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16. Abstract

The objectives of this study include the identification of aspects of locomotive design and operation related to crew egress or access by rescuers in accidents, with the goal of improving crew survivability. This work identifies the considerations and options available for improving and optimizing locomotive egress/access methods.

A sizable information and data gathering effort is reported here to aid the understanding of many egress issues for contemporary locomotives, including those in the areas of locomotive design, crashworthiness, personnel training, the applicable regulations, and industry practices. Specific chapters address: Assessment of cab egress and identify areas for improvement; design approaches for improving the crashworthiness of the cab structure; design approaches to improving door and window emergency operation; improvements for visibility and access to egress routes; improvements for interior survivability; and conclusions and recommendations.

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SI* (MODERN METRIC) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
in	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
		AREA		
in^2	square inches	645.2	millimeters squared	mm^2
ft^2	square feet	0.093	meters squared	m^2
yd^2	square yards	0.836	meters squared	m^2
ac	acres	0.405	hectares	ha
mi^2	square miles	2.59	kilometers squared	km^2
		VOLUME		
fl oz	fluid ounces	29.57	milliliters	ml
gal	gallons	3.785	liters	l
ft^3	cubic feet	0.028	meters cubed	m^3
yd^3	cubic yards	0.765	meters cubed	m^3
NOTE: Volumes greater than 1000 l shall be shown in m^3.				
		MASS		
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams	Mg
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5(F-32)/9 or (F-32)/1.8	Celcius temperature	°C
		ILLUMINATION		
fc	foot-candles	10.76	lux	l
fl	foot-Lamberts	3.426	candela/m^2	cd/m^2
		FORCE and PRESSURE or STRESS		
lbf	poundforce	4.45	newtons	N
psi	poundforce per square inch	6.89	kilopascals	kPa

APPROXIMATE CONVERSIONS FROM SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
mm	millimeters	0.039	inches	in
m	meters	3.28	feet	ft
m	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi
		AREA		
mm^2	millimeters squared	0.0016	square inches	in^2
m^2	meters squared	10.764	square feet	ft^2
m^2	meters squared	1.195	square yards	ac
ha	hectares	2.47	acres	mi^2
km^2	kilometers squared	0.386	square miles	
		VOLUME		
ml	milliliters	0.034	fluid ounces	fl oz
l	liters	0.264	gallons	gal
m^3	meters cubed	35.71	cubic feet	ft^3
m^3	meters cubed	1.307	cubic yards	yd^3
		MASS		
g	grams	0.035	ounces	oz
kg	kilograms	2.202	pounds	lb
Mg	megagrams	1.103	short tons (2000 lb)	T
		TEMPERATURE (exact)		
°C	Celcius temperature	1.8C + 32	Fahrenheit temperature	°F
		ILLUMINATION		
lx	lux	0.0929	foot-candles	fc
cd/m^2	candela/m^2	0.2919	foot-Lamberts	fl
		FORCE and PRESSURE or STRESS		
N	newtons	0.225	poundforce	lbf
kPa	kilopascals	0.145	poundforce per square inch	psi

* SI is the symbol for the International System of Units

536-Conversion Factors

(Revised January 1992)

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- Massachusetts Bay Transportation Authority (MBTA), Boston, MA.
- Altamont Commuter Express (ACE), Stockton, CA.
- Metro North Commuter Railroad, New York.
- Providence & Worcester Railroad, Worcester, MA.
- CSX Railroad, Beacon Park, Boston, MA.
- Amtrak, Boston, MA.
- Guilford Transportation Industries, Billerica, MA.
- Sound Transit, Seattle, WA.
- GO Transit, Toronto, Canada.
- SEPTA, Philadelphia PA.

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ACRONYMS

AAR	Association of American Railroads
ACE	Altamont Commuter Express
APTA	American Public Transportation Association
ATD	Anthropomorphic Test Dummy
CFR	Code of Federal Regulations
EMD	Electromotive Division, General Motors
FAA	Federal Aviation Administration
FAR	Federal Air Regulations
FE	Finite Element
FEMA	Federal Emergency Management Administration
FHWA	Federal Highway Administration
FMVSS	Federal Motor Vehicle Safety Standards
FRA	Federal Railroad Administration
GE	General Electric
GM	General Motors
HIC	Head Injury Criteria
IMO	International Marine Organization
ISO	International Standards Organization
LLEPM	Low-Location Exit Path Marking Systems
MBTA	Massachusetts Bay Transportation Authority
MOW	Maintenance of Way
NTSB	National Transportation Safety Board
ORD	Office of Research and Development
PRESS	Passenger Rail Equipment Safety Standards Task Force
ROW	Right-of-Way

EXECUTIVE SUMMARY

Locomotive operating crews and rescue workers need improved means of cab access and egress. Interior survivability for cab crews is also a prime concern in locomotive accidents. Although present regulations and practices address this need in a limited way, further measures can provide substantial improvements in the survivability of crews in these situations.

The objectives of this study were to determine which aspects of locomotive cab egress by crews, or access by rescuers could be modified or changed, given the goal of improving crew survivability. Improvements may include changes to the locomotive structure (crashworthiness); hardware modifications (seats, doors, windows, roof hatch); revisions to crew and emergency responder egress/access measures and training, and having interior and exterior markings added or changed for improved visibility and comprehension.

A multi-faceted assessment of the present cab egress situation was the basis for identification of several general areas for improvement. An extensive review was conducted of current regulations, rail industry standards and practices, and also applicable regulations or equipment used in other transportation modes such as in aircraft and highway vehicles. Site visits to both commuter and freight railroads were made to survey locomotive types, interview train crews and observe emergency preparedness training. Pertinent National Transportation Safety Board (NTSB) accident investigation reports, and the Federal Railroad Administration (FRA) accident database were also reviewed.

Computerized dynamic accident simulation techniques demonstrated how such simulations could be useful in visualizing the accident process insofar as it affected egress or rescue in and around the cab area. Potential improvements to cab structure include strengthening of the windshield frame, upper corner post, adjacent roof, and the interconnection of members at the windshield-corner post-roof area.

Evaluation of typical door and window emergency operation identified several areas of needed improvement. This not only addressed the mechanical and functional design of windows, doors and their latches, but also assessed some current inspection and maintenance practices which could compromise operation. The need for significantly larger emergency openings, such as removable wall or ceiling panels, detachable hinges, or removable frames was identified and concepts offered. Uniformity of the opening motion for both doors and windows, and the need for maintaining and checking their tracks for freedom of movement was also emphasized.

The issues related to in-cab visibility and crew access to egress routes after accidents were addressed, and improvements in emergency lighting, markings, and hardware for improving visibility and access to exit routes was described. This included having the emergency lighting hard wired to the main battery, and provision of luminescent outlining of the egress openings.

Determining practical improvements for interior survivability were also of prime importance. Beneficial changes to cab mounted equipment, including control stands, seats, and safety related equipment were suggested, based on observations of computerized “dummies” in simulations of selected collisions and rollover. The incorporation of occupant restraints in conjunction with strengthened crew seats was also suggested, especially when the seat could be provided with a full headrest and reversed prior to a collision. Other survival aids for crewmembers, such as smoke hoods, breakout tools, etc., were identified, some of which are used in other transportation modes.

The findings of this study showed that many of the above areas would benefit from further investigation, since many different locomotive configurations, accident situations, operating practices and economic factors could only be touched on in this initial effort. Further investigation and effort is recommended.

1. INTRODUCTION

1.1 Background and Objectives

Locomotive operating crews and rescue workers need improved means of cab egress and access. Interior survivability for cab crews is a prime concern in locomotive accidents. Train accidents can involve severe damage to cab volume, detaching of cab equipment, failure of glazing, locomotive overturning, and possibly even the penetration and crushing of the cab structure itself. Although present regulations and practices address this need in a limited way, further measures are needed to enhance the survivability of crews in these situations.

The objective of this study is to identify potential improvements related to egress for improved survivability of the crew in accident situations. This required a major information and data gathering effort to understand the many existing aspects of egress—including technical, personnel, regulatory, cab equipment, and locomotive design. This was supported by many analytic and other research efforts. Examples of several different types of egress/access issues can include design modification concepts, equipment specifications, and operational procedures and emergency response training. Improvements include changes to the locomotive structure (crashworthiness); hardware modifications (seats, doors, windows, roof hatch); crew and emergency responder egress/access assistance measures and training, and interior and exterior markings added or changed for improved visibility and comprehension.

This document is intended as a reference for use by government, railroad operators, locomotive and car builders, emergency response agencies and other interested professionals of the considerations and options available for improving and optimizing locomotive egress/access methods.

1.2 Technical Approach

In order to meet the objectives of this study, five major activities were undertaken. The following sections of the report describe these activities.

- Assessment of the cab egress situation and target areas for improvement (Section 2).
  - Review the current regulatory environment and industry standards and practices for the rail industry and other modes of transportation.
  - Conduct surveys of locomotive configurations in use by the railroads.

- Conduct site visits to both commuter and freight railroads.

- Survey and observe train crew and emergency responder training.

- Examine emergency preparedness training programs.

- Review National Transportation Safety Board (NTSB) Accident investigation reports and FRA accident databases.

- Interview crewmembers involved in rail accidents.

• Design approaches to improving the crashworthiness of the cab structure (Section 3).

  - Develop and apply modern analysis methods to adequately simulate typical collisions.

  - Assess the crashworthiness of cab structures.

  - Assess targeted improvements to the cab structure.

• Design approaches to improving door and window emergency operation (Section 4).

  - Review the design of doors and their latches, window design and operation, with the objective of improving emergency egress capability.

  - Assess current inspection and maintenance practices with the objective of improving emergency egress.

• Assessment of improvements for visibility and access to egress routes (Section 5).

  - Assess the potential for improvements in emergency lighting, markings and hardware for improving visibility and access to emergency egress routes.

• Assessment of improvements for interior survivability (Section 6).

  - Examine changes to cab mounted equipment, including control stands, seats, and safety related equipment with the objective of improving interior survivability.

  - Examine the suitability of occupant restraints in the cab environment.

  - Examine the use of survival aids for crewmembers with the objective of improving interior survivability.

Section 7 contains conclusions and recommendations. The nature of this subject and the findings provided many areas that would benefit from further development of improvements, since many different locomotive configurations, accident situations, operating practices and economic factors could only be touched on in this initial effort. Further investigations and productive follow-up efforts can be made to capitalize on these findings for improved safety of locomotive engineers.

2. ASSESSMENT OF CURRENT ISSUES FOR CREW EGRESS FROM, AND RESCUER ACCESS TO, LOCOMOTIVE CABS

This initial task gathered information relevant to the many aspects of the crew egress situation in U.S. railroading today. It comprises technical data, operating practices, training, physical layouts and safety equipment, and inputs from operating personnel. Comparable regulations and practices for other modes of transportation - highway, transit and marine - were also included on a selected basis. This provided insights potentially useful for rail applications. This information was then used as a general reference in the succeeding tasks in which these aspects were individually investigated and improvements proposed.

This information gathering activity included:

- Review of current regulatory environment and industry standards and practices for the rail industry and other modes of transportation related to crew safety or egress.
- Conduct surveys of locomotive configurations in use by the railroads.
- Conduct site visits to both commuter and freight railroads.
- Survey and observe train crew and emergency responder training.
- Examine Emergency Preparedness Plans of various commuter railroads.
- Review National Transportation Safety Board (NTSB) Accident investigation reports and FRA accident databases.
- Interview crewmembers involved in rail accidents.

2.1 Review of Current Regulations and Industry Standards and Practices

Current federal regulations and rail industry standards and practices pertaining to cab design features, including emergency exits, lighting and markings were reviewed by consulting the Code of Federal Regulations (CFR), Title 49 Parts 200 to 399, revised October 1, 1999. Relevant regulatory and industry standards and practices from other modes of transportation were also reviewed for this task, and are shown in Table 1.

In an attempt to determine whether or not current safety practices provide for the adequate means of locomotive cab egress by onboard personnel and sufficient cab access by emergency responders in the event of an emergency requiring rescue, current practices as well as

Table 1. Regulatory data summary

Topic	Regulation/Standard	Applicability
Glazing	• 49 CFR 223	• Locomotive safety glazing
	• 49 CFR 393	• Truck window dimensions, markings
	• APTA Standard for Front and Side Facing Exterior Glazing Systems	• Evaluates exterior glazing and glazing systems against impact
Locomotive Safety Standards	• 49 CFR 229.119, 238.307	• Cabs, floors, passageways – freedom from slip/trip hazards • Fusee/torpedo container requirements
Cab Lights	• 49 CFR 229.127	• Location, construction and maintenance of adequate cab lighting • Adequacy of cab passageway lighting
	• 49 CFR 238.115	• Emergency lighting – passenger cars
	• 14 Federal Air Regulations (FAR) 25.812	• Emergency lighting
Railroad Safety Appliance Standards	• 49 CFR 231	• Locomotive steps, handrails
Safety Markings	• 49 CFR 229.93	• Safety cut-off device clearly marked on interior and exterior of cab
	• 49 CFR 229.85	• Doors to high voltage equipment marked
	• 14 FAR 25.811	• Emergency exit marking (aircraft)
	• APTA SS-PS-002-99	• Emergency exit marking/signage
Emergency Exits	• 49 CFR 238.113	• Specifies number, placement, removal and dimensions of passenger car emergency windows
	• 49 CFR 223.9	• Specifies the markings/signage and instructions for passenger car emergency windows
	• APTA SS-PS-002-99	• Detailed specifications for all emergency signage/marking on passenger cars
	• 49 CFR 393 (FHWA)	• Markings/instructions for bus emergency exits
	• Federal Motor Vehicle Safety Standard (FMVSS) 571.217 (motor vehicle, bus)	• Number, configuration, markings for emergency bus exits
	• 14 FAR 25.805	• Emergency exit type, dimensions, distribution (aircraft)
	• 14 FAR 25.809	• Emergency exit arrangement (aircraft)
	• International Standards Organization (ISO) 15370	• Low-location lighting on passenger ships
Control Stand Components	• 49 CFR 229.25	• Periodic inspection requirements
	• 49 CFR 238.447	• Sharp edges/corners eliminated
Body Structure	• 49 CFR 229.141	• Body structure strength, anti-climbers
	• APTA C&S-013-99	• Corner post structural strength requirements
	• APTA C&S-014-99	• Collision post structural strength for rail passenger equipment

Table 1. Regulatory data summary (continued)

Topic	Regulation/Standard	Applicability
Passenger Equipment Safety Standards	• 49 CFR 238	• Emergency exits • Passenger car lighting levels • Interior fittings, g-loads
Passenger Train Emergency Preparedness	• 49 CFR 239 • 14 CFR 121.417	• Crewmember emergency training • Emergency responder training • FAA requirements for crew emergency training
	• 14 CFR 121.427 • CFR 4610.205	• FAA crew refresher training requirements • IMO emergency preparation, evacuation
Emergency Equipment:	• 49 CFR 229.45 • 49 CFR 239.101 • 49 CFR 238	• General locomotive safety standards • Passenger car onboard emergency equipment • Passenger car onboard emergency equipment

alternatives need to be identified and evaluated. Since safety is not a static state, conditions and procedures accepted in the past may no longer be tolerable as technological advances are made and improvements in procedures, training and testing and communications occur as well.

2.1.1 Regulatory Background of Rail Safety Standards

Equipment design and other safety features of railroad rolling stock have been traditionally regulated by the FRA, with the Association of American Railroads (AAR) also promoting its own industry Standards and Recommended Practices. The AAR has not revised its Manual of Standard and Recommended Practices for Passenger Car Requirements since 1984. The AAR, together with FRA developed a set of locomotive crashworthiness standards, referred to as S-580 which came into force in 1990. While this is discussed in more detail below, these principally addressed the structural crashworthiness features of locomotives, not other cab design features.

Federal regulations governing railroad locomotive safety standards, including inspection, testing, maintenance and training can be found in Title 49 of the Code of Federal Regulations (5-9):

- Part 223, Safety Glazing Standards – Locomotives, Passenger Cars, Cabooses.
- Part 229, Railroad Locomotive Safety Standards.
- Part 230, Locomotive Inspection – applies to steam locomotive inspection.
- Part 231, Railroad Safety Appliance Standards.
- Part 238, Passenger Equipment Safety Standards.
- Part 239, Passenger Train Emergency Preparedness.

In the Federal Railroad Safety Authorization Act of 1994, Congress included a requirement that FRA develop regulations setting minimum safety standards for railroad vehicles, including crashworthiness, passenger safety, maintenance and inspection, and emergency response procedures and equipment.

FRA's response to the 1994 Congressional directive for minimum safety standards was to invite a variety or organizations representing the passenger rail industry to work together to develop industry consensus standards. The American Public Transportation Association (APTA) took on the responsibility to develop an updated *Manual of Standards and Recommended Practices for Passenger Rail Equipment* through a process known as the Passenger Rail Equipment Safety Standards Task Force (PRESS) as part of the effort towards complying with the Congressional mandate as well as a move towards industry self-regulation.

PRESS has developed a body of standards and recommended practices, including these topics (13-20):

- Standard for Emergency Communication.
- Standard for Emergency Signage for Egress/Access of Rail Passenger Equipment.
- Standard for Emergency Lighting Design for Passenger Rolling Stock.
- Standard for Equivalent Evacuation Units.
- Standard for Low Level Exit Path Marking.
- Standard for Cab Crew Seating Design and Performance.
- Recommended Practice for Passenger Equipment Roof Emergency Access.
- Standard for Collision Post Structural Strength for Railroad Passenger Equipment.
- Standard for Corner Posts Structural Strength for Railroad Passenger Equipment.

In 1996, FRA published a comprehensive assessment of issues affecting the safety and working conditions of locomotive cab crews (2). This report to Congress included the crashworthiness design, need for egress or refuge in accidents, and the environmental facilities in cabs.

Standard 580, or S-580, is now being expanded and revised and will apply to locomotives manufactured after January 1, 2003 (1). This is a comprehensive standard for structural performance of the locomotive, specifically the front end and cab-related areas, with the objective of increasing the protection of the crew in a variety of potential accident situations. (This standard requires the locomotive to sustain various static equivalent loads without damage, which can be applied to many different front end zones. However, an alternative acceptable approach includes the use of dynamic, finite-element analyses to show adequate performance in idealized accident scenarios.) The improved crashworthiness provided via this standard affects egress and rescue capability. The stronger cabs, hood structure, collision posts, and draft gear structure required by this standard could reduce deformations and loss of cab volume in severe crashes, thereby helping to retain the integrity of egress routes such as windows, doors, and potential new routes such as rooftop hatches.

A 1996 rail vehicle crashworthiness symposium sponsored by the FRA/Volpe Center included review of the above efforts (3).

In summary, there is a substantial body of existing rail industry and equipment standards that are directly or indirectly related to the important issues of egress from, and access to, occupants of rail vehicles which may be involved in accidents. Many of these build upon or elaborate on FRA regulations to enhance the survivability of crewmembers and passengers, either through safe evacuation and/or rescue of passengers and crewmembers from equipment and/or by seeking to mitigate the effects of a collision through improved equipment design features. However, the specific desire to improve the egress/access for locomotive crewmembers in accidents will be addressed in this project, and it is necessary to be familiar with the existing related requirements. Much of the work in this project will seek to utilize new approaches to accomplish this, while also taking advantage where possible of the existing body of regulations cited above.

2.1.2 Window Glazing and Markings

Part 223, Safety Glazing Standards – Locomotives, Passenger Cars, Cabooses requires that all locomotives built after June 30, 1980 be equipped with certified glazing in all locomotive cab windows. Appendix A to this regulation provides further discussion on the criteria for certification of glazing materials, including ballistic impact and large object impact tests.

There is also a Federal regulation related to emergency egress from passenger cars, and while not applicable to locomotives (or the cab section of cab cars), it serves as a valuable guide to the approaches that could be adapted to improve locomotive crew egress. Again, this is included in an effort to utilize all sources of potential guidance developed by the government and industry for egress needs. In 1998, regulatory language was added to Section 223.9 with regard to the number and marking of emergency windows in passenger cars, four of which are required per passenger car. This requirement is also found in Section 238.113, Emergency Window Exits. These regulations were developed in response to several passenger train accidents, most notably the Silver Spring, Maryland accident in which passengers had difficulty in evacuating a train after an accident while simultaneously, emergency responders had difficulty in gaining access to the interior of the passenger cars after the accident. These window marking requirements for passenger cars include:

- Each emergency window must be conspicuously and legibly marked with luminescent ("glow-in-the-dark") material.
- Each emergency window must have conspicuous and legible operating instructions located at or near it.
- Each window intended for emergency access by emergency responders must be marked using retroreflective material.
- Clear and easily understood instructions for removal of window by emergency responders must be located at each window or at either end of the car.
- Each emergency window exit shall be designed to permit rapid and easy removal during an emergency situation without requiring the use of a tool or other implement.

Federal Highway Administration (FHWA) regulations, found in Title 49 CFR Section 393 (10), contain requirements for emergency windows and the marking of emergency door and window exits for buses and trucks. Section 393.61 requires that "…each truck… shall have, in addition to the windshield, at least one window on each side of the driver's compartment, which window shall have sufficient area to contain either an ellipse having a major axis of 18 inches and a minor axis of 13 inches or an opening containing 200 square inches formed by a rectangle 13 inches by 17 3/4 inches…"

2.1.3 Cab Interior - Seating, Fittings, Passages

Part 229, Railroad Locomotive Safety Standards, Section 229.119: Cabs, floors, and passageways specifies, in part, that:

- Cab seats shall be securely mounted and braced and that cab doors shall be equipped with a secure and operable latching device. Section 238.233 further states that seats must be attached to withstand loads of 8-4-4 g's (longitudinal, lateral and vertical, respectively) (Figures 1, 2).

Figure 1. Cab seat mounting - F59 rebuild

Figure 2.   Cab door latching device - F59 rebuild

- Cab windows of the lead locomotive shall provide an undistorted view of the right-of-way from the crew's normal position in the cab (see also 223, Glazing Standards).

- Similar locomotives with open end platforms coupled in multiples and used in road service shall have a means of safe passage between them.

- There shall be a continuous barrier across the full width of the end of a locomotive or a continuous barrier between locomotives.

- Containers shall be provided for carrying fusees and torpedoes. A single container may be used if it has a partition to separate fusees from torpedoes. Torpedoes shall be kept in a closed container.

- Floors of cabs, walkways, compartments shall be kept clear of slipping, tripping or fire hazards.

Interior fittings are defined in Part 238 as "any component in the passenger compartment which is mounted on the floor, ceiling, sidewalls, or end walls and projects into the passenger compartment more than 1 inch from the surface to which it is mounted." They are addressed in Section 238.233, Interior Fittings and Surfaces; 238.435, Interior Fittings and Surfaces and 238.447 Train Operator's Controls and Power Cab Layout (for Tier II – High-Speed Passenger Equipment), with the major difference being that the equipment operated at higher speeds must be designed to withstand higher g-force acceleration in the event of a crash.

In Section 238.233, applicable to conventional equipment, the regulatory language allows for greater flexibility and judgment in attaining compliance. It states, "***To the extent possible,*** all interior fittings in a passenger car, except seats, shall be recessed or flush mounted. Sharp edges and corners in a locomotive cab and a passenger car shall be either avoided or padded to mitigate the consequences of an impact with such surfaces. Section 238.447, which applies to the higher speed Tier II equipment, requires that "Sharp edges and corners ***shall be eliminated*** from the interior of the power cab car, and interior surfaces of the cab likely to be impacted by an employee during a collision or derailment shall be padded with shock-absorbent material." (emphasis added)

Section 238.447, (Tier II equipment) also specifies the layout in the power cab car, including ergonomic considerations such as the control layout and field of view. Additionally, requirements for seating design are very specific with regard to safety and ergonomic considerations.

2.1.4 Lighting, Exit Pathways

Section 229.127: Cab lights, specifies in part that:

- Each locomotive shall have cab lights that will provide sufficient illumination for the control instruments, meters, and gauges to enable the engine crew to make accurate readings from their normal positions in the cab.

- These lights shall be located, constructed and maintained so that light shines only on those parts requiring illumination and does not interfere with the crew's vision of the track and signals.

- Each controlling locomotive shall have a conveniently located light that can be readily turned on and off by the persons operating the locomotive and that provides sufficient illumination for them to read train orders and timetables.

Recent regulation introduced in Section 238.115 includes minimum illumination level requirements for emergency lighting in passenger cars, including back-up power and the ability to withstand specific g-force accelerations.

Through the previously mentioned APTA PRESS effort of promulgating industry standards, a number of standards and recommended practices were developed with the intent of improving exit path marking and the identification and operation of egress/access points. Oftentimes during an accident, the normal and emergency lighting powered by a car's main battery system fails in a collision or derailment because the emergency lighting power circuit is damaged and the train may be in total darkness. Thus, it was reasoned in the Standard for Low-Location Exit Path Marking Systems (LLEPM), APTA Safety Standard SS-PS-004-99, that the presence of a clearly marked visible path to exit the train, located in close proximity to the car floor could contribute to safe egress/access.

This concept has already been long accepted in other modes of transportation, and is incorporated into Federal Aviation Administration (FAA): Floor Proximity Emergency Escape Path Marking Systems (12); and International Marine Organization (IMO) Resolution Guidelines for the Evaluation, Testing and Application of Low-Location Lighting of Passenger Ships (22).

The LLEPM Standard applies "…to all new and remanufactured passenger and crew carrying equipment placed in service after January 1, 2000." All existing passenger equipment must be in compliance by January 1, 2006, with the exception being equipment that does not meet minimum emergency lighting levels established in the APTA Standard for the General Emergency Lighting Design for Passenger Rolling Stock; in that case, existing equipment must come into compliance by July 1, 2002.

2.1.5 Emergency Lighting

The APTA Standard for Emergency Lighting System Design for Passenger Cars, APTA SS-E-013-99, specifies minimum performance criteria for emergency lights for existing, new, and rebuilt vehicles, *including* the "Crew Area of Locomotive/Cab car." Section 5.7 of the Standard states that "Illumination shall be provided within the cab area to allow safe passage of crew from this area to the aisle/passageway or exit/entrance location." In the case of existing locomotive equipment, initial minimum value for emergency lighting is 0.5 foot-candles when measured 25 inches above the floor. After 1-1/2 hr, the value is 0.3 foot-candles.

The value of the emergency lighting depends upon the battery back-up system and its maintenance, since emergency lighting is powered either by a car-borne central battery or a self-contained battery.

This standard was approved by the APTA Task Force in March 1999 and took effect on January 1, 2000. It is intended to be used in conjunction with the other safety standards developed by APTA, including the low-location path marking and emergency signage standards to form a systems approach to ensure safe evacuation of passengers and crewmembers in an emergency.

FAA regulations also require the installation of emergency lighting, stating in Section 25.812 that the emergency lighting system must be independent of the main lighting system (12). Existing locomotives meet this with a self-contained battery, but would benefit if a separate circuit to the main battery were available.

2.1.6 Emergency Evacuation Units

The ability to evacuate the locomotive or passenger car immediately following an emergency situation is partially determined by the number of *usable* exits and alternative options for egress. FRA regulations require each passenger car built after 2002 to have a minimum of two exterior side doors with minimum dimensions of 30 inches wide and 74 inches high. Section 238.113 requires each level of each passenger car to have a minimum of four emergency window exits, "designed to permit rapid and easy removal during an emergency situation without requiring the use of a tool or implement."

As previously mentioned, bus exit arrangements are based on seating capacity and bus type, e.g., school bus. The FAA also requires in Title 14, Section 25.809, Emergency Exit Arrangement, that "(a) each emergency exit, including a flight crew emergency exit must be a movable door or hatch in the external walls of the fuselage, allowing unobstructed opening to the outside;
(b) each emergency exit must be openable from the inside and the outside except that sliding window emergency exits in the flight crew area need not be openable from the outside if other approved exits are convenient and readily accessible to the flight crew area." The regulation further states in (g) of this section that "There must be provisions to minimize the probability of jamming of the emergency exits resulting from fuselage deformation in a minor crash landing."

This was also supplemented by FAA testing of evacuation strategies, as reported in (2).

2.1.7 Railroad Safety Appliance Standards

Part 231, Railroad Safety Appliance Standards applies primarily to different types of freight cars, older-style passenger cars, and a certain type of freight switching locomotive. This section addresses regulations for:

- Locomotive Steps:
  - Number of steps – a switching locomotive must have 4.
  - Dimensions of steps – minimum width of 24 inches and minimum depth of 12 inches with the bottom step not more that 19 and preferably 15 inches from the top of the rail to the safety tread.
  - Visibility of steps – outer edge of step either illuminated or painted a contrasting color.
- Locomotive Handrails:
  - Vertical handrails on either side of steps beginning not less than 6 inches above the bottom step extending to at least 48 inches above and painted in a contrasting color.
  - Handrails must provide at least 2-1/2 inches of usable hand clearance throughout entire length.

2.1.8 Passenger Equipment Safety Standards

In May of 1998, the FRA issued the Final Rule of the Passenger Equipment Safety Standards, 49 CFR Part 238. The purpose of the new regulation was to prescribe minimum federal safety standards to "…prevent collisions, derailments, and other occurrences involving railroad passenger equipment that cause injury or death to railroad employees, railroad passengers or the general public; and to mitigate the consequences of such occurrences to the extent that they cannot be prevented." Part 238 regulates training, inspection, safety appliances and various train emergency systems. It is important to note that according to the definition of Passenger Equipment in Section 238.5, passenger equipment includes: **"…a locomotive not intended to provide transportation for a member of the general public that is used to power a passenger train."** (*emphasis added*)

For railroad passenger equipment operating at speeds between 125 and 150 mph (referred to as Tier II equipment), the federal minimum requirements are more stringent and specific. For example, Section 238.441 prescribes that each passenger car and power cab car shall have a minimum of one roof hatch emergency entrance location with minimum dimensions of 18 inches x 24 inches or at least one structurally weak point in the roof of the same dimensions.

Federal Motor Vehicle Safety Standards, Section 571.217, Standard No. 217 (11); Bus emergency exits and window retention release, describes the provisions for emergency exits on buses in S5.2. Based upon seating capacity and gross vehicle weight, buses must have emergency exits that are clearly marked with the words "Emergency Exit" or "Emergency Door," have easily operated mechanisms for release. School buses and buses that weigh over 10,000 lb must be equipped with one rear emergency door **that opens outward and is hinged on the right side** *(emphasis added*). An exception for non-school buses permits that "When the bus configuration precludes installation of an accessible rear exit, a roof exit that meets the requirements of S.5.3 through S.5.5 when the bus is overturned on either side, with the occupant standing facing the exit, shall be provided in the rear half of the bus."

2.1.9 Emergency Preparedness Training

Part 239, Passenger Train Emergency Preparedness Final Rule was introduced May 4, 1998. This new regulation – in Section 239.101(a)(2)(i) – requires initial as well as periodic training (at least once every two years) for onboard crewmembers of commuter and intercity passenger train service that includes:

(a) Rail equipment familiarization.

(b) Situational awareness.

(c) Passenger evacuation.

(d) "Hands-on" instruction concerning the location, function and operation of onboard emergency equipment.

This regulation – located in Section 239.101(a)(5)— also requires a railroad to establish and maintain a working relationship with on-line emergency responders by:

(a) Developing training programs for emergency responders "…which shall include an emphasis on access to railroad equipment…."

(b) Make the training program available to emergency responders who could reasonably be expected to respond to a railroad emergency call (this could include the distribution of printed materials, videotapes etc.).

(c) Inviting emergency responders to participate in emergency simulations.

(d) Distributing the railroad emergency preparedness plan (applicable parts) to emergency responders.

In Section 239.103(a), the requirements for performing emergency drills are stipulated, including:

(a) Each railroad operating passenger train service shall conduct full-scale emergency simulations to determine its capability to execute the emergency preparedness plan and ensure coordination with all its emergency responders.

(b) Depending upon number of system route miles, annual passenger load, and type of service, each passenger train service shall conduct either one such simulation annually or biannually.

And finally, in Section 239.105, a debriefing and critique session is required to be held within 60 days of the date of the emergency simulation to determine the efficiency of:

- Communication.
- Response.
- Evacuation.

Though these regulations are applicable to railroads that operate commuter and intercity passenger train service, there are requirements for emergency preparedness coordination with other rail modes of transportation, including joint operations (239.101(a)(3)) and parallel operations (239.101(a)(4)(iii)).

Emergency Preparedness Plans were examined from several commuter and passenger railroads, all of which presented the aforementioned requirements in a complete and orderly manner, with several including schematics of their locomotives as well as passenger cars.

2.2 Assessment of Present Cab Design Layout and Development of Issues Related to Emergency Egress

To determine the range of different cab models and configurations used in current railroad operations, both commuter and freight, with the objective of assessing their implications for locomotive cab emergency egress/access, the following information gathering tools were used:

- Surveys.
- Site visits.
- Schematics.
- Interviews.

2.2.1 Locomotive Configuration Surveys Distributed to Railroads

Detailed locomotive surveys were developed and distributed to both freight and passenger railroad properties to determine the variety in the interior measurements of different locomotive types for locomotive cab doors, windows, steps/ladders, and cab dimensions. In addition to these measurements, other relevant safety features were noted, including seating configuration, lighting, emergency tools and equipment, handhold/handrail locations, door and window arrangement, including the method of their operation, as well as the available egress/access routes in/out of locomotive cabs (Appendix A).

2.2.2 Site Visits to Commuter and Freight Railroads

To view first hand the range of different cab models and configurations used in railroad operations, site visits were made to both commuter and freight railroad locations. Observations were made of different types of locomotives, ranging from the smaller (shorter and lighter weight) passenger locomotives, to the narrow and wide nose versions of several types of freight locomotives.

The aforementioned survey (Section 2.2.3) was used to ensure consistency in documenting the data collected. Photographs and videotaped footage were taken as well, with the following checklist of items to consider:

Locomotive Cab interior and exterior photos, including:

- Seating arrangement - engineer, other crewmembers.

- Control stand relative to engineer’s seating arrangement.

- Side Doors - show opening in or out.

- Other Entry/Exit Doors - leading to outside, to engine room, etc.

- Windows (side) - to show how they open, show size relative to a person.

- Other Windows (windshield, doors).

- Ladder/steps leading to/from cab.

- Lighting Placement: normal and emergency (if any).

- Door Handles - to show size, type, how they are operated.

- Fire Extinguisher placement, mounting.

- Other emergency tool placement.

- Signage or markings indicating doors, window, exits.

- Other — any other items that may be of interest with regard to the topic of engineer egress/ emergency responder access of the locomotive cab in the event of an accident or emergency situation.

Placement and operation of doors and windows were noted, as well as location of all the seats and the engineer's control stand. Measurements were taken of the height and width of doors and windows, the length of the risers of steps leading to the cab, and dimensions of the cab itself. From the site visits, photographs, schematics, and discussions with manufacturers, it was noted that there are many variations in even the "standard" or required equipment on a locomotive.

Photographs of locomotives and interviews with employees with regard to locomotive equipment were conducted at site visits to the following railroad properties:

- Massachusetts Bay Transportation Authority (MBTA), Boston, MA.
- Altamont Commuter Express (ACE), Stockton, CA.
- Metro North Commuter Railroad, New York.
- Providence & Worcester Railroad, Worcester, MA.
- CSX Railroad, Beacon Park, Boston, MA.
- Sound Transit, Seattle, WA.
- GO Transit, Toronto, Canada.

One of the commuter rail sites visited predominantly used two types of passenger locomotives: the F40 and GP40 both manufactured by General Motors (GM). Although the two locomotives share the same feature of having a wide nose, the configurations of the cabs were quite different, particularly the locations of the doors, where the F40's doors were located on either side, requiring ladder-like steps to enter/exit the locomotive, while the cab doors on the GP40 were located directly behind the seat opposite the engineer's and the engineer's seats. The F40 cab also had a door behind the engineer's seat, leading into the engine room, with means of egress through the back door of the engine room. Another notable contrast in configuration was the

F40's AAR-type control display stand located left of the engineer's seat near the center of the cab, while the GP40 had the 'clean cab' design of a control display console, located in front of the engineer's seat.

The classic AAR control stand location can be seen in Figures 3 through 5 in this section, and a photo is seen in Section 5, Figure 92. In this arrangement, the older-style controls are on a tall console placed to the engineer's left so that forward vision is clear. The newer "clean cab" type of configuration has a more compact set of gages and quadrant-type controls on a desk-like surface ahead of the engineer. Thus, the floor area in the cab center is unobstructed. This can be seen in the photo in Section 5, Figure 93.

A commuter rail survey detailed the cab configuration and measurements of the F40 PH3C passenger locomotive originally manufactured by General Motors Electro-Motive Divisions and rebuilt by Boise Locomotive in 1998. It was noted that it had a similar layout as the previous (and older model) F40 observed, except that it had the "clean cab" design of the control display console located in the cab in front of the engineer's seat. The side windows are single sliding. A door to the engine room is located behind the engineer's seat, which, after walking down a passageway the length of the engine, leads to another door which opens to a small platform allowing egress from the rear of the locomotive (Figure 3).

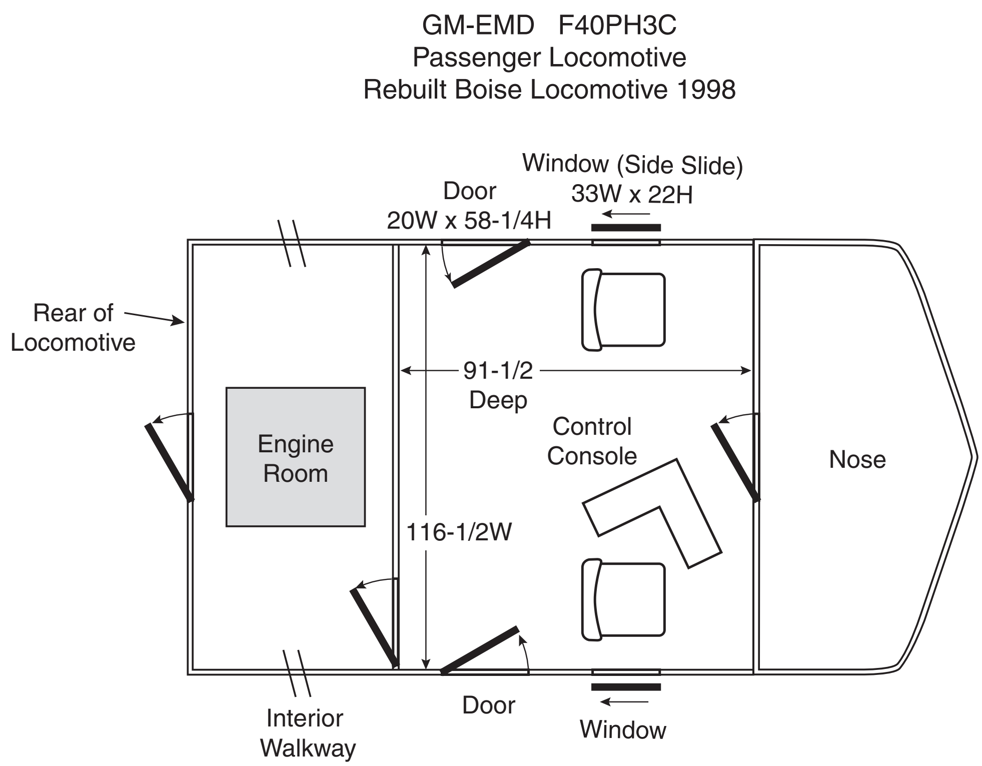


***Figure 3.	GM-EMD F40PH3C passenger locomotive rebuilt Boise locomotive 1998***

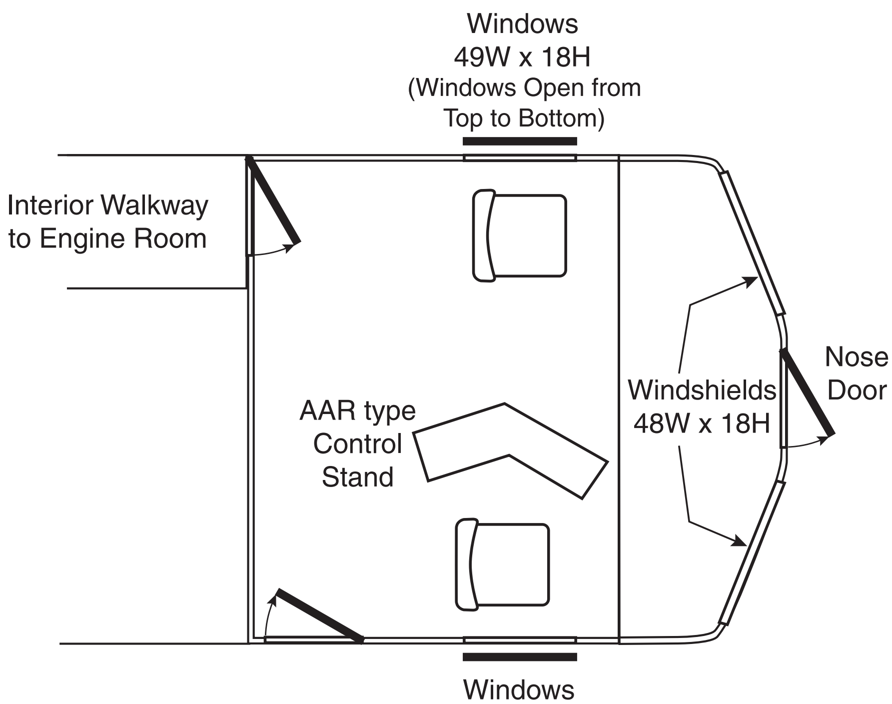


Figure 4. GM-EMD FL9M remanufactured by Morrison-Knudsen (M-K)

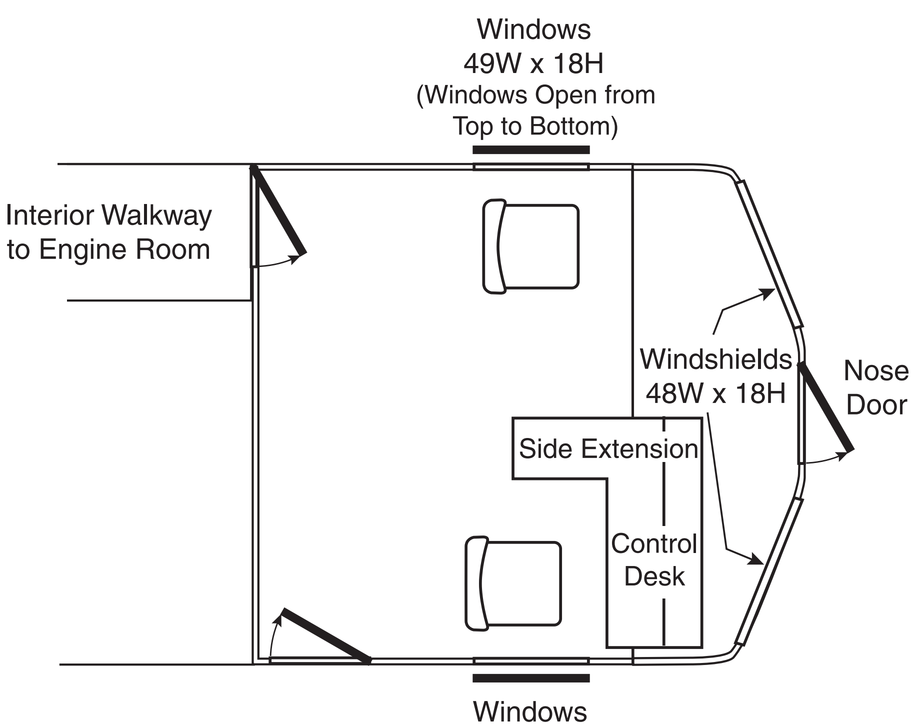


Figure 5. GM FL9C (chrome rebuild)

Surveys were made of several of Metro North Commuter Railroad's locomotive fleet. Two locomotives, the FL9-M and FL-9-AC (Figures 4, 5) were originally built by GM and remanufactured by Morrison Knudson and ABB, respectively. One interesting variation on this type of locomotive is the operation of the cab side windows, which are opened by pushing down on the handle or handles at the top of the window frame and then sliding down. Figures 6, 7 and 8 illustrate three varieties of rebuilt FL-9 locomotives used on one property with three different side windows.

Metro North's P32AC-DM, manufactured by GE has a flat, angled front (Figure 9) with two side doors, and a nose hatch hinged at the bottom edge opening out (Figure 10). Access to the emergency nose hatch, however, is impeded by the location of a refrigerator that would have to be moved in order to exit via this route (Figure 11).

The door to the engine room, located adjacent to the side door on the engineer's side, behind the engineer's seat and the side doors had inconsistent door handle placement, where the side door handles are located to the right, while the engine room door handle is located to the left. Also, both doors open differently, the side door by pulling towards you to open (into the cab occupied space) while the engine room door opens by pushing outward (into the engine room) (see Figure 12).

This arrangement comes about because doors (or any other hardware) cannot open outward into the section envelope; therefore side doors open inward. But, the adjacent engine room door would then interfere if it also opened inward, so it opens outward into the engine room.

Figure 6. FL9AC single lever 16 x 18 side window

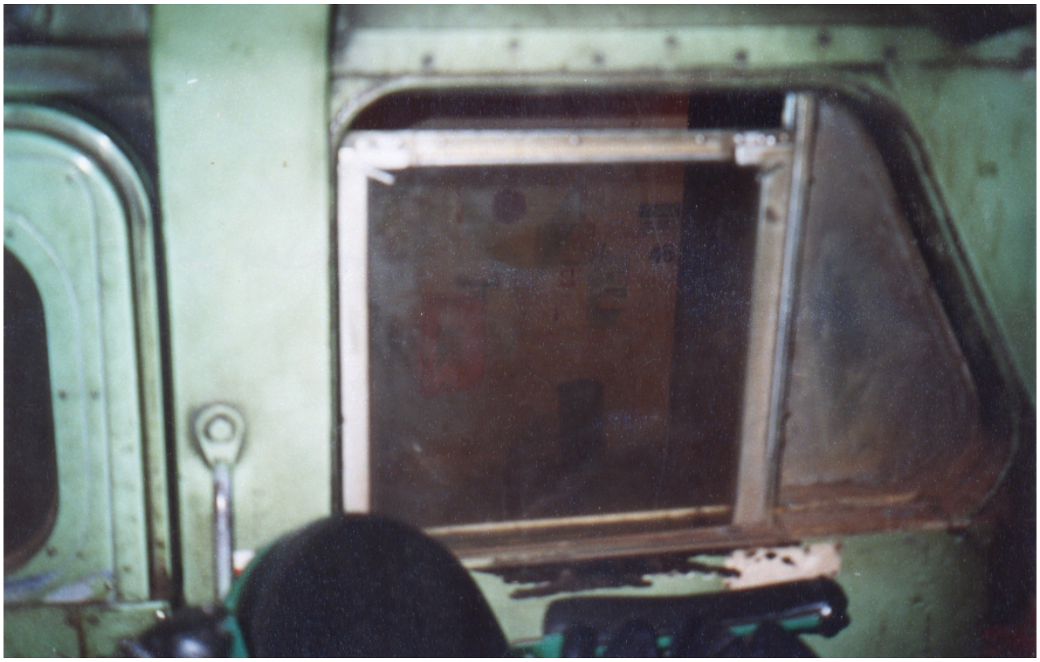


Figure 7. FL9C two lever side window (21 x 22)

Figure 8. FL9M side window slides up and down (29 x 22)

Figure 9. GE P32AC-DM

Figure 10. Close-up view of nose hatch

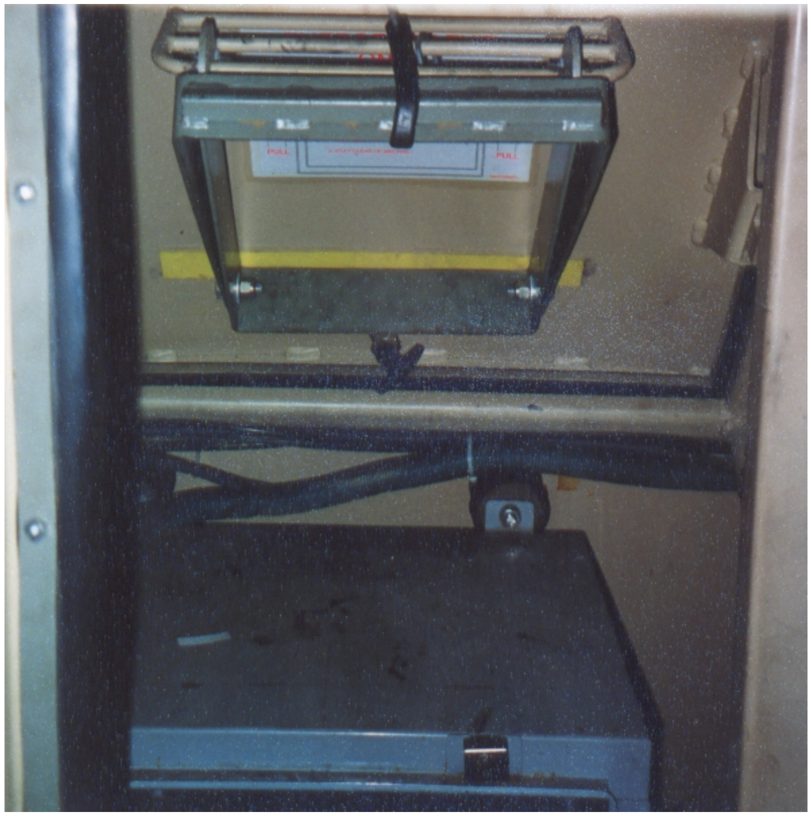


Figure 11. Interior view of nose hatch (refrigeration unit located below)

However, with the hinging direction on the right hand exit door, it could block the engine room opening if it were open (into the cab).

There are three seats in the cab, one opposite the engineer's side, and one located near the center behind the other two seats. There is one long control console, extending from the engineer's side to the seat opposite the engineer's side. The side windows are opened by the single side-sliding panel (Figure 13).

The P42AC-DM, a later model GE unit, has a similar configuration to that of the P32, with a flat, angled front. It does not have a nose hatch, but has the side doors and the door leading into the engine room. The control display console extends the width of the cab to accommodate both the engineer's and seat opposite the engineer's seats. There are three seats, one on the engineer's side, one on the seat opposite the engineer's side and another toward the center of the cab behind the two other seats.

On a Boise Locomotive yard switcher, a narrow nose locomotive, it was observed that the cab doors were located in front of the seat opposite the engineer's seat, with the second door located on the rear side of the cab behind the engineer's seat leading to a walkway. The controls on the engineer's side are displayed on a stand, located to the left of the engineer's seat. A third seat

***Figure 12.	Side cab entry/exit door on left of photo: handle on right side of door, pull open into cab. Engine room door on right: handle (recessed) on left side of door, push to open into engine room***

was situated in between the engineer's seat and the seat opposite the engineer's seat. The front windshields on this switcher engine are large square-shaped fixed windows.

2.2.3 Summary of Present Cab Design Layout Issues

Passenger Locomotives

Passenger locomotives viewed on site or through detailed surveys and photographs exhibit many variations in configuration. The two primary locomotive cab entry/exit doors are located either:

- On the sides of the locomotive with ladder-like steps (Figure 14)
- At the nose of the locomotive and behind the engineer's seat (Figures 15, 16), or

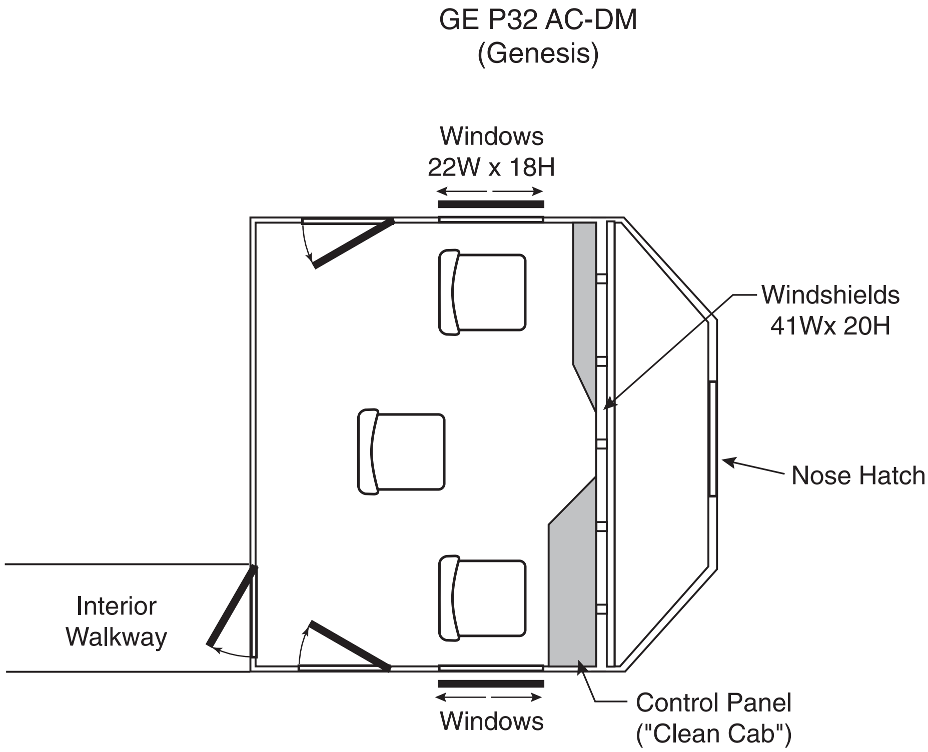


Figure 13. GE P32AC-DM (Genesis)

Figure 14. GE Genesis P42 side view

Figure 15. SD 70 MAC nose door to platform, stairs on either side

- Behind the engineer to an exterior walkway and in front of the seat opposite the engineer's (Figure 17).

The F40 locomotive, which makes up about 62 percent of the current U.S commuter rail locomotive fleet (ref. APTA 2000 Transit Vehicle Data Book), have locomotive entry/exit doors located on the sides of the locomotive. The side windows on the F40s are generally double paneled windows, with either one fixed, and the other sliding to open or both sliding open from a mid-point position. A recently rebuilt F40 passenger locomotive seen at one property had weather stripping around the windshields on the exterior of the locomotive. This stripping can be pulled off and the glass panels removed from the outside of the locomotive, though it was noted that there were no interior or exterior marking, signage, or instructions to that effect. In contrast to this model F40, another model of the same locomotive was viewed at another commuter railroad facility, this time with bars installed over the exterior of the windshields (as an added precaution against glass breakage from vandalism). Both could present barriers to egress/access, since, as noted, there are no removal instructions on the F40 with removable windshields, rendering them ineffectual, while the other F40 has no egress/access potential through the permanently welded, barred windshields.

Figure 16. Door to rear of engineer's seat, to walkway

Both F40 locomotives have a door behind the engineer's seat leading to the engine room, with means of egress through the rear door of the locomotive. This is not only an added means of egress, since it provides another way to evacuate the locomotive, but can also be used as a refuge in the event of an impending collision in which jumping from the locomotive may be deemed impractical. Also, in a collision where there is structural deformation to the cab such that the side doors and windows are collapsed and/or jammed, the crewmember(s) would have the rear door from which to exit.

The SD-70 MAC (GM) and CW40-8 (GE), two newer freight locomotives had similar configurations: both were wide-cab, wide-nose with three seats in the cab, one on the engineer's side, and one behind the other on the side opposite the engineer's seat. The locomotives have a "clean cab" design, where the control display is on a workstation console, with a desk in front of the conductor's seat on the seat opposite the engineer's side. The locomotives have a door on the front of the locomotives, as do all wide-nose locomotives. The second door to egress is located on the rear behind the engineer's seat (Figure 18). The side windows on the SD70 are double sliding panels, which when fully opened measure 33 inches wide x 22 inches high while the

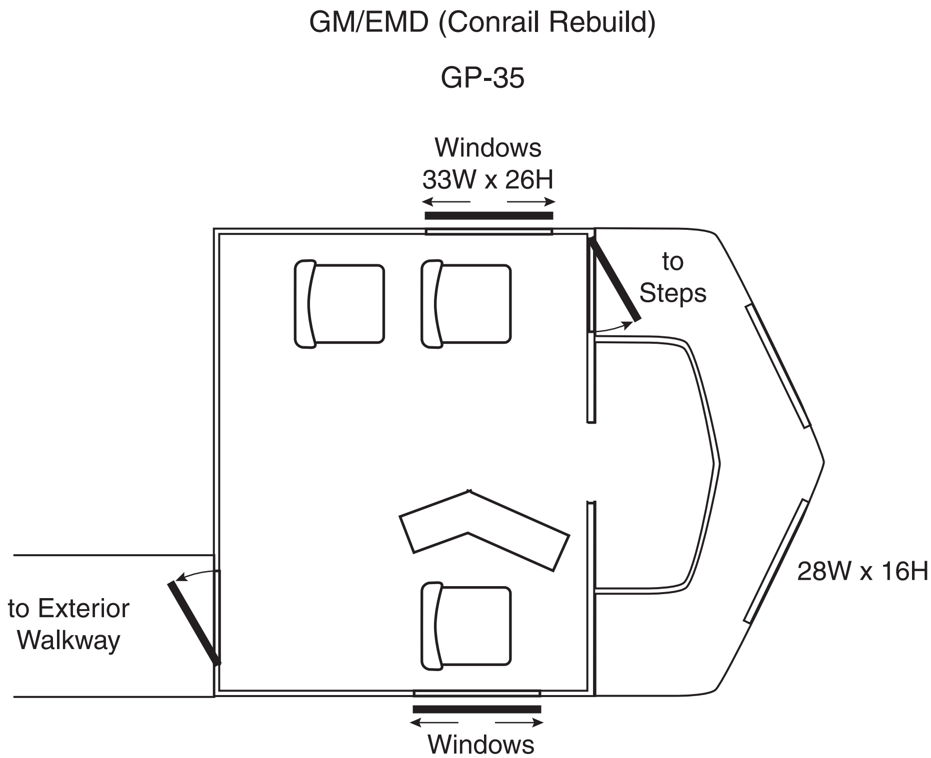


Figure 17. GM/EMD (Conrail rebuild)

CW40-8 windows consist of a fixed and single sliding panel, with a fully-opened width of 21 inches and height of 24 inches The windows on the CW40-8 are smaller since there is only a single sliding panel. Although it could possibly take less time for a person to open a single sliding panel as opposed to a double sliding panel, adequate size of the clear opening is the main issue if this is the only viable means of egress for the crewmember.

For both the SD70 and the CW40-8 (Figure 19), there are stairs leading from the cab to the vestibule area containing the toilet room, and then a door leading to a small compartment, with access to the nose door leading to the outside. The vestibule door opens outwards to the left with the handle on the right side of the door, while the nose door opens to the right, with the handle on the left side of the door. This inconsistency in placement of handles and difference in the side on which the doors are hinged could arise as an egress issue in the case of a collision. Crewmembers, who may be injured, disoriented, and without adequate light, may have difficulty in locating the handles to open the doors if expectations and assumptions are that the handles will be in the same location for both doors. Having to locate the handle, then figure out how to operate each handle adds to egress time. Circumstances such as fire, hazardous material leaks, or spills are situations in which expeditious evacuation is essential for survival.

The F38, U23-B, and SD40-2, all narrow nose freight locomotives, were observed during visits to freight railroads. These three models had a door in the front of the locomotive, in front of the seat opposite the engineer's seat, and a door on the engineer's side of the cab, located behind the engineer's seat. The F38 has three seats total, one on the engineer's side, and two, one directly

Figure 18. GE CW40-8 - door behind engineer's seat to exterior walkway

behind the other, opposite the engineer’s side. The U23B has the same seat configuration – three seats total, two on the side opposite the engineer’s side, one on the engineer’s side (Figure 20). The SD40-2 has three seats in a row across the cab. The second seat is towards the center of the cab, between the two other seats. This seat could pose an egress problem since it must be circumnavigated in order to reach either cab door, due to tight space limitations. A wide cab design allows crewmembers the greatest amount of room possible to reach the nearest exit as quickly and easily as possible in an accident scenario.

Two GP-40 locomotives were observed during site visits, one at a commuter railroad and the other at a freight railroad. The GP40MC used in passenger service was a wide nose design, with two doors located on each side of the rear of the locomotive. This GP40 had a control display console located in front of the engineer’s chair. The GP40-2 locomotive used in freight service was a narrow nose, with a total of three cab seats, two on the side opposite the engineer’s seat, one on the engineer’s side. It had two doors to egress, one at the rear behind the engineer’s seat, and the other in front of the seat opposite the engineer’s seat. The GP40 freight locomotive had an AAR type control display stand, located to the left of the engineer’s seat. The control stand

Figure 19. Steps from cab interior to door leading to vestibule, GE CW40-8

could become an obstruction to rapid egress in an emergency situation. This has not specifically been documented in accidents, but in a rollover it could also be a hindrance to a crewmember trying to escape the cab, because it is towards the center of the cab and thus located in the exit path. It could also hinder rescue of the engineer from that side.

Cab design layout considerations can be summarized into the following categories:

Differences in Seating Arrangements:

1. 2 fixed seats – 1 engineer, 1 opposite engineer.
2. 3 fixed seats – 1 engineer, 2 (1 behind the other) on side opposite engineer.
3. 3 fixed seats in a row.

Differences in Control Stands:

1. AAR-type control stand.
2. Desktop workstation.

GE U23-B

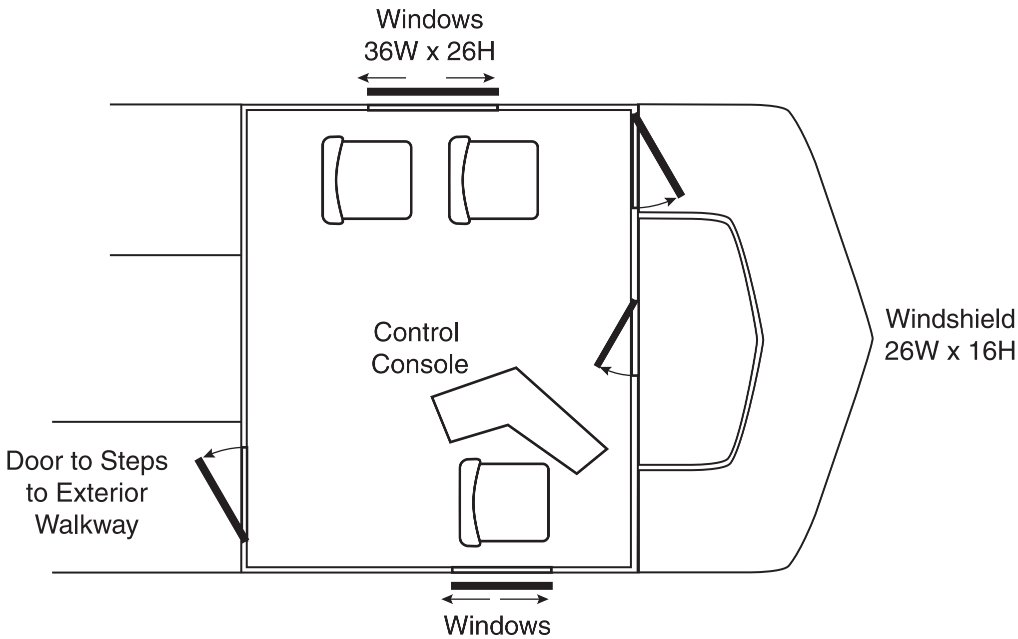


Figure 20. GE U23-B

Locations of Entry/Exit Doors

1. 2 side doors, a door to engine room then out the back of the locomotive.
2. 2 rear cab doors.
3. Door on nose and door on cab rear, engineer's side.
4. Door in front of cab on side opposite engineer, rear door behind engineer.

Different Types of Windows:

1. Single side slide panel.
   - One-handed or two-handed operation required.
   - Operates up and down or slides across.
2. Double slide panels – opens from center.
3. Fixed windows, on side, in door panels.

Lighting Placement:

1. 2 lights, one above each seat.
2. 2 lights on walls, "map" lights above workstations.
3. Center fluorescent lighting.
4. Low-level lighting, directional lighting.

Door Handles:

1. Ranged between 5 and 7 inches in length.
2. Push down to open with spring-back feature.
3. Pull up to open (hatch-type handles) then push door.

Emergency Equipment:

1. Cab fire extinguishers: located in cab anywhere from in front of or behind the seat opposite the engineer to the front middle portion of the cab to behind the engineer. Most were secured though some were observed as not.

2. Fusees, emergency tools: located in nose of cab or just inside the engine room door or in front of or behind the seat opposite the engineer.

2.3 Train Crew and Emergency Responder Training for Locomotive Egress/Access

Training and preparation of crewmembers and emergency responders are important factors in locomotive egress/access. Training program methods and content have made continual improvements over the years, including innovations such as computer-based-training. Over the past 30 years, the National Transportation Safety Board (NTSB) has made many recommendations to various railroads and the FRA with regard to locomotive cab egress, including:

- No. R-71-36, the NTSB recommended that the FRA consider possible changes in the design of locomotive control compartments and that such studies should include the development of escape plans and the assurance of their performance by tests.

- No. R-74-21, NTSB recommended to FRA that they "Review past escapes of motormen and engineers from operating compartments of rail transit and commuter cars during crash situations in order to establish design requirements and definite procedures for an operator's escape during impending crashes."

- No. R-76-30, NTSB recommended to FRA that they require railroads to include emergency procedures for cab evacuation in its training program for operating employees.

Inquiries were made to the NTSB to determine what, if anything resulted from these recommendations. A response to this request indicated that R-74-21 was "Closed –Acceptable" as a result of a response from FTA saying that transit properties would individually develop training programs with FTA to monitor. R-76-30 was considered "Closed – Unacceptable," though FRA indicated that they had contracted with Edwards Air Force Base to develop a model plan regarding emergency response procedures. This topic, moreover, was addressed by the FRA recently in 49 CFR Part 239, emergency preparedness plans for passenger (intercity, commuter, other short-haul rail passenger service) and freight railroads hosting passenger operations.

2.3.1 Rail Industry Survey of Crew and Emergency Responder Training

To determine the current state of training in the rail industry for both railroad onboard crewmembers as well as emergency responders, a questionnaire was developed for railroad safety and training officers.

Questions were specifically designed to determine the extent of crewmember training with regard to familiarization of locomotive egress/access routes and any other training that may be geared toward enhancing the survivability of crewmembers located in the locomotive in the event of a collision. The questionnaire was also intended to determine the extent of emergency responder training, including locomotive equipment familiarization and hands-on training and participation in emergency simulations.

The questionnaire is contained in Appendix B, followed by a table in Appendix C, summarizing the information gathered from the questionnaires.

Efforts have been made in crew training as well as emergency responder training, since the Passenger Train Emergency Preparedness Final Rule was introduced (49 CFR Part 239). This new regulation – in Section 239.101(a)(2)(i) – requires initial as well as periodic training (at least once every two years) for onboard crewmembers *of commuter and intercity passenger train service* that includes:

- Rail equipment familiarization.
- Situational awareness.
- Passenger evacuation.
- "Hands-on" instruction concerning the location, function and operation of onboard emergency equipment.

2.3.2 Examination of Emergency Responder Training Programs and Videos

To obtain information about what is actually being taught to emergency responders, we observed a hands-on emergency responder training session and a subsequent emergency response drill in which responders demonstrated the removal of an injured crewmember from a passenger locomotive. Additionally, a video that is part of a training program, developed by Operation Lifesaver in conjunction with the UP Railroad, was reviewed in which an emergency response team performed an evacuation from a freight locomotive.

A video obtained from GO Transit (Ontario, Canada) demonstrated passenger rail equipment and railroad environment familiarization for responders with sufficient essential information to:

1. Shut down and secure a locomotive.

2. Evacuate a passenger coach by removing a window from the exterior or from the interior.

3. Become familiar with the interior cab configuration and the location of safety and emergency tools, including fire extinguishers and first aid kits on each locomotive as well as on each coach. (Note: All rear coaches on a train have a stretcher, unlike any system examined in the United States).

The video showed that the engine room compartment is accessible from either end of the locomotive. There was also a demonstration of bi-level passenger coach window removal, both from inside and out, of the car.

Another video obtained was from Colorado Operation Lifesaver. It is an excellent example demonstrating the evacuation of a crewmember from a locomotive, using four different methods.

These videotaped scenarios were an excellent educational tool. They showed step-by-step what the responders did to extricate the victim from the locomotive, even illustrating how they re-thought their positions and re-positioned their ladders, trucks, personnel, etc., to achieve a successful removal.

2.4 National Transportation Safety Board (NTSB) Accident Investigation Reports

A sampling of NTSB reports were reviewed for relevant data regarding locomotive collisions (head-on, side, raking), particularly including information regarding crew survivability and detailing the extent of damage to the locomotives involved.

2.4.1 Sample Accident Scenarios

Three accidents were examined:

- Union Pacific Freight Trains 5981 North and 9186 South.
- Burlington Northern Trains 602 and 603.
- Amtrak Train and Maintenance of Way (MOW) Equipment.

Data gathered from these reports included information on damage sustained by the locomotives, crewmembers and methods of egress.

The NTSB has noted in several reports that locomotive crashworthiness continues to be a problem affecting the safety of crewmembers, including the following Safety Recommendation with respect to locomotive cab environments:

- *Promptly require locomotive operating compartments to be designed to provide crash protection for occupants of locomotive cabs (R-87-23).*

2.5 Examination of FRA Accident Database

The FRA accident database was searched for accident/incident data to determine the types of locomotives involved in collisions. This was done to select a few representative type units for performing computerized collision simulations under various conditions. The purpose for this modeling was to estimate cab damage and the effects on crew members (see Section 3).

An accident review for three years, 1997, 1998, and 1999, was completed using the FRA safety databases. A representative sample is shown in Table 2. These files contained a broad spectrum of detailed information on accidents involving rail equipment, but pertinent informatin is shown in the table.

Table 2. Selection of locomotive types from the 1999 FRA safety database

Railroad	Engine No.	Year	Manufacturer	Model	W/N Nose	W/N Hood
AMT	000807	93	GE	DASH8-P40B	W	W
NIRC	000195	91-92	GM	F40PHM-2	W	W
SP	008115	94	GE	DASH9-4400CW	W	N
UP	008025	96	GM	SD90/43MAC	W	N
AMT	000008	97	GE	DASH9-P42B	W	W
AMT	000075	97	GE	DASH9-P42B	W	W
AMT	000831	93	GE	DASH8-P40B	W	W
UP	009777	94	GE	DASH9-44CW	W	N
AMT	000082	97	GE	DASH9-P42B	W	W
BNSF	009931	98	GM	SD70MAC	W	N
ATK	000116	97	GE	DASH9-P42B	W	W
SP	008171	94	GE	DASH9-4400CW	W	N
PTRA	009620	96	GM	MP1500D	None	LONG/N
WTRY	001204	66	GM	SW1200	None	LONG/N
HRT	000136	65	GM	GP35	N	N
BNSF	006393	72	GM	SD40-2	N	N
BN	007041	78	GM	SD40-2	N	N
BNSF	006207	85	GM	SD39	N	N
UP	004741	99(RBLT)	VMW(GM)	SD40-2	N	N
SP	009609	88	GM	GP60	N	N
UP	001826	72	GM	GP38-2L	N	N
CSXT	008151	81	GM	SD40-2	N	N
CSXT	008124	80	GM	SD40-2	N	N
IC	009609	72-74	GM	GP38-2	N	N
UP	009179	88	GE	DASH8-40C	N	N
UP	000477	80	GE	C30-7	N	N
UP	009117	87	GE	DASH8-40C	N	N
BNSF	002141	70	GM	GP38	N	N
BN	002874	91	GM	GP39M	N	N

From these accident files, selected data was extracted that would provide information on the nature of the collision and the types of locomotives involved. The fields selected, some of which are portrayed in Table 2, included type of consist, type of collision, and engine number. This was later used to look in a locomotive roster to obtain information on the model of the locomotives involved in the accident, and whether they were narrow or wide nose, as well as other data relevant to this analysis.

FRA staff assisted in selecting and providing relevant accident investigation reports. Of particular interest was FRA accident report C-09-97 in which an Amtrak train consist of a GE locomotive, Model Dash 8/40BP, and 10 cars collided with a truck stalled at a highway/rail grade crossing. In this instance, egress from the locomotive was identified as an issue due to the rollover of the locomotive onto its right side (engineer's side) and the inability of the crewmembers to reach the opposite side door/window to evacuate. After a sustained effort, the engineer's side front window was broken using a sledgehammer, and the crew escaped through the broken window.

These databases coupled with the NTSB reports were used to identify accidents in which egress may have been an issue for crewmembers who were still located inside the locomotive cab after impact occurred.

2.6 Interviews with Crewmembers Involved in Rail Accidents

Interviews were conducted with locomotive engineers and train crewmembers seated in locomotives during, or just prior to, a collision. This was done to identify if difficulty of locomotive egress was a factor in evacuation or, if the crew was unable to exit the locomotive without aid, whether accessing the locomotive cab by rescuers was a problem. Additionally, crews were questioned as to the extent of their training with regard to various emergency scenarios, and whether it was of any use during a real emergency situation.

2.6.1 Summary of Locomotive Engineers' Suggestions for Improved Survivability

- All doors should open outward.
- All doors should open easily from inside without having to kick or push to open.
- Maintenance issues – all windows, doors, onboard safety tools and equipment inspected and tested and known to be operating properly, without any hang-ups.
- Design issues – easier opening, weight of doors, pneumatic doors, etc.
- Door handles should be large enough to be operated easily with a large (95 percent male), gloved hand.
- Door handles mechanisms to open doors should all be operated the same way.

- Engineer's egress from the cab with a "desktop unit" versus the old-style control stand may be difficult in an emergency situation as the seat may have to be moved back to gain enough room. Since a mechanism is needed to unlock the seat, this should have a uniform configuration and location for all locomotive models.

2.7 Summary

By reviewing the various cab configurations, interviews with railroad employees, and reviewing current regulatory and industry standards and practices, suggestions for further improvements to egress/access were identified.

3. APPROACHES TO IMPROVE THE CRASHWORTHINESS OF CAB STRUCTURES

This section addresses the ability to understand the crash behavior of locomotives and their cab structure in a variety of serious accident types that threaten the crewmembers. Advanced structural simulation methods with the use of LS-DYNA (1) will be utilized in predicting deformations in critical cab areas such as the door, window hood, and windshield areas that affect the ability to exit after an accident/impact occurs. The selection of accident conditions is intended to capture situations in which there would be egress or survivability problems. Solutions to these problems are presented.

It was necessary to capture a satisfactory range of accident situations, which could affect egress in order to recommend a balanced selection of improvements. For this, various aspects of typical rail accidents such as locomotive and cab collision damage, g-loads in the cab, operability of doors and windows, and post crash visibility/accessibility (fire, darkness, overturning) are recognized. These conditions would then be represented by a good "short list" of realistic but not necessarily historical accident scenarios for analyses. This task describes the modeling techniques involved in the analyses as well as the design approaches to strengthening target areas related to egress.

This work comprises the following elements:

- Develop and apply simulation tools for use in accurately simulating typical collisions.
- Assess the crashworthiness of cab structures.
- Assess targeted improvements to the cab structure.

3.1 Selection of Representative Locomotive Types for Analysis

Three locomotive types representing different broad configurations were identified. Locomotive types can be broadly represented by three categories:

1. Wide nose heavy freight, likely with S-580 collision crashworthiness features.
2. Narrow nose freight locomotives, likely with some crashworthiness features such as collision posts but not meeting S-580 strengths.
3. Passenger locomotives, which are shorter and lighter that most freight locomotives, and which also have different door and cab layouts.

These three represented a road-haul freight locomotive (SD-70 MAC), switcher type locomotive (SD70 narrow nose) and a passenger diesel locomotive (F-40).

3.2 Evaluation of Collision Scenarios

Three different collision scenarios were selected based on reviewing various actual accidents. Although these may not be the exact situations, they all address the egress problems and will give a good sampling of accident outcomes that can guide suggestions for mitigation. The collision scenarios selected were:

1. A derailment where the primary action is the overturning of the lead locomotive. This will capture the wide range of derailments (with or without collisions, addressed in the first two situations above), in which the consequences of overturning, such as lateral G-s (interior reference), blocking of the windows, and damage to side doors and windows, etc., will be seen. This provides a situation where the locomotive derailed after crash and turned over with some of the windows and doors jammed, posing a threat to egress routes.

2. A train-to-train raking-type collision where the lateral overlap is small, and where the side of the cab is threatened. A scenario in which a locomotive-headed consist strikes a standing hopper car consist, with only 40 inches of lateral overlap (such as a train fouling a turnout) was used, at two different speeds of 30 and 50 mph, representing two levels of severity (even the 30 mph collision is severe in that injuries and substantial damage would likely occur to cab occupants). This captures many types of non-"head-on" raking accidents in which damage and later derailment can occur and simulates a grazing collision situation where a moving locomotive was sideswiped by either a standing or moving consist. This address a situation where the side escape routes such as windows and doors will be crushed.

3. A train-to-train collision, still slightly offset but much more "head-on" in character, where the lateral overlap is large at 80 inches, with the same primary locomotive headed consist striking a more massive locomotive-headed standing consist. Since the primary locomotive structures are involved (collision post on one side and underframe), the deceleration and damage is much higher. However, the offset nature still preserves the realism of cab threat and lateral forces contributing to the complexity of the cab egress situation (cab sides, derailment, etc.). Again, the two different speeds of 30 and 50 mph, representing two levels of severity were used. This was intended to capture the head-on or near-head-on situations with massive locomotives involved. This will cause severe damage and loss of cab volume and pose an extreme egress problem.

The last scenario can easily be simulated, and is representative of an accident involving the head-on collision of two SD-70 narrow nose locomotives, which occurred in Devine, TX in 1997. Based on the actual NTSB report, this is a classic example for egress evaluation. The combination of these analytical and historical conditions will then be used as a framework to perform the several types of egress evaluations as a part of this study.

3.3 Model Development

Finite element (FE) models of three types of freight locomotives were generated; a General Motors (GM) SD-70 MAC locomotive, a GM SD-70 narrow nosed freight locomotive and an F-40 passenger locomotive as shown in Figures 21 through 23. They were modeled using HYPERMESH (2). HYPERMESH from Altair Engineering, MI was used in the development of the detailed finite element model of all the locomotives as well as the consists.

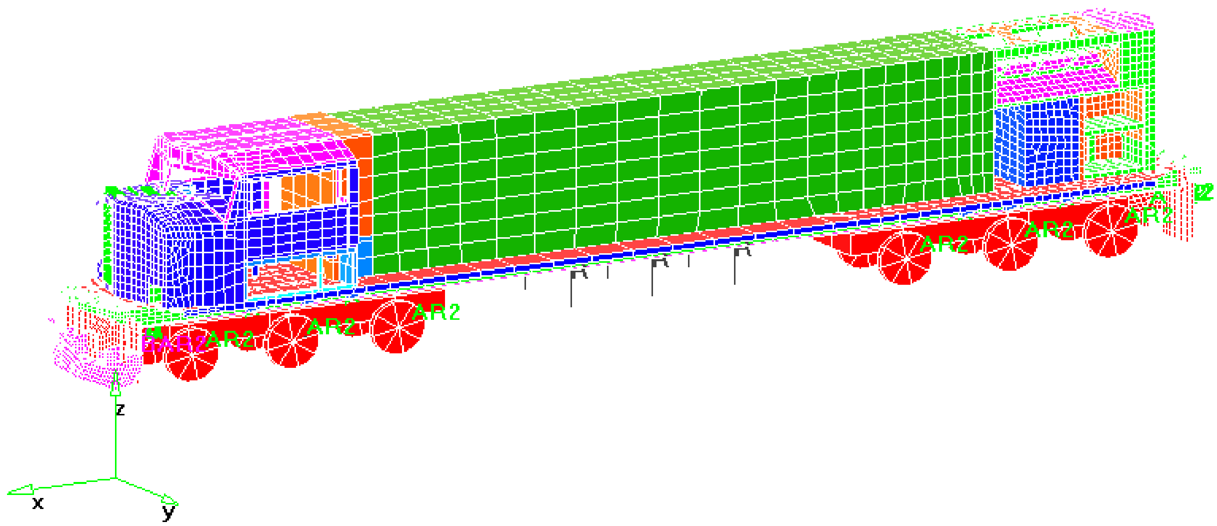


Figure 21. A FEA model of a SD-70 MAC freight locomotive

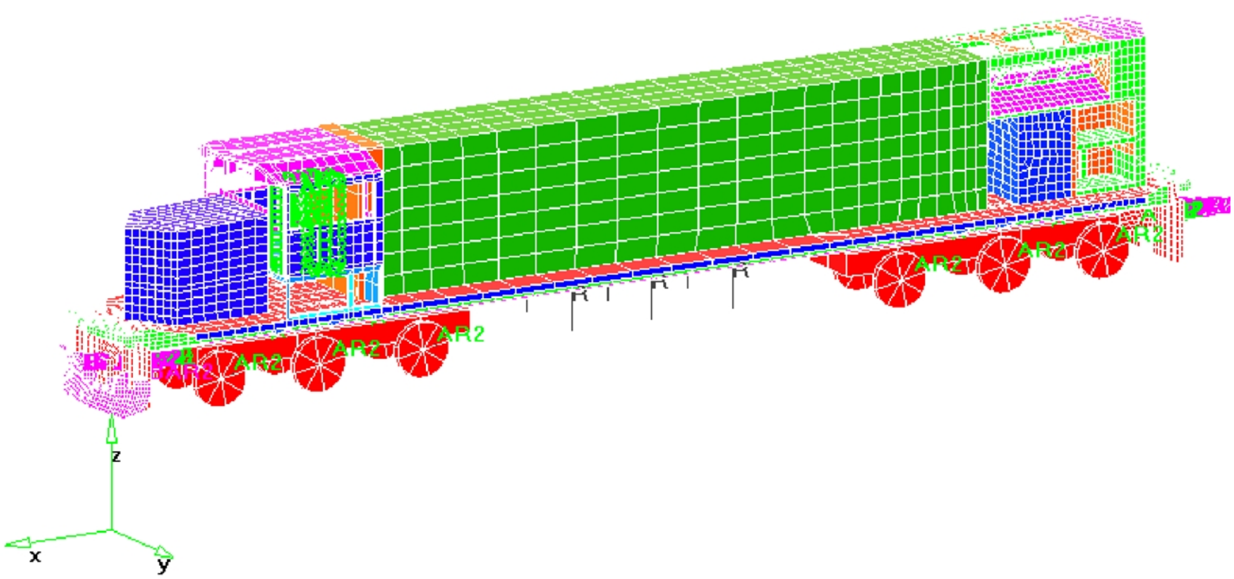


Figure 22. HYPERMESH model of the GM SD-70 narrow nose locomotive

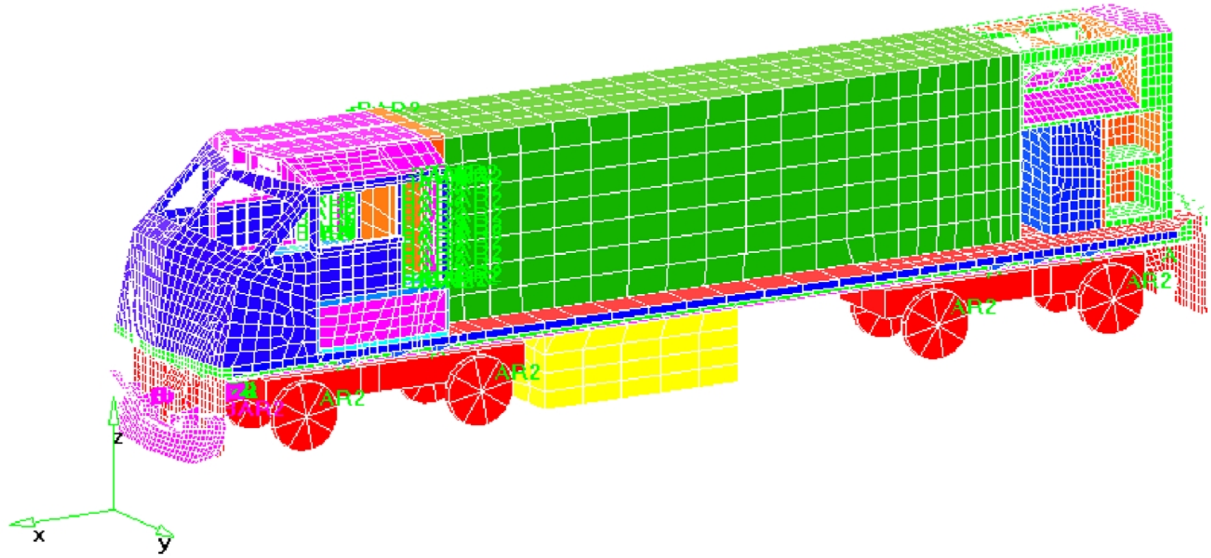


Figure 23. HYPERMESH model of the F-40 passenger locomotive

3.3.1 Locomotive Modeling

The frontal structures of the locomotive were modeled in detail due to their direct involvement in collisions. These structures include short hood, collision posts, cab including the windshield and corner post area, frontal portion of the platform, and other structures including draft gear pocket, endplate, anticlimber and snow plow. These structures are represented using shell elements. The suspension including the primary and secondary springs was simulated in detail in order to properly represent the various motion modes and limit stops of the truck relative to the platform. The fuel tank was hung to the platform and is thus represented by proper mass elements.

The SD-70, shown in Figure 22, was adapted from the SD-70 MAC model from our previous crashworthiness studies (Figure 21). The locomotives are very similar, except for the nose, which on the SD-70 is much narrower and does not contain any collision posts. Narrow nose locomotives are mainly used in switching and low speed traveling situations. An FE model of a passenger locomotive made by GM (F-40) was also developed in our egress study. It is much shorter in length than the freight locomotives. The nose of the F-40 locomotive runs all the way up to the anticlimber and there are no collision posts in it either. Modifications were made to these models to more closely represent the actual locomotives and cab cars involved in the selected collision scenarios. Consist models were then developed based on these models containing models of trailing locomotives and cars in the same manner as in our previous consist models.

The F-40, shown in Figure 23, is much shorter in length than the SD-70 or SD-70 MAC. As in the SD-70, there are no collision posts present in this model. The gas tank on the bottom of the locomotive was modeled explicitly in the F-40 instead of representing it by masses and rigid links as in past models.

Egress studies were performed on these three types of locomotives. The first step in this analysis was to simulate and evaluate various locomotive mishaps that might potentially hinder the egress routes from the locomotives. Of the many potential accidents or mishaps, three collision scenarios were chosen, modeled and analyzed. LS-DYNA was used in performing the detailed dynamic analysis. The levels of the accelerations in terms of g-forces were evaluated along with damage to the door and windows that might hinder egress. Loss of cab volume was also considered with each of the scenarios. Below are the details of the simulated accidents with the various locomotive models. Table 3 lists the various collision scenarios that were considered for the egress analysis.

Although numerous crash scenarios are available from NTSB reports, the typical crash scenarios as selected represent a balance of locomotives already modeled in our previous studies and a variety of the selection of door and window system in locomotives for egress evaluation.

3.4 Egress Analysis and Cab Occupant Behavior in Accidents

Overall cab g-loads (primarily decelerations) are provided in the analyses to estimate the potential severity of injuries that can occur to an in-cab crewmember. To do this, a single g-load can be taken at the floor level and this can be used as a general index or criterion for evaluation. Typical analytical studies were conducted on an F-40 locomotive colliding with a hopper consist, and in a slow-speed rollover onto soft ground. Inclusion of a computerized human "dummy" in the modeling gave the approximate injury loads that resulted using the in-cab floor g-loads with a highly simplified interior.

However, the detailed behavior of the human operator/engineer will involve contact with the various internal cab structural parts such as electrical compartments, overhead steel plates, windshield area, etc. Measurement of various injuries such as head, neck, chest, knees and legs would vary widely with small differences in these details. Also, small changes in the initial position, size, and motion of the occupants can often have a great influence on the details of their behavior in the accident.

The survivability of a human occupant inside a locomotive depends on the occupant kinematics during collision. The injury to a human is usually measured in the form of ‘g’ loads that he experiences during the crash event. The human injury is represented by the head and chest

Table 3. Accident scenarios

Type of Locomotive	Accident Scenario 1	Accident Scenario 2	Collision Scenario 3
	Slow overturning onto wayside A) Soft surface (earth) B) Hard surface (pavement)	Locomotive in offset collision with stationary hopper car consist at 30 and 50 mph	Two locomotives in head-on collision at 60 mph closing speed
SD-70MAC	Yes	Yes	
SD-70	Yes	Yes	SD70 to SD70
F-40	Yes	Yes	

accelerations, neck flexion and moments, and femur loads. Threshold injury criteria have been established by the National Highway Traffic Safety Administration (NHTSA) and the automobile industry. In the case of locomotive crashworthiness, areas of injury and fatality are hard to address when the train collision dynamics are not predictable. Due to a wide range of potential injuries and numerous collision modes, there is a lack of criteria in applying these to train collisions. As a safe limit a 2 to 3 g load level at the floor level will not harm the human occupant and between 3 to 6 g's may cause human injury, and fatality will occur beyond these levels.

The g-loads during a rollover or collision process occur during a fraction of a second. The survivability of a human during this process will also depend on the environment conditions such as the cabin loss of volume, debris/glass fragments, and loose equipment. Observations of the kinematics made during the collision process (a typical "snapshot" during an offset collision of a passenger locomotive is shown in Figure 24), clearly show that the anatomical parts of the unbelted engineer will make contact with the surrounding structural parts of the cabin and could sustain injuries or even death. The severity of the injury/death can be measured at the in-cab floor level as well as the g-loads at the head. The NHTSA FMVSS 208 criterion for survival is about 60 g's at the chest level.

Head injury is usually measured as Head Injury Criteria (HIC) and is directly related to the maximum head acceleration over a timeframe of 16 or 33 msecs (see equation (1)). A HIC value of 1000 is considered to be safe for human survival.

$$HIC = (t_2 - t_1)\left[\frac{1}{(t_2 - t_1)}\int_{t_1}^{t_2} a(\tau)d\tau\right]_{max}^{2.5} \qquad (1)$$

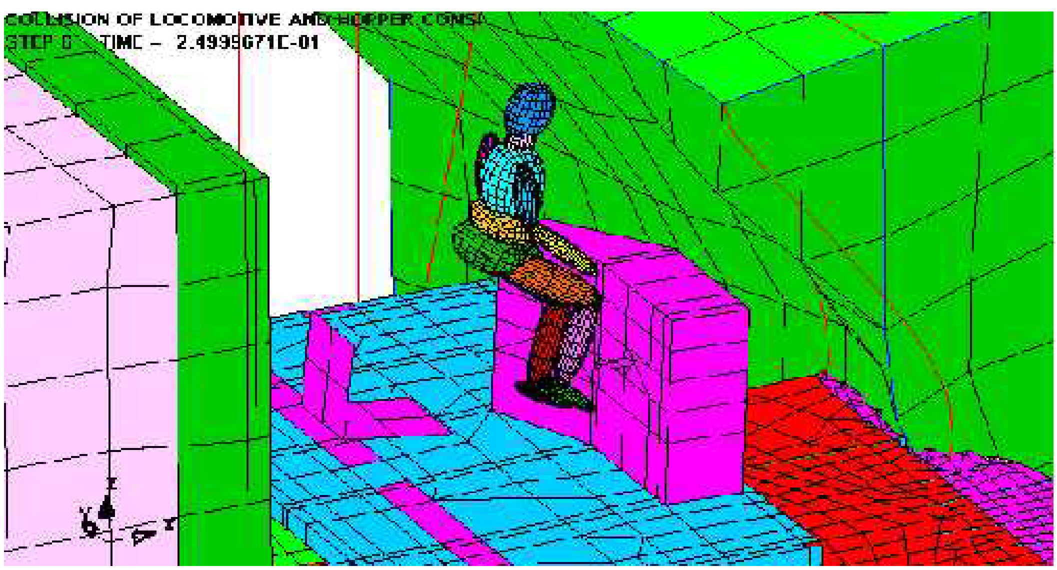


Figure 24. ***"Snapshot" of seated crewmember "dummy" during a 30 mph offset collision of a typical passenger locomotive***

where t_1, t_2 are two points in time during the head impact in seconds, and $a(\tau)$ is the resultant head acceleration during the head impact in multiples of g's.

The analytical results of a F40 rollover and F40 collision with a hopper car consist show the peak g-levels, due to the head striking interior surfaces, can exceed 100 g's (Figures 25 and 26). Our HIC calculations based on the head accelerations as shown in Figures 25 and 26 far exceed 10,000, well above the threshold limit of 1000. Fatality will occur at this level. This assumed a seated, unrestrained crewmember. The respective g-loads for this case are 3 g and 5 g's at the in-cab floor levels (Figures 36 and 44). This comparison shows that g-levels of 5 g's or less could in some cases produce severe injury or death based on the high localized head g-loads observed on the human dummy. However, if the occupant is well braced or avoids head contact, it is possible in at least the low-g situations (3g range) that the occupant could survive, perhaps with non-serious injury. Therefore, we can conclude that a measurement of the floor g-loads can give a general estimate of potential survival, but also that circumstances could produce a serious or fatal injury under the same conditions.

Further conclusions would have to involve a detailed study of a large variety of accident conditions and in-cab details. Cab g-levels for collision decelerations that reach the 5 to 6 g level can be assumed to be potentially serious or fatal in their effects on unprotected crewmembers. The initial position of the crewmember (standing, sitting, lying on floor, etc.) can strongly affect the outcome.

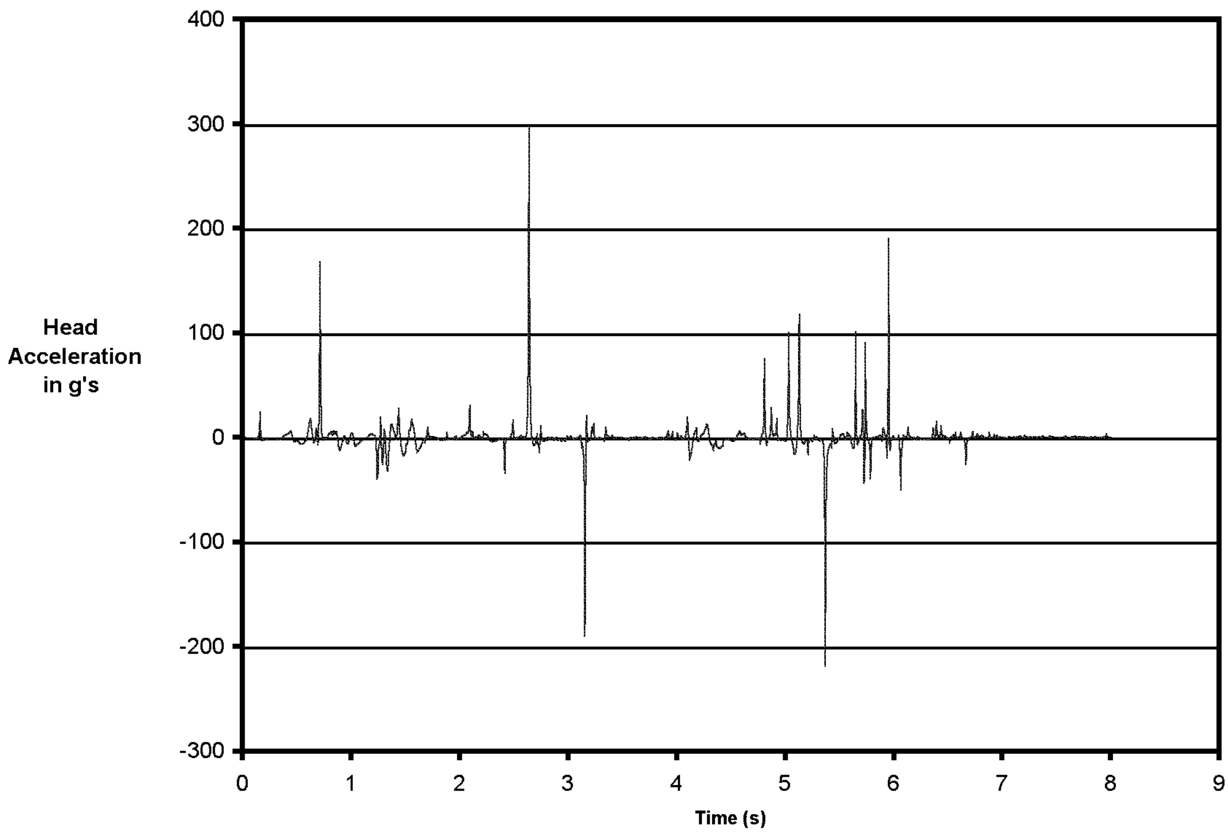


Figure 25. Head accelerations due to interior contact during rollover

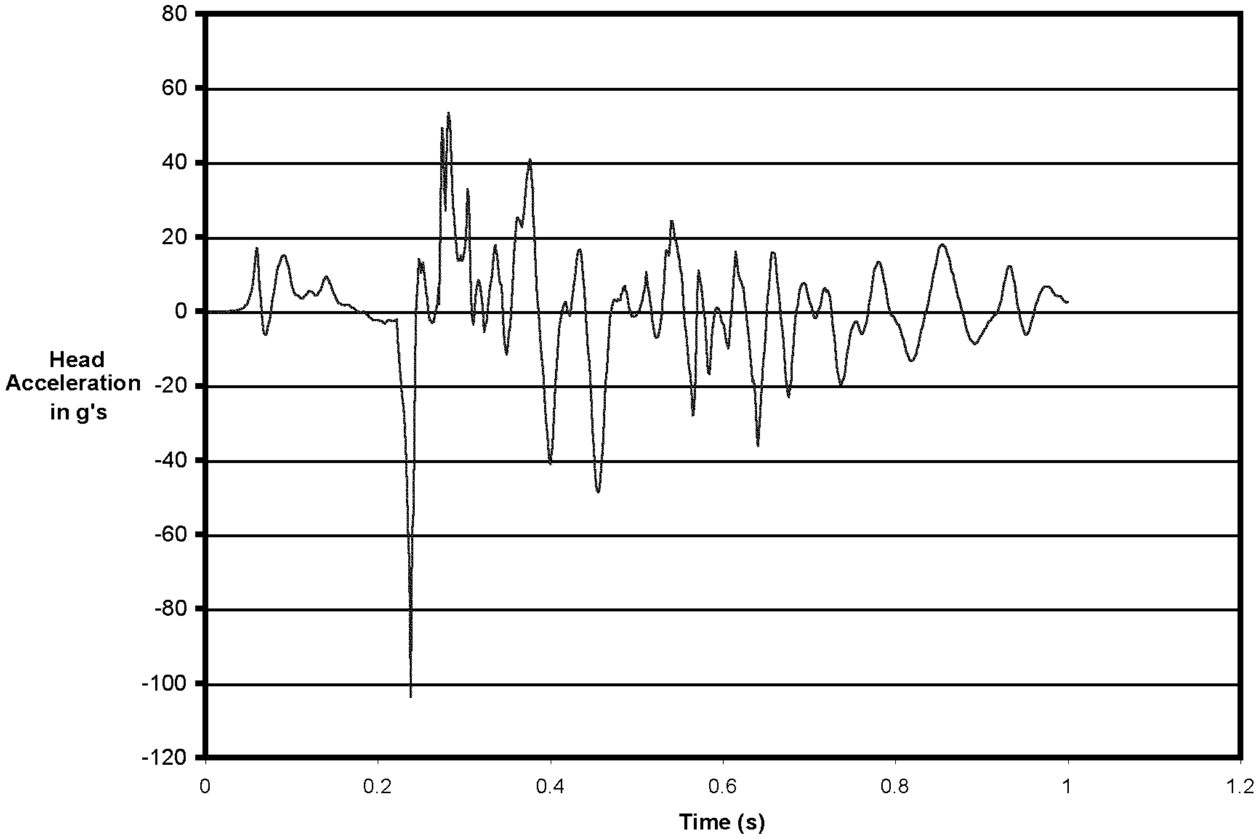


Figure 26. Head acceleration due to interior contact during offset collision with freight consist

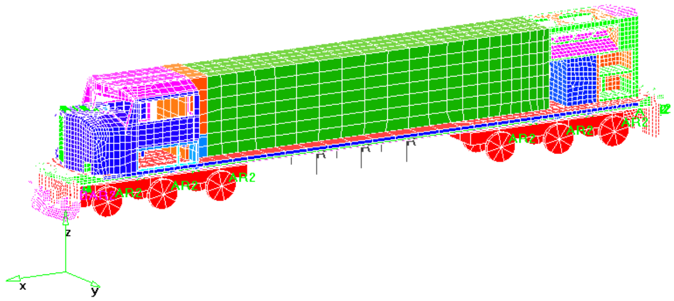
3.4.1 Scenario 1 - Rollover Analysis

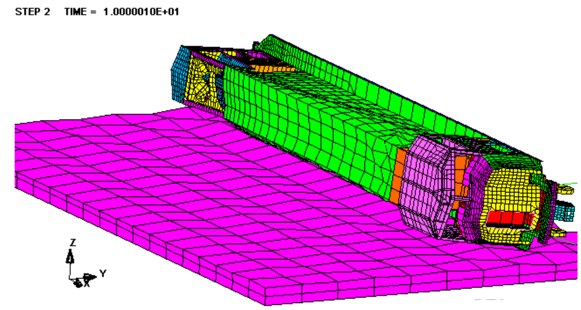
The three locomotives were rolled onto their side by the application of a gravity force and a slight rotational velocity to determine the extent of damage that could occur, what the in-cab g-values were, and what if any escape routes could have been blocked. This crash scenario represents a slow-speed rollover which would occur after a derailment or collision, and is a critical situation for cab egress. Damage to the egress routes and measurement of g-loads that a crewmember can sustain during the collision was obtained from this study. The acceleration in g's was obtained as a function of collision time at a location on the locomotive platform.

3.4.1.1 Rollover Studies on SD-70 MAC

A three-dimensional finite element model of the GM SD-70 MAC as well as the final rollover of the locomotive is shown in Figure 27. A FEA model of the ground was also taken into consideration for the analysis. This can be used to vary conditions of the ground soil upon impact of the rollover of the locomotive.

The maximum acceleration found in the cab was about 3 g's, which occurred upon impact with the ground. While this is not a negligible load, a human can survive this scenario without injury. A graph of the g-forces with respect to time is shown in Figure 28.





(a) *(b)*

Figure 27. (a) Finite element model of SD-70 MAC in hypermesh pre-processor and (b) LS-DYNA model of SD-70 MAC rolling on its side

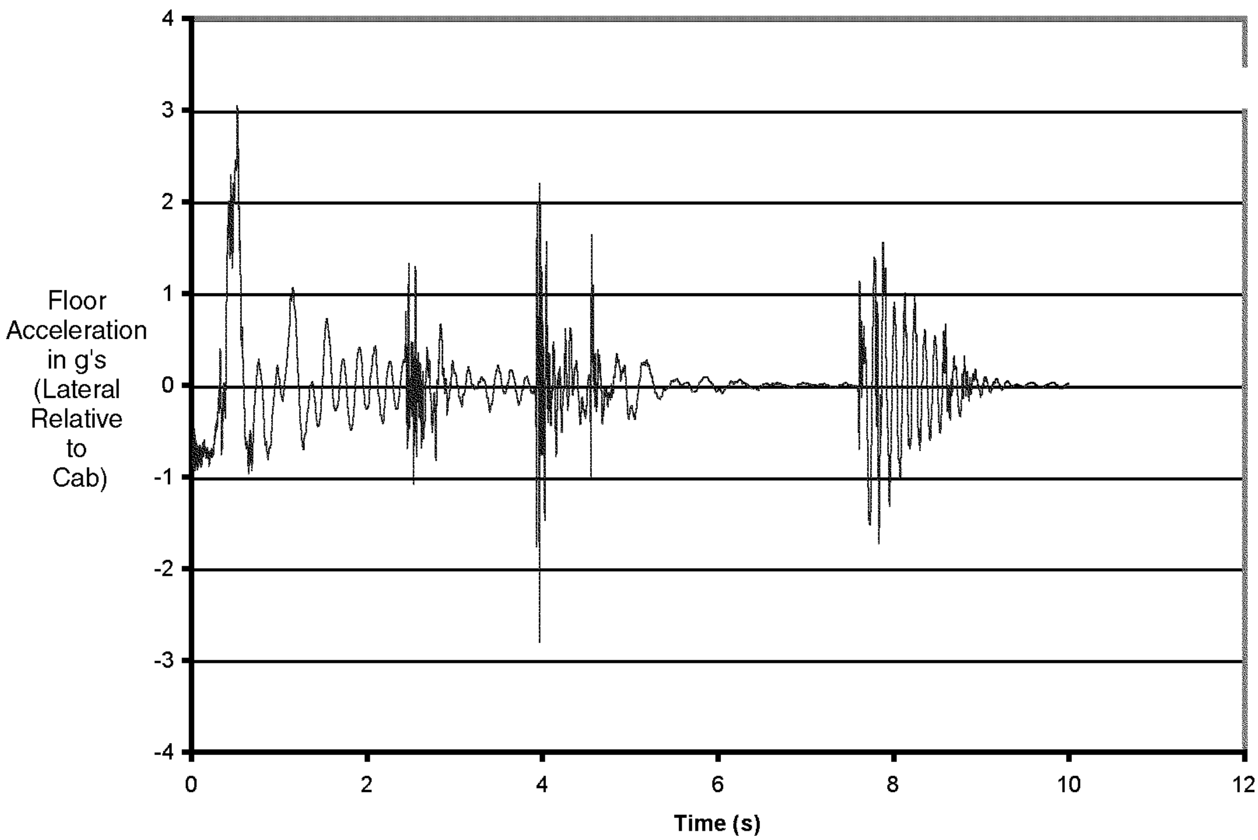


Figure 28. Overall cab g-loads in a SD-70 MAC rollover onto average soil

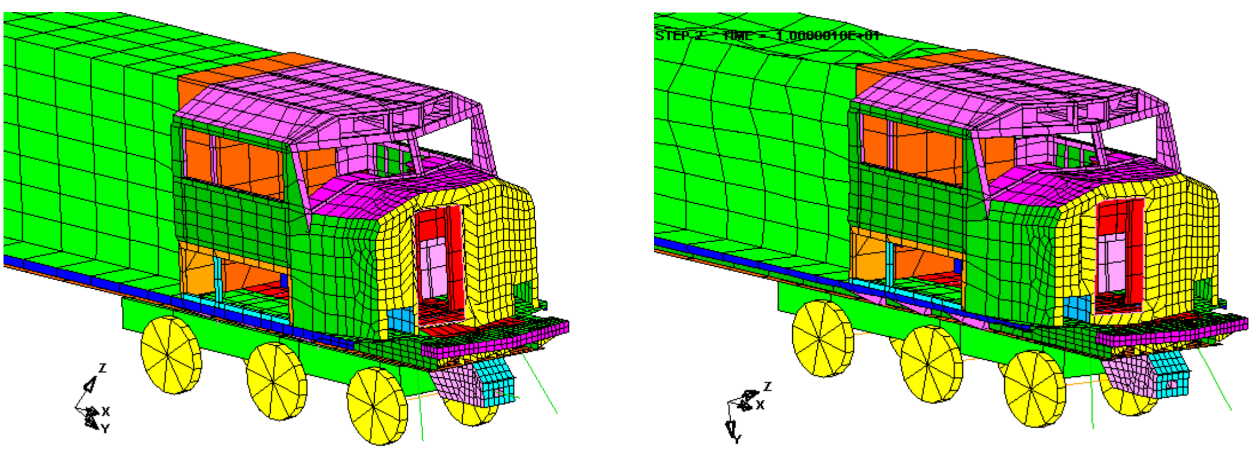
Only small deformations occurred in the plane of the door frame. The damage to the cab was minimal and the doors can still be opened. There was no significant damage to the doors or windows, as is shown in Figure 29. Also the loss of cab volume was minimal. In conclusion, for this scenario, the locomotive engineers in the cab would have survived and would have been able to escape.

The material characteristic of the ground used in the above analysis was made to simulate soft loose soil. Analyses also were completed in cases when the same locomotives was tipped onto ground and coming in contact with harder ground, such as concrete. A chart of the g-loads at a point on the platform is shown in Figure 30.

The g-load on impact is around 6 g's and as discussed earlier in Section 3.4.1 the risk of human injury is high for this case. This analysis shows that the condition of the ground plays an important part on the extent of human injury that can occur to a crewmember during a collision process. With this level of g-load, there is also the risk of objects within the cab coming loose and causing injury. The damage to the cab and the loss of volume, however, was still minimal. The expected cab damage is shown in Figure 31.

3.4.1.2 SD-70 Narrow Nose Freight Locomotive

A similar analysis was performed on the SD-70 narrow nose locomotive. Because of the great similarities of the two (length, weight, etc.), the results are also very similar. Figure 32 shows the graph of acceleration in g's and Figure 33 shows the deformations of the locomotive when rolled onto soft ground.



(a) *(b)*

Figure 29. SD-70 MAC locomotive (a) before rolling over and (b) after illustrating minimal damage

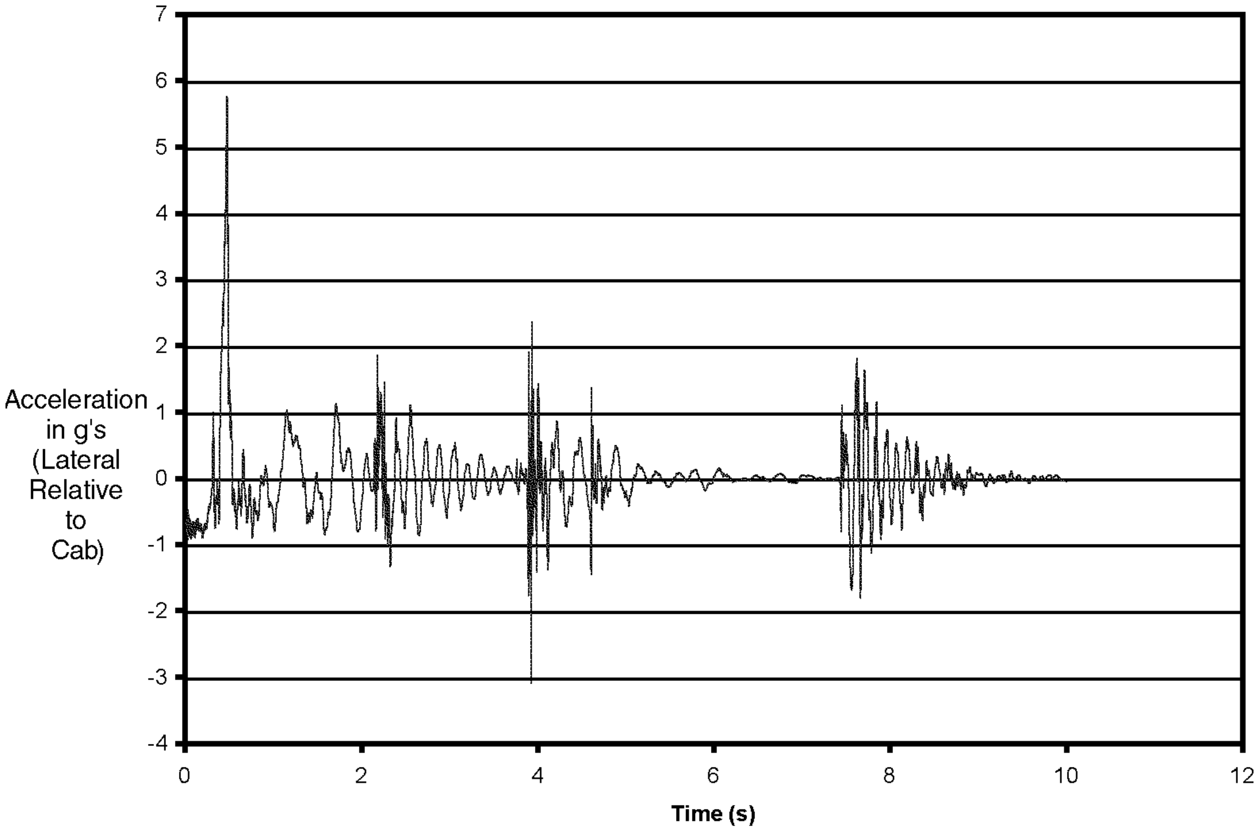
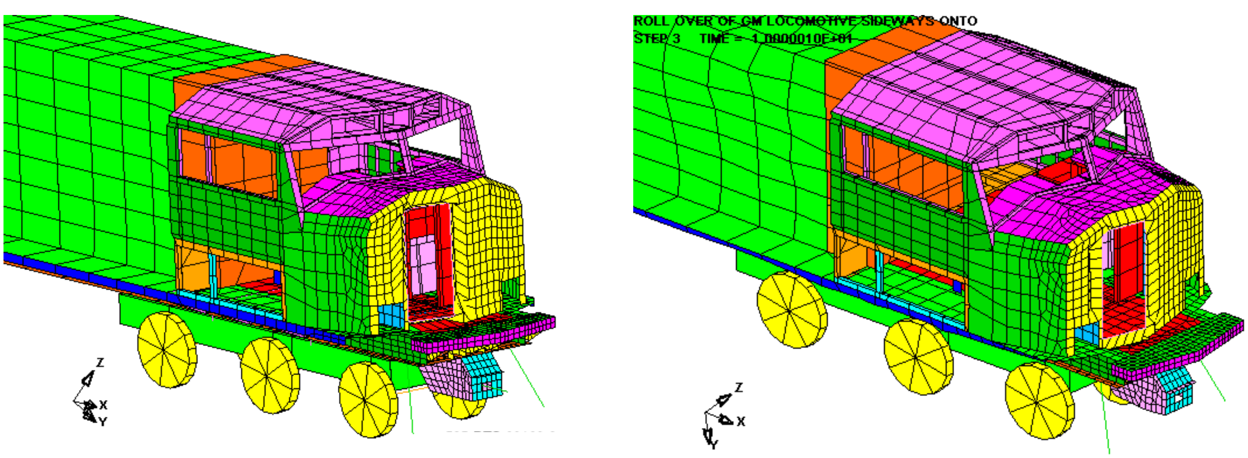


Figure 30. Overall cab g-loads for a SD-70 MAC rollover onto concrete



(a) *(b)*

Figure 31. (a) Initial and (b) final deformations of a SD-70 MAC rolling over onto concrete

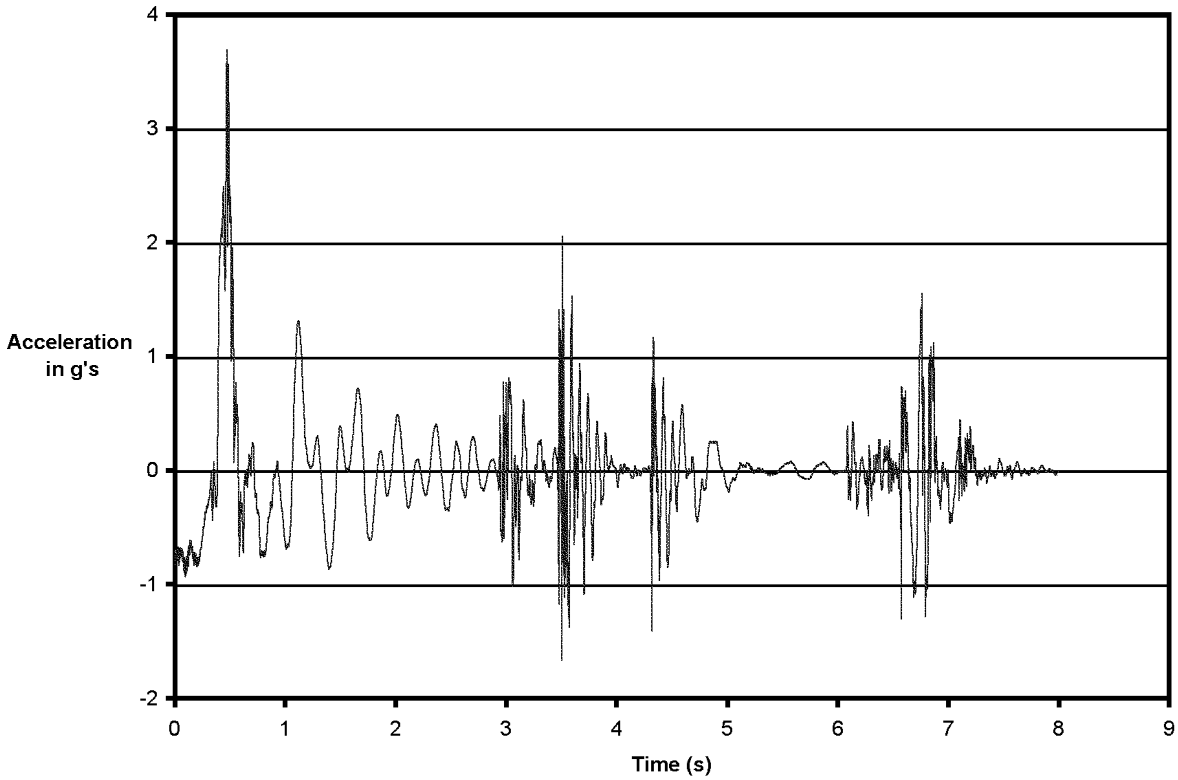
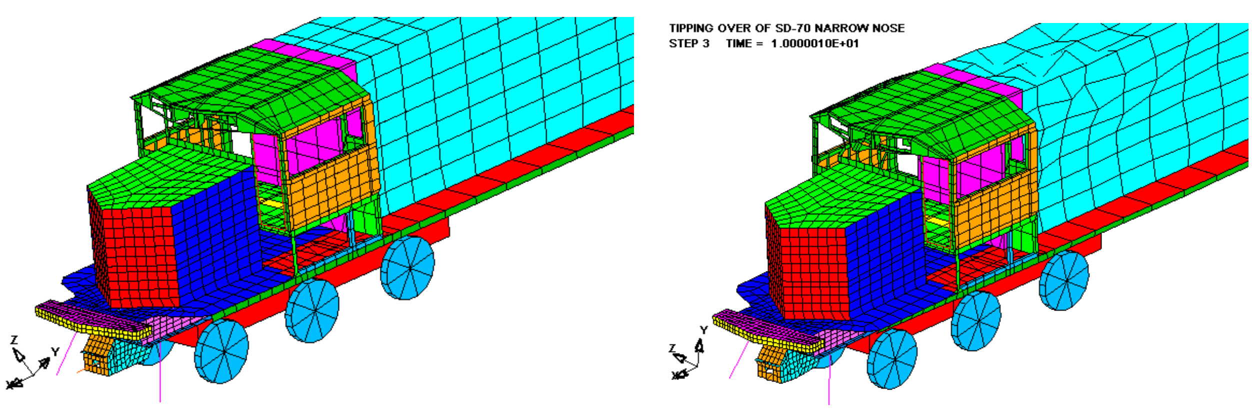


Figure 32. G-load versus time for a rolling over SD-70 narrow nose onto soft ground



(a) ***(b)***

Figure 33. SD-70 narrow nose locomotive (a) before and (b) after rolling over onto soft ground

The level of g's upon impact is very similar to the SD-70 MAC. In this case, it was about 3.5 g's. There is little or no actual damage to the cab of the SD-70, as is illustrated in Figure 33.

The same locomotive was analyzed again for impact with a concrete surface. The g-values increased, while the damage to the cab was minimal. Figure 34 shows the g-values as a function of time for the SD-70 narrow nose locomotive falling over onto concrete ground. The maximum value (on impact) was about 6 g's, about the same as the corresponding analysis of the SD-70 MAC. A g-load this high can cause human injury or even death if detailed interior circumstances resulted in head contact. Also, at g levels this high, equipment is likely to come off the walls so that flying debris could strike the engineer, causing further injury.

Figure 35 shows that there was nearly no damage to the cab, nor was there any loss of volume. All the doors and windows in the locomotive are intact and a non-injured person should be able to exit the locomotive using normal means of egress.

3.4.1.3 F-40 Passenger Locomotive

A simulation of the F-40 passenger locomotive rolling on its side was performed. The results were very similar to those for the previous two analyses. Similar g-loads were recorded and there was no significant damage to the cab. Figures 36 and 37 show the overall lateral cab g-load as a function of time, and the damage done to the cab respectively.

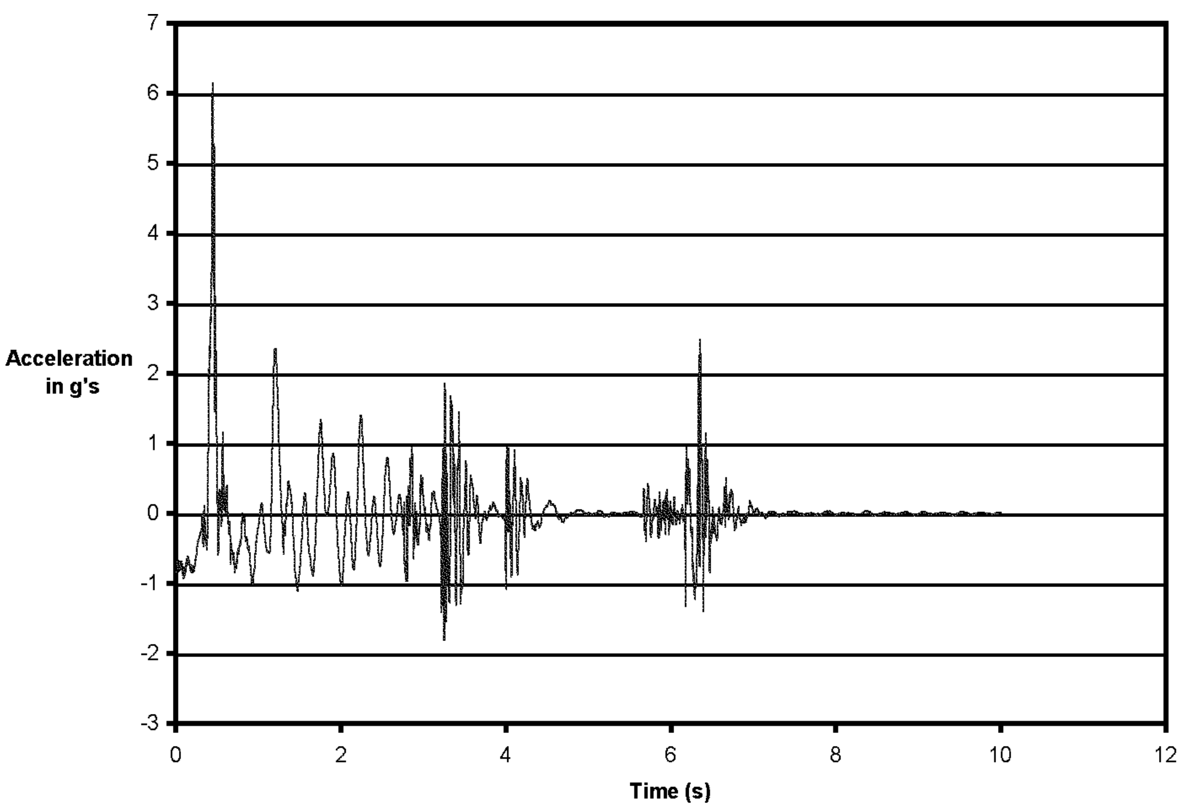
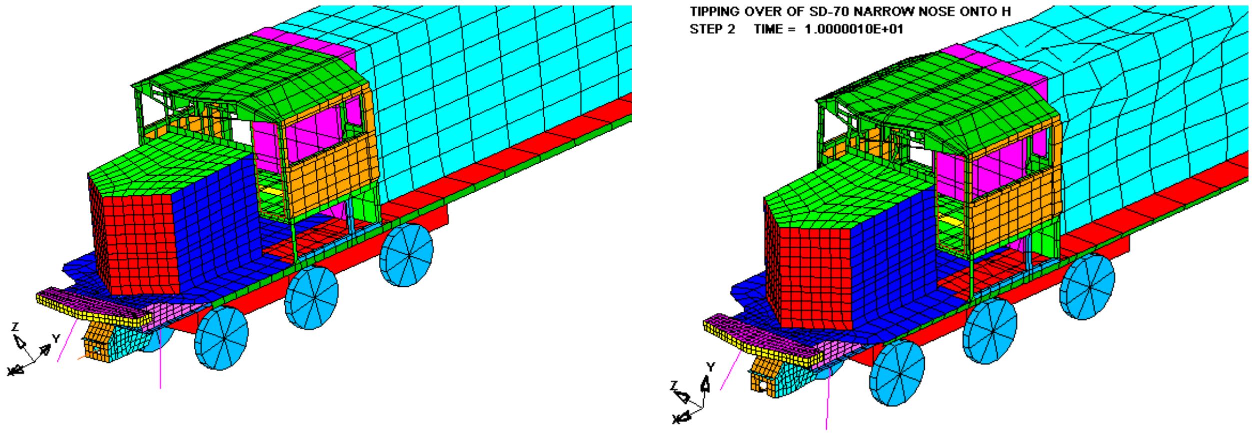


Figure 34. Floor acceleration in cab for a SD-70 narrow nose locomotive rolling over onto concrete



(a) *(b)*

Figure 35. SD-70 narrow nose locomotive (a) before and (b) after rolling over onto concrete ground

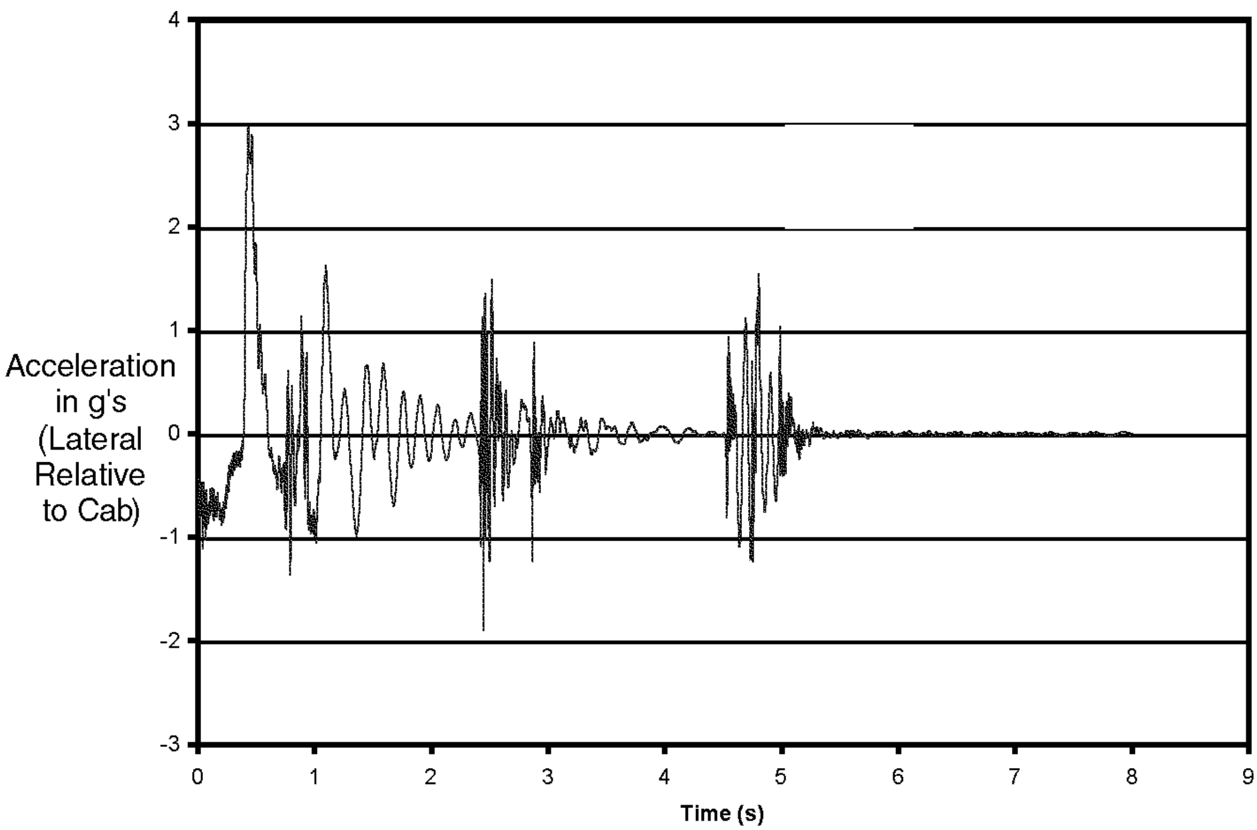
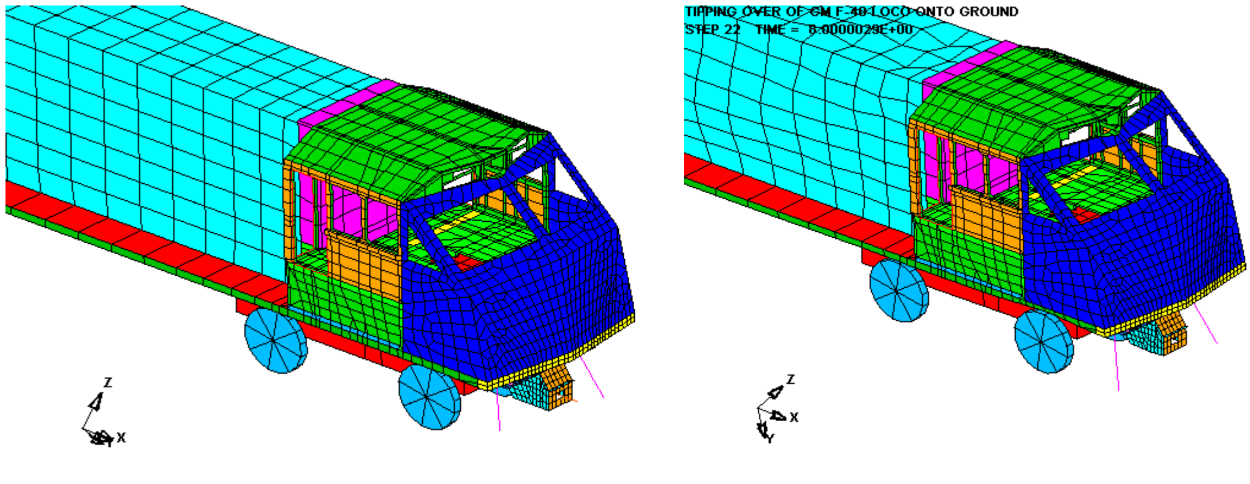


Figure 36. Overall cab g-load versus time for F-40 passenger locomotive rollover onto soft ground



(a) *(b)*

Figure 37. F-40 passenger locomotive (a) before and (b) after rolling over onto soft ground

Figure 36 shows that the maximum g-load was around 3 g's, which was the same as in the other two locomotives collisions. There was minimal damage to the cab, so that no doors or windows would have been damaged thus making egress quite possible.

While the aforementioned analyses showed that there was little damage to the doors or windows, this does not rule out the fact that the doors might be jammed shut. It would not take much frame deflection to do so. Factors such as these are presently being discussed and assessed.

The ground used in this analysis was first made to simulate soft loose soil. Analyses were also conducted for the F-40 in a rollover situation onto harder ground, such as concrete. The g-loads at a point on the platform is shown in Figure 38.

As shown in the figure, the g-load on impact was around 6 g's which as before, is capable of causing severe or fatal injuries if head contact occurs. These results show that the condition of the ground could play an important part on the extent of human injury in a locomotive rollover situation. With this level of g-load, there is again the risk of objects within the cab getting loose and causing injury. The damage to the cab and the loss of volume, however, was still minimal. The damage to the cab is shown in Figure 39.

3.4.2 Scenario 2 - Locomotive to Hopper Car Raking Collision Studies

The second type of crash scenario is a train-to-train raking-type collision in which the lateral overlap is small, so that the side of the cab is threatened. This scenario represents a locomotive-headed consist striking a standing hopper car consist, with only 40 inches of lateral overlap (such as a train fouling a turnout). The crash scenario was run at two different speeds of 30 and 50 mph, representing two levels of severity. This crash scenario captures many types of non-"head-on" raking accidents in which damage and later derailment can occur.

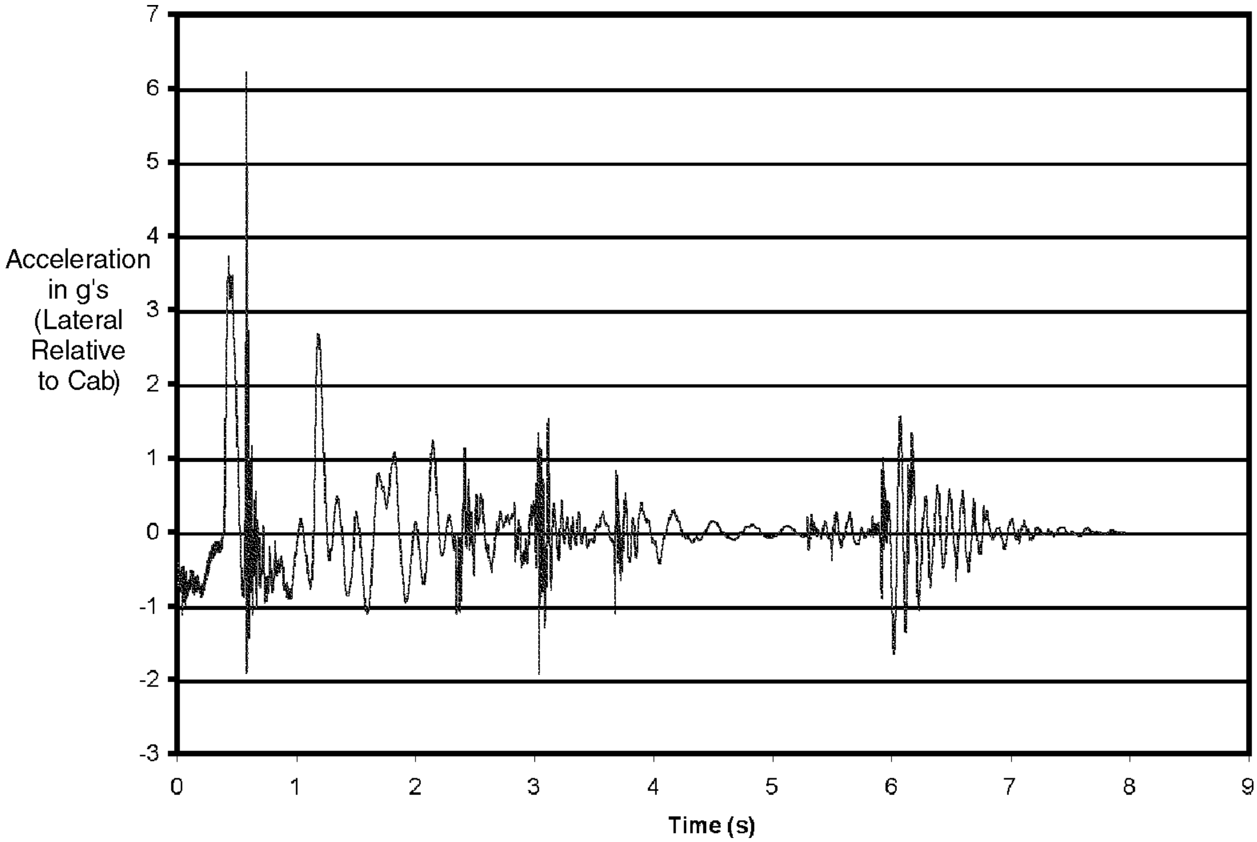
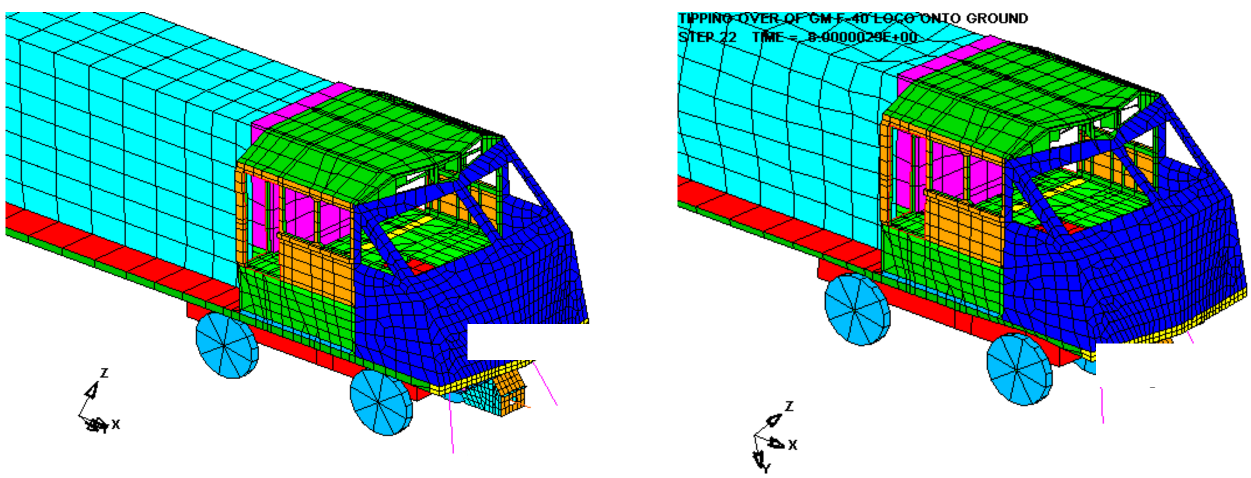


Figure 38. Overall cab g-load versus time for F-40 rollover onto concrete



(a) *(b)*

Figure 39. Picture of the F-40 (a) before and (b) after rolling over onto concrete

Simulations were performed where the three above-mentioned locomotives collided with a hopper consist at 30 and 50 mph speeds. As before, the collisions were performed using the SD-70 MAC, SD-70 narrow nose, and the F-40 passenger locomotives. These collisions were not head on, but had 40 inches of lateral overlap, and at an angle of 8 deg in a fouled right of way (ROW) situation as shown in Figure 40.

3.4.2.1 SD-70 MAC Collision Studies

The SD-70 MAC was analyzed with LS-DYNA in the offset collision with the hopper consist. The first case was performed with the SD-70 MAC moving at 30 mph into the stationary hopper. The configuration of the collision was as described above and as shown in Figure 41. The deformations before and after the collision are shown in Figure 41.

The deceleration in g's as a function of time for a point on the cab platform area of the SD-70 MAC is shown in Figure 42. The graph shows that the maximum deceleration is around 4.5 g's. This level of deceleration can cause injury either from loose objects in the cab or from objects that come loose during the collision or from the impact itself launching a human from his/her seat.

The damage incurred to the cab during this simulation is shown in Figure 43. No significant damage was done to the exits on the rear of the cab. Unless these doors are blocked with debris

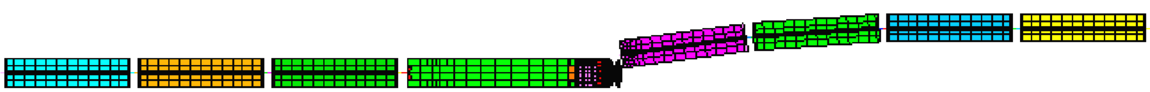
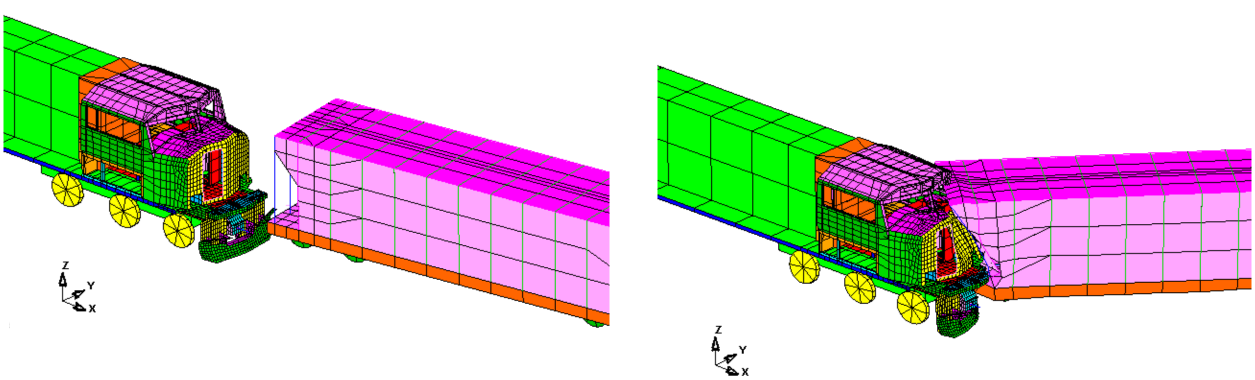


Figure 40. Top view showing a typical collision between a locomotive and hopper car consist



(a) *(b)*

Figure 41. SD-70 MAC locomotive (a) before and (b) after a collision at 30 mph collision with a hopper car consist

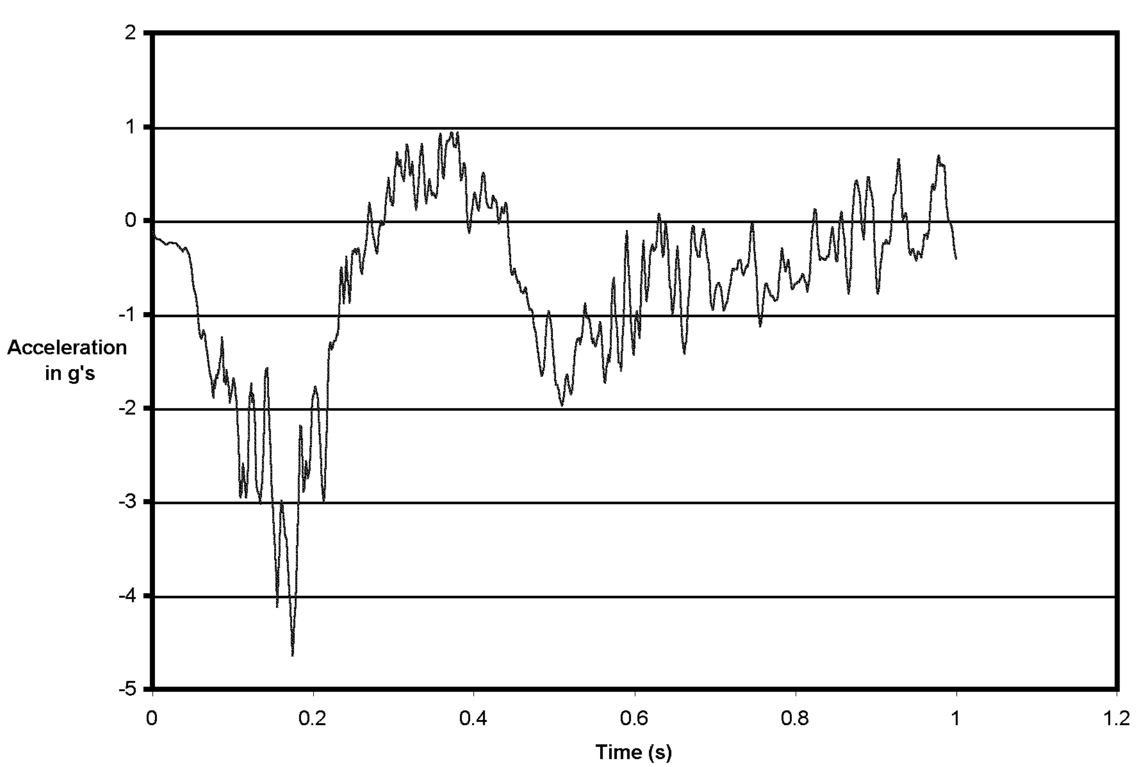


Figure 42. ***Deceleration in g's for cab platform area of SD-70 MAC during a 30 mph, offset collision with a hopper car consist***

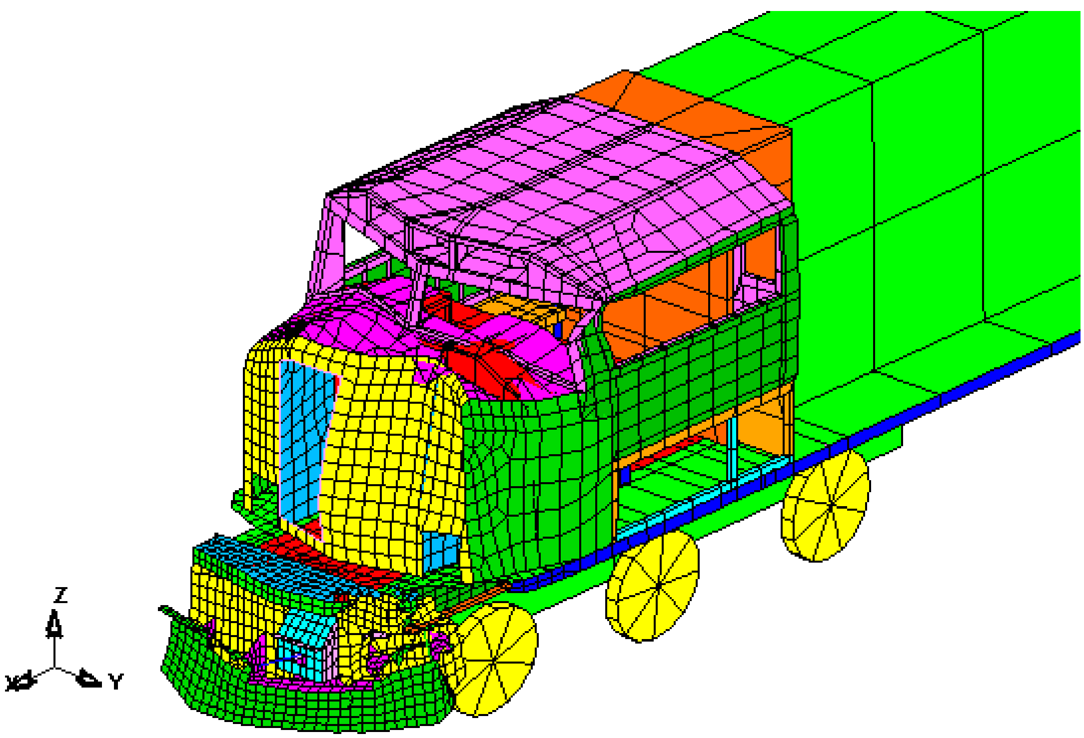


Figure 43. ***Front end of the SD-70 MAC after a 30 mph collision with a hopper car consist, showing incurred damage to the cab***

from the inside of the cab during the wreck, egress should be possible. The front door frame was severely deformed. These doors could be jammed shut, possibly making this exit an impractical choice for egress. The windows on the collision side seem to be deformed, but sufficient space is still available for a crewmember to escape, assuming that the window was not jammed.

The hopper car collision was also performed at 50 mph to simulate an extreme case for the cab egress. The results show that a collision at this speed causes considerably more destruction than the previous simulation. Figure 44 shows before and after the collision process.

This simulation study showed that there was much more penetration of the hopper car into the cab of the SD-70 MAC, making egress all but impossible on the impact side of the locomotive. The cab deceleration was around 5 g's. As before, this is capable of causing severe occupant injuries. The effect of secondary collision due to the impact of trailing cars can be easily seen with higher positive g peaks after the initial collision. Figure 45 depicts the g-level induced in the cab.

The damage to the cab in the 50 mph accident scenario is shown in Figure 46. The cab was virtually destroyed. The entire wall on the side of the collision was caved in, causing some loss of volume in the cab. As before, the front doorframe was heavily damaged so that jamming of the door and handles is very likely to occur. The windows on the side of the collision are heavily damaged and the hopper car is jammed right up against them, thus eliminating egress from that area. The rear door on the driver's side remains undamaged and egress could be possible through this exit.

3.4.2.2 SD-70 Narrow Nose

Similar collision studies were simulated with the SD-70 narrow nose freight locomotive. The results were somewhat similar to that of the SD-70 MAC, since the two locomotives are very alike structurally. The "before" and "after" deformations of the locomotive are shown in Figure 47.

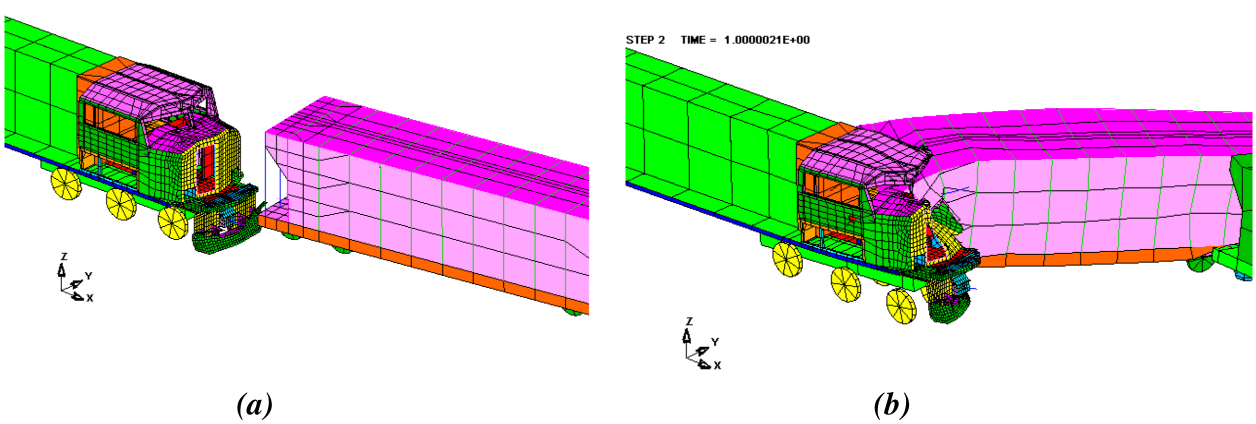


Figure 44. SD-70 MAC locomotive (a) before a 50 mph collision with a hopper car consist and (b) after the collision

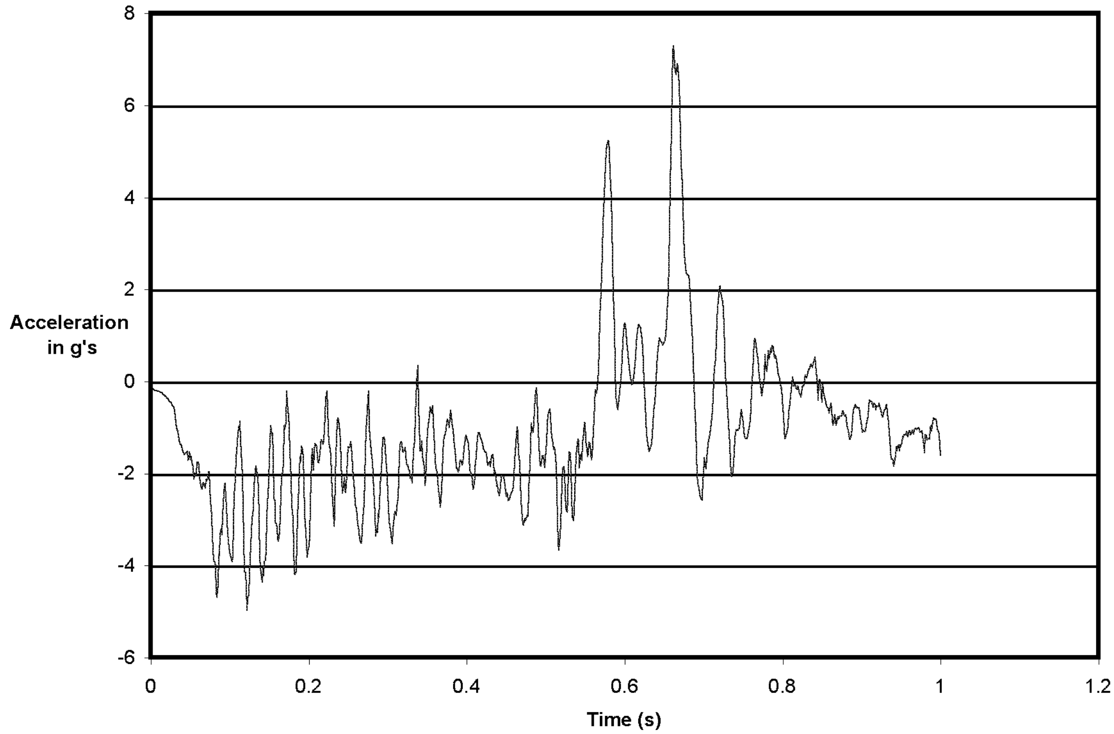


Figure 45. ***The deceleration in g's as a function of time for a point on the platform of the SD-70 MAC during a 50 mph collision with a hopper car consist***

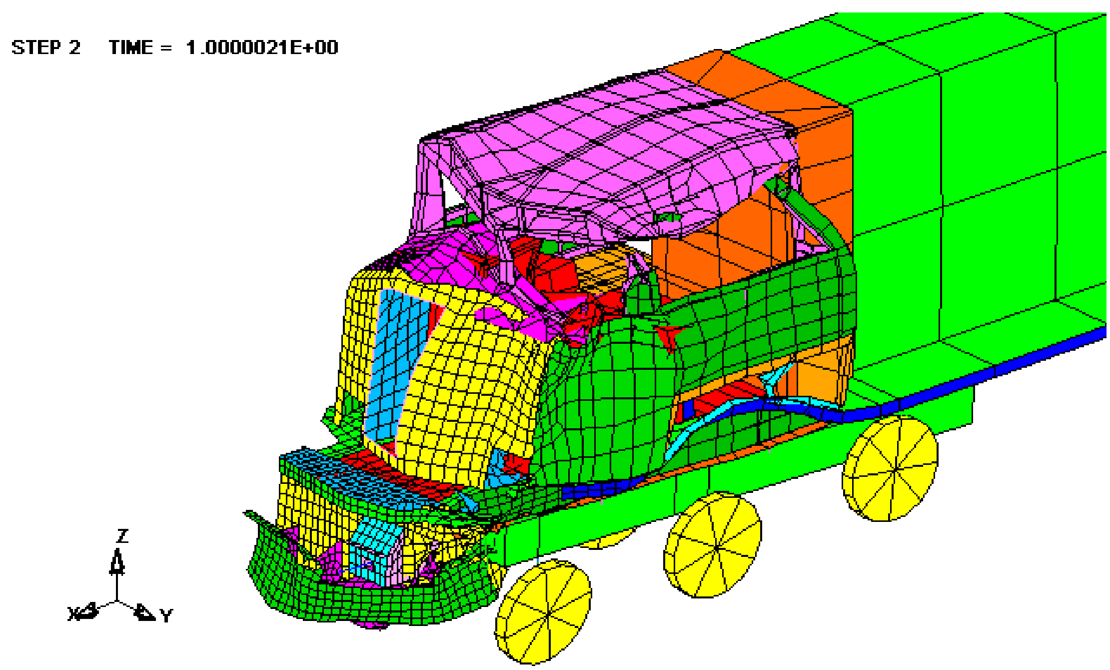
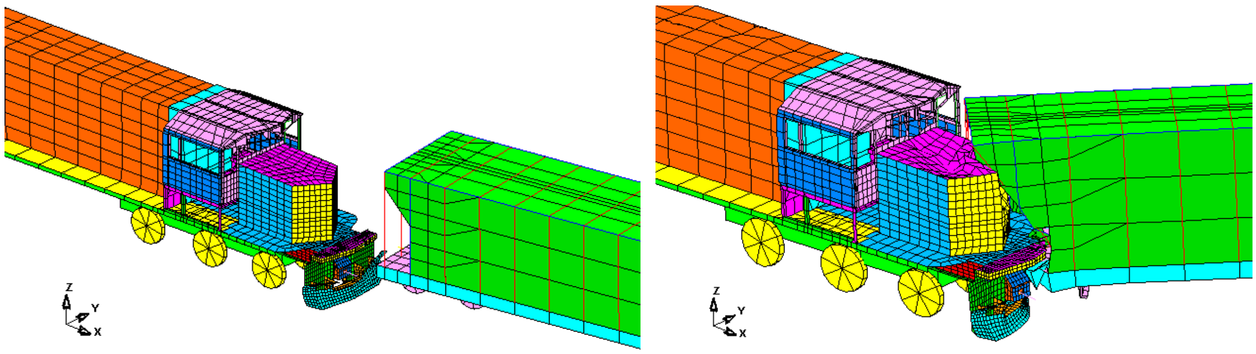


Figure 46. ***Front end of SD-70 MAC after a 50 mph offset collision with a hopper car consist, showing damage to the cab***



(a) *(b)*

Figure 47. SD-70 narrow nose locomotive (a) before and (b) after a 30 mph offset collision with a hopper car consist

From Figure 47, it can be seen that the hopper car never actually hits the cab, only the nose, so not much damage happens to the cab. The g-values as a function of time are shown in Figure 48. As in the SD-70 MAC simulation, the peak deceleration upon impact was around 4.5 g's. This is dangerous and could cause injuries and flying debris within the cab. The secondary peak (3g) occurs at around 0.4 sec into the accident and a third peak (2g) occurs around 0.8 sec. These peaks in acceleration are from the rear cars impacting the vehicles (i.e., locomotive or other cars) that lie in front of them.

The damage incurred to the SD-70 narrow nose is shown in Figure 49.

In this simulation, light damage occurred to the cab. There is little loss of interior volume with minimal distortion to the front door. Figure 47b shows the results of this simulation. Because of this, the opening of that door would be hindered, blocking escape through that exit. The right read door exit seems to be free and is available for escape.

The simulation was also performed at 50 mph to see an extreme case of the collision. This analysis yielded results that are much more destructive. Figure 50 shows the before and after collision deformation of the locomotive and the hopper car.

The penetration of the hopper car into the cab of the narrow nose locomotive is much more severe than in the 30 mph crash. The g-values as a function of time are shown in Figure 51.

The maximum g-force on impact was around 5.5 g's, enough to cause injury/death under some conditions. The damage to the cab during this collision process is shown in Figure 52.

The cab has been destroyed. The hopper car crushed the nose of the locomotive and went through the doors and windows, thus reducing cab volume greatly. Since the hopper car is in

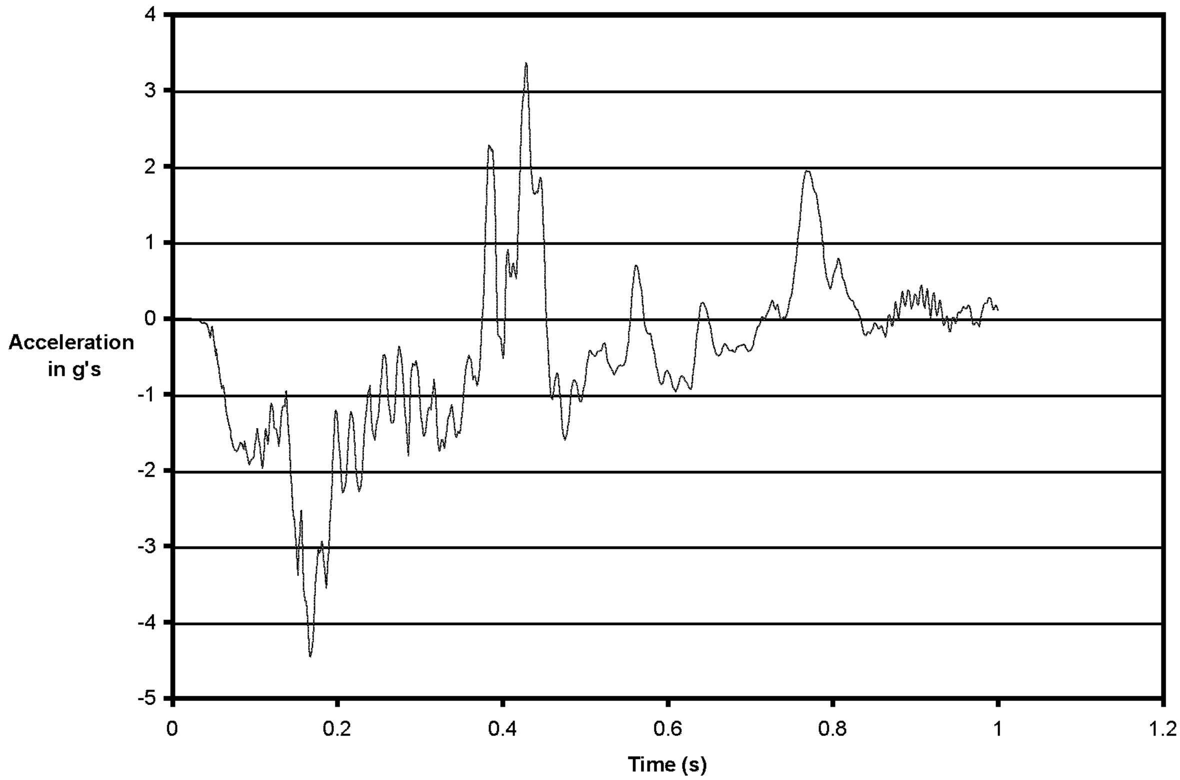


Figure 48. ***Overall cab deceleration in g's at 30 mph – offset collision with a hopper car consist***

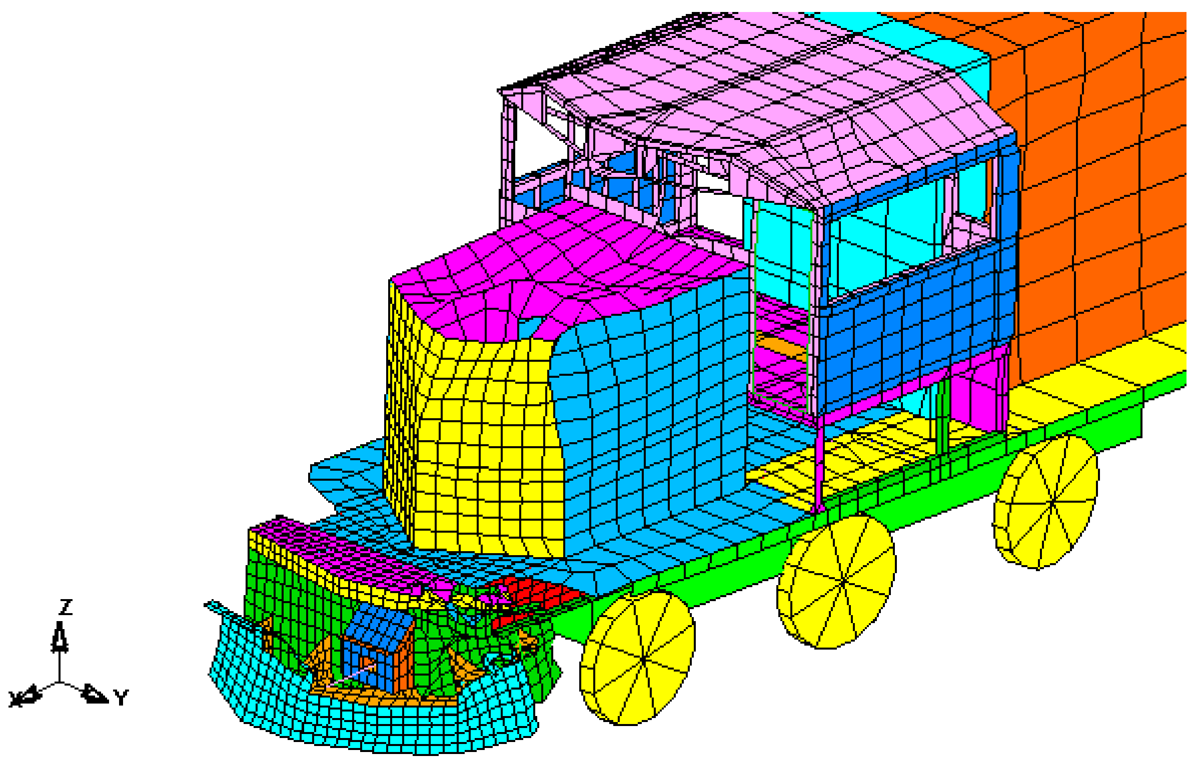
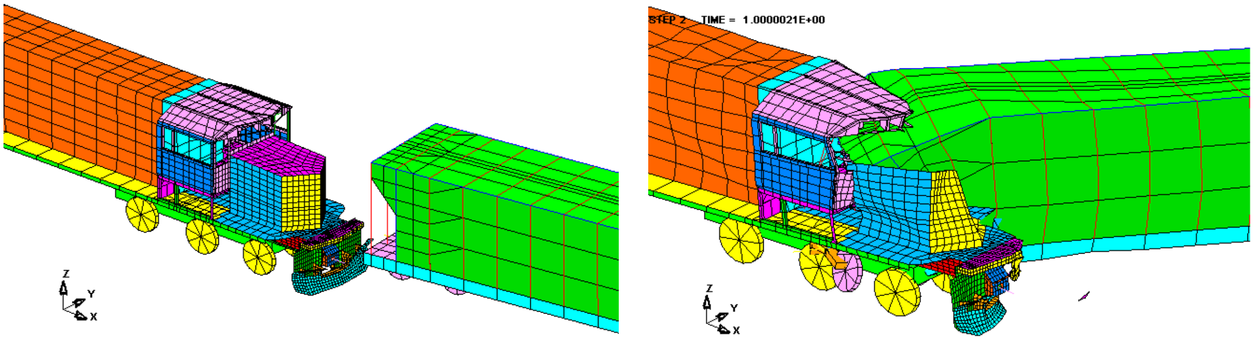


Figure 49. ***Front-end deformations of the SD-70 narrow nose locomotive after a 30 mph collision with a hopper car consist***



(a) *(b)*

Figure 50. ***SD-70 narrow nose locomotive (a) before and (b) after a 50 mph collision with a hopper car consist***

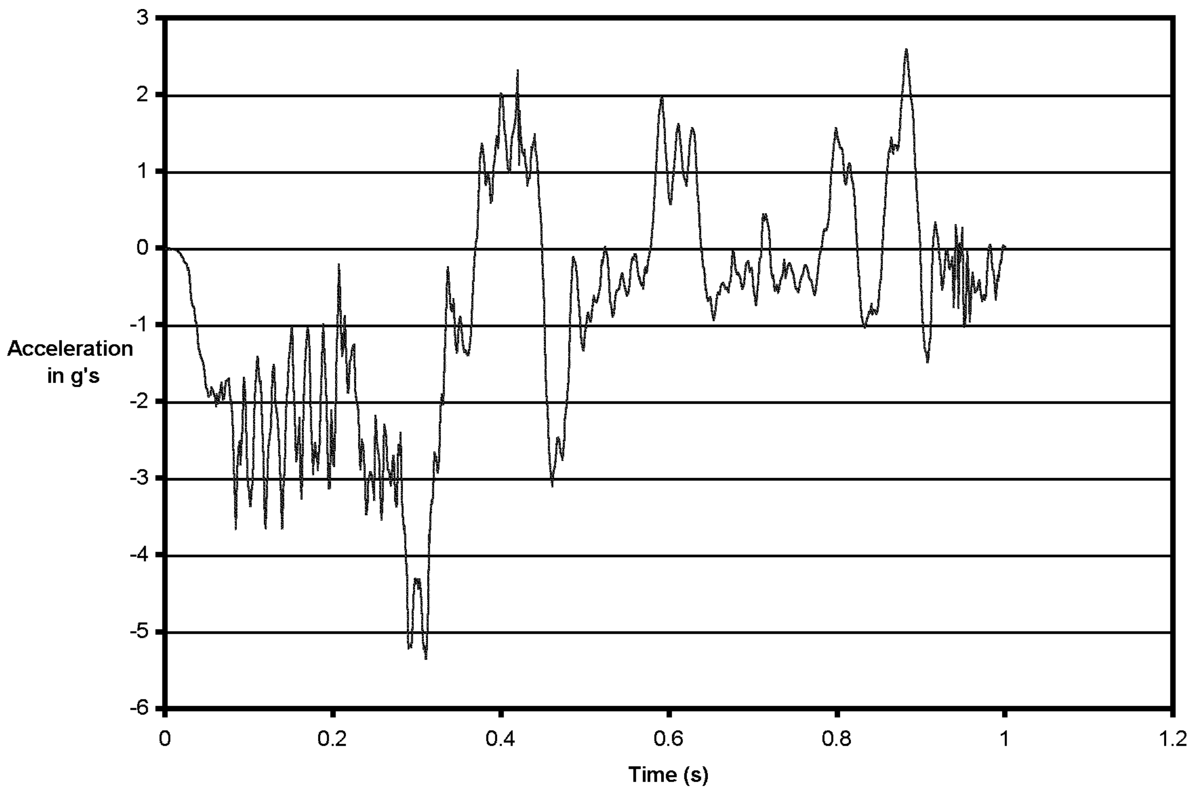


Figure 51. ***Overall cab deceleration in g's for SD-70 narrow nose locomotive during a 50 mph offset collision with a hopper car consist***

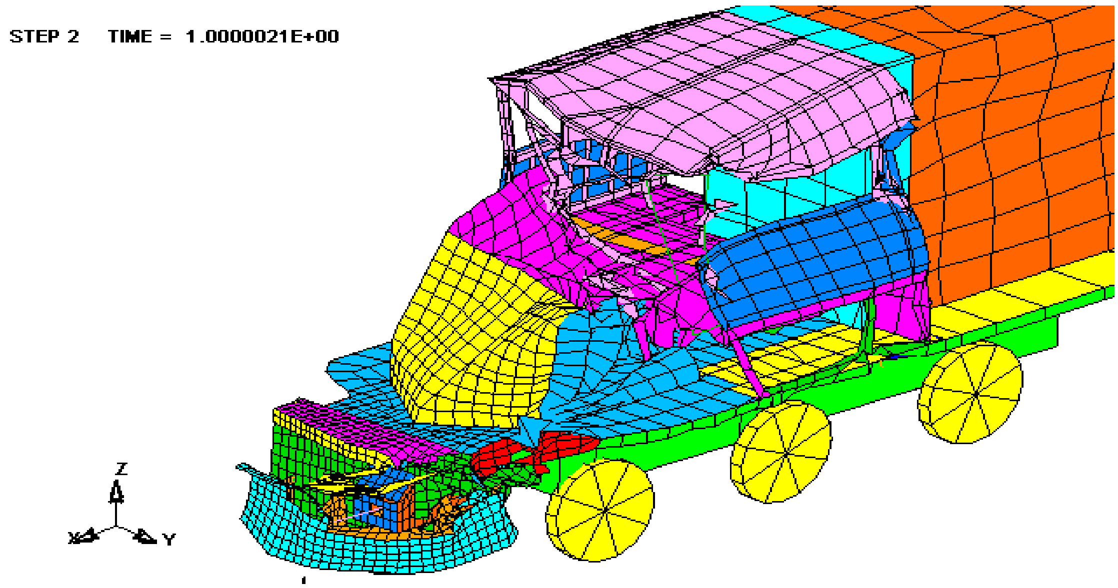


Figure 52. Front end of the SD-70 narrow nose locomotive after a 50 mph offset collision with a hopper car consist, showing incurred damage to the cab

contact with the cab on the impact side, egress in this area is not possible. The door on the right rear side is intact and is a possible exit for a trapped crewmember.

3.4.2.3 F-40 Passenger Locomotive

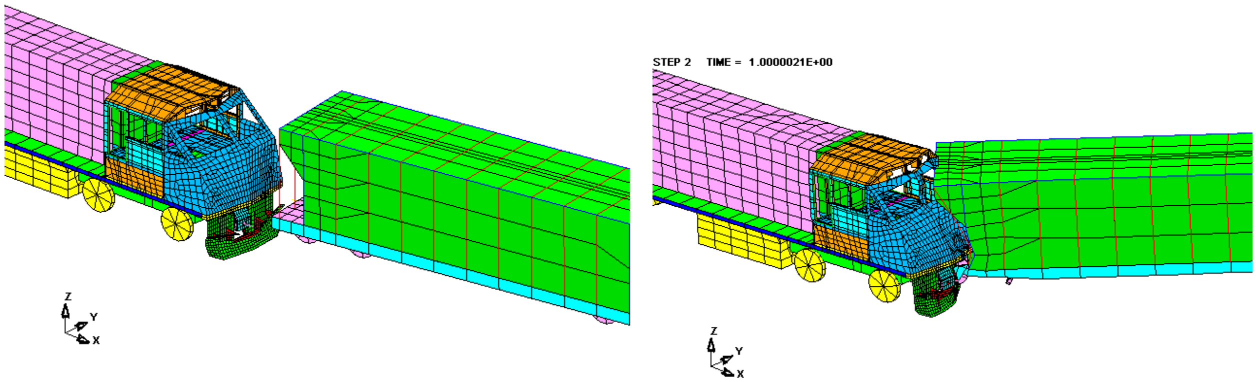
A simulation study was also conducted on the F-40 passenger locomotive in the same offset collision with a hopper car consist. First, the analysis was performed with the locomotive initially traveling at 30 mph. The damage done to the cab was minimal. A before and after deformation of the nose of the cab shown in Figure 53.

From this simulation, it can be seen that the hopper car damages only the front end of the cab and never actually contacts the doors or windows near the rear of the cab. A graph of the acceleration in g's is shown in Figure 54.

The maximum acceleration during impact is around 5 g's, similar to the other locomotive collisions and dangerous levels for occupant survival. There was some damage sustained to the front, impact side windows, as shown in Figure 55, but the other egress route (R side door) is open and can be used for escape.

As in the case of the previous locomotives, a similar analysis was performed at 50 mph. As expected, these simulations showed much more severe damage than at 30 mph. Figure 56 shows the model before and after the collision.

The damage to the cab is much more severe in this simulation. The figure shows that the hopper penetrates the cab and destroys the entire impact side. Figure 57 shows the acceleration in g's as



(a) *(b)*

Figure 53. F-40 passenger locomotive (a) before and (b) after a 30 mph offset collision with a hopper car consist

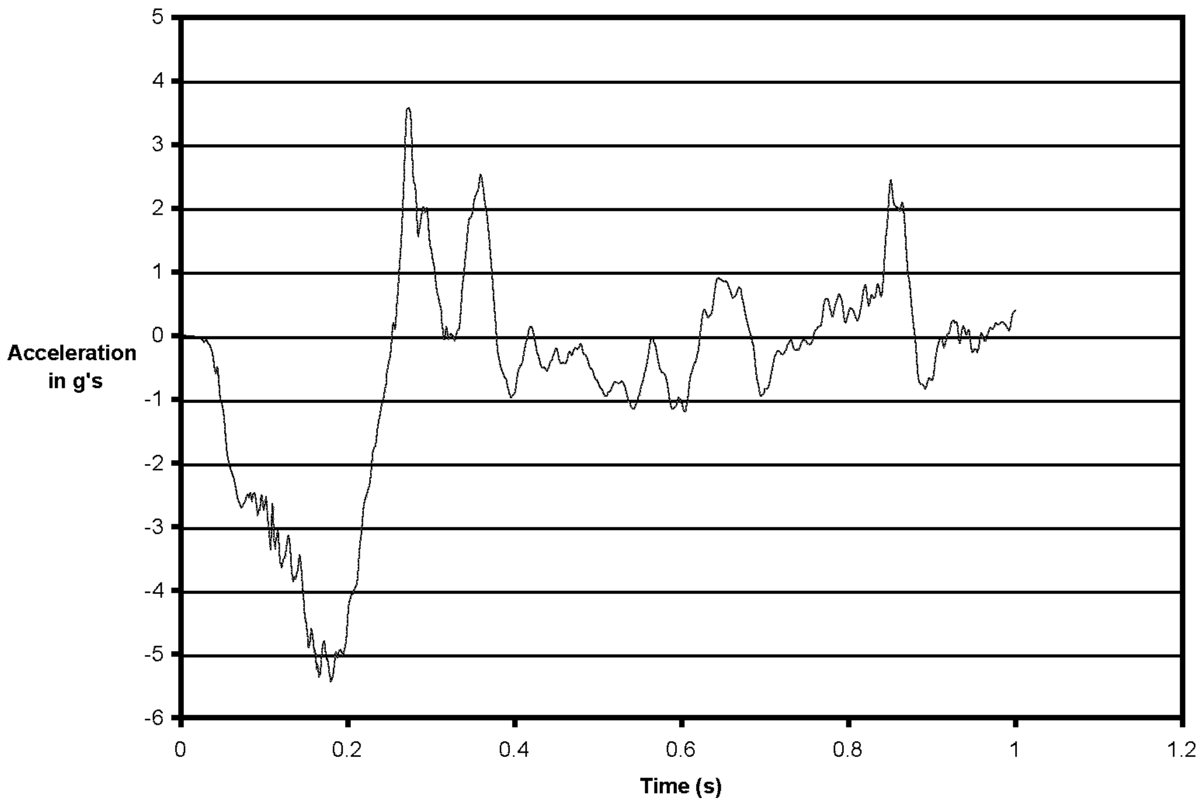


Figure 54. The deceleration in g's as a function of time for a point on the platform of the F-40 passenger locomotive during a 30 mph collision with a hopper car consist

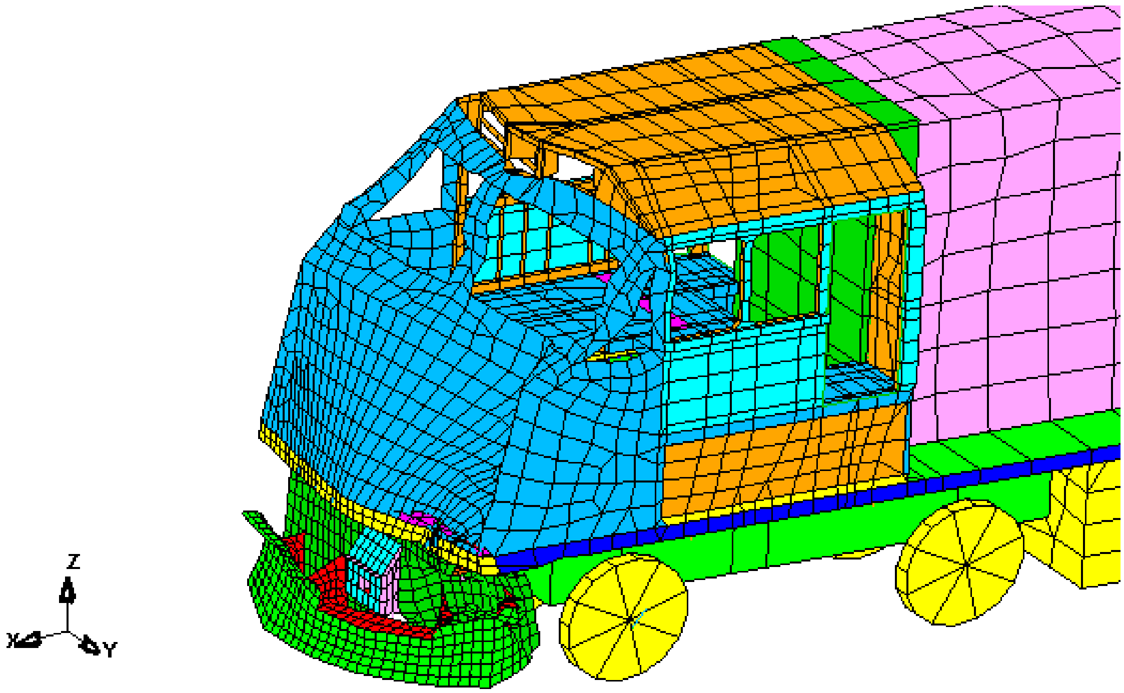
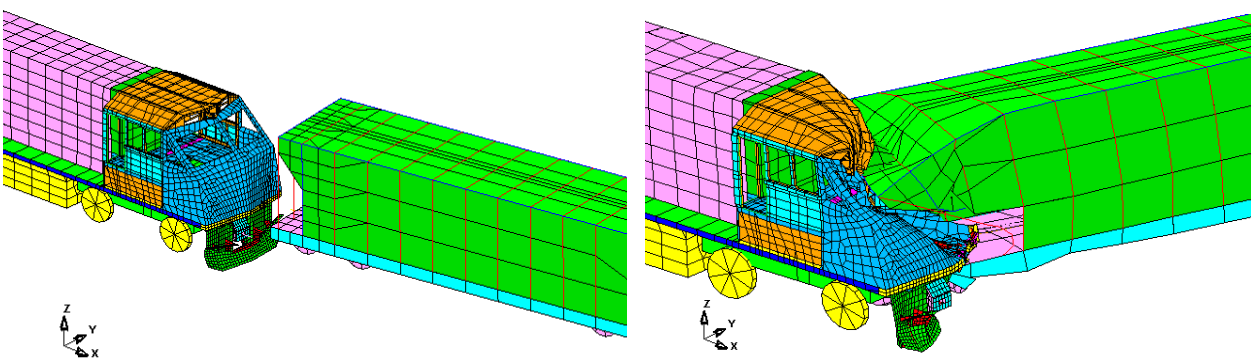


Figure 55. Front end of the F-40 passenger locomotive after a 30 mph offset collision with a hopper car consist



(a) *(b)*

Figure 56. F-40 passenger locomotive (a) before and (b) after a 50 mph offset collision with a hopper car consist

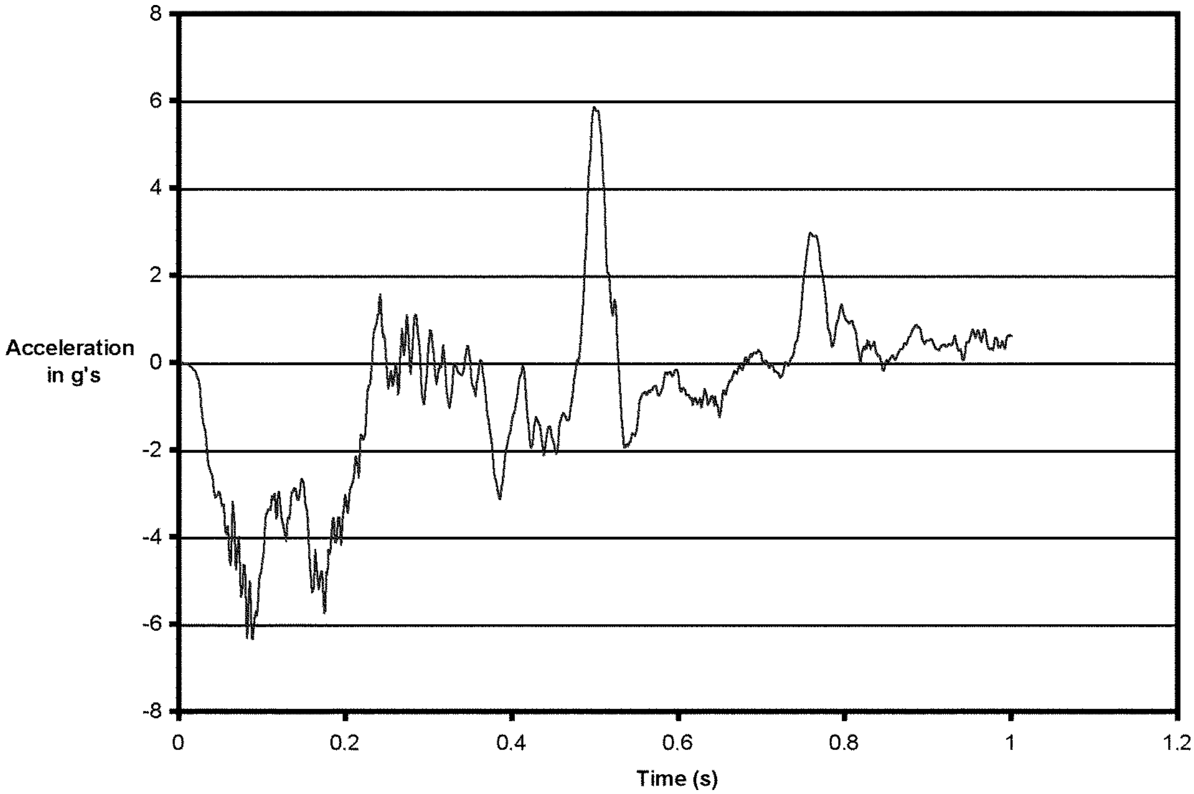


Figure 57. Overall cab deceleration in g's as cab platform area of F-40 passenger locomotive during a 50 mph offset collision with a hopper car consist

a function of time during the accident. The entire impact side of the F-40 cab was destroyed and the hopper car is wedged up against it, making any attempt at egress on that side impossible. The door on the opposite side of the locomotive seems to be intact and unless there are any debris/obstacles hindering escape, this exit should function well for egress.

The figure shows results that are very similar to the 50 mph simulations for the previous locomotives. The peak deceleration during the impact is around 6 g's. This value is high and severe injuries to crewmembers could occur. The damage to the front end of the locomotive is shown in Figure 58.

3.4.3 Scenario 3 - Locomotive to Locomotive Head-On Collision

For this egress study to represent the actual head-on collision, two SD-70 narrow nose road locomotives were chosen. LS-DYNA was used for the analysis, which approximately simulated an accident involving the head-on collision of two SD-70 narrow nose locomotives that occurred in Devine, TX in 1997. In the simulation, one SD-70 moving at 60 mph, collided with a standing SD-70 in the same track. The result of the simulation is shown in Figure 59.

The moving locomotive overrode the stationary locomotive after the collision. Although the cab nose deformed heavily, the cab itself sustained light damage. The back door(s) are available for easy exit for crewmembers. The acceleration in g's as a function of time on the platform of the

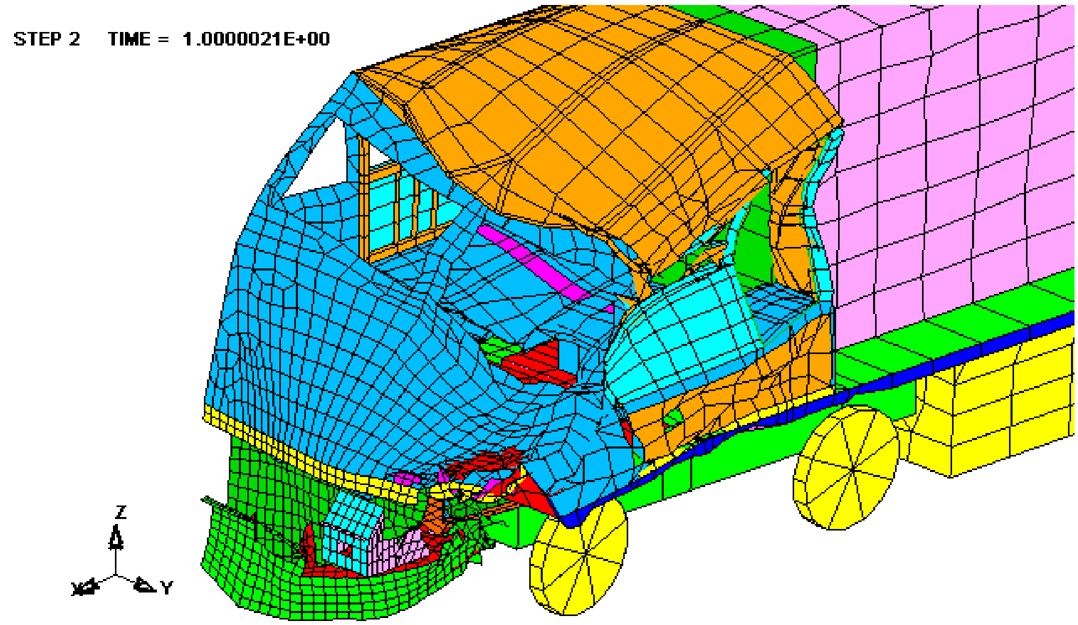


Figure 58. Front end of the F-40 passenger locomotive after a 50 mph collision with a hopper car consist

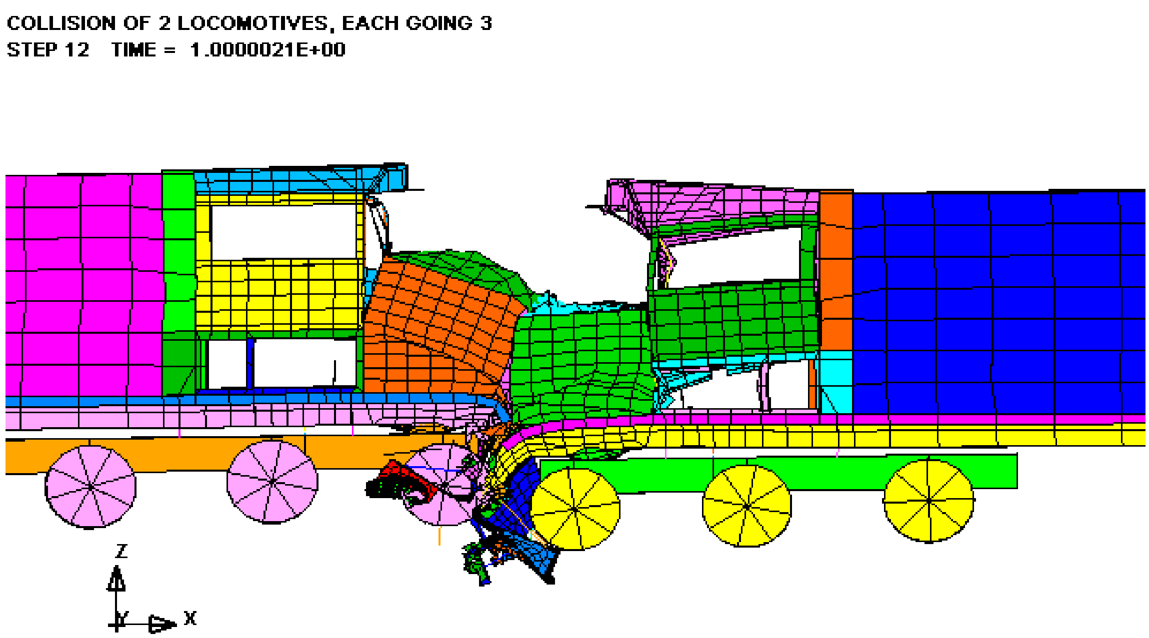


Figure 59. Two SD-70 narrow nose locomotives in a head-on collision, lower locomotive stationary, higher locomotive traveling at 60 mph

moving locomotive is shown in Figure 60. Again, the peak g-loads exceed 25g, well above the level which could produce severe or fatal injuries to unrestrained crewmembers.

3.5 Structural Improvements

Investigations also were made to demonstrate that some locomotive strengthening measures could improve survivability in some collisions through: 1) reducing intrusion or loss of cab volume; and 2) by reducing in-cab deceleration g-levels. For the scope of this project, which comprised an evaluation of many factors affecting egress, only selected situations were evaluated to show the nature of such improvements, and use of collision accidents which might be considered severe but possibly survivable. Neither the scope nor intent of this project was intended to provide a complete optimization of the structural features which, for example, could meet the new (2000) version of the AAR Standard 580; however, the types of strengthening shown below are typical strategies used by manufacturers, and these are used to show examples of how a significant, but practical upgrade affects the locomotive behavior.

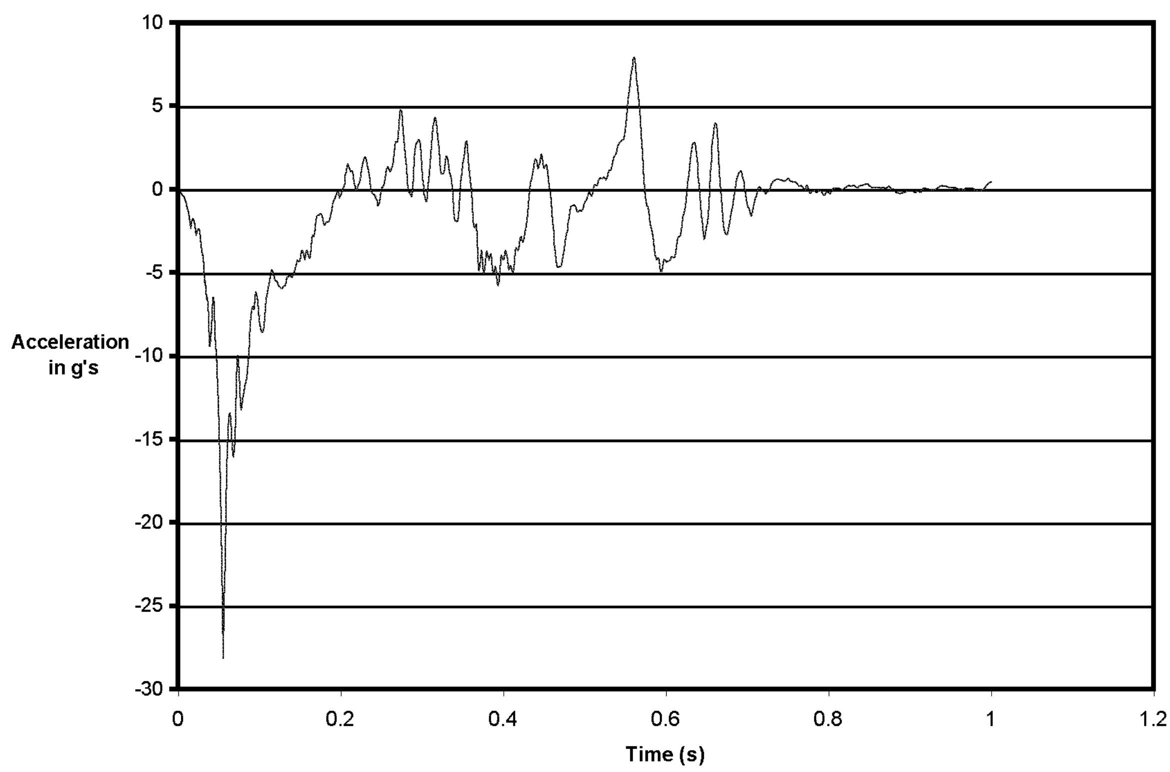


Figure 60. Overall cab acceleration in g's of the moving SD 70 narrow nose locomotive in head-on collision with opposing locomotive

The structural improvements to the locomotive cab, hood and other areas were helpful in mitigating damage to cab areas in the hopper car consist collisions. For example, in the SD-70 narrow nose locomotive, improvements that have been investigated included:

- The steel skin of the nose was originally made 0.38 inches thick on its front and sides, and 0.19 inches on the top. These plates were thickened to 0.5 inches to strengthen the nose.

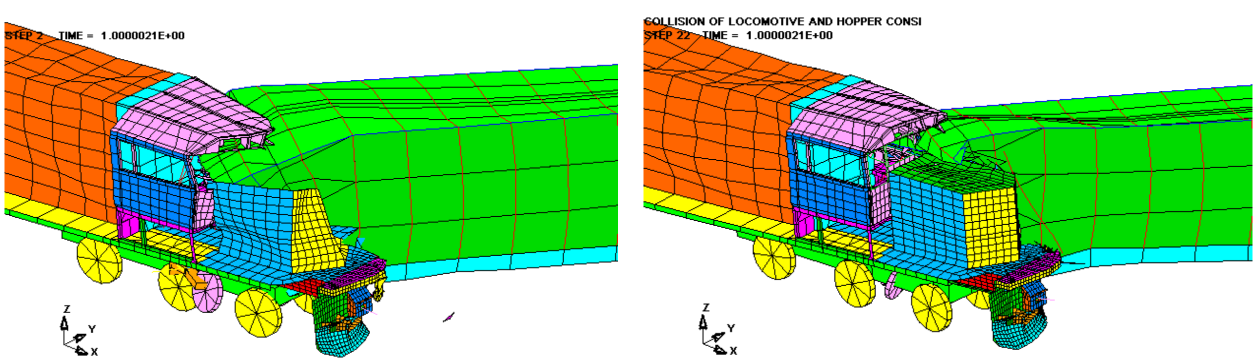
- The SD-narrow nose locomotive had no collision posts, because it was designed before the S-580 rules. Two collision posts, 1 inch thick, were placed in the nose to meet the standards and absorb energy and thereby provide less damage to the cab.

- The cab side plate that was severely damaged in the 50 mph hopper car collision was thickened from 0.188 inches to 0.375 inches to provide additional strength.

- The doorframes were also strengthened using a 2 inches x 2 inches x 0.25 inches wall tubular structure. Tubular beams were also added to the window sheet metal frames in the front of the locomotive to strengthen the window frames and to provide more stiffness.

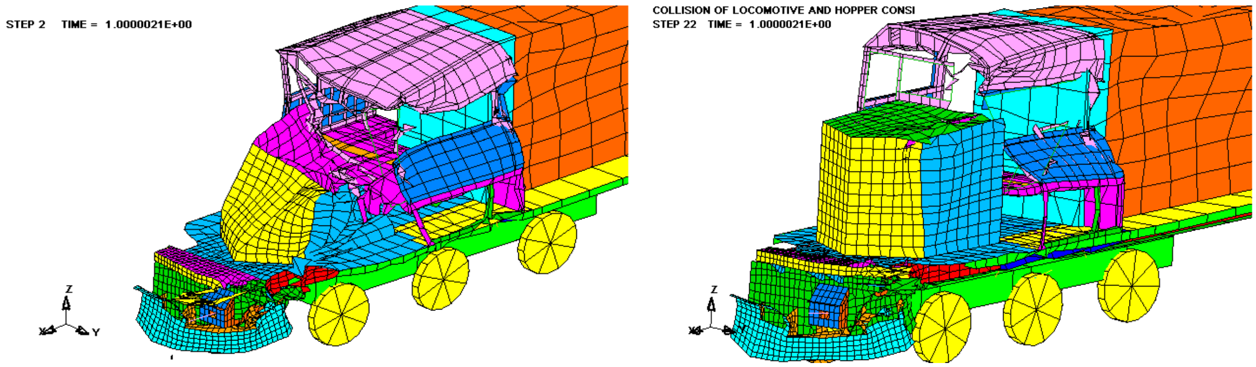
An analysis was performed with LS-DYNA in which this structurally improved model was crashed into a hopper car consist at 50 mph with the same configuration as in Task 2. The results of the analyses are shown in Figures 61 to 63. Figure 61 shows the collision process before (a) and after (b) the structural improvements.

The nose of the locomotive is much less deformed when the plate is thickened and the collision posts are present. The roof did not cave in. This may be due to combination of thickening the side plates and the door/window frames. A better view of the damage comparison is shown in Figure 62 with the locomotive with the hopper car removed for clarification purposes.



(a) *(b)*

Figure 61. ***SD-70 narrow nose colliding with a hopper car consist (a) without structural improvements and (b) with improvements***



(a) *(b)*

Figure 62. Damage sustained by the existing (a) SD-70 narrow nose locomotive and (b) with structural improvements in 50 mph offset collision with hopper cars

This shows that there was much less cab volume reduction in the reinforced model. The side panel, however, still caves in because of the near direct hit of the hopper car. The acceleration as a function of time is shown in Figure 63.

The g-levels were in the range of 5.5 g's for the locomotive without any improvements. In the improved case, the peak acceleration is about 4.8 g's. Although lower g-loads should help in egress situations, the crewmembers would still be prone to injury, if they remain inside the cab.

Several collision analyses were performed with LS-DYNA in which this structurally improved model collided into a standing hopper consist partially fouling the ROW. This is the same accident scenario described in Task 2. As an example, the results for a collision at 50 mph were shown in Figures 59 and 60. A "before" and "after" comparison shown in Figure 64 shows the effect of these structural improvements.

The nose of the locomotive is much less deformed when the plate is thickened and the collision posts are added. Also, the roof did not buckle inward with the improvements. This is likely due to a combination of thickening both the side plates and the door/window frames. Another view of this damage comparison is shown in Figure 65 with the hopper car removed for clarification.

There was much less cab volume reduction in the reinforced model. The side panel, however, still buckles in somewhat because of the near direct hit of the hopper car bodywork.

The in-cab g-levels were in the range of 5.5 g's for the locomotive without any improvements, decreasing to about 4.5 to 5 g's with the improvements. Although lower g-loads help in egress situations, the crewmembers would still be prone to injury, if they remain inside the cab. The primary benefit is less cab damage and intrusion of the colliding vehicle into the cab volume.

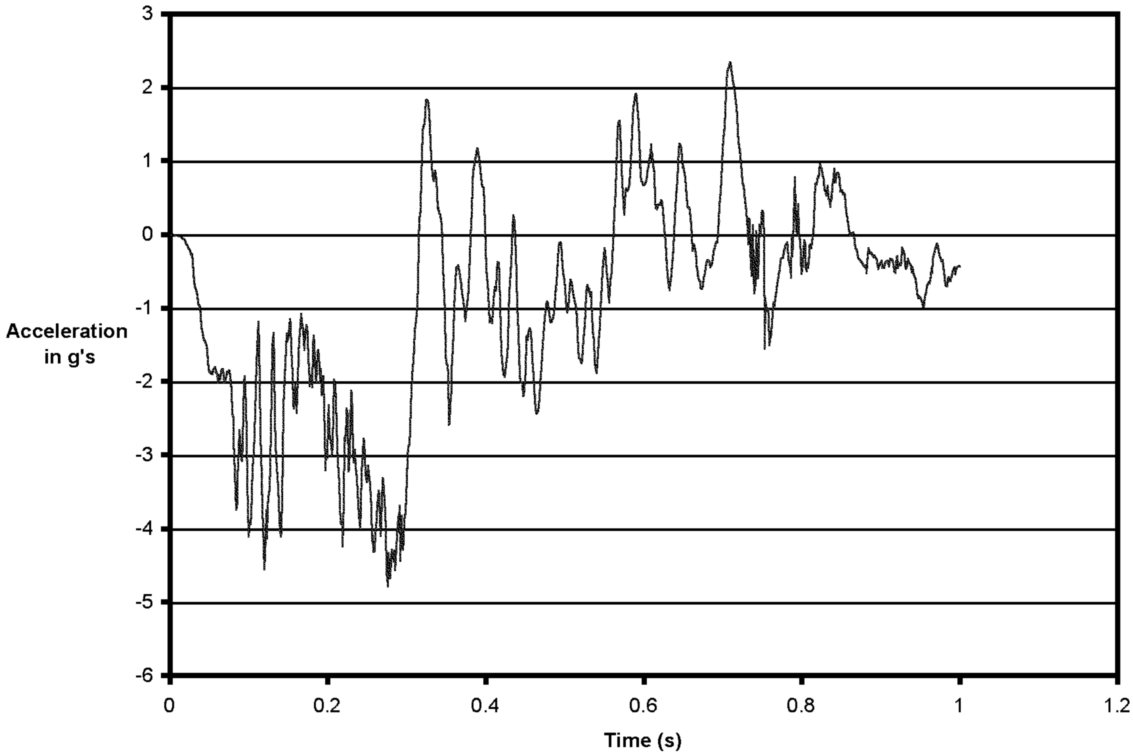
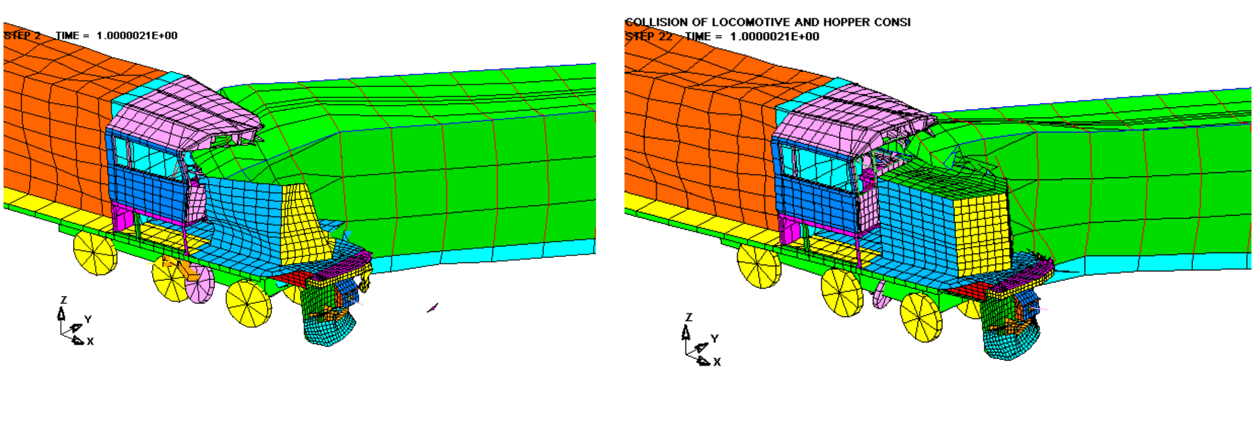
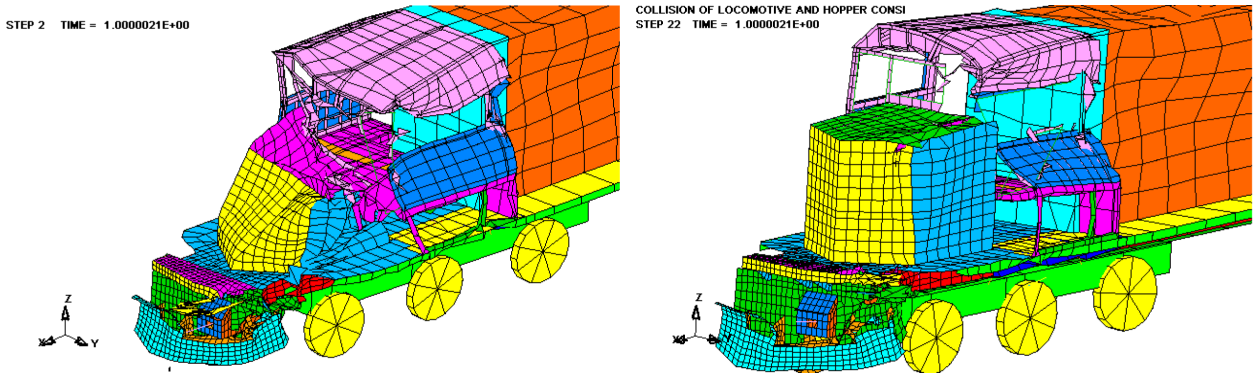


Figure 63. ***Overall cab deceleration in g's of the structurally improved SD-70 narrow nose locomotive during a 50 mph offset collision with a hopper car consist***



(a) *(b)*

Figure 64. ***SD-70 narrow nose locomotive in offset collision with hopper car consist - (a) without structural improvements and (b) with improvements***



(a) *(b)*

Figure 65. Damage sustained in offset hopper car collision (a) by existing SD-70 narrow nose locomotive and (b) with structural improvements

Table 4 summarizes the in-cab g-loads found in the various combinations of accident situations and locomotive types investigated.

Similar studies for other locomotive models are expected to provide similar results, although in these complex interactions, a case-by-case approach together with practical design intuition is essential.

3.6 Summary

The evaluation of locomotive crash scenarios and egress and further strengthening studies gave us the insight to reducing crewmember injuries with the measurement of reduction in cab volumes. In general, the primary benefit from the strengthening of the cab structures was

Table 4. In-cab decelerations (g-loads) for different accident scenarios

Scenario	SD-70 MAC	SD-70 Narrow Nose (No S-580)	F-40 Passenger	Structurally Improved SD-70
Rollover Derailment (Lateral G—Relative to Cab)				
Soft Ground	3.0	3.5	3.0	
Hard Ground	6.0	6.2	6.2	
Loco-Hopper Offset/Raking Collision (Longitudinal G — Relative to Cab)				
30 mph	4.5	4.5	55 (see Figure 57)	
50 mph	7.0	5.3	5.7	4.8
Loco-Loco Offset/Head on Collision (Longitudinal G — Relative to Cab)				
60 mph		28		

improved integrity, not g-load reduction, although Table 4 shows that some reduction in g-load is possible. This will lead into further studies on human survivability shown later on in Section 6.

In all of the scenarios analyzed, at least one emergency egress route was preserved. However, for the case of the raking head-on collision, ease of egress would depend upon whether the raking collision occurred on the left side or right side of the locomotive. For the case of the raking collision occurring on the engineer's side of the cab, potential structural damage could hamper egress through the rear door (usually found only on the right rear side). This could then require that one of the side windows become the primary emergency egress route.

Some of the specific results showed that the highest g-load occurred for the 60 mph locomotive-to-locomotive head-on collision. This was expected, as it is the most direct impact orientation and the highest speed. For the case of the SD-70 narrow nose, the resulting g-load exceeded 20 g's, possibly related to the lack of collision posts in that version. For the other accident scenarios simulated - rollovers and raking collisions - the cab floor g-loads varied from about 3 g's to 7 g's depending on the scenario and the locomotive simulated. Rollover derailments where the rollover occurs on soft ground, the in-cab lateral g-loads varied from about 3 to 3.5 g's. These values nearly doubled for the case where the rollover occurred on hard ground, such as concrete. In the raking collision scenarios, the g-loads varied from about 4.5 g's to 7 g's, depending upon the velocity scenario.

For the structurally improved SD-70 narrow nose locomotive, the results showed only a slight improvement of about a 10 percent reduction in g-load for the 60 mph raking collision condition. However, as a result of the structural improvements much less reduction in the cab volume was observed.

Also, we should reiterate that a full study of possible injuries which result in these collisions to the cab crew is also a major project in itself, outside the scope of this program, since so many variables affect the outcome. These include, but are not limited to: details of each individual locomotive interior, each of which must be modeled or tested; position of crewmember at instant of collision; behavior of all interior attached equipment which could become injurious if detached; and the nature of the collision itself, which has not only an initial ("primary collision") phase, but follow-on behavior such as pileup of the consist, derailment followed by rollover, fire, etc. Rather, the in-cab floor g-levels certainly are related to the severity of interior "secondary collisions" of the crew with the interior, so it is a valid if simple indicator of potential injury. Also, the time duration of the deceleration/acceleration pulses (which often alternate after the initial collision due to dynamics of the multicar consists involved) is extremely important in determining the kinematics and injury of occupants in any vehicular collision. So, the peak g-level observed is only an overall relative indicator used for comparing a collision result before and after a specific improvement. This is valuable in that it will then provide suggestions and guidance for designers as to which measures might be considered when their detailed designs are evaluated.

4. ASSESSMENT AND IMPROVEMENTS TO LOCOMOTIVE DOOR AND EMERGENCY WINDOW OPERATION

Doors and windows naturally are the primary means of egress and access to the locomotive cab in emergency situations, barring the provision of special escape hatches. The design of doors and their latches, window design and operation, with the objective of improving emergency egress capability was reviewed. Current inspection and maintenance practices for these important components were assessed, since functions originally "designed-in" can be foiled through poor maintenance or design configurations that trap dirt, encourage corrosion, etc. This effort is aimed at developing suggestions for improving the capability of doors and windows to provide emergency egress, and when possible, better outside emergency access to the cab.

4.1 Current Practice in Locomotive Cab Window and Door Operation

A selected survey was conducted of locomotive cab windows and doors. Locomotive cabs generally have two windows that open on each side of the cab. These windows are of varying shapes and sizes, dependent on the locomotive type and model. Locomotives are built with a minimum of two egress doors. The typical configuration for a modern narrow-nose freight locomotive has one door facing forward at the front of the cab on the left side. The other door faces to the rear at the back of the cab and is usually on the right side. Both doors open onto a narrow platform. A wide-nose locomotive generally has its front door located at the nose of the unit and is accessible from steps. Locomotives designed specifically for passenger service are an exception to this general configuration. Their access doors are generally located on both sides of the locomotive and are reached by climbing a set of vertical steps or ladder rungs. In addition to exit doors, most locomotives have another door at the rear of the cab that leads to an equipment room which in some cases also leads to the engine room, thus providing another emergency egress route out the back of the locomotive.

Examples of windows in passenger and freight locomotives are shown in the following figures. Figures 66 and 67 are the side window and front windshield of an F40-PH type passenger locomotive. The 23 inches wide x 9 inches high side window is opened by horizontally sliding it forward. The front of the locomotive has two barred and relatively large windshields.
Figures 68 and 69 show the side window and windshield for a Dash 8 type freight locomotive, manufactured by General Electric. The side window for this unit contains two windowpanes, but only one of which is movable. As seen in Figure 69, this unit is a wide-nose locomotive and has two relatively large windshields and an outward opening nose door.

Figure 66. Cab view of side window and door for F40-PH locomotive

Figures 70 and 71 show the side window and windshields, respectively, of a SD-70 MAC freight locomotive manufactured by EMD. The side window is a double sliding unit that opens from the center and has an approximate opening size of 33 x 22 inches. (These can vary depending on the railroad ordering the locomotive.) The two large contoured windshields, each are 17 inches (minimum) high and 55 inches wide.

Some examples of egress doors used in locomotives are shown in the following figures. Figure 72 shows the side entrance door as seen from the exterior of a F40 passenger locomotive. This door is about 19 inches wide and is accessed by a set of vertical steps. A view of this door from inside the cab is shown on the right side of Figure 66. Figure 73 shows the front hood door of the SD-70 locomotive; note that egress from the cab itself would involve descending the interior steps and proceeding forward within the hood. Figure 74 shows the rear cab door for the SD-70 (only provided on the right side). This has a clear opening of approximately 16 inches wide. Figure 71 also shows the nose door for the SD-70 MAC locomotive, also an outward opening door. The door handle configuration shown here is typical for a locomotive installation.

Figure 75 shows an exterior view of the recently introduced F59-PHI passenger locomotive. The side window has two panes having a total width of about 25 inches. It is designed to have only one pane that can be opened in normal operation. The side window for this unit has been specifically designed for emergency egress. Figure 76 shows a view of that window as seen from the interior of the cab. The emergency egress features of this window will be further discussed later in this section. The inward-opening entrance door shown in Figure 75 is located on the side of the locomotive and is reached by a set of vertical steps.

Figure 67.   Front view of F40-PH locomotive

Figure 68. View of side window (Dash 8 locomotive) from inside cab

Figure 69. Front view CW40-8 (General Electric) (Dash 8)

Figure 70. View of side window (SD-70 MAC) from inside cab

Figure 71. Front windshield area of SD-70 MAC locomotive

Figure 72. Side entry door of the F40-PH locomotive

Figure 73. Nose entry door of SD-70 MAC freight locomotive

Figure 74. Rear cab door of SD-70 MAC freight locomotive

Figure 75. Exterior view of F59 passenger locomotive

Figure 76. Interior view of F59 cab emergency exit window

The windows and doors shown are illustrative of current practice for modern locomotives. In general, cab windows have horizontal side-opening features, and with the exception of locomotives designed specifically for passenger service, have outward opening doors. Table 5 contains the results of that selective survey. Their design features and operation specific to emergency egress are further discussed below.

4.2 Design and Operation of Locomotive Doors and Windows

Window and door size and shape configurations are usually custom designed to meet a locomotive builder's specification for a particular locomotive type and model. There are currently two principal U.S. suppliers of rail and transit windows, namely R.E. Jackson, Co. Inc. and Young Windows, Inc. Preliminary contact made with these suppliers confirmed that the specification for a cab window is almost always unique and is manufactured solely in response to a locomotive builder's specification. These suppliers do have generic catalog data for many different window styles and configurations. A typical locomotive-window generic configuration offered by these suppliers is shown in Figure 77.

Table 5. Windows and door data for selected locomotives

		Windows			Doors		
Locomotive	Type	Number	Size (WxH) (in.)	Type Opening	Number	Size (WxH) (in.)	Location
GP38	Double SL[1]	2	32 x 38	Outward	2	20 x 70	Front and Rear
GP40	Double SL	2	32 x 27	Outward	2	19 x 70	Front and Rear
GP 40-WH	Double SL	2	33 x 27	Outward	2	19 x 70	Rear
SD70MAX	Double SL	2	33 x 22	Outward	2	23 x 69 17 x 72	Nose Rear
U23B	Double SL	2	36 x 26	Outward	2	16 x 65	Front and Rear
CW40-8W	Single SL	2	21 x 24	Outward	2	18 x 73	Front and Rear
GP35	Single SL	2	33 x 26	Outward	2		Front and Rear
F59PH	Double SL	2	23 x 29	Outward	2	19 x 64 18 x 66	Front Rear
F59PHI	Single SL	2	23 x 29[2]	Inward	2	21 x 60	Side
F40PH	Single SL	2	23 x 29	Inward	2	20 x 58	Side
P32 (Genesis)	Single SL	2	22 x 18	Inward	2		Side
F10	Single SL	2	21 x 22	Inward	2		Side
RL1000	Double SL	2	35 x 27	Outward	2	19 x 70 19 x 66	Front Rear
FL9AC	Up-Down	2	16 x 18	Inward	2		Side

Notes:
[1]Double SL –Double Slider.
[2]Push out Emergency Window.

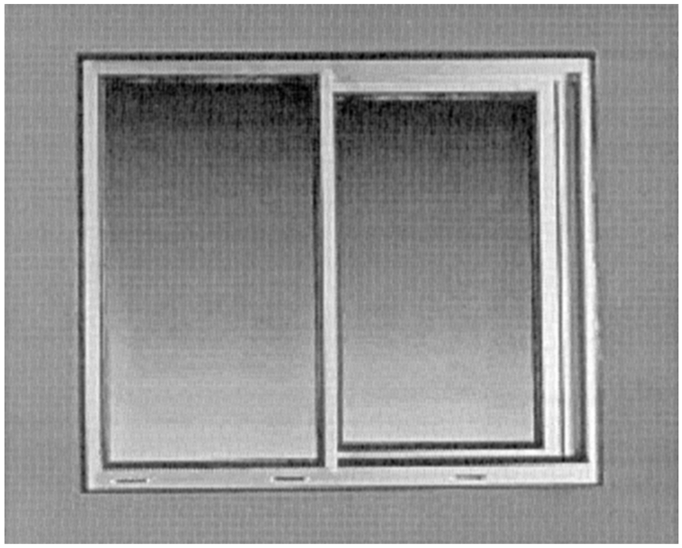


Figure 77. Locomotive cab single slider window manufactured by R.E. Jackson Co.

The current design practice for modern locomotive side windows is to use horizontally sliding windows of the type seen in Figures 68 and 77. Some installations make use of a single-window slider while others make use of a double slider. The typical operation for opening requires that a lever or handle be depressed and then the window physically slid open. Observations from our survey showed that while some windows opened with ease, other windows required a moderate amount of force in order to open them. This was sometimes an uncomfortably large effort, since tracks can collect dirt or become stiff with disuse.

Double-window sliders typically have window openings of up to about 24 inches in width, although in some older versions, the window width can be as large as 36 inches. Locomotive windshields have varying shapes and sizes as can be seen in Figures 67, 69 and 71. They are typically narrow in height with vertical dimensions of about 20 inches or less. The widths depend on specific locomotives. For example, most wide nose units have a windshield width of about 50 inches. These are almost always sealed units and in some cases they are externally barred for protection, as in Figure 67. Because of the proximity of control consoles and other cab equipment, front windshields on the engineer's side of the cab can have limited access from inside of the cab.

The material used in the locomotive windows and windshield is in compliance with FRA glazing standards, 49 CFR Part 223, Safety Glazing Standards-Locomotives, Passenger Cars and Cabooses. Note that the standard for forward-facing glazing is considerably higher than for side-facing "window" glazing. A window for railroad usage is extremely difficult to break. This makes emergency egress through a sealed window difficult or impossible to accomplish without tools or rescuers. Emergency egress through such a window must be accomplished by either opening or removing the window.

A recent trend for locomotive builders has been for them to manufacture as well as to design their own cab doors, although some window suppliers also offer doors. The physical layout of a typical locomotive cab door is shown in Figure 78. Door attachment is generally through the use of a conventional pin-type hinge and provision is made for the installation of a door opening-closing mechanism usually in the form of a door handle. Door opening latches are typically spring-loaded handles of the type shown in Figure 79. Both horizontally and vertically mounted handles and clockwise as well as counterclockwise handle rotations were observed in our limited inspections. It appears that most of the locomotive access doors we examined have their handles in the horizontal position and are operated by pushing down on the handle to open the door. There is not any standardization with regard to the orientation of the door handle and also with regard to the direction of motion of the handle. The cab doors used on locomotives almost always contain a fixed window. For freight locomotives, this is true for the forward-facing door used on narrow-nose locomotives (Figure 78), and for the rear-facing door used on both wide and narrow-nose locomotives (Figure 74). This is also true for the side-facing doors on the passenger configurations. However, on wide-nose locomotives (nearly all of which have a single cab door, in the right rear), the nose door is the only other door with access to the cab. This door never has a window, and would not be termed an "in-cab" door. The front doors on narrow-nose locomotives also contain an opening for a window.

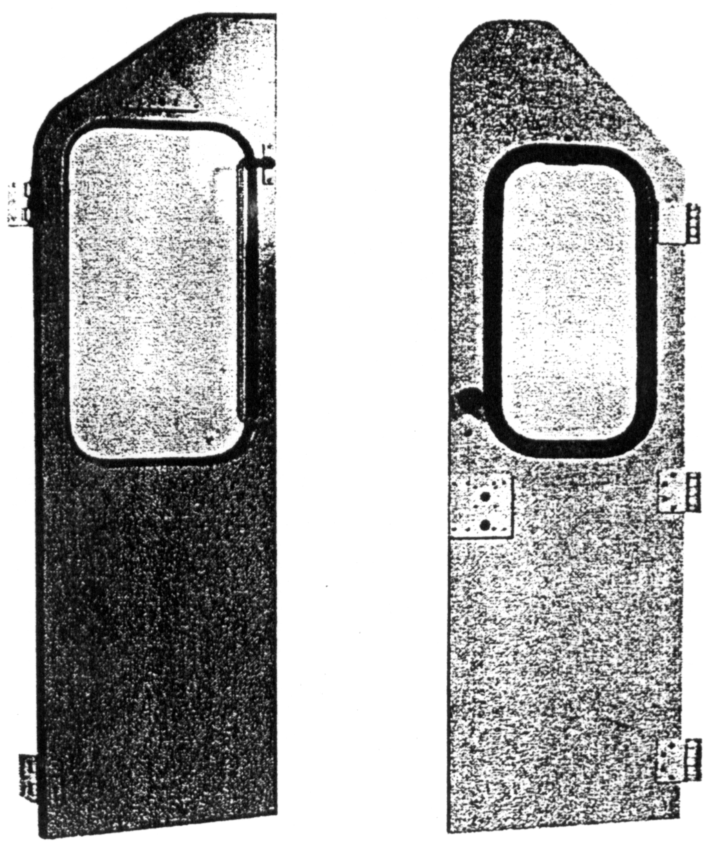


Figure 78. Locomotive cab doors typically used on narrow nose configurations

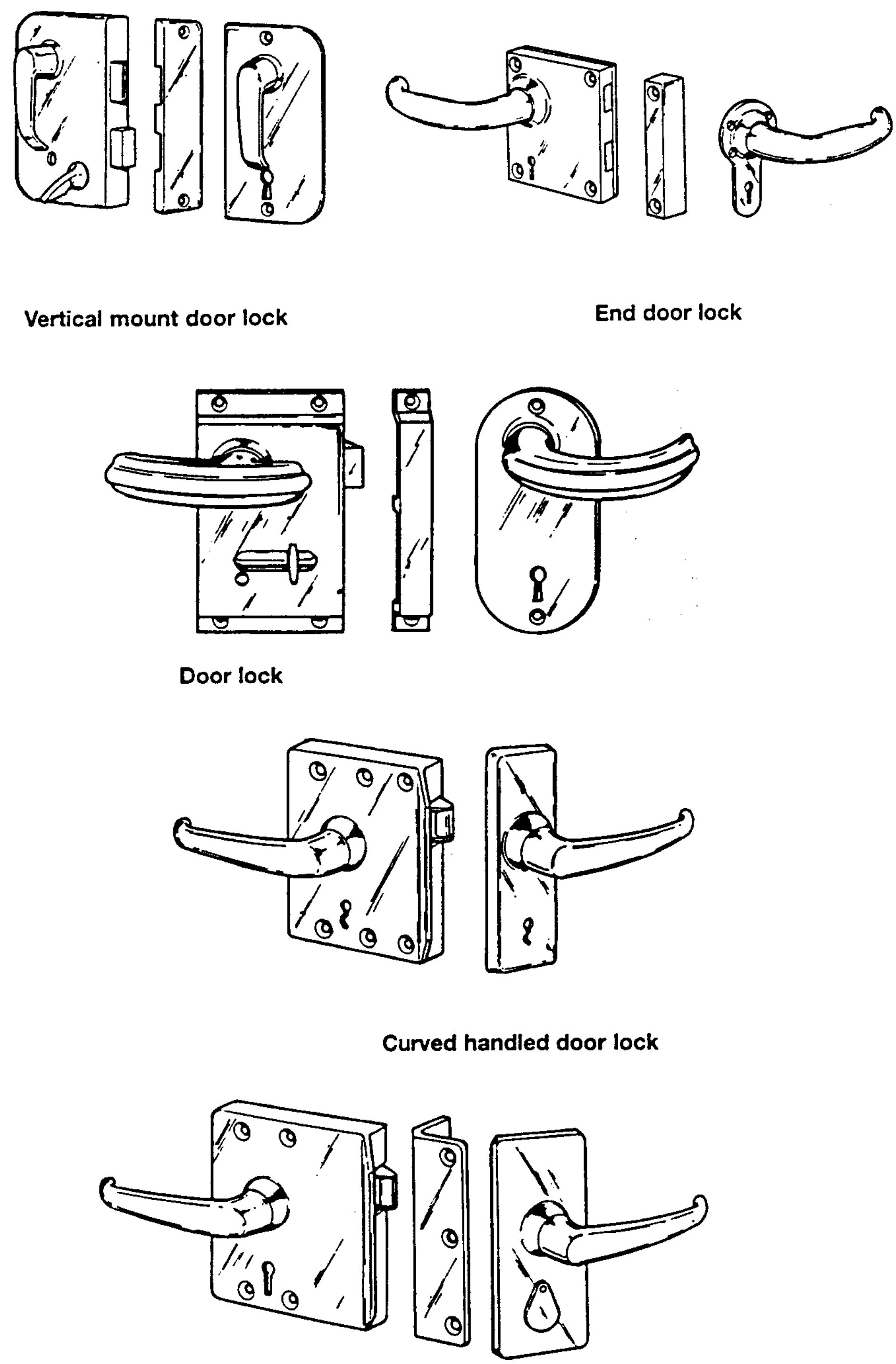


Figure 79. Typical door latching assemblies used on locomotives

The size of the door opening is determined by its location on the locomotive. For example, a narrow nose locomotive has its two doors opening onto forward and rear facing catwalk-type platforms. The opening width is restricted, with clear dimensions varying between 17 inches and 19 inches. In the wide nose locomotive, the nose-opening door does not have some of the platform width restrictions and typically has a width of about 20 to 24 inches. Modern passenger locomotives are mostly manufactured with inward-opening side doors accessed by ladder-like steps. These doors generally have opening widths of about 19 to 24 inches or more.

Use of outward-opening front and rear doors is the current practice for both narrow nose and wide nose freight locomotive cabs. For passenger locomotives, inward opening doors is the current practice, particularly those with side doors, since this avoids entering the required outside clearance envelope. In addition to outside egress, there also are doors located within the cab for access to the engine compartment or to an equipment room. These doors could be either inward or outward opening in their operation with handles in almost any orientation.

4.3 Emergency Egress Requirements and Design Approaches for Improvements to the Operation of Windows and Doors

Design features specifically aimed at improving emergency egress have not generally been designed into locomotive windows and doors. Rather, the designs have simply addressed the need for normal operation. As seen from Table 5, in almost all cases the window opening size, particularly for the double sliding configuration, does meet the emergency window opening size standard (26 x 24) recently implemented by the FRA for passenger rail car equipment. Door opening sizes are restricted by cab space availability, but their size restriction is not an impediment to emergency egress. The main issue for emergency egress that needs some attention is when normal window and door operation has become hampered as a result of cab structural damage or because of inaccessibility that would prevent their normal operation. The following are some suggested design approaches toward improving emergency egress for these situations.

The provision of window emergency egress has been made for some time in passenger rail car equipment. For example, with sealed windows, an emergency deployment arrangement using a strippable gasket has been available, as seen in Figure 80. This capability is now required by the newly issued 49 CFR Part 238, Passenger Equipment Safety Standards, Section 238.113, Emergency Window Exits. Passenger rail cars must be equipped with a minimum of four emergency exit windows. Further, the regulation requires that all cars ordered or first placed into service on or after September 8, 2000, have emergency exit windows with an unobstructed opening of 26 inches horizontally and 24 inches vertically.

Figure 80 is an example of an emergency exit window used in a passenger rail car. This window is a sealed unit. It has the design feature of being able to remove one of the gasket seals and thus remove the window in the event of an emergency. Its operation involves the use of a handle that enables the removal of the inner gasket of the window. This gasket is sometimes referred to as a “zip strip.” Upon removal of the gasket, the window can then be removed from its frame. For the case of a sealed locomotive cab window that would be of sufficient size to warrant its usage for emergency egress, the use of removable gaskets should be investigated.

Figure 80. Emergency exit window on rail passenger car

The recently manufactured F59-PHI passenger locomotive in west coast commuter operations (e.g., Amtrak trains in California, and Seattle Sound Transit) makes use of the approach of window removal for emergency egress. Figure 81 shows a plan view drawing of the side window for that locomotive. In normal operation it functions as a conventional single-open sliding window with an approximate horizontal opening of about 12 inches. Figure 82 is a side view of the window and shows the emergency egress design feature. Emergency egress instructions are provided on the panel located directly above the window and the instructions are adjacent to a window-removal pin assembly. They state: "Remove pin and pull release bar down. Push window out." Upon removal of the pin and the movement of a handle, the entire window assembly can be rotated and pushed out, thus providing an emergency egress path. The emergency opening (sliding frames removed) has a height of 24 inches and a width of 29 inches. Based on the brief examination of the windows we observed, we have determined that such an emergency egress approach should be capable of being implemented into existing equipment currently in use for any of the sliding window designs that we saw. This would of course have to be subjected to a thorough cost-benefit assessment before any firm recommendation is made.

Another design approach to improving the emergency egress through windows would include the use of the zippered gasket approach similar to that used on passenger rail cars discussed above. Not only would this enable the easy removal of a sealed window, the same approach also could be used on the sliding window as an alternative to the approach used on the F59-PHI.

Another approach to consider for assuring emergency egress would be the rapid removal of the entire window frame assembly. In our preliminary discussions with locomotive builders, contemporary locomotive fabrication practice makes use of a pre-assembled window unit. This window assembly is typically riveted to a frame on the side of the locomotive. The fabrication process usually has these rivets accessible from the interior side of the locomotive as can be seen

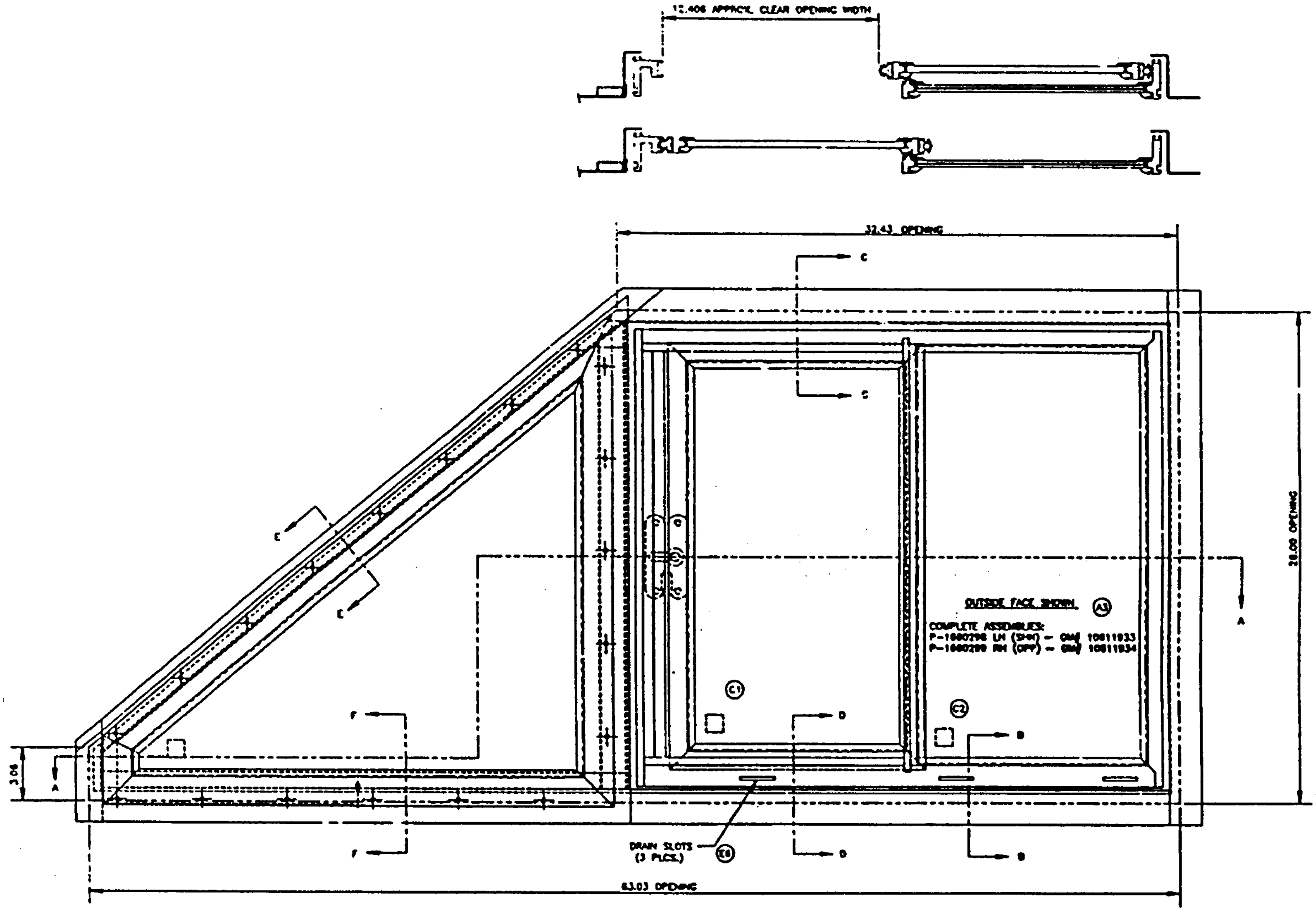


Figure 81. Mechanical details of emergency exit window

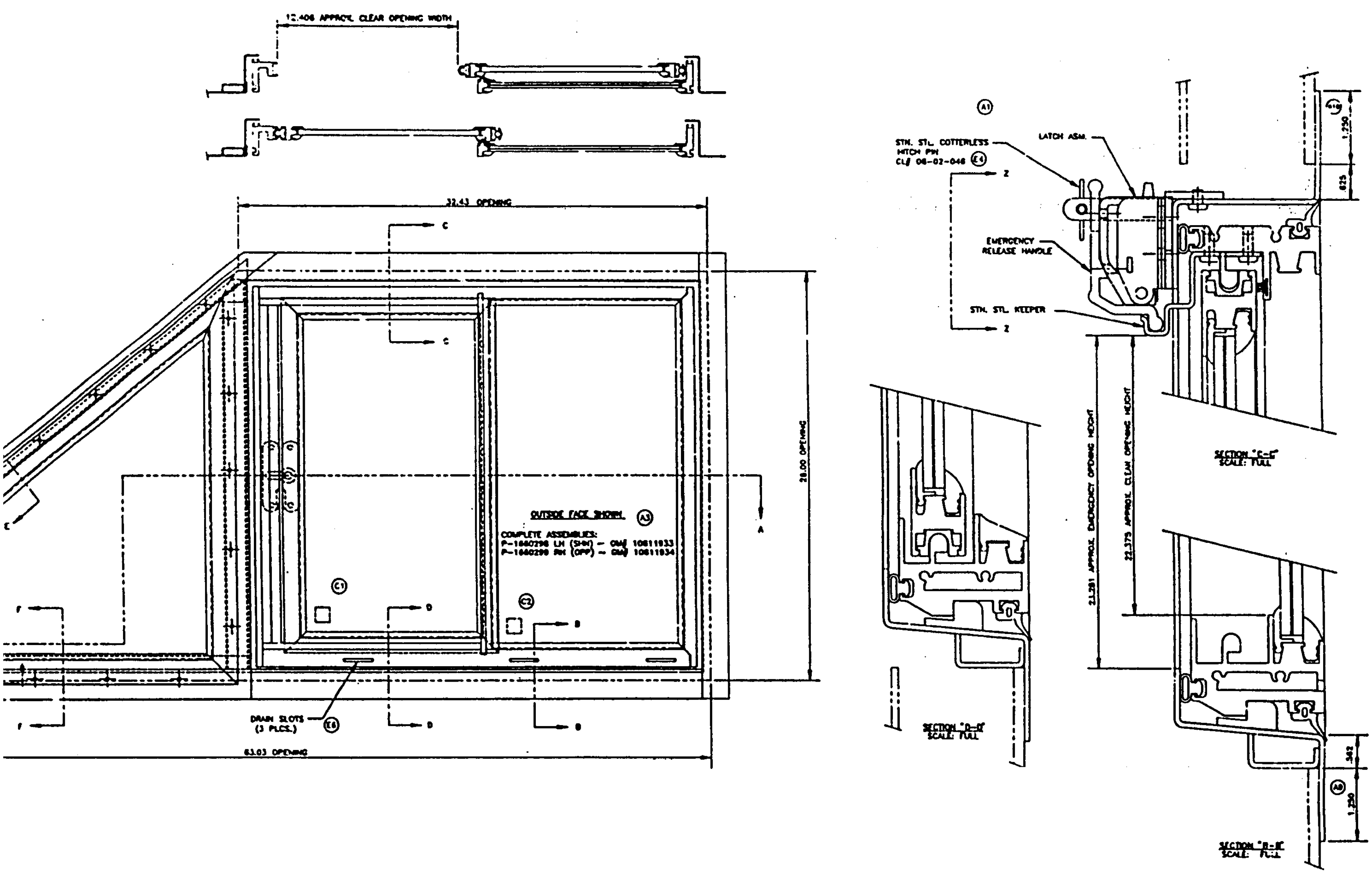


Figure 82.   Section view detail of the emergency opening

in Figure 81. A means for frame removal using a quick-disconnect fastening assembly should be investigated.

The use of pop-out or kick-out panels on doors should be considered where appropriate. The most recent version of 49 CFR Part 238, Section 439 does have the requirement for certain vestibule door configurations used in passenger rail cars to have kick-out panels. An alternative to kick-out panels on doors would be removal of the entire door. For example, a jammed door may, as a result of a collision, be capable of being physically removed if easy access to its hinges existed. Accessible and easily removal of door hinge assemblies on egress doors should therefore be considered. Having this feature available for both inside and outside access could be an aid for rescue personnel for cab entry. This capability may require some design modifications to the door locking assembly to enable the door to be readily rotated and removed.

FRA glazing strength standards make it very difficult for rescue personnel to gain access to the cab through sealed windows because they cannot be easily broken. It was reported in the FRA database that a rescue worker, with a sledgehammer, required at least 20 minutes of effort to break a locomotive side window in order to gain emergency access. Window gasket design and sealed window installation should be such that window removal can be easily accomplished in an emergency situation. The gasket and sealing materials used should be capable of being cut open and pulled off using standard tools, such as knives and pliers. One should then have the ability of being able to pry off an unsealed window. An alternative to this would be to design the window with some sort of built-in emergency access through the use of a device such as a ring permanently attached to the gasket seal. Emergency response personnel should then be trained in a procedure for removing such a window. The relative ease of being able to remove a window would then have to be demonstrated.

The primary intent of the approaches discussed here is to enable quick egress from the cab interior by its occupants. Many of these approaches also could be made to work by rescue personnel in their gaining emergency access to the cab. The approaches discussed here are summarized in Table 6.

Table 6. Selected approaches for improving window and door emergency egress

Design Approach	Comment
Windows	
Gasket Removal Around Sealed and Unsealed Windows.	Presently implemented in passenger rail car emergency exit windows.
Cab-Side Window Removal	Presently implemented on the F59-PHI locomotive.
Window Frame Assembly Removal	Alternative approach to window removal to enable larger emergency opening.
External-Side Window Removal	Outside access to cab by rescue personnel.
Doors	
Kick-Out Panels	Enable access through a jammed/damaged door.
Removable Hinge Assembly	Enable access through a jammed/damaged door.

4.4 In-Service Inspection and Verification Requirements

Emergency egress capability should require periodic testing. The need for periodic inspection and testing was recently reinforced as a result of the MARC-Amtrak train collision that occurred near Silver Spring, MD in 1996. Lack of easily accessible egress was reported to have been a factor in the loss of life for several passengers on the MARC train. NTSB post-accident investigation of emergency egress issues related to windows showed that the lubricant used on the removable gaskets on the emergency windows had age hardened. Further it had been determined that the windows had not been subject to any periodic testing and operational verification. As a result of this, NTSB in its post-accident testimony found that through its own testing, excessive force was required in order to remove the gasket on an example car. Our limited observations also showed that in a few instances an excessive force was required to open a cab sliding window (by our subjective standards), thus indicating a need for maintenance and inspection to assure proper functioning.

Awareness of this problem and the need for assuring proper operation has resulted in the newly issued FRA requirement contained in Part 238, Section 307, for periodic testing and verification of emergency window exit operation. It is recommended that inspection and test verification procedures be developed and implemented as part of any effort to improve locomotive emergency egress capability.

A cursory review of some operators' maintenance procedures for window and door operation showed that there are daily inspection requirements for cab window cleaning. There are also periodic inspections to assure the integrity of window and door weather stripping. However, with one exception, there does not appear to be any requirement for inspection and maintenance to ensure the ease of opening cab windows. The one exception found in our review did call for periodic lubrication of the window slider. As noted earlier, we found some instances of difficulty in opening slider windows. Having a requirement for the periodic inspection and lubrication of sliding windows should assure their availability for emergency egress through those windows.

4.5 Summary

In general, the side-opening windows in use in modern locomotives do have adequate dimensions to enable their use for emergency egress. However, in those installations where single slider windows are the preferred configuration, limited egress space of 16 inches or less exists through the opening space of the single window. This limited space may not be adequate for certain situations. An unintended result of the window glazing standards required by FRA regulation makes entry into the cab, by breaking a cab window, a time consuming task and, based on some of accident report data reviewed here, a sometimes formidable and nearly impossible task.

Door opening widths are restricted to the cab space available and their use has shown them to be adequate for normal operation. Emergency egress through these doors also should be adequate provided door-opening operation has not been hampered as a result of a collision. Cab doors may be of insufficient width to accommodate emergency responder access when wearing emergency equipment or personal protective equipment. However, as shown in our crashworthiness simulations, the potential for structural damage around doors is highly likely. Therefore, impeded door-opening capability should be assumed to be the normally expected result of a collision.

5. IMPROVEMENTS FOR VISIBILITY AND EGRESS/ACCESS ROUTES

Normal pathways to egress are not always available in a post-accident or post-collision scenario, therefore, alternative or emergency methods of locomotive egress are necessary for enhanced survivability and evacuation of the locomotive cab. In addition to the door and window construction and operation aspects addressed in Section 4, this section will explore various alternatives for enhancing locomotive cab egress access by crewmembers and emergency response personnel.

5.1 Markings

From the extensive review of FRA standards and other industry standards and recommended practices (e.g., APTA, buses and other motor vehicles, aircraft, ships, and buildings), there are many precedents to justify the installation of markings on locomotives to improve the identification, visibility, and accessibility of egress/access routes.

While the intent of the scope and applicability of the APTA standard was for passenger rail cars, it could be interpreted that "crew carrying equipment" has applicability to locomotives – interior and exterior.

In 1997, the National Transportation Safety Board (NTSB) made the following recommendation to the FRA (R-97-17) after investigating a passenger train accident:

Issue interim standards for the use of luminescent or retroreflective material or both to mark all interior and exterior emergency exits in all passenger rail cars as soon as possible and incorporate the interim standards into minimum car standards.

Again, while this refers to passenger rail cars only, it may be beneficial to install this type of marking, particularly for new or rebuilt equipment or when phased in over a period of time.

5.1.1 Interior Markings

To provide enhanced visibility of egress/access routes, elements of an interior marking system in a locomotive could provide:

- Readily identifiable exit path to all primary and emergency exits.
- Readily identifiable exit door markings applied to door frames or partial frame (e.g., photoluminescent, retroreflective, "barber pole" striping, etc.).

- Markings to indicate door handles, latches or other operating apparatus.

- Signage for primary exit doors clearly marked “EXIT” located on or immediately adjacent to each door.

Interior markings can help crewmembers locate and access doors, windows, door handles in the evacuation of a locomotive in the event of an emergency. These feature(s) could be beneficial in post-accident conditions if power and lighting is lost.

As an example, one of the commuter properties surveyed and visited has a locomotive windshield that can be removed in an emergency by pulling the rubber gasket off from around the window then removing the window. There are, however, *no instructions* on the exterior of the locomotive regarding this feature. Neither is it included in the written portion of the training materials given to emergency responders. If this is going to be a viable escape option, then instructions to emergency responders must reflect this, both during their training and with the introduction of signage/markings to indicate emergency window operation.

5.1.2 Exterior Markings

Marking of the outside perimeter of locomotive egress/access doors and emergency windows with retroreflective material could make for expedited identification of the means of access to locate cab crewmembers in an emergency. Additionally, step visibility could be enhanced by marking steps with retroreflective and/or luminescent markings (see Figure 83).

5.2 Windows

Federal Highway Administration regulations prohibit bus windows from being obstructed by “bars or other such means located whether inside or outside such windows such as would hinder the escape of occupants unless such bars or other such means were constructed as to provide a clear opening, at least equal to the opening provided by the window to which it is adjacent….” Unrestricted accessibility to egress paths and openings is essential for rapid and easy evacuation during an emergency.

During our research, including the site visits and equipment surveys, we noted that one of the properties had barred the locomotive windshield for extra protection from breakage due to vandalism. Because of these permanently welded bars on the windshield, egress/access through the windshield is rendered impossible unless extraordinary efforts were taken. The side windows on this locomotive (an F-40), are double-slide windows on either side of the locomotive cab, which when fully-opened measure on average 29 inches high x 23 inches wide – sufficient size for the egress of a 95th percentile male. We also noted that windshields, due to strength requirements, were not yet visualized as escape routes, although that should be future considerations.

As previously discussed in Section 4, a recent innovation observed in new equipment included the installation of an emergency window in the locomotive, an F59-PHI. This innovation

Figure 83. SD-70 MAC retroreflective step markings

provides yet another option for egress, particularly in the event that a collision has occurred and the windows/doors may be jammed because of crush damage. This emergency window had emergency markings, with instructional signage in red with white photoluminescent lettering for ease of identification and comprehension.

5.3 Training

Crew and emergency responder training improvements have been made partly due to FRA regulatory initiatives. Work has also been done in partnership with Operation Lifesaver, a national non-profit organization whose mission is to reduce/eliminate rail-related injuries and deaths at highway-rail grade crossings. One of the ways in which they have attempted to reach this goal has been to develop training programs for emergency responders. Training has also involved more coordination with federal and state emergency organizations such as the Federal Emergency Management Administration (FEMA) to promote awareness and emergency preparedness in the event of a rail accident.

While the emphasis on training of railroad operating crews is on the *prevention* of accidents, there should be some focus on what to do in the event of an impending accident. Some railroads have begun to institute training modules for "Critical Decision Making" (New Jersey Transit Rail Operations). During the review of NTSB accident data and during interviews with railroad employees involved in accidents, there was the almost universal expression that they could not believe what they were seeing, thus increasing reaction time.

A relatively new Federal Railroad regulation – 49 CFR Part 239– requires that railroads provide initial as well as periodic training for onboard crewmembers and emergency responders in commuter and intercity passenger train service territory that includes:

- Equipment familiarization.
- Situational awareness.
- Passenger evacuation.
- "Hands-on" instruction concerning the location, function and operation of onboard emergency equipment.

(See Appendix I for Insert Training Program Excerpts – Crewmember and Emergency Responder.)

These regulations are primarily applicable to railroads that operate commuter and intercity passenger train service, and include requirements for emergency preparedness coordination with other rail modes of transportation, including joint operations (239.101(a)(3)) and parallel operations (239.101(a)(4)(iii)). This regulation could also be evaluated to determine potential benefits if applied to crew rescue for freight trains as well.

The impact of this regulation could also be enhanced if railroads include schematics of locomotives in addition to passenger rail cars in their Emergency Preparedness Plans, identifying egress/access routes and markings, as discussed in Section 1. Figures 84 (a), (b), (c) and (d) depict removal of injured crewmember from locomotive by emergency responders during a recent drill.

5.4 Design Considerations

5.4.1 Doors

The F-59 locomotives have a succession of doors (leading to the exit door in the nose of the locomotive). All of these doors have raised sills of 2 to 3 inches in height. This presents a tripping hazard, particularly in low-level lighting conditions and in an emergency situation, where haste and panic may be factors in evacuation. Designing interior doors so that sills are flush or nearly flush with floor could help to prevent tripping hazards. Figures 85 and 86 show raised door sills.

Figure 84a. Emergency responders ascending ladder and locomotive ladder to begin removal of "injured" engineer from F40 passenger locomotive

Figure 84b. Injured engineer strapped to backboard being "fed" out window by one emergency responder in cab and another responder on ground

Figure 84c. Injured engineer descending ladder on backboard. Note: top of backboard secured by a rope, being lowered using the rope

Figure 84d. Injured engineer removed from ladder

Figure 85. View from locomotive cab of SD-70 MAC to nose door (door sill 3 to 4 inches high)

During several of the interviews with crewmembers as well as from information from NTSB accident reports, we noted that rapid egress from a locomotive was often hindered after an accident in which the locomotive had derailed and was leaning to one side or was on its side. Crewmembers located in the cab after such an accident reported having difficulty, particularly after sustaining injuries from the accident, climbing from a sidewall – which was now the "floor," to the opposite sidewall to the usable door or window exit – which then became the "ceiling."

Ideas to be explored include strategically placed, vertically-oriented grab-handles or flip-down steps located on the back wall of the cab that could be used to climb out a locomotive door or window in the event that a locomotive was on its side. Also, consider making grab-handles wide enough to accommodate a booted foot.

Research into what other modes of transportation have developed would be beneficial. FAA requires for aircraft that "There must be provisions to minimize the probability of jamming of the

Figure 86. Door sill height

emergency exits resulting from fuselage deformation in a minor crash landing." Also, Standard No. 217, Bus Emergency Exits, specifies that school bus rear emergency exit doors should open outward and be hinged on the right side, providing consistency in operation.

5.4.2 Steps

Another design consideration should be consistency of step width and depth. Several locomotive engineers mentioned this as an important issue which is not adequately addressed. It was definitely thought that irregular or excessive step heights are a potential hazard, and a continuing annoyance. This applies to both the conventional steps outside and inside the cab, as well as to the ladders to the wayside. This fact has long been recognized in buildings, in which residential and commercial building codes have rigorous requirements for uniformity of steps; a step-to-step height consistency of 1/8 inch to 3/16 inch is typically required. Also, depth (foot room) of steps must be uniform, particularly when exiting a locomotive down the ladder-type steps, which must be accomplished facing the locomotive and carrying gear or paperwork. The lack of visible markings on these steps as discussed earlier adds to the problem. Figures 87 and 88 show steps of a Genesis locomotive.

5.4.3 Emergency Roof Entrance

FRA regulation 49 CFR Section 238.441 requires each Tier II passenger rail car and power cab car to have a minimum of one roof emergency exit location with minimum dimensions of 18 x 24 inches with the option of having one clearly marked structural weak point in the roof having the same minimum dimensions to provide quick access for properly equipped emergency response personnel.

An APTA Recommended Practice for Passenger Equipment Roof Emergency Access recommends that at least one extra provision for emergency access to crewmembers be incorporated into locomotive crew cabs in addition to doors and side windows. This recommended practice advises that the roof access either be built-in and covered by a hatch or a designed and identified area that can be cut-away, unimpeded by wiring, cables, etc. There may prove to be a conflicting demand, as there has been a desire expressed by representatives of a

Figure 87. View of side door ladder-type steps

Figure 88. Angled view of steps

locomotive engineer's group to require all locomotive cabs to have air conditioning units installed. The most likely location for installation is the roof of the locomotive cab.

5.5 Normal and Emergency Lighting

A review of past passenger rail accidents involving passenger and train crew emergency evacuation has indicated that both passengers *and* emergency responders lacked sufficient information necessary for the expedient emergency egress and access due to the absence of clear markings and instructions. The lack of adequate signage in conjunction with lighting system failures and/or low levels of illumination during these accidents was cited as a cause of confusion and as a contributing factor to the injuries and casualties that resulted.

Improvements have been made to locomotive cab lighting such as those observed on a new SD-70 MAC, with the placement of continuously illuminated directional lighting, aimed at illuminating potential tripping hazards. Figures 89 and 90, SD-70 MAC show low location lighting and improvements to overhead cab lighting as well, Figure 91.

The APTA emergency lighting design standard for passenger equipment applies to lighting levels in the crew occupied areas of passenger locomotive cabs as well as passenger cars. This

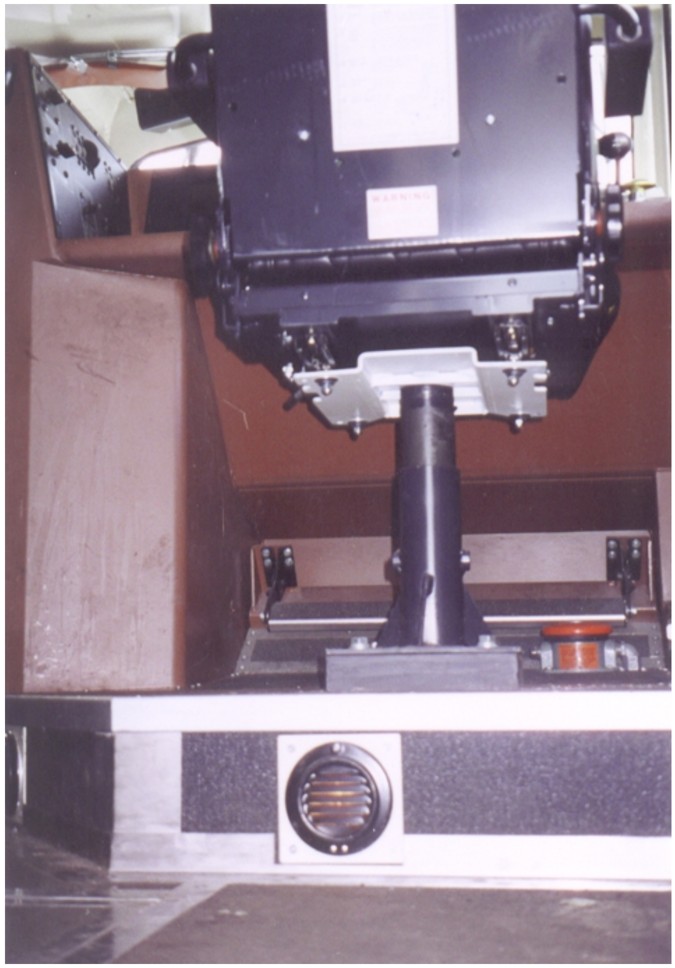


Figure 89. Low-location continuously illuminated lighting SD-70 MAC

standard, which went into effect on January 1, 2000, requires minimum emergency light levels for new/rebuilt equipment and minimum levels for existing equipment. It requires lighting be provided in passageways, stairways, entrances/exits for general orientation and obstacle avoidance. Emergency lighting must be powered with independent battery backup or some form of illumination, passive or active that will activate automatically upon loss of normal lighting.

Additionally, Part 239 requires each onboard passenger crewmember to carry a flashlight. Requiring locomotive engineers, both passenger service and freight, to carry a flashlight or have one located in cab as part of the emergency equipment in the cab, in a secure, recessed container, sufficient to provide illumination for at least 90 min should be considered. Additional equipment could include a bullhorn as an additional source of communication when radios and public address systems are inoperative.

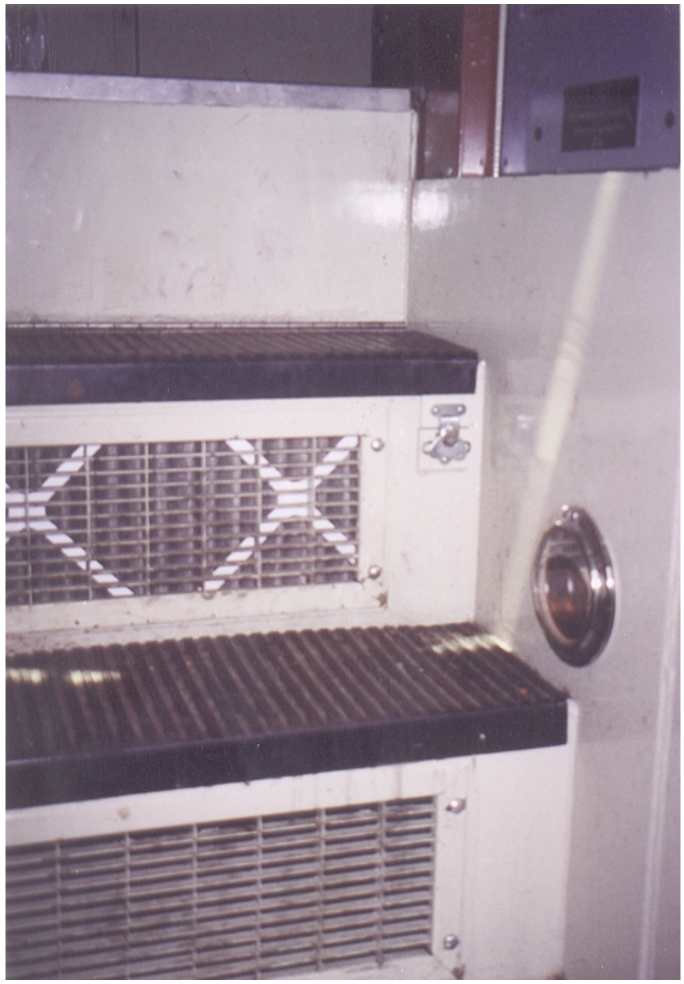


Figure 90. Directional, low-location, continuously illuminated lighting SD-70 MAC

5.6 Obstructions

FRA regulations require floors of cabs, passageways and compartments to be free from obstructions that may cause slipping or tripping hazards. On a survey returned for a P-32 - Genesis locomotive, there is a small nose hatch in the locomotive, obstructed by a refrigerator that has been placed between the engineer's seat and the seat opposite the engineer's seat. In order to access the nose hatch, the refrigerator would have to be moved, an access door slid open, and the hatch opened from the cab interior and then electrical equipment navigated to exit through the nose.

During site visits, it was sometimes observed that clutter, debris, unsecured fire extinguishers, crew accessories, etc. provided obstructions to the exit paths from the cab. Crew training (both operating and mechanical) should provide heightened awareness of the importance of keeping passageways and pathways clear of obstructions (see Figures 92 and 93).

Figure 91. Overhead cab lighting, over the seat opposite engineer's seat (SD-70 MAC) (Note double-opening window)

Figure 92. Narrow passageway to nose door of F59 is easily obstructed

Figure 93. Side doors that open in cannot be used if obstructed

5.7 Maintenance Procedures

Proper maintenance to ensure the adequate functioning of doors and windows is essential to assuring ease of egress/access routes in the event of an emergency. Locomotive Inspection, Testing and Maintenance Procedures were obtained from several commuter rail properties to assess the extent of the requirements in place to assure the proper functioning of doors and windows.

During one interview with a crewmember who had been involved in an accident where locomotive (a GP-9) egress was an issue, it was revealed that the door had been sealed with duct tape to keep out the cold air because the weather-stripping was missing.

Of the four properties whose maintenance procedures were reviewed, there are minimal tasks, which could ensure proper door and window operation. For example, one commuter rail property includes:

- 92 day Locomotive Inspection Task List to lubricate door hinges, locks and miscellaneous hardware.

- Annual inspection Task List requires that all weather-stripping be checked.

In order to be effective, consistent standards should be developed to address what constitutes "rapid and easy" opening for doors and windows. These inspection items should be periodically tested and verified.

Other considerations for Inspection and Maintenance items could be, depending on geographical area, clean all doorways, windows free of ice and snow. Additional tools could be located in the locomotive for this purpose for use by crews on-line, such as brooms and/or ice scrapers.

6. IMPROVEMENTS FOR INTERIOR SURVIVABILITY

Several aspects of survivability improvements were addressed. These are related to egress either in that cab damage, if reduced, can improve egress; or, in that injury-reduction measures can enhance survivability which is also a related goal of egress improvement.

The analytical-structural crashworthiness work using LS-DYNA, with the addition of computerized human “dummies” into selected accident cases, was used to gage the effects on the crew occupants and suggest techniques to reduce injury. This included some modeling of typical major interior features such as control stands. Interior cab decelerations in accidents were taken from the analysis described in Section 2 and used to evaluate the situation for interior mounted equipment such as fire extinguishers which could come loose in accidents.

A final area comprises suggestions for improvements in seating and crewmember restraint. Some of these measures could provide very substantial injury reduction in the “moderate” range of accidents in which cab volumes are preserved, but interior g’s are still high. The pros and cons of some of the potential improvements are discussed, which can be a guide for further work on those considered most acceptable.

6.1 Structural Improvements

Structural improvement studies, reported in Section 3, have shown that strengthening the front end of the locomotive and the door and window frames, will improve crew survivability. The front end improvements included the furnishing of S-580 collision posts in the narrow-nose freight locomotive. The cab improvements studied highlighted the need for a strengthened windshield post-to-side and top frame connection in both narrow and wide nose locomotives. Note that some of these latter improvements would be required, to a degree, in the newly implemented version of the S-580 standard. However, some of the improvements evaluated here are likely beyond those currently being considered.

6.2 Interior Survivability

To better understand the effects on a crewmember in the cab of a locomotive during a collision, a human “ATD” (anthropomorphic test dummy—a standard computerized human body) representing the engineer in the F-40 locomotive was modeled and placed in a sitting position in a cab seat. This was used in representative locomotive collisions using LS-DYNA dynamic modeling. Both the immediate environment in frontal crashes, plus the human dummy model in the cab seats were incorporated, thereby showing the “secondary” collisions of the human occupant with the cab interior structure. The scenario of the accident selected for illustration was similar to the previous hopper car consist collisions discussed in Section 3. The human dummy model (50 percentile) was generated using the GEBOD human database (3). The seat and an electrical control console was modeled inside the cab of the F-40 locomotive as an example. Figure 94 shows the model of the crewmember on the seat in the cab of the F-40. The roof of the cab is removed for clarification purposes.

The F-40 locomotive and consist, with the human dummy model inside, was analyzed in an offset/oblique collision with a standing hopper car consist at 30 mph (grazing, in that lateral offset was 80 inches). The result of the study is shown in Figure 95. Upon impact, it can be clearly seen that the unbelted human model is launched up and forward, and impacted the interior of the cab.

The human model then was flipped over the top of the console. The engineer or other crewmember (unrestrained) would be susceptible to being thrown about the interior, potentially leading to serious injury. As is usual with unrestrained occupants, the head injuries can be the most serious.

This could be mitigated with the use of restraints (discussed in a following subsection). A plot of the acceleration in g's on the head in contact with the interior is shown in Figure 96.

In this particular situation, the head impact is around 18 g's. A Head Injury Criteria (HIC) calculation was made in LS-POST (4) to calculate the HIC value based on the collision scenario. The HIC is defined in equation (1) in subsection 3.4.

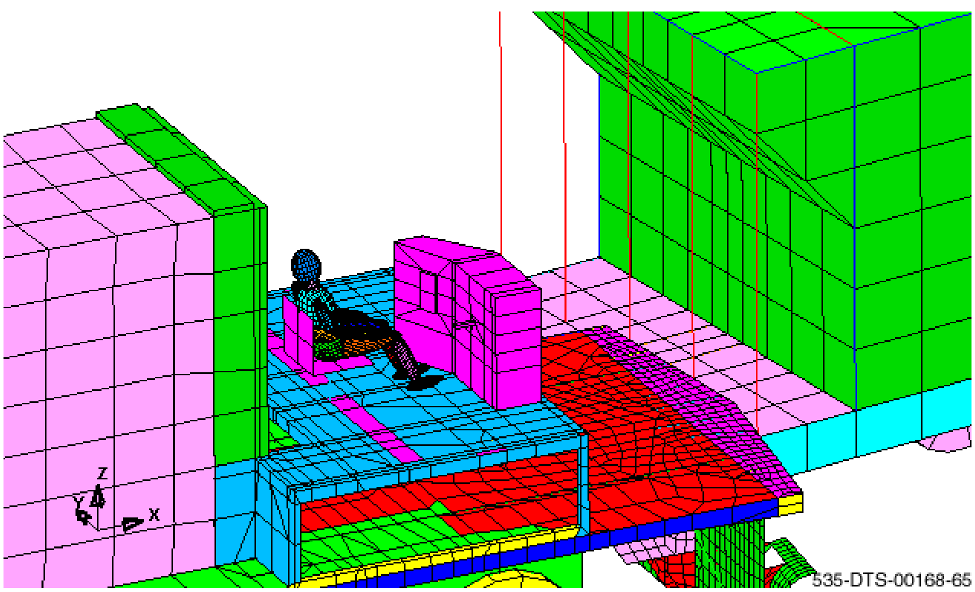


Figure 94. Inside of F-40 cab showing the occupant, seat, and control console

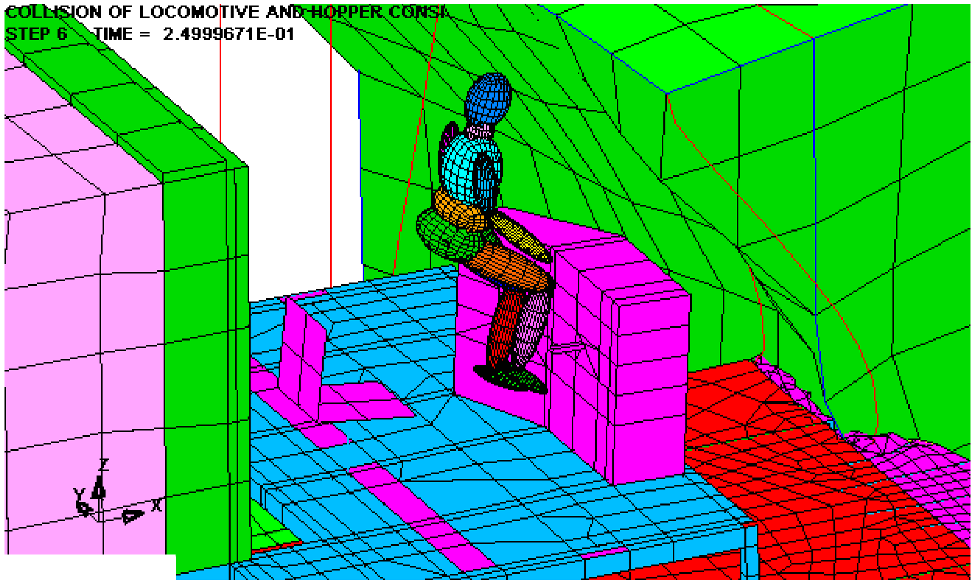


Figure 95. Inside of the F-40 cab showing the occupant colliding with the console upon impact with the hopper consist – 30 mph offset/oblique collision with hopper car

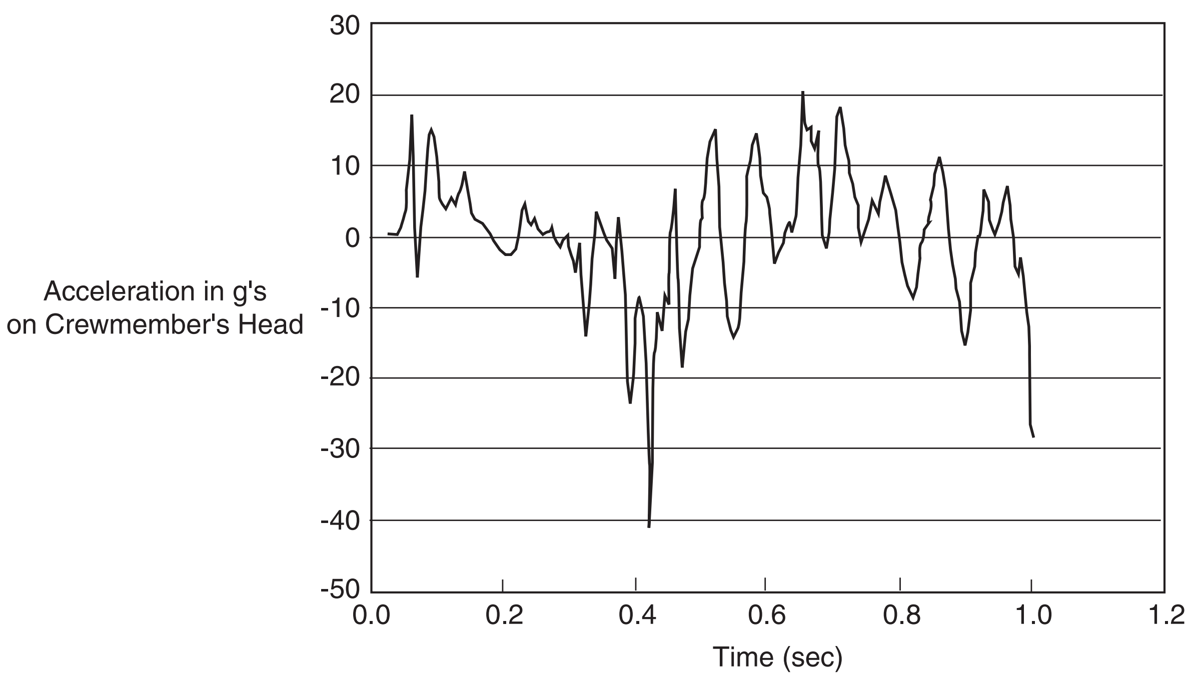


Figure 96. Head deceleration in g's with interior contact for a 50 percentile dummy inside the F-40 locomotive — 30 mph offset/oblique collision with a hopper car consist

The maximum HIC value for a human to survive is 1000, but in this case HIC is substantially greater than that being of the order of 10,000 or more. This shows the potential lethality of this situation, for unrestrained occupants inside the cab, following a severe collision.

6.2.1 Interior Survivability During Locomotive Rollover

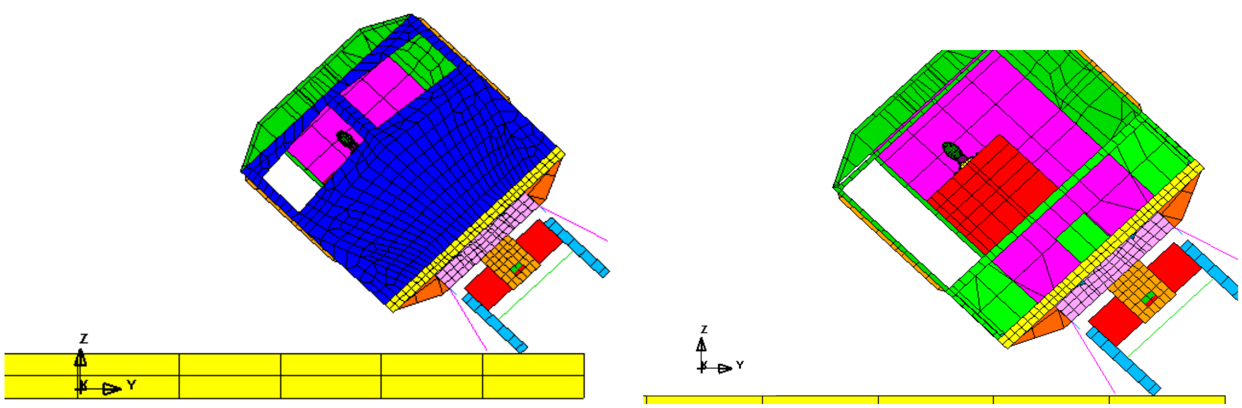
Slow speed rollovers are another accident type in which egress is compromised, and which was evaluated earlier for structural damage and door blockage. Here, a human dummy model was added into the cab of the F-40, rolling over onto "soft" ground to gage the effects of human survivability. (The same human ATD that was used in the hopper car collision was used for this simulation.) Figure 97 shows the model of the locomotive with the 50 percentile dummy in the driver's side.

The F-40 was then slowly rolled over in the same way as discussed in Section 3 onto a soft right-of-way (ROW). This showed the dummy falling to the side and colliding with the interior side panels of the cab, as shown in Figure 98. In continuation of the collision process, the dummy kept tumbling along the wall. Recall that the rollover analyses showed in-cab lateral g's in the 2 to 3 g's range.

The g-load on the occupant versus time is shown in Figure 99. The maximum acceleration is around 300 g's. This is due to the contact with metal interior structure in that particular situation. The head injury criterion (HIC) for this simulation would be well beyond the ability of a human being to survive – about a value of 1000.

6.3 Improvements for Interior Survivability

The results of our human dummy models inside the cab and the analytical predictions from the LS-DYNA analyses as described in the previous sections, has given us the the means of providing potential structural improvements inside the cab.



(a) *(b)*

Figure 97. F-40 locomotive with human dummy model (a) shown inside the cab and (b) with the nose removed for clarity

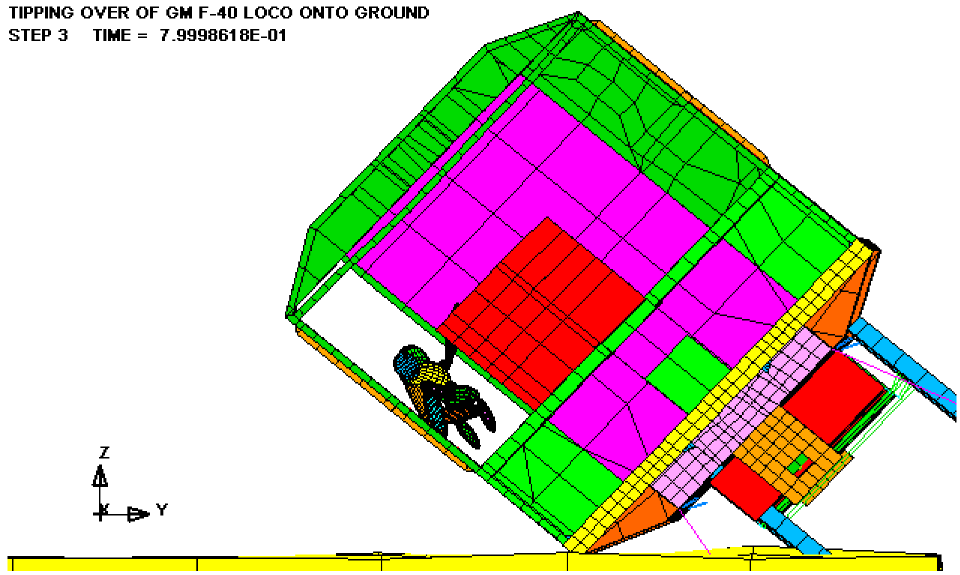


Figure 98. Inside of F-40 cab showing the human dummy colliding with inside wall upon ground impact

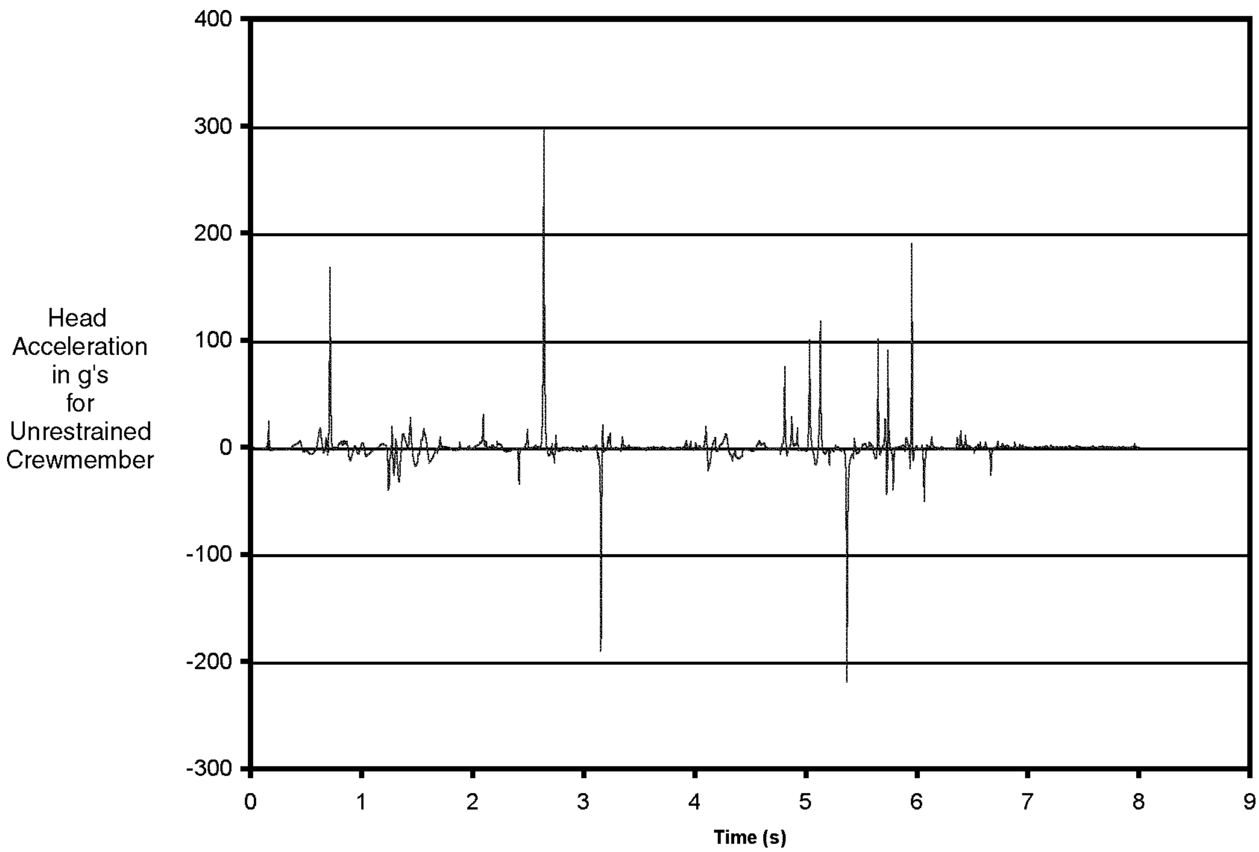


Figure 99. Head acceleration in g's with interior contact for crewmembers of the F-40 locomotive in rollover situation

6.4 Survivability Improvements for Engineer’s or Conductor’s Position

Even raking collisions with other trains at moderate speeds (30 mph) can produce g-levels (decelerations) that are high enough to produce severe injuries to unrestrained occupants inside the cab—on the order of 5 to 6 g's, and double that in a direct head-on collision. Also, collisions with highway vehicles (not the oversize or overweight extreme case) or with dislodged intermodal containers from adjacent tracks can easily produce decelerations in the 2 to 3 g's range. Peaks are lower and longer than in autos (due to mass) but can exist for a significant fraction of a second. The potential for injury to the crewmembers in the cab exists due to “secondary” collisions of those crewmembers with the interior. Naturally, many accident variables can influence the nature of these injuries. However, several approaches can be considered in improving the interior survivability and will be addressed here. Supporting this will be the large amount of information related to the many interior features found in passenger and freight locomotives. These approaches broadly include:

- Improve design of key interior features to reduce human impact injuries (so-called "de-lethalization").
- Protective seat configuration or orientation.
- Restraint of crewmembers (belts, airbags).

Note that pre-impact escape, or egress before collision, has been covered in earlier sections of this report.

6.4.1 Interior Design Improvements for Injury Reduction

Even if the locomotive cab is protected from direct intrusion by massive collision posts and underframe, reducing crew impact injuries at the engineer’s or conductor’s station is a worthwhile objective. This has been accomplished to a degree in autos and aircraft. This means reasonable efforts can be made to reduce the lethality of sharp, hard or projecting interior components such as levers, console edges, large switches, etc. The new AAR locomotive crashworthiness standard, S-580, has mentioned this as a general goal in Sec. 5.8.1: “Protruding parts, sharp edges and corners shall be rounded, radiused or padded to mitigate the consequences of an occupant impact with such surfaces.”

From the simulations in frontal collision using human dummies, it is clear that the most likely initial source of injury would be due to the occupant’s impact with a control stand or console. Two types of injury could be considered most likely: 1) the head being vulnerable (using HIC) in impacts with the console upper edges, and 2) frontal impact with projecting stick-like levers or large switches, which could puncture or penetrate the body or head. The first would be improved by addition of crushable molded padding as in an auto or aircraft glareshield or eyebrow projecting padded edge. More analysis and ergonomic design would produce the exact type and size of such padding, but both auto and air applications have been seen to use a projection of 2 to 3 inches with a padding height of 1 to 2 inches with a high-density foam construction plus integral skin. For the second type of improvement, a breakaway design for the levers should be used: see Figure 100 for the old-style control stand, and Figure 101 for the newer console or desk-type station. This would either be a literal breakaway type of lever or a load-limit-release type joint for the lever, designed to fold up at high loads not normally reached in operation. These would typically fall in the 50 to 100 pounds range, applied normal to the lever. Also, the ball-end on later console levers reduced lethality.

6.4.2 Protective Seat Configuration or Orientation

The configuration of the current modern crew seat in the cab has been seen in earlier sections of this report. These are for the engineer, a pedestal mounted unit with swiveling action. The seats do not include headrests, at least to the extent they would support the head in a crash, nor do they have restraints of any kind. Most have folding armrests. It is apparent from the approximate 5 g's levels seen in the modeled 30 mph collisions that a necessary objective would be to prevent high-speed contact of the crewmember with the cab interior to the front (in frontal collisions) or to the side (in the aftermath, or in rollovers). Barring restraints or airbags, one practical way of protecting the operator is to allow the seat to support him by being reversed in direction, and having a seat configuration capable of supporting his head, body and limbs while facing rearward during the collision. Federal regulations for the pedestal require an 8 g load capability, and this should be preserved with the 95 percentile weight crewmember in the seat (approximately 6 feet 2 inches and 205 pounds). A seat with a high, integral headrest and a limited degree of envelopment from the side ("bucket seat") would provide protection in 5 to 6 g longitudinal situations, if it could be quickly positioned by the operator through 180 deg and be facing rearward before the collision. Without belted restraints, the aftermath of collisions could dislodge the person or his limbs, but there is a tradeoff in practicality and day-to-day usability of the seat. This would be the subject of a recommended dialog between operators, manufacturers and rulemakers.

This swiveling could be permitted with a protected lever lock projecting from under the seat, which would release the seat for swiveling, plus have a spring to assist rotation, see Figure 102. Such a lever would be prominently marked and demonstrated in training. A convenient existing feature on the side wall, such as a vertical window ledge, could provide a hand-hold for assistance.

6.4.3 Restraint of Crewmembers with Belts and Airbags

This is a subject approached many times for both passenger and crewmember protection in rail accidents. Without revisiting the many pros and cons that have been presented, it is clear that none have yet been utilized for either passengers or crew because of doubts about the need for these devices and skepticism about the inconvenience that might result in day-to-day operations. These parallel to some degree the similar discussions held in the 1950's and 60's regarding their use in automobiles. However, it has been repeatedly demonstrated (in highway vehicles) that properly designed seat belts, and supporting structure, would reduce injuries in at least moderately severe accidents, i.e., those in which volume of occupied spaces was preserved, and debris was not lethal. Use of three-point restraints for rail passengers were shown to greatly

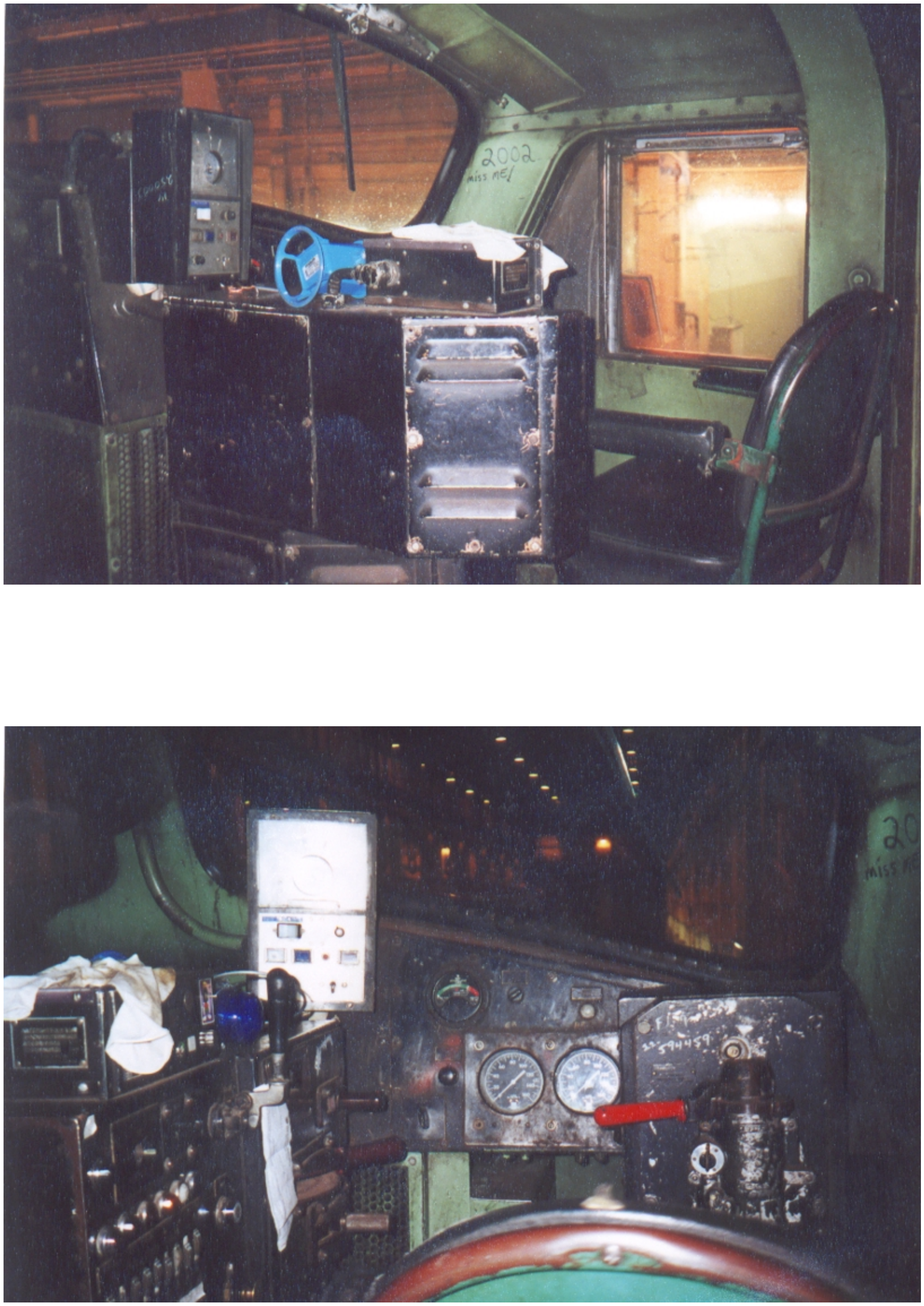


Figure 100. AAR type control stand in front of engineer

Figure 101. Desk-type station control stand

reduce injuries in an unpublished study performed by Foster-Miller by preventing the unrestrained head and body from contacting the interior to the front in a "standard" 8 g, 0.25 sec triangular "crash pulse." Neck injury was minimized through controlled failure of the seatback, to which the shoulder harness was attached. This was not perfect - neck loads were close to injury producing levels - but head injuries without the belts were lethal. Combined with a rear-swiveled seat, injury mitigation could be very significant. Engineering evaluations through simulations and design changes could be made to assess the practicality of adding standard auto-type seat belts to a strengthened seat and a pedestal of the right plastic deformation characteristic. This was successfully accomplished with the standard Amtrak seat in the referenced study.

Air bag use in a locomotive is also capable of reducing injuries without belts, as in cars. However, their use in a cab is even more controversial, due to the fear of unwanted deployments, reliability of deployment, recurrent inspection and testing, etc. Also, the great interior volume of the cab, plus the desire to move about by crewmembers, makes this approach difficult for overall protection. However, it could be considered for a particularly difficult control stand or unavoidable in-cab projection. Studies using simulations would have to be conducted to insure that some other unwanted byproduct of such an approach would not be produced, for example, deflection of the crewmember into another area of the interior. It remains a less desirable alternative than provision of a proper seat and belt combination.

Summary: Several approaches to reduce the severity of secondary (occupant) impacts with the interior can be utilized, some with demonstrated success in other modes or locations in trains. These would benefit from joint evaluation and discussion through an RSAC-like process involving government, industry and labor.

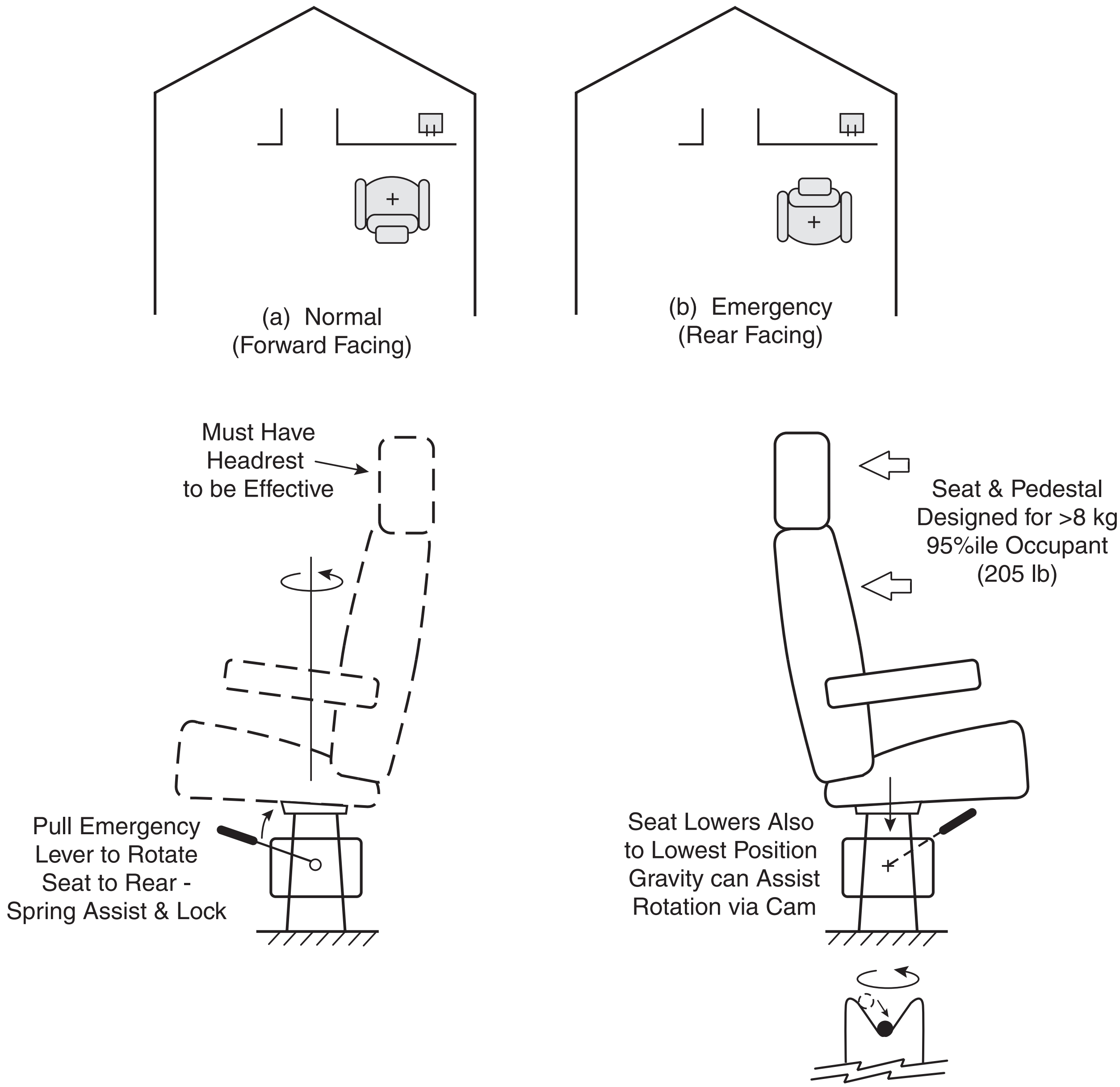


Figure 102. Rear-facing positioning of engineer seat in emergency (collision imminent)

6.5 Cab Mounted Equipment

6.5.1 Existing Cab Mounted Equipment

In addition to control consoles, safety related cab mounted equipment are typically installed in the locomotive cab. These include air circulation fans, fire extinguishers, emergency tools and other required safety-related equipment. The issue to be addressed is the potential for such equipment to become air-borne projectiles in the event of a severe collision. The following are some of our observations from the survey and site visits that we conducted.

Wide nose locomotives similar to the SD-70 MAC have a closed off foyer in the nose section. This area would appear to offer a good place for the storage of portable cab mounted equipment in that it is isolated from the occupant portion of the cab. Figure 103 is a view of the foyer as seen from the cab for the SD-70 MAC. As seen from this figure, a fire extinguisher is located adjacent to the stairway down to the nose. Its location here would appear to be based on the need for immediate access. Also shown in Figure 103 directly below the emergency brake lever is the first aid kit. A close-up view of this is shown in Figure 104, which shows the kit installed behind a flush-mounted cover on the conductor's console. The emergency tools and other components are located in the nose side of the foyer. Figure 105 shows the fusee and torpedo box, which for this locomotive is mounted on the nose interior door. Figure 106 shows the location and mounting arrangements for other emergency tools. The location appears to be ideal from the perspective of eliminating the potential for flying projectiles. Some of the collision scenarios we analyzed shows that this portion of the locomotive could experience severe damage, thus preventing access.

Figure 103. SD-70 MAC fire extinguisher located on cab side wall near the observer's station

Figure 104. ***SD-70 MAC recessed first aid kit located near the conductor's chair***

Figure 107 shows the location of some of the cab-mounted equipment for the F40-PH passenger locomotive. For the same rationale as above, the fire extinguisher is mounted on the front bulkhead near the conductor's station, while other equipment, such as the fusees and torpedoes are located in the nose compartment. Figures 108 and 109 are for the more modern P32-AC passenger locomotive. These figures show the bulkhead immediately located behind the engineer's seat. Both the first aid kit and fire extinguisher are anchored to the bulkhead with a fastening mechanism. Figure 110 shows the location for some of the emergency tools. These are located on the rear wall near the door to the engine room.

We have concluded that cab mounted equipment could become sources of potential injury to locomotive cab occupants. We found that these objects are generally fastened to cab walls and other surfaces and in some installations are typically located in close proximity to cab occupants. From our analysis, we also have concluded that cab mounted equipment will be subjected to the same g-loads previously discussed in Section 3 for the various collision scenarios we addressed.

Figure 105. SD-70 MAC fusees and torpedoes box mounted on the nose side of the vestibule door

From our work on this project we have been able to quantify the typical g-loads resulting from certain collision scenarios.

Fasteners for mounting equipment to the cab interior, unless specifically designed to withstand these g-loads, will likely fail. If the fastener fails, the equipment it holds could become a projectile causing potentially serious injury. It is recommended that the g-load ratings as given in Section 5.8, Interior Configuration, in S-580 be used for specifying the expected g-levels for the attachments of cab-mounted equipment. The proposed standard specifies a longitudinal force of 3.0g, a lateral force of 1.5g and a vertical force of 2.0g. Since the expected g-loads from the collisions analyzed in this study exceed those of S-580, it also is recommended that the availability of even higher-g load impact fastener designs from other applications and installations be investigated to determine whether they would be feasible and cost-effective for use in locomotive cabs.

Figure 106. ***SD-70 MAC emergency tools located in the nose side of the vestibule***

6.5.2 Survival Aid Equipment

One use of survival aid equipment in locomotives for emergency egress would be to enable the occupants to use such equipment in extracting themselves from the cab in the absence of normal egress capability. Another use of survival aid equipment would be to provide a temporary means of breathing in the event of a toxic atmosphere. Aids in the first category would include special tools for breaching the cab such as axes for breaking windows and punching holes, and cutting/ bracing devices for forcing an opening to the cab. Because of FRA glazing strength requirements, the use of axes may prove to be formidable in breaking through windows.

Emergency response personnel with experience in extricating people from auto wrecks have long used jaws-of-life type hydraulic equipment. Such equipment is commercially available and comes in a variety of shapes and sizes. They are available as individual cutting and bracing units

Figure 107. F40-PH3 fusees and torpedos located in nose compartment

or as combination units. An example of a combination cutting and bracing tool is shown in Figure 111. The device shown weighs about 33 pounds and is about 33 inches long. It is built specifically for automotive extraction applications. The device has both cutter and hydraulic bracing built into the same unit. It can create an opening of about 16 inches and has a spreading force capability of about 13,000 pound-force (57.8 kN). They are available in larger and heavier sizes for making openings as much as 3 feet wide. Devices of this type would have to be evaluated to determine their ability to breach the skin of a locomotive as well as their ability to be successfully used in the confined spaces of a locomotive cab.

The second category of usage of survival aid equipment is to provide temporary breathing capability. Equipment falling into this category would include such devices as emergency escape smoke hoods. Another device is the supplementary oxygen tank, sometimes referred to as a pony bottle in the underwater recreational industry. Smoke hoods are generally compact and portable units and are designed for preventing smoke inhalation. Such devices are beginning to

Figure 108. First aid kit located on right side of cab below engineer's side window

see widespread usage as a survival aid by airline industry employees. Smoke hoods are effective in filtering out toxic fumes and the capability to typically provide about 20 minutes of filtered air. An example of a commercially available device is shown in Figure 112. The device shown consists of both the hood and chemical filtration cartridge. The effectiveness of its use as a cab emergency egress aid would have to be tested.

The supplementary oxygen tank, or pony bottle, is about the size of a portable fire extinguisher. Depending upon its size and usage rate, it should be able to provide up to about 20 minutes of toxic free air. These units can be built as stand-alone cylinders or can be equipped with a body harness.

Again, all such devices would have to be evaluated to determine their suitability in the cab of a locomotive. Based on the accident statistics we reviewed, the availability of survival aid equipment of the type described here along with the other improvements to the cab interior discussed earlier should be instrumental in improving crew survivability.

Figure 109. P32-AC fire extinguisher located immediately behind engineer's seat

Figure 110. P32-AC emergency tools located on wall behind cab near door to engine room

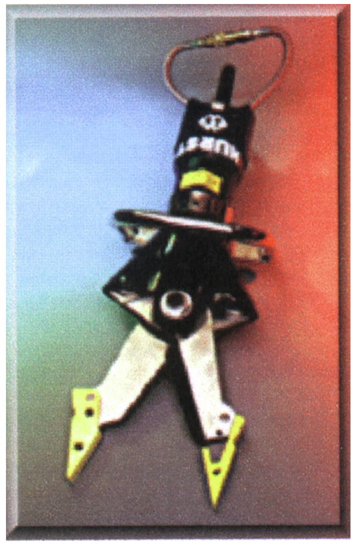


Figure 111. Cutter and hydraulic bracing unit (for automotive extraction)

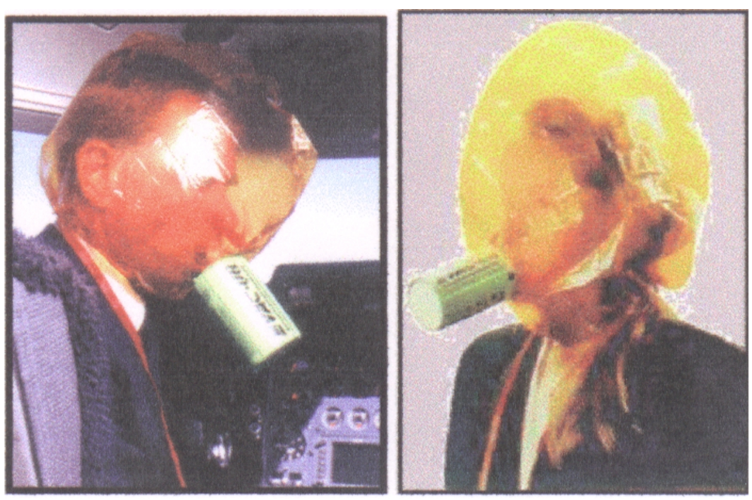


Figure 112. Commercially available smoke hood

7. CONCLUSIONS AND RECOMMENDATIONS

Rail industry standards and best practices are continually changing, due to changes in technology, tasks, and the desire to reduce deaths or injuries in the rail industry. Research-driven strides for improvements in the survivability of locomotive crewmembers have resulted in new and proposed federal and industry standards and practices, several of which have been discussed in this report. Some of those which directly impact the emergency egress/access situation include: improvements in the locomotive structure; interior design changes, including the clean cab design, increasing use of wide-cab locomotives and improved seating configurations; and, improved lighting. Related standards and practices also include requirements for emergency lighting in cars and locomotives; ergonomically designed and mounted seats for crewmembers; and, introduction of improved signage and markings, though these are still primarily used on the interior/exterior of passenger cars.

Significant further improvements are needed, and this report has developed a range of recommendations and observations after evaluating the broad field of emergency egress/access issues overall. Most important, the priority areas for further work are identified, many of which involve the design of windows and doors especially their emergency operation, surrounding structural integrity, and consistency of cab configuration. Further, the need for additional, new egress routes for some accident situations is also a subject for further work.

The discussion and recommendations summarized below for improving locomotive crew survivability are based on the results of our analysis, computer modeling and simulation, direct observations from our site visits, and interviews with rail industry personnel. Many of these suggestions may be particularly suited for consideration with regard to the design of new equipment and/or to rebuilt equipment.

7.1 Improving Crashworthiness of Locomotive and Cab Structure

Raking-type collisions can threaten the side and windshield areas of the cab, which lie outside the collision post zone. Even if these occur at moderate (30 mph) speeds, windshield and side window area damage, and some reduction in cab volume are noticeable and could pose problems in egress situations.

Independent of collision posts, the following structural improvements provide benefits in the form of reduced cab intrusion and window or door structure integrity:

- Thickness of cab side plates increased by 50 percent.

- Stiffness and strength of framing members for the windshield, front and side windows and cab corner connections increased through use of closed-section member designs rather than existing open-formed sections. The cross-sectional increases were on the order of two in bending properties.

- A 1/3 to 2/3 increase in thicknesses of the front, side and top skin plates of the short hood (primarily wide-nose locomotives). These helped delay cab contacts in the offset collisions. Roof strengthening would also be needed for the cases in which loose containers or objects were struck high on the hood, pitching down onto the roof.

Although these structural improvements slightly reduced the in-cab g decelerations in the example collisions analyzed, the main benefit was the reduction in cab intrusions and preservation of in-cab volume. The skin thicknesses for the cab itself would remain unchanged to permit cutting tool rescue access; however, the existing frame members in the windshield and roof would be strengthened.

These structural improvements only serve to represent the type and general nature of the improvements that were studied here. It is recommended that further work with the locomotive manufacturers and FRA now be done, using these studies as a framework, so that the practical and cost issues for various detail designs can also be considered. As part of this work, locomotive cab window frames themselves also can be designed with stronger cross sectional members (to be determined), in which they can materially reinforce the cab wall frame. This would help preserve the egress function of the windows which are critical escape routes in the event of door damage. Both side (passenger locomotive) and rear (freight) doors were shown to be damaged in the sample collisions, potentially causing a jam.

Since window and door escape routes can be compromised structurally in some collision situations, the provision of egress capability through the roof of the cab should be seriously considered again. This was one of the key recommendations made in the FRA 1996 congressional report on locomotive crashworthiness and cab working conditions. It also addresses the egress problems in the overturning situations, which was shown in this study to be capable of causing injuries and emphasizes the need for an easier egress route.

7.2 Improvements to Door and Window Emergency Operation

Some side-opening windows in use in modern locomotives do have adequate dimensions to enable their potential use for emergency egress. These are typically double-slider, “layer opening” design. However, the single slider windows, and all windows with limited egress space of 16 inches or less in either height or width do not provide adequate dimensions for certain situations or crews.

Door opening widths are restricted for rear- or front-facing cab doors which can have clear openings in the 16 to 17 inch range. These doors are narrow reflecting the outside walkways provided on the locomotive. Emergency egress through these doors can be difficult for larger crew members, such as a 95th percentile male weighing over 200 pounds. Heavy clothing worsens the problem. The opening may also be of insufficient width to accommodate rescuers wearing emergency or protective equipment.

We recommend the following approaches to window and door operation be evaluated by the FRA as a means of improving emergency egress/access capability:

- Several options for improving the emergency egress capability of cab windows should be examined. These include removable side window glazing, removable window frame assemblies, and removable internal gasket seals of the type seen in rail passenger equipment. Removable side window glazing has already been adopted for some high-speed passenger and commuter locomotives.

- Emergency cab egress capability could be greatly improved by providing for large kick-out or detachable side wall panels which contain the normal side windows or doors, and the feasibility of these should be investigated.

- Where possible, all new locomotive designs should incorporate cab windows having an emergency exit mode of operation.

- The use of easily accessible and removable door hinge assemblies should be evaluated. This would facilitate emergency removal of the entire door, even in some cases of frame distortion.

- Periodic inspection, maintenance and verification of operation for both normal and emergency egress capabilities is recommended to demonstrate emergency usage readiness. Where necessary, weather and geographical-specific maintenance procedures may be required.

To improve cab access by emergency responders we recommend that:

- The design of external gaskets and window installation enable ease of entry by being able to easily remove the gasket/window without the use of any special tools. One approach to consider is a handle-type device similar to that used on passenger car emergency exit windows.

- Emergency response personnel should be trained in the appropriate procedure for quick window removal.

7.3 Improvements for Interior Crash Survivability

Collisions with other trains can produce g-levels high enough to cause severe injuries to unrestrained occupants, though the degree and nature of these are highly dependent on many factors such as: initial position and size of the occupants; the specific interior equipment design features; and the type of collision encountered. Even collisions at moderate speeds (30 mph) with substantial lateral offset of the consists were found to produce overall in-cab decelerations of up to 4 to 5 g's, with much higher levels possible in direct frontal collisions. Also, with slow rollover collisions, the 2 to 3 lateral g-level was reached in cabs, with double that possible on hard surfaces. Current locomotive cabs contain numerous locations where sharp, hard and projecting components exist, all of which can be likely sources of injury under these conditions.

Some strategies for improvement that we recommend be evaluated for feasibility by the FRA include:

- Compliance with the more stringent requirements specified for Tier II equipment in Section 238 with regard to interior fittings, including eliminating sharp edges and adding shock-absorbent padding.

- Provision of strengthened crew seats incorporating lap and shoulder belt restraints. The use of belted restraints should be promoted via a dialogue between operators (both labor and management representatives), manufacturers and rulemakers.

- Incorporation into cab seats a rotating, locking arrangement that would permit rotating the seat 180 degrees to face aft in imminent collision situations. A supporting headrest and lock-down capability would need to be provided.

- Evaluate the many design changes implemented in the auto and airline industries for potential application to the locomotive cab environment to reduce the lethality of cab mounted equipment and other projecting components and surfaces.

- Cab mounted equipment fasteners and brackets should be designed to withstand higher expected g-loads than currently contained in the proposed S-580 Standard. A minimum of 5 to 6 g's longitudinal loading should be considered as a standard for mounting requirements.

- Evaluate the potential usage of emergency cutting and bracing tools for occupant extraction, particularly as they would have to apply to the confined spaces of a locomotive cab.

7.4 Improvements for Visibility and Access to Egress Routes

We recommend that the following items be considered:

- Freight railroads should comply with the requirements of Part 239 - Emergency Preparedness Plan. All railroads should consider developing and adding a training/instructional element for Critical Decision-Making to instruct crews in critical thinking skills regarding emergency response for enhanced survivability.

- Freight railroads also should comply with Part 239 - liaison with emergency responders; all railroads should include the addition of locomotive schematics in materials published and distributed for training purposes. Also all railroads should consider adding to emergency response drills, the scenario of removing someone from a locomotive or alternately obtaining a film demonstrating this exercise.

- Photoluminescent or retroreflective material or both should be used as a means to mark all interior and exterior emergency exits on locomotives, including step edges.

- Signage should be provided for the instructions for locating and operating these exits (e.g., mark door handles, emergency window instructions and handles).

7.5 Cab Design and Layout Considerations for Improvement to Egress/Access

We recommend that the following items be considered:

- Standardize the approximate location of all emergency tools and safety related equipment in the cab.

- Consider the inclusion of an emergency egress ladder (chain or rope type) to enable access to doors and windows.

- When possible, standardize door operation throughout a particular locomotive (e.g., same size/type door handles, with all operating by pushing downward, then pushing door outward to open).

- Standardize the height of step risers on locomotives, for conventional steps (those outside cab doors and interior passages), and for outside ladders down to the wayside. This is particularly important for ladder-type side-entry steps which must be descended "backwards" and often-times while carrying gear, tools, paperwork and other items. This need for such uniformity has long been recognized in building codes as necessary for safety and comfort. Excessive step heights should be avoided, and the subject needs further detailed review (somewhat larger values typically permissible on ladders relative to steps). High traction for outside ladders and steps must also be assured, especially in coping with poor weather conditions.

- Where possible, locomotive cab side windows should be of sufficient dimensions to accommodate a fully clothed 95th percentile male during egress, that is, having a minimum of 24 inches.

- Window operation should be "rapid and easy," optimally operated using one hand.

- Consider the benefits of adding an emergency roof hatch or provide for a structurally accessible cab entry point ("cut here") from the roof. This may be the only reasonably accessible egress route in a rollover situation, and was recommended in the 1996 FRA Report to Congress.

7.5.1 In-Cab Lighting

We recommend that the following items be considered:

- Locomotive cabs should be equipped with emergency lighting with independent battery backup.

- Low-location directional lighting should be installed on new locomotives (e.g., steps, doorways, seat pedestal, other potential tripping areas).

- The APTA Standard for Emergency Lighting Systems Design should be adapted to freight as well as passenger locomotives for minimum locomotive cab emergency light placement and levels of illumination.

8. REFERENCES

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2. Locomotive Crashworthiness and Cab Working Conditions, FRA Office of Safety, Report to Congress, September 1996.
3. Rail Vehicle Crashworthiness Symposium, June 24-26, 1996, Volpe National Transportation Systems Center, Cambridge, MA, DOT/FRA/ORD-97/08, March 1998, Final Report.
4. Human Factors Guidelines for Locomotive Cabs, Volpe National Transportation Systems Center, November 1998.
5. 49 CFR Part 223 – Safety Glazing Standards – Locomotives, Passenger Cars and Cabooses.
6. 49 CFR Part 229 – Railroad Locomotive Safety Standards.
7. 49 CFR Part 231 – Railroad Safety Appliance Standards.
8. 49 CFR Part 238 – Passenger Equipment Safety Standards.
9. 49 CFR Part 239 – Passenger Train Emergency Preparedness.
10. 49 CFR Part 393.92 – Buses, marking emergency doors.
11. 49 CFR Part 517—Federal Motor Vehicle Safety Standards, Section 517.217 Standard No. 217; Bus emergency exits and window retention and release, revised October 1, 1999.
12. FAA Title 14 CFR Section 25.807 - .812, Emergency Exits.
13. APTA SS-PS-002-99, Standard for Emergency Signage for Passenger Car Egress/Access.
14. APTA SS-E-013-99, Standard for Emergency Lighting System Design for Passenger Cars.
15. APTA SS-PS-003-99, Standard for Emergency Evacuation Units.
16. APTA SS-PS-004-99, Standard for Low-Location Exit Path Marking Systems.
17. APTA RP-C&S-001-99, Recommended Practice for Passenger Equipment Roof Access.
18. APTA SS-C&S-011-98, Standard for Cab Crew Seating Design and Performance.
19. APTA SS-C&S-014-99, Standard for Collision Post Structural Strength for Railroad Passenger Equipment.
20. APTA SS-C&S-013-99, Standard for Corner Posts Structural Strength for Railroad Passenger Equipment.
21. Aircraft Evacuation Testing: Research and Technology Issues, background paper, Office of Technology Assessment, U.S. Congress.
22. Draft International Standard for low-location lighting on passenger ships, ISO/DIS 15370, October 23, 1998.

APPENDIX A

LOCOMOTIVE EQUIPMENT SURVEY

Property: ______________________________________ **Locomotive Number** ________________

Locomotive Builder: _______________ **Model #**________________ **Year Built:** _____________

Rebuild/overhaul by: ______________________ **Date:** __________________________________

CAB LAYOUT			
Seats in cab – describe type (e.g. swivel, with headrest, etc.)			
Seating Layout			
Cab Dimensions			
DOORS			
List all entry doors	Side Nose Doors leading to walkways Door to engine room Other		
List width & height of all doors	Side Nose Doors leading to walkways Door to engine room Other	W W W W W	H H H H H
How do doors open (e.g., inward hinge)	Side Nose Doors leading to walkways Door to engine room Other		
Describe mechanism for opening doors; describe door locking method	Side Nose Doors leading to walkways Door to engine room Other		

WINDOWS	
Where are windows located? Name of manufacturer?	
How do they open?	
Window dimensions, width, height	W: H:
Any emergency windows?	
LIGHTING	
Where is lighting located in the cab	
What type of lighting? How is it activated?	
How is normal lighting powered?	
Emergency back-up power?	
Safety Features	
What types of emergency tools in the cab and in what location?	
Any type of markings, decals, emergency instruction in cab? Type (reflective, photoluminescent)	
Any type of markings, decals, emergency instructions on the **outside** of the locomotive? Type (reflective, photoluminescent)	
Any other cab safety features (e.g., "clean cab" design, roof hatch, etc.)	

STEPS/LADDERS	
How may rungs/steps to enter cab	
Rung/step width and depth	
Spacing between rungs/steps	
Describe surface of rung/step	
Handholds	
Where are handholds located outside the cab? Describe (e.g., recessed, etc.) Location(s) inside the cab?	
RADIO/PA	
Can radio/PA operate from emergency power?	
What is the redundant method of communication?	

Use back of sheet for any other comments

APPENDIX B

EMPLOYEE AND EMERGENCY RESPONDER TRAINING

TRAINING QUESTIONNAIRE

1. Do any of your training plans/programs (e.g., Emergency Preparedness Plan) have an element covering the egress/access of locomotive in accident scenarios for:
   - Crewmembers.
   - Emergency responders.

2. If yes, do you include (as a handout distributed to participants) a schematic of locomotives, identifying windows, doors, location of emergency tools, etc.?

3. Is there a written portion of the instruction program re: locomotive access/egress? Are questions regarding locomotive egress/access included on the final test? If yes, please attach copies of relevant questions and training outline.

4. Is there a practical, hands-on drill involving locomotive egress/access?

5. Do mock disaster drills include removing an injured person from the locomotive cab?

6. Does engineer and train crew training include familiarization with locomotive egress/ access routes, methods?

7. For crewmembers, is there a training segment that covers what to do in the event of an emergency to maximize their own survivability — a discussion of "lessons learned"?

   Any other relevant training given to engineers or emergency responders?

APPENDIX C

TRAINING PROGRAM SUMMARY

Training Questionnaire Matrix

Railroad/ Agency	Do any training programs cover emergency egress/access of locomotives	If yes, any examples of printed materials regarding locomotive characteristics	Any written instruction examples regarding locomotive egress or access	Hands-on or practical drill involving locomotive egress or access	Do emergency response drills include demonstrating rescue from locomotive	Does engineer and conductor training include familiarization with locomotive egress routes and methods	Are crews given any training in what to do in event of emergency to maximize their survivability
New Jersey Transit – commuter rail	Yes, for both emergency responders and crewmembers	Yes, schematics distributed, including equipment maintenance manuals	Yes, Emergency Response Guidelines – though no test for emergency responders, crews only	Yes	Yes	Yes, all transportation personnel trained as required by 49 CFR Part 239	No, no specific segment detailing "survivability"- focus is on preventing accidents
Altamont Commuter Express	Yes, for both emergency responders and crewmembers	Yes, for T&E crews, not for responders yet	No, though for crews there are questions on emergency equipment, including fire extinguishers, fusees, fuel cut-off and engine shut-down switches	No	No	Yes, during initial T&E training	Yes, informally. Overall advice is NOT to jump from a locomotive – that is a last resort in a desperate situation
Burlington Northern Santa Fe	Yes, for both emergency responders and crewmembers	No	No, though for crews there are questions on emergency equipment, including fire extinguishers, fusees, fuel cut-off and engine shut-down switches	Fire/police shown how to exit/access locomotive via regular doors, nose doors, engine room, etc.	No, not usually	Yes, with peer instructor	Not formal part of training, though peer instructors pass on stories

Railroad/ Agency	Do any training programs cover emergency egress/access of locomotives	If yes, any examples of printed materials regarding locomotive characteristics	Any written instruction examples regarding locomotive egress or access	Hands-on or practical drill involving locomotive egress or access	Do emergency response drills include demonstrating rescue from locomotive	Does engineer and conductor training include familiarization with locomotive egress routes and methods	Are crews given any training in what to do in event of emergency to maximize their survivability
Guilford Transportation Industries	Yes, for both emergency responders and crewmembers	No – rail tank cars only (for hazmat training)	No	No	No	Yes	No, nothing specifically focusing on this but trained expressed the opinion that it would be a good idea
P&W	Yes, for both emergency responders and crewmembers	No, schematics of tank cars	Not really – crews trained in emergency engine shut-down procedures	No	Yes, have done emergency responder training both on site and off using the Stokes basket simulating removal of injured crewmember from locomotive	Yes, including getting on and off equipment safely	Not really –
GO Transit	Yes, for both emergency responders and crewmembers	Printed material as well as videotaped	No	Yes, when feasible	Not usually	Yes	Nothing specific

Railroad/ Agency	**Do any training programs cover emergency egress/access of locomotives**	**If yes, any examples of printed materials regarding locomotive characteristics**	**Any written instruction examples regarding locomotive egress or access**	**Hands-on or practical drill involving locomotive egress or access**	**Do emergency response drills include demonstrating rescue from locomotive**	**Does engineer and conductor training include familiarization with locomotive egress routes and methods**	**Are crews given any training in what to do in event of emergency to maximize their survivability**
Metro North	Yes, for both emergency responders and crewmembers	No	Not for responders; questions for crews include emergency equipment	Responders shown how to enter/exit locomotives through all viable means, whenever possible, through hands-on training. Otherwise, there is a video shown. Engineer training also includes heavy emphasis on equipment familiarization	No, all drills are staged with MU equipment (passenger cars)	Yes	No, though likely stories shared by other engineers. Have pondered this topic and felt that there is no way to teach "best practices" since there are so many variables in an accident scenario. During training, however, engineers are given training in the principles of critical decision-making
Long Island Rail Road	Yes, for both emergency responders and crewmembers	Yes	Yes	Yes	Yes – at the Nassau Fire Academy	Yes	Situational awareness, how to use emergency equipment

Railroad/ Agency	Do any training programs cover emergency egress/access of locomotives	If yes, any examples of printed materials regarding locomotive characteristics	Any written instruction examples regarding locomotive egress or access	Hands-on or practical drill involving locomotive egress or access	Do emergency response drills include demonstrating rescue from locomotive	Does engineer and conductor training include familiarization with locomotive egress routes and methods	Are crews given any training in what to do in event of emergency to maximize their survivability
Amtrak	Yes, for both emergency responders and crewmembers	Yes, booklet distributed to emergency responders detailing locomotive features; in the process of being revised	Not for responders; questions for crews include emergency equipment, emergency shut-offs, etc.	Yes, crews trained and tested in equipment familiarization; responders taken into locomotives whenever possible to inspect cab layout	Not too often; just had one in Attleboro on 9/17/00	Yes, per 239 requirements	Yes, though not a part of formal training – it is usually passed on anecdotally when qualifying with certified locomotive engineers
UP/SP	Yes, for both emergency responders and crewmembers	Yes, locomotive maintenance manuals	Yes	Yes	Yes (see video)	Yes	No
Sound Transit (Seattle)	Yes, both	Yes	No, verbal only	Yes	Yes, drill involved removal from locomotive	Yes	Yes – though engineer's are told to remain in the locomotive as long as possible as they are the primary radio link

APPENDIX D

TRAINING VIDEO SCENARIOS - LOCOMOTIVE EGRESS

Emergency Responder Training Video

Operation Lifesaver with Union Pacific Railroad
Engine 9140

Scenario 1

Engine 9140 not on level ground; ground falls away several feet from the ballast.

Several responders are shown entering the locomotive through the engineer's side rear door with a backboard and strapped the injured engineer to a backboard. The victim was turned sideways by 3 or 4 responders and taken out sideways through the rear engineer's side door onto the walkway, down two steps. He was placed on the walkway, still sideways – leaning against the handrails - while 4 other responders leaned 2 ladders against the engine; 2 held the ladders while 2 climbed the ladders simultaneously. 3 responders from the walkway eased the victim horizontally from the walkway to the responders on the ladders. A person also assisted the responders on the ladders on the ground who reached up to steady the backboard.

Scenario 2

Two (2) ladders were leaned against the locomotive, leading up to the walkway, with an emergency responder positioned on each ladder. The victim is brought out of the cab on the backboard, carried sideways by several responders. The victim is then lowered down the ladders on the backboard, vertically (feet first), with the head of the backboard secured by a rope. A responder stood on the walkway and fed the rope down as responders lowered him down the ladders.

Scenario 3

CNW 6564

Responders back a truck up to the engineer's side window with a ladder propped against the window like a ramp to the top of the truck. The victim was lowered from the window on the backboard, at an extremely sharp angle, secured at the top by a rope. He was then taken from the top of the truck to the ground by 2 responders, while still on the backboard, down another ladder used as a ramp.

Scenario 4

CNW 6564

In this scenario, three ladders were placed against the locomotive up to the engineer's side window. The victim was lowered out the window on backboard, feet first – at a precariously steep angle – nearly parallel to the locomotive. Responders were located on either side of the victim, one at the foot, one at the top. The backboard was secured by a rope at the top, used as a pulley, draped over top of ladder and let out by another responder on the ground to lower the victim slowly to the ground.

APPENDIX E

FRA/NTSB ACCIDENT SUMMARIES

Accident Scenario #1

Collision and Derailment of Union Pacific Railroad Freight Trains 5981 North and 9186 South in Devine, Texas June 22, 1997

Summary:

Head-on collision, two locomotive units and 14 cars derailed from train 9186 South; both locomotives and 2 cars were destroyed. Three locomotives and six cars were derailed from Train 5981 North; one locomotive and five cars were destroyed.

The lead locomotive unit UP5981 exhibited massive catastrophic structural damage; the short-hood structure, cab assembly, and electrical cabinet were effectively sheared off horizontally at the top of the frame assembly deck plate surface. The diesel engine was displaced aft about 8 feet, and the main generator had separated from the engine. The frame of the locomotive had bowed downward, displaying a bend estimated at one (1) foot. The remaining car body sheet metal was heavily deformed, and the fire had consumed the entire unit.

The operating cab of the lead locomotive of train 5981 North had separated from the unit, was found crushed beneath the pile of wreckage debris, and was fully consumed by the fire. The engineer successfully jumped from the unit several hundred feet before impact. The body of the conductor was found adjacent to the track beneath wreckage debris. Given the injuries sustained, massive crush, and severe burn trauma, his death resulted from being crushed near the point-of-impact (POI) beneath wreckage debris, which was further engulfed in the fire. Based on the available evidence, the conductor may not have jumped before impact but may have been on or near the left front corner of the locomotive at the time of impact.

The operating cab of the lead locomotive of train 9186 South was not significantly crushed on impact, but the unit derailed and was then fully consumed by the massive fire.

Type of Locomotives:

Train 5981 North: EMD SD60, SD-40-2, and SD50M, and 83 loaded and 11 empty freight cars.
Train 9186 South—GE C-40-8 (Dash 8), and EMD SD60-M and 62 loaded freight cars.

Deaths:

Conductor from 5981 North
Engineer from 9186 South
2 Unidentified Individuals

Egress Issues:

Based upon the estimated speeds of the locomotives at impact (give speeds of trains) the loss of survival space in the locomotives, and the severity of the massive fire, the NTSB concluded that the collision in Devine was not survivable for crewmembers or for anyone occupying the locomotive equipment at the time of the impact.

Accident Scenario #2

Head-on Collision of Burlington Northern Trains 602 and 603, Ledger, Montana, 1991

Summary: A head on collision occurred between two Burlington Northern Railroad freight trains. Three crewmembers were killed, and four were severely injured. The three fatalities were due to blunt force impact, extensive internal injuries due to blunt force - predominantly to the chest, abdomen, and pelvis. NTSB investigator s could not determine if the fatalities had jumped or been thrown from the trains. The collision was the result of an improper readback of a mandatory directive by the crew, which was compounded by the train dispatcher failing to hear the error during the repeat of the mandatory directive.

Train 602's lead unit, a GP38, had the cab found in front of the train 603 lead unit about two car lengths beyond the impact point. It had been severed from the frame, split into two sections, and completely engulfed in the ensuing fire, which destroyed the control stand, instruments, seats, and electrical cabinet.

Train 603's lead unit, an SD40, had the superstructure displaced to the left side and the cab displaced downward and rearward. The seat opposite the engineer's seat frame and pedestal remained attached to the control compartment's left side, and another seat was found on the cab left side exterior. The cab right side was crushed downward. The unit sustained major thermal damage.

From site distance tests used in the post-accident investigation, officials determined that it took approximately 21 seconds before the crewmembers applied the emergency brakes. If they had immediately applied the brakes upon seeing the other train, the speed upon impact would have been dramatically reduced, with less catastrophic damage. The crewmembers said that there was no expectation of another train, so when they did see one approaching, they were in disbelief and were too stunned to act. Due to the speeds of the trains, any crewmembers aboard the locomotives during the collision most likely would not have been able to survive.

NTSB Accident Report Data

Accident:#1_____Ledger, MT (Burlington Northern)______________________________

Locomotive Number	Model	Year Built	Anticlimber
Train 602			
2275	GP-38-2	1973	No
8009	SD-40-2	1977	Yes
6909	SD-40-2	1973	Yes
Train 603			
6905	SD-40-2	1973	Yes
6901	SD-40-2	1973	Yes
2287	GP-38-2	1974	No
2283	GP-38-2	1974	No
2274	GP-38-2	1973	No
2289	GP-38-2	1974	No

Speed at time of accident

Train 602 - 40 mph
Train 603 - 47 mph

Damage to Locomotive(s)

Locomotive Number	Damage
Train 602	
2275 (lead locomotive)	Cab found in front of 603's lead unit about 2 car lengths from point of impact
8009	Cab crushed downward & forward, sustained thermal damage; electrical cabinet crushed forward into cab compartment
6909	Engineer's side cab crushed even with long hood car body downward on control stand; windshield broken, side window glass broken but in place; door totally crushed
Train 603	
6905 (lead loco)	Superstructure displaced to the left side, at which the cab was displaced downward and rearward. Brakeman's seat frame and pedestal stayed attached (left side) and another seat was found on the cab left side exterior. Cab right side crushed downward; major thermal damage.
6901	Superstructure, including cab and engine compartments, totally sheared off frame.
2287	Short nose hood (which housed toilet) in place but badly mangled. Cab brakeman's side collapsed and minimal thermal damage. Engineer's side in original configuration, no thermal damage

Locomotive Number	Damage
2283	Major structural damage; cab top collapsed downward against engineer's control stand, thermal damage
2274	Short nose thin gauge metal torn open and bent, though not totally crushed. Cab roof collapsed downward in center between missing windshield at the headlight area and against engineer control stand - thermal damage. Engineer's side crushed inward, squeezing the door against car body. Brakeman's side door crushed and inoperable
2289	Brakeman side crushed and door inoperable. Cab top was in position with the windshields present, though both windows missing. Engineer side bent, door sprung open and thermal damage to outside; cab accessible through doorway. Door window was 2 meshed panes - outer pane sustained thermal damage and separated from inner pane, which was still in place. Engineer's control stand and instruments and main electrical cabinet in place w/ no damage. Minimal fire damage.

Type of Collision

Head-on collision on single track, dark territory

Time of Day (night)

5:50 p.m.

Visibility Factors - fog, rain, clouds, etc.

Temperature mid-90s, partly cloudy skies, visibility of 45 miles

Length of time elapsed between knowledge of impending impact and actual impact

Based on post-accident tests of average sight distances, trains 602 and 603 could see each other about 1,946 and 2,305 feet respectively from the point of impact (3/4 mile).

Crew Survival Factors

602 (the southbound) - conductor in lead unit 2275 (GP-38, narrow nose) seated on left side (opposite the engineer) exited from the front left side to the platform and steps, and jumped backwards. 602 brakeman in a trailing unit saw a train approaching, then heard warning to jump (issued by 602 engineer); he also jumped, followed immediately after by another brakeman.

603 (northbound) - conductor in lead unit 6905 (SD-40, narrow nose) stated that as train came around curve, saw another train, thought he heard someone (his Engineer) yell to jump. He ran outside, got down on the platform facing the equipment then stepped off. Engineer 603 saw headlight of an approaching train, put his train in emergency and yelled to jump. He ran out rear door, hung onto vertical handrail post, placed feet on diesel fuel tank and jumped.

Accident #3

Collision and Derailment of Amtrak Passenger Train with MOW Equipment, October 1987.

Deaths, Injuries
15 injuries to crewmembers. A BN crewmember accompanied the Amtrak crew.

Type of Locomotives:

The Amtrak locomotives comprised two 3,000-hp F40PH diesel electric passenger units, manufactured by EMD GM.

The train consisted of two F40PH passenger locomotive units, manufactured by the Electro-Motive Division (EMD) of GM. Each unit had collision posts with the low front hood welded to the underframe and had a protective horizontal bar attached to the front cab wall over the seat opposite the engineer's controls. The locomotive side doors were opposite each other, one on each side of the cab. They were located behind the engineer's and seat opposite the engineer's positions.

Damage to Locomotives:

Most of the interior damaged sustained by the lead F40 unit was in the seat area opposite the engineer's side. The sidewall was displaced inward from the rear of the seat opposite the engineer's door opening to the windshield post with a maximum displacement of about 2 inches at the post between the front and rear windows on the seat opposite the engineer's side. The top hinge of the seat opposite the engineer's door was broken and the door window was crazed. The rear-sliding window was crazed and the front sliding window was missing because it had been broken out in the accident. The seat opposite the engineer's windshield was removed when the crew evacuated the locomotive. There was a “spider web” crack at the bottom center of the engineer's windshield.

Crew Survival Factors:

At or just after impact, the three crewmembers on the lead locomotive were thrown to the left – towards the seat opposite the engineer's side of the locomotive. When the locomotive came to a stop, the engineer noted that the BN crewmember appeared to be injured. The fireman opened the doors to the electrical cabinet, located in the rear portion of the cab, and, using them as a ladder, climbed up to the engineer's side, opened the door, and climbed onto the side of the engine. The engineer, meanwhile, got the fire extinguisher from the cab, broke out the seat opposite the engineer's windshield, and started to remove the BN crewmember from the cab. Seeing this from above, the fireman climbed back down into the cab and assisted the engineer.

Egress Issues:

The lead locomotive rolled over onto the seat opposite the engineer's side, so egress from the seat opposite the engineer's side door was impossible. The fireman was able to use the cabinet doors and electrical switches for steps to get out through engineer's side door, which was now the ceiling of the cab interior. Emergency response personnel removed the windshield to evacuate the crewmembers; also, broken glass from the windows poses a hazard when exiting and could be a cause for further injury when moving about the cab to evacuate. There were 15 crewmembers and 107 passenger injuries, no fatalities. Difficulty in transporting the injured BN crewmember through the engineer's side may have been the reason the conductor broke the windshield, since after the accident it was closer to the ground and more accessible.

APPENDIX F

INTERVIEW WITH CREWMEMBERS INVOLVED IN RAILROAD ACCIDENT WITH LOCOMOTIVE EGRESS IMPLICATIONS

This accident is of particular interest from a human factors perspective.

Crewmember Interview –
Mechanicville, NY 12/18/73

Speed at time of accident

40 mph

Locomotive Number	Model
1702	GP-9

Type of Collision

Train on adjacent track derailed cars onto track occupied by an oncoming train, traveling in opposite direction. Knocked oncoming train's locomotive down an embankment; engine 1702 came to rest on engineer's side (engineer's side of locomotive ended up facing the ground). Fireman's side completely covered with debris – unable to open window or door.

Length of time elapsed between knowledge of impending impact and actual impact

Few seconds; was able to shut the throttle down from the 8th notch to off using one hand, while simultaneously put the train into emergency with the other.

Crew Survival Factors

Engineer stated that he did not have much time to react – engineer stayed in seat until engine came to rest. He exited out the door located behind the engineer's seat – had to kick it open (NOTE: door had been taped shut with electrical tape to keep the cold out) and crawl down the catwalk, digging out since it was covered over with debris – could just see light at the end of the walkway (like a tunnel).

Injuries

Injuries to crew included bruises; engineer banged ribs on control stand (AAR-type).

APPENDIX G

DEFINITIONS

Cab

That portion of the superstructure designed to be occupied by the crew operating the locomotive

Collision Posts

Structural members of the end structures of a vehicle that extend vertically from the underframe to which they are securely attached and that provide protection to occupied compartments from an object penetrating the vehicle during a collision.

Corner Posts

Structural members located at the intersection of the front or rear surface with the side surface of a rail vehicle and which extend vertically from the underframe to the roof. Corner posts may be combined with collision posts to become part of the end structure.

EMD

Electro-Motive Division of General Motors, a major locomotive manufacturer

Emergency Responder

A member of a police or fire department, or other organization involved with public safety charged with providing or coordinating emergency services who responds to a train emergency

Emergency Window

A window that has been designed to permit rapid and easy removal during a critical situation

Emergency Lighting

Lighting mode available when normal lighting is lost, usually battery-powered either off the main battery or an independent battery back-up, with lighting fixtures operating during emergency or normal as well as emergency lighting modes.

Exit Path

The path or corridor/walkway providing the path of evacuation from the locomotive

GE — General Electric

A major locomotive manufacturer

Handrails

Safety appliances installed on either side of a rail vehicle's exterior doors to assist passengers and crewmembers to safely board and depart the vehicle

HEP – Head-end power

Power generated on-board a passenger locomotive for heating, cooling and illumination

Interior Fittings

Any component in the cab which is mounted to either the ceiling, side walls, end walls or floors that protrudes more than one (1) inch into the cab

Locomotive

Self-propelled unit of equipment designed primarily for moving other equipment.

Narrow nose locomotive – engine room accessed from outside of the locomotive from doors off the walkways…

Wide nose locomotive – a diesel locomotive with a full-width cab

Wide-body locomotive – a locomotive with a full width body, from the nose to the rear that is vital to the structural integrity of the unit. There are no exterior walkways – access to the engine room is provided by a door leading from the cab to an interior walkway through the engine room compartment the length of the unit

APPENDIX H

EMPLOYEE TRAINING - PROGRAM EXCERPT

This appendix contains an excerpt from the "Emergency Preparedness Training Syllabus" used by the Long Island Railroad.

EMPLOYEE TRAINING AND QUALIFICATIONS - 101(a)(2)(I)

A. Rail equipment familiarization

1. Give multimedia presentation together with hand-outs on equipment familiarization, including on-board emergency equipment, emergency exits and evacuation techniques.

2. Review communication procedures set forth in 49 CFR Prat 239.101(a)(1).

B. Situational awareness. Training in characteristics and appropriate responses to emergencies.

1. Operating Rules and Special Instructions as appropriate.

2. Standard Operating Procedures - Guidelines for all normal, abnormal and emergency operations.

   a. Scenario
      1. Illness/injury
      2. Stalled train
      3. Sudden stop/Collision (bumping block).
      4. Trespasser Incident
      5. Derailment
      6. Fire/smoke
      7. Fire/smoke in Tunnel
      8. Derailment/collision with fire/smoke
      9. Derailment/collision with fire/smoke in Tunnel
      10. Derailment/collision with water immersion (Lead, Dutch Kills)
      11. Severe weather conditions/nature disasters
      12. Wires down on/entangled with train
      13. Smoke/fire on/adjacent to track
      14. High water
      15. Security concerns/assistance

C. Passenger Evacuation

1. Assess situation - communicate with other crew members
2. Communicate with Movement Bureau
3. Assess limitations and injuries to passengers/crew
4. Provide the safest route and destination
5. Meet and coordinate functions with emergency responders and supervision

D. Coordination of Function (Protocol and Responsibilities)

Conductors will initially be in charge of coordinating operations and responsible for contacting the Movement Bureau to provide adjacent track and third rail protection. The Conductor will advise the passengers of the nature and severity of the incident and periodically update passengers as the incident progresses. The Engineer will maintain contact with the Movement Bureau and Emergency Responders.

1. Conductors
   a. Responsible for protecting train and adjacent track.
   b. Assess emergency situation and advise Movement Bureau as soon as possible by the quickest means available.
   c. Keep passengers safe and informed.
   d. In charge of incident until advised by the local Police or Fire agency that they now have the incident under their command and control. (Check credentials and take name.)
   e. Remain at scene to act as liaison between railroad and emergency responder until relieved by supervision.
   f. If necessary to evacuate train, be sure it is properly secured first.

2. Other Crew Members
   a. Assist the conductor in assessing the incident and in keeping the passengers safe and informed.

3. Engineer
   a. Maintain contact with Movement Bureau.
   b. Act as liaison via radio between Control Center/Dispatcher and on-scene emergency responders until relived by supervision.
   c. Secure train before leaving when evacuation is called for.

4. Movement Bureau/Dispatcher
   a. Promptly and efficiently notify the appropriate personnel for the reported incident.
   b. Keep accurate records as the incident progresses.

E. "Hands-On" Instructions

1. Employees will receive hands-on training instruction concerning the location, function and operation of on-board emergency equipment, stressing the following:

a. Recognition of emergency markings and decals on emergency windows, door release handles and emergency tools.
b. Opening emergency exits, windows and doors emphasizing adverse conditions.
c. Use of emergency tools and fire extinguishers.
d. Use of portable lighting (flashlight) when the main power source is out.
e. Use of public address system or bullhorns if provided.

2. Hands-on training will be done utilizing full-scale equipment or mock ups.

3. Hands-on performance must be completed within 5 days of classroom training.

4. A record will be retained with the results of the qualifying exam grade of the employees participation with regards to the hands-on portion of this program.

LIAISON WITH EMERGENCY RESPONDERS

COURSE OUTLINE

I Scope of Operations
- A. Company goals
- B. Facilities
- C. Organization
- D. Control

II Equipment
- A. Locomotives
- B. Power Units
- C. M-1, M-3 Rail Cars
- D. Diesel Hauled Cars
- E. Freight
- F. Other equipment (bi-levels, dual mode locomotives)

III Power Distribution
- A. Electrified operations (AC & DC), third rail/catenary
- B. High voltage transmission lines
- C. Power Director

IV Emergency Procedures
- – Determining nature and severity (size up)
- – Establishing communications
- – Communicating needs to railroad
- – Safety procedures (remove power), stabilization of equipment
- – Gaining access to equipment
- – Emergency evacuation options

V Summary and Review

VI Hands-On Equipment Familiarization
- A. Equipment stabilization
- B. Access/Egress
- C. Evacuation

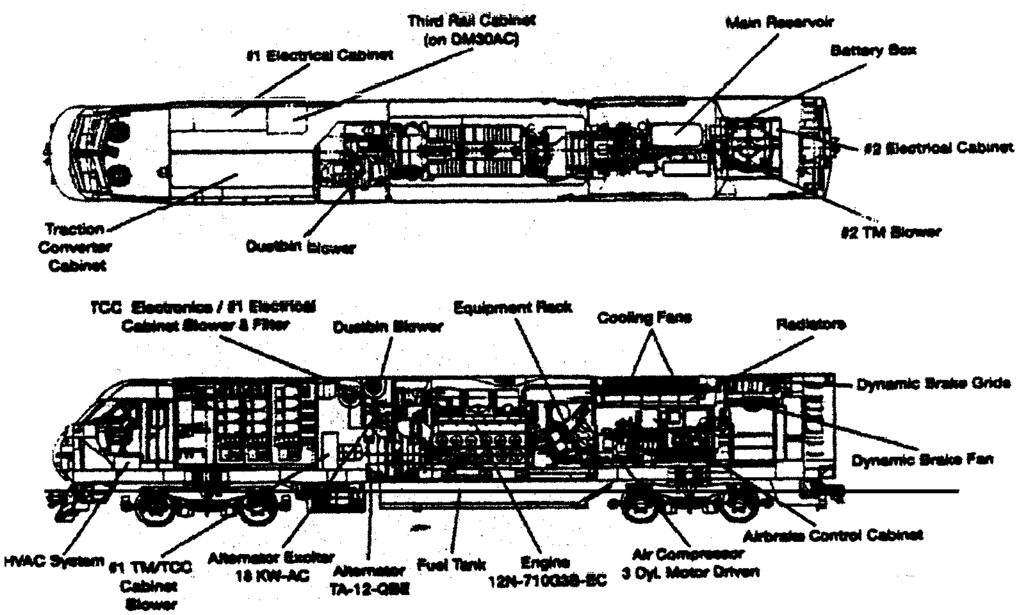
APPENDIX I

TRAINING PROGRAM EXCERPTS - LOCOMOTIVE SCHEMATICS

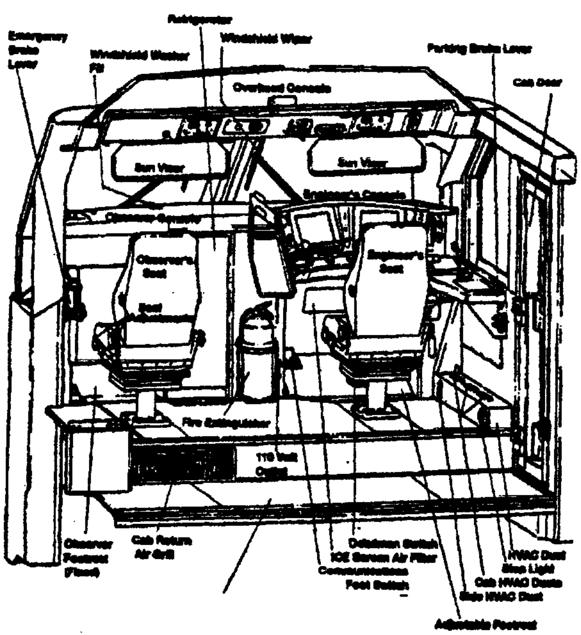
Locomotives

DE/DM30AC Locomotives

TOP VIEW



CAB LAYOUT



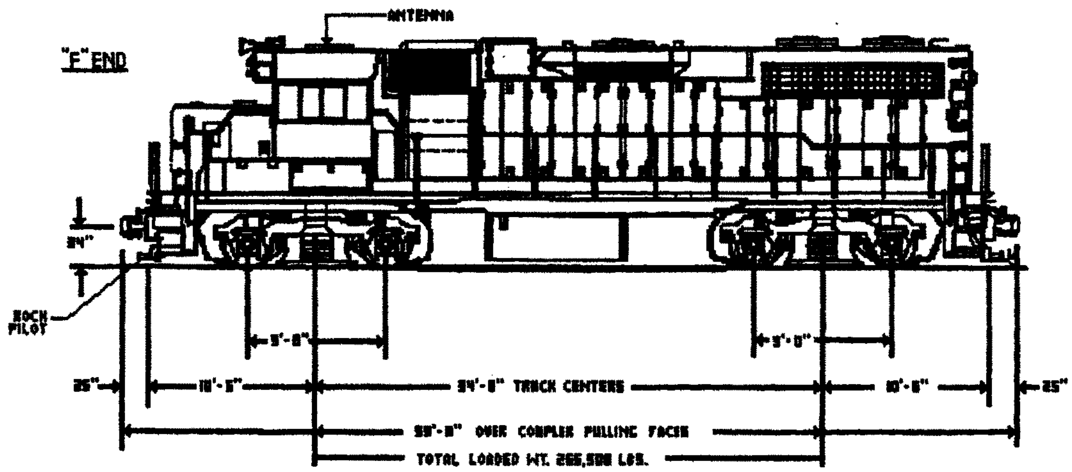
Fire Extinguishing System Control on Overhead Console, Right Side

Emergency Fuel Cut-Off on Rear Cab Bulkhead Wall

Locomotives

GP-38 / E-20 Multi-Purpose Locomotive

Manufacturer: Electromotive Division, General Motors Corporation



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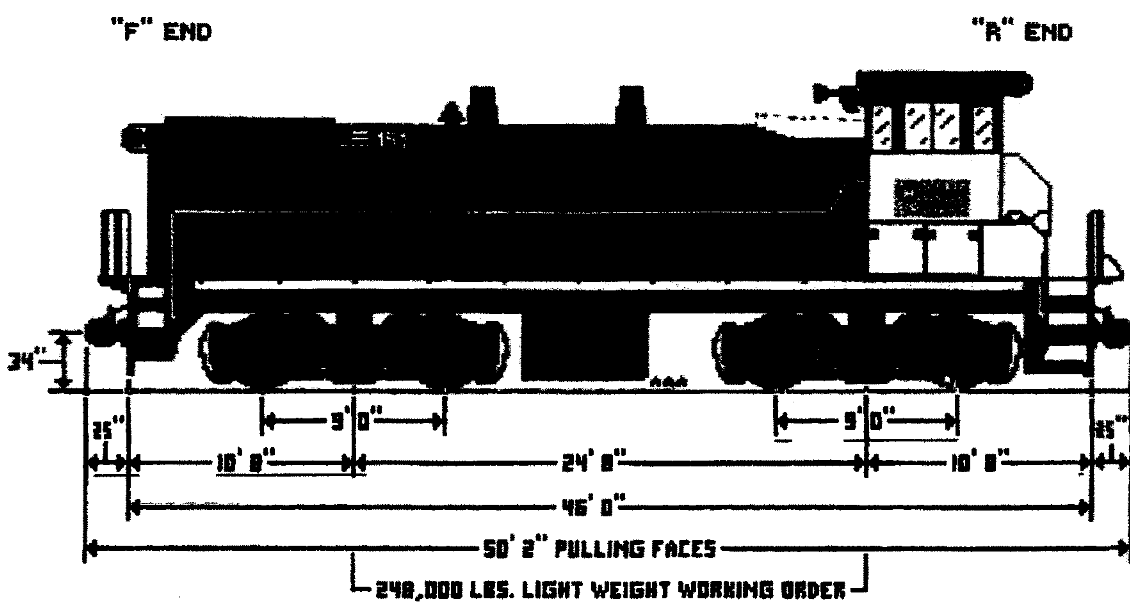
E-15 Multi-Purpose Locomotive

Manufacturer: Electromotive Division, General Motors Corporation



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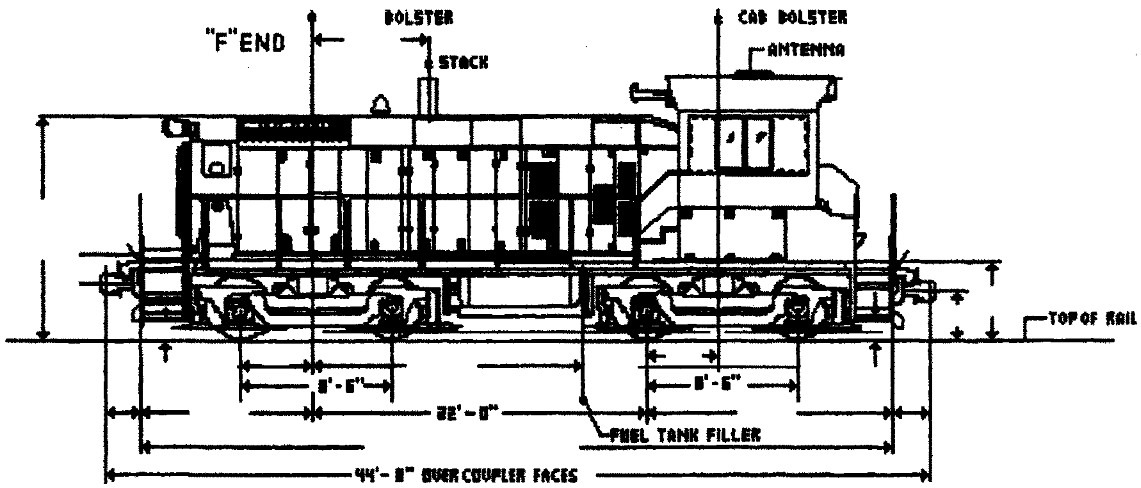
Locomotives

E-10 Switcher Locomotive

Manufacturer: Electromotive Division, General Motors Corporation



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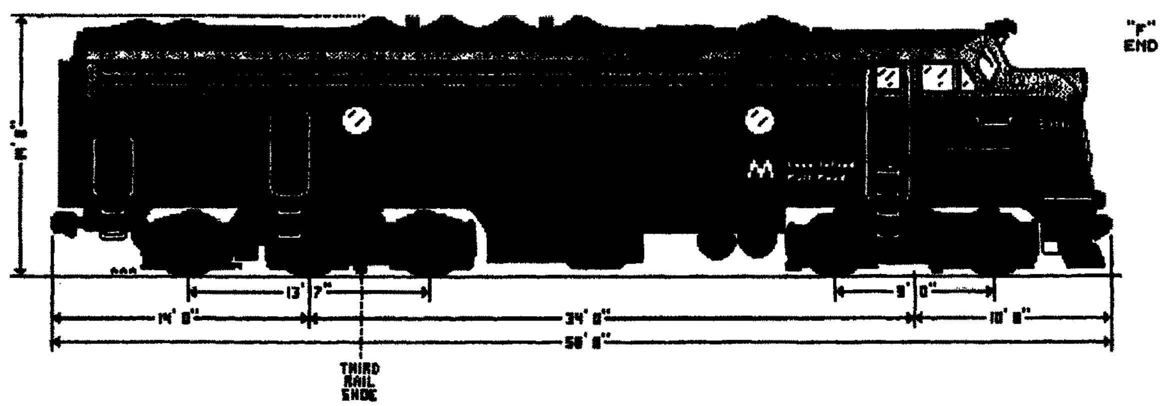
FL-9 Dual Mode Passenger Locomotive

Manufacturer: Asea Brown Boveri



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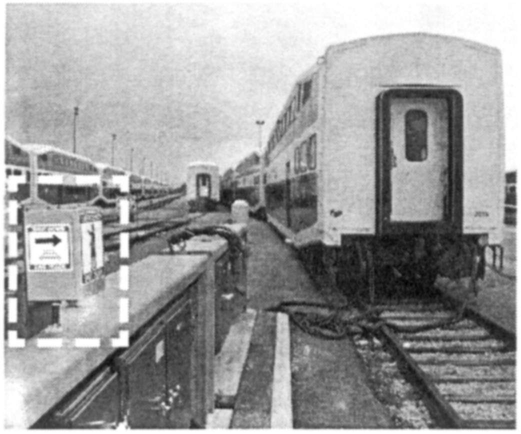
APPENDIX J

EMERGENCY RESPONDER TRAINING PROGRAM EXCERPT

GO Transit Emergency Information

For Firefighters

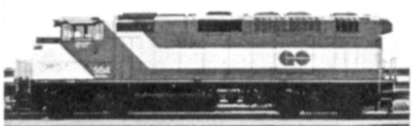
Wayside Power



In addition to locomotive-generated power, high voltage (575 VAC) is supplied by hydro-electric sub-stations when a train is on wayside power. Each plug-in site of every train is equipped with a clearly marked **Emergency Shutdown Box** on top of each wayside power stand. To remove the high-voltage power, cut the padlock on this box and depress the **red** button inside. When the high voltage power is shut down, most interior car lighting and all HVAC fans will stop.

Emergency Entry & Exit

Locomotive



The front and rear doors are relatively safe entrances into the locomotive. They are unlocked when train is in service, locked when train is on wayside power. Space is tight and access difficult, especially if breathing apparatus must be worn.

NOTE - **Use of the side man door entrance is <u>not</u> recommended.**

Side doors in the engine compartment of the locomotive can only be opened from inside. In the event of a major fire in the engine compartment, these doors may be opened from outside by cutting the top and bottom of the non-hinged side of the door or the top and bottom center area of double doors.

APPENDIX K

MAINTENANCE CHECKLIST EXCERPT

Mechanical and Materials System
Task List by Task
Locomotive, Inspection, Daily Locomotive Inspection, No Detail

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Task ID: L001D **Task Name:** Gauge indications
Craft: **Component:** **Labor:** 0.00
Description: With engine running inspect inlet water temperature and oil pressure guages. Inspect spin-on fuel filter bypass sight glass for fuel. Indication will result in the renewal of spin-on fuel filters. Inspect primary fuel filter bypass guage. Red zone indication will result in the renewal of the primary fuel filter.

Task ID: L002 **Task Name:** Inspect Cab
Craft: **Component:** **Labor:** 0.00
Description: Inspect cab seats and mountings, cab windows, sun visors, mirrors and doors including latching mechanisms and safety retainers. (FRA 229.119)

Task ID: L003 **Task Name:** Check Engine Noises, etc.
Craft: **Component:** **Labor:** 0.00
Description: With engine running listen for unusual noises in diesel engine, auxiliary blower assembly, main generator and air compressor.

Task ID: L004 **Task Name:** Check Cooling Water System
Craft: **Component:** **Labor:** 0.00
Description: Check the following main engine fluids and replenish levels to the full mark: crankcase oil, compressor oil, actuator oil and coolant.

Task ID: L008 **Task Name:** Check for Fuel, Oil & Exhaust Leaks
Craft: **Component:** **Labor:** 0.00
Description: With engine running inspect for oil, fuel, coolant and exhaust leaks.

Task ID: L011 **Task Name:** Drain Condensates
Craft: **Component:** **Labor:** 0.00
Description: Drain main reservoirs and final filters of condensate. (FRA 229.46)

Task ID: L012 **Task Name:** Check Drain Valves
Craft: **Component:** **Labor:** 0.00
Description: Ensure automatic drain valves are set in the automatic position. Check for proper operation. Ensure air dryer valve is in the cut-in position. Inspect air dryer humidity indicators. Blue color represents proper operation. (FRA 229.46)