National Transportation Safety Board

Office of Railroad, Pipeline, and Hazardous Materials Investigations
Human Performance and Survival Factors Division
Washington, DC. 20594

Crashworthiness Factual Report[1] – Addendum # 1

Supplementary Information on the Locomotives Involved in the Accident[2]

Collision of SCRRA ("Metrolink") Train 111 with Union Pacific Train LOF65-12, in the Chatsworth District of the City of Los Angeles, California, on September 12, 2008

NTSB Accident Number: DCA 08 MR 009

Compiled by: // s // Date July 7, 2009 .
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Supervisory review: // s // Date July 7, 2009 .
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[1] This report exclusively addresses selective vehicle crashworthiness elements of the accident, where, as a basic definition (as applied to this Investigation), *crashworthiness* is the ability of the vehicle to provide for the survival of its occupant(s) as a result of a collision / impact event.
[2] ref. Crashworthiness Factual Report, § 4.2.

Summarized - Table of Contents

Select Acronym Nomenclature used in this Report

~	approximate, or approximately
≅	equals approximately
AAR	Association of American Railroads, a professional trade association, as described in >> http://www.aar.org/Homepage.aspx
APTA	American Public Transportation Association, a professional trade association, as described in http://www.apta.com/
EMD	Electro-Motive Diesel, Inc.
FRA	Federal Railroad Administration
ft	feet [dimensional distance]
gals	gallons [liquid / fuel]
kips	1,000 lbs.
LAFD	City of Los Angeles Fire Department
RSAC	Rail Safety Advisory Committee; an advisory committee established by the FRA to develop consensus recommendations on safety issues, as described in http://www.fra.dot.gov/us/content/53.
SCRRA	Southern California Regional Rail Authority
UP	Union Pacific Railroad

A. Accident Reference Information

NTSB Accident Number:	DCA 08 MR 009
Location:	Chatsworth, CA.
Date / Approx. Time of Event:	September 12, 2008 / 4:22 p.m. (PDT)[3]
NRC Report No.	883610
Type of Incident	Collision of two trains
Railroad Property	Southern California Regional Rail Authority {SCRRA} (also known locally as "Metrolink")
Track Ref. Location (approx.)	Ventura Sub-Division, MP 444.12

B. Synopsis

See Crashworthiness Factual Report of the Investigation.

C. Crashworthiness - Working Group Participants

See Crashworthiness Factual Report of the Investigation.

D. Facts of the Investigation

To potentially address factual considerations and observations of locomotive crashworthiness safety, relative to the two specific model locomotives involved in the Accident, which were reviewed / documented by the Investigation subsequent to completion of the Crashworthiness Factual Report[4], and discuss considerations of locomotive emergency egress, participants of the Crashworthiness Working Group engaged in dialog with technical principals of the locomotive manufacturer (a company that is currently named Electro-Motive Diesel, Inc.). The purpose of the discussion was to garner useful technical insight into locomotive crashworthiness and crewmember safety, as might not be apparent by field examination of the equipment or review of technical documentation describing same, from a locomotive manufacturer that actively promotes safety initiatives and features relevant to it's railroad locomotive product-line[5]. A summarization of the technical dialog with technical principals of the locomotive manufacturer, and obtained supplemental information on this topic of the Investigation, is as follows[6].

1.0 Vehicle Dynamics / Kinetic Energy Attenuation and Identified Injuries

1.1 Likely Accident Scenario

[3] Pacific Daylight Time
[4] ref. report section describing the locomotive models Involved in the Accident (§ 4.2)
[5] technical discussion meeting was conducted at the locomotive manufacturer's facility on March 10, 2009 (in LaGrange, IL), in which this report also includes the essence of prior, and subsequent dialog (both phone and email).
[6] the topics presented in this report are not necessarily is the sequence as discussed.

As a summarized description, to potentially assess vehicle dynamics / kinetic energy attenuation aspects of the 'head-on collision' event, the evidence identified in the Investigation is generally consistent with a likely accident scenario that occurred as follows[7]:

- Westbound (timetable direction) SCRRA regional commuter passenger train:
  - comprised of 1 diesel-electric locomotive (in the lead) + 3 passenger railcars (trailing)
  - ~ 43 mph (≅ 63.2 ft/sec), with no braking occurring.
  - train weight ~ 616 kips, length ~ 313 ft.
- Eastbound (timetable direction) UP freight train:
  - comprised of 2 diesel-electric locomotives (lead Unit with cab leading, 2nd Unit with cab at aft end) + 17 freight railcars.
  - ~ 41.3 mph (≅ 60.7 ft/sec), with essentially no braking occurring[8].
  - train weight ~ 3,044 kips, length ~ 1,164 ft.
- Track Terrain / Topography / Environmental:
  - single-track territory, having an east / west geographical orientation[9].
  - track has ~ 0.75 % upgrade to the west.
  - point-of-collision occurred within the full-body of a curve, measuring ~ 6° ('outer-side' of the curve is to the north).
  - daylight, clear weather, ~ 74° F, negligible wind, and benign other environmental factors.
- Collision occurred at 4:22:23 pm, at a point ~ 634 ft east of the east portal of tunnel # 28.
- the Aftermath:
  - SCRRA train:
    - lead end of locomotive came to rest on its right side (north side of the track), ~ 76 ft east of the identified point-of-collision, resolutely wedged against the front[10] end of the lead UP locomotive.
    - leading end of the locomotive compressed ~ 15 feet, resulting from the front 'cowl' and entire end structure (preceding the cab), being forcibly displaced in an aft direction, which breached the front wall structure of the locomotive cab, where the displaced mass of dislodged / displaced / crushed internal components and structure filled the cab with wreckage debris, and resulted in the locomotive cab sustaining essentially a complete loss of occupant survival space.
    - the locomotive fuel tank:
      - separated from the locomotive (attachment / mounting bolts had been sheared),

[7] summarization as collectively sourced from the Crashworthiness Factual Report of the Investigation.
[8] emergency airbrake application occurred moments before impact.
[9] the east / west directional orientation reference is cited here as a simplified point of reference (for discussion purposes), and is not (given that the collision occurred on a curve) intended to be expressive of the actual physical parameters of the site.
[10] note – irrespective of directional references that might be used by this equipment manufacturer, in this report, forward (lead end) and aft directional references, as well as left and right sides of the equipment, are relative to the normal [forward] direction of travel.

    - came to rest to the right side of the track, between the track and the front of the locomotive,
    - the tank sustained substantial impact damage to / breach of the leading end plate,
    - the impact damage resulted in a substantial fuel loss / ground spill,
    - a fire ignited in an open space between the separated SCRRA fuel tank and the front end of the overturned UP locomotive (# 8485), the fuel of which is suspected to have been sourced from the breached SCRRA fuel tank.
  - the aft end of the locomotive penetrated the leading bulkhead panel of the 1st passenger coach to which it was coupled (SCAX # 185), where the locomotive came to rest within the confines of the occupant compartment of the leading approximately two-thirds segment of that coach railcar[11].
  - the 2nd passenger coach separated from the 1st passenger coach (fractured coupler shank), where the two coaches came to rest separated by a distance of ~ 32 ft, where the 2nd passenger coach remained coupled to the 3rd passenger coach and both passenger coach cars did not derail.
- UP train:
  - lead end of the lead locomotive came to rest on its left side (north side of the track), ~ 76 ft east of the identified point-of-collision, resolutely wedged against the front end of the SCRRA locomotive.
  - lead end of the lead locomotive sustained impact damage consisting principally of:
    - the front 'buff plate' was bent inward and under,
    - the front coupler draft gear was displaced inward,
    - the front coupler shank was fractured and coupler head was separated,
    - the front cowl was displaced inward an estimated 3 ft.
  - lead locomotive fuel tank:
    - remained attached to the locomotive,
    - sustained relatively minor damage,
    - negligible fuel loss observed,
    - no fire observed (relative to this fuel tank).
  - aft end of lead locomotive came to rest wedged against the lead end of the 2nd UP locomotive.
  - the 2 crewmembers of the lead locomotive, who were injured and unable to escape the cab unaided, were extricated a short time later by responding Fire / Rescue.
  - the 2nd locomotive of the Train Consist:
    - came to rest upright, with the 'long hood' (carbody) structure substantially undamaged,
    - the end of a freight car came to rest on a portion of the cab roof (which was located at the aft [trailing] end of the Unit),

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[11] the penetration of a colliding railcar, or locomotive, into the occupant compartment of another railcar during severe end-structure collisions is referred to in railroad accident investigations as a carbody 'telescoping' action.

- a segment of the roof panel was lifted upon apparently being contacted, during the collision / derailment dynamics, by one or more of the derailed freight railcars, resulting in substantial distortion to the roof structure.
- the crewmember (riding in the Unit), who sustained minor injury, was able to escape the damaged cab unaided.

1.2 Casualties[12]:

SCRRA train:	fatalities	1 locomotive engineer + 24 passengers	=	25 total
	injuries	1 train conductor + 98 passengers	=	99 total
UP train:	fatalities	0		
	injuries	3 train crewmembers		

2.0 Collectively Identified Factual Observations – General

Dialog of Crashworthiness Working Group participants with technical principals of the locomotive manufacturer, in discussing technical aspects of this locomotive design and in considering factual observations of the collision event (identified in the Investigation), resulted in the following collectively identified factual observations (which are briefly summarized, in no particular sequence order).

2.1 Locomotives of the UP Train (UP # 8485 and # 8491)[13]

Both units were a model SD70ACe locomotive, which were manufactured in 2006 by Electro-Motive Diesel, Inc. (which is also known in the railroad business by it's initials 'EMD'). SD70ACe model locomotives were built to the industrial standard 'performance requirements' of AAR Standard S-580 (Revision date 2005) for the locomotive, and AAR Standard S-5506 (Revision date 2001) for the fuel tank, as further described in this report (see § 4.4.1.a, and § 3.4.1.a, respectively). End-sill height of this model locomotive is ~ 73 inches from top of rail.

2.2 Locomotive of the SCRRA Train (SCAX # 855)[14]

This unit is a model F59PH locomotive, which was manufactured in 1992, by the Canadian subsidiary of the Electro-Motive Division of the General Motors Corporation, in which the operations of this firm (which was recently divested from the General Motors Corporation) are now conducted by a company named Electro-Motive Diesel, Inc. The F59PH locomotive of the Accident, which was manufactured in 1992, was built pursuant to a crashworthiness design standard as prescribed in AAR Standard S-580, revision date 1989 (effective August 1990), as further described in this report (see § 4.4.1.a). The fuel tank of the F59PH model locomotive was not built to any industrial, or regulatory design standard (there were no industrial, or

[12] count (tabulation) data as reported to local authorities / identified by the Investigation.
[13] this report section provides summarized background information on this specific locomotive model, to supplement the narrative content of the Crashworthiness Factual Report, § 4.2.1.
[14] this report section provides summarized background information on this specific locomotive model, to supplement the narrative content of the Crashworthiness Factual Report, § 4.2.2.

regulatory design standards in effect at the time). Technical principals of EMD noted to the Investigation that the company has implemented, for some 30 years now, as a design assessment, through calculations, as a minimum, a '3-g longitudinal loading', a '2-g vertical loading', and a '1½ -g lateral loading' design criteria for the attachment of it's locomotive fuel tanks, fully loaded with fuel, to the locomotive main frame-rail [centersill] structure (i.e. the loaded fuel tank is designed to successfully resist separation from the locomotive as a result of an imposed force, as a minimum, of 3 times that of gravity along the longitudinal centerline, 2 times that of gravity in the up / down direction, and 1½ times that of gravity in the horizontal / transverse direction). End-sill height of this model locomotive is ~ 65 inches from top of rail.

2.3 Considerations of Collision (Kinetic) Energy Attenuation in the Accident

Briefly summarized, based upon review of post-recovery photographs, and information of the Crashworthiness Factual Report, it was the collective observation of the participants of the technical dialog that:

- although the end-sill height of the SD70ACe model locomotive is ~ 8 inches higher than the F59PH model locomotive, end-sill override of the SD70ACe locomotive did not appear to have occurred, to a significant degree.

- the overall damage sustained by the respective leading locomotives (of the two trains) was reasonably consistent with the quantity of kinetic energy exchanged in the collision.

- (as a theoretical question / observation) had the F59PH model locomotive been constructed to an industrial or regulatory Crashworthiness design standard that was comparable to that as the SD70ACe model locomotive, given that the Crashworthiness design standard that the SD70ACe locomotive was built to results in a more rigid (robust / resilient) Crashworthiness structure, the overall damage sustained by the SD70ACe model locomotive might have been greater than what was observed, where correspondingly, the injury sustained by the two SD70ACe locomotive crewmembers might have been more severe than what was observed.

2.4 Proactive Initiatives of the Locomotive Manufacturer to Enhance Locomotive Crashworthiness and Crewmember Safety

Briefly summarized, this locomotive manufacturer[15]:

- is pursuing ongoing research on crew emergency egress (from the cab), such as the installation of quickly removable windows and/or roof hatches, although issues of practicality of implementation (e.g. water intrusion, impact capability, access security, etc.) and cost considerations, remain as challenges to completion of this research, and implementation of such features.

- has actively participated in, and continues to support the FRA 'Rail Safety Advisory Committee' (RSAC) activities relative to locomotive Crashworthiness design standards and specifications, and corresponding similar safety initiative activities of the AAR.

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[15] Electro-Motive Diesel, Inc. (initiative points as identified during dialog with technical principals of the company)

- has supported FRA / RSAC efforts to:
  - conduct computer-aided simulation modeling, for various theoretical collision impact scenarios, in an effort of optimizing the structural strength of locomotive cabs in order to afford, to the extent possible, an optimum degree occupant protection.
  - assess locomotive fuel tank and cab safety by supplying fabricated hardware for structural testing.
- has contacted the AAR Locomotive Committee regarding emergency escape [route methods] when a locomotive is lying on its left side, and AAR Committee has expressed interest in a joint effort / conversation on the subject[16].

2.5 Damage Documentation of the Equipment Owner

Subsequent to the completion of the Crashworthiness Factual Report and the technical dialog conducted with principals of the locomotive manufacturer (as described in this report), report documentation was received from the owner of the two freight locomotives (UP Railroad), describing the sustained physical damage detail of the two locomotives involved in the Accident, a copy of which is provided in Exhibit 1.

3.0 Locomotives Fuel Tanks

3.1 Basic Description

The locomotives of the Accident all operated on conventional diesel fuel[17], which is stored in an 'external' fuel tank[18], which is fitted to each individual locomotive. The tank is a fabricated weldment assembly, which is manufactured of carbon steel plate and assembled somewhat in the shape of a solid rectangular polygon. Simplistically described, the tank has a flat front and back surface plate, somewhat parabolically curved (left and right) sidewall plates, and flat top and bottom surface plates[19]. Internal, vertically oriented, perforated baffle plates help reduce sloshing of the fuel. The assembled tank is suspended by mounting bolts from the underside of the main frame rails ('centersill') of the locomotive, between a pair of two-, or three-axle, power truck assemblies, where it extends almost the full width of the locomotive, with about 8 inch of underside clearance provided to the railhead (top surface).

An 'external' (design type) fuel tank is typified by the fuel tank that's fitted to a F59PH model locomotive, an illustration of which is included in the Parts Manual for that product, a copy of which is provided in Exhibit 2.

3.2 SD70ACe (model locomotive of the UP Train)

[16] NTSB Investigation staff will follow-up on this topic, to the extent possible, with the AAR and this locomotive manufacturer, and report, to the extent possible, resulting dialog content and/or actions on this topic.
[17] grade # 2 distillate (per ASTM D-975 Standard Specification for Diesel Fuel Oils).
[18] *external* [fuel tank] refers to (as sourced from 49CFR229.5 Definitions) "a fuel containment vessel that extends outside the car body structure of a locomotive".
[19] the plate surfaces are also referred to as 'panels'.

3.2.1 Background

Both locomotives of the UP train consist (UP # 8485 and # 8491), which were a SD70ACe model, are fitted with a fuel tank having a [published] capacity of about 5,000 gals. The fuel tanks of the SD70ACe model locomotives (of this Accident) were built to 'performance requirements' as prescribed in AAR Standard S-5506 "Performance Requirements for Diesel Electric Locomotive Fuel Tanks"; Revised 2001 (as further described in this report; see § 3.4.1.a).

3.2.2 Post-Recovery Damage Examination[20]

a. Lead Unit (UP # 8485)

The fuel tank of this locomotive remained attached to the Unit, and showed evidence of ground (ballast) contact abrasion and batter damage to the left side panel of the fuel tank, but did not display any significant leakage. The locomotive manufacturer also did not identify any significant damage or leakage in its damage report documentation on this locomotive (as further described in this report; see § 2.5).

b. Trailing Unit (UP # 8491)

The fuel tank of this locomotive remained attached to the Unit, and did not display any obvious leakage, or fire damage, as a result of the event.

3.3 F59PH (model locomotive of the SCRRA Train)

3.3.1 Background

The fuel tank of the SCRRA locomotive involved in the Accident (SCAX # 855), having a [published] capacity of 2,200 gals, contained an estimated 1,800 gals of diesel fuel at the time of the Accident[21]. The fuel tank is secured to the underside of the locomotive by four 1½-6 x 9 (inch [diameter] - thread [count] x length) mounting bolts, with locking nuts.

Due to its 'date of manufacture' (1992), the Investigation recognized that because the F59PH model locomotive involved in the Accident was manufactured prior to the "applicability" date of subsequently implemented Industry Standards and/or Regulation, the requirements of such industry standards and/or Regulation would not apply. For contemporary-built locomotives (e.g. the SD70ACe model locomotive, as described in § 3.2 of this report), the design / construction of fuel tanks are subject to Industry Standards, and/or Regulation, as further described in this report (see § 3.4).

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[20] this report documentation (described here) supplements the narrative content of the Crashworthiness Factual Report, § 7.1.3.

[21] ref. Crashworthiness Factual Report; § 7.1.1, and Exhibit 16 (notations in Crashworthiness Field Notes).

3.3.2 Post-Recovery Damage Examination[22, 23]

The fuel tank separated from the locomotive during the event, and was found resting on the track ballast, between the track and the front of the locomotive[24].

The fuel tank had been breached and experienced a loss of its contents (diesel oil), and had sustained obvious fire damage as a result of the event. Photographs obtained by the Investigation depicted a fire that was located in an open space between the separated fuel tank and the front end of (overturned) UP locomotive # 8485, where flames that extended to a visually estimated height of at least 15 ft were observed.

The breach of the fuel tank occurred at the upper / leading edge (welded) seam, which appeared to have split-open, with the breach visually estimated (from obtained photographs) to measured at least several inches in height by several feet in length. Additional impact batter damage was apparent on the aft end (plate) surface of the fuel tank, although no obvious breach was evident. Two of the tank mounting support bolts (identified in obtained photographs) indicated damage characteristics that were consistent with bolts that had been subjected to loading in shear.

Additional damage may have been sustained by the fuel tank, which the Investigation was unable to identify / document to any degree of accuracy, due to this piece of equipment having been disturbed as a result of initiating the wreckage recovery / site clean-up process (by the wreckage recovery / site clean-up contractor), and the subsequent removal of the tank from the site (to a remotely located salvage yard site). The Investigation also wasn't able to identify / document the extent of fire damage to the tank and close-by railroad equipment (which flames may have impinged upon), and the condition of railroad trackage and the right-of-way. Accordingly, pursuant to prevailing Crashworthiness Working Group investigative practice (regarding documentation of on-scene evidence[25]), with its value as an evidentiary artifact having been compromised, no effort was made to further conduct a technical examination of the fuel tank (at the salvage yard site), or the close-by railroad equipment, and the condition of railroad trackage and right-of-way[26].

3.4 Industry Standards, and/or Regulation

3.4.1 Industry Standards / Recommended Practices

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[22] this report section is provided to supplement the narrative content of the Crashworthiness Factual Report, § 6.2.1, and § 7.1.1 (and, as referenced therein, Exhibit 16 of that report).
[23] descriptive narrative (of this report section) is also based upon photographs supplied to the Investigation.
[24] note – irrespective of directional references that might be used by this equipment manufacturer, in this report, forward (lead end) and aft directional references are relative to the normal [forward] direction of travel.
[25] 'procedures / best practices' for the identification and documentation of on-scene evidence by the Crashworthiness Investigation (and the Survival Factors Investigation as well) are generally in accordance with, to the extent possible, those prescribed by the American Academy of Forensic Science {AAFS; as further described in [Internet] http://www.aafs.org}, which are also described in a number of professional publications on that topic as utilized by the forensic science profession (e.g. Siegel, Jay A., et al., Encyclopedia of Forensic Sciences, Academic Press, New York, NY, © 2000 – 3 volume set).
[26] ref. Crashworthiness Factual Report; § 6.2, which describes other pieces of railroad equipment / railroad trackage and right-of-way, it which the value as an evidentiary artifact had been compromised.

a. AAR

Two industry standard / recommended practice guidance documents, applicable to locomotive fuel tank safety, were developed, and were/are promulgated by the AAR, the latter of which is currently included in the AAR Manual of Standards and Recommended Practices, both documents of which are briefly summarized as follows.

- RP-506

The AAR Recommended Practice RP-506 "Performance Requirements for Diesel Electric Locomotive Fuel Tanks" was a recommended practice ('guidance' document) adopted the AAR, which became effective Sept. 1, 1995, a copy of which is provided in Exhibit 3.

The AAR RP-506 has subsequently evolved since its inception, the content of which is now as prescribed in the AAR [Standard] S-5506, as further described (below).

- S-5506

AAR Standard S-5506 "Performance Requirements for Diesel Electric Locomotive Fuel Tanks"; Revised 2001, is a Standard ('required practice' document) adopted the AAR, which became effective in October 2001. The requirements of S-5506 were formerly classified as an AAR Recommended Practice, RP-506 [27]. The S-5506 Standard provides structural strength requirements, and other criteria, to be incorporated into the fuel tank construction, such as a minimum / equivalent plate thickness (of the weldment material), impact resistance specification, and contents spillage control features. AAR Standard S-5506 is "incorporated by reference" in the Regulation under 49 CFR 229.217, a copy of which is provided in Exhibit 4.

b. APTA

A voluntary compliance, industry guidance document, applicable to passenger locomotive fuel tank safety, titled <u>APTA SS-C&S-007-98, Rev. 1 Standard for Fuel Tank Integrity on Non Passenger Carrying Locomotives</u>, was developed, and is promulgated by the American Public Transportation Association {APTA, which is currently included in the APTA Manual of Standards and Recommended Practices for Rail Passenger Equipment, as published by that organization)[28].

3.4.2 Regulatory Requirements

a. Freight Railroad Equipment

Regulation of locomotive fuel tanks are cited under 49 CFR § 229.97, § 229.217, a copy of which is provided in Exhibit 5.

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[27] ref. Fed. Register: June 28, 2006; U.S. D.O.T, FRA, 49 CFR Parts 229 and 238, Locomotive Crashworthiness; Final Rule, as available at [Internet] http://www.federalregistersearch.com/2006/6/28/06-5667.asp

[28] this document is maintained under copyright protection of the APTA, in which a copy is also available from that organization (see [Internet] >> http://www.apta.com/).

Review of 49 CFR 229.217 indicates that the crashworthiness design criteria as prescribed in the AAR Standard S-5506 are "incorporated by reference" in the Regulation, as further described in this report (see § 3.4.1.a).

b. Passenger Railroad Equipment

Regulation of locomotive fuel tanks are cited under 49 CFR § 229.97, § 238.223 and § 238.423, a copy of which is provided in Exhibit 5.

3.5 Research on Locomotive Fuel Tank Safety

Identified research includes:

- FRA – summary report titled "Locomotive Fuel Tank Safety", dated January 2003 (Research Results report # RR03-05).
- NTSB – Safety Study report titled "Locomotive Fuel Tank Integrity", dated (adopted on) October 27, 1992 (NTSB Report # SS--92-04).
- AAR – Report WP-161, Locomotive Fuel Tank Integrity Study, February 1994
- FRA – Locomotive Crashworthiness and Cab Working Conditions, Report to Congress, September 1996
- Rail Safety and Standards Board[29] (of the U.K.) – report titled "Review of Measures to Reduce Risk From Passenger Train Fuel Tanks", dated May, 2003 (RSSB Report # AEATR-TEP-2003-808)[30].

4.0 Locomotive Operator's Cab – Emergency Egress[31]

4.1 Background / Summarized Description of the Equipment

As a basic description, the locomotive operator's cab is a compartment, typically constructed of a relatively heavy-gauge sheet steel material, which is fitted to a locomotive that provides a protected workstation space where the crew normally is located during operation of the locomotive. The operator's cab, which also contains the 'control stand' (also referred to as a 'control console'), is usually[32] located at the lead (front) end[33] of the locomotive, immediately aft of the 'front cowl' structure (often also referred to as the 'short hood') of the locomotive.

[29] ref., and for further information, see [Internet] >> http://www.rssb.co.uk/index.asp

[30] this document is maintained under copyright protection of the RSSB, in which a copy is also available from that organization (see [Internet] >> http://www.rssb.co.uk/index.asp).

[31] this topic is examined by the Crashworthiness Investigation in conjunction with, and is provided as support to the Survival Factors Investigation, and refers to locomotives that are <u>not</u> of the "MU" type of equipment or service (i.e. 'cab cars', and 'power cars'), as described under 49 CFR § 229.141.

[32] as this Investigation is addressing railroad freight locomotives of the type involved in the Accident, *usually* in this application refers to "road" or "road-switcher" type locomotives, although some locomotive design types, such as "switcher" type locomotives, have the operator's cab located at the mid-section of the locomotive.

[33] note – irrespective of directional references that might be used by this equipment manufacturer, in this report, forward (lead end) and aft directional references are relative to the normal [forward] direction of travel..

For locomotives in freight-service operations[34], a locomotive crew might typically be comprised of a locomotive engineer, a train conductor, and sometimes a switchman (which could also be referred to as a brakeman). A seat is provided in the cab for each crewmember; i.e. one seat at the locomotive engineer's control console on the right side of the cab, adjacent to the window, and the other seats on the opposite side of the cab, adjacent to the side-facing window. Crew access to the locomotive cab is normally by 'service doors', two of which are typically provided; one in the front cowl[35], and one usually located behind the locomotive engineer's seat. The operator's cab typically occupies a space that extends the full width of the locomotive (usually measuring about 9½ feet), measures longitudinally (front to rear) about 7½ feet, and has a ceiling height that accommodates standing crewmembers. Windows fitted to a typical locomotive cab include a windshield (allowing a frontal view), side-facing windows (one in each sidewall), and rear-facing windows (usually one in the door behind the locomotive engineer's seat, and another on the opposite side of the cab). The windshield is usually comprised of two glass panels and is 'fixed' in place by a hard-rubber grommet or similar means (i.e. is not intended to be normally opened by the crew), the side-facing windows are usually comprised of two glass panels (one panel of which is capable of sliding open), and the rear-facing windows are usually comprised of single-glass panels each and are 'fixed' in place (i.e. is not intended to be normally opened by the crew).

For locomotives in local passenger-service operations[36], the locomotive crew is typically comprised only of a locomotive engineer, where the cab interior layout is somewhat similar to a freight locomotive. Crew access to the operator's cab is similar to a freight locomotive, although side access doors may replace the front / rear access doors (as is found on the SCRRA). The cab interior size is about the same as a freight-service locomotive, with the window arrangement correspondingly similar to a freight-service locomotive.

Emergency egress from a locomotive cab by locomotive crewmember(s), and access by emergency responders, for both freight-, and passenger-service locomotive types, would be essentially similar, by utilizing any operable door, and/or window, of the cab.

It has been the observation of the Investigation staff[37], that normally, supplementary means of emergency egress are not provided to locomotive cabs (e.g. rapid and easily removable *emergency window exits*, as are required of passenger railcars, pursuant to 49 CFR § 238.113), as was the case for the locomotives of both railroads in this Accident.

4.2 Pre- / Post-Recovery Damage Examination, and Identified Pre-Collision Sequence of Events / Crewmember Actions – Relative to Emergency Egress of the Crew

[34] i.e., in this context, this paragraph describes the type of freight locomotive as involved in the Accident.
[35] for locomotives having a front cowl, access to the cab is actually through a short passageway that's fitted to the front cowl structure.
[36] i.e., in this context, this paragraph describes the type of passenger locomotive as involved in the Accident.
[37] cited as an informal / anecdotal observation of the Crashworthiness Group Chairperson, based upon 30+ years of first-hand familiarization with railroad locomotive equipment.

4.2.1 Locomotives of the UP Train

Prior to the compilation of this report, the Crashworthiness Investigation was unable to obtain from the equipment owner a detailed technical description of damage sustained by the locomotives, in which a brief damage description summarization, as obtained by the Crashworthiness Working Group during the on-scene phase of the Investigation, is provided in the Crashworthiness Factual Report, and repeated (in brief) as follows[38].

a. Lead Unit (UP # 8485)[39]

Briefly summarized, the front end of this locomotive came to rest firmly wedged against the front end of the SCRRA locomotive (SCAX # 855) and the front cowl area of the locomotive was compressed / displaced in an aft direction, by several feet, which, as a result, rendered the crew access 'service door' in the front cowl, inoperable / impassible. No loss of occupant survival space (aft of the front cowl) was observed in the cab of this locomotive.

No images of the crewmembers of this locomotive were observed in the On-Board Video/Audio Recording in the timeframe immediately preceding (several minutes prior to impact), or during, the collision / derailment dynamics[40].

Interview testimony of the crewmembers indicated, in the timeframe immediately preceding, during, and immediately succeeding the collision, to the effect (as a brief summarization)[41]:

- The locomotive engineer recalled that (upon first seeing the oncoming SCRRA locomotive) he stood-up, and initially proceeded toward the rear cab door (which is immediately behind the control stand), but then, upon recognizing that this would not be a "viable choice", remained standing in the center of the locomotive cab compartment. No mention was made of recollections of events / activities during the collision. The locomotive engineer recalled that after the collision, as the locomotive had turned-over and came to rest on its left side, he was located at the bottom / left corner of the cab, under the conductor's desk.

- The train conductor recalled only that he saw the oncoming SCRRA locomotive and that he stood up (at his seat), but has no recollection after that of the events / activities during, and subsequent to the collision.

b. Trailing Unit (UP # 8491)

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[38] multiple requests for a copy of detailed damage report documentation were made by the Crashworthiness Investigation to the owner of the locomotive equipment (i.e. the designated Party to the Investigation representative of the Union Pacific Railroad), in which a response was not forthcoming until July 1, 2009 (see § 2.5 in this report).
[39] ref. Crashworthiness Factual Report, § 7.1.3.a., and the On-Board Video/Audio Recording Group Chairman's Factual Report for this Investigation, and observations in the subject video.
[40] Investigative staff (Crashworthiness Group Chairperson) further observed that the On-Board video image was lost (became a 'frozen image') for about 3 minutes 16 seconds at the onset of the collision / derailment dynamics, whereupon the image then returned and continued in a normal manner for the duration of the recording.
[41] source: transcripts of the individual crewmember Interviews (conducted supportive of the Operations Working Group Investigation); as available in the NTSB public docket, in which quotations cited are from the transcript(s).

Briefly summarized, the damage sustained to this locomotive in the accident, relevant to Locomotive Crashworthiness, which was occupied by the one crewmember, consisted essentially of substantial distortion to the roof structure of the Operator's Cab, where a segment of the roof panel was lifted upon apparently being contacted, during the collision / derailment dynamics, by one or more of the derailed freight railcars[42].

In the timeframe immediately preceding the event (several minutes prior to impact), no images of the crewmember of this locomotive were observed in the On-Board Video/Audio Recording, in which also, a sustained view of the end-panel of a railroad boxcar was the only image identified in the video, where also, the video image was lost [went blank] at the onset of the collision / derailment dynamics[43].

Interview testimony of the crewmember indicated, in the timeframe immediately preceding, during, and immediately succeeding, the collision, information to the effect (as a brief summarization)[44]:

- The brakeman recalled that he was sitting in one of the locomotive crew seats as the train moved along (either the fireman's seat or the conductor's seat, in which the specific seat was not specified), when he heard the application of the emergency brake, in which this crewmember then "braced" himself (in what manner that was not specified). He recalled the collision impact occurring, hearing the noise of the collision (a loud "grinding" sound) and feeling the sensations of the collision / derailment dynamics ("it was a long -- the worst earthquake you can imaging"), and that he did not loose consciousness. During this, he recalls thinking that the cab [roof / ceiling] structure might start to collapse, and as a reaction, he "rolled out of the seat and crawled to the engineer's console and I just bunched up in a ball and all the debris is coming off, and it finally stopped".

4.2.2 Locomotive of the SCRRA Train (SCAX # 855)[45]

As a result of the collision, the locomotive came to rest fully on its right side, a short distance to the right side of the track structure. The leading end of the locomotive compressed a distance of about 15 feet, which resulted from the overall front 'cowl' structure of the leading end of the locomotive (preceding the cab), and the components thereof, being forcibly displaced in an aft direction, where the displaced components breached the front wall structure of the locomotive cab. This displacement, accordingly, compressed into a tightly compacted mass of dislodged / displaced / crushed internal components of the front 'cowl' structure, which filled the cab with wreckage debris, and resulted in the locomotive cab sustaining essentially a complete loss of occupant survival space.

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[42] ref. Crashworthiness Factual Report, § 6.2.3.b.

[43] source: notations regarding the on-board video/audio recording for UP locomotive # 8491, as described in the On-Board Video/Audio Recording Group Chairman's Factual Report for this Investigation.

[44] source: transcripts of the individual crewmember Interviews (conducted supportive of the Operations Working Group Investigation); as available in the NTSB public docket, in which quotations cited are from the transcript(s).

[45] ref. Crashworthiness Factual Report, § 6.2.1, photographic documentation supplied to the Investigation, and L.A. County Coroner's Office documentation

Evidence of the Investigation was consistent with, and correspondingly identified that the locomotive engineer was seated at, or located proximate to, the locomotive engineer's control console at the time of the Accident (which is on the right side of the cab, immediately adjacent to the right-side cab window). The locomotive engineer, who apparently was the sole individual in the locomotive cab at the time, sustained fatal injury in the Accident. The upper approximate half of the locomotive engineer's body was found resting on the ground, in a supine orientation, and wedged in the opening of the right side cab window, and oriented in a manner suggestive of, and consistent with, being partially ejected from the locomotive cab (through the window opening). The lower approximate half of the body was pinned in the compressed wreckage content inside the locomotive cab (resulting from essentially a complete loss of occupant survival space, as noted above).

4.3 Emergency Egress of the Crewmember(s) in the Accident

4.3.1 Locomotives of the UP Train

Interview testimony of the crewmembers, and/or information as archived by event recording devices (as obtained by the Investigation, as noted) indicated, in the timeframe succeeding the collision, information to the effect (as a brief summarization):

a. Lead Unit (UP # 8485)[46]

The accident occurred at 4:22:23 pm. At 4:30:11, as depicted by visible smoke outside the locomotive cab windshield (visible in the on-board video recording of this locomotive), fire apparently ignited a short distance from the locomotive cab. Firefighters responded to the scene, and commenced to suppress the fire[47]. At 4:42:00, images of responding firefighters are observed outside the locomotive cab windshield, in a manner suggesting fire suppression efforts. A short time later, those firefighters heard, and then observed crew inside the locomotive cab, who were in obvious distress, and in possible peril due to the close proximity of the fire. At 4:43:42, firefighters initiated a process to gain access to the locomotive cab by attempting to remove one glass pane of the windshield, which initially involved the striking of the windshield glass pane with a firefighters' axe, which was not successfully. This was succeeded by manually prying-loose the rubber perimeter gasket of the windshield, which required a pry-tool to execute. At 4:46:17, the windshield pane removal effort was completed, which required 2 minutes 35 seconds to accomplish. The windshield pane removal allowed, immediately thereafter, the egress through the windshield opening of one crewmember (i.e. the locomotive engineer, who affirmed this observation in Interview testimony) and access into the locomotive cab by firefighters, who proceeded with an extrication of the other crewmember (who was unable to egress through the windshield opening on his own).

In Interview testimony, when asked if either crewmember was able to break or attempt to break the [locomotive windshield] window [to escape on their own], the locomotive engineer

[46] source: the on-board video/audio recording for UP locomotive # 8485, as described in the On-Board Video/Audio Recording Group Chairman's Factual Report for this Investigation, and Interview testimony, as otherwise noted.
[47] as described in the Survival Factors - Group Chairman's Factual Report for this Investigation.

responded that "neither one of the personnel in the cab, the conductor or myself, I don't believe was – either physically capable of even attempting that".

b. Trailing Unit (UP # 8491)[48]

With the conclusion of the collision / derailment dynamics (as a continuation of the actions as previously described in this report; see § 4.2.1.b), the brakeman recalled that he realized that the locomotive was still upright, and he saw that "the roof of my engine was peeled back". He determined that he was not seriously injured, where then stood up, and could see the wreckage ahead of his locomotive, and recognized what had occurred. Using the locomotive service radio, he attempted to make a 'mayday call' [priority request for emergency assistance] to Railroad Dispatch, but received no response. He then located his portable service radio (in the cab), and again attempted a mayday call, but received no response. Some debris had struck his leg, which resulted in some pain, but he could still walk. He then determined the front cowl door to be blocked by debris (impassible). The Investigation identified, in obtained pre-recovery photographs, that a freight car (covered hopper) appeared to have come to rest on a portion of the roof of this locomotive, although the damage detail could not be determined. The brakeman found the rear cab door (behind the control console) to be operable and not blocked by debris, and used that door to exit the locomotive cab, and climb to the ground.

4.3.2 Locomotive of the SCRRA Train (SCAX # 855)

The complete loss of occupant survival space, and the fatal injury sustained by the crewmember, precluded the prospect of emergency egress from this locomotive[49].

4.3.3 Actions of the Emergency Responders[50]

Interview testimony of a principal of the emergency response Incident Command indicated to the effect (as a brief summarization):

Emergency Response resources (firefighters, and emergency medical services {EMS} / ambulance units) of the LAFD, were dispatched to, and began to arrive at the Accident scene. They initiated search and rescue, patient extrication / decedent recovery, fire suppression (of the fire proximate to the two lead locomotives involved in the collision), and patient triage and preparation for transport. One firefighter of the fire suppression team, who was working to extinguish flames of the fire, thought he heard a "pounding" noise coming from the [UPRR] locomotive located adjacent to the fire, and when several firefighters approached the cab, they observed (through the windshield) an individual inside the locomotive cab. As this (presumed) crewmember inside the locomotive cab was in obvious distress, and in possible peril due to the close proximity of the fire, the firefighters initiated an immediate extrication effort. While

[48] source: transcripts of the individual crewmember Interviews (conducted supportive of the Operations Working Group Investigation); as available in the NTSB public docket, in which quotations cited are from the transcript(s).
[49] the crewmember fatality, and complete loss of occupant survival space, obviated further assessment of emergency egress from this locomotive.
[50] source: transcript of an Interview conducted with a principal of the emergency response Incident Command (a Captain of the LAFD), which was conducted supportive of the Survival Factors Working Group Investigation (available in the NTSB public docket), in which quotations cited are from the transcript.

firefighters of the fire suppression team continued fire suppression activities, several other firefighters of same then commenced to break (remove) the locomotive windshield with a firefighters' axe, which required a "few minutes" to complete (note - the windshield window pane was actually removed by prying-loose the rubber perimeter gasket of the windshield, as further described in this report; see § 4.3.1.a). The firefighters then successfully extricated the two crewmembers from the locomotive cab; the locomotive engineer was manually assisted out of the cab compartment through the removed window opening, while the conductor was manually carried out of the cab by firefighters / EMS.

4.4 Industry Standards / Recommended Practice, and/or Regulation

4.4.1 Industry Standards / Recommended Practice

a. AAR[51]

AAR Standard S-580 "Locomotive Crashworthiness Requirements" was originally Adopted in 1989, which indicated "Effective for New Road Type Locomotives Built After August 1, 1990", addressed, as a basic description, strength requirements of anti-climbers, collision posts, and the short hood structure. Subsequent revisions of Standard S-580 further addressed design criteria that includes the strength requirements of anti-climbers, collision posts, and the short hood structure, and also added design criteria for cab structural strength, [cab] interior emergency lighting, fuel tank strength (by incorporation of a separate Standard [S-5506]), interior configuration [of the cab], truck attachment means, underframe strength, as well as the means of [locomotive cab] emergency egress. The most recent version of Standard S-580 was revised in 2008, and was implemented effective March 29, 2008, a copy of which is provided in Exhibit 6.

b. APTA

None identified [52].

4.4.2 Regulatory Requirements

No regulatory requirements were identified to be in effect at the time of the UPRR equipment manufacture[53].

Regulation of emergency egress from a locomotive cab, currently in effect[54], is cited under 49 CFR § 229.206, which indicates that the design requirements of same are as set forth in the AAR Standard S-580, and are "incorporated by reference" in the Regulation, as further described in this report (see § 4.4.1.a).

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[51] ref. Crashworthiness Factual Report, § 4.3.1.
[52] the APTA, a professional trade association, addresses passenger railroad equipment, and as such, the compiled Standards and/or Recommended Practices wouldn't normally address freight railroad equipment.
[53] manufacture date of the UPRR locomotive equipment was June, and July, 2006.
[54] ref. 49 CFR § 229.203 Applicability, which became effective October 1, 2006, which applies to locomotive equipment manufactured, or remanufactured, on, or after, January 1, 2009.

4.5 Research on Locomotive Operator's Cab – Emergency Egress

Identified research includes:

- FRA – report titled "Design and Evaluation of Advanced Systems for Locomotive Crew Emergency Egress", dated Oct. 2006 (FRA Report # DOT/FRA/ORD-06/18).
- FRA summary report – titled "Locomotive Crew Egress", dated April 2005 (Research Results Report # RR05-02).
- FRA – report titled "Evaluation of Concepts for Locomotive Crew Egress", dated March 2003 (FRA Report # DOT/FRA/ORD-03/07).

E. Exhibits[55]

1. Report Documentation – Sustained Physical Damage Detail of the Two UP Locomotives Involved in the Accident (received from the owner of the equipment)

2. Illustration of Fuel Tank (diagram & parts list) Fitted to a F59PH Locomotive

3. AAR Recommended Practice RP-506

   "Performance Requirements for Diesel Electric Locomotive Fuel Tanks"

4. AAR Standard S-5506

   "Performance Requirements for Diesel Electric Locomotive Fuel Tanks"

5. Regulation of Locomotive Fuel Tanks

   49 CFR § 229.97, § 229.217, and § 238.423

6. AAR Standard S-580

   "Locomotive Crashworthiness Requirements"

[55] the Exhibits of this report commence on the following page

Exhibit 1.

Report Documentation – Sustained Physical Damage Detail of the Two UP Locomotives Involved in the Accident (received from the owner of the equipment)[56]

[56] ref. email correspondence received from the UP Railroad Law Department, dated July 1, 2009

UP LOCOMOTIVE – UP 8485

Dave Busse prepared the following repair and replacement estimates before he retired.

Repairs Needed:

Left side of cab carbody
Auxillary cabinet – clean acid out
Handrails and upright post
Carbody damages
Rear dynamic brake section and headlight
Clean cab interior
Realign and repair engine and main alternator
Engine water piping
Exhaust stack hatch

Replacements Needed:

Inverter cabinet
Damaged radiator section
Front pilot sheets
Step sheets
Steps
Front handrails and upright post
Front draft gear pocket and front draft gear coupler
Front pin lifters and bail
Front track receivers
Step lights
MU plug and wiring
MU air piping
Front windshield
Front snow plow
HVAC unit
All electrical equipment affected by acid from the batteries
All traction motor leads and associated wiring and air piping
Rear pilot sheets
Rear step sheets
Rear step lights

UP 8485 (continued)

Rear steps
Walkway light
Handrails and upright post
Rear draft gear pocket, draft gear, coupler, pin lifters and bil
Rear porch and hose box
Spare knuckle holders
Rear dynamic brake section and headlight
Batteries
Right side air box door
Right side air piping
Conductor's seat
Engineer's console fire screens
Antennas on roof

UP LOCOMOTIVE – UP 8491

Dave Busse prepared the following repair and replacement estimates before he retired.

Repairs Needed:

Front pilot sheets
Steps
Step sheets
Track receivers
Step lights
Ditch lights
Snow Plow
Front MU plug
Pin lifters
Handrails
Carbody doors

Replacements Needed:

Entire cab and nose with all electrical wiring and devices located in operator cab area, along with all interior trim
HVAC Unit and door on left side of unit
Auxillary cab louver doors
Handrails and uprights
Rear pilot sheets
Step sheets
Steps
Step lights
Draft gear pocket, draft gear
Coupler
Porch
MU plug
MU air piping
Handrails and piping
Rear headlight and dynamic brake hatch

Exhibit 2.

Illustration of Fuel Tank (diagram & parts list) Fitted to a F59PH Locomotive[57, 58]

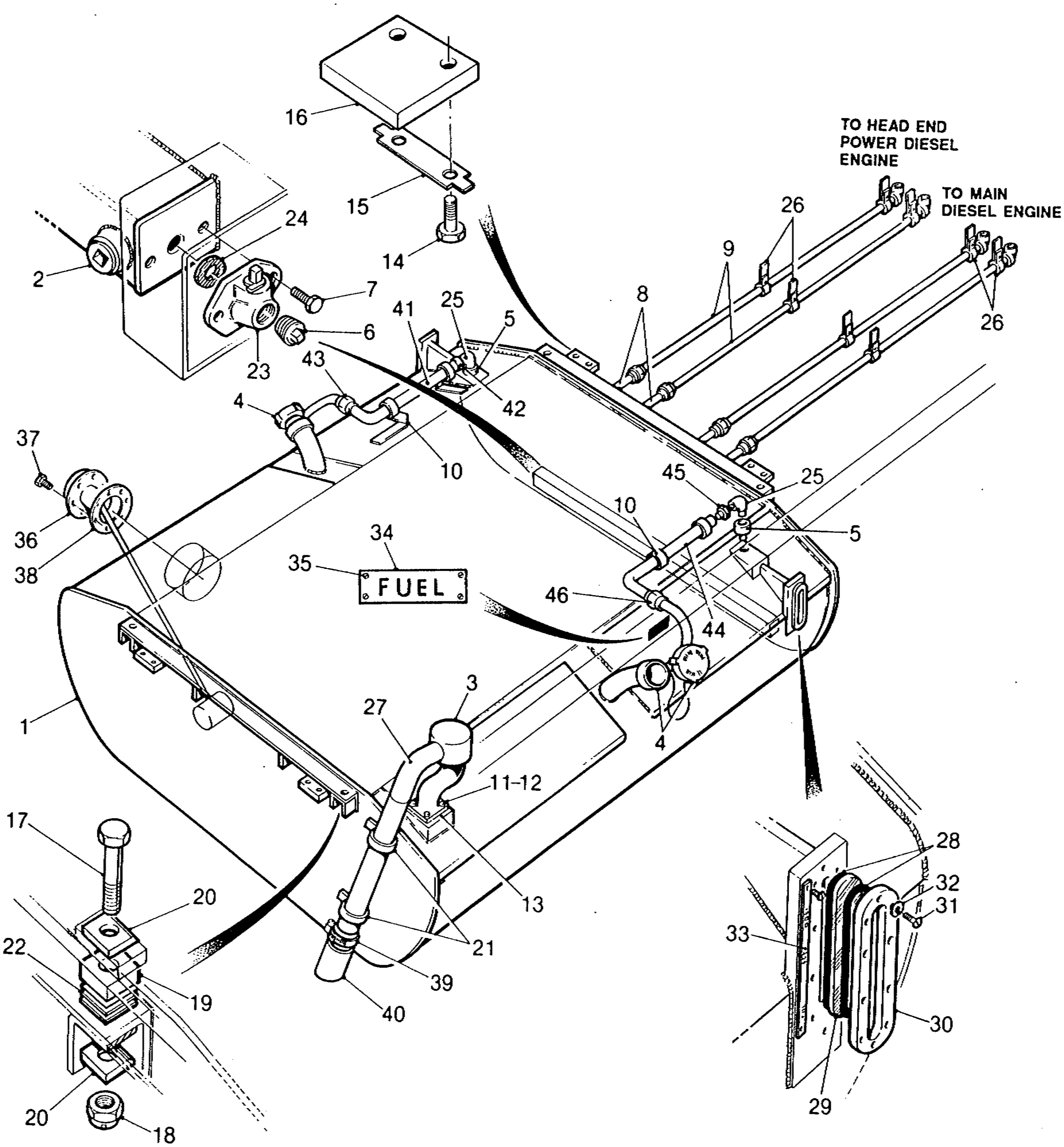
[57] source: SCRRA model F59PH Parts Catalog # 618, by GM Locomotive Group, LaGrange, IL., [dated] Aug. 1992.
[58] the reader is advised that this document is maintained under copyright protection of the publisher

FUEL TANK AND EQUIPMENT

FUEL TANK APPLICATION

Plate A720D-7/1

1277



FUEL TANK AND EQUIPMENT

FUEL TANK APPLICATION

Plate A720D-7/1

Note	Ref.No.	Part No.	Qty.	Description
	1	10587182	1	**TANK ASSEMBLY** - Fuel - 1850 Imp. Gallons - 2220 U.S. Gallons
	2	426810	3	• **PLUG** - Pipe - 2 MPT
	3	10572696	1	**VENT ASSEMBLY** - Fuel Tank
	4	10593790	2	**FILLER ASSEMBLY** - Fuel Tank - Includes Vent Hose
	NI	103881	2	• **PLUG** - Pipe - 3/4 MPT
	NI	10532182	1	• **CAP AND CABLE ASSEMBLY**
	NI		1	• **HOSE** - Vent - 16 Inches Long (Order 10532183 Vent Hose - 20 Inches Long and cut to length)
	NI	10532184	2	• **CLAMP** - Hose - Stainless Steel
	NI	10532185	2	• **FITTING** - Male
	5	10529763	2	**SHUTOFF ASSEMBLY** - Fuel
	6	113176	1	**PLUG** - Pipe - 1/2 MPT
	7	180121	2	**BOLT** - 3/8-16 x 7/8
	8	10587121	4	**PIPE ASSEMBLY**
	9	10587992	4	**PIPE ASSEMBLY**
	10	8315118	2	**CLAMP ASSEMBLY**
	11	180177	4	**BOLT** - 1/2-13 x 1-1/2
	12	120384	4	**WASHER** - Lock - 1/2
	13	9571182	1	**GASKET**
	14	271859	8	**BOLT** - 1-8 x 3
	15	8369574	4	**PLATE** - Locking
	16	9507857	4	**PAD** - Spacer
	17	40019587	4	**BOLT** - 1-1/2-6 x 9
	18	9416572	4	**NUT** - Lock - 1-1/2 - 6
	19	8482284	4	**PAD** - Spacer
	20	8388609	8	**PAD** - Spacer
	21	8440680	2	**CLAMP**
	22	8355363	A/R	**SHIM** - 1/8 Inch Thick
	22	8355364	A/R	**SHIM** - 1/16 Inch Thick
	22	8355365	A/R	**SHIM** - 1/32 Inch Thick
	23	9323901	1	**VALVE ASSEMBLY** - Ball Cock
	24	8306501	1	**GASKET**
	25	108686	2	**ELBOW** - 1/2
	26	8108217	8	**CLAMP ASSEMBLY**
	27	10587128	1	**PIPE ASSEMBLY**
	28	8338890	4	**GASKET**
	29	8338889	2	**GAUGE**
	30	8338907	2	**HOUSING**
	31	153802	20	**SCREW** - Machine 1/4-20 x 1-1/4 - Fillister C/Rec
	32	8035649	20	**WASHER** - Lock 1/4
	33	10587279	2	**PLATE** - Calibration
	34	8350090	2	**NAMEPLATE** -"FUEL"
	35	145386	12	**SCREW** - Drive - No. 10
	36	10588427	1	**GAUGE** - Fuel Level
	37	180020	6	**BOLT** - 1/4-20 x 3/4
	38	8227223	1	**GASKET**
	39	8157344	1	**CLAMP** - Open End
	40	10538300	1	**HOSE**
	41	10590645	1	**PIPE ASSEMBLY**
	42	8044160	1	• **UNION** - 1/2 MPT
	43	187397	1	• **COUPLING**
	44	10590646	1	**PIPE ASSEMBLY**
	45	8044160	1	• **UNION** - 1/2 MPT
	46	187397	1	• **COUPLING**

Exhibit 3.

AAR Recommended Practice RP-506

"Performance Requirements for Diesel Electric Locomotive Fuel Tanks" [59]

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PERFORMANCE REQUIREMENTS FOR DIESEL ELECTRIC LOCOMOTIVE FUEL TANKS

Recommended Practice
RP-506
Adopted 1995
Effective: July 1, 1995

1.0 SCOPE

The objective of this recommended practice is to provide the basic performance requirements for four and six axle diesel electric locomotives. This Recommended Practice is effective for all freight locomotives built after its effective date.

2.0 BACKGROUND

By virtue of their location beneath the underframe and between the trucks, locomotive fuel tanks are vulnerable to damage from impact during a derailment or collision, or by debris and loose equipment on the roadbed. Typically, damage during derailment is caused by impact with the track structure, or from a puncture by a broken rail or debris from other equipment, such as the locomotive truck components. During a collision, the damage can either be caused by impact with the structure of another vehicle or by deformation of the structure of the locomotive itself. Severe damage to or puncture of the tank results in fuel spillage and all the associated problems that accompany it. Fuel loss can also occur in cases where the tank structure is not damaged, but the locomotive comes to rest at an attitude where the fuel can leak from the filler/vent assembly.

3.0 LIMITATIONS

The performance requirements contained in this recommended practice are intended to address the structural and puncture resistance properties of the locomotive fuel tank to reduce the risk of fuel spillage to acceptable levels under derailment and minor collision conditions. The complete elimination of fuel spills under the most severe accident conditions is considered to be impractical.

4.0 STRUCTURAL STRENGTH REQUIREMENTS

4.1 Design Considerations

4.1.1 Load Case 1—Minor Derailment

Support on the end plate of the fuel tank a sudden loading of one half the weight of the car body at a vertical acceleration of 2 g's, without exceeding the ultimate strength of the material. The load is assumed to be supported on one rail, within a plus or minus an eight inch band at a point nominally above the head of the rail, on tangent track.

Consideration should be given in the design of the fuel tank to maximize the vertical clearance between the top of the rail and the bottom of the fuel tank.

4.1.2 Load Case 2—Jackknifed Locomotive

Support on the fuel tank transversely at the center for a sudden loading equivalent to one half the weight of the locomotive at a vertical acceleration of 2 g's, without exceeding the ultimate strength of the material. The load is assumed to be supported on one rail, distributed between the longitudinal center line and the edge of the tank bottom, with a rail head surface width of two inches.

4.1.3 Load Case 3—Side Impact

Consider the case of a side impact collision at the longitudinal center of the fuel tank by an 80,000 pound GVW tractor/trailer. The fuel tank shall withstand, without exceeding the ultimate strength, a 200,000 pound load (2.5 g's) distributed over an area of six inches by forty-eight inches (half the bumper area) at a height of thirty inches above the rail (standard DOT bumper height).

4.1.4 Load Case 4—Penetration Resistance

The minimum thickness of the sides, bottom sheet and end plates of the fuel tank shall be equivalent to 5/16 inch steel plate at 25,000 psi yield strength (where the thickness varies inversely with the square root of yield strength). The lower one third of the end plates shall have the equivalent penetration resistance by the above method of 3/4 inch steel plate at 25,000 psi yield strength. This may be accomplished by any combination of materials or other mechanical protection.

4.2 Sideswipe

To minimize fuel tank damage during sideswipes (railroad vehicle and grade crossings), all drain plugs, clean-out ports, inspection covers, sight glasses, gauge openings, etc., must be flush with the tank surface or adequately protected to avoid catching foreign objects or from breakage. All seams must be protected or flush to avoid catching foreign objects.

4.3 Spill Controls

Vents and fills shall be designed to avert spillage of fuel even in the event of a roll over.

4.4 Fueling

Internal structures of tank must not impede flow of fuel through the tank while fueling at a rate of 300 gpm.

Exhibit 4.

AAR Standard S-5506

"Performance Requirements for Diesel Electric Locomotive Fuel Tanks" [60]

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PERFORMANCE REQUIREMENTS FOR DIESEL ELECTRIC LOCOMOTIVE FUEL TANKS

Standard
S-5506

Adopted as Recommended Practice: 1995
Revised and Adopted as Standard: 1999; Revised 2001

1.0 SCOPE

The objective of this standard is to provide the basic performance requirements for four- and six-axle diesel electric locomotives. This standard is effective for all freight locomotives built after July 1, 1995.

2.0 BACKGROUND

By virtue of their location beneath the underframe and between the trucks, locomotive fuel tanks are vulnerable to damage from impact during a derailment or collision or by debris and loose equipment on the roadbed. Typically, damage during derailment is caused by impact with the track structure or from a puncture by a broken rail or debris from other equipment, such as the locomotive truck components. During a collision, the damage can be caused either by impact with the structure of another vehicle or by deformation of the structure of the locomotive itself. Severe damage to or puncture of the tank results in fuel spillage and all the associated problems that accompany it. Fuel loss also can occur in cases where the tank structure is not damaged but the locomotive comes to rest at an attitude where the fuel can leak from the filler/vent assembly.

3.0 LIMITATIONS

The performance requirements contained in this standard are intended to address the structural and puncture resistance properties of the locomotive fuel tank to reduce the risk of fuel spillage to acceptable levels under derailment and minor collision conditions. The complete elimination of fuel spills under the most severe accident conditions is considered to be impractical.

4.0 STRUCTURAL STRENGTH REQUIREMENTS

4.1 Design Considerations

4.1.1 Load Case 1—Minor Derailment

Support on the end plate of the fuel tank a sudden loading of one half the weight of the car body at a vertical acceleration of 2 G, without exceeding the ultimate strength of the material. The load is assumed to be supported on one rail, within a ±8-in. band at a point nominally above the head of the rail, on tangent track.

Consideration should be given in the design of the fuel tank to maximize the vertical clearance between the top of the rail and the bottom of the fuel tank.

4.1.2 Load Case 2—Jackknifed Locomotive

Support on the fuel tank transversely at the center for a sudden loading equivalent to one half the weight of the locomotive at a vertical acceleration of 2 G, without exceeding the ultimate strength of the material. The load is assumed to be supported on one rail, distributed between the longitudinal centerline and the edge of the tank bottom, with a railhead surface width of 2 in.

4.1.3 Load Case 3—Side Impact

Consider the case of a side impact collision at the longitudinal center of the fuel tank by an 80,000-lb GVW tractor/trailer. The fuel tank shall withstand, without exceeding the ultimate strength, a 200,000-lb load (2.5 G) distributed over an area 6 in. × 48 in. (half the bumper area) at a height of 30 in. above the rail (standard DOT bumper height).

4.1.4 Load Case 4—Penetration Resistance

The minimum thickness of the sides, bottom sheet, and end plates of the fuel tank shall be equivalent to 5/16-in. steel plate at 25,000 psi yield strength (where the thickness varies inversely with the square root of yield strength). The lower one third of the end plates shall have the equivalent penetration resistance by the above method of 3/4-in. steel plate at 25,000 psi yield strength. This may be accomplished by any combination of materials or other mechanical protection.

4.2 Sideswipe

To minimize fuel tank damage during sideswipes (railroad vehicle and grade crossings), all drain plugs, clean-out ports, inspection covers, sight glasses, gauge openings, etc., must be flush with the tank surface or be adequately protected to avoid catching foreign objects or from breakage. All seams must be protected or flush to avoid catching foreign objects.

4.3 Spill Controls

Vents and fills shall be designed to avert spillage of fuel even in the event of a rollover. Where possible, vents shall be internal to the fuel tank.

4.4 Fueling

Internal structures of the tank must not impede flow of fuel through the tank while fueling at a rate of 300 gpm.

Exhibit 5.

Regulation of Locomotive Fuel Tanks[61]

As applicable to both Freight and Passenger service:

§ 229.97 Grounding fuel tanks.
Fuel tanks and related piping shall be electrically grounded.

As applicable to Freight service:

§ 229.217 Fuel tank.
(a) *External fuel tanks.* Locomotives equipped with external fuel tanks shall, at a minimum, comply with the requirements of AAR S–5506, "Performance Requirements for Diesel Electric Locomotive Fuel Tanks" (October 1, 2001), except for section 4.4. This paragraph does not apply to locomotives subject to the fuel tank safety requirements of §238.223 or §238.423 of this chapter. The Director of the Federal Register approves incorporation by reference of the AAR S–5506, "Performance Requirements for Diesel Electric Locomotive Fuel Tanks" (October 1, 2001) in this section in accordance with 5 U.S.C. 552(a) and 1 CFR part 51. You may obtain a copy of the incorporated standard from the Association of American Railroads, 50 F Street NW., Washington, DC 20001. You may inspect a copy of the incorporated standard at the Federal Railroad Administration, Docket Clerk, 1120 Vermont Ave., NW. Suite 7000, Washington, DC 20590 or at the National Archives and Records Administration (NARA). For more information on the availability of this material at NARA, call 202–741–6030, or go to *http://www.archives.gov/federal_register/code_of_federal_regulations/ibr_locations.html.*
[71 FR 36914, June 28, 2006]

As applicable to Passenger Tier I service[62]:

§ 238.223 Locomotive fuel tanks.
Locomotive fuel tanks shall comply with either the following or an industry standard providing at least an equivalent level of safety if approved by FRA under §238.21:
(a) *External fuel tanks.* External locomotive fuel tanks shall comply with the requirements contained in Appendix D to this part.
(b) *Internal fuel tanks.* (1) Internal locomotive fuel tanks shall be positioned in a manner to reduce the likelihood of accidental penetration from roadway debris or collision.
(2) Internal fuel tank vent systems shall be designed so they do not become a path of fuel loss in any tank orientation due to a locomotive overturning.
(3) Internal fuel tank bulkheads and skin shall, at a minimum, be equivalent to a 5/16-inch thick steel plate with a yield strength of 25,000 pounds per square inch. Material of a higher yield strength may be used to decrease the required thickness of the material provided at least an equivalent level of strength is maintained. Skid plates are not required.
[67 FR 19991, Apr. 23, 2002]

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[61] source, and available from >> http://ecfr.gpoaccess.gov/
[62] [defined as] equipment operating at speeds not exceeding 125 mph (ref. 49 CFR 238.5 Definitions).

§ 238.423 Fuel tanks.
(a) *External fuel tanks.* Each type of external fuel tank must be approved by FRA's Associate Administrator for Safety upon a showing that the fuel tank provides a level of safety at least equivalent to a fuel tank that complies with the external fuel tank requirements in §238.223(a).
(b) *Internal fuel tanks.* Internal fuel tanks shall comply with the requirements specified in §238.223(b).

Appendix D to Part 238—Requirements for External Fuel Tanks on Tier I Locomotives
The requirements contained in this appendix are intended to address the structural and puncture resistance properties of the locomotive fuel tank to reduce the risk of fuel spillage to acceptable levels under derailment and minor collision conditions.
(a) *Structural strength* —(1) *Load case 1—minor derailment.* The end plate of the fuel tank shall support a sudden loading of one-half the weight of the car body at a vertical acceleration of 2g, without exceeding the ultimate strength of the material. The load is assumed to be supported on one rail, within an eight inch band (plus or minus) at a point nominally above the head of the rail, on tangent track. Consideration should be given in the design of the fuel tank to maximize the vertical clearance between the top of the rail and the bottom of the fuel tank.
(2) *Load case 2—jackknifed locomotive.* The fuel tank shall support transversely at the center a sudden loading equivalent to one half the weight of the locomotive at a vertical acceleration of 2g, without exceeding the ultimate strength of the material. The load is assumed to be supported on one rail, distributed between the longitudinal center line and the edge of the tank bottom, with a rail head surface of two inches.
(3) *Load case 3—side impact.* In a side impact collision by an 80,000 pound Gross Vehicle Weight tractor/trailer at the longitudinal center of the fuel tank, the fuel tank shall withstand, without exceeding the ultimate strength, a 200,000 pound load (2.5g) distributed over an area of six inches by forty-eight inches (half the bumper area) at a height of thirty inches above the rail (standard DOT bumper height).
(4) *Load case 4—penetration resistance.* The minimum thickness of the sides, bottom sheet and end plates of the fuel tank shall be equivalent to a 5/16-inch steel plate with a 25,000 pounds-per-square-inch yield strength (where the thickness varies inversely with the square root of yield strength). The lower one third of the end plates shall have the equivalent penetration resistance by the above method of a3/4-inch steel plate with a 25,000 pounds-per-square-inch yield strength. This may be accomplished by any combination of materials or other mechanical protection.
(b) *Sideswipe.* To minimize fuel tank damage during sideswipes (railroad vehicles and grade crossings), all drain plugs, clean-out ports, inspection covers, sight glasses, gauge openings, etc., must be flush with the tank surface or adequately protected to avoid catching foreign objects or breakage. All seams must be protected or flush to avoid catching foreign objects.
(c) *Spill controls.* Vents and fills shall be designed to avert spillage of fuel in the event of a roll over.

Exhibit 6.

AAR Standard S-580

"Locomotive Crashworthiness Requirements" [63]

note – certain sections of this Standard have been selectively hi-lighted (in yellow) to emphasize emergency egress related aspects of the Standard

[63] the reader is advised that this document is maintained under copyright protection of the publisher

LOCOMOTIVE CRASHWORTHINESS REQUIREMENTS

Standard
S-580

Adopted: 1989; Revised: 1994, 2001, 2005, 2008

1.0 SCOPE

1.1 These specifications for crashworthiness enhancements cover requirements applicable to all new road-type locomotives, except for passenger-occupied vehicles, manufactured after December 31, 2008, for use on standard gauge track on North American railroads in revenue freight service or in commuter/passenger service.

1.2 The following locomotives are exempted from this standard:

- Locomotive not equipped with an operator's cab structure.
- Locomotive that is designated and marked in cab "Trail Only—Do Not Occupy (Except Hostlers)"

2.0 PURPOSE

The primary purpose of these requirements is to minimize the potential for injuries and fatalities to train crews and others involved in the transportation of freight and passengers.

3.0 BACKGROUND

This standard provides design requirements for locomotives with improved crashworthiness features. The design requirements were developed as enhancements to AAR S-580 (1989) by the Locomotive Crashworthiness Working Group of the Railroad Safety Advisory Committee (RSAC), a federally-chartered advisory committee. This Working Group was comprised of AAR member railroads, rail labor, locomotive manufacturers, the Federal Railroad Administration, and the National Transportation Safety Board. This standard has been approved for use by the Federal Railroad Administration under the locomotive crashworthiness requirements of 49 CFR Part 229, Subpart D.

4.0 DEFINITIONS (PAGE 1 OF 2)

Dual cab	A locomotive design incorporating cab structures at each end (longitudinally) of the vehicle.
Monocoque design locomotive	A locomotive design where the shell or skin acts as a single unit with the supporting frame to resist and transmit the loads acting on the locomotive.
Narrow-nose locomotive	A locomotive with a short hood that spans substantially less than the full width of the locomotive.
Permanent deformation	The undergoing of a permanent change in shape of a structural member of a rail vehicle.
Roof rail	The longitudinal structural member at the intersection of the sidewall and the roof sheathing.
Semi-monocoque design locomotive	A locomotive design where the shell or skin acts, to some extent, as a single unit with the supporting frame to resist and transmit the loads acting on the locomotive.
Skin	The outer covering of a fuel tank and a rail vehicle. The skin may be covered with another coating of material such as fiberglass.

4.0 DEFINITIONS (PAGE 2 OF 2)

Ultimate strength	The capacity of a structure to resist a load that, when exceeded, causes the structure to fail due to excessive buckling, yielding, and/or fracture such that the structure can no longer function as intended.
Wide-nose locomotive (North American cab)	A locomotive used in revenue freight or commuter/passenger service that is not of narrow-nose or monocoque/semi-monocoque design.
Yield strength	The capacity of a structure to resist a load that, when exceeded, causes permanent deformation of the structure.

5.0 GENERAL PROVISIONS

Unless specifically stated otherwise, all loads are applied opposite the direction of locomotive travel. The locomotive is assumed to be operated cab-end forward. For dual-cab designs, both ends of the locomotive must meet applicable requirements of this standard.

6.0 REQUIREMENTS FOR WIDE-NOSE LOCOMOTIVES

6.1 Anticlimbers

6.1.1 Width	Each locomotive must have an anti-climber that extends to the approximate 1/3 points across the width on its cab end.
6.1.2 Depth	The center of the anti-climber must extend to within 4 in. of the pulling face of the coupler with the draft gear fully compressed and be no less than 10 in. from the locomotive front plate for its required width.
6.1.3 Load	The anti-climber must be able to resist an upward or downward vertical force of 100,000 lb applied over a 12-in. width anywhere along the anti-climber perimeter.
6.1.4 Criteria	The load must be applied without exceeding the ultimate strength of the anti-climber.

6.2 Collision Posts

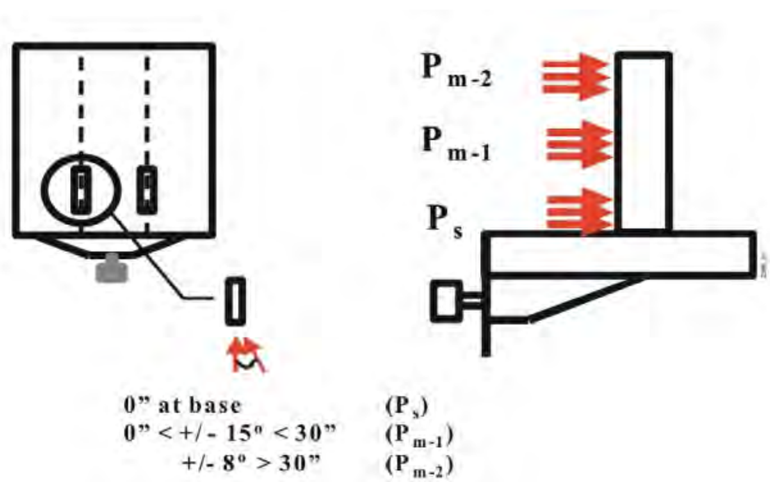

Fig. 6.1 Schematic of collision post loads

6.2.1 Each locomotive must be equipped with at least two collision posts or equivalent structures that are located as follows:

- at the approximate 1/3 points across the width of the locomotive
- in their entirety forward of the seating position of any crew person
- must extend in height to a distance 24 in. above the finished cab floor.

6.2.2 Each collision post must be continuously attached/welded to the front skin and roof of the short hood.

6.2.3 Each collision post must withstand the following loads without exceeding the ultimate strength of the posts and their attachments to the underframe:

- A 750,000-lb load applied over the bottom 10% of the overall height of the collision post at the base (Ps), at any angle in the horizontal plane in the range of ±15° of the longitudinal axis of the locomotive
- A 500,000-lb load applied over an area, the width of the post structure and the height of 10% of the overall height of the post on each collision post, centered at a height 30 in. above the top of the underframe (Pm-1), at any angle in the horizontal plane in the range of ±15° of the longitudinal axis of the locomotive
- Any load (Pm-2) that
  - is applied at a vertical location greater than 30 in. above the top of the underframe up to the top of the collision post.
  - develops the same moment at the base as a 500,000-lb load applied at 30 in. above the underframe ($F \times L = 15{,}000{,}000$ in.·lb for $L > 30$ in. where L=height above underframe).
  - is applied at any angle in the horizontal plane in the range of ±8° of the longitudinal axis of the locomotive.
  - is distributed over an area the width of the post and 10% of the height of the post.

6.3 Emergency Egress

The locomotive cab must allow for exit through at least one opening (e.g., engineer's side door, nose door, windows) in any locomotive orientation.

6.4 Emergency Interior Lighting

6.4.1 Illumination design shall provide sufficient illumination within the cab area to allow for safe egress from the locomotive cab in the event of a collision.

6.4.2 Emergency interior lighting shall activate automatically upon emergency brake application for a minimum of 20 minutes at the following levels: the exit path from each seat position to each exit door shall be automatically illuminated to a level of 0.5 lux in general and 2.5 lux on each stair step to be negotiated to the exit door and 2.5 lux at each door threshold higher than 1 in. Illumination shall be measured at floor level and perpendicular to the floor.

6.4.3 Emergency interior lighting shall operate in all equipment orientations.

6.4.4 The locomotive main battery system or a separate battery power source shall provide for a manual reset to extinguish emergency interior lighting (not required if other power source is utilized).

6.5 Fuel Tank

Each main diesel fuel tank used for the propulsion prime mover must meet the requirements of *MSRP* Standard S-5506, "Performance Requirements for Diesel Electric Locomotive Fuel Tanks," latest revision.

6.6 Interior Configuration

6.6.1 Protruding parts, sharp edges, and corners in a locomotive cab must be rounded, radiused, or padded to mitigate the consequences of an occupant impact with such surfaces.

6.6.2 All appurtenances mounted in the locomotive cab, including cab seats, must be securely fastened and capable of withstanding without permanent deformation the following service forces:

- Longitudinal: 3.0 G
- Lateral: 1.5 G
- Vertical: 2.0 G

6.7 Short Hood Structure

6.7.1 The short hood must be capable of supporting a longitudinal load of 400,000 lb. applied to the front of the short hood in the upper corner over an area that is 12 in. wide starting 30 in. above the top of the deck and extending to the nose cab roof sheet without exceeding ultimate strength (see Fig. 6.2). An acceptable method other than finite element analysis of determining compliance with the above is the load-thickness formula that follows. A short hood capable of meeting this requirement has its side and top surface material properties determined by the formula contained in paragraph 6.7.2. The length of the short hood must be at least one-half the total height for the equation to be applicable. The base of the short hood must be securely and continuously attached to the locomotive underframe to develop the full strength of the connection.

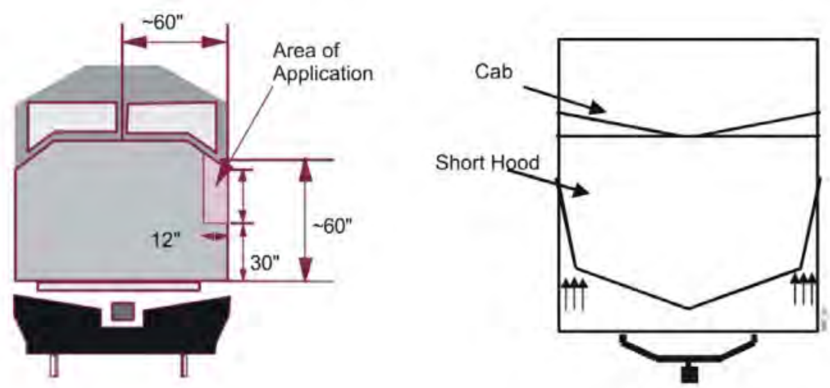

Fig. 6.2 Diagram of short hood load application

6.7.2 The minimum sheet thicknesses of the short hood skin must be selected to satisfy the following equation:

$$P_m = 6.36\sigma_o (b_1 t_1^2 + b_2 t_2^2)^{1/3} \frac{(t_1 t_2)}{(t_1 + t_2)}$$

where

P_m = mean crush force (400,000 lb)
b_1 = half dimension of short hood roof width (~60 in.)
b_2 = average hood height (~60 in.)
t_1 = thickness of short hood roof structure
t_2 = thickness of side walls
σ_o = material flow stress [$(\sigma_y \times \sigma_u)^{0.5}$] (see paragraph 6.7.2.1)

6.7.2.1 The flow stress is given by the formula

$$\sigma_o = (\sigma_y \times \sigma_u)^{0.5}$$

where

σ_y = material yield stress (psi)
σ_u = material ultimate stress (psi)

6.7.3 All skin on the front-facing portion of the short hood, including personnel doors, must be the equivalent strength of 1/2-in.-thick steel plate at 25,000 psi yield strength. (Thinner high-strength steel may be substituted where thickness varies inversely with the square root of yield strength.)

6.7.4 Any windows must meet FRA glazing standards per 49 CFR Part 223.

6.8 Truck Attachment

Attachment of each truck to the frame of the locomotive must withstand an equivalent ultimate shear value of 250,000 lb from the longitudinal to lateral, inclusive.

6.9 Underframe Strength

The underframe must be capable of withstanding a longitudinal load of 1,000,000 lb applied at the inner draft stops without permanent deformation of the body structure.

7.0 REQUIREMENTS FOR NARROW-NOSE LOCOMOTIVES

7.1 Anti-Climbers

Narrow-nose locomotives must meet the anti-climber requirements for wide-nose locomotives in paragraph 6.1 of this standard.

7.2 Collision Posts

Narrow-nose locomotives must meet collision post requirements for wide-nose locomotives in paragraph 6.2 of this standard.

7.3 Emergency Egress

The locomotive cab must allow for exit through at least one opening (e.g., engineer's side door, nose door, windows) in any locomotive orientation.

7.4 Emergency Interior Lighting

7.4.1 Illumination design shall provide sufficient illumination within the cab area to allow for safe egress from the locomotive cab in the event of a collision.

7.4.2 Emergency interior lighting shall activate automatically upon emergency brake application for a minimum of 20 minutes at the following levels: the exit path from each seat position to each exit door shall be automatically illuminated to a level of 0.5 lux in general and 2.5 lux on each stair step to be negotiated to the exit door and 2.5 lux at each door threshold higher than 1 in. Illumination shall be measured at floor level and perpendicular to the floor.

7.4.3 Emergency interior lighting shall operate in all equipment orientations.

7.4.4 The locomotive main battery system or a separate battery power source shall provide for a manual reset to extinguish emergency interior lighting (not required if other power source is used).

7.5 Fuel Tank

Narrow-nose locomotives must meet fuel tank requirements for wide-nose locomotives in paragraph 6.5 of this standard.

7.6 Interior Configuration

Narrow-nose locomotives must meet interior configuration requirements for wide-nose locomotives in paragraph 6.6 of this standard.

7.7 Operator's Cab Corner Posts

7.7.1 Corner posts must be provided at all corners of the cab structure.

7.7.2 Each corner post, supporting structure, and intervening connection must resist the following horizontal loads individually applied in the direction stated:

- Minimum of 300,000 lb applied at a point even with the top of the underframe without exceeding the ultimate strength of the post. This load must be applied at any angle in the horizontal plane in the range of ±8° from the longitudinal axis of the locomotive.
- Minimum of 100,000 lb applied at a height from the finished cab floor to a point 30 in. above the finished floor of the cab. This load must be applied at any angle in the horizontal plane in the range of ±8° from the longitudinal axis of the locomotive. This load must be applied without exceeding the ultimate strength of the post or its connections.
- Minimum of 45,000 lb applied anywhere between the top of the post at its connection to the roof structure and the top of the underframe without exceeding the ultimate strength of the post or its connections. This load must be applied toward the inside of the locomotive in any direction from the longitudinal to the transverse.

7.8 Operator's Cab and Hood Structure

7.8.1 The skin of the short hood end-facing area shall be equivalent to 1/2-in. steel plate at 25,000 psi yield strength (where thickness varies inversely with the square root of yield strength).

7.8.2 This end nose plate assembly shall be securely fastened to the collision posts.

7.8.3 Any personnel doors in the short hood end-facing area shall be suitably reinforced to the equivalent strength of the short hood skin.

7.8.4 Any windows must meet Federal Railroad Administration (FRA) standards.

7.9 Truck Attachment

Attachment of each truck to the frame of the locomotive must withstand an equivalent ultimate shear value of 250,000 lb from the longitudinal to lateral, inclusive.

7.10 Underframe Strength

Narrow-nose locomotives must meet underframe strength requirements for wide-nose road freight locomotives in paragraph 6.9 of this standard.

8.0 MONOCOQUE OR SEMI-MONOCOQUE LOCOMOTIVE DESIGNS

8.1 Anti-Climbers

Monocoque design and semi-monocoque design locomotives must meet the anticlimber design requirements for wide-nose locomotives in paragraph 6.1 of this standard.

8.2 Car Body Underframe Strength

The underframe must be capable of withstanding a longitudinal load of 800,000 lb applied at the inner draft stops without permanent deformation of the body structure.

8.3 Collision Posts

8.3.1 Collision posts must be located at the approximate 1/3 points across the width of the vehicle and must, in their entirety, be forward of the seating position of any crew person.

8.3.2 Each collision post, supporting car body structure, and intervening connection must resist the following loads individually applied at any angle in the horizontal plane in the range of ±8° of the longitudinal axis of the locomotive.

- Minimum 500,000 lb applied at a point even with the top of the underframe, without exceeding the ultimate strength of the post and its attachment
- Minimum 200,000 lb applied at a point 30 in. above the top of the underframe, without exceeding the ultimate strength of the post and its attachment
- Minimum 60,000 lb applied anywhere along the post above the top of the underframe, without permanent deformation

8.3.3 The area properties of the collision posts, including any reinforcement required to provide the specified 500,000-lb shear strength at the top of the underframe, must extend from the bottom of the end sill to at least 30 in. above the top of the underframe.

8.4 Emergency Egress

The locomotive cab must allow for exit through at least one opening (e.g., engineer's side door, front sheet door, windows) in any locomotive orientation.

8.5 Emergency Interior Lighting

8.5.1 Illumination design shall provide sufficient illumination, within the cab area to allow for safe egress from the locomotive cab in the event of a collision.

8.5.2 Emergency interior lighting shall activate automatically upon emergency brake application for a minimum of 20 minutes at the following levels: the exit path from each seat position to each exit door shall be automatically illuminated to a level of 0.5 lux in general and 2.5 lux on each stair step to be negotiated to the exit door and 2.5 lux at each door threshold higher than one inch.

Illumination shall be measured at floor level and perpendicular to the floor.

8.5.3 Emergency interior lighting shall operate in all equipment orientations.

8.5.4 The locomotive main battery system or a separate battery power source shall provide for a manual reset to extinguish emergency interior lighting (not required if other power source is utilized).

8.6 Corner Posts

8.6.1 The forward end structure shall have two full-height corner posts or equivalent structure.

8.6.2 Each corner post shall be capable of withstanding the following:

- A horizontal, longitudinal, or lateral shear load 300,000 lb applied at its joint with the underframe. This load shall be applied without exceeding the ultimate strength of the joint.
- A horizontal, longitudinal, or lateral force of 100,000 lb applied at a point 18 in. above the top of the underframe. This load shall be applied without exceeding ultimate strength.
- A minimum load of 45,000 lb applied anywhere between the top of the post at its connection to the roof structure and the top of the underframe, without permanent deformation.

8.6.3 Corner posts in locomotives with isolated cabs may be discontinuous at the boundary of the isolated cab, but shall otherwise meet the requirements of this part for corner posts. This may require intermediate supports for the portions of the corner posts of the locomotive platform structure and in the isolated cab, and limit stops on the possible displacement of the isolated cab.

8.7 Operator's Cab and Front End Structure

8.7.1 The skin of the front end-facing structure shall be equivalent to 1/2-in. steel plate at 25,000 psi yield strength (where thickness varies inversely with the square root of yield strength).

8.7.2 The skin of the front end-facing structure shall be securely fastened to the collision posts.

8.7.3 Any access opening in the front end-facing structure shall be suitably reinforced to the equivalent strength of the skin.

8.7.4 Any windows must meet Federal Railroad Administration (FRA) standards.

8.8 Fuel Tank

Monocoque and semi-monocoque design locomotives must meet the fuel tank requirements for wide-nose locomotives in paragraph 6.5 of this standard.

8.9 Interior Configuration

Monocoque and semi-monocoque design locomotives must meet the interior configuration requirements for wide-nose locomotives in paragraph 6.6 of this standard.

8.10 Truck Attachment

Attachment of each truck to the frame of the locomotive must withstand an equivalent ultimate shear value of 250,000 lb from the longitudinal to lateral, inclusive.

8.11 Roof Load and End Structure

8.11.1 Each roof rail shall be able to support a longitudinal load of 80,000 lb without permanent deformation.

8.11.2 Under load conditions that cause permanent deformation of the end structure, the roof structure must help support the load.

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(44 pages, total, in this report)