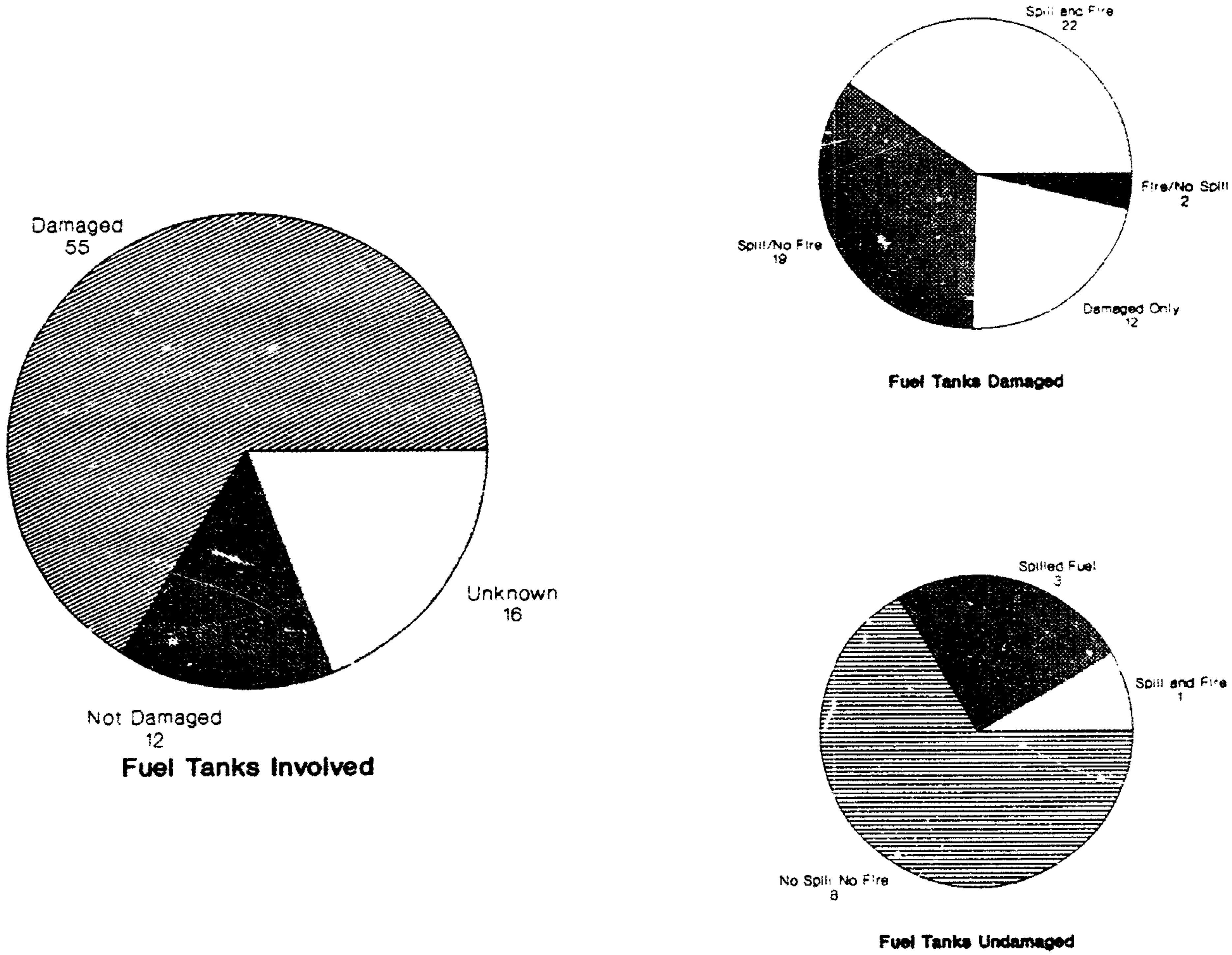

Figure 5.—Status of fuel tank damage on the 83 locomotives that derailed.

before Safety Board investigators arrived. In other instances, the fuel tank was either partially or deeply buried, and, consequently, the condition of the fuel tank could not be ascertained. In most instances, however, if fuel was not spilled and fire was not involved, the condition of the tank was not documented. Based on the assumption that none of the tanks on the undocumented locomotives was breached, it can be conservatively concluded that at least two-thirds of the fuel tanks on the locomotives that derailed were damaged.

Of the 83 locomotives that derailed, fuel was documented as having spilled from 47 tanks (56 percent). (Fuel also spilled from one locomotive that did not derail.)[12] Of the 55 damaged tanks, 41 (76 percent) spilled fuel (fig. 5). (Fuel spilled from four tanks that were not damaged and from two tanks, the damage of which was not known. (See table 3 in appendix B.)

Of the 83 locomotives that derailed, 23 units (28 percent) caught fire from the ignition of spilled diesel fuel from their tanks. (See figure 5.) Two additional locomotive units were documented as having caught fire, but fuel spillage was unknown. (In these two instances, the locomotive units were believed to have caught fire as a result of leaking fuel from the tanks of adjacent locomotive units that ignited.)

A total of 33 crewmembers were onboard the 25 locomotive units that caught fire; the fires were a consequence of nine accidents. A total of seven crewmembers were fatally injured on locomotives that caught fire in four of the nine accidents: Bill, Wyoming (one fatality); Ledger, Montana (three fatalities); Knox, Indiana (one fatality); and Pinecliffe, Colorado (two fatalities).[13] (Five locomotive units were involved in the four accidents: in two instances, two crewmembers that were fatally injured were onboard one locomotive unit that caught fire.) Nine other crewmembers onboard locomotive units that caught fire were seriously injured; another nine received minor injuries, and eight were uninjured.

Crash Dynamics and Nature of Damage of Fuel Tanks in Three 1992 Accidents

To learn more details about damage to fuel tanks in derailments, the Safety Board documented the sequence of events associated with fuel tank damage and diesel fuel spills in three accidents in early 1992 in which a locomotive derailed. The accidents included (a) a low-speed head-on collision in which one locomotive overrode another, (b) a rear-end collision with locomotives derailing and overturning, and (c) a side collision that also resulted in locomotives derailing and overturning. Metallurgical examinations of the fuel tanks involved in two of the derailments were also conducted in conjunction with the onsite investigation. Details of the accidents and fuel tank damage follow.

Kansas City, Missouri.—About 3:00 p.m. central standard time on March 7, 1992, Kansas City Southern Railway (KCS) freight train 81 South, traveling at a reported 10 mph through a 90°-angle railroad crossing, struck Gateway Western Railway (GWWR) train 1-332-07 East at Kansas City, Missouri. Train 1-332-07 East was traveling at 25 mph. Train 81 South struck the second locomotive unit of train 1-332-07 East. The locomotive of train 81 South consisted of two General Motors (GM) locomotive units, KCS714 and KCS725. The locomotive of train 1-332-07 East consisted of three GM locomotive

[12] Of the tanks that spilled fuel, 14 (29 percent) were manufactured by GE, 31 (65 percent) by GM, and 1 by another manufacturer. The manufacturer of two of the tanks that spilled fuel was not recorded.

[13] The cause of death of two of these crewmembers was attributed to thermal burns and smoke inhalation—one in the Knox, Indiana, accident, and one in the Pinecliffe, Colorado, accident. The cause of death of the other five crewmembers was attributed to blunt traumatic injuries suffered before the fire.

units: SF2354, SF2052, and GWWR2037. The three crewmembers on train 81 and the two crewmembers on SF2354 sustained minor injuries jumping off the trains prior to impact.

The first unit of the three-unit locomotive consist for train 1-332-07 East, SF2354, had just passed the railroad crossing. The second unit of its consist, SF2052, was struck just behind its lead trucks from the side by the first locomotive unit of the two-unit consist of train 81 South, KCS714. The force of the collision of the KCS unit derailed SF2052. As the collision progressed, locomotive unit SF2052, while derailed, continued to move forward, as did the striking locomotive, KCS714. KCS714 overturned, and a fuel leak occurred at a crack in the bottom of the tank as a result of these events. KCS714 was dragged along the side of locomotive unit SF2052.

The fuel tank on SF2052 was severed from its mountings as the fastening bolts sheared. The tank on this unit subsequently struck the rail and track structure. As the tank bolts and fastenings sheared, the tank was driven back about 30 inches. During the course of this event, both filler pipes were sheared at the center sill access holes and the tank disengaged and dropped to the ground. The fuel tank on locomotive SF2052 was punctured at two locations on its bottom and torn at the lead and trail end walls (fig. 6). The derailed locomotive unit, SF2052, was shoved and rotated by the following locomotive unit, GWWR2037. The GWWR2037 then came in contact with the overturned locomotive unit KCS714 and the upright SF2052. The sidewalls of the fuel tank on the left side of locomotive unit GWWR2037 were torn open (fig. 7), as was the weld that fastens the trailing fuel tank bulkhead to the side wall on the right side of the locomotive. The lead locomotive unit of 1-332-07 East, SF2354, was also rotated to the south and derailed.

The derailment marks on the bottom of the fuel tank of SF2354 indicate that the tank struck the rail and track structure. The impact on the tank resulted in rail impact dents to the tank bulkhead at the leading and trailing ends of the tank. Heat discoloration on the metal surfaces, indicating high temperature, occurred on the trailing bulkhead, probably created by the friction of the tank moving over the rail. The weld fastening the trailing fuel tank bulkhead to the side of the tank and the tank's bottom plate structure separated in the weld. A hole about 20 inches in length developed along this tank tear.

A condensation water-collecting tank drain was attached adjacent to the rear bulkhead of this tank. The weld to this structure was also torn at an area adjacent to the terminus of the tank drain plug bolt. Because this is the lowest point in the tank, water collects at this location and can be drained from the fuel tank at the drain plug. The fuel from the tank drained out from this trailing corner location from both the water drain collection unit and the tear.

As a result of the collision damage, four of the five fuel tanks involved in the collision were ruptured (the tank on KCS725 was not ruptured), spilling most of the fuel contained therein in the derailment area. No fire occurred. Safety Board investigators examined the traction motor and other electrical cables, some of which were severely damaged and severed. No evidence of arcing at or near the locomotive fuel tanks was observed.

The metallurgical examination revealed no pre-existing corrosion damage. All fractures examined were typical of overstress separations.

Fulton, Kentucky.—On March 22, 1992, at about 5:03 a.m. central standard time, Illinois Central Railroad Company (IC) train Extra 9570 North, traveling about 9 mph, collided head-on with IC train Extra 3105 South, traveling about 20 mph, at the south end of a 1° curve at MP 403.9 in Fulton, Kentucky. The weather was clear.

IC train Extra 9570 North consisted of three locomotive units: 9570, 9607, and 9450. All were GM units. IC train Extra 3105 South consisted of three GM locomotive units: 3105, 3128, and 3124.

When the two trains collided, units 9570 and 9607—the first and second locomotive units in the consist of train Extra 9570 North—derailed, but the fuel

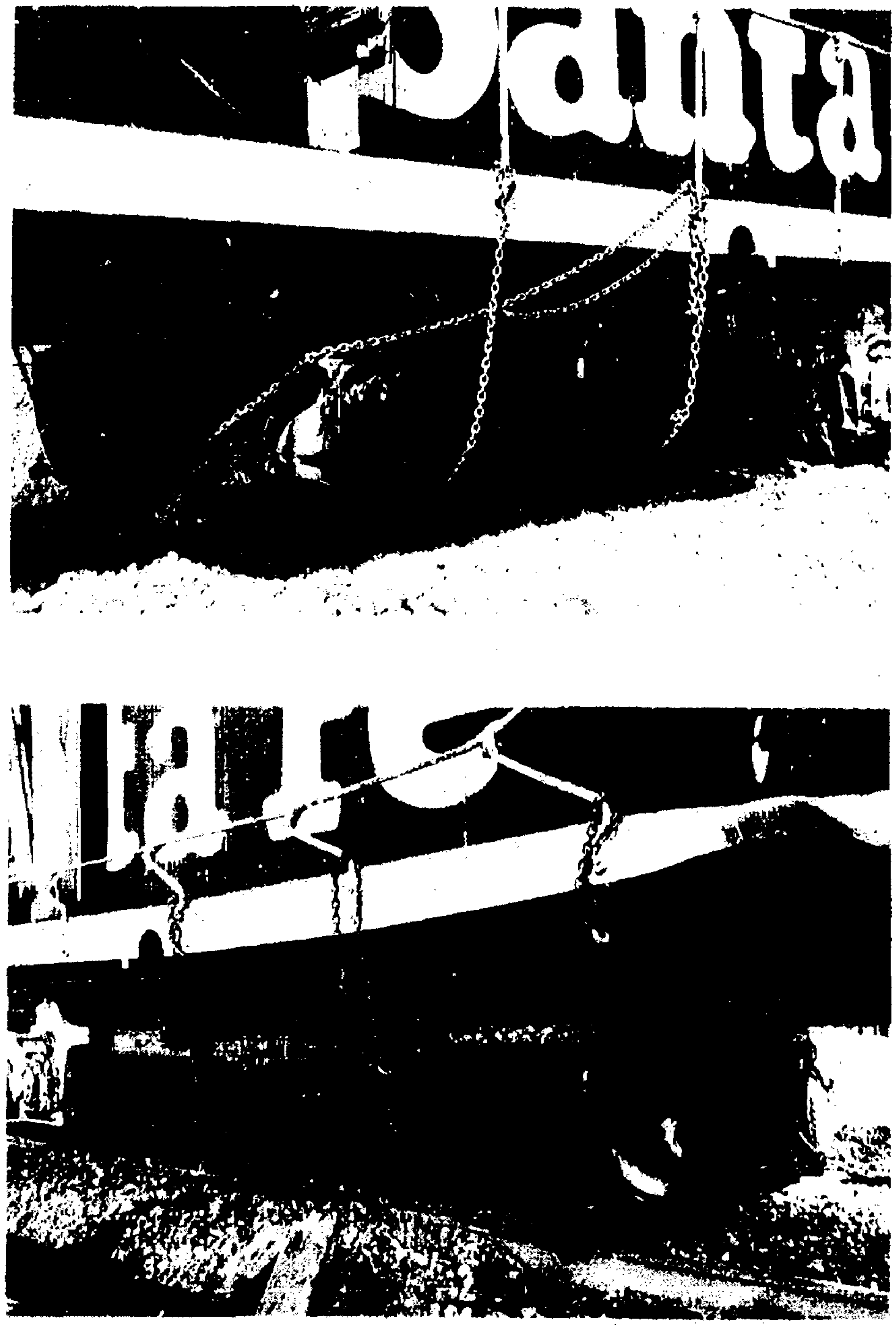

Figure 6.—Damage to fuel tank on locomotive unit SF2052 at Kansas City, Missouri.

Figure 7.—Damage to locomotive fuel tank on locomotive unit CWRR 2017 at Kansas City, Missouri. "A" [illegible] "F" refer respectively to the aft and forward walls of the fuel tank.

tanks were not damaged and no diesel fuel was spilled. Locomotive unit 9450, the third unit in this consist, did not derail. The fuel tank was undamaged and no fuel was spilled.

The locomotive units on the southbound train (Extra 3105) struck the opposing consist. The lead locomotive unit of this consist, 3105, overrode locomotive unit 9570 (fig. 8). The fuel tank on the overriding locomotive unit was dented and ruptured (fig. 9). A tear at the tank side and bottom end plate weld occurred. All of the fuel was lost from this tank.

Locomotive unit 3128 derailed and the fuel tank was dented; however, no fuel was lost. Locomotive unit 3124 was undamaged. No diesel fuel fire occurred in this accident. A detailed metallurgical examination of the fuel tanks involved in this accident was not conducted because there was no evidence of damage other than that attributed to collision forces. The conductor on Extra 9570 was fatally injured in this accident. The engineer on Extra 9570 and three crewmembers on Extra 3205 sustained minor injuries.

Eggleston, Virginia.—On March 22, 1992, about 9:55 a.m. eastern standard time, Norfolk Southern Corporation (NS) freight train 66V421 was proceeding through a 3-2° curve near Eggleston, Virginia, at about 22 miles per hour, when it collided with the rear of a 150-car standing coal train. At the time of the accident, it was 38° F and snowing.

Freight train 66V421 consisted of 4 locomotive units and 104 cars. The locomotive units in the order of their entrainment were General Electric (GE) unit NS3963, GE unit NS3951, GM unit BN7021, and GM unit BN1106. The fuel tanks on the first three units were damaged and the fuel was spilled, but there was no fire.

The two train crewmembers placed the brakes in emergency and jumped off the locomotives before the collision. They each sustained minor injuries.

Figure 8.—Damage to overridden locomotive unit 9570 at Fulton, Kentucky.

Figure 9.—Damage to fuel tank of overriding locomotive unit 3105 at Fulton, Kentucky.

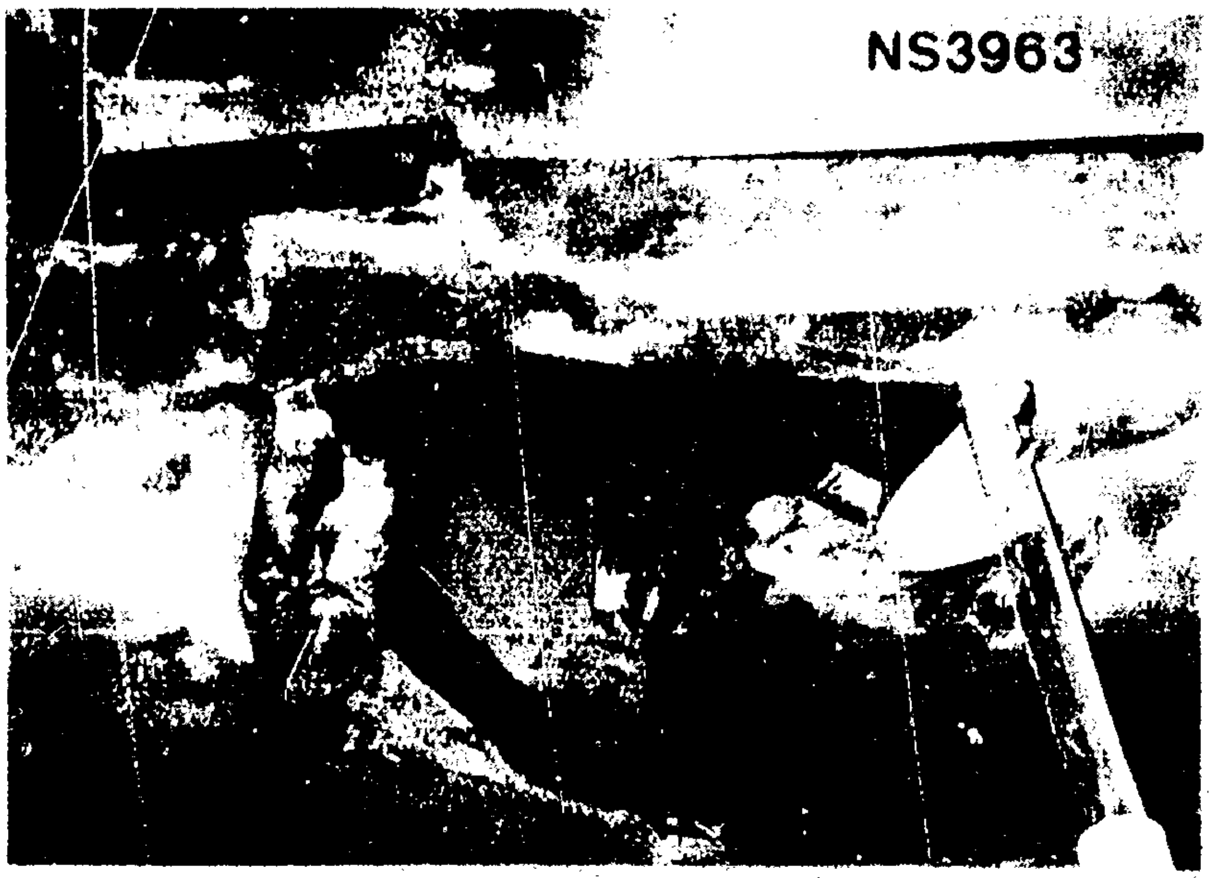

Figure 10.—Damage to the leading end of the bottom of the fuel tank from locomotive unit NS3963. View looking up and opposite the direction of travel. (Eggleston, Virginia.)

The first unit of the locomotive consist, NS3963, struck the rear coal car of the standing train. As this event occurred, the coupler draft gear of this locomotive unit was restrained by the coal car as the locomotive unit moved forward. Subsequently, the locomotive draft gear pocket was severed from the lead end (direction of travel) of this locomotive unit.

The locomotive derailed. The unit's front trucks overrode the draft gear pocket.[14] A rail was fractured and was overturned. The locomotive began to overturn to the inside of the curve. The derailed locomotive's air reservoir located to the front of the fuel tank was punctured by a rail. Subsequently, the lead end (by direction of travel) of the fuel tank was struck by disengaged locomotive components and by the rail. The overturned rail punctured the bottom of the fuel tank, but there was no fire.

A large hole, about 2 feet in diameter, was found in the bottom surface of the fuel tank adjacent to the leading end of the tank. As shown in figure 10, flaps of metal from the perimeter of the hole were bent upward into the tank. In addition, some of the tank internal structure in the vicinity of the hole was heavily deformed and torn.

The bottom of the fuel tank was also breached in three other areas. A localized area of the tank bottom near the leading end and approximately above the right rail had been crushed upward and the bottom plate split in two locations. Two 6-inch-long punctures were found one-third of the way back from the leading end along the left side of the tank bottom. The sediment channel at the trailing end of the tank had been crushed (see figure 11), with pieces of the channel splayed opposite to the direction of travel. Other scraped and dented areas (that did not result

[14] The draft gear pocket provides the lateral, vertical, and longitudinal limits of coupler travel.

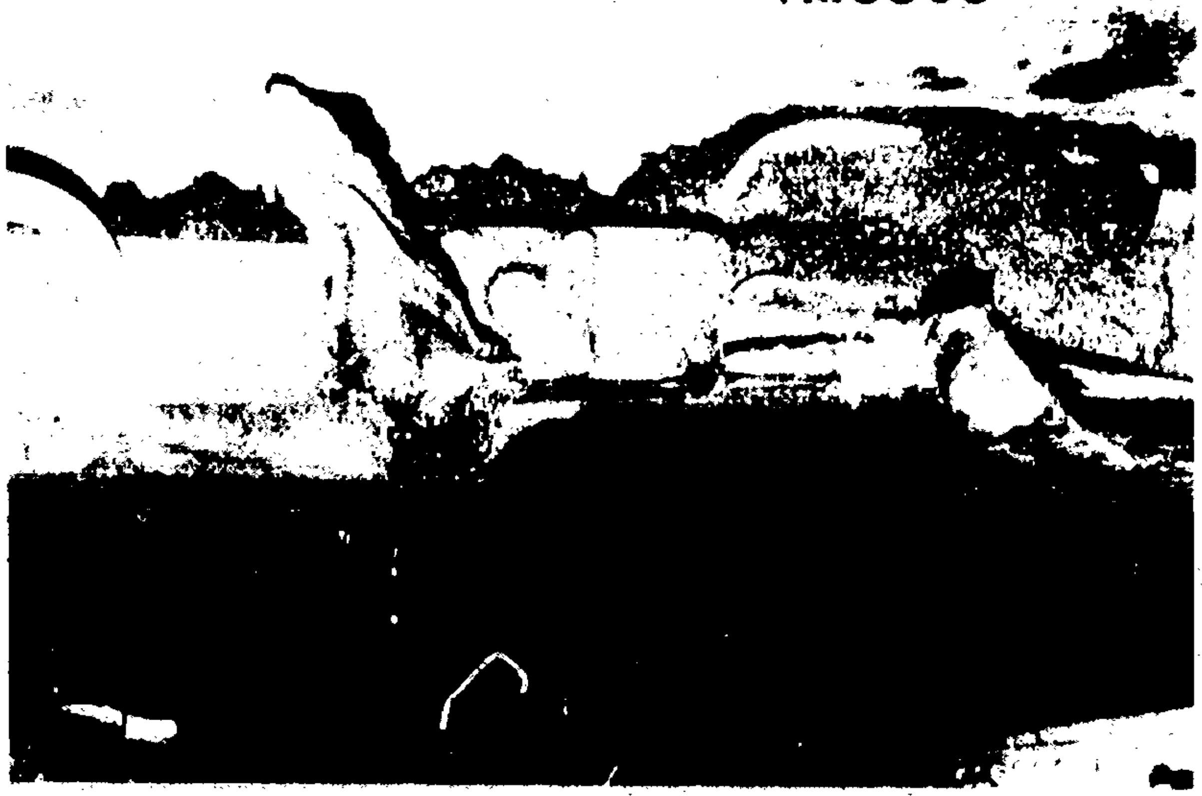

Figure 11.—Damage to the sediment channel at the trailing end of the fuel tank on locomotive unit NS3963. View looking in the direction of travel at the trailing end.

in localized breaching of the tank) were noted on the tank bottom.

The following locomotive unit, NS3951, also derailed and overturned to the inside of the curve. The bottom of the fuel tank from this locomotive unit was breached in two locations. A puncture was found in the tank bottom about 6 feet from the trailing end of the tank. The puncture was above the right rail and measured 4 inches long by about 3/4 inch wide (fig. 12). In addition, the sediment channel at the trailing end of the tank was crushed and split in an area above the right rail, as shown in figure 13.

Unit BN7021 also derailed but remained upright. The bottom of the fuel tank of this locomotive was breached in one location--in the sediment channel at the trailing end of the tank. As shown in figure 14, the channel was cut in a shape that matched the base of an overturned rail. The brace in figure 15 indicates the portion of the cut in the channel that would correspond to the bottom of the rail. Lips of metal extended in the trailing end direction from the perimeter of the cut area, consistent with the fuel tank moving forward over a stationary object. The bottom of the tank also contained a long crease that extended from the channel cut toward the lead end. A portion of this crease is visible in figure 14, indicated by the arrows. The crease is also indicated by the arrows in figure 15, in a view looking opposite the direction of travel

No evidence of corrosion or preexisting cracks was found on any of the fuel tanks examined.

The fourth locomotive fuel tank was not damaged or breached.

On the first two locomotive units, heavy electrical cables to the traction motors and other locations were observed to be severed or damaged. No evidence of arcing at these locations was observed by the Safety Board investigators. The fuel tank overflow pipes could have contributed to the fuel loss on the breached tanks; however, this could not be determined because the two lead locomotive tanks were also breached by the collision with the locomotive and track structure components.

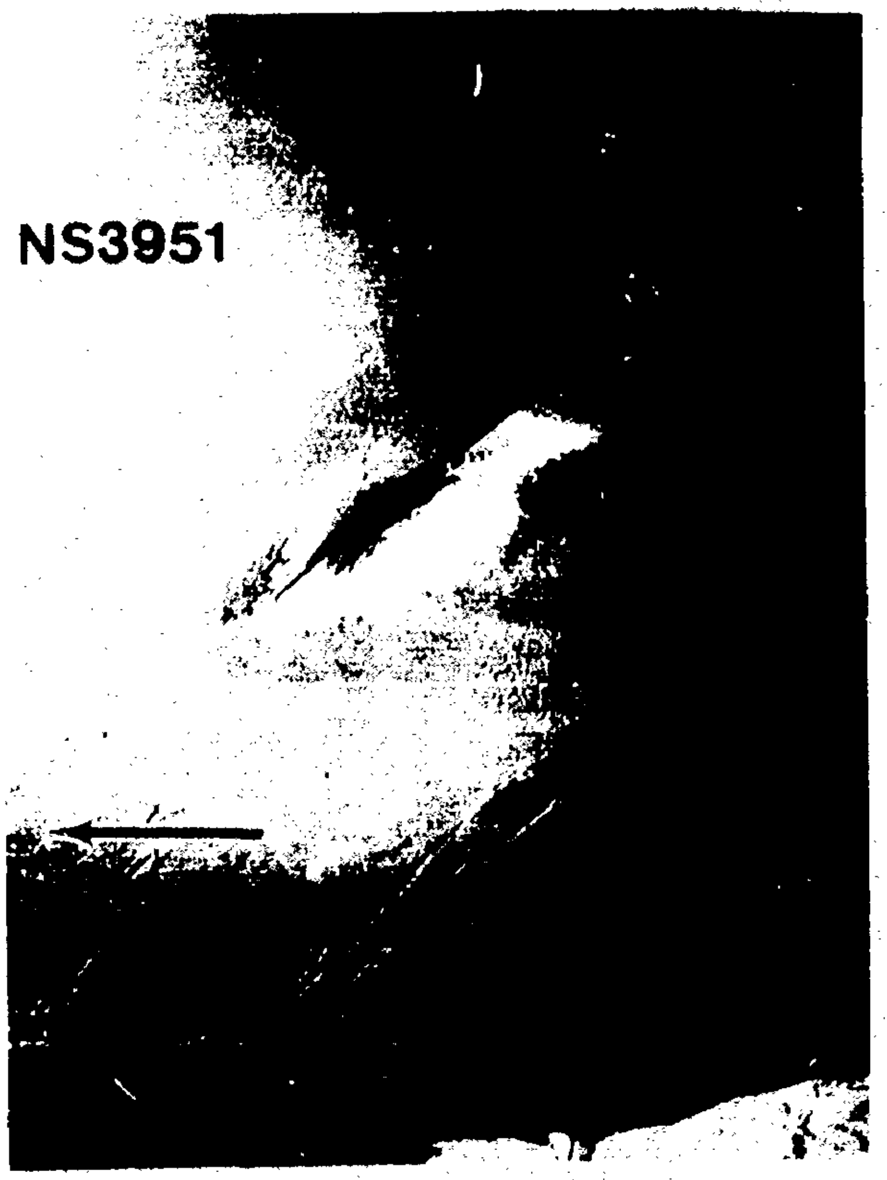

Figure 12.—Puncture area on the bottom of the fuel tank on locomotive unit NS3951. Arrow indicates the direction of travel.

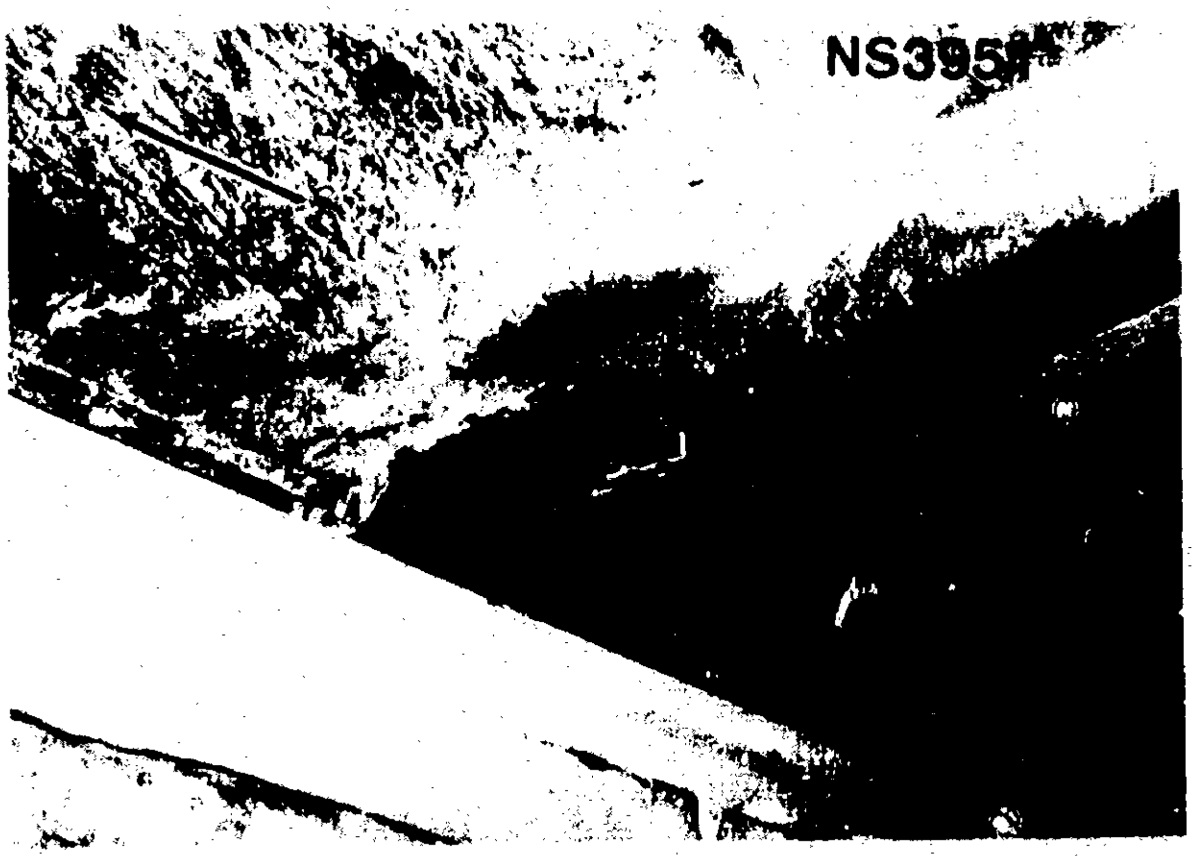

Figure 13.—Crushed and split sediment channel on the trailing end of the fuel tank on locomotive unit NS3951. Arrow indicates the direction of travel.

Figure 14.—Damage to sediment channel on the trailing end of the fuel tank from locomotive unit BN7021. View looking in the direction of travel. The brace indicates a portion of a cut that corresponds to the bottom of a rail. Arrows indicate a crease that extends from the cut toward the leading end.

Figure 15.—Arrows indicate the crease on the bottom of the fuel tank from BN7021. View looking opposite the direction of travel. The cut in the sediment channel is indicated by the brace.

Background Information on Locomotive Fleet Size, Fuel Tanks, and Diesel Fuel

Locomotive Fleet

The Safety Board received information from the Association of American Railroads (AAR) regarding the Nation's locomotive fleet size. Figure 16 illustrates the number of locomotives in service and the age distribution of the locomotive fleet, as of December 31, 1990.

Fuel Tank Design

The Safety Board contacted the two major locomotive manufacturers—General Electric and the Electro-Motive Division (EMD) of General Motors—regarding the design of locomotive fuel tanks. Of the existing locomotive fleet, about 75 percent are GM-manufactured locomotives (fig. 17) and 25 percent GE-manufactured locomotives (fig. 18). However, since 1989, about 60 percent of the new freight locomotives have been manufactured by GE.

According to the EMD, the fuel tank size is specified by the customer based on the distance between the customer's refueling facilities. The largest fuel tank currently built by the EMD holds 5,000 gallons and is 23 feet long. The end plate is 3/8-inch thick, and the fuel tank side wall thickness is 3/16 inch; both the end plate and the side wall are made of steel. According to the EMD, the fuel tank is a "lightweight, monocoque[15] structure" designed to support the weight of the fuel and to accomodate fuel sloshing. To accomodate the pressure loading during automatic fuel filling, the fuel tank has been designed to withstand a pressure load of 3-6 psi. The bottom of the fuel tank is 6 1/4 to 6 1/2 inches above the top of the rail.

General Electric also indicated that the fuel tank design is not typically specified by the purchaser beyond "a performance requirement (i.e., capacity)." The usual request, according to GE, is to provide the largest fuel capacity possible within applicable design limitations or constraints. These primarily include the "maximum allowable total locomotive weight and the available space (volume)."

According to GE, current design and construction practices include: a minimum wall thickness of 0.25 inch, an end plate thickness of 0.50 inch, provisions for purging impurities (water/sediment), and removability in at least one direction. A minimum 6-inch clearance between the top of the rail and the bottom of the fuel tank is a criterion for a newly constructed locomotive fully serviced (with fuel, water, oil, sand).

Federal Regulations and Industry Standards

Pertinent Federal regulations applicable to the locomotive fuel tank are contained in Title 49 Code of Federal Regulations (CFR) Part 229, as follows:

> 229.45 General Condition.
>
> All systems and components on a locomotive shall be free of conditions that endanger the safety of the crew, locomotive or train. These conditions include:

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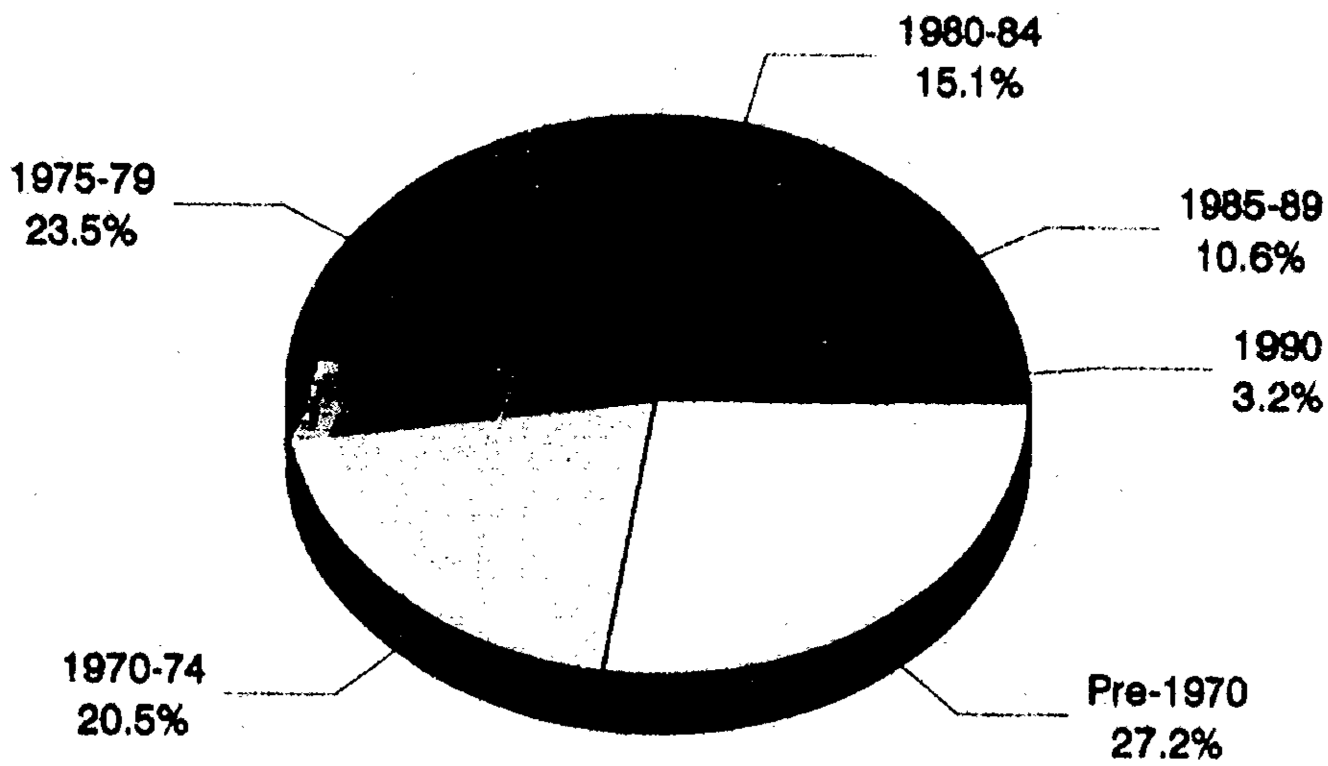
[15] A metal structure in which the covering absorbs a large part of the stresses to which the body is subjected.

BUILD DATE OF LOCOMOTIVES

(as of December 31, 1990)



Date built	Locomotives in age bracket	
	(Number)	*(Percent)*
01/01/90 - 12/31/90	608	3.2
01/01/85 - 12/31/89	1,989	10.6
01/01/80 - 12/31/84	2,837	15.1
01/01/75 - 12/31/79	4,432	23.5
01/01/70 - 12/31/74	3,852	20.5
Before 1970	5,117	27.2
Total	18,835	100.0

Figure 16.—Age distribution of U.S. locomotive fleet, as of December 31, 1990. (Source: Association of American Railroads.)

Figure 17.—GM locomotive. (Courtesy: General Motors.)

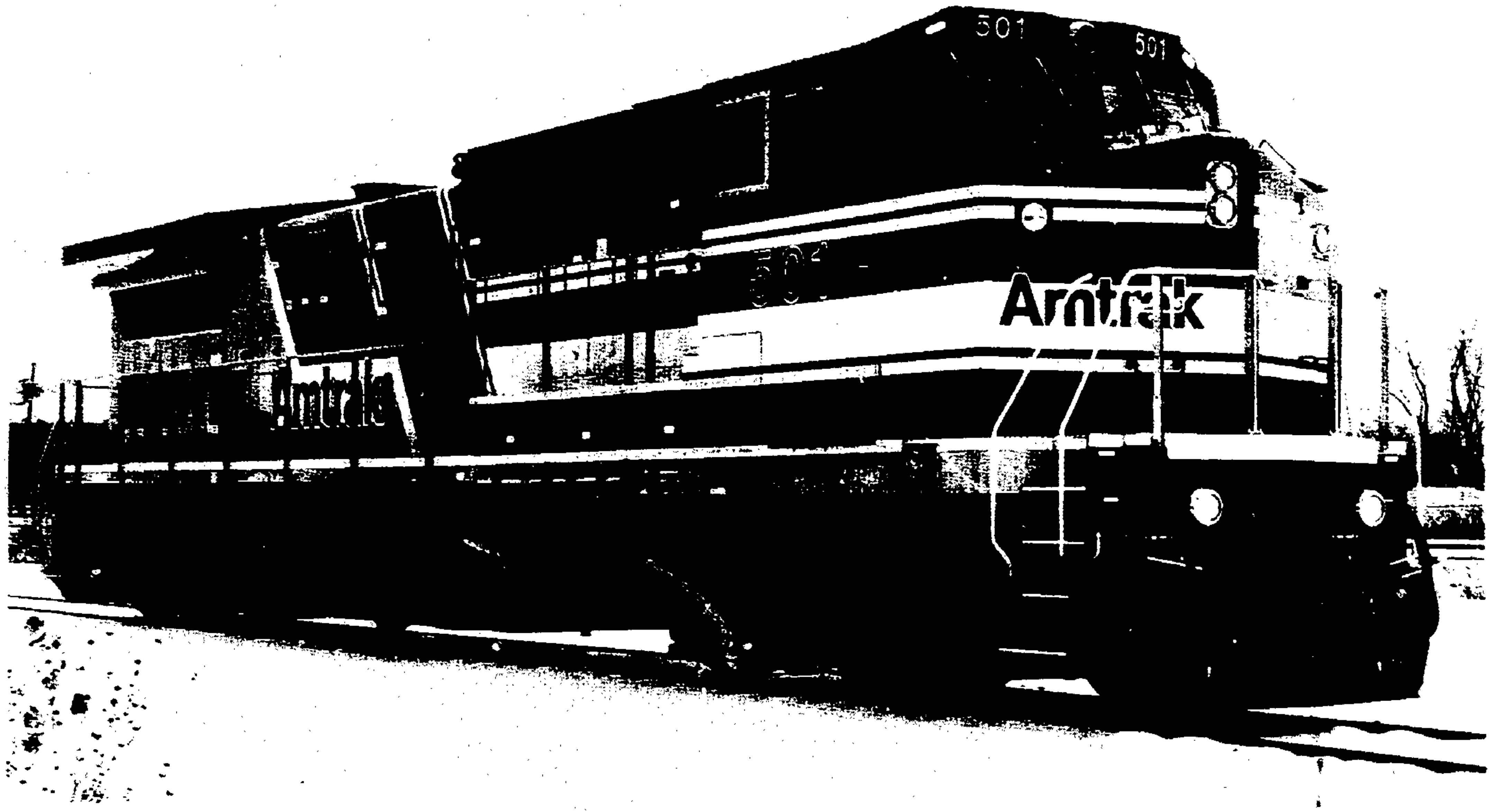


Figure 18.—GE locomotive. (Courtesy: General Electric.)

insecure attachment of components, including third rail shoes or beams, traction motors and motor gear cases, and fuel tanks; fuel, oil, water, steam, and other leaks and accumulations of oil on electrical equipment that create a personal injury hazard; improper functioning of components, including slack adjusters, pantograph operating cylinders, circuit breakers, contactors, relays, switches, and fuses; and cracks, breaks, excessive wear and other structural infirmities of components, including quill drives, axles, gears, pinions, pantograph shoes and horns, third rail beams, traction motor gear cases, and fuel tanks.

229.71 Clearance above top of rail.

No part or appliance of a locomotive except the wheels, flexible nonmetallic sand pipe extension tips, and trip cock arms may be less than 2 1/2 inches above the top of rail.[16]

Federal regulations regarding the inspection of locomotives are listed in appendix C. The fuel tank is not specifically mentioned as an item to be checked during the various inspections. Federal regulations do not address the design, size, or performance of fuel tanks.

The FRA informed the Safety Board in a letter dated July 28, 1992, that it is studying the need for additional Federal requirements for locomotive fuel tanks. The FRA's letter further stated:

> Accident data is being reviewed to determine the frequency and consequences of locomotive fuel tank failures. In addition, FRA's field personnel have been asked to collect on-site information about the extent of structural damage to locomotives involved in collisions. Fuel tank damage is an item of specific interest.

The AAR, Mechanical Division, establishes clearance standards for railroad equipment. (See appendix D.) The standards list the maximum width, for various truck centers, and the height to which cars (including locomotives) can be constructed. The standards also indicate that 2 3/4 inches above top of rail is the absolute minimum under any and all conditions of lading operation and maintenance.

Industry Initiatives to Improve the Integrity of Locomotive Fuel Tanks

Safety Board staff contacted several industry representatives and visited facilities of General Electric and the Electro-Motive Division of General Motors to discuss current and future considerations for improving the integrity of locomotive fuel tanks. Representatives from these two locomotive manufacturers indicated that the performance of fuel tanks in the collision and derailment environment has not been routinely monitored and that, consequently, the performance of fuel tanks has not dictated changes in the design.

Electro-Motive Division of General Motors.—According to information received from the EMD, there have been relatively few changes to the fuel tank design during the last 30 years. The most recent change in the design occurred about 7 years ago, when the fuel tank length was increased by 7 inches and the height by 2 inches, resulting in a fuel tank capacity increase from 4,500 gallons to 5,000 gallons. The EMD has considered several changes in the past, including increased strength material, increased thickness materials, compartmentalized

[16] According to the FRA, the above-the-rail clearance has historically been 2 1/2 inches, dating back to the period of steam engines. The clearance was established, in part, because of deviations in the track structure and the profile conditions of highway grade crossings.

fuel tanks, bladders in fuel tanks, raised fuel tanks, and rerouting of the fuel tank vent to minimize spillage. The EMD stated that feedback from one of its customer railroads indicated a concern about fuel loss and contamination of the environment resulting from fuel spills in derailments and accidents. However, no such changes in the design of the fuel tank are currently in service.

General Electric.—At the request of one of its customer railroads, GE constructed fuel tanks with a 1-inch end wall thickness and 3/4-inch bottom and side wall thickness. According to GE, the request was made in an effort to prevent fuel spills.

General Electric is currently working with Amtrak on a new design for a fuel tank that will be installed on 32 new Amtrak locomotive units. The new design involves tank compartmentalization to minimize fluid loss in the event of tank damage. According to information received from Amtrak, "This invention consists of dividing the tank into two or more compartments, along with a novel fill and vent system, to reduce the possible loss of fluid in the event of tank damage or it being tipped on its side." In addition, the fuel tank will be incorporated into the monocoque structure of the locomotive unit and will be about 29 inches above the top of the rail. According to a spokesperson for Amtrak, Amtrak specifies that the locomotive manufacturer stress test the locomotive structure to predict where strains or stresses on the structure may occur. The stress test is conducted with the use of a large press. Crash testing of the locomotive with the newly designed fuel tank is not planned. The FRA has indicated that it has been monitoring the development of this new Amtrak locomotive fuel tank.

Long Island Rail Road.—The Long Island Rail Road (LIRR) has contracted to build three "spill resistant locomotive tanks" that will be installed on the three FL-9 locomotives that the LIRR plans to operate into Penn Station in New York City. Each of the tanks holds about 1,200 gallons of fuel. The tanks have been constructed and will be installed on the locomotives in late 1992. According to a representative of the LIRR, fuel tank technology, as applied to military aircraft and race cars, was reviewed and was the basis for the specifications used to build the locomotive fuel tanks. According to the LIRR, features of the spill resistant fuel tank that distinguish it from a conventional locomotive tank are: (1) a structural steel outer tank with greater strength than the conventional tank, (2) a composite carbon fibre (kevlar) bladder of the same shape as the steel tank and inserted inside the steel tank, and (3) a set of open-celled foam blocks inserted inside the bladder; the foam blocks completely fill the inside space to prevent fuel sloshing and to reduce the rate of fuel leakage. (See figure 19.) The LIRR provided the following information with respect to the three features described above:

> The structural steel outer tank has been designed to protect from failure under normally encountered derailments and damage from debris. The tank is designed to support the weight of the locomotive on the running rails, such as can occur in a derailment. The tank is designed to accept up to a 250,000 pound horizontal load without failure; this load could occur in a derailment or an encounter with large debris. The tank sides, end, and bottom are better designed than conventional tanks to withstand puncture and denting by small objects at high velocities.
>
> The bladder installed in the spill resistant tank has high tear and puncture resistance. Therefore, in addition to providing a secondary container for the fuel, it provides a second line of defense against puncture and resultant leaking should the steel tank be penetrated.
>
> The foam inserts inside the spill resistant tank provide slosh resistance for the fuel. The foam will reduce the fuel leak rate over that resultant from a puncture in a conventional steel tank. The foam also reduces the risk of explosion associated with pockets of vaporized fuel.

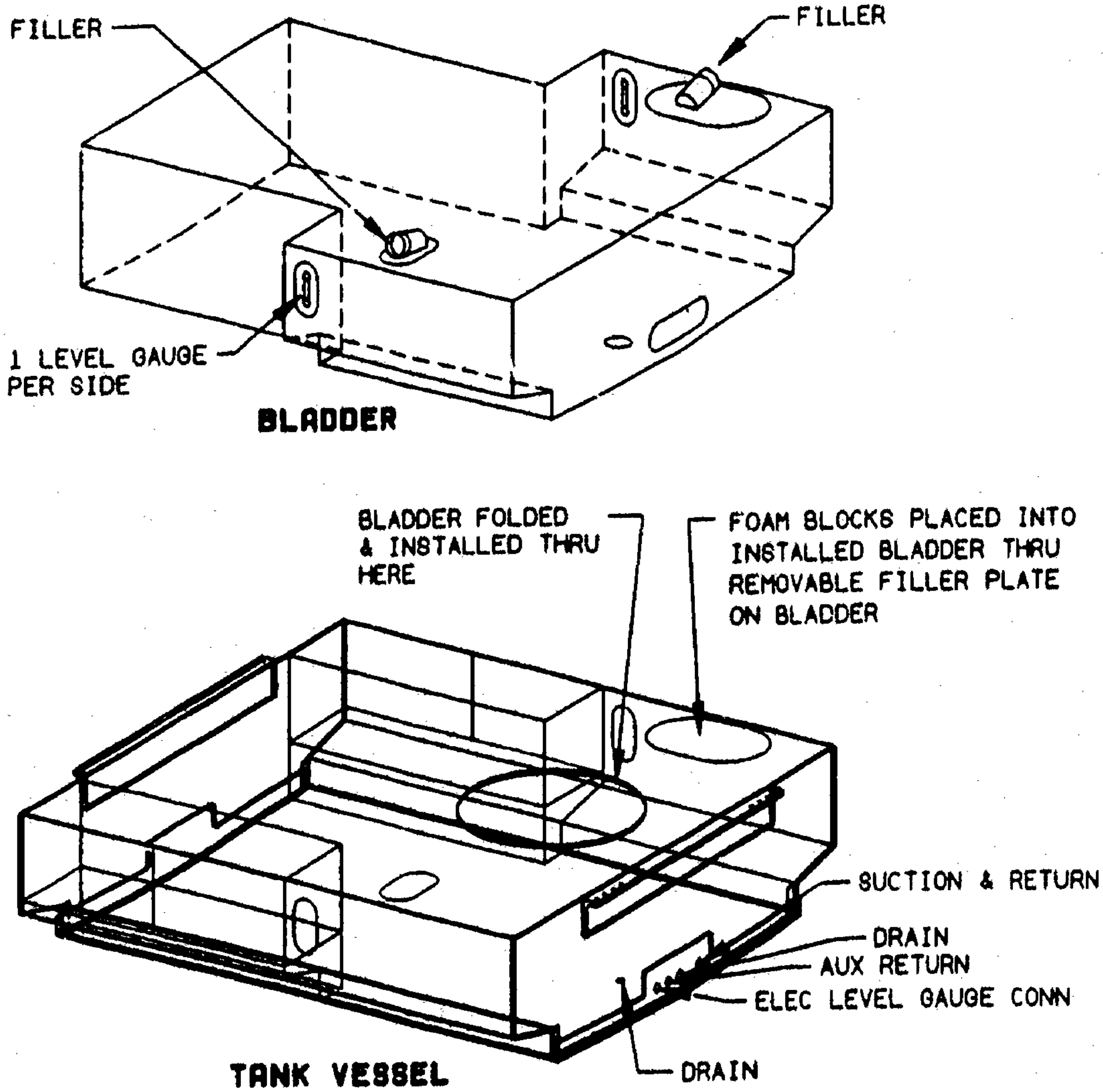


Figure 19.—Schematic of the Long Island Rail Road "spill resistant locomotive tank." (Courtesy: The Long Island Rail Road.)

Association of American Railroads.—The AAR provided the following information on July 24, 1992, regarding the Locomotive Committee's[17] activity on fuel containment and fuel tank integrity:

> ...the Locomotive Committee is overseeing research projects and closely monitoring the projects of individual railroads in developing and testing candidate fuel containment modifications under service conditions. One of the tasks which the Committee is currently attempting to come to grips with is that of reliably determining the extent of potential fuel containment systems. Findings to date indicate that:
>
> (1) There has not been any significant change in the flash point of the diesel fuels actually used in locomotives in recent years.
>
> (2) It is not clear that there really has been a trend toward an increasing number of spills or fires from locomotive fuel tank failures during accidents. One of the reasons for uncertainty in this respect is the data base. The reporting in general is now much more rigorous than in the past—which makes comparative performance analysis difficult.

The AAR further stated:

> Nevertheless, the AAR is committed, on behalf of member railroads, to continue the program to minimize fuel spillage and the occurrences of fires ensuing from collisions or accidents. From the plans, studies, and in-service tests which are firmly focused on producing a performance specification for fuel tank integrity, we [the AAR] should (within the next several months) have greatly enhanced assessments of the scope and nature of needs and a much better estimate of the effectiveness of most feasible solutions.

Diesel Oil Properties and Railroad Quality Assurance Programs

The Safety Board contacted several railroads—including Amtrak, Conrail, CSX, the Union Pacific, the Santa Fe, and the Burlington Northern—regarding the grade of diesel fuel used and the quality control programs implemented by the railroads to ensure that the diesel fuel meets the requirements of American Society for Testing and Materials (ASTM) Standard D 975.[18] With the exception of Amtrak, all the railroads surveyed indicated that throughout the year they use a grade 2 diesel fuel that has a flash point of at least 135 °F, somewhat higher than the ASTM required minimum of 125 °F.[19] Amtrak indicated that it uses grade 1 diesel fuel during the winter and grade 2 during the summer.

With respect to the quality control programs that monitor flash point, cetane number (equivalent to octane in gasoline), pour point, cloud point, water content, stability, specific gravity, and other properties (see appendix E), all the railroads surveyed

[17] The Locomotive Committee is a subordinate committee of the Mechanical Division Management Committee of the AAR, which oversees locomotive safety and environmental matters. The Locomotive Committee is charged with improving overall locomotive safety and minimizing safety risks to cab occupants. These committees are supported by the AAR Research and Test Department and the North American locomotive manufacturers.

[18] ASTM Standard D 975, "Standard Specification for Diesel Fuel Oils," covers the three grades of diesel fuel oils suitable for various types of diesel engines. (See appendix E.)

[19] The flash point is the temperature at which the fuel will emit sufficient vapors to support combustion. As indicated in ASTM Standard D 975, the minimum flash point temperature for grade 1 diesel fuel is 100 °F; for grade 2 diesel fuel, the minimum flash point temperature is 125 °F. A flash point much lower than 100 °F is likely to result in pre-ignition in the locomotive diesel engine, resulting in mechanical failures and possibly engine destruction.

indicated that such programs have been implemented, although the type of program varies among railroads. Some railroads, such as Conrail, have their own test laboratories. Other railroads contract for laboratory testing of their diesel fuel, while others rely on the fuel supplier for quality assurance. Union Pacific, for example, receives about 96 percent of its diesel fuel by pipeline and relies on the supplier or refinery for compliance with ASTM requirements. According to the railroads contacted, they buy fuel in bulk, but also have suppliers meet locomotives at given locations to fuel the locomotive directly from the tank truck. The railroads indicated that it is easier to monitor the quality of the fuel when it is bought in bulk, and that fuel delivered directly to the locomotives is usually not tested unless a problem develops. In the case of direct deliveries, the industry relies on the threat of canceling a contract with a supplier if the fuel does not meet the ASTM requirements.

Other Issues

Fuel Tenders.—In the late 1970s, Amtrak experimented with automatic, en route fueling of locomotives from fuel tenders coupled to the locomotives. The Burlington Northern (BN) implemented the concept of fuel tenders in 1982 and eventually had 175 fuel tenders in service, by converting tank cars to fuel tender service. According to the railroad industry, the driving force behind the use of fuel tenders is the high cost of diesel fuel oil at certain locations around the country.[20] The high cost of diesel fuel in Montana, in fact, was the main reason both Amtrak and BN tested (and in BN's case operates) fuel tenders on their Chicago-Pacific Northwest trains. The Soo Line Railroad has also used fuel tenders and in the late 1980s converted two retired diesel locomotives to fuel tenders. The FRA is unaware of any other railroad currently using fuel tenders.

The BN provided the following information regarding the use of diesel oil fuel tenders:

> The tenders are operated in the middle of the locomotive consist, and provide fuel to each locomotive on a demand basis, with the pumping and sensing devices mounted on each locomotive. There are no pumps on the tender car. Fuel is carried to each locomotive by a transfer line, which is installed on each locomotive, and is interconnected between locomotives and from locomotive to fuel tender by the use of flexible hoses and quick disconnect fittings. When the fuel level in the locomotive fuel tank drops to a certain level, a suction transfer pump on the locomotive is activated, which pumps fuel out of the transfer line and into the locomotive fuel tank. When the fuel level in the locomotive tank reaches a predetermined level upon the addition of more fuel, the transfer pump is deactivated. The transfer line between locomotives and on the fuel tender is never pressurized. Each locomotive draws fuel according to its need.

The FRA and the BN indicate that they have worked cooperatively over the years with respect to the use of fuel tenders. The FRA has an ongoing program to monitor the industry's use of fuel tenders. According to the FRA, there have been no accidents involving locomotive fuel tenders. Fuel tenders are considered by the FRA as part of the locomotive and, as such, are subject to the locomotive inspection requirements. There are no other regulations or standards that address this type of operation.

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[20] To provide some measure of the amount of diesel fuel used by the industry, the Burlington Northern alone burns over 500 million gallons of diesel fuel each year.

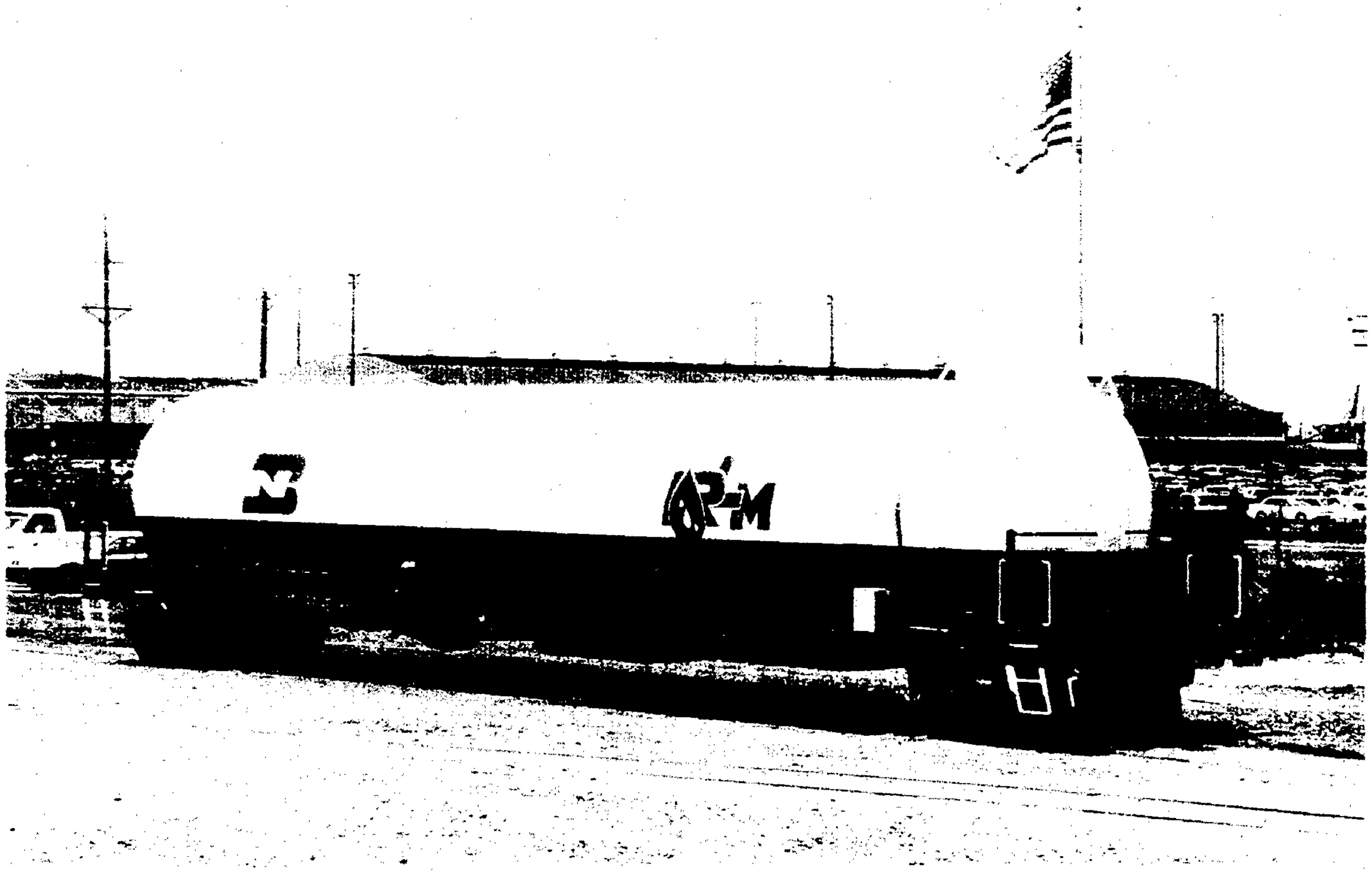


Figure 20 —Burlington Northern fuel tender of refrigerated liquid methane. (Courtesy Burlington Northern Railroad Company.)

Alternatives to Diesel Oil Fuel.—In the early 1980s, the BN retrofitted a GP9 locomotive to burn natural gas instead of diesel oil. According to the BN, the driving force at the time was "to put some money into quick-payoff research and development efforts to come up with an alternative to oil that was cheaper and less susceptible to severe price fluctuations."

Currently, the BN has entered into a joint project with Energy Conversions, Inc., to build equipment that will allow the railroad to convert an unspecified number of locomotives to run on either diesel fuel or refrigerated liquid methane (RLM), a purer version of liquified natural gas. Los Alamos National Laboratory in New Mexico is also involved in the project and is conducting safety studies on the proposal for the locomotive and the RLM fuel tender. (See figure 20.) At the request of the BN, Los Alamos National Laboratory in 1990 "assessed the relative safety of five alternative locomotive fuels in ten specific accidents."[21] As stated in the report, the "safety assessments were performed by asking an interactive panel of experts to estimate the hazardous behavior of the five fuels [compressed natural gas, refrigerated liquid methane, liquefied petroleum gas, methanol, and diesel fuel] in each specified accident."[22] The purpose of the report was "to address the relative safety of refrigerated liquid methane in railroad accidents as a locomotive fuel when compared with existing and other alternative fuels currently being promoted as safe alternative transportation fuels." The BN is looking at "methane-fueled locomotives to power unit coal trains in the Powder River Basin area of Wyoming and Montana, where natural gas prices are among the lowest in the nation." RLM also burns cleaner and with almost no pollution compared to other fuels. Among the conclusions reached in the report was that "diesel fuel was the safest, with a very small likelihood of fire, but in the absolute sense, the alternative fuels were only slightly less safe."

Vehicle [locomotive] fuels, including diesel oil and refrigerated liquid methane, carried in tank cars, are not cargo and, therefore, are not subject to the hazardous materials regulations contained in 49 CFR Parts 171 through 179. For example, if methane, a flammable gas, was transported in a tank car as cargo, it would be subject to the position requirements of Section 174.85 and could not be placed next to the locomotives.

[21] Kidman, R.B.; Krupka, M.C.; Streit, G.E.; and others. 1990. Safety assessment of alternative locomotive fuels. Los Alamos, NM: Los Alamos National Laboratory.

[22] Tenders were used for all five fuels, and the study assessed the safety of each alternate-fuel system, including the tender.

Discussion

Although improvements in track maintenance, employee training, and train separation should decrease the rate of occurrence of railroad accidents, clearly accidents will continue to occur. Therefore, it is important to examine, in accident investigations, methods to reduce the severity of these accidents. Although the Safety Board's data are limited and biased toward the more severe accidents (accidents that tend to result in injuries or fatalities), these data create concern about postcrash fires in the more severe derailments. Diesel fuel spills occurred from 47 (56 percent) of the 83 locomotives that derailed in the 29 locomotive derailment accidents investigated; further, fuel ignition occurred on 23 (28 percent) of the 83 locomotives that derailed.

Safety Board metallurgical examinations of fuel tanks conducted in conjunction with this study revealed that neither corrosion nor pre-existing cracks compromised the integrity of fuel tanks that were breached. Thus, fuel tank inspection and maintenance were not factors in the accidents investigated. The percentage of GE versus GM locomotives involved in the accidents investigated is proportional to the percentage in the Nation's fleet. The make of the locomotives involved in the accidents does not, therefore, appear to be a factor in the release of fuel in accidents.

The Board's selective investigation of the severe locomotive derailment accidents and the limited data available on locomotive fuel tank spills and fires precluded a comprehensive determination of the failure modes of locomotive fuel tanks. The investigations do demonstrate, however, that even in the low speed derailments, rail can dent and puncture the tank. The investigations also show that locomotive components and the track structure not only can dent and puncture, but they can crush the tank during the more severe derailments and head-on collisions, particulary if a locomotive turns over or one locomotive overrides another. Further, although the 9 accidents investigated by the Board in 1991 in which there were fuel tank fires represent only about 4 percent of the 237 FRA reportable accidents involving locomotive derailments for that year, these 9 accidents include 100 percent of the onboard crewmember fatalities. Thus, fuel tank damage, fuel spills, and fuel fires are a safety issue in the more severe locomotive derailment accidents.

It has been argued that fuel tanks cannot reasonably be designed for and placed on locomotives in a manner to reduce or eliminate ruptures in the more severe accidents (such as those discussed in this report). However, the Safety Board is not convinced that this is so. More importantly, it is clear that current fuel tanks have not been so designed nor has adequate research been performed to determine if improvements sufficient for fuel tanks to survive such accidents are possible. Several changes need to be considered.

Location and Design of Locomotive Tanks

The proximity of the bottom of the locomotive fuel tank to the top of the rail makes it highly susceptible to damage in the event of a derailment. Although the FRA only requires that no part or appliance of a locomotive (except the wheels, nonmetallic sand pipe extension tips, and trip cock arms) may be less than 2 1/2 inches above the top of the rail, information from the manufacturers indicates that fuel tanks are installed such that the bottom of the fuel tank is normally about 6 to 6 1/2 inches above the rail. However, even at that height, if the locomotive wheels come off the rails, fuel tank contact with the rails is likely to occur, as the Board's accident investigations illustrate. The current location of locomotive fuel tanks extending to each side of the locomotive and underneath the locomotive frame also makes them vulnerable in side collisions and during overrides.

Amtrak's efforts to raise the fuel tank to a height of 29 inches above the rail and to compartmentalize the tank to minimize fuel loss in the event of tank damage appear to be improvements over the current design and location. In a low-speed derailment, tank damage would probably be minimal, if not eliminated. The Board recognizes that raising the location of fuel tanks above their current position and the possible concomitant need to raise other equipment could result in an increase in the center of gravity of the locomotive. Such an increase may have some effect on the maximum speed at which a locomotive could safely negotiate a curve. Clearly, center of gravity needs to be taken into consideration if the solution to improving fuel tank performance includes relocation of the fuel tank. Implementation of any strategy or concept to mitigate fuel tank breaches should be carefully evaulated and tested, through either simulation or crash testing, to assure that potential changes do not introduce new safety hazards—in particular, new breach mechanisms—and to determine the applicability of the concept or strategy to the industry. However, the Safety Board is not aware of any plans to test the Amtrak locomotive fuel tank to determine how the tank will perform in an accident environment.

According to the locomotive manufacturers, there has been little change to the design of fuel tanks over the years, with the exception of tank capacity. However, even when the tank size was increased, the effect of increasing the quantity of locomotive diesel fuel onboard was not analyzed to determine if new safety hazards would be introduced. The Safety Board is concerned that in the event of a breach and ignition, the duration of a fire may be prolonged and the severity increased. The Safety Board believes, therefore, that the FRA, in documenting fuel tank damage and breaches during onsite investigations, should also document fuel tank size and the duration and severity of fires. In reviewing Safety Recommendation R-91-40, the Safety Board believes that it may not have conveyed as succinctly as possible the information that should be collected onsite with respect to fuel tank damage, fuel spills, and fuel fires. Consequently, the Safety Board has placed Safety Recommendation R-91-40 in a "Closed—Acceptable Action/Superseded" status and has issued a new recommendation that more clearly outlines the data collection needed.

Of particular concern to the Safety Board is that fuel tank design specifications appear to be inadequately based on safety factors. Tank capacity was increased to enable railroads to travel greater distances without stopping to refuel and to bypass locations where the cost of diesel fuel was high. Although public concern about the harmful effects of releases of hazardous materials on the environment has been heightened in the last couple of years, the cost associated with cleaning up these spills appears to have been the driving force in one railroad's request to the manufacturer that the thickness of metal used on the end plates and side walls of the fuel tank be increased. Although the increased wall thickness should prevent some, if not many, of the breaches that would normally occur with the thinner metal, there have been no tests conducted to determine how the newly designed fuel tank would perform in an accident environment and what benefits would accrue.

The Long Island Rail Road has increased the strength of the structural steel outer tank to protect against tank breach and has inserted a carbon fibre bladder and foam blocks to prevent against fuel leak and ignition in the event of a breach. The two locomotive manufacturers have considered similar design changes. Again, however, the safety implications of these modifications have not yet been adequately evaluated.

The lack of any substantive change to the locomotive fuel tank over the last 30 years indicates that little effort has been made in the past to determine if the integrity of the fuel tank can be improved or if fuel containment could be improved. Only recently has the issue been addressed. The Safety Board believes that the FRA, in conjunction with the AAR and the two major locomotive manufacturers—General Electric and the Electro-Motive Division of General Motors—should conduct research to determine if the locomotive fuel tank can be improved to withstand the forces encountered in the more severe locomotive derailment accidents or if fuel containment can be improved to reduce the rate of fuel leakage and, consequently, fuel ignition. The research should include crash or simulated testing and evaluation of recent and proposed design modifications to the locomotive fuel tank, including increasing the structural strength of end and side wall plates, raising the tank higher above the rail, and using internal tank bladders and foam inserts. The FRA should establish, if warranted, minimum performance standards for the locomotive fuel tank based on the results of the research.

Diesel Fuel

The Safety Board's survey of the types of diesel fuel being used by the industry and the quality assurance programs that have been implemented suggests that the industry is using a grade 2 diesel fuel that meets the minimum specifications of the ASTM and the recommendations of the manufacturers. The type of fuel being used, therefore, is not considered a factor in the propensity for fire in the event the locomotive tank is breached.

Diesel fuel, unlike fuels such as gasoline, is difficult to ignite primarily because it does not produce a flammable vapor cloud above its surface under normal ambient conditions. The fact that diesel fuel is comparatively difficult to ignite is probably the reason why more fires do not occur in cases involving tank breach. Diesel fuel will ignite, particularly if it is vaporized or expelled as a mist. The sequence of events in a collision or derailment can result in the discharge of liquid fuel from the tank in the form of a mist or vapor, particularly if the fuel tank is compressed. The ignition of misted or vaporized diesel fuel can occur in the presence of mechanical sparks, electrical arcing, or hot surfaces, all of which can occur in the accident sequence. Although the Board's investigations could not determine definitively the source of diesel fuel ignitions, there are sufficient sources of ignition in a railroad accident sequence, even low-speed derailments, to ignite vaporized or misted diesel fuel oil.

Fuel Tenders and Alternative Fuels

The Safety Board is aware that the industry is experimenting with the use of fuel tenders, alternative fuels, and other fuels in combination with diesel fuels. The increased use of alternative fuels could conceivably reduce the incidence of diesel fuel fires or introduce new hazards in the accident sequence. The Safety Board acknowledges and supports the industry's efforts to assess the safety implications of alternative fuels and fuel tenders in the accident environment. With stricter emission standards expected in the near future, the use of alternative fuels can be expected to increase. The Safety Board, in noting the FRA's monitoring of the industry's experiments with the use of fuel tenders and alternative fuels, urges the FRA to establish specific criteria for the use of fuel tenders and alternative fuels for the railroad industry.

Findings

1. Because of the limited data available, it is difficult to evaluate the extent of locomotive fuel tank damage and locomotive fuel tank spills in the railroad industry annually.

2. In the 29 locomotive derailment accidents investigated by the Safety Board in 1991, diesel fuel spills occurred from 47 (56 percent) of the 83 locomotives that derailed; further, fuel ignition occurred on 23 (28 percent) of the 83 locomotives that derailed.

3. Metallurgical examinations of fuel tanks conducted in conjunction with this study revealed that neither corrosion nor pre-existing cracks compromised the integrity of fuel tanks that were breached; thus inspection and maintenance of fuel tanks were not factors in the accidents investigated.

4. Although changes to the fuel tank design have recently been explored by the railroad industry, this study found no evidence that the industry has performed systematic engineering analyses to determine the feasibility of providing better crash protection for the fuel tank systems.

Recommendations

As a result of the safety study, the National Transportation Safety Board made the following safety recommendations:

—to the U.S. Department of Transportation, Federal Railroad Administration:

Conduct, in conjunction with the Association of American Railroads, General Electric, and the Electro-Motive Division of General Motors, research to determine if the locomotive fuel tank can be improved to withstand forces encountered in the more severe locomotive derailment accidents or if fuel containment can be improved to reduce the rate of fuel leakage and fuel ignition. Consideration should be given to crash or simulated testing and evaluation of recent and proposed design modifications to the locomotive fuel tank, including increasing the structural strength of end and side wall plates, raising the tank higher above the rail, and using internal tank bladders and foam inserts. (Class II, Priority Action) (R-92-10)

Establish, if warranted, minimum performance standards for locomotive fuel tanks based on the research called for in recommendation R-92-10. (Class III, Longer Term Action) (R-92-11)

Instruct field personnel to obtain from accident investigations locomotive fuel tank size and, to the extent practicable, the duration and severity of locomotive fuel fires in conjunction with the agency's ongoing efforts to improve the recording of data pertaining to postcrash fires involving locomotive fuel tank rupture and spillage. (Class II, Priority Action) (R-92-12)

Develop, in conjunction with the Association of American Railroads, a formal methodology for reviewing the use of alternative fuels and fuel tenders in the railroad industry. (Class III, Longer Term Action) (R-92-13)

—to the Association of American Railroads:

Conduct, in conjunction with the Federal Railroad Administration, General Electric and the Electro-Motive Division of General Motors, research to determine if the locomotive fuel tank can be improved to withstand the forces encountered in the more severe locomotive derailment accidents or if fuel containment can be improved to reduce the rate of fuel leakage and fuel ignition. Consideration should be given to crash or simulated testing and evaluation of recent and proposed design modifications to the locomotive fuel tank, including increasing the structural strength of end and side wall plates, raising the tank higher above the rail, and using internal tank bladders and foam inserts. (Class II, Priority Action) (R-92-14)

Develop, in conjunction with the Federal Railroad Administration, a formal methodology for reviewing the use of alternative fuels and fuel tenders in the railroad industry. (Class II, Longer Term Action) (R-92-15)

— to General Electric:

Conduct, in conjunction with the Federal Railroad Administration, the Association of American Railroads, and the Electro-Motive Division of General Motors, research to determine if the locomotive fuel tank can be improved to withstand the forces encountered in the more severe locomotive derailment accidents or if fuel containment can be improved to reduce the rate of fuel leakage and fuel ignition. Consideration should be given to crash or simulated testing and evaluation of recent and proposed design modifications to the locomotive fuel tank, including increasing the structural strength of end and side wall plates, raising the tank higher above the rail, and using internal tank bladders and foam inserts. (Class II, Priority Action) (R-92-16)

— to the Electro-Motive Division of General Motors:

Conduct, in conjunction with the Federal Railroad Administration, the Association of American Railroads, and General Electric, research to determine if the locomotive fuel tank can be improved to withstand the forces encountered in the more severe locomotive derailment accidents or if fuel containment can be improved to reduce the rate of fuel leakage and fuel ignition. Consideration should be given to crash or simulated testing and evaluation of recent and proposed design modifications to the locomotive fuel tank, including increasing the structural strength of end and side wall plates, raising the tank higher above the rail, and using internal tank bladders and foam inserts. (Class II, Priority Action) (R-92-17)

As a result of this study, the National Transportation Safety Board classified the following recommendation to the Federal Railroad Administration (FRA) "Closed."

R-91-40

To enhance current accident data collection and analysis, require the recording of data pertaining to postcrash fires involving locomotive fuel tank rupture and spillage, as well as types of locomotive units involved.

Status: "Closed—Acceptable Action/Superseded" by Safety Recommendation R-92-12.

By the National Transportation Safety Board

Carl W. Vogt
Chairman

Susan M. Coughlin
Vice Chairman

John K. Lauber
Member

Christopher A. Hart
Member

John A. Hammerschmidt
Member

Adopted: October 27, 1992

Vice Chairman Coughlin filed the following concurring statement:

While I am concurring with the final version of the safety study as approved by the full Board, I question the depth of the problem of fuel tank integrity. In order to resolve that question, I fully support the recommendations directed toward the collection of more complete postaccident data. In that way, the Safety Board, the Federal Railroad Administration, and the industry will benefit from an enhanced portrayal of the risks posed by fuel tanks in accident scenarios and whether inadequacies exist with regard to their integrity.

Calling for locomotive fuel tank research, including costly crash and simulated testing and possible redesign efforts, may be premature in view of the stated absence of complete accident data, and may divert scarce research funds from more fully documented safety concerns.

Appendix A

Federal Railroad Administration's Definitions of Train Accident, Train Incident, and Nontrain Incident

Reportability Requirements

The rules governing the monthly reporting of railroad accidents/incidents in effect at the end of 1991 define a reportable accident/incident as an event arising from the operation of a railroad which, with minor exceptions, results in one or more of the following circumstances:

(a) Any impact between railroad on-track equipment and an automobile, bus, truck, motorcycle, bicycle, farm vehicle, pedestrian, or other highway user at a rail-highway crossing;

(b) Any collision, derailment, fire, explosion, act of God, or other event involving the operation of railroad on-track equipment, standing or moving, which results in more than $6,300 in damages to railroad on-track equipment, signals, track, track structures, and roadbed; and

(c) Any event arising from the operation of a railroad which results in:

(i) the death of one or more persons;

(ii) an injury to one or more persons; other than railroad employees, which requires medical treatment;

(iii) an injury to one or more employees which requires medical treatment or results in: restriction of work or motion for one or more days, or one or more lost work days; transfer to another job; termination of employment; or loss of consciousness; or

(iv) any occupational illness of a railroad employee as diagnosed by a physician.

Classification of Accidents/Incidents

Train Accident.—A collision, derailment, or other event involving the operation of railroad on-track equipment resulting in damages that exceed the reporting threshold.

Train Incident.—Any event involving the movement of railroad on-track equipment that results in a death, reportable injury, or a reportable illness, but in which railroad property damage does not exceed the reporting threshold.

Nontrain Incident.—An event arising from railroad operations but not from the movement of on-track equipment, which does not exceed the reporting threshold, and results in a death, a reportable injury, or a reportable occupational illness.

Appendix B

Data on Safety Board's Investigations of 29 Accidents

Table 3.--Summary of data on the locomotives involved in the 29 accidents, 1991

Event number, location, train, and locomotive unit	Type of accident	Train speed (mph)	Derailed	Tank damage	Fuel spill	Fire
1. Roebuck, SC:	Head-on collision					
Train A--		35				
Locomotive 7564			X	X	X	
Locomotive 7627						
Locomotive 6648						
Train B (standing)--		0				
Locomotive 8475			X			
Locomotive 8618						
Locomotive 8103						
2. Northbrook, IL:	Grade crossing					
Train A--		65				
Locomotive 610			X	X		
3. Waterfall, WY:	Rear-end collision					
Train A (standing cars)--		0				
Train B--		35				
Locomotive 6192			X			
Locomotive 6284			X		X[a]	X
Locomotive 6058			X			
(continued)						

Table 3.--Summary of data on the locomotives involved in the 29 accidents, 1991 (continued)

Event number, location, train, and locomotive unit	Type of accident	Train speed (mph)	Derailed	Tank damage	Fuel spill	Fire
4. Lompoc, CA:	Culvert wash out					
Train A--		55				
Locomotive 7555						
Locomotive 7471			X	X	X	
Locomotive 7310			X	UNK	X	
5. Peotone, IL:	Grade crossing					
Train A--		75				
Locomotive 368			X	X		
6. Gypsum, KS:	Head-on collision					
Train A (standing)--		0				
Locomotive 6833			X	X	X	X
Locomotive 5321						
Train B--		38				
Locomotive 6726			X	X	X	X
Locomotive 6719			X	X	X	X
7. Melrose, MT:	Grade crossing					
Train A--		20				
Locomotive 3681			X	X		
Locomotive 3422			X	UNK		
Locomotive 3502			X	X	X	X
Locomotive 3694			X	X	X	X

(continued)

Table 3.--Summary of data on the locomotives involved in the 29 accidents, 1991 (continued)

Event number, location, train, and locomotive unit	Type of accident	Train speed (mph)	Derailed	Tank damage	Fuel spill	Fire
8. Sodorus, IL:	Rear-end collision					
Train A--		18				
Locomotive 6579			X	UNK		
Locomotive 2840			X	X	X	
Train B (standing)--		0				
Locomotive 7084						
Locomotive 3556						
9. Chase, MD:	Side collision					
Train A--		50				
Locomotive 390			X	X	X	
Locomotive 601			X[b]			
Locomotive 604			X[b]			
Locomotive 320						
Train B--		30				
Locomotive 6516						
Locomotive 6476						
Locomotive 6500						
Locomotive 6475						

(continued)

Table 3.–Summary of data on the locomotives involved in the 29 accidents, 1991 (continued)

Event number, location, train, and locomotive unit	Type of accident	Train speed (mph)	Derailed	Tank damage	Fuel spill	Fire
10. Roper, KS:	Broken rail, derailment					
Train A–		50				
Locomotive 5517						
Locomotive 5068			X			
Locomotive 5527			X			
11. Frisco, TX:	Head-on collision					
Train A–		30				
Locomotive 3516			X	X	X	
Locomotive 4017			X	X	X	
Locomotive 4062			X	UNK		
Locomotive 21			X	UNK		
Train B (runaway cars)–	UNK					
12. Bill, WY:	Rear-end collision					
Train A–		62				
Locomotive 3555			X	X	X	X
Locomotive 7302			X	X	X	X
Locomotive 6921			X	X		
Train B (standing)–		0				
Locomotive 8536						
Locomotive 6144						
Locomotive 9176						
(continued)						

Table 3.--Summary of data on the locomotives involved in the 29 accidents, 1991 (continued)

Event number, location, train, and locomotive unit	Type of accident	Train speed (mph)	Derailed	Tank damage	Fuel spill	Fire
13. Baltimore, MD:	Head-on collision					
Train A--		15				
Locomotive 6064			X	X	X	
Locomotive 6856			X	X		
Train B--		20				
Locomotive 6141			X	X		
Locomotive 6143			X	X		
14. Fountain City, WI:	Track wash out					
Train A:		44				
Locomotive 3111						
Locomotive 4047			X	X		
Locomotive 2000			X	X	X	
15. Dunsmuir, CA:	Derailment (cars)					
Train A--		12				
Locomotive 9693						
Locomotive 9333						
Locomotive 8373						
Locomotive 7561			X		X[c]	

(continued)

Table 3.--Summary of data on the locomotives involved in the 29 accidents, 1991 (continued)

Event number, location, train, and locomotive unit	Type of accident	Train speed (mph)	Derailed	Tank damage	Fuel spill	Fire
16. Douglas, WY:	Side collision					
Train A--		45				
Locomotive 6913			X	X		
Locomotive 7502			X	UNK		
Locomotive 7213			X	UNK		
Train B (m-o-w equipment)--		0				
17. Dobbin, TX:	Head-on collision					
Train A--		33				
Locomotive 8518			X	X	X	X
Locomotive 8568			X	X	X	X
Train B--		15				
Locomotive 3502			X	X	X	X
18. Sprague, WA:	Overspeed derailment at siding					
Train A--		81				
Locomotive 8532			X	X		
Locomotive 8521						
Locomotive 8509						

(continued)

Table 3.--Summary of data on the locomotives involved in the 29 accidents, 1991 (continued)

Event number, location, train, and locomotive unit	Type of accident	Train speed (mph)	Derailed	Tank damage	Fuel spill	Fire
19. Ledger, MT:	Head-on collision					
Train A--		50				
Locomotive 2275			X	X	X	X
Locomotive 8009			X	X		X
Locomotive 6909			X	X		X
Train B--		50				
Locomotive 6905			X	X	X	X
Locomotive 6901			X	X	X	X
Locomotive 2287			X	X	X	X
Locomotive 2283			X	X	X	X
Locomotive 2274			X	X	X	
Locomotive 2289			X	X	X	
20. Knox, IN:	Head-on collision					
Train A--		30				
Locomotive 6134			X	X	X	X
Train B--		30				
Locomotive 6207			X	X	X	X
Locomotive 8642			X	X	X	X
Locomotive 4636			X	X	X	X

(continued)

Table 3.--Summary of data on the locomotives involved in the 29 accidents, 1991 (continued)

Event number, location, train, and locomotive unit	Type of accident	Train speed (mph)	Derailed	Tank damage	Fuel spill	Fire
21. Merrill, OR:	Stub track derailment					
Train A--		40				
Locomotive 6829			X	X	X	
Locomotive 8320			X	UNK		
Locomotive 9353			X	X	X	
Locomotive 7455			X	X		
Locomotive 7450			X	UNK		
22. Mountain Home, ID:	Broken rail, derailment					
Train A--		18				
Locomotive 9451						
Locomotive 9307						
Locomotive 9118						
Locomotive 3693			X			
23. Pinecliffe, CO:	Struck boulder on track					
Train A--		25				
Locomotive 3115			X	X	X	X
Locomotive 7317			X	X	X	X
Locomotive 3010			X	UNK		
(continued)						

Table 3.--Summary of data on the locomotives involved in the 29 accidents, 1991 (continued)

Event number, location, train, and locomotive unit	Type of accident	Train speed (mph)	Derailed	Tank damage	Fuel spill	Fire
24. Gouverneur, NY:	Siding derailment					
Train A--		0				
Locomotive 6752			X	X	X	
Locomotive 6030			X			
25. Minneapolis, MN:	Side collision					
Train A--		30				
Locomotive 5054			X		X[d]	
Locomotive 7258				X[e]	X	
Train B--		30				
Locomotive 6934						
Locomotive 753						
Locomotive (UNK)						
26. Harrisburg, OR:	Side collision					
Train A--		50				
Locomotive 7950			X	X	X	X
Locomotive 7967			X	UNK		
Locomotive 1602			X			
Locomotive 7964			X	UNK		
Locomotive 7949			X	UNK		
Locomotive 7955			X	UNK		
(continued)						

Table 3.--Summary of data on the locomotives involved in the 29 accidents, 1991 (continued)

Event number, location, train, and locomotive unit	Type of accident	Train speed (mph)	Derailed	Tank damage	Fuel spill	Fire
Train B (entering siding)--		10				
Locomotive 7966						
Locomotive 1605						
Locomotive 7943						
Locomotive 4372						
27. Belen, NM:	Side collision					
Train A--		21				
Locomotive 551			X	X	X	
Locomotive 501			X	UNK	X	
Locomotive 3821			X	UNK		
Locomotive 4007						
Locomotive 3828						
Locomotive 3832						
Locomotive 5514						
Train B--		2				
Locomotive 2328			X	X	X	
28. Palatka, FL:	Overspeed derailment					
Train A--		72				
Locomotive 310			X	X		

(continued)

Table 3.--Summary of data on the locomotives involved in the 29 accidents, 1991 (continued)

Event number, location, train, and locomotive unit	Type of accident	Train speed (mph)	Derailed	Tank damage	Fuel spill	Fire
29. Cottondale, FL:	Side collision					
Train A–		26				
Locomotive 2608			X	X	X	
Locomotive 5574			X	X	X	
Locomotive 5806			X	X	X	
Locomotive 5813			X	X	X	
Locomotive 5546			X		X[f]	
Train B (standing cars)–		0				

UNK = unknown; m-o-w = maintenance of way.

[a] Instance in which fuel leaked from the overflow and vent pipe because of the orientation of the pipe after derailment. No tank damage. Small fire extinguished immediately after ignition.

[b] Locomotive units 601 and 604 were electric units only; therefore, they are not included in the total of 83 derailed locomotive units–the units that were studied to observe fuel tank damage.

[c] Whether the fuel spilled from the overflow vent pipe or through the fuel filler pipe could not be determined. Tank was not damaged.

[d] Instance in which fuel leaked from cap of fuel tank. No tank damage.

[e] Fuel tank on locomotive 7258, which did not derail, was sideswiped by a derailed flat car and derailed hopper car. Because this locomotive did not derail, fuel tank damage and fuel spillage on this unit are not included in the numbers discussed in the section "Summary of 1991 Accidents" of the text nor in figure 5.

[f] Instance in which fuel leaked from the overflow and vent pipe because of the orientation of the pipe after derailment. No tank damage.

Appendix C

Federal Regulations Regarding the Inspection of Locomotives, 49 CFR 229 Subpart B

or at the head of a train or locomotive consist.

(e) A locomotive does not cease to be a locomotive because its propelling motor or motors are inoperative or because its control jumper cables are not connected.

(f) Nothing in this section authorizes the movement of a locomotive subject to a Special Notice for Repair unless the movement is made in accordance with the restrictions contained in the Special Notice.

§ 229.11 Locomotive identification.

(a) The letter "F" shall be legibly shown on each side of every locomotive near the end which for identification purposes will be known as the front end.

(b) The locomotive number shall be displayed in clearly legible numbers on each side of each locomotive.

§ 229.13 Control of locomotives.

Except when a locomotive is moved in accordance with § 229.9, whenever two or more locomotives are coupled in remote or multiple control, the propulsion system, the sanders, and the power brake system of each locomotive shall respond to control from the cab of the controlling locomotive. If a dynamic brake or regenerative brake system is in use, that portion of the system in use shall respond to control from the cab of the controlling locomotive.

§ 229.14 Non-MU control cab locomotives.

On each non-MU control cab locomotive, only those components added to the passenger car that enable it to serve as a lead locomotive, control the locomotive actually providing tractive power, and otherwise control the movement of the train, are subject to this part.

§ 229.17 Accident reports.

(a) In the case of an accident due to a failure from any cause of a locomotive or any part or appurtenance of a locomotive, or a person coming in contact with an electrically energized part or appurtenance, that results in serious injury or death of one or more persons, the carrier operating the locomotive shall immediately report the accident by toll free telephone, Area Code 800-424-0201. The report shall state the nature of the accident, number of persons killed or seriously injured, the place at which it occurred, the location at which the locomotive or the affected parts may be inspected by the FRA, and the name, title and phone number of the person making the call. The locomotive or the part or parts affected by the accident shall be preserved intact by the carrier until after the FRA inspection.

(b) Written confirmation of the oral report required by paragraph (a) of this section shall be immediately mailed to the Federal Railroad Administration, RRS-25, Washington, DC 20590, and contain a detailed description of the accident, including to the extent known, the causes and the number of persons killed and injured. The written report required by this paragraph is in addition to the reporting requirements of 49 CFR part 225.

§ 229.19 Prior waivers.

All waivers of every form and type from any requirement of any order or regulation implementing the Locomotive Inspection Act, applicable to one or more locomotives except those propelled by steam power, shall lapse on August 31, 1980, unless a copy of the grant of waiver is filed prior to that date with the Office of Safety (RRS-23), Federal Railroad Administration, Washington, DC 20590.

Subpart B—Inspections and Tests

§ 229.21 Daily inspection.

(a) Except for MU locomotives, each locomotive in use shall be inspected at least once during each calendar day. A written report of the inspection shall be made. This report shall contain the name of the carrier; the initials and number of the locomotive; the place, date and time of the inspection; a description of the non-complying conditions disclosed by the inspection; and the signature of the employee making the inspection. Except as provided in § 229.9, any conditions that constitute non-compliance with any requirement of this part shall be repaired before the locomotive is used. A notation shall be made on the report indicating the nature of the repairs that have been made. The person making the repairs shall sign the report. The report shall be filed and retained for at least 92 days in the office of the carrier at the terminal at which the locomotive is cared for. A record shall be maintained on each locomotive showing the place, date and time of the previous inspection.

(b) Each MU locomotive in use shall be inspected at least once during each calendar day and a written report of the inspection shall be made. This report may be part of a single master report covering an entire group of MU's. If any non-complying conditions are found, a separate, individual report shall be made containing the name of the carrier; the initials and number of the locomotive; the place, date, and time of the inspection; the non-complying conditions found; and the signature of the inspector. Except as provided in § 229.9, any conditions that constitute non-compliance with any requirement of this part shall be repaired before the locomotive is used. A notation shall be made on the report indicating the nature of the repairs that have been made. The person making the repairs shall sign the report. The report shall be filed in the office of the carrier at the place where the inspection is made or at one central location and retained for at least 92 days.

(c) Each carrier shall designate qualified persons to make the inspections required by this section.

[45 FR 21109, Mar. 31, 1980, as amended at 50 FR 6953, Feb. 19, 1985]

§ 229.23 Periodic inspection: General.

(a) Each locomotive and steam generator shall be inspected at each periodic inspection to determine whether it complies with this part. Except as provided in § 229.9, all non-complying conditions shall be repaired before the locomotive or the steam generator is used. Except as provided in § 229.33, the interval between any two periodic inspections may not exceed 92 days. Periodic inspections shall only be made where adequate facilities are available. At each periodic inspection, a locomotive shall be positioned so that a person may safely inspect the entire underneath portion of the locomotive.

(b) The periodic inspection of the steam generator may be postponed indefinitely if the water suction pipe to the water pump and the leads to the main switch (steam generator switch) are disconnected, and the train line shut-off-valve is wired closed or a blind gasket applied. However, the steam generator shall be so inspected before it is returned to use.

(c) After April 30, 1980, each new locomotive shall receive an initial periodic inspection before it is used. Except as provided in § 229.33, each locomotive in use on or before April 30, 1980, shall receive an initial periodic inspection within 92 days of the last 30-day inspection performed under the prior rules (49 CFR 230.331 and 230.451). At the initial periodic inspection, the date and place of the last tests performed that are the equivalent of the tests required by §§ 229.27, 229.29, and 229.31 shall be entered on Form FRA F 6180-49A. These dates shall determine when the tests first become due under §§ 229.27, 229.29, and 229.31. Out of use credit may be carried over from Form FRA F 6180-49 and entered on Form FRA F 6180-49A.

(d) Each periodic inspection shall be recorded on Form FRA F 6180-49A. The form shall be signed by the person conducting the inspection and certified by that person's supervisor that the work was done. The form shall be displayed under a transparent cover in a conspicuous place in the cab of each locomotive.

(e) At the first periodic inspection in each calendar year the carrier shall remove from each locomotive Form FRA F 6180-49A covering the previous calendar year. If a locomotive does not receive its first periodic inspection in a calendar year before April 2 because it is out of use, the form shall be promptly replaced. The Form FRA F 6180-49A covering the preceding year for each locomotive, in or out of use, shall be signed by the railroad official responsible for the locomotive and filed as required in § 229.23(f). The date and place of the last periodic inspection and the date and place of the last test performed under §§ 229.27, 229.29, and 229.31 shall be transferred to the replacement Form FRA F 6180-49A.

(f) The mechanical officer of each railroad who is in charge of a locomotive shall maintain in his office a secondary record of the information reported on Form FRA F 6180-49A under this part. The secondary record shall be retained until Form FRA F 6180-49A has been removed from the locomotive and filed in the railroad office of the mechanical officer in charge of the locomotive. If the Form FRA F 6180-49A removed from the locomotive is not clearly legible, the secondary record shall be retained until the Form FRA F 6180-49A for the succeeding year is filed. The Form F 6180-49A removed from a locomotive shall be retained until the Form FRA F 6180-49A for the succeeding year is filed.

[45 FR 21109, Mar. 31, 1980, as amended at 45 FR 39852, June 12, 1980; 50 FR 6953, Feb. 19, 1985]

§ 229.25 Tests: Every periodic inspection.

Each periodic inspection shall include the following:

(a) All gauges used by the engineer for braking the train or locomotive, except load meters used in conjunction with an auxiliary brake system, shall be tested by comparison with a dead-weight tester or a test gauge designed for this purpose.

(b) All electrical devices and visible insulation shall be inspected.

(c) All cable connections between locomotives and jumpers that are designed to carry 600 volts or more shall be thoroughly cleaned, inspected, and tested for continuity.

(d) Each steam generator that is not isolated as prescribed in § 229.23(b) shall be inspected and tested as follows:

(1) All automatic controls, alarms and protective devices shall be inspected and tested.

(2) Steam pressure gauges shall be tested by comparison with a dead-weight tester or a test gauge designed for this purpose. The siphons to the steam gauges shall be removed and their connections examined to determine that they are open.

(3) Safety valves shall be set and tested under steam after the steam pressure gauge is tested.

§ 229.27 Annual tests.

Each locomotive shall be subjected to the tests and inspections included in paragraphs (b) and (c) of this section, and each non-MU locomotive shall also be subjected to the tests and inspections included in paragraph (a) of this section, at intervals that do not exceed 368 calendar days:

(a)(1) The filtering devices or dirt collectors located in the main reservoir supply line to the air brake system shall be cleaned, repaired, or replaced.

(2) Brake cylinder relay valve portions, main reservoir safety valves, brake pipe vent valve portions, feed and reducing valve portions in the air brake system (including related dirt collectors and filters) shall be cleaned, repaired, and tested.

(3) The date and place of the cleaning, repairing, and testing shall be recorded on Form FRA F 6180-49A and the person performing the work and that person's supervisor shall sign the form. A record of the parts of the air brake system that are cleaned, repaired, and tested shall be kept in the carrier's files or in the cab of the locomotive.

(4) At its option, a carrier may fragment the work required by this paragraph. In that event, a separate air record shall be maintained under a transparent cover in the cab. The air record shall include the locomotive number, a list of the air brake components, and the date and place of the last inspection and test of each component. The signature of the person performing the work and the signature of that person's supervisor shall be included for each component. A duplicate record shall be maintained in the carrier's files.

(b) Load meters shall be tested. Errors of less than five percent do not have to be corrected. The date and place of the test shall be recorded on Form FRA F 6180-49A and the person conducting the test and that person's supervisor shall sign the form.

(c) Each steam generator that is not isolated as prescribed in § 229.23(b), shall be subjected to a hydrostatic pressure at least 25 percent above the working pressure and the visual return water-flow indicator shall be removed and inspected.

EDITORIAL NOTE: For a limited temporary waiver of compliance document affecting § 229.27 (a)(2), see 50 FR 3910, Jan. 29, 1985.

§ 229.29 Biennial tests.

(a) Except for the valves and valve portions on non-MU locomotives that are cleaned, repaired, and tested as prescribed in § 229.27(a), all valves, valve portions, MU locomotive brake cylinders and electric-pneumatic master controllers in the air brake system (including related dirt collectors and filters) shall be cleaned, repaired, and tested at intervals that do not exceed 736 calendar days. The date and place of the cleaning, repairing, and testing shall be recorded on Form FRA F 6180-49A, and the person performing the work and that person's supervisor shall sign the form. A record of the parts of the air brake system that are cleaned, repaired, and tested shall be kept in the carrier's files or in the cab of the locomotive.

(b) At its option, a carrier may fragment the work required by this section. In that event, a separate air record shall be maintained under a transparent cover in the cab. The air record shall include the locomotive number, a list of the air brake components, and the date and place of the inspection and test of each component. The signature of the person performing the work and the signature of that person's supervisor shall be included for each component. A duplicate record shall be maintained in the carrier's files.

EDITORIAL NOTE: For a limited temporary waiver of compliance document affecting § 229.29(a), see 50 FR 3910, Jan. 29, 1985.

§ 229.31 Main reservoir tests.

(a) Except as provided in paragraph (c) of this section, before it is put in service and at intervals that do not exceed 736 calendar days, each main reservoir other than an aluminum reservoir shall be subjected to a hydrostatic pressure of at least 25 percent more than the maximum working pressure fixed by the chief mechanical officer. The test date, place, and pressure shall be recorded on Form FRA F 6180-49A, and the person performing the test and that person's supervisor shall sign the form.

(b) Except as provided in paragraph (c) of this section, each main reservoir other than an aluminum reservoir shall be hammer tested over its entire surface while the reservoir is empty at intervals that do not exceed 736 calendar days. The test date and place shall be recorded on Form FRA F 6180-49A, and the person performing the test and that person's supervisor shall sign the form.

(c) Each welded main reservoir originally constructed to withstand at least five times the maximum working pressure fixed by the chief mechanical officer may be drilled over its entire surface with telltale holes that are three-sixteenths of an inch in diameter. The holes shall be spaced not more than 12 inches apart, measured both longitudinally and circumferentially, and drilled from the outer surface to an extreme depth determined by the formula—

$$D=(.6PR/(S-0.6P))$$

where:

D = extreme depth of telltale holes in inches but in no case less than one-sixteenth inch;

P = certified working pressure in pounds per square inch;

S = one-fifth of the minimum specified tensile strength of the material in pounds per square inch; and

R = inside radius of the reservoir in inches.

One row of holes shall be drilled lengthwise of the reservoir on a line intersecting the drain opening. A reservoir so drilled does not have to meet the requirements of paragraphs (a) and (b) of this section, except the requirement for a hydrostatic test before it is placed in use. Whenever any such telltale hole shall have penetrated the interior of any reservoir, the reservoir shall be permanently withdrawn from service. A reservoir now in use may be drilled in lieu of the tests provided for by paragraphs (a) and (b) of this section, but it shall receive a hydrostatic test before it is returned to use.

(d) Each aluminum main reservoir before being placed in use and at intervals that do not exceed 736 calendar days thereafter, shall be—

(1) Cleaned and given a thorough visual inspection of all internal and external surfaces for evidence of defects or deterioration; and

(2) Subjected to a hydrostatic pressure at least twice the maximum working pressure fixed by the chief mechanical officer, but not less than 250 p.s.i. The test date, place, and pressure shall be recorded on Form FRA F 6180 49A, and the person conducting the test and that person's supervisor shall sign the form.

§ 229.33 Out-of-use credit.

When a locomotive is out of use for 30 or more consecutive days or is out of use when it is due for any test or inspection required by §§ 229.23, 229.25, 229.27, 229.29, or 229.31, an out-of-use notation showing the number of out-of-use days shall be made on an inspection line on Form FRA F 6180 49A. A supervisory employee of the carrier who is responsible for the locomotive shall attest to the notation. If the locomotive is out of use for one or more periods of at least 30 consecutive days each, the interval prescribed for any test or inspection under this part may be extended by the number of days in each period the locomotive is out of use since the last test or inspection in question. A movement made in accordance with § 229.9 is not a use for purposes of determining the period of the out-of-use credit.

Subpart C—Safety Requirements

General Requirements

§ 229.41 Protection against personal injury.

Fan openings, exposed gears and pinions, exposed moving parts of mechanisms, pipes carrying hot gases and high-voltage equipment, switches, circuit breakers, contactors, relays, grid resistors, and fuses shall be in non hazardous locations or equipped with guards to prevent personal injury.

§ 229.43 Exhaust and battery gases.

(a) Products of combustion shall be released entirely outside the cab and other compartments. Exhaust stacks shall be of sufficient height or other means provided to prevent entry of products of combustion into the cab or other compartments under usual operating conditions.

(b) Battery containers shall be vented and batteries kept from gassing excessively.

§ 229.45 General condition.

All systems and components on a locomotive shall be free of conditions that endanger the safety of the crew, locomotive or train. These conditions include: insecure attachment of components, including third rail shoes or beams, traction motors and motor gear cases, and fuel tanks; fuel, oil, water, steam, and other leaks and accumulations of oil on electrical equipment that create a personal injury hazard; improper functioning of components, including slack adjusters, pantograph operating cylinders, circuit breakers, contactors, relays, switches, and fuses; and cracks, breaks, excessive wear and other structural infirmities of components, including quill drives, axles, gears, pinions, pantograph shoes and horns, third rail beams, traction motor gear cases, and fuel tanks.

Brake System

§ 229.46 Brakes: General.

The carrier shall know before each trip that the locomotive brakes and devices for regulating all pressures, including but not limited to the automatic and independent brake valves, operate as intended and that the water and oil have been drained from the air brake system.

§ 229.47 Emergency brake valve.

(a) Except for locomotives with cabs designed for occupancy by only one person, each road locomotive shall be equipped with a brake pipe valve that is accessible to a member of the crew, other than the engineer, from that crew member's position in the cab. On car body type locomotives, a brake pipe valve shall be attached to the

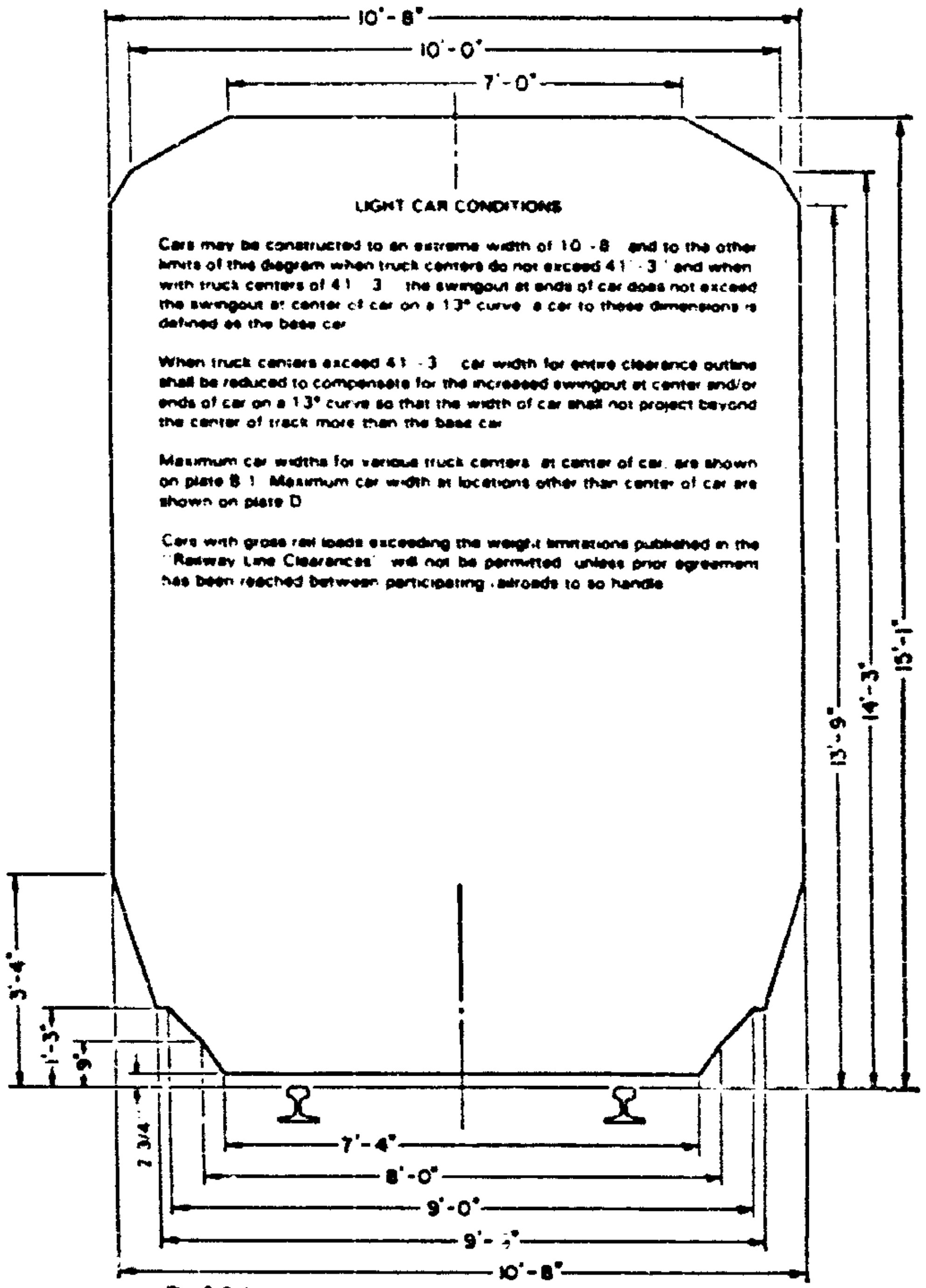
Appendix D

Association of American Railroads
Clearance Standards

PLATE B, PLATE B-1

EQUIPMENT DIAGRAM
FOR UNRESTRICTED INTERCHANGE SERVICE
STANDARD
ADOPTED 1948. REVISED, 1963 1966, 1967, 1968
ASSOCIATION OF AMERICAN RAILROADS
MECHANICAL DIVISION

DATE: MARCH 1, 1972 | PLATE B



LIGHT CAR CONDITIONS

Cars may be constructed to an extreme width of 10'-8" and to the other limits of this diagram when truck centers do not exceed 41'-3" and when with truck centers of 41'-3" the swingout at ends of car does not exceed the swingout at center of car on a 13° curve. A car to these dimensions is defined as the base car.

When truck centers exceed 41'-3" car width for entire clearance outline shall be reduced to compensate for the increased swingout at center and/or ends of car on a 13° curve so that the width of car shall not project beyond the center of track more than the base car.

Maximum car widths for various truck centers, at center of car, are shown on plate B-1. Maximum car width at locations other than center of car are shown on plate D.

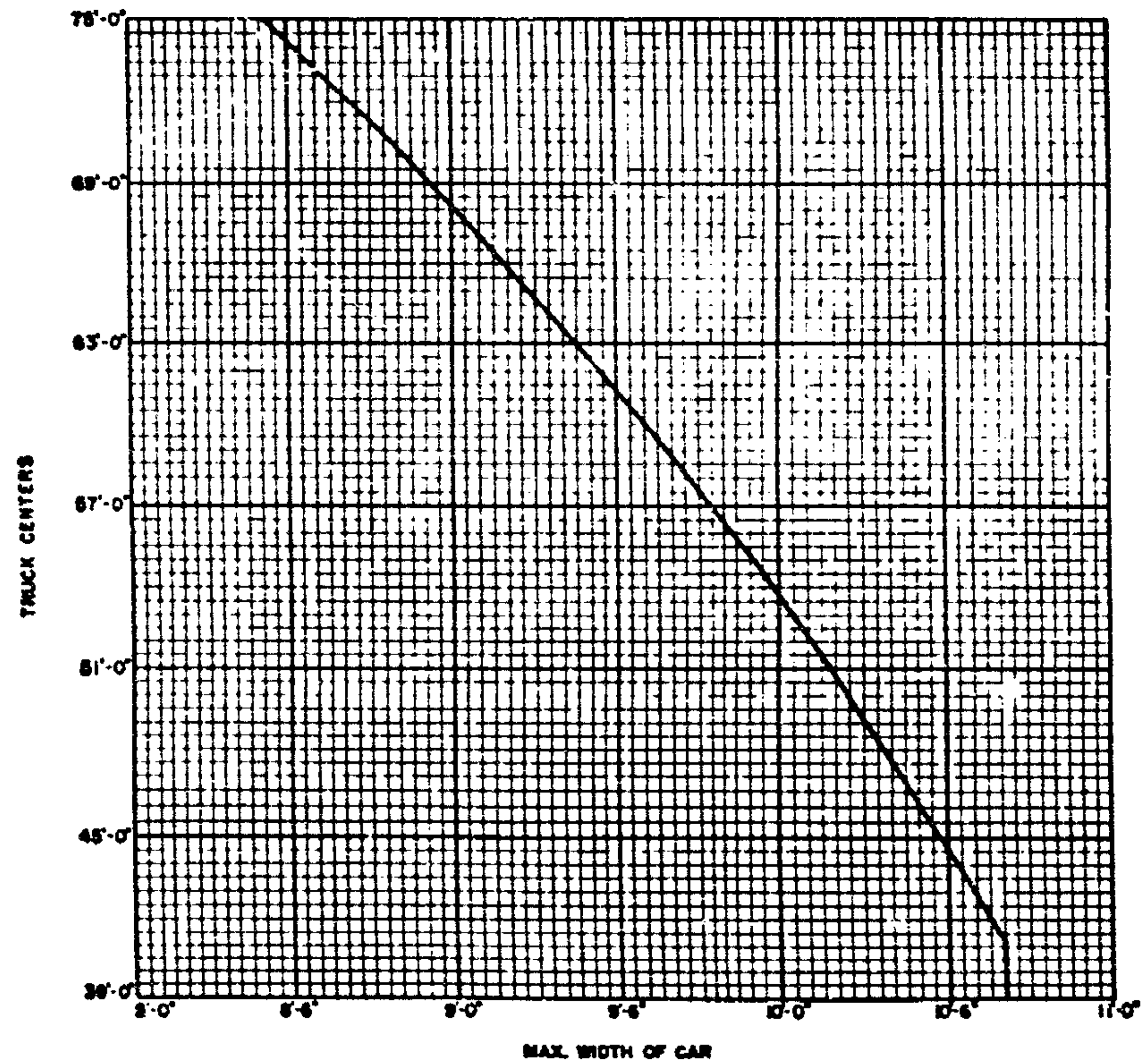
Cars with gross rail loads exceeding the weight limitations published in the "Railway Line Clearances" will not be permitted unless prior agreement has been reached between participating railroads to so handle.

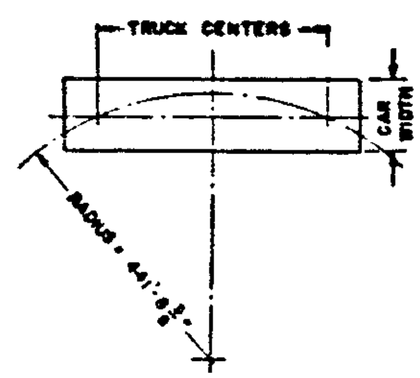
The 2 3/4" above top of rail is absolute minimum under any and all conditions of lading operation and maintenance.

NOTE: FOR USE WITH PLATE "B"

MAXIMUM WIDTH OF CARS WITH
VARIOUS TRUCK CENTERS
STANDARD
ADOPTED, 1962; REVISED, 1963, 1966
ASSOCIATION OF AMERICAN RAILROADS
MECHANICAL DIVISION

DATE: MARCH 1, 1967 | PLATE B-1





THE REDUCTION IN WIDTH IS PREDICATED ON THE BASE CAR, DEFINED ON PLATE B, AND ON 13° CURVE.

BASE CAR - (EXTREME WIDTH 10'-8"; TRUCK CENTERS 41'-3")

13° CURVE = 441'-8 5/8" RADIUS.

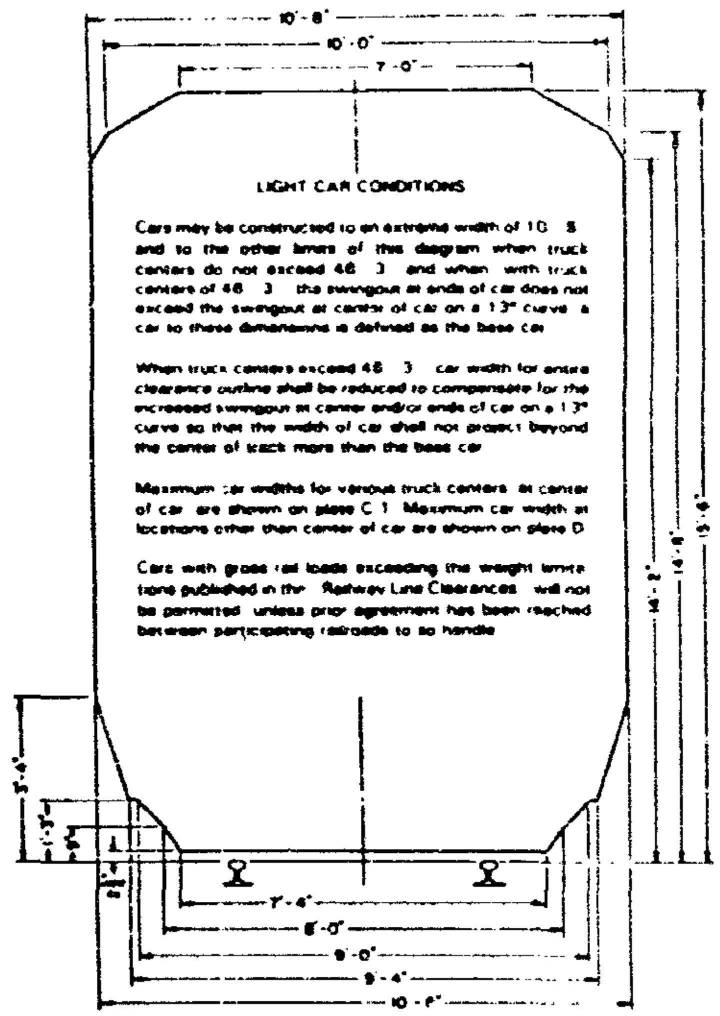
MAXIMUM SWINGOUT AT CENTER OF CAR WITH 41'-3" TRUCK CENTERS = 5 3/4"

NOTE: THE MAXIMUM WIDTHS SHOWN ARE BASED ON THE SWINGOUT AT CENTER OF CAR WHICH USUALLY GOVERNS. MAXIMUM ALLOWABLE WIDTH OF CAR, OTHER THAN AT CENTER OF CAR, IS SHOWN ON PLATE D. ON CARS WITH LONG OVERHANGS, THE SWINGOUT AT ENDS OF CAR MUST ALSO BE CHECKED.

PLATE C, PLATE C-1

EQUIPMENT DIAGRAM
FOR LIMITED INTERCHANGE SERVICE
STANDARD
ADOPTED, 1963: REVISED, 1965, 1966, 1967, 1991
ASSOCIATION OF AMERICAN RAILROADS
MECHANICAL DIVISION
DATE: MARCH 1, 1968 — PLATE C

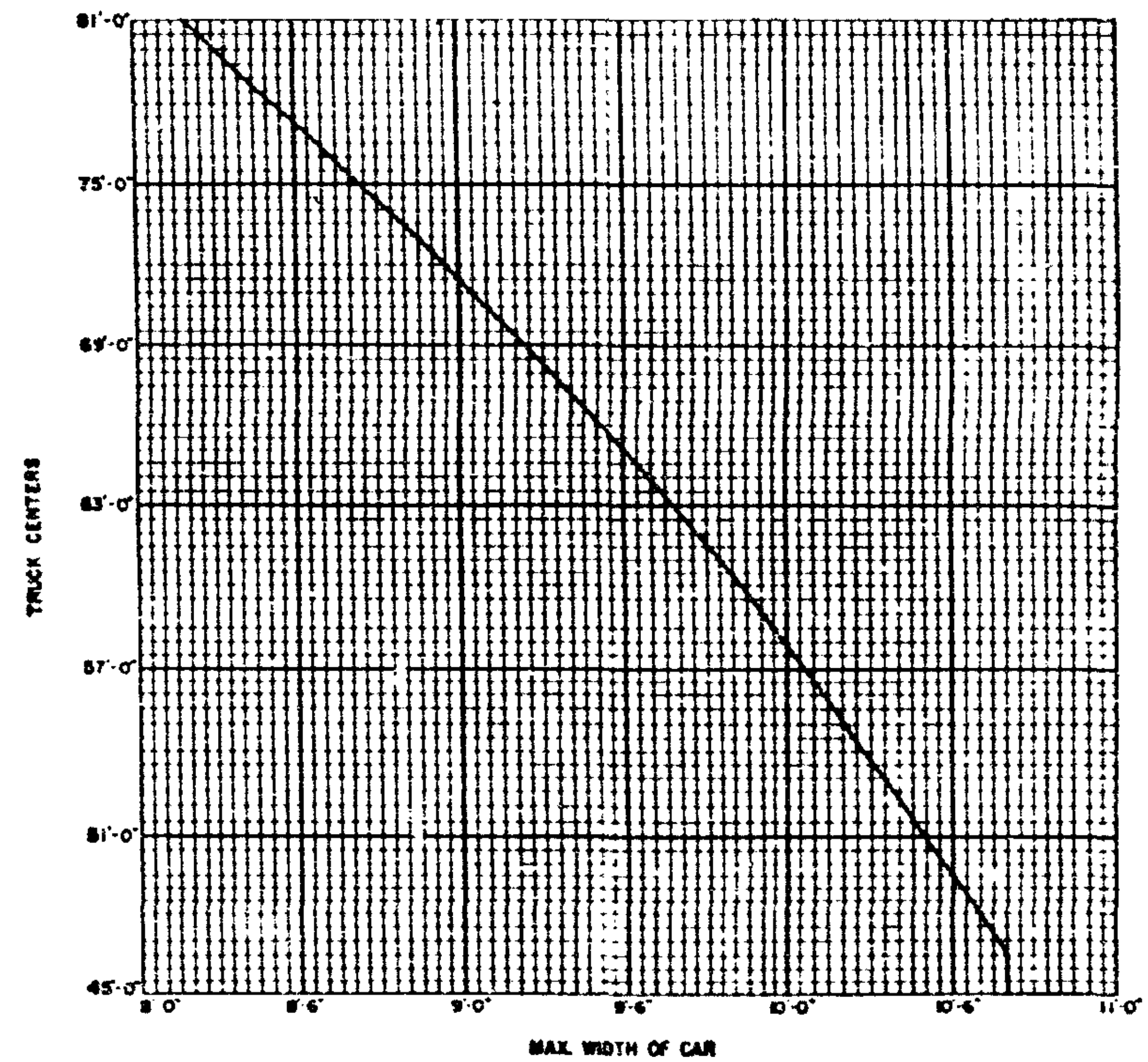
Unrestricted on all roads except on certain routes. For specific restricted areas on such roads see "Railway Line Clearances"

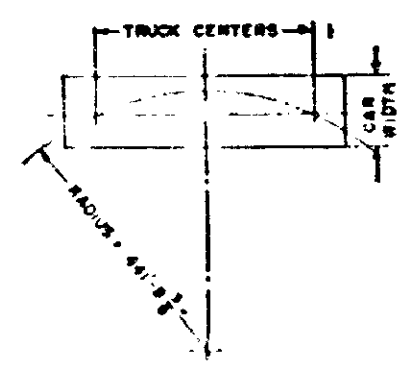


The 2 3/4" above top of rail is absolute minimum under any and all conditions of lading, operation and maintenance.

NOTE: FOR USE WITH PLATE "C"

MAXIMUM WIDTH OF CARS WITH VARIOUS TRUCK CENTERS
STANDARD
ADOPTED 1963. REVISED 1966
ASSOCIATION OF AMERICAN RAILROADS
MECHANICAL DIVISION
DATE: MARCH 1, 1967 | PLATE C-1





THE REDUCTION IN WIDTH IS PREDICATED ON THE BASE CAR, DEFINED ON PLATE C, AND ON A 13° CURVE.

BASE CAR – { EXTREME WIDTH 10'-8"; TRUCK CENTERS 46'-3" }

13° CURVE = 441'-6 3/8" RADIUS.

MAXIMUM SWINGOUT AT CENTER OF CAR WITH 46'-3" TRUCK CENTERS = 7 1/4"

NOTE. THE MAXIMUM WIDTHS SHOWN ARE BASED ON THE SWINGOUT AT CENTER OF CAR WHICH USUALLY GOVERNS MAXIMUM ALLOWABLE WIDTH OF CAR. OTHER THAN AT CENTER OF CAR IS SHOWN ON PLATE D. ON CARS WITH LONG OVERHANGS THE SWINGOUT AT ENDS OF CAR MUST ALSO BE CHECKED.

Appendix E

American Society for Testing and Materials Standards for Diesel Fuel Oils

The three grades of diesel fuel oils suitable for various types of diesel engines are described in ASTM Standard D 975 as follows:

Grade No. 1-D—A special purpose, light distillate fuel for automotive diesel engines in applications requiring higher volatility than that provided by Grade No. 2-D fuels.

Grade No. 2-D—A general purpose, middle distillate fuel for automotive diesel engines, which is also suitable for use in non-automotive applications, especially in conditions of frequently varying speed and load.

Grade No. 4-D—A heavy distillate fuel, or a blend of distillate and residual oil, for low- and medium-speed diesel engines in non-automotive applications involving predominantly constant speed and load.

Table 4.--Detailed requirements for diesel fuel oils[a]

Property and unit	Grade: No. 1-D	No. 2-D	No. 3-D
Flash point, °C (°F), min.	38 (100)	52 (125)	55 (130)
Water and sediment, % vol, max.	0.05	0.05	0.50
Distillation temperature °C (°F) 90% vol. recovered:			
min.	NA	282 (540)[b]	NA
max.	288 (550)	338 (640)	NA
Kinematic viscosity, mm^2/s^c at 40 °C (104 °F):			
min.	1.3	1.9[b]	5.5
max.	2.4	4.1	24.0
Ramsbottom carbon residue on 10% distillation residue, % mass. max.	0.15	0.35	NA
Ash, % mass, max.	0.01	0.01	0.10
Sulfur, % mass, max.[d]	0.50	0.50	2.00
Copper strip corrosion rating, max. 3 hr at 50 °C (122 °F)	No. 3	No. 3	NA
Cetane number, min.[e]	40[f]	40[f]	30[f]
Cloud point, °C (°F), max.	8	8	8

NA = not applicable.

[a] To meet special operating conditions, modifications of individual limiting requirements may be agreed upon between purchaser, seller, and manufacturer.

[b] When a cloud point less than -12°C (10 °F is specified, the minimum viscosity shall be 1.7 mm^2/s (31.4 SUS) and the minimum 90% recovered temperature shall be waived.

[c] One millimeter squared per second.

[d] Other sulfur limits may apply in selected areas in the United States and in other countries.

[e] Where cetane number by Test Method D 613 is not available, Method D 4737 may be used as an approximation.

[f] Low ambient temperatures as well as engine operation at high altitudes may require the use of fuels with higher cetane ratings.

[g] It is unrealistic to specify low temperature properties that will ensure satisfactory operation at all ambient conditions. However, satisfactory operation should be achieved in most cases if the cloud point (or wax appearance point) is specified at 6 °C or higher above the tenth percentile minimum ambient temperature for the area in which ambient temperatures for U.S. locations are shown (in Appendix X2) [of the ASTM Standards]. This guidance is general. Some equipment designs or operation may allow higher or require lower cloud point fuels. Appropriate low temperature operability properties should be agreed upon between the fuel supplier and purchaser for the intended use and expected ambient temperatures.

Source: American Society for Testing and Materials.

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