Caltrain 2025 European EMU CFR Compliance Assessment

Revision 8

December 1, 2009

1. EXECUTIVE SUMMARY

This document summarizes a compliance analysis that was performed for the Caltrain 2025 project, which includes the operation of non-FRA-compliant Electric Multiple Units (EMUs) in revenue service, mixed with FRA-compliant locomotive-hauled commuter trains, and temporal separation from freight trains. Several candidate European double deck EMUs (designed to EN15227 [1] and EN12663 [2]) were compared to the Code of Federal Regulations as applied to rail vehicles (49 CFR 200-299) [3] for the purpose of identifying regulations that are met by the current designs, regulations that could be met with practicable design changes, and regulations where compliance is not feasible. Figure 1 provides a flow chart that describes the process for determining whether to seek a waiver on each item in question. Based on the analysis, Caltrain intends to petition the FRA for waivers of the following regulations:

- 49 CFR 238.203 Static End Strength
- 49 CFR 238.205 Anti-Climbing Mechanism
- 49 CFR 238.207 Link Between Coupling Mechanism and Car Body
- 49 CFR 238.211 Collision Posts
- 49 CFR 238.213 Corner Posts

This analysis highlights the areas that require further study to determine the extent and practicability of changes to the vehicle or operation required to provide compliance. A formal system-level hazard analysis has been implemented by Caltrain to examine the necessary mitigation of known risks and demonstrate that overall system safety has not been reduced for this mixed equipment service in comparison to an operation with compliant rolling stock only.

Summary of CFR Titles, Parts, Sections, and Paragraphs in Question

While the existing European EMU designs do not meet many of the individual Title 49 CFR requirements, it should be possible to resolve the majority of non-compliance issues with only minor design modifications, mandated through the procurement technical specifications. Only a small number of CFR requirements will actually require a waiver, due to impracticability of design modifications and availability of adequate mitigation to maintain system safety. Table 1 contains a matrix that summarizes which Title 49 CFR requirements will require design changes, which are currently deemed impracticable and will require a waiver, and which require further study by the car builders to determine whether they are practicable or whether adequate system safety can be demonstrated. Many regulations are not addressed in this report. Those regulations for which switching to non-compliant EMUs will not change Caltrain's ability to comply or the applicability of that particular regulation are not addressed here in an effort to keep the report concise.

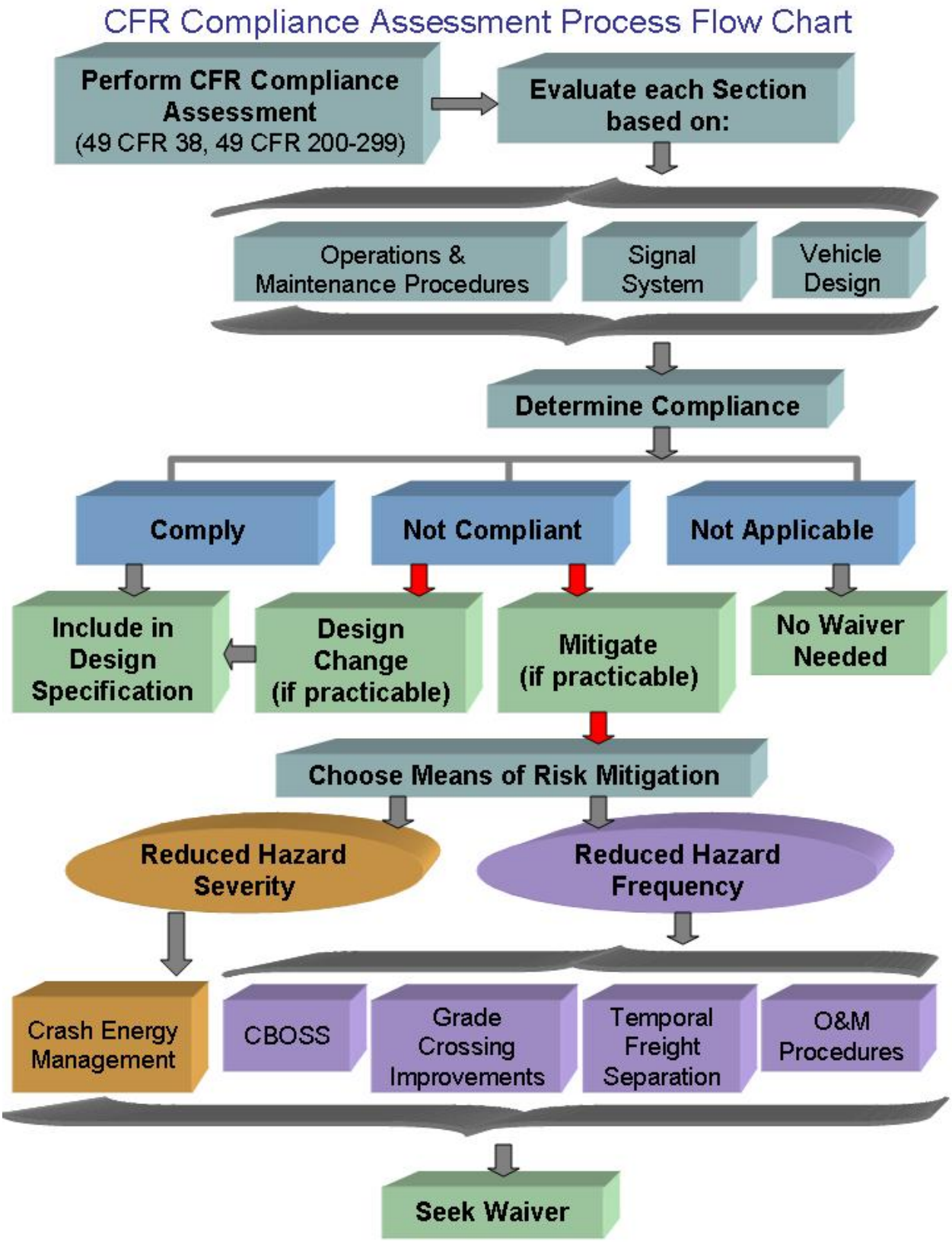


Figure 1. CFR Compliance Assessment Process

Table 1. Compliance Analysis Summary

Sub-section	Title/Description	Requires Further Analysis	Intend to Request Waiver	Intend to Specify CFR Compliance	Design Change Anticipated	Comments
49CFR38	**Americans with Diasabilities Act (ADA)**					
49CFR38 Subpart E	Commuter rail cars and systems			x	x	Current design is not fully compliant but compliance will be specified.
49CFR223	**Safety Glazing Standards**					
Appendix A	Certification of glazing materials			x	x	Current side glazings do not comply, but compliance will be specified.
49CFR229	**Railroad Locomotive Safety Standards**					
229.51	Aluminum main reservoirs			x	x	Current design is not built to ASME code, but compliance will be specified.
229.125	Headlights and Auxiliary Lights			x	x	Current design may meet requirements for triangular pattern. Candlepower unknown.
229.141	Body Structure, MU Locomotives			NA		Interpereted as not applicable. Identical requirements addressed in 49 CFR 238 for EMUs and Cab Cars
49CFR231	**Railroad Safety Appliance Standards**					
231.14	Passenger-train cars without end platforms			x	x	Current design does not fully meet requirements for handbrake, sill steps, handholds, handrails, side door steps, uncoupling levers. However, compliance should be feasible.
49CFR236	**Signal and Train Control Systems**					
236	Signal and Train Control Systems			x	x	Onboard equipment must comply with the forthcoming requirements for positive train control and must be compatible with Caltrain CBOSS specification.
49CFR238	**Passenger Equipment Safety Standards**					
238.103	Fire Safety	x		x	x	LTK is preparing a comparison of standards. Caltrain intends to meet with FRA separately on this issue. Biggest challenge may be floor burn-through requirement.
238.105	Train electronic hardware and software safety			x		Specification will require FMECA
238.113	Emergency window exits			x	x	Caltrain will specify compliance with emergency exit window placement, dimension, and marking requirements.
238.114	Rescue access windows			x	x	Caltrain will specify compliance with emergency access window placement, dimension, and marking requirements.
238.115	Emergency lighting			x	x	Caltrain will specify compliance with emergency lighting requirements.
238.121	Emergency communication			x	x	Likely that current backup power system does not comply.
238.123	Emergency Roof Access			x	x	May require relocating wiring or other elements to clear away soft spot in roof.
238.201	Scope/alternative compliance			NA		This method of alternative compliance will not be used, due to CFR-mandated operational restrictions.
238.203	Static end strength		**X**			800,000 pound buff strength will not be required in specification
238.205	Anti-climbing mechanism		**X**			Current CEM design is not compatible with this requirement, but equivalent safety can be demonstrated.
238.207	Link between coupling mechanism and car body		**X**			Current CEM design is not compatible with this requirement, but equivalent safety can be demonstrated.

Caltrain current and future operation complies with all CFR parts, sub-parts, and paragraphs not listed in this summary table

Table 1. Compliance Analysis Summary (Continued)

Sub-section	Title/Description	Requires Further Analysis	Intend to Request Waiver	Intend to Specify CFR Compliance	Design Change Anticipated	Comments
238.209	Forward-facing end structure of locomotives			x	x	Current design may not have skin strength equivalent to 25,000 psi yield 1/2" steel, but design modifications should be practicable.
238.211	Collision posts		**x**			Will specify compliance via new 238 Appendix F if released in time, otherwise equivalent safety will be demonstrated. Intermediate collision post requirement met through alternative means.
238.213	Corner posts		**x**			Will specify compliance via new 238 Appendix F. Need to analyze corner post at intermediate connections.
238.215	Rollover strength	x		x		Initial analyses indicate that current designs should meet requirement without modification. Compliance will be specified. Additional analysis will be required to determine if minor design changes are needed.
238.217	Side structure	x		x		Initial analyses indicate that current designs should meet requirement without modification. Compliance will be specified. Additional analysis will be required to determine if minor design changes are needed.
238.219	Truck-to-car body attachments			x	x	Current design does not comply but minor modifications can be made to comply.
238.221	Glazing			x	x	Compliance will be specified.
238.225	Electrical system			x		Compliance with US EMI requirements will be specified.
238.229	Safety appliances - general			x	x	Current design does not comply but minor modifications can be made to comply.
238.230	Safety appliances - new equipment			x	x	Current design does not comply but minor modifications can be made to comply.
238.231	Brake system			x	x	Compliance will be specified and may be achieved through a combination of design and inspection practice (pit).
238.233	Interior fittings and surfaces			x	x	Current design will not meet strength requirements for seats, and other interior fittings, but modifications are feasible, so compliance will be specified.
238.235	Doors			x	x	Compliance will be specified, knowing that minor modifications will likely be required to meet door emergency release requirements
238.301	Scope			x		Inspection, testing and maintenace for Tier 1 Passenger Equipment
238.307	Periodic mechanical inspection of passenger cars and unpowered vehicles used in passenger trains		x			Intend to propose inspection practices based on criteria other than specified time intervals in a separate waiver petition
238.309	Periodic brake equipment maintenance		x			Intend to propose maintenance practices based on criteria other than specified time intervals in a separate waiver petition
238.311	Single car test			x		Compliance will be specified as applicable to the vehicle design
49CFR239	**Passenger Train Emergency Preparedness**					
239.107	Emergency Exits			x	x	Caltrain will specify compliance with emergency access and egress window placement, dimension, and marking requirements.

Caltrain current and future operation complies with all CFR parts, sub-parts, and paragraphs not listed in this summary table
Any waiver to 238.307 and 309 would be sought later, after proving safety of alternate maintenance and inspection standards

2. SPECIFIC CFR PARTS OF TITLE 49

49 CFR 38 Americans with Disabilities Act (ADA) Accessibility Specifications For Transportation Vehicles

Full compliance with *Subpart E—Commuter Rail Cars and Systems* will be a requirement in the vehicle technical specifications. The current European EMU designs are compliant with European access requirements, which are similar to ADA, but not identical. It is anticipated that these requirements will primarily be met during the course of laying out the interior of the vehicle for Caltrain. However, it is likely that some design changes may be necessary simply to meet ADA.

It is yet undetermined how Paragraph 38.93(d) will be met. This dictates the interface between car door threshold and platform. This decision will be based on other factors, including existing state of station platforms, clearance required for other rolling stock on the right of way, and interface with existing Caltrain fleet. At this point, it is likely that very little modification of the EMU door threshold will be specified.

49 CFR 223 Safety Glazing Standards--Locomotives, Passenger Cars and Cabooses

Full compliance with this regulation will be a requirement in the vehicle technical specifications, including the process for certification of glazing materials. Recent studies have shown that European windshields should meet FRA Type I requirements, so it is likely that the supplier will not be required to modify the design. However, testing must be performed and the windshields properly etched.

FRA Type II side glazings are far different from the current European design. Type II impact requirements essentially lead to either polycarbonate or laminated glass, rather than the tempered glass solution used in Europe. Type II compliant side windows will be required in the specification. This will require a design modification by the car builder in three ways. First, a new glazing will be required, complete with test results and proper etching. Second, a new window gasket must be provided to fit the redesigned glazing. Third, the tempered glass provided emergency egress via the use of a hammer. This will no longer be the case, so emergency exit and access windows must be designed to meet the requirements of *49 CFR 238.113 Emergency Window Exits, 49 CFR 238.114 Rescue Access Window*s, and *49 CFR 238.221 Glazing*. This should not constitute a design change so radical that it places undue burden on the car builder.

49 CFR 229 Railroad Locomotive Safety Standards

The Code of Federal Regulations, part 49 CFR 229, discusses Locomotive Safety Standards. While it is anticipated that the majority of this regulation's requirements will be met, two subparts (C and D) of this regulation contain sections that will require design modification, waiver, or consideration for alternate compliance. All other sections either do not apply or are met by the current design. The two subparts and associated sections in question are:

- Subpart C – Safety Requirements
    - 49 CFR 229.51 - Aluminum Main Reservoirs
    - 49 CFR 229.125 - Headlights and Auxiliary Lights
- Subpart D - Locomotive Crashworthiness Design Requirements
    - 49 CFR 229.141 - Body Structure, MU Locomotives

49 CFR 229.51 Aluminum Main Reservoirs

It is Caltrain's intent to specify a compliant reservoir. Aluminum Main reservoirs, if used, shall be manufactured of Aluminum Association Alloy No. 5083-0 and produced in accordance with ASME SB-209. If alternate (European) design criteria are considered, proof of equivalency will be required via a waiver petition as outlined in 49 CFR 211.41. Given the time available in this program, it should be feasible for a European car builder to obtain reservoirs that meet 49 CFR 229.51.

49 CFR 229.125 Headlights and Auxiliary Lights

It is Caltrain's intent to specify a compliant light arrangement. Current vehicle designs appear to meet the triangular location and spacing requirements for headlights and auxiliary lights outlined in 49 CFR 229.125 as provided below. It is important that the triangular pattern be maintained, as it should provide a similar look to the older equipment, as it approaches a grade crossing.

"(ii) The auxiliary lights shall be spaced at least 36 inches apart if the vertical distance from the headlight to the horizontal axis of the auxiliary lights is 60 inches or more."

"(iii) The auxiliary lights shall be spaced at least 60 inches apart if the vertical distance from the headlight to the horizontal axis of the auxiliary lights is less than 60 inches."

The specification will require compliance with the lighting intensity requirements of the CFR. Bulb selection is limited at present and it would be expected that the builder may have to change fixtures to accommodate a compliant bulb.

49 CFR 229.141 - Body Structure, MU Locomotives

Subpart D is intended for locomotives, and in general, cab cars and EMUs are exempt, as referenced in 49 CFR 229.203 Applicability - (b) Cab cars and power cars. "The requirements of this subpart do not apply to cab control cars, MU locomotives, DMU locomotives, and semi-permanently coupled power cars that are subject to the design requirements for such locomotives set forth in part 238 of this chapter." However, 49 CFR 229.141(6) states "…Paragraphs (a)(2) through (a)(4) of this section do not apply to "passenger equipment" as defined in §238.5 of this chapter … unless such equipment is excluded from the requirements of §§238.203 through 238.219, and §238.223 of this chapter by operation of §238.201(a)(2) of this chapter." Section §238.201(a)(2) deals with alternative compliance for vehicles of special design that do not meet 49 CFR 238. Caltrain is not seeking approval through alternative compliance, but rather waivers to specific sections of 49 CFR 238, and interprets Subpart D to therefore be not-applicable.

The four 49 CFR 229.141 paragraphs that the EMU would not comply with (if applicable) are briefly discussed below. As noted in each case, waivers are being sought for the same design requirement under 49 CFR 238.

229.141 (a) (1) It is anticipated that a European EMU will not meet the 800,000 pound static end load requirement, and a waiver of this requirement will be petitioned. This subject is further discussed in the section of this report that addresses 49 CFR 238.203.

(2) The crash energy management (CEM) design utilizes many components and features specifically designed to prevent overriding or telescoping. However, it is likely that these elements are not designed to withstand a 100,000 pound vertical force, and re-design may compromise the effectiveness of the CEM design. Thus, a waiver will be requested, and is further discussed in the section of this report that addresses 49 CFR 238.205.

(3) The coupler carrier and its structural connections to the car body must withstand a 100,000-pound vertical down force. Compliance with this requirement may also impact the CEM system design. A waiver will be requested, and is further discussed in the section of this report that addresses 49 CFR 238.207.

(4) The requirement for vertical end members cannot be met with the current designs, but may be met through alternative means or waived, as discussed further in the section of this report that addresses 49 CFR 238.211 and 213.

(5) Truck-to-car body attachment strength is required to be at least the equivalent of an ultimate shear value of 250,000 pounds. It is anticipated that additional means other than the singular car body attachment may be required to achieve the 250,000 pound requirement. Compliance with this specification section will be required in the technical specification, and is further discussed in section of this report that addresses 49 CFR 238.219.

49 CFR 231 Railroad Safety Appliance Standards

The Code of Federal Regulations provides requirements for safety appliances on a variety of railcars. This requirement is statutory, so obtaining relief from it is much more difficult. Additionally, it would be best to provide safety appliances that matched those of the existing Caltrain fleet to the extent possible.

49 CFR 231.14 Passenger-Train Cars without End Platforms

This CFR paragraph requires a hand brake that operates in harmony with the existing power brake and can be safely operated while the car is in motion. Most European equipment of this class uses a spring-applied parking brake. 49 CFR 238.5 places both types of equipment in the same category; “Brake, parking or hand brake means a brake that can be applied and released by hand to prevent movement of a stationary rail car or locomotive.” The use of a spring-applied parking brake has been accepted by the FRA on other compliant EMUs as an acceptable substitute to a hand brake. Caltrain will allow either a hand brake or spring-applied parking brake in the specification provided it meets the basic criteria set forth in this CFR.

Locations and quantities of hand holds and steps are also provided in this section. Figure 1 shows a typical European EMU, and notes where compliance may or may not be achieved. Provided the overall dimensions and fastening methods are in accordance with 49 CFR 231.14(c)(4) the vertical handholds (1) and side door steps (2) would likely comply with 49 CFR 231.14(f). Non-compliance with 49 CFR 231.14(d) and 49 CFR 231.14(f)(4)(iii) is noted with regard to the absence of end (3) and side (door) handholds (4).

Figure 1. Safety Appliances

49 CFR 231.18 Cars of Special Construction

The contoured cabs of the European EMUs, their unit-train design, and the automatic couplers may not facilitate exact conformance with 49 CFR 231, and the use of this paragraph will likely be necessary to present the differences between the EMU safety appliances and those described previously. The EMU specification will require compliance, and the use of 49 CFR 231.18 would not be preferred. Obtaining approval from the FRA for deviations would be at the car builder's risk, even though the request would be made by Caltrain. A preliminary analysis was provided to the car builders for comment in 2008 [4].

49 CFR Part 236 – Signal and Train Control Systems

The Rail Safety Improvement Act (RSIA) of 2008 [5] was enacted on October 16, 2008. Among the safety initiatives, the RSIA requires implementation of Positive Train Control (PTC) on all passenger lines plus freight lines of any significance by the year 2015. Each affected railroad must develop an implementation plan by April, 2010.

Positive Train Control is not new terminology with RSIA; it has been used for many years as the general term for any "high tech" system that enforces train movement authority thereby preventing trains from colliding. Various PTC development and demonstration projects have been undertaken over the last two decades. None of the "high tech" PTC systems are in regular use in the United States today.

The RSIA defines a PTC as a system that provides four specific protections:

- It reduces the probability of trains colliding
- It reduces the probability of trains running at unsafe speeds, e.g., on curves
- It reduces the probability of trains running through switches set the wrong way
- It reduces the probability of trains entering work areas

Existing railroad signal systems and operating rules provide these protections, but in ways that can be subject to human error. RSIA requires these protections to be automatically provided by technical system(s) to avoid human error.

The RSIA does not specify how these protections are to be achieved. Within the industry there are a number of "lower tech" solutions that satisfy or come close to satisfying the definition of PTC. It is likely that replacement with a "high tech" form of PTC of such systems will not be required. In other words, the RSIA does not rule out meeting the requirements with an enhanced form of existing signal technology.

The RSIA gives the Secretary of Transportation – in practice, the FRA – the responsibility to define the regulations for PTC in "appropriate technical detail" and to provide "technical assistance" to railroads in implementing PTC.

RSIA also requires that each railroad, in developing its plans for PTC, address the question of interoperability, that is, the ability of trains from other railroads to provide the required protections when operating on the host railroad's PTC system. While not explicitly requiring a standardized PTC system, this part of RSIA does strongly encourage that outcome.

Caltrain is in the process of developing the functional / performance requirements specification for its Communication Based Overlay Signal System (CBOSS) [6]. CBOSS exceeds the protections mandated by the RSIA for PTC and will be applied across their fleet. Car-borne equipment for the EMU fleet, and the existing fleet of locomotives and cab cars, will incorporate CBOSS for compliance with the RSIA.

49 CFR 238 Passenger Equipment Safety Standards

Various subparts, specifically those concerning structural elements, are redundant to locomotive safety requirements listed in 49 CFR 229, but more applicable to passenger equipment. The most restrictive applies. This CFR part contains the majority of issues that must be addressed through design change mandated by specification or waiver. A section by section review of 49 CFR 238 is provided, even though no exceptions are taken to many of the sections. This was deemed useful given the focus of 49 CFR 238 on passenger railcars.

49 CFR 238.103 Fire Safety

This CFR is still under review by European car builders. While European vehicles meet similar smoke and flame requirements, the standards are not written the same, and it makes a direct comparison difficult. It is likely that some of the materials used in the European EMUs will not meet 238.103. Additionally, U. S. regulations require a high degree of floor fire resistance that is not required by European standards, and it is likely that substantial modifications would be necessary to the floor assembly to meet the U. S. requirement. While other European vehicles have been granted waivers on this requirement, providing other means were used to mitigate the risk, Caltrain will specify compliance with 49 CFR 238.103 in the EMU procurement. Caltrain will continue to work with the builders to determine the effect of this specification requirement on the procurement. An interim summary report of that study was provided to car builders for consideration [7].

49 CFR 238.105 Train Electronic Hardware and Software Safety

No exceptions to this part are anticipated. The technical specification will require a formal safety methodology that includes Failure Modes, Effects, Criticality Analysis (FMECA), and verification and validation testing for all hardware and software components. The verifications and validations will be required to follow a Capability Maturity Model Integration (CMMI) or equivalent methodology. It is anticipated that these requirements should already be in place, and since these are proven products, the documentation should be fairly complete already.

49 CFR 238.107 Inspection, Testing and Maintenance Plan

No exceptions to this part are anticipated. The car builder will be expected to fully support the development of the inspection, testing and maintenance plan by providing recommended intervals, testing procedures, maintenance procedures and special tools and test equipment.

49 CFR 238.109 Training, Qualification and Designation Program

No exceptions to this part are anticipated. The car builder will be responsible for training and designating its own test personnel as Qualified Mechanical Persons (QMPs) prior to the start of pre-revenue service testing.

49 CFR 238.111 Pre-Revenue Service Acceptance Testing Plan

No exceptions to this part are anticipated. A pre-revenue service acceptance testing plan will be required to be submitted to FRA at least 30 days in advance of the start of acceptance testing. The car builder will be expected to fully support this effort, and to provide all testing and scheduling documentation. Typically FRA also requests that a sample car inspection be incorporated into this effort. The car builder will also be expected to fully support this effort inclusive of providing a set of "FRA Drawings" illustrating the vehicle safety appliances cross referenced to the requirements of part 231.

49 CFR 238.113 Emergency Window Exits

No exceptions to this part are anticipated. While it will be necessary for a design change from current equipment configurations, the requirement for a minimum of four exit windows per upper and lower level, and two per end level will be incorporated in to the technical specification. Emergency windows must meet the 26" horizontal by 24" vertical dimensions and provide for unobstructed access. Design of the window frame and gasket must take into consideration the testing intervals required by 49 CFR 239.301.

49 CFR 238.114 Rescue Access Windows

No exceptions to this part are anticipated. Rescue Access Windows and Emergency Exit Windows may be combined into a single enclosure and shall be appropriately marked, if necessary due to existing car body design constraints.

49 CFR 238.115 Emergency Lighting

No exceptions to this part are anticipated. Emergency lighting, including a back-up power system capable of maintaining a minimum average of one foot-candle in all car body lean orientations within 45 degrees of vertical for a period of 90 minutes will be incorporated into the technical specification. This may require minor changes to the current designs, including larger batteries, and modifications to light

fixtures and placement. Back-up power systems may consist of secondary battery or capacitor based systems. As part of this requirement the Car builder will be required to provide a detailed load scheme including load shedding.

49 CFR 238.117 Protection Against Personal Injury

No exceptions to this part are anticipated. All moving parts, high voltage equipment, electrical conductors, switches, etc. shall be appropriately equipped with interlocks or guards to minimize the risk of personal injury and be appropriately marked. Again, this is good practice and likely not a change for the current designs.

49 CFR238.119 Rim-Stamped Straight-Plate Wheels

The technical specification will prohibit the use of rim-stamped straight-plate wheels.

49 CFR 238.121 Emergency Communication

Full compliance with the requirement for a standard intercom and passenger emergency intercom will be specified. This includes the post-derailment operational requirements for the power supply, including high acceleration and car lean angle. It is likely that the communication systems in the existing vehicles will be capable of providing the necessary features, but that the requirements for impact resistance and operation at a 45-degree car lean angle may require design modifications to the battery enclosures by the car builder.

49 CFR 238.123 Emergency Roof Access

Compliance with the requirement for provisions and marking for emergency roof access will be specified. The existing car body designs should have areas between structural elements that can be designated for this purpose, but existing wiring may need to be re-routed to avoid this area. This would be a minor design modification for the car builder.

49 CFR 238.201 Scope/Alternative Compliance

It is anticipated that Alternate Compliance will not be used in petitioning the FRA, as the operational requirements for grade separation and vehicle type separation are too restrictive for Caltrain's operating plan and current infrastructure.

49 CFR 238.203 Static End Strength

It is not practicable to modify a European EMU to provide 800,000 pounds of buff strength. This level of design change would not be feasible for a small order, and to require compliance would result in no bids

received. Thus, it is necessary to mitigate any risk through other means. The combination of a positive train control system and EN15227 compliance with CEM will reduce the probability of an impact and the severity of the outcome to the degree necessary to maintain system safety. **Thus, a waiver for 49 CFR 238.203 will be requested.**

Multiple analyses have been prepared in an effort to assist Caltrain and the FRA in determining overall occupant volume strength. These analyses, summarized in *Evaluation of European EMU Structure for Shared Use in the Caltrain Corridor* [8] indicate that, collisions between like EMU trains and between EMU and locomotive-hauled trains at closing speeds below 20 mph are survivable by passengers and crew, and that the performance of EMUs is at least equal to compliant equipment in these scenarios. The use of a positive train control system should greatly reduce the probability of higher speed collisions in which neither the EMU trains nor compliant equipment can prevent the loss of occupied space.

It can be shown that the most quantifiable data point is the speed at which the maximum force required to crush the car body is reached during full-train collisions. At this force level, the body will continue to plastically deform without providing a substantial increase in force. While this is idealized in that these types of collisions rarely happen in perfect alignment, the analysis is a very good measure of the bulk strength of each vehicle type. Figure 2 provides a summary of occupant volume crush values at different speeds, and indicates where the outcome would be considered **serious** (occupied space maintained, minor injuries, no loss of life), **critical** (cab space compromised, passenger space maintained, limited major injuries, possible loss of life), or **catastrophic** (passenger space compromised, loss of life, multiple major injuries).

The analyses performed by the Volpe Center [9] for cab-car-leading and locomotive-leading trains impacting a locomotive-led train seem to bracket the results for the EMU. However, the results for the locomotive-leading case are actually very similar to the EMU case. At speeds above 25 mph, the results would be classified as catastrophic because in addition to the cab, passenger-occupied space is compromised, implying multiple cases of serious injury or loss of life. At speeds below 15 mph, the results would be classified as serious for all vehicle designs, as there would be no loss of operator or passenger occupied space. In the 15 mph to 25 mph range, each vehicle type undergoes a transition in which some space is lost. For a typical cab car, the operator's space is compromised above 15 mph, indicating a critical outcome, and at about 18 mph, the passenger-occupied space is compromised. For the EMU, the operator's space is compromised above 20 mph, at which the outcome is considered critical. It is unknown at what speed the cab space in the locomotive is compromised, so the transition from serious to critical is unknown.

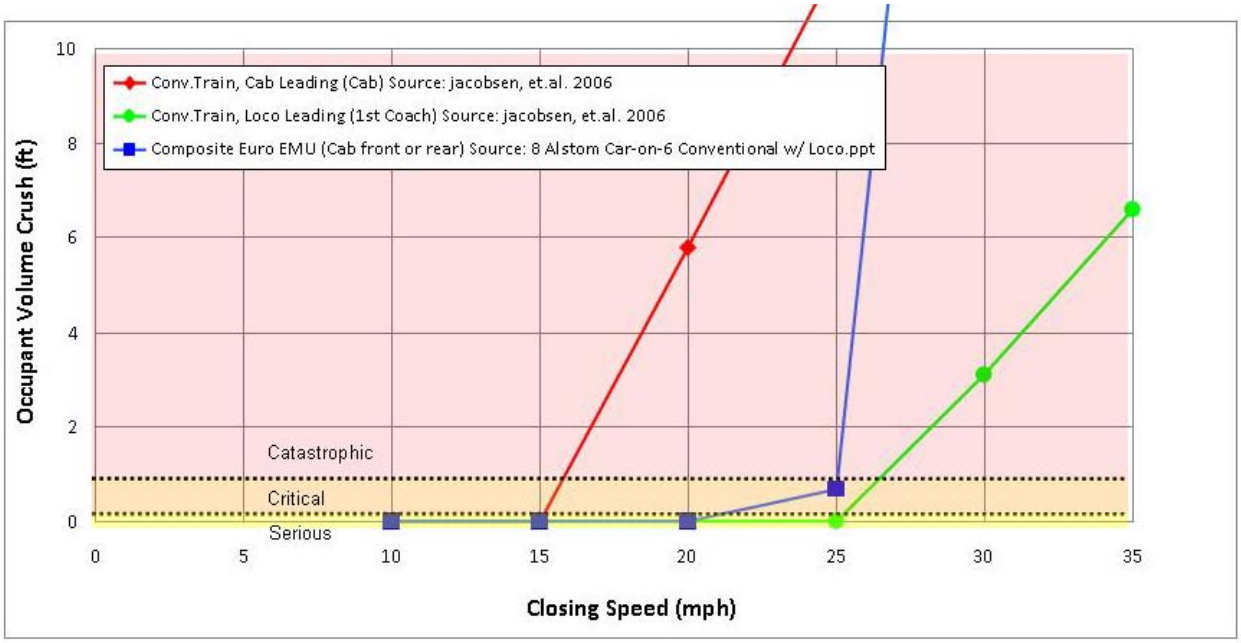


Figure 2. Train-to-Train Collision Crush at Various Speeds [8]

For the Caltrain waiver, it is the responsibility of the petitioner to prove that the system safety has not been compromised. This analysis does not examine the system as a whole, but only the vehicles. These analyses, performed by multiple organizations, indicate that the EN15227-compliant EMU provides the same occupied volume protection as an FRA-compliant cab car or coach in these train-to-train collision scenarios. Thus, it is not necessary to make alterations to other parts of the system to maintain system safety. However, it is clear that above about 25 mph, a means of mitigating the risk of serious injury or death to passengers is desirable for EMUs and compliant equipment alike. This was recognized by the FRA in a recent report and letter to Congress [10], as well as the Rail Safety Improvement Act of 2008 requiring positive train control. The argument presented in these documents is the same as the approach that Caltrain proposed at the beginning of this project, which is the use of a positive train control system to greatly reduce the probability of train-to-train collisions.

Any specific requirements relative to occupant volume strength that result from further analyses will be included in the EMU procurement specification. At a minimum, EN15227 and EN12663 compliance will be required, and analyses of the final design (after contract award) must be submitted by the car builder for Caltrain and FRA review.

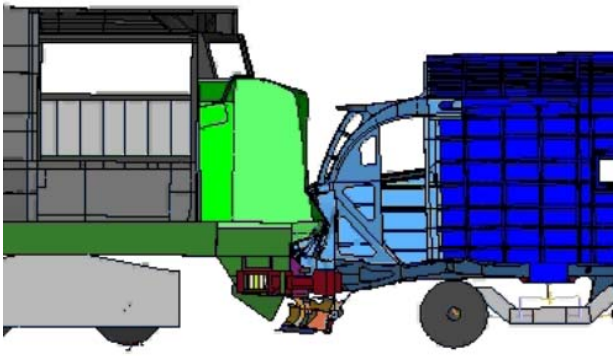
49 CFR 238.205 Anti-Climbing Mechanism

As stated in the 49 CFR 229.141 discussion, the CEM design utilizes many components and features specifically designed to prevent overriding or telescoping. However, it is likely that these elements are not designed to individually withstand a 100,000-pound vertical force as required by this CFR section, and

re-design may compromise the effectiveness of the CEM design. **Thus, a waiver for 49 CFR 238.205 will be requested.**

Inherently, CEM designs are intended to serve the function of anti-climbers, and can be much more effective than anticlimbers mounted on a compliant car. This is because CEM is meant to control the way that the energy is expended on impact, in all of the crushing of elements specifically designed for that purpose. The FRA's own research has concluded that CEM helps to prevent telescoping, and that railcars of a more rigid design can override or bypass each other laterally if the anti-climbers fail to engage. Figure 3 shows how the deformable elements in the nose of the EMU provide anti-climbing protection.

Alstom Coradia EMU-to-EMU Collision



Siemens Desiro EMU-to-Locomotive Collision

Figure 3. EMU Anti-Climbing Features [8]

These are post-impact images are for nominally 20 mph collisions between like trains and between dissimilar trains. In both cases, overriding or bypassing is not seen, because the crushable elements conform to the shape of the opposing structure, effectively locking the two trains together.

The intermediate connections within the EMU train take advantage of an energy-absorbing drawbar connection and anticlimber/absorbers, and while some deformation of the structure in this area may take place, the vehicles stay connected, preventing override or bypass.

49 CFR 238.207 Link Between Coupling Mechanism and Car body

The coupler carrier must withstand a downward force of 100,000 pounds without deforming (yield). However, the CEM design requires that both the couplers and the intermediate drawbars be allowed to move longitudinally under a load that is large enough to begin activation of the energy absorbing elements. Some vertical motion of the shear-back coupler may be necessary under these conditions to

allow the CEM system to be fully effective. As this CFR section does not allow yielding of the coupler carrier material, this requirement may interfere with the CEM design and is therefore not suggested as a practical design modification. In addition, the anti-climber characteristics provided by the drawbars and CEM design (as described for 49 CFR 238.205) will provide an equal level of override prevention required by this regulation. **Thus, a waiver for 49 CFR 238.207 will be requested.**

49 CFR 238.209 Forward-Facing End Structure of Locomotives

Caltrain will require compliance with 49 CFR 238.209 in the vehicle specification. However, the requirement in 238.209 for a ½" thick (or equivalent) end sheet may not be met with the current European designs. This is still under review. While this would be a relatively simple modification to an existing design, close attention must be paid not to alter the performance of the CEM system, and care must be taken not to increase the weight of the EMU beyond acceptable levels. If such an alteration is found to negatively affect CEM performance during the procurement, a waiver will be sought, providing assurance of intrusion prevention can be demonstrated.

This regulation is currently undergoing revision by the FRA, to allow an alternate method of proving the strength of the end structure of the locomotive or cab car. This is further discussed in sections 49 238.211 and 213 where it is most applicable.

49 CFR 238.211 Collision Posts

Collision posts are required at both ends of every car body, per 49 CFR 238.211. This section is very prescriptive in that it provides the basic physical features of the posts and the static loads that it must react. Current European EMU designs do not meet this requirement, but do provide an end structure that provides at least equal protection in frontal impacts, whether it be train-to-train or grade crossing train-to-truck. **As currently written, a waiver for 49 CFR 238.211 will be requested.**

The FRA is currently revising this section and it is likely that the revision will include an alternate method of proving the cab-end collision post (and corner post) compliance: *Appendix F to Part 238 – Alternative Dynamic Performance Requirements for Front End Structures of Cab Cars and MU Locomotives*. [11] Several European builders have already provided preliminary analyses that show that the current EN15227-compliant cab designs can withstand an impact with the steel coil, as originally proposed by the FRA. They should be able to meet the revised requirements for the proxy object cart test, as the impact energy is virtually the same. If the revision to the regulation is made, the EMU specification will require compliance via this method, including verification of final design, and the waiver will not be required.

In addition to train-to-train collisions, which have already been discussed in the section on 49 CFR 238.203, the end frame must protect against impacts with large obstacles, like highway trucks, at grade crossings. Two scenarios were examined in the Caltrain team analysis [8]; collision with a large

deformable truck per EN 15227 and collision with a steel coil on a flatbed trailer per the proposed 49 CFR 238 Appendix F. The FRA-compliant cab car and the EN15227-compliant EMU perform favorably and similarly in grade crossing collisions, with one exception. Limited data exists for the FRA-compliant cab car in a 70-mph impact with the deformable tank truck. Table 8 provides a summary of outcomes for use in the hazard analysis. An independent analysis performed by The Volpe Center [12] yielded results that were very similar to the Caltrain team analysis.

Table 1. Grade Crossing Collision Outcomes with Respect to Railcar and Passengers

Mishap	Speed	Outcome	Classification
EMU strikes trailer with rigid object on deck	<21 mph	Damage to railcar requiring repair prior to placing back in service (limited to fiberglass cowlings and crushable elements). No injuries to crew or passengers.	Serious
Compliant Cab Car strikes trailer with rigid object on deck	<21 mph	Damage to railcar requiring repair prior to placing back in service. Replacement of end sheet, collision post or corner post required. Minor injuries to operator, no injuries to passengers.	Serious
EMU strikes deformable semi trailer	<70 mph	Damage to railcar requiring repair prior to placing back in service (limited to replaceable elements at the front of the vehicle). Minor injuries to operator, no injuries to passengers.	Serious
Compliant Cab Car strikes deformable semi trailer	<50 mph*	Damage to railcar requiring repair prior to placing back in service. Replacement of end sheet, collision posts and corner posts required. Minor injuries to operator, no injuries to passengers.	Serious

* Volpe did not report results above 53 mph.

This regulation also requires collision posts at the rear of each car, or each end of a semi-permanently coupled multiple unit. Thus, the rear end of the power car and both ends of the intermediate cars must also be equipped with collision posts. Current European designs do not provide structure that would meet this requirement. However, 238.211 (c) (1) states that collision posts may not be required if: “The railroad submits to the FRA Associate Administrator for Safety under the procedures specified in §238.21 a documented engineering analysis establishing that the articulated connection is capable of preventing disengagement and telescoping to the same extent as equipment satisfying the anti-climbing and collision post requirements contained in this subpart” It is expected that the current designs combining anti-telescoping connections and CEM will provide a convincing argument to the FRA. However, the specification will require the car builder to submit the final design to support that argument.

49 CFR 238.213 Corner Posts

See the explanation for 49 CFR 238.211 in regards to forward facing corner post. **As currently written, a waiver for 49 CFR 238.213 will be requested.** If the proposed revision to the regulation is made, the EMU specification will require compliance via this method, including verification of final design, and the waiver will not be required for the cab-end corner posts. However, no relief for rear corner posts is provided for drawbar-connected cars. It is not likely that the corner post at the intermediate connection of an existing European EMU was designed to meet the regulation, as some crushing of that area may be allowed as part of the CEM design. Ultimately, intermediate car-to-car connections are well controlled in a collision due to the drawbar connection, the controlled crushing of CEM elements, and ultimately a rigid frame protecting the passenger compartment, which is the objective of this requirement. **Thus, a waiver for 49 CFR 238.213 will be requested for non-cab ends.**

Figure 4 shows the post-collision position of the rear of the EMU cab car and the front of the second car, after a 25-mph impact with a locomotive. The drawbar prevents override and bypass, and the two structures come together without compromising occupied space. Since the drawbar and the anticlimber/absorbers keep the two cars connected and aligned, there is no need to protect against impacts with other objects. This arrangement provides a level of protection from impacts that is, at a minimum, equivalent to the non-cab end frame requirement of 49 CFR 238.211 and 213. Note that the converging lines indicate that the finite element model of the trailing car was simplified through the use of beam elements based on the assumption that similarity between the two bodies would yield equally similar results.

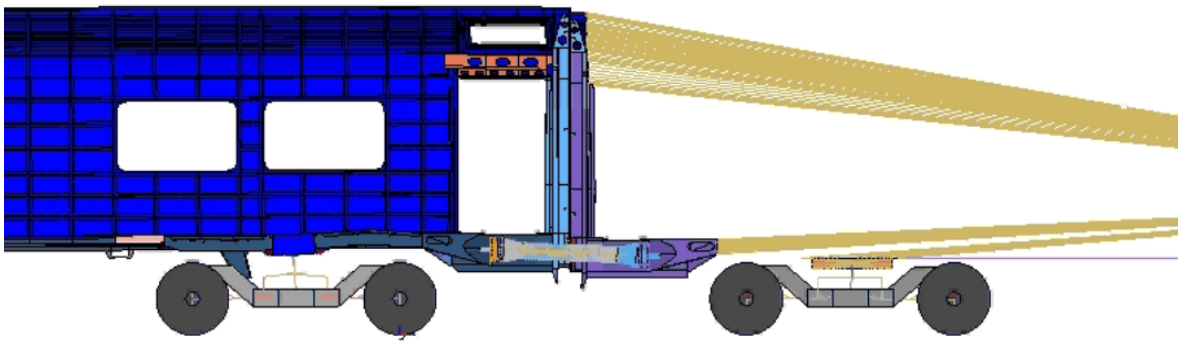


Figure 4. EMU Intermediate Connections in a Train-to-Train Collision [8]

49 CFR 238.215 Rollover Strength

Preliminary analysis of one European EMU indicates that the basic monocoque design provides a level of strength that would meet the load that simulates the car on its roof or side, with a 2.0 safety factor. Thus, the existing designs will likely meet this requirement without modification. Compliance with this section will be required in the vehicle specification.

49 CFR 238.217 Side Structure

This requirement, for the most part, is met by providing a certain section modulus with the side structure. Most vehicles meet this requirement because a typical sidewall design provides such a modulus. It is likely that the current designs will meet it, based on preliminary car builder calculations. Compliance with this section will be required in the vehicle specification.

49 CFR 238.219 Truck-to-Car Body Attachment

As stated in 49 CFR 229.141, car body attachment strength is required to be at least the equivalent of an ultimate shear value of 250,000 pounds. Although not clear in truck drawings reviewed to date, it is anticipated that additional means other than the singular car body attachment may be required to achieve the 250,000 pound requirement. This could be achieved through calculating the attachment strength of all components such as the traction rods or by simply adding a secondary securement means such as chains or J-hooks. Caltrain will require compliance with 49 CFR 229.141 in the vehicle technical specification.

49 CFR 238.221 Glazing

No exceptions to this part are anticipated. The technical specification will require full compliance with this part with regards to window securement and the requirements of part 223. Design changes may be necessary to meet the projectile impact requirements outlined in part 223 as well as the manufacturer validation and certification requirements.

49 CFR 238.223 Locomotive Fuel Tanks

Not applicable

49 CFR 238.225 Electrical Systems

No exceptions to this part are anticipated. The technical specification will require compliance with regard to the sizing of conductors, main battery system, power dissipation resistors (if applicable) and Electrical Magnetic Interference (EMI). North American EMI standards [13] are very conservative and will require extensive testing to insure radiated, inducted and conducted emission levels are within appropriate limits so as to avoid interference issues with the vehicles, other rolling stock, and the operating environment.

49 CFR 238.227 Suspension System

No exceptions to this part are anticipated. The technical specification will require vehicle stability and freedom from hunting oscillations at all operating speeds. Stability will be demonstrated during pre-revenue testing at all operating speeds up to 5 mph in excess of the maximum intended speed of 79 mph.

Various “worst case conditions” will be required to be simulated. via a proven vehicle dynamics model like NUCARS or VAMPIRE. No design changes are expected.

49 CFR 238.229 Safety Appliances - General

See previous discussion in 49 CFR 231. Compliance with this regulation will be specified unless it is deemed impracticable. The technical specification will reinforce the need for the car builder to comply with fastening methods and material dimensions dictated by the regulation, in addition to appliance placement.

49 CFR 238.230 Safety Appliances – New Equipment

No exceptions to this part are anticipated. Applicability of this section will be determined by the proposed design. If the car builder proposes a safety appliance and/or supporting component attachment scheme other than mechanical fastening, it will be Caltrain’s responsibility to seek approval from the FRA, but the approval itself will be at the car builder’s risk.

49 CFR 238.231 Brake System

No exceptions to this part are anticipated. However, an exterior brake indicator scheme (Figure 5) may require a design change and the addition of exterior indicator lights, cab indications, and associated circuitry for each truck (local identification) and overall trainline integration. Handbrakes and/or parking brakes will be required to be applied or activated by hand and provide a visual status indication. This may require some level of design modification, as the European EMU parking brake systems are not designed to comply with these requirements. During the procurement phase, computer modeling or dynamometer simulations will be required to demonstrate the friction braking system does not introduce excessive thermal stress to braking components or wheels. The specification will require air dryers that will provide main reservoir air with a dew point of at least 10°F below ambient temperature.

49 CFR 238.233 Interior Fittings and Surfaces

All interior fittings, including overhead storage racks, will be required to meet the 8g/4g/4g securement requirements by the technical specification. This will likely require some design changes as securement requirements in Europe are not so severe. Each seat shall be securely fastened to the car body as to withstand an individually applied acceleration rate of 4g acting in the lateral and upward vertical direction on the dead weight of the seat or seats. Additionally, the seat attachment must also be able to withstand a longitudinal inertial force of 8g. The Car builder will be required to fully comply with this requirement without exception.

Figure 5. Brake Indicator Locations

49 CFR 238.235 Doors

No exceptions to this part are anticipated. Current equipment designs appear to be fully compliant. A manual door override feature will be required, however it is anticipated that most modern day door manufacturers already include this feature as part of their design. However, the Car builder will be required to have provisions in the car body to accept this feature.

49 CFR 238.237 Automated Monitoring

No exceptions to this part are anticipated. The technical specification will require the use of an alerter and the supporting analysis for the timing sequence. It is likely that the existing designs will require some changes to provide alerter, event recorder, train control, and other cab equipment that do not match the current European equipment. However, these changes should be minor. The specification will advise the car builder to take note of the minimum event recorder channel requirements.

49 CFR 238 Subpart D – Inspection, Testing, and Maintenance Requirements for Tier I Passenger Equipment

This subpart is more applicable to the operation and maintenance practices of Caltrain and less applicable to specific rolling stock. However, the introduction of an entirely new and modern fleet provides Caltrain with a unique opportunity to propose modified maintenance procedures that better suit the envisioned operation. Caltrain may request a waiver to certain sections of this subpart after new equipment is in service and in can be proven that modified inspection and maintenance procedures are warranted.

49 CFR 238.301 Scope

No exceptions to this part are anticipated.

49 CFR 238.303 Exterior Calendar Day Mechanical Inspection of Passenger Equipment

No exceptions to this part are anticipated. Exterior calendar day inspections will be performed and documented as required.

49 CFR 238.305 Interior Calendar Day Mechanical Inspection of Passenger Equipment

No exceptions to this part are anticipated. Interior calendar day inspections will be performed and documented as required.

49 CFR 238.307 Periodic Mechanical Inspection of Passenger Cars and Unpowered Vehicles used in Passenger Trains

Caltrain intends to propose an inspection program based on mileage rather than calendar day intervals. This would be a separate waiver petition. Alternate periodic inspection intervals will require application to FRA supported by robust reliability assessment conducted under a system safety plan subject to peer audit. The Car builder and it suppliers will be required by contract to fully support this effort.

49 CFR 238.309 Periodic Brake Equipment Maintenance

Caltrain intends to propose a periodic brake equipment maintenance (COT&S) program that best suits the equipment used, rather than calendar day intervals. This would be part of the separate waiver petition mentioned previously or a completely separate petition. Alternate periodic brake inspection intervals to those listed will require submission of a waiver petition to FRA and be subject to a representative sample of teardown inspections from the initial interval to the target interval. The Car builder and its suppliers will be required by contract to fully support this effort.

49 CFR 238.311 Single Car Test

No exceptions to this part are anticipated, if this section is deemed applicable to the proposed design.

49 CFR 238.313 Class I Brake Test

No exceptions to this part are anticipated as this is an operational requirement. However, if the equipment design does not permit the visual observation of brake actuation and release without the inspector going on, under, or between equipment, additional over-pit inspections at an interval not-to exceed five (5) days will be written into the maintenance procedure, which is the current inspection procedure at Caltrain, as the disc-brake equipped coaches are regularly inspected over a pit.

49 CFR 238.315 Class IA Brake Test

No exceptions to this part are anticipated as this is an operational requirement as applicable. The brake indicators identified in 49 CFR 238.231 can be utilized for this task.

49 CFR 238.317 Class II Brake Test

No exceptions to this part are anticipated as this is an operational requirement. A communicating signal system will be required in the technical specification to assist in with this task.

49 CFR 238.319 Running Brake Test

No exceptions to this part are anticipated as this is an operational requirement.

49 CFR 238.321 Out of Service Credit

No exceptions to this part are anticipated as this is a means of extending periodic inspection mechanical inspection and periodic brake equipment maintenance intervals for a vehicle out of service for more than 30 consecutive days.

3. RISK MITIGATION FOR WAIVED REGULATIONS

Caltrain intends to petition the FRA for waivers for up to five regulations, depending on the outcome of proposed rulemaking. The following measures are proposed to mitigate any risk of operating equipment under waiver:

System-wide Measures

- Positive Train Control meeting FRA regulations currently under development
- Temporal separation of freight and passenger trains
- Continuous improvement of grade crossing protection systems
- Over-dimensioned lading detection in strategic locations

Rolling Stock Measures (by procurement specification)

- EN12663 PII Compliance
- EN15227 CI Compliance with following specifics:
    - Train-to-train collision scenario with 8-car like trains (22.5 mph)
    - Truck impact speed 110 km/hr (69 mph)
- Additional train-to-train impact scenario
    - 8-car EMU at 20 mph impacts locomotive at the head of a stationary 5-car train
        - EN 15227 performance criteria for train-to-train collision apply with one exception. Strains in excess of 10 percent would be reviewed on a case-by-case basis.
- Minimum car body ultimate buff (buckling) strength of 1.3 million pounds
    - Maximum load resisted while buckling or crushing
- Show that the train-to-train impact scenarios above do not result in overriding or bypass at the impact interface (cab end) as well as at the intermediate connections within the train
- Provide calculations showing the vertical and horizontal strength of all elements acting to restrain the vehicles during such impacts
- Compliance with the FRA collision post “proxy object cart” impact requirement currently proposed for 49 CFR 238.205 Appendix F
- Calculations showing the amount of deformation of the corner structure of the rail car when the static loads prescribed by 49 CFR 238.213 are applied does not compromise the occupied space

4. REFERENCE DOCUMENTS

The following documents were used as reference in preparing this analysis:

[1] EN15227 *Railway Applications – Crashworthiness requirements for railway vehicle bodies,* European Committee for Standardization, September 2007

[2] EN12663:2000, *Railway applications – Structural requirements of railway vehicle bodies,* European Committee for Standardization, 2000

[3] Code of Federal Regulations, Title 49, Office of the Secretary of Transportation, Subtitle B--Other Regulations Relating to Transportation, 200-299 Federal Railroad Administration, 2009

[4] ***Code of Federal Regulation Safety Appliance Overview*, LTK Engineering Services, 2008**

[5] H.R. 2095 -- *The Rail Safety Improvement Act of 2008* -- As enacted by Congress on October 1, 2008

[6] Caltrain Technical Document; *Specification for Communications-Based Overlay Signal System (CBOSS)*, 2009

[7] **LTK Engineering Services; *Comparison of U.S. and European Railway Vehicle Fire Protection Requirements,* LTK Engineering Services, February, 2009**

[8] Caltrain Technical Document - *Evaluation of European EMU Structure for Shared Use in the Caltrain Corridor Revision 2*, October 2009

[9] Jacobsen, Severson, Pearlman; *Effectiveness of Alternative Rail Passenger Equipment Crashworthiness Strategies,* USDOT, FRA, June 2006

[10] USDOT; FRA, *Report to the House and Senate Appropriations Committees: The Safety of Push-Pull and Multiple-Unit Locomotive Passenger Rail Operations,* Office of Safety of Railroad Development, June 2006

[11] Passenger Safety Working Group; *For Use of Passenger Safety Working Group's Crashworthiness Task Force Deliberative Document – Revision to 49 CFR 238.209*, 2009

[12] Llana, Patricia; Volpe Center; FRA, *Comparison of US & European Grade Crossing Impact Scenarios,* APTA, February 25, 2009

[13] LTK Engineering Services; *New Jersey Transit Arrow IV Technical Specification*; 2008

References in bold are attached in full.