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Preface

This document was prepared by the Railway Rolling Stock - Body Structural Requirements - Part 3 - Passenger Development Group, overseen by the RISSB Rolling Stock Standing Committee.

Objective

The objective of this document is to describe requirements for the structural strength of railway passenger rolling stock including crew cars.

The main purpose of the requirements are to:

1. prescribe the minimum structural integrity levels of the vehicle body to ensure safe performance under the operating conditions that the rolling stock will be subject to; and
2. minimize risks to persons (including train crew, train passengers and persons external to the train) and damage to railway infrastructure and other rolling stock in the event of collisions or derailments.

This document is intended to compliment the rolling stock compliance certification process outlined in AS 7501, including all vehicle types such as new, modified and heritage rolling stock.

The document has been significantly amended from the previous version with major changes throughout the document. It is recommended a thorough comprehensive review is undertaken for any users of the current version that will be applying this new revision of AS 7520.3.

Compliance

There are four types of provisions contained within Australian Standards developed by RISSB:

(a) Requirements.

(b) Recommendations.

(c) Permissions.

(d) Constraints.

Requirements – it is mandatory to follow all requirements to claim full compliance with the Standard. Requirements are identified within the text by the term ‘shall’.

Recommendations – do not mention or exclude other possibilities but do offer the one that is preferred. Recommendations are identified within the text by the term ‘should’.

Recommendations recognize that there could be limitations to the universal application of the control, i.e. the identified control is not able to be applied or other controls are more appropriate or better.

Permissions – conveys consent by providing an allowable option. Permissions are identified within the text by the term ‘may’.

Constraints – provided by an external source such as legislation. Constraints are identified within the text by the term ‘must’.

For compliance purposes, where a recommended control is not applied as written in the standard it could be incumbent on the adopter of the standard to demonstrate their actual method of controlling the risk as part of their WHS or Rail Safety National Law obligations. Similarly, it could also be incumbent on an adopter of the standard to demonstrate their method of controlling the risk to contracting entities or interfacing organisations where the risk may be shared.

RISSB Standards address known hazards within the railway industry. Hazards, and clauses within this Standard that address those hazards, are listed in Appendix B.

Appendices in RISSB Standards may be designated either “normative” or “informative”. A "normative" appendix is an integral part of a Standard and compliance with it is a requirement, whereas an "informative" appendix is only for information and guidance.

Commentary

Commentary *C Preface*

This document includes a commentary on some of the clauses. The commentary directly follows the relevant clause, is designated by ‘C’ preceding the clause number and is printed in italics in a box. The commentary is for information and guidance and does not form part of the document.

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Section 1 Scope and general

1.1 Scope

This document applies to:

(a) new and modified passenger rolling stock and crew cars; and

(b) the design, construction and maintenance of passenger rolling stock and crew cars.

The requirements mandated in this document do not retrospectively apply to any existing rolling stock other than rolling stock which is being modified in areas covered by this document so far as reasonably practicable.

The objective of this document is to mitigate, as far as is reasonably practicable, safety risks to the passenger rolling stock and crew car occupants due to derailments, collisions and roll-overs throughout the design life of the rolling stock asset. This document adopts European Norm (EN) structural integrity and crashworthiness standards as the foundation for designing and constructing passenger rolling stock and crew cars. It is further supplemented with additional international, national, and local standards and requirements to facilitate customization for the intended Australian rail networks. This approach also considers local safety incidence experience and collision scenarios not explicitly covered in the EN standards.

This document does not include the operation of rolling stock or cover rolling stock used on light rail, cane railways and monorail networks. Still, items from this document can be applied to such systems as deemed appropriate by the relevant RTO.

This document excludes passenger rolling stock utilising alternate fuels such as hydrogen, liquified natural gas (LNG) and compressed natural gas (CNG).

1.2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document:

- AS 3990, *Mechanical equipment - Steelwork*
- AS 4100, *Steel structures*
- AS 7470, Human factors integration in engineering design - General requirements
- AS 7501, *Railway rolling stock - Rolling stock certification*
- AS 7507, *Rolling stock outlines*
- AS 7509, *Rolling stock – Dynamic behaviour*
- AS 7522, *Access and Egress*
- AS/NZS 1554, *Structural steel welding*
- AS/NZS 2080, *Safety glass for land transport*
- AS/NZS 2208, *Safety glazing materials in buildings*
- EN 12663-1, *Railway applications – Structural requirements of railway vehicle bodies - Part 1: Locomotives and passenger rolling stock (and alternative method for freight wagons)*
- EN 15085 Series, *Welding of railway vehicles and components*
- EN 15152, *Railway applications - Front windscreens for train cabs*
- EN 15227, *Railway applications - Crashworthiness requirements for railway vehicles*

- EN 17149 Series, *Strength assessment of rail vehicle structures*
- EN 17460, *Railway applications - Adhesive bonding of rail vehicles and their components*
- EN 17976, *Railway applications - Bolting of rail vehicles and components*
- AAR M-1001, *Design fabrication and construction of freight cars (manual of standards and recommended practices section C, part II)*
- AAR Standard S-5506, *Performance requirements for diesel electric locomotive fuel tanks*
- AAR Standard S-580, *Locomotive crashworthiness requirements*
- APTA SS-C&S-034-99, *Standard for the design and construction of passenger railroad rolling stock*
- FRA Standard 49 CFR Part 223, *Safety glazing standards - Locomotives, passenger cars and cabooses*
- UK RSSB Standard GM/RT2100, *Requirements for rail vehicle structures*
- VDV Recommendation 152, *Recommendations on the design for strength of urban rail rolling stock according to BOStrab*

NOTE: Documents for informative purposes are listed in a Bibliography at the back of the document.

1.3 Terms, abbreviations and definitions

For the purposes of this document, the following terms and definitions apply:

1.3.1

AAR
Association of American Railroads

1.3.2
APTA
American Public Transportation Association

1.3.3
AW0
tare mass

load condition of a passenger vehicle or crew car carrying no passengers (or crew) in a serviceable condition.

Note 1 to entry: Includes (where applicable) the full operating reserves of water, sand and fuel.

1.3.4
AW1
AW0 plus load (or simulated load) of crew and seated passengers only (all seats occupied). Includes (where applicable) additional equipment such as catering and an allowance for passenger luggage

1.3.5
AW2
AW0 plus load (or simulated load) of crew and includes a combination of both seated (all seats occupied) and standing passengers

1.3.6
AW3
gross mass
crush condition

crush load
maximum service mass

AW0 plus load (or simulated load) of crew and the maximum possible number of passengers both seated (all seats occupied) and standing

1.3.7
CEMS
crash energy management system

1.3.8
CFR
US Code of Federal Regulations

1.3.9
CNG
compressed natural gas

1.3.10
crew area
space within a vehicle, or a complete vehicle allocated to the crew for work, rest or access path that leads to the allocated areas

1.3.11
crew car
relay car
rail test car

hauled vehicle utilized for the transport of workers in trains

1.3.12
critical design stress
taken as either the yield stress (0.2% proof limit) or 80% of the ultimate stress or 80% of the critical buckling stress whichever is less

1.3.13
EN
Euronorm - official European standard

1.3.14
external door
door on the side or end of a vehicle which provides access between the outside and the inside for either the train crew or the passengers

1.3.15
FEA
finite element analysis

1.3.16
GRP
glass reinforced plastic or glass reinforced polymer

1.3.17
heavy duty crew car
crew car used for example in freight heavy haul or standard gauge interstate operations, with potential trailing load greater than 5,000 tonnes

1.3.18
HF
human factors

1.3.19
human factors integration plan (HFIP)
plan that outlines how human factors are integrated into the overall engineering, assurance, and project management processes

1.3.20
light duty crew car
crew car used for example in light duty freight operations, with maximum trailing load of less than 1,000 tonnes, and a maximum tractive effort of 600 kN

1.3.21
LNG
liquified natural gas

1.3.22
long distance trains
trains operating with journeys of long distance and duration

Note 1 to entry: Typically, journey times are greater than several hours, for example on intrastate and interstate journeys.

1.3.23
medium distance trains
trains operating with journeys of intermediate distance and duration (typically between one and several hours), for example between urban centres

Note 1 to entry: Typically, journey times are between 1 and several hours greater, for example between urban centres.

1.3.24
medium duty crew car
crew car used for example in intrastate main and branch line operations, with maximum trailing load of greater than 1,000 tonnes and less than 5,000 tonnes and a maximum tractive effort of 1,200 kN

1.3.25
modifications
changes to a railway vehicle body structure or components which could affect its original structural integrity or safety in areas covered by this document

1.3.26
operating conditions
all expected conditions of payload, infrastructure interfaces and operating parameters that the rolling stock will be subject to throughout its operating life

1.3.27
RIM
rail infrastructure manager as defined by Rail Safety National Law

1.3.28
RSO
rolling stock operator as defined by Rail Safety National Law

1.3.29
RTO
rail transport operator as defined by Rail Safety National Law

1.3.30
RSSB
UK railway safety and standards board

1.3.31
short distance trains
trains operating with journeys of short distance and duration

Note 1 to entry: Typically journey times are under 1 hour.

1.3.32
UIC
International Union of Railways

1.3.33
underframe
metal framework carrying the main body structure of a vehicle usually located under the floor level

1.3.34
wheel guard
lifeguards
guard-irons

deflector mounted in front of the leading wheels of a vehicle to deflect small obstacles from the track

General rail industry terms and definitions are maintained in the RISSB Glossary:

https://www.rissb.com.au/glossary/

Section 2 General

2.1 Interpretation of vehicle structural requirements

The requirements in this document primarily relate to passenger vehicles (i.e. a single vehicle), however the design, construction and maintenance of the vehicles specified in this document shall include incorporation of all interfaces between vehicles that can make up a train, including crew cars.

2.2 Human factors integration

Human factors (HF) shall be incorporated from the inception of the procurement and design process.

Persons undertaking any HF activities shall be competent in human factors at a level appropriate to the activity being undertaken.

For the design of the body structural requirements, HF shall be applied for the following aspects at a minimum:

(a) identification of the full range of users and the context of use (e.g., drivers, train crew and passengers);

(b) assessment of train crew tasks, passenger access/egress and emergency egress;

(c) identification of HF issues and management of those issues throughout the design process including an assessment of compliance with the above requirements and restrictions; and

(d) design and undertaking of user testing to evaluate options and determine final design.

Human factors integration (HFI) into these design elements shall be undertaken in accordance with AS 7470, with the HFI process documented in that standard applied.

Verification of compliance with the requirements of this document shall be undertaken by calculation, inspection, comparison with other vehicles or test.

Commentary *C2.2*

The above process helps to ensure that the context of use and end users are appropriately identified, that HF requirements for the design are specified, that the required HF analyses are completed, that HF issues are systematically identified and managed throughout the design lifecycle, and that evidence of the HFI activities (through submission of a human factors integration plan (HFIP) and summary report) is documented.

The intent is to avoid issues where human interfaces are not optimized due to the structural design. Examples can include train crew interface with controls and safety devices, emergency egress of persons of the train, emergency access from persons external to the train and passenger/crew interfaces within the passenger/crew compartments.

RISSB Guideline – Integration of Human Factors In Engineering Design provides guidance on the human factors design process to assist in ensuring the asset is efficient and effective, meets its intended performance levels and is able to deliver the expected benefits to users and customers.

RISSB Guideline – Integration of Human Factors across the Project Lifecycle provides guidance on the implementation and effectiveness of HF Integration into projects by providing guidance on scaling and managing HF activities across a project lifecycle.

2.3 Inspection access

The design of the passenger vehicle or crew car shall assess areas of critical importance which will require inspection throughout the operating life of the vehicle.

Appropriate access to such areas shall be included as part of construction if it is practical to do so.

2.4 Marking and identification of rolling stock

The marking and identification of passenger rolling stock shall be in accordance with AS 7503.

The marking and identification of crew cars shall be in accordance with the passenger (locomotive hauled) rolling stock identifiers and markings defined in AS 7503 with additional marking and identification as below:

(a) the type of crew car (e.g., light, medium or heavy);

(b) the maximum rated trailing load (in tonnes); and

(c) the maximum rated motive power tractive effort (in kN).

The marking and identification of crew cars shall be clearly displayed on both sides and each end of the crew car in a predominant position.

Commentary *C2.4*

The purpose of marking the crew cars with the above information is to assist the train crew in assuring the correctly rated crew car has been marshalled into the train consist.

Section 3 Design verification

Verification of compliance with the requirements of this document shall be undertaken by calculation, inspection, comparison with other vehicles or test in accordance with EN 12663-1, EN 15227, EN 17149 and VDV Recommendation 152 as applicable.

Where requirements in this document differ from the listed standards above, the requirements of this document shall take precedence.

Verification of compliance with the requirements of this document shall account for the full range of variations in vehicle conditions that are likely to be experienced.

Where experimental verification is undertaken, a correlation between the analysis and test results should be carried out.

Commentary *C3-1*

It is suggested to apply a load factor to the proof load cases defined within this document where demonstration of compliance is exclusively by calculation to account for the possible inaccuracies in the assessment.

EN 12663-1 considers:

1. a proof load factor of 1.15; and
2. an ultimate load factor to prevent structural failure or instabilities of 1.5.

The stress criteria used in this document is the Critical Design Stress. Using a no significant permanent deformation criterion instead of the Critical Design Stress is also acceptable.

If demonstration of compliance with this document is undertaken using Finite Element Analysis, high localized stresses can exceed the stress criteria limits set in this document so long as one of the following conditions is fulfilled:

3. They are associated with model singularities; or
4. They would not result in significant permanent deformation being experienced by the vehicle structure when the load is removed.

Methods used to demonstrate that no significant permanent deformation is experienced include:

5. engineering judgement;
6. the use of non-linear analysis to determine if there is any deformation after a load application/removal cycle; and
7. relating the results of physical tests to analysis results.

Where this document adopts a prescribed load case from a specific nominated Standard (i.e. AAR, EN etc.) then the stress criteria proposed in that particular standard would be used.

Further guidance on the Finite Element Analysis of rolling stock body structures and the acceptability of calculated stresses is available in the AAR Manual M-1001 Section C-II and EN 12663-1.

The vehicle supplier shall provide the vehicle purchaser (which may be an RSO) all stress and fatigue analysis reports, model validation report, and physical test reports, concerning the structural integrity and crashworthiness of the rolling stock.

The reports shall include all necessary information, to enable the vehicle purchaser or RSO to conduct due diligence, including but not limited to the following:

(a) Structural representation – 2D and 3D drawings and models to fully define the primary carbody structures for FEA analysis, including detailed cross-sectional

areas and critical dimensions of individual structural members, subassemblies and general assemblies.

(b) Design concepts – detailed description of the structural and crashworthiness design concept including the main load paths in normal and collision scenarios and the position and stroke of energy absorbing elements during different stages of a collision.

(c) Structural connections – details of connections between structural members such as bolted, riveted and welded connections including details of webbing and flanges.

(d) Material properties – details of the materials used including strength and fatigue properties.

Commentary *C3-2*

The primary purpose of the vehicle supplier providing the above information is to allow the vehicle purchaser to undertake repairs or potential modifications to the rolling stock in the future.

APTA PR-CS-S-034-99 provides guidance on the type of information and details that is expected in the stress and fatigue analysis reports, model validation report, and physical test reports.

Section 4 Construction

4.1 General

Construction (other than metallic welding, bolted joints or bonding) shall be in accordance with relevant Australian or international standards applicable to the material.

The quality of the workmanship in construction shall ensure that the actual structure meets the structural requirements of this document.

The construction of the passenger vehicle or crew car shall be verified in accordance with the design documentation.

4.2 Welding/Fabrication

Metallic welding including repair and rectification shall be in accordance with EN 15085, AS 1554 or equivalent international standard.

4.3 Bolted Joints

Bolted joints shall be in accordance with EN 17976, AS 3990 or AS 4100.

4.4 Bonding

Adhesive bonding shall be in accordance with EN 17460.

Section 5 Maintenance and repair

5.1 General

Passenger rolling stock and crew cars shall have the structural integrity maintained over the asset service life including all external doors and window glazing.

The physical condition and functionality of crashworthiness elements shall be assessed and non-destructively tested as required during the service life to ensure performance meets the original requirements.

The vehicle designer should demonstrate that the output from fatigue assessments have been incorporated into the vehicle maintenance manual to guide the operator and maintainer on what critical areas of the vehicle structure are to be inspected to ensure structural integrity.

Any changes to operating conditions and/or parameters during the asset service life should be assessed in terms of any effect on the rolling stock structural integrity and crashworthiness.

Commentary *C5.1-1*

The weld categories in EN 15085 can be used as guidance for determining critical areas that could require inspection during the asset service life.

Crashworthiness elements include, but are not limited to, the following:

- collision post and corner post and their connections to the underframe
- energy absorbing elements of the crashworthiness system such as crash boxes, and draft gear deformable tubes that can possibly be affected by corrosion and degradation.
- anti-climber connections and interfaces
- secondary structural elements that interfaces with and protect crew and passengers in collisions and rollovers, such as vehicle side windows and windscreens

Some crashworthiness elements and secondary structural elements can be designed to last the life of the vehicle and are not typically replaced or overhauled unless damaged or are no longer fit for service. However, aging and degradation due to operating and environmental factors such as water ingress, extended exposure to solar radiation and minor collisions can affect the required functionality and performance of these elements. In some circumstances additional testing (e.g., destructive testing) could be required to sufficiently demonstrate compliance with original requirements.

Structural condition assessment and testing to detect deterioration of strength due to impact damage, cracking, erosion, and corrosion that can negatively impact the theoretical remaining fatigue life and structural safety of the passenger vehicle or crew car should be performed to industry recognized standards when the passenger vehicle or crew car:

(a) is subjected to a collision, derailment or other incident (e.g., high shunting loads);

(b) has a major overhaul or upgrade;

(c) is subject to potential degradation from corrosion, minor collisions or other causes;

(d) the designated design life is affected by a change in operating parameters; and/or

(e) as defined in the technical maintenance plan.

For passenger vehicles or crew cars that have reached the designated design life and are to have its asset life extended, structural condition assessment and testing to detect deterioration of the original strength due to asset operation shall be performed to industry recognized standards to determine the theoretical remaining fatigue life.

Commentary *C5.1-2*

An example of an industry recognized standard is EN 17149-3.

Any structural damage to a passenger vehicle or crew car body shall be repaired in such a way that the structural integrity is fully restored to at least as good as original condition.

Where a structural repair introduces design features that are different from the original design, the structural integrity of these features shall be demonstrated to meet the requirements of this document so far as is practicable, either absolutely or by comparison with other local design features.

5.2 Body mounted equipment

Fasteners, brackets and supports associated with equipment mounted to the exterior of the body including but not limited to:

(a) underframe mounted equipment;

(b) modular vehicle attachments, including cabs;

(c) end mounted equipment; and

(d) roof mounted equipment,

shall be maintained to prevent the equipment from detaching from the vehicle, encroaching upon the kinematic envelope, or adversely affecting the crashworthiness performance of the vehicle.

Commentary *C5.2*

The above intends to ensure adequate controls are introduced to address hazards associated with the failure of mounting systems due to inadequate maintenance procedures. When determining appropriate maintenance procedures, considerations can include material type, component serviceable life, failure modes of mounting system components and the effects of corrosion on structural integrity.

Section 6 Vehicle masses

Unless otherwise stated, the passenger vehicle and crew car masses to be used in all structural assessment presented in this document shall be AW0 and AW3.

Unless specified by the RTO, the mass per person for all types of passenger trains or crew cars used for payload calculations shall be 80 kg.

Unless specified by the RTO, the quantity of persons per square meter for standing persons in available standing spaces and additional mass allowances for luggage shall be:

(a) short distance trains:
  (i) AW2 – 4 persons/m^2
  (ii) AW3 – 6 person/m^2

(b) medium distance trains:
  (i) additional (average) luggage allowance per person – 5 kg
  (ii) AW2 – 2 persons/m^2
  (iii) AW3 – 4 person/m^2

(c) long distance trains:
  (i) additional (average) luggage allowance per person – 15 kg
  (ii) AW2 – 0 persons/m^2
  (iii) AW3 – 0 persons/m^2

(d) crew cars:
  (i) additional (average) luggage allowance per person – 20 kg
  (ii) number of persons per crew car - 8
  (iii) AW2 – 0 persons/m^2
  (iv) AW3 – 0 persons/m^2

Commentary *C6*

EN 15663 and AS 7501 provide definitions of vehicle reference masses and further guidance.

iMOVE 6-002, *Australian Size Variation for Design, M004: Detailed anthropometry dataset V2.0 30/06/2023* provides guidance and the most recent set of Australian persons anthropometric data.

Crew cars could need extra ballast mass added to the vehicle to control long train derailments from string lining or jack knifing. The designer could reference AS 7509 on longitudinal loads in curves and the maximum tractive effort of intended train operation.

Section 7 Structural rating

Passenger vehicle and crew car designs shall comply with the structural loads defined in this document based on the intended mode of operation and the likely loads the vehicle will experience in service.

For new passenger vehicles and crew cars, the structural rating used for the design and assessment of the structural performance in accordance with this document shall be either:

(a) marked on the underframe of the vehicle; or

(b) recorded in the vehicles data register as per the requirements of AS 7501.

The categories as per EN 12663-1 applicable to this document shall be:

(c) P-I for locomotive hauled carriages and crew cars

(d) P-II for vehicles for heavy rail multiple unit trains

(e) P-III for metro multiple unit trains operating on dedicated lines

Crew cars shall have specific requirements as defined in this document consistent with train forces in a freight operational environment.

Section 8 Structural requirements

8.1 Longitudinal proof loads

8.1.1 Compressive loads

Vehicle bodies shall be designed to withstand a compressive longitudinal load, applied along the centre line of the draft gear at each end of the body without exceeding the critical design stress, of the following applicable magnitude:

(a) 4,450 kN for heavy duty crew cars.

(b) 3,500 kN for medium duty crew cars.

(c) 2,000 kN for light duty crew cars.

(d) 2,000 kN for both P-I and P-II category vehicles.

Commentary *C8.1.1*

EN 12663-1 specifies a P-II compressive load of 1,500 kN. This document requires a greater than EN 12663-1 compressive load for P-II category vehicles.

(e) 800 kN for P-III category vehicles.

8.1.2 Tensile loads

Vehicle bodies shall be designed to withstand a tensile longitudinal load, applied along the centre line of the draft gear at each end of the body without exceeding the critical design stress, of the following applicable magnitude:

(a) 3,375 kN for heavy duty crew cars.

(b) 2,700 kN for medium duty crew cars.

(c) 1,500 kN for light duty crew cars.

(d) 1,500 kN for both P-I and P-II category vehicles.

Commentary *C8.1.2*

EN 12663-1 specifies a P-I and P-II tensile load of 1,000 kN. This document requires a greater than EN 12663-1 tensile load for P-I and P-II category vehicles.

(e) 600 kN for P-III category vehicles.

8.2 Anti-climb devices - general

Anti-climb devices shall be fitted to both ends of passenger vehicles as a means of constraining overriding by adjacent vehicle ends, and over-riding of vehicles within train sets, for the specified collision scenarios.

Commentary *C8.2-1*

Overriding constraint can be enhanced by:

1. a coupler with vertical movement constraint; and/or
2. articulated vehicles that share a common bogie.

Anti-climb devices should be fitted to crew cars.

Anti-climb devices shall be compatible and maintain override prevention with rolling stock within the same train, operating on the same network/s, and with buffer stops on the network/s of operation.

The anti-climb device and the structure behind the anti-climb device shall be compatible with structural requirements of the crash energy management system.

The design of the anti-climb devices shall allow for pitching of vehicles to minimize the risk of anti-climb devices not engaging at intercar connections for the specified collision scenarios.

Commentary *C8.2-2*

The configuration of the anti-climb devices ideally matches that of anti-climb devices on other rolling stock with which the vehicle is most likely to encounter.

8.2.1 Anti-climb devices – P-I and P-II category vehicles and crew cars

Vehicle bodies shall be designed to withstand a vertical load upwards or downwards of 200 kN applied on the anti-climb devices, without exceeding the critical design stress.

The vertical load shall be applied individually to each shelf of an anti-climb device, centrally and uniformly between centre sill webs.

The shelves or bars on anti-climb devices shall consist of the following physical characteristics:

(a) a minimum number of 3 shelves or bars;

(b) spaced vertically 50 mm to 110 mm apart;

(c) located horizontally to cover the fullest width of the body structure as practicable;

(d) not be less than 12 mm thick (vertically);

(e) protrude 25 mm or more (horizontally); and

(f) be located vertically to span the range of other rolling stock operating on the network.

8.2.2 Anti-climb devices - P-III category vehicles

Anti-climb devices for P-III category vehicles shall be compatible with the CEMS requirements of EN 15227.

8.3 Collision posts general

Commentary *C8.3*

The purpose of the collision posts is to prevent intrusion of colliding objects (e.g., other rail vehicles, freight containers, road vehicles, etc) into the occupiable spaces in the event of a collision or similar occurrence.

The purpose of the collision posts between each vehicle in the multiple unit trainset (i.e., intercar connections) is to primarily prevent over riding and telescoping of vehicles in the trainset into the occupiable spaces in the event of a collision or similar occurrence.

It is acceptable for cabs with noses to profile or even split the collision posts so as to match the general shape of the vehicle end.

8.3.1 Collision posts - P-I and P-II category vehicles and crew cars

Commentary *C8.3.1*

Collision posts can either be corner posts and/or gangway posts depending on the vehicle construction.

A minimum of two collision posts shall be provided at each end of the vehicle body.

Collision post should be located at each end, approximately 1/3 of the width in from the edge of the vehicle.

For vehicles with two collision posts, the collision post shall be designed to withstand the following applicable above-floor loading:

(a) a longitudinal load applied at 1,650 mm above rail level of 550 kN each for the two posts combined with a lateral force of 90 kN applied at diagonally opposite corners at the same height without exceeding the critical design stress of any vehicle body member; and

(b) each full height collision post shall be designed to withstand a longitudinal load of 150 kN applied to any point from top of underframe to cant rail without exceeding the critical design stress.

For vehicles with two collision posts, the collision posts shall be designed to withstand a longitudinal load applied at the lower connection to the underframe of 1,300 kN without exceeding the critical design stress of any vehicle body member.

When there are more than two collision posts, the total load prescribed for two collision posts may be distributed evenly between all collision posts.

8.3.2 Collision posts – P-III category vehicles

Collision posts (if fitted) for P-III category vehicles should be compatible with the CEMS requirements of EN 15227 and the load cases in EN12663-1.

8.3.3 Collision posts crew cars

With two collision posts, the collision post shall be designed to withstand the following applicable above-floor loading:

(a) For heavy duty crew cars as stated in AAR Standard S-580 for narrow nose locomotives.

(b) For medium duty crew cars, each collision post designed to withstand a longitudinal load applied 760 mm above the top surface of the underframe of 890 kN without exceeding the ultimate strength of the material.

(c) For light duty crew cars, each collision post designed to withstand a longitudinal load applied 760 mm above the top surface of the underframe of 445 kN without exceeding the ultimate strength of the material.

With two collision posts, the collision posts shall be designed to withstand the following applicable at-floor loading:

(d) For heavy duty crew cars as stated in AAR Standard S-580 for narrow nose locomotives.

(e) For medium duty crew cars, each collision post designed to withstand a longitudinal load applied in line with the top surface of the underframe of 2,250 kN without exceeding the ultimate strength of the material.

(f) For light duty crew cars, each collision post designed to withstand a longitudinal load applied in line with the top surface of the underframe of 1,000 kN without exceeding the ultimate strength of the material.

When there are more than two posts, the total load prescribed for two posts should be distributed evenly between all posts.

8.4 Corner posts

8.4.1 P I and P II category vehicles and crew cars

Corner posts shall be provided at each corner of each vehicle.

Each corner post shall be designed to withstand:

(a) a longitudinal compressive uniformly distributed force of 300 kN applied to the end of the vehicle at cantrail height without exceeding the critical design stress of any vehicle body member; and

(b) a longitudinal load of 150kN applied to any point from top of underframe to cantrail without exceeding the critical design stress of any vehicle body member.

8.4.2 P-III category vehicles

Corner posts (if fitted) for P-III category vehicles should be compatible with the CEMS requirements of EN 15227 and the load cases in EN12663-1.

8.5 Vertical proof loads

8.5.1 Live loads

Passenger vehicle and crew car bodies, when loaded to AW3, shall be capable of supporting the effects of a dynamic load factor representative of its operation for that load without exceeding the critical design stress.

Commentary C8.5.1

EN 12663-1 uses a dynamic factor of 1.3.

8.5.2 Vertical and longitudinal loads

Passenger vehicle and crew car bodies, when loaded to AW0 and AW3, shall be capable of supporting that load in the static condition combined with the longitudinal loads according to Clauses 8.1.1 and 8.1.2 of this document without exceeding the critical design stress.

8.5.3 Lifting and Jacking

Passenger vehicles and crew cars shall be designed to incorporate facilities for jacking and lifting operations during maintenance or after derailment.

Jacking and lifting points should be located as such to provide sufficient space underneath and around each jacking and lifting point to allow installation of rerailing and lifting devices both during maintenance and rescue/recovery.

Commentary *C8.5.3-1*

It is recommended that the RTOs existing emergency recovery equipment (e.g., jacks, lifting posts, lifting beams, lifting brackets, etc) and processes are evaluated against the jacking and lifting points of the new or modified rolling stock. The new or modified rolling stock could require additional recovery equipment to be acquired by the RTO or vehicle owner.

Vehicles at AW0 complete with bogies, shall withstand the loads arising from lifting and jacking in the following situations:

(a) Lifting or jacking from either end, on or near the draft gear carrier plate and coupler, with the vehicle supported by the other bogie without exceeding the critical design stress.

(b) Lifting or jacking the whole vehicle on jacking pads, or lifting brackets where fitted, without exceeding 0.6 x critical design stress.

Commentary *C8.5.3-2*

The supplementary requirements of AS 4991 can be used for the design of lifting devices used to lift railway vehicles.

8.5.4 Coupler vertical loads

The interface between the vehicle body and coupler shall be designed to withstand the loads applied to the coupler, both upwards and downwards, without exceeding the critical design stress, as per the following:

(a) A vertical coupler load of 220 kN for crew cars fitted with freight/general duty auto-knuckle couplers.

(b) A vertical coupler load of 150 kN for P-I category vehicles with passenger/light duty auto-knuckle couplers.

(c) A vertical coupler load of 100 kN, combined with a lateral load of 100 kN applied in either direction, for P-I, P-III and P-III category vehicles.

8.6 Crew car lateral proof loads

Heavy duty crew cars shall be able to withstand lateral coupler loads that result in the crew car experiencing 100 % wheel unloading.

Calculation should be used to determine this load from the maximum vehicle mass and the coupler height.

Medium duty crew cars shall be able to withstand a 450 kN lateral coupler load or lateral loads resulting in 100 % wheel unloading.

Light duty crew cars shall be able to withstand a 250 kN lateral coupler load or lateral loads resulting in 100 % wheel unloading.

Section 9 Testing

9.1 Static proof load testing

The static proof loads according to Clauses 8.1.1 and 8.1.2 of this document shall be verified by testing the vehicle structure on a bare vehicle car body shell in accordance with EN 12663-1.

The vehicle shall be supported on bogies and loaded with dead weight, simulating the weight distribution of an AW0 mass vehicle.

The FEA model being validated, shall accurately represent this structural support and vehicle weight distribution.

For new vehicles using existing vehicle designs:

(a) where no structural design changes to the FEA model are required, results of the original static proof load testing and evidence of correlation with FEA model is acceptable if it meets the testing requirements and correlation requirements of this document;

(b) where structural design changes will affect the structural performance of the vehicle necessitating a new FEA model, new static proof load testing and FEA model correlation assessment shall be conducted as per this document.

Commentary *C9.1*

Structural design changes to an existing vehicle structure can include:

- use of different materials

- change to fabrication methods (e.g., rivetted to welded)

- design improvements (e.g., for manufacturing)

- changes to proof loading requirements

9.2 Torsional load testing

The vehicle shall be tested to resist a three-point jacking case at most extreme outboard jacking locations, without permanent deformation and without damage to any component as per APTA PR-CS-S-034-99.

Section 10 Fatigue loads

A fatigue assessment shall be performed for all new and modified passenger vehicle and crew car designs.

Where available, load spectra that reflect the anticipated operating condition should be used.

Fatigue and stress analysis of the vehicle car body and other structural components, including load carrying brackets and their attachment to the car body, shall be in accordance with EN 12663-1 and/or VDV Recommendation 152.

Network specific track twist geometry data should be used for fatigue assessment of vehicle body twist. Ideally the twist displacement data would be used for the near same bogie spacing as the vehicle design. The twist displacement may be calibrated to twist loads based on AS 7509 twist test unloading data.

Commentary *C10-1*

Most Australian rolling stock operate on track alignments of historical curved and canted designs. As such Australian rolling stock operate in significantly more extreme track twist environments than typically used in international rail car standards.

Crew cars shall be assessed for longitudinal train force fatigue.

Crew cars should use AAR M-1001 spectra in the absence of train force measurement.

Heavy duty crew cars should use AAR ARC 5-pack loaded for longitudinal train force.

Medium duty crew cars should use 60 % cycle count AAR ARC 5-pack loaded for longitudinal train force.

Light duty crew cars should use 60 % cycle count and 60 % load factor AAR ARC 5-pack loaded for longitudinal train force.

Commentary C10-2

A suitable example of the process for fatigue assessment is described in the AAR Manual of Standards, Section C, Part II and EN 12663-1.

Generic structural standards such as AS 4100 or AS 3990 (for steel) and AS/NZS 1664 (for aluminium), or international equivalents such as BS 7608 and EN 1993-1-9, also contain suitable fatigue assessment processes.

An example of the fatigue assessment process (from BS 7608) is provided below:

1. The fatigue loading spectrum is determined from direct measurement, simulation, from other standards, or sinusoidal approximation (e.g., for locomotives +/-0.2g vertical for 107 cycles and + /-0.25g lateral for 107 cycles extracted from EN 12663);
2. the designer identifies all locations that are subject to fatigue loading;
3. for non-welded details and fusion welded fabrications BS 7608 is used to determine relevant classification and associated allowable stress at 107 cycles;
4. Miner's rule is used to add cumulative damages from each load case at each critical location; and
5. Mean - 2 Standard deviation data (i.e. 97.7% probability of survival) is the minimum level of confidence for fatigue life acceptance.

EN 1993-1-9 can also be used and details an alternate fatigue assessment process to the example above.

Section 11 Crashworthiness performance

11.1 Collision performance

Passenger vehicle structures shall be designed with a CEMS (crash energy management system) to dissipate kinetic energy during a collision as per the requirements of the crashworthiness design category C-I of EN 15227, with the following additional and amended requirements:

(a) low speed collisions at 5 km/h at AW0 shall not result in damage to the draft gear or vehicle structure;

(b) for vehicles operating in trains of up to 4 cars, the collision simulation shall replicate EN 15227 collision scenario 1 (leading end impact between two identical trains), but with a modification of the collision speed to 50 km/h;

(c) for vehicles operating in trains of between 5 cars and up to 8 cars, the collision simulation shall replicate EN 15227 collision scenario 1 (leading end impact between two identical trains), but with a modification of the collision speed to 42 km/h; and

(d) for vehicles operating in trains of over 8 cars, the collision simulation shall replicate EN 15227 collision scenario 1 (leading end impact between two identical trains), with the EN 15227 collision speed to 36 km/h.

For EN 15227 design collision scenario 2 (impact against an 80 t freight vehicle), the purchaser shall provide the supplier with the dimensions, geometry configuration and buffer type (e.g., side buffer or centre buffer coupler) of freight vehicles that operate on the network where the passenger vehicles or crew car shall also operate.

Design collision scenario 2 shall be assessed with the purchaser supplied information.

Commentary *C11.1*

AS 7524 can be a further reference for coupler heights.

The CEMS shall provide a controlled deformation and collapse of designated sections (crumple zones) to absorb collision energy and to reduce the decelerations on passengers and crew members.

11.2 Collision scenarios

The details of the collision scenarios beyond the scenarios according to Clause 11.1 of this document (i.e., applicable collision scenarios, impact speeds, state of braking, mass of vehicles, angle of impact, etc) and acceptance criteria shall be defined by the purchaser prior to contract award and shall reflect all operating positions and all operating conditions for which the vehicle was designed and include all directions of travel.

Commentary *C11.2*

Collisions not explicitly covered by or beyond the scope of EN 15227 and this document could include:

- collision speeds that exceed EN 15227 and this document collision scenario collision speeds;
- collisions with other rolling stock with higher or lesser crashworthiness or structural integrity (for mixed traffic operations);
- side-on impact collisions by a road truck or heavy motor vehicle at level crossings (for operations with no grade separation with road traffic);
- frontal collision with a road truck or heavy vehicle at level crossings (for operations with no grade separation with road traffic);

- collisions where the front CEMS does not activate and results in body pitching leading and inter-car anti climb devices not engaging;

- non-ideal collisions that occur on curved tracks, switches and crossings rather than direct head-on idealized collisions on straight tracks;

- collisions due to derailments causing a vehicle to enter the path of another vehicle resulting in partial frontal impacts or side swiping impacts; and

- vehicle rollovers due to derailment.

The supplier shall demonstrate how the rolling stock design performs in collisions defined by the purchaser not explicitly covered by or beyond the scope of EN 15227, this document and its design collision scenarios.

This demonstration may involve providing a combination of the following:

(a) Requirements already defined in this document.

(b) Simplified 1-dimensional collision simulations or static analysis of the additional design collision scenario simulations.

(c) Qualitative analysis of the inherent structural and crashworthiness design of the vehicle, incorporating design provisions from other industry-recognized standards and existing local practices.

(d) Analysis of the vehicle's design performance in previous real-world incidents.

The acceptance criteria should include:

(e) a limit on deceleration of the vehicles or a maximum collapse force; and

(f) a requirement that collapse of the vehicle structures is confined to the areas that have been identified in the CEMS as crumple zones.

Particular attention should be given to choosing crashworthiness requirements that are compatible with the proof strength requirements according to Clauses 8.1.1 and 8.1.2 of this document.

11.3 Penetration resistance

The front exterior face of the driver's cab, except for glazing, but including framework, panels and external doors shall have sufficient impact strength to resist penetration into the vehicle in accordance with the impact resistance requirements of EN 15152.

Commentary *C11.3*

The previous version of this document defined a sharp-cornered hollow steel cube based on the withdrawn standard BS 566.

The new requirement utilizes a different projectile in accordance with EN 15152.

Refer to Section 15 for glazing requirements.

11.4 Rollover performance

Vehicle bodies shall be capable of supporting the total mass of a fully loaded car (including bogies) with the car on its side or its roof without exceeding the critical design stress in the main structural members.

Commentary *C11.4-1*

Safety risks associated with vehicle rollover events can include, but are not limited to, the following:

- Loss of vehicle body structural integrity;

- Detachment of the drivers cab from the vehicle structure;

- Ejection of vehicle occupants from the vehicle or direct contact with the ground due to the loss of structural integrity of the vehicle body, bodyside doors and windows;

- Ingress of foreign matter such as dirt and ballast, due to dislodgement of doors and windows, and impacting vehicle occupants;

- Secondary impacts of vehicle occupants with the vehicle interior; and

- Delayed rescue or self-evacuation of passengers due to lack of egress points when the vehicle is resting on its side.

The supplier shall provide detailed information on the design provisions used to address rollover safety risks.

Other than the cab structure, vehicle bodies shall be capable of retaining the principal components (e.g., engine, alternator, bogies, compressor, HVAC equipment, onboard energy storage system) in the event of derailments, collisions, and rollovers.

Commentary *C11.4-2*

The intent is to provide a survival space for the passengers and crew within the vehicle in the case of rollover. Therefore, it is important to consider to what extent the adjacent structure such as vestibules or end wall cabinets are able to contribute.

Compliance with Clause 16.3 of this document can be an acceptable method of demonstrating retention of principal components in the event of derailments, collisions, and rollovers.

APTA SS-C&S-034-99 provides guidance on applied loads that can be incorporated into the design.

Refer to AS 7522 for emergency access and egress requirements.

11.5 Side impact protection

Vehicle body structures shall be designed to resist without exceeding the critical design stress an inward-directed load of:

(a) 180 kN applied to the full vertical dimension of the solebar for a distance of 2.4 m in the direction of the length of the vehicle; and

(b) 30 kN applied to the full vertical dimension of the waistrail for a distance of 2.4 m in the direction of the length of the vehicle.

Local yielding or failure of the skin or cladding is permissible in these load cases.

11.6 Roof structure penetration

The roof structure shall be capable of resisting the penetration of a concrete block weighing 100 kg (typical block size 300 mm x 300 mm x 300 mm) with the flat surface of the block impacting the roof surfaces of occupied areas of the vehicle dropped from 3 m above the roof without loss of interior ceiling height.

Commentary *C11.6*

Clause 11.6 provides a requirement to assist with managing impacts which could arise from a number of scenarios including but not limited to vehicle rollover on uneven surface or falling objects impacting the vehicle roof.

Section 12 Cowcatchers

A cowcatcher (also known as an obstacle deflector) shall be fitted to the leading ends of self-propelled passenger vehicles and comply with the requirements of AS 7507.

The cowcatcher shall comply with the requirements of EN 15227.

The cowcatcher should be detachable from the vehicle structure to assist with maintainability and ease of repair.

Commentary *C12*

A detachable cowcatcher also assists with recovery operations after a derailment and/or frontal impact.

Section 13 Wheel guards

As an additional safety measure, the leading bogie of self-propelled passenger vehicles should be fitted with wheel guards to minimize the risk of derailment due to small objects on the rails.

If fitted, wheel guards shall comply to the requirements of lifeguards in EN 15227.

Commentary *C13*

As per EN 15227, an obstacle deflector could negate the requirement for a wheel guard.

Section 14 Doors

14.1 General requirements

Doors shall comply with the passenger rolling stock requirements of AS 7522.

The design of the doors and surrounding areas shall assess and incorporate into the design the effects of events such as collision and vehicle rollover.

The vehicle designer shall identify potential failure modes of the external doors during collision and rollover and include design solutions that address these failure modes.

External doors shall be retained closed and latched under all normal operating conditions including shock/minor impact loads according to Clause 16.3 of this document and aerodynamic loads.

Door hinges, door latching mechanism, door lock, door structure and surrounding structural frame shall be designed to ensure that door failure (and thus ingress of debris such as ballast and soft earth) cannot occur following a rollover derailment at the maximum operating mass and speed.

The door assembly shall have an equivalent strength (i.e., perpendicular load over a given area) and penetration resistance to the neighbouring side walls of the vehicle structure.

If the doors are powered, the emergency ingress operation shall be available from ground level.

If the doors are manually operated, then the door handles/locks shall be accessible from ground level, inset and still be usable from both inside the vehicle and external to the vehicle in the event of a collision and/or rollover,

Door handles, or door operating buttons, should be recessed to help eliminate snagging that could otherwise occur in a rollover derailment.

Handrails should not block access to the doorways in the event of handrail detachment/distortion in the event of a collision and/or rollover.

The details of the load cases above (for external doors) shall be defined by the purchaser prior to contract award.

These details shall reflect all operating conditions for which the rolling stock will operate on and include all directions of travel.

An acceptance criterion shall be defined and agreed between the purchaser and the manufacturer.

Commentary *C14.1*

APTA SS-C&S-034-99 provides guidance on transverse strength requirements.

14.2 Retention of vehicle occupants

A closed and latched door panel, including any of its components such as:

(a) glazing;

(b) frame/mounting system(s); or

(c) associated door hardware such as latches, locks, hinges and tracks/runners,

shall be capable of retaining the vehicle occupants within the survival space.

Passenger external doors shall meet the requirements of static and aerodynamic load cases in GM/RT2100.

Commentary *C14.2*

The intent of Clause 14.2 is to ensure that the vehicle occupants are retained within the vehicle survival space.
Refer to AS 7522 for other requirements on doors.

Section 15 Glazing

15.1 Bonding

For glazing that is fastened by bonding (i.e., non-mechanically fastened), the bonding shall maintain the structural requirements in accordance with Section 15 of this document.

If any degradation of the bonding due to the effects of solar radiation, cleaning chemicals, applied graffiti, use of graffiti removal chemicals or any other potential reasons reduces the ability of the bonding to maintain the structural requirements specified in this document, then the supplier shall provide this information to the vehicle owner and/or RSO and include an appropriate inspection, testing and/or replacement regime in the maintenance documentation supplied with the vehicle.

15.2 Windscreens

Front windscreens shall comply with the passenger rolling stock requirements of AS 7522.

Windscreens include front and rear facing glazing.

The windscreens of passenger rolling stock shall be manufactured to comply with the requirements of AS/NZS 2080 supplemented by the impact requirements defined in one of the following standards:

(a) FRA Standard 49 CFR Part 223 Type 1;

(b) EN 15152; or

(c) GM/RT2100.

Windscreen mounting attachments, fixings and surrounding structure shall withstand the aerodynamic loads defined in GM/RT2100 without failure.

To control the risks of a windscreen detaching under impact (e.g., from derailment, impact or vehicle rollover), the windscreen, attachments, fixings and surrounding structure shall comply with the requirements of GM/RT2100.

The inside faces of the front windscreen and side windows of vehicle ends, which can be impacted or deformed during the design collision scenarios, shall be supported along their edges by overlapping the structure to limit intrusion into the vehicle in the event of a collision in accordance with EN 15227.

Commentary *C15-2*

The intent of this Clause 15.2 is to maintain a survival space for the crew in the crew cab.

15.3 Side windows

NOTE

Side windows include both passenger and crew area side glazing.

Side windows shall comply with the passenger rolling stock requirements of AS 7522.

All side window units and their attachment to the vehicle body (including windows fitted to side access doors) shall be manufactured to comply with the requirements of AS/NZS 2080 supplemented by the impact requirements defined in the following standards:

(a) FRA Standard 49 CFR Part 223 Type 2; and

(b) GM/RT2100.

Side windows including mounting attachments, fixings and surrounding structure shall withstand the aerodynamic loads, pressure pulse test and passenger containment test requirements defined in GM/RT2100 without failure.

In addition to the requirements of GM/RT2100, side windows shall be designed to minimize the possibility of a person being ejected from the vehicle in the event of a vehicle rollover and the injury to persons from glass shards inside the vehicle.

This shall be demonstrated by an appropriate series of type tests as per Appendix A.

Commentary *C15-3*

The additional tests proposed in this document are deemed more representative in terms of retention of persons in a rollover event.

15.4 Interior glazing

All interior glazing shall be manufactured to comply with the requirements of AS/NZS 2080 or AS/NZS 2208.

Section 16 Body-mounted equipment

16.1 General requirements

Body mounted components including hatches or expendable items that are hinged or moveable and can open and exceed the vehicle kinematic envelope shall incorporate a secondary method of restraining the component within the kinematic envelope.

Commentary *C16.1*

AS 7507 provides additional requirements for hatches and expendable items.

16.2 Underframe components

For underframe components that if detach could result in vehicle derailment, retention of these components to the rolling stock shall have at least one level of redundancy.

Commentary *C16.2*

Appropriate ways of meeting the requirements of Clause 16.2 can include a secondary restraint system, the over design of mountings and attachments, additional fasteners, captive connections or the provision of emergency restraints in addition to ensuring mountings and attachments meet the shock/minor impact loading requirements of Section 16.3.

Particular attention is warranted to the mounting and support of underframe equipment that is frequently removed.

16.3 Shock loading

The following accelerations applied individually to components and their mountings to the body shall not cause the critical design stress to be exceeded in any member:

(a) For PI category vehicles longitudinally +/- 5 g

(b) For PII and PIII category vehicles longitudinally +/- 4 g

(c) Laterally +/- 2 g

(d) Vertically +/- 2 g

The accelerations defined above shall also be combined with the load due to 1 g vertical acceleration (i.e. gravity).

The accelerations quoted above should be applied to the centre of inertia of the equipment.

Commentary *C16.3*

Refer to EN 12663-1.

Section 17 Diesel fuel tanks

Diesel fuel tanks mounted beneath the underframe shall comply with the requirements of AAR S-5506.

The requirement to design the diesel fuel tank to satisfy load cases 1, 2 and 3 of AAR S 5506 may be waived if it can be reasonably demonstrated that the design is safe so far as is reasonably practicable (SFAIRP) for the operating environment of the rolling stock to which the fuel tank is fitted.

Appendix A Side window testing (Normative)

This Appendix A details a series of type test scenarios to be applied to ensure compliance with the requirements according to Clause 15.3 of this document.

Modified or additional tests could also be applied to ensure compliance.

A test window frame shall be created to replicate the window frame to which the window glazing is bonded to on the vehicle.

The bonding of the test window glazing to the test window frame shall be representative of the actual installation on the vehicle.

A.1.1 Twist test

The test window frame, with glazing installed, shall be supported at two diagonally opposite corners.

A force shall be applied to the other two diagonally opposite corners to induce a deflection of not less than 6% of the diagonal dimension of the glazed area.

No debonding of the window glazing from the window frame shall occur.

Commentary *A1.1-1*

The intent of this test is to ensure that the bonding of the glazing to the frame does not fail due to torsional deflection experienced in a vehicle rollover.

As an example, deflection applied to a known Australian passenger vehicle window design was 120 mm.

The window shall be flipped over and the same twist test conducted on the other side of the window assembly on the other corners of the window assembly.

No debonding of the window glazing from the window frame shall occur.

Commentary *A.1.1-2*

The flipping of the window assembly is to reverse the torsion applied to the glazing, not to simulate any dynamic forces during a rollover. Although in a roll over the direction of the torsional forces on the window can change. It also ensures the window is symmetrically broken for the containment test per Appendix A.1.2 of this document.

Damage (e.g., fracturing) of both the inner and outer window glazing panels is permissible, however, there shall be no release of glass material from the inner side of the window or the formation of glass shards that could injure persons within the passenger or crew compartments.

Commentary *A1.1-3*

It is expected that a spall shield or window film would be applied to the window to assist in protecting passengers and crew from glass fragments.

If the glazing does not fracture during testing, the applied deflection shall be gradually increased until failure occurs.

The deflection at fracture shall be recorded. This is necessary to prepare a test specimen with fractured glazing for the containment test as per Appendix A.1.2 of this document, which requires both sides of the glazing to be fractured.

A.1.2 Containment test post twist test damage – 6 kPa pressure test

Following the test described above in Appendix A.1.1 where the window is fractured on both sides of the glazing panels, a containment frame shall be placed on the perimeter of the window frame and a

plastic sheet or similar applied inside and over the window frame edges to form a containment that can be filled with water.

The framed plastic sheet containment shall be slowly filled with the required volume of water that will exert a specified average pressure over the top surface of the window glazing of 6 kPa.

The amount of deflection or bowing at the centre of the window surface as the containment is filled with water, shall be measured and recorded.

The final deflection at the centre of the window shall be measured and not to exceed a pre-determined threshold.

Commentary *A1.2-1*

As an example, deflection threshold to a known Australian passenger vehicle window design was 100 mm.

The window shall be able to support the water filled containment at the maximum pressure, with no delamination of the bond and no further breakage of the interlayer for a period of 60 s.

Commentary *A1.2-2*

The purpose of this test and test A.1.2 are to ensure that a glass panel already subject to some damage will contain persons inside the vehicle in the event of vehicle rollover.

Appendix B Hazard Register (Informative)

Hazard Number	Hazard
5.1.1	Rolling Stock - Harm to the environment - Derailment or Collision, Human Error, Design Failure, Organisational SMS Failure, Security Breach, Loads not Secure and or Vandalism
5.2.1	Rolling Stock - Harm to infrastructure by rolling stock - Derailment or Collision, Human Error, Design Failure, Security Breach, Loads not Secure, and or Vandalism
5.3.1	Rolling Stock - Harm to persons - Derailment or Collision, Human Error, Track Failure, Design Failure, Health, Organisational SMS Failure, Security Breaches, Loads not Secure and or Vandalism
5.4.1	Rolling Stock - Harm to Rolling Stock - Derailment or Collision, Human Error, Track Failure, Track Obstruction, Design Failure, Health Failure, Organisational SMS Failure, Security Breach, Load not Secure and or Vandalism
5.7.1	Rolling Stock - Path Infringement - Derailment or Collision, Human Error, Track Failure, Track Obstructions, Design, Health Failures, Environmental Impact, Security Breach, Load not Secure, Vandalism and or Threat
5.8.1	Rolling Stock - Collision - Derailment, Human Error, Track Failure, Track Obstructions, Design Failure, Health Failure, Organisational SMS Failure, Security Breach, Load not Secure and or Vandalism
5.19.1	Rolling Stock - Derailment - Collision, Human Error, Track Failure, Track Obstructions, Design Failure, Health Failure, Security Breach and or Vandalism
5.28.1	Rolling Stock - Vehicles overturning - Derailment or Collision, Human Error, Track Failure, Track Obstructions, Design Failure, Health Failure, Organisational SMS Failure, Security Breach and or Vandalism

Bibliography (Informative)

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