Technical Report for

Interior Passive Safety in Railway Vehicles

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Foreword

The content of this document (UNIFE REF 001) has been prepared as a result of the outcomes of the EU funded project SafeInteriors. The Safe Interior project partners were: Alstom Transport, the Association of Train Operating Companies (ATOC), Bombardier Transportation, the University of Bolton, Fundación para la Investigación y Desarrollo en Automoción (CIDAUT), Deutsche Bahn (DB), Institut National de Recherche sur les Transports et leur Sécurité (INRETS), Instituto Superior Técnico, MIRA, Rail Safety and Standards Board (RSSB), Siemens, Société Nationale des Chemins de Fer Français (SNCF), UNIFE – The European Rail Industry Association, VUKV and Newcastle University.

The document aims to serve as input towards the European Standardisation and Regulation framework in regard to the development of common European requirements for Interior Passive Safety in Railway Vehicles. In particular, this document aims to provide an input towards the activities of the European Railway Agency regarding any definition of requirements in TSI concerning interior passive safety.

The normative references related to this document can be found in chapter 2 (Normative References) of this document.

**Eventual Publication as a TecRec (Technical Recommendation)**

The content of this document has been approved by UNIFE and is currently pending approval by UIC. When such approval is received this document will be superseded by a joint UNIFE-UIC Technical Recommendation (TecRec) and subsequently withdrawn.
Introduction

This document is a UNIFE technical report representing the outcomes of the joint UIC-UNIFE working group that at the request of the rail sector was asked to develop a TecRec. The content of this document has been approved by UNIFE and is currently pending approval by UIC. Individual companies may choose to mandate it through internal instructions/procedures or contract conditions.

Purpose of this document

- This document provides a voluntary standard for "Interior Passive Safety in Railway Vehicles" for use by companies in the rail sector if they so choose.

- The document is set out in the same format used in EN standards including, where appropriate, normative and informative annexes. This is so as to facilitate the interface with the ENs.

Application of this document

- These standards are voluntary. Individual companies may however elect to mandate all or part of its use through company procedures or contract conditions. Where this is the case, the company concerned must specify the nature and extent of application.

- Specific compliance requirements and dates of application have therefore not been identified since these will be the subject of the internal procedures or contract conditions of the companies which choose to adopt this standard.

Safety responsibilities

- Users of this document are reminded of the need to consider their own responsibilities under the relevant European or national safety legislation.

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Approval and authorisation of this document

- The content of this document was approved for publication by the UNIFE Technical Committee on 11 June 2014.
CONTENTS

Foreword ........................................................................................................................................ 2
Introduction ................................................................................................................................... 3
1. Scope ........................................................................................................................................ 6
  1.1 Application .......................................................................................................................... 6
2. Normative references ............................................................................................................... 7
3. Terms and Definitions ............................................................................................................. 7
4. Interior passive safety objectives (Informative) ..................................................................... 12
  4.1 Interior passive safety objectives ..................................................................................... 12
  4.2 Interior passive safety design considerations .................................................................. 12
5. Rail vehicle interior structural design criteria ....................................................................... 15
  5.1 Material properties for rail vehicle interiors (informative) ................................................ 15
  5.2 Structural acceptance criteria for rail vehicle interiors .................................................... 15
  5.3 Structural requirements for interior equipment attached to vehicle bodies ...................... 16
6. Rail vehicle interior design ....................................................................................................... 18
  6.1 General requirements ......................................................................................................... 18
  6.2 Rail vehicle interior areas subject to secondary impact .................................................... 18
  6.3 Interior doors, glazing and partitions ............................................................................... 22
  6.4 Handrails and hand holds .................................................................................................. 25
  6.5 Interior fixtures and fittings ............................................................................................... 26
  6.6 Luggage stowage ................................................................................................................ 28
7. Seats for passengers or staff ................................................................................................... 31
  7.1 Seats for passengers or staff ............................................................................................. 31
  7.2 Seat mounted tables .......................................................................................................... 36
  7.3 Dynamic assessment requirements for transverse passenger seats .................................. 37
8. Tables for passengers or staff .................................................................................................. 44
  8.1 Tables .................................................................................................................................. 44
  8.2 Dynamic assessment requirements for fixed tables for seated passengers ...................... 47
9. Dynamic methods for injury potential assessment (Informative) .......................................... 52
  9.1 Dynamic methods for injury potential assessment ............................................................. 52
  9.2 Dynamic unidirectional seat assessment for injury potential ........................................... 52
  9.3 Dynamic table assessment for injury potential .................................................................. 55
10. Verification ............................................................................................................................... 56
  10.1 Demonstration of railway vehicle interior structural integrity ........................................ 56
  10.2 Dynamic testing, computer simulations and calculations ................................................ 56
Annex A. Dynamic Test Procedures for Passenger Seats or Tables ........................................... 57
  A.1 Introduction ......................................................................................................................... 57
  A.2 Preparation of seats or tables for dynamic testing .............................................................. 57
  A.4 Dynamic test ....................................................................................................................... 58
Annex B. Longitudinal dynamic test pulse .................................................................................. 59
  B.1 Introduction ......................................................................................................................... 59
Annex C. Preparation and Setting Up Procedures for Anthropomorphic Test Devices (ATDs) .... 60
  C.1 ATDs for dynamic assessment ......................................................................................... 60
  C.2 ATDs for structural assessment ....................................................................................... 60
  C.3 ATDs for assessment of injury potential .......................................................................... 60
  C.4 Certification and calibration of ATDs ............................................................................... 61
  C.5 ATD preparation ................................................................................................................ 61
  C.6 Physical ATD positioning .................................................................................................. 62
  C.8 Instrumentation .................................................................................................................. 63
Annex D. Measurements and data requirements for dynamic testing ......................................... 64
  D.1 General Requirements ........................................................................................................ 64
  D.2 Motion analysis and contact point markings ..................................................................... 64
  D.3 Minimum ATD position measurement requirements ........................................................ 64
  D.4 ATD measurement and data requirements for physical and virtual tests ......................... 65
  D.5 Seat geometry measurements ........................................................................................... 66
  D.6 Table geometry (bay or seat back) measurements ............................................................. 66
Annex E. Injury Criteria .................................................................68
  E.1 Injury criteria assessment ......................................................68
  E.2 Head injury criteria ...............................................................69
  E.3 Neck injury criteria ...............................................................69
  E.4 Upper chest (thorax) injury criteria .........................................70
  E.5 Lower chest (abdomen) injury criteria .....................................70
  E.6 Leg injury criteria .................................................................71
Annex F. Residual space ................................................................73
  F.1 Introduction ...........................................................................73
  F.2 Residual space envelopes for seated passengers .........................73
  F.3 Determination of residual space for seated passengers ...............74
Bibliography ...............................................................................75
1. **Scope**

(1) This document sets out requirements to achieve an acceptable level of interior passive safety based on extensive research, for example the EU funded SafeInteriors research project, existing European and national standards and practical experience.

(2) This document is applicable to passenger vehicles designed for operation on TEN routes, international, national and regional networks (e.g. coaches, fixed units, trainsets), corresponding to categories P-I and PII as given in EN 12663-1 and categories C-I as given in EN 15227.

1.1 **Application**

1.1.1 **General requirements**

(1) It is intended that the interior passive safety requirements apply to vehicle interior elements that interface with passengers or staff as set out in this document.

(2) For new designs of vehicle the requirements set out in Chapters 6, 7 and 8 apply in full.

(3) For modifications to existing vehicles the requirements of Chapter 6 and Chapter 7 shall apply as set out in 1.1.2 and 1.1.3.

(4) Where additional vehicles of an existing design are added to an existing fleet or existing trainsets are extended or vehicles are built to replace damaged vehicles, it is permissible to comply with the original specifications and standards with respect to interior passive safety.

**NOTE 1:** Where additional vehicles are added into an existing fixed formation unit, for example lengthening an existing four vehicle trainset to five vehicles, it is intended that the original specifications and standards should be applicable provided that the design of the new vehicles is consistent with the existing vehicles.

1.1.2 **Minor changes**

(1) It is permissible to make changes or enhancements to a vehicle interior or to a distinct area of the interior using items to the same design principles as the existing vehicle interior.

**NOTE 1:** An example of the type of minor change envisaged would be a rearrangement of a vehicle saloon, without any modification to the component parts, to change the mix of bay and unidirectional seating (using the existing seats and tables if fitted).

(2) Where seating layouts are modified to rearrange the layout of seats and tables, if any new or replacement items are consistent with the existing vehicle interior in terms of design principles, method of construction, installation and validation, the requirements of this document are not applicable.

**NOTE 2:** An example of the type of new or replacement item envisaged would be a mirror copy of an existing luggage stack.

(3) Where items to a new design are substituted or added, for example panelling, partitions, doors, grab rails, grab poles, luggage stacks or luggage racks, the substitute or additional items shall comply with the relevant requirements of Chapter 6 in this document.

1.1.3 **Refurbishment**

(1) For refurbishment of existing vehicles, the requirements shall apply to new components in the areas where the vehicle interior is removed and replaced with a new design.

(2) Where due to limitations imposed by the underlying vehicle structure or sub-structures, it is not practicable to achieve full compliance, the requirements of this document should be applied as far is reasonable to improve the level of interior passive safety and the overall result shall, as an absolute minimum, achieve the same design standard as the existing vehicle interior.
NOTE 1: For some older vehicles it is recognised that the side wall or floor structures might not be sufficient to permit full compliance without substantial re-engineering in which case a compromise between the requirements and the build standard is justified on the grounds that a reasonable opportunity to achieve compliance with the requirements does not exist.

2. Normative references

The following referenced documents are indispensable for the application of this document. ENs are developed by CEN (www.cen.eu) or CENELEC (www.cenelec.eu) and are made available for their members.

(1) EN 12663-1:2010, Railway applications – Structural requirements of railway vehicle bodies – Part 1: Locomotives and passenger rolling stock (and alternative methods for freight wagons)

3. Terms and Definitions

For the purposes of this document, the following terms and definitions apply. Definitions do not contain requirements.

3.1 Access panel
A panel or other part which can be opened or removed for maintenance purposes, or for access to equipment or controls when in service.

3.2 Anthropomorphic test device (ATD)
Full-scale dummies which simulate the dimensions, articulation and mass distribution of the human body.

Note to entry: Also known as crash test dummies. ATDs are often instrumented to record acceleration, force and displacement data in impacts.

3.3 Mobile equipment
3.3.1 Fixed catering trolley
A removable or exchangeable part of the catering equipment which in service is secured so that it forms part of the fixed furniture and equipment.

3.3.2 Mobile catering trolley
Mobile equipment which staff move through a train to provide at-seat catering services.

3.3.3 Service trolleys
Mobile equipment used for purposes other than catering.

Note to entry: Examples are trolleys for the distribution and collection of bedding in sleeper vehicles or trolleys for the collection of refuse.

3.4 Edge
The outside limit of an object, area, or of a thin flat object, one of the narrow surfaces showing the ‘thickness’ or smallest dimension.

3.4.1 External edge
See figure 3.1.

3.4.2 Internal edge
See figure 3.1.
3.4.3 Corner
The junction between two or more surfaces or edges.

3.4.4 Exposed edge
An edge which, in normal service, can be contacted by any part of a person's body.

3.4.5 Directly exposed edge
Exposed edge visible from a seated or standing position.

3.5 Free flight velocity
The relative velocity of an unrestrained occupant or object with respect to the vehicle.

3.6 Handrail
Continuous element for passengers to use to aid stability by gripping around.

3.6.1 Grab rail
Continuous handrail for passenger stability and support normally fitted in a horizontal orientation.

3.6.2 Grab pole
Continuous handrail for passenger stability and support normally fitted in a vertical orientation.

3.6.3 Grab handle
Short handrail designed to be gripped or held for support and to aid personal stability.

Note to entry: typically intended for a single user.

3.7 Hand hold
A shaped protrusion designed to be gripped or held in order to aid personal stability.

Note to entry: typically intended for one hand, for a single user.

3.8 H-point
The position of the pivot centre of the human torso and thigh defined by X, Y and Z coordinates.
3.9 Interior
Internal areas of a vehicle, excluding driving cabs, accessible to passengers and/or staff.

3.10 Interior door
A door which provides access from one part of a vehicle interior to another.

3.11 Interior glazing
Glass used exclusively in the interior of a vehicle.

Note to entry: Bodyside or any other windows between the vehicle interior and exterior are excluded.

3.11.1 Interlayer
One or more layers of material acting as an adhesive and separator between plies of glass and/or plastic glazing sheet material. (Source: EN ISO 12543-1:2011)

Note 1 to entry: The interlayer can also give additional performance to the finished product, for example impact resistance, resistance to fire, solar control and acoustic insulation.

Note 2 to entry: The interlayer itself can also encapsulate non-adhesive films and plates, wires, grids, etc.

3.11.2 Laminated glass
Assembly consisting of one sheet of glass with one or more sheets of glass and/or plastic glazing sheet material joined together with one or more interlayers. (Source: EN ISO 12543-1:2011)

3.11.3 Laminated safety glass
Laminated glass where in the case of breakage the interlayer serves to retain the glass fragments, limits the size of opening, offers residual resistance and reduces the risk of cutting or piercing injuries. (Source: EN ISO 12543-1:2011)

3.11.4 Toughened safety glass
Glass within which a permanent surface compressive stress, additionally to the basic mechanical strength, has been induced by a controlled heating and cooling process in order to give it increased resistance to mechanical and thermal stress and prescribed fracture characteristics. (Source: EN 12600:2002)

Note to entry: Thermally toughened glass is difficult to penetrate, but if broken it fragments into small relatively harmless pieces.

3.12 Luggage rack
Rack installed at ceiling height intended for stowing of passenger items.

Note to entry: Equivalent to baggage racks as specified in UIC leaflet 562.

3.12.1 Auxiliary luggage rack
A shelf provided for stowing small passenger items for example coats or walking sticks.

Note to entry: Typically these are positioned beneath and in parallel with luggage racks. Equivalent to stick-racks as specified in UIC leaflet 562 and umbrella racks as specified in UIC leaflet 566.

3.13 Luggage stack
A low-level unit intended for stowing large or heavy items of passenger luggage.

Note to entry: Typically a floor or wall mounted unit. Equivalent to baggage shelves as specified in UIC leaflet 562.

3.14 Post-yield plasticity
The ability of a material to continue deforming in a plastic manner after it has reached yield point.

3.15 Primary impact
The original or initial impact of a colliding vehicle with another vehicle or obstacle.
3.16 Primary structure
The vehicle bodyshell or an intermediate sub-structure directly attached to the bodyshell to which the vehicle interior is mounted.

Note to entry: Examples are a resiliently mounted floor or the intermediate floor sub-assembly in a double deck vehicle.

3.17 Proof load
A load which represents or is intended to be equivalent to an exceptional maximum load that could be encountered when in normal service and which, when applied and removed, results in no damage, loosening of fixings or deformation that would require repair or replacement.

Note to entry: Normally a proof load is a static or quasi-static load which has been derived from more complex dynamic conditions.

3.18 Residual space
The space remaining around a person inside a rail vehicle due to deformation of the vehicle or its interior after an accident.

Note to entry: Residual space requirements are intended to maximise the possibility of survival in cases of gross deformation or collapse and generally to minimise the risk of injury for passengers or staff in case of an accident.

3.19 Seats
3.19.1 Seat assembly
A seat or set of seats and all supporting structures required for attachment to the vehicle interior, typically to the vehicle floor or bodyside or a combination of both.

Note to entry: A seat assembly may be a single, double or other multiple seat item. Any additional brackets or supports between the vehicle interior and the vehicle primary structure are not included.

3.19.2 Folding seat
A seat which can be fully or partially folded away when not required and which is secured in or out of use by the intervention of the train crew using locks or latches.

3.19.3 Longitudinal seat
A seat installed so that the occupant sits sideways with respect to the direction of travel.

3.19.4 Tip-up seat
A seat where the base is folded up when not in use. The seat is not secured in or out of use and can be deployed by the user without intervention by train crew.

3.19.5 Transverse seat
A seat installed transversely across the vehicle, so that the occupant sits either facing or with their back to the direction of travel.

3.20 Secondary impact
Impacts inside a vehicle resulting from a primary impact.

Note to entry: Examples include passengers impacting other passengers, passengers impacting interior features of the vehicle, luggage impacting passengers or luggage impacting interior features of the vehicle.

3.21 Sharp edge
Thin edge which has the potential to cause injury by cutting.

3.22 Sharp point
Point which has the potential to cause injury by cutting.

3.23 Table
A flat level surface providing an area for working, dining or on which to place things.
3.23.1 Table assembly
A table including the table top and all supporting structures required for attachment to the vehicle interior, typically to the vehicle floor or bodyside or a combination of both, for use with single, double or other multiple seat assemblies.

Note to entry: Any additional brackets or supports between the vehicle interior and the vehicle primary structure are not included.

3.23.2 Fixed table
A permanently installed table which overlaps fully or partially the intended users seat space.

Note to entry: A fixed table may include movable hinged or sliding elements to facilitate access for associated seats. Fixed tables are permanently installed when in service, hinges or other features may be incorporated to facilitate vehicle servicing or cleaning.

3.23.3 Seat mounted table
A table mounted on a seat, which may be folded away or stowed when not required.

3.23.3.1 Seat back table
A table mounted on a seat back which may be folded away or stowed when not required.

3.23.3.2 Side mounted seat table
A table mounted on a seat at the side of the seat, which may be folded away or stowed when not required.

3.23.4 Side table
A bodyside mounted table for small items such as refreshments.

Note to entry: Equivalent to window tables in UIC leaflets.

3.24 Trainset
Fixed formation that can operate as a train, it is by definition not intended to be reconfigured except within a workshop environment. It is composed of motored and non-motored vehicles. (Source: TSI Loc&Pas)

3.25 Trim panel
A panel intended only to affect the appearance of the interior, the presence of which does not contribute to the structural performance of the vehicle.

3.26 Ultimate load
A load which represents or is intended to be equivalent to an exceptional load outside of normal service conditions due to overloading or accident which may result in significant damage or permanent deformation that will require repair or replacement.

Note to entry: An ultimate load may be a static, quasi-static or dynamic load.
4. Interior passive safety objectives (Informative)

4.1 Interior passive safety objectives

(1) The purpose of this Chapter is to set out the high level objectives to be considered in the application of the measures in Chapters 5, 6, 7 and 8 which set out normative requirements.

(2) The primary objective of interior passive safety is to minimise the risk of injury to passengers and staff in the event of a collision or derailment. An objective of the requirements set out in this document is that even if the possibility of injury cannot be eliminated, the seriousness of potential injuries is at least reduced.

(3) A complimentary objective is to maintain the structural integrity of the interior, with the objectives of preserving occupant residual space and minimising the risk of injury due to detached or loose objects or debris.

4.2 Interior passive safety design considerations

4.2.1 General design considerations

(1) In applying the design principles contained in this document, it should be taken into account that the risks to be controlled arising from collisions and derailments relate to relatively infrequent events. A proportionate and balanced view of the full range of vehicle design requirements is therefore required.

NOTE 1: A benefit of the application of interior passive safety design principles is in reducing the level of typically minor injuries through trips, slips and falls that can result from unexpected vehicle movements caused by for example emergency braking or track irregularities.

(2) The vehicle layout, in particular the seating and the arrangement of screens, partitions and grab rails or poles will play a key role in determining potential trajectories for passengers in the event of a collision.

(3) In terms of passive safety objectives, a primary objective is to ensure, as far as possible that, in the event of an accident, passengers and staff are contained within the vehicle.

NOTE 2: The objective of ensuring overall containment i.e. the containment of passengers and staff inside the vehicle is addressed by the applicable carbody structural and crashworthiness standards (EN 12663 and EN 15227) and by national performance specifications for bodyside windows.

(4) Inside the vehicle, containment measures have the objective of managing the risk of uncontrolled movement of people in the vehicle interior space. Vehicle interior layouts that offer good levels of containment limit the length and number of potential trajectories from a given passenger location (seated or standing) and therefore reduce the risk of injury.

(5) This document does not set out explicit requirements relating to containment inside the vehicle since such measures could have the undesirable and potentially counterproductive effect of prescribing vehicle interior layouts which are subject to a wider range of considerations relating to, for example operational needs and aspirations, the type of service (distance, speed, duration), vehicle ambience and security, loading and unloading times.

4.2.2 Secondary impact

(1) In a collision or derailment, a vehicle typically experiences a primary external impact or a series of impacts, and a very rapid deceleration. Some of the vehicle’s kinetic energy is retained by the passengers and objects, which is then dissipated by secondary impacts inside the vehicle.

(2) The severity of a secondary impact injury is dependent upon the person’s kinetic energy and the rate of energy dissipation (the relative deceleration at the point of contact) on impact. The rate of energy dissipation is related to the stiffness of the contact surface, the concentration of energy per unit area at the point of contact and the body region involved.
(3) To minimise the severity of injuries, design for interior passive safety therefore takes account of the following:

   a. The person’s velocity and kinematics at the point of contact.
   b. The characteristics of features or structures impacted.
   c. Probable impact areas relative to the person and their proximity to vital organs.

4.2.3 Interior passive safety design scenarios
(1) The initial effect of many accidents is predominately longitudinal but even in these cases, due to the dynamics of the train or external influences such as for example track curvature, switches and crossings, some or all of the vehicles involved may come to rest having been subject to large lateral, vertical, yaw, pitch or roll movements. Accidents due to defective track or landslides may include significant non-longitudinal effects from the outset.

(2) Where dynamic testing is required, the principal design scenario is based around a longitudinal crash pulse. This pulse is designed to generate impact velocities consistent with the severity of injuries encountered in typical accidents and which permit injury criteria to be assessed using physical tests or numerical simulations.

(3) Specific interior design scenarios have not been developed for situations where lateral, vertical, yaw, pitch and roll accelerations or a combination of these occur. For this type of scenario, any additional risks are controlled using requirements expressed in terms of design requirements or recommendations (relating to shape and geometry) and proof loads.

4.2.4 Containment
(1) The objective for internal containment is to reduce the risk of injury by ensuring that, in the event of a collision or derailment, passengers or staff are contained in the area of the vehicle where they are located and equally heavy items such as luggage or on-board equipment are contained in their respective areas. For internal containment the principal objectives are to prevent long excursions through the vehicle and therefore reduce the velocity of secondary impacts and interaction with other passengers.

(2) Research suggests that unidirectional seating provides a better level of containment for seated passengers compared to bay seating, as the passenger’s movement is restricted to the immediate area.

(3) Bay seating can also give a high level of containment where fixed tables are installed, however open bay seating arrangements without tables can lead to increased injury severity and numbers of injuries because of the longer distances the passenger can be displaced before impacting the seat or person opposite.

(4) Longitudinal seating is often preferred for suburban operations where station to station times are short and passenger loading, and unloading times are critical. Longitudinal seating arrangements may not appear to give the same control as transverse seating, but when groups of longitudinal seats are sub-divided for example by grab poles or draughtscreens, it is considered that the risk is adequately controlled and experience with these types of arrangement has been satisfactory.

(5) Providing specific guidance for the containment of standing passengers is not attempted in this document. Vehicle layouts should however consider aspects of the design such as the location of draughtscreens and grab poles, the relationships between standing areas and seating areas, and operational parameters, for example whether standing passengers are unlikely (inter-city services where seat reservations are required) or if a metro style operation is envisaged.

(6) For suburban applications there will often be a considerable number of standing passengers who will usually make use of grab poles, grab rails and grab handles, providing elements of support and restraint in the event of a sudden deceleration due to an accident.
4.2.5 Minor Details

(1) Accident investigations and research has shown that the majority of injuries in an accident or collision can be attributed to impact against seats and tables. However, the causes of a significant proportion of injuries are uncategorised and therefore the potential effects of minor details should also be considered.

(2) Accident injury data is often not able to directly identify the effects or influence of other less significant items, however the detail design of seemingly minor items, for example partition edges, luggage racks, coat hooks, magazine racks and table lights, can significantly influence injury levels, even if they are not directly responsible for the most serious injuries.
5. Rail vehicle interior structural design criteria

5.1 Material properties for rail vehicle interiors (informative)

(1) In selecting materials in terms of interior passive safety an objective is to minimise the risk of injury due to severe abrasion, lacerations or stab wounds if parts of a vehicle interior are fractured, deformed, or dislodged under impact conditions.

NOTE 1: The suitability of materials used in vehicle interiors, in addition to fulfilling structural and impact requirements, has to take into account other foreseeable material requirements, for example: durability, including behaviour under fatigue loading, fire performance, safety in manufacture, repair and disposal and the potential for degradation due to ageing or environmental factors such as temperature, humidity, sunlight etc. Compromises will therefore always be required when selecting materials.

(2) When items are broken or ruptured due to impact by people or unrestrained objects under the conditions set out in this document, sharp spikes, splinters or fragments should not be formed and, for composite panels or substructures, aggressive internal components (for example metallic inserts) should not be exposed.

(3) When loaded beyond the specified proof loads, vehicle interior structures or sub-structures should collapse in a controlled and predictable manner and have good post-yield plasticity and/or energy absorption properties. Non-ductile or brittle materials should therefore be used with caution to avoid situations where they could, under these conditions, act as elements of the final load path.

5.2 Structural acceptance criteria for rail vehicle interiors

5.2.1 General requirements

(1) Where a 50th or 95th percentile male or 5th percentile female passenger is specified, the dimensions and masses of the standardised ATDs specified in Annex C shall be used.

(2) Where dimensions are specified, these are nominal values as given on the applicable component, assembly or installation drawings.

(3) Requirements for specific items of the railway vehicle interior are set out as follows:

   a. Seats (7)
   b. Seat back tables (7.2)
   c. Tables (8)
   d. Interior doors, glazing and partitions (6.3)
   e. Grab handles, poles, rails and handrails (6.4)
   f. Interior fixtures and fittings (6.5)
   g. Luggage stowage (6.6)

(4) General verification criteria are set out in Chapter 10.

5.2.2 Proof load safety factor

(1) The use of a proof load safety factor is intended to ensure that there is no significant permanent deformation under proof load conditions.
NOTE 1: The proof load safety factor is defined as the allowable material proof stress divided by the calculated or measured stress for a given proof load case.

(2) The yield or proof strength criteria and safety factor values set out in EN 12663-1 clause 5.4.2 shall be applied.

(3) For glass or materials with similar characteristics, the proof load safety factor shall be equal to the ultimate load safety factor.

(4) For seats and tables, after application of the specified proof loads if physical testing is undertaken, it is permissible for any permanent deformation to be of greater magnitude than would normally be considered to be acceptable for structural testing for EN 12663, if the following conditions are satisfied:

   a) The permanent deformation is the result of post-yield plastic deformation.

   b) The second application of the specified proof load leads to no additional permanent deformation.

5.2.2.1 Explanatory notes (informative)

(1) After testing seats and tables to the specified proof loads, it is possible to have, at positions remote from the attachment points, deformations of a magnitude that would be usually considered to be 'significant permanent deformation' and therefore fail the test. For a seat installation, a small permanent deformation at floor level could result in a deformation two orders of magnitude greater at headrest height by simple leverage.

(1) For glazing, specific load requirements are set out as ultimate loads.

5.2.3 Ultimate load safety factor

(2) The objective for the use of an ultimate load safety factor is to ensure that the structure does not fail catastrophically, for example by rupture or gross instability, when the proof loads are exceeded.

NOTE 1: The ultimate load safety factor is defined as the material ultimate tensile stress divided by the calculated or measured elastic stress for a given proof load case.

(3) Where an ultimate load case is specified, an ultimate load safety factor for any corresponding proof load case is not required.

(4) Where an ultimate load case is not specified, the ultimate failure criteria and safety factor values set out in EN 12663-1 clause 5.4.3 shall be applied to the proof load case.

NOTE 2: As set out in EN 12663-1 clause 5.4.3 the ultimate failure criteria do not apply for parts of the vehicle interior which are specifically designed to collapse in a controlled manner.

5.3 Structural requirements for interior equipment attached to vehicle bodies

5.3.1 General requirements

(1) Where dynamic testing is required, this may be physical testing or it may be virtual testing using computer simulations and calculations. See sub clause 10.2.

(2) For proof, ultimate and dynamic load conditions specified in this document, with the exception of glazing, the following requirements shall be satisfied:
a) Attachments to the primary structure shall remain connected for all load conditions specified in this document. For ultimate loadings there shall be sufficient connection retained to ensure the location of the item or assembly is maintained.

b) A continuous load path shall be maintained under all load conditions specified in this document without uncontrolled changes in force levels due to, for example, catastrophic (global) buckling, snap-through or fracture.

c) No parts are exposed or detached to expose sharp points or edges.

NOTE 1: The vehicle interior, interior fittings and any associated equipment directly or indirectly attached to vehicle bodies are required by the LOC&PAS TSI to withstand the proof acceleration loads specified in EN 12663-1 (EN 12663-1, sub-clause 6.5.2 and tables 13, 14 and 15).

(3) When installed in a rail vehicle, components for which dynamic performance requirements are specified shall satisfy the following conditions:

a) All relevant test and analysis reports are available to demonstrate that the relevant requirements in Chapter 7 or 8 are satisfied.

b) Dynamic load data has been obtained from the original test series to define the dynamic load requirements for the item's installation, attachment points and fixings.

(4) For minor interior items, for example panelling, where there are no specific proof, ultimate or dynamic load requirements set out in this document, the attachment strength shall be assessed unless it can be demonstrated that:

a) For a given type or method of attachment, items at or below a given mass will be securely retained for the acceleration loads specified.

Or

b) An item is contained or enclosed to prevent it becoming a potential hazard if detached in the event of a collision or derailment or for any other reason.

Or

c) Service experience in an equivalent or more demanding environment has shown the installation to be satisfactory.

5.3.1.1 Explanatory notes (informative)

(1) The static proof and dynamic loading requirements set out in this document for items such as seats, tables, grab handles, grab poles, grab rails, luggage stowage for example mean that separate assessments against the acceleration loads set out in EN 12663-1 may not be necessary because the requirements in this document derived from service and accident conditions are more onerous and any requirements relating to EN 12663-1 are therefore satisfied.

(2) To maintain a continuous load path for all load conditions and to absorb energy requires ductile behaviour. Many interior elements will however use some non-ductile components, for example a table, where the table top is often made from a non-ductile composite or wood based material but the legs and mountings are made from ductile materials such as steel or aluminium. As a result the overall assembly or sub-structure can exhibit the desired behaviour when overloaded through plastic deformation of the ductile parts when subject to the loadings set out in this document.

(3) For what can be considered a minor item, where an installation has been used for an extended period in service in a similar or more arduous environment and has performed satisfactorily with no records of consistent unscheduled maintenance, this can be taken as evidence of acceptable performance. If adopted, this approach should be documented.
(4) Quasi-static inertia proof loads (Mass × specified acceleration) may be applied dynamically using the dynamic test pulse set out in Annex A or the dynamic test pulse set out in Annex A, scaled to the acceleration level required. The required acceleration level should be sustained for at least 80ms for consistency with the dynamic test pulse.

6. Rail vehicle interior design

6.1 General requirements

6.1.1 Longitudinal and multi-level seating areas

(1) Longitudinal and multi-level seating areas provide limited containment compared for example to transverse seating arrangements, in particular where unidirectional ‘airline’ seating is used (see 4.2.4). To control the risks for these types of layout, due to loss of containment in the event of a collision or derailment, the following measures are recommended.

(2) For continuous rows of longitudinal seats, it is recommended that there should be no more than three adjacent longitudinal seating positions without features to limit the potential longitudinal motion of the occupants.

(3) Where there are different floor levels within a passenger seating area, seating in raised areas should not directly face a lower area unless there are means provided to prevent passengers being projected forwards over the top of the lower seats.

6.2 Rail vehicle interior areas subject to secondary impact

6.2.1 Secondary impact review

(1) Areas which are accessible to passengers and staff in normal service shall be subject to a secondary impact review to examine the general features and detailing of the vehicle interior considering the risk of injury due to secondary impact against surfaces or items.

(2) The design and installation of the interior, with the exception of seats and tables, which are subject to the requirements set out in Chapters 7 and 8, shall be examined for potentially aggressive features with respect to:

a) Exposed corners and edges.

b) Recesses.

c) Protrusions.

(3) The following may be omitted from the secondary impact review:

a) Items shielded by another item when potential impact is considered in longitudinal, lateral or vertical directions.

b) Items which cannot be contacted by a 100 mm diameter sphere (see 6.2.2.1).

(4) The secondary impact review should be based on an examination using the definitions in this document and recommended criteria set out in 6.2.2.

6.2.1.1 Explanatory notes (informative)
(1) The secondary impact review can be considerably simplified since in a rail vehicle there will be many items which are repeated throughout the train, such as for example, handholds, handrails, partitions, draughtscreens, doors etc. Only one example of an item or component that is repeated needs to be assessed.

(2) Some areas or features of a vehicle interior may be used infrequently, for example some areas exclusively for the use of traincrew, where the use as a proportion of time in service is very low. In such cases a risk based argument may form part of the review. It is not recommended that similar arguments are applied to toilets or areas such as vestibules or corridors where passengers might stand, since such areas are always potentially in use or occupied when the train is in service, irrespective of levels of loading or times of peak demand.

(3) A sphere of 100 mm diameter can be considered to represent a person’s arm or a leg. A sphere of 165 mm is often used to represent an average person’s head in automotive standards however in a rail environment making a clear distinction between areas for head contact and arm or leg contact is not straightforward and as a filter mechanism, the 100 mm sphere gives a more conservative result.

6.2.2 Interior features with injury potential

6.2.2.1 Exposed edges in rail vehicle interiors

(1) Only exposed rigid edges which can be contacted by a 100 mm diameter sphere shall be considered. Edges of components which are not directly exposed (for example sheet metal fabrications beneath seats) shall be de-burred or chamfered to give smooth edge profiles.

(2) In differentiating between an external and an internal edge, where a panel edge fits up against another element to form a step or a recess that edge shall be considered to be internal (for example where rebated panel joints are used).

(3) A rigid edge shall be considered to be one using material with a Shore A hardness greater than 50.

(4) With the exception of glass edges, there shall be no exposed rigid external edges where the predominant radii (i.e. ignoring transition and blending radii) are less than 3 mm.

(5) For exposed rigid external edges, where the edge projects not more than 3.2 mm from the adjacent surfaces, the requirements for minimum radii shall not apply, provided that the height of the projection is not more than half its width and its edges are blunted.

(6) All exposed glass edges shall be arrissed or bevelled to give smooth edge profiles.

(7) There is no restriction on the use of alternatives to the specified or recommended dimensions where evidence of their suitability can be presented in terms of injury potential. The specified dimensions may be used as the basis for comparison.

6.2.2.2 Edge profile recommendations

(1) For solid or framed partitions, where there are no exposed glass edges, the predominant corner radii (i.e. ignoring transition and blending radii) for all exposed rigid external edges should be:

d) For longitudinal partitions at least 10 mm and the exposed edge should have a minimum overall thickness of 35 mm unless the edge is shielded by a grab pole, grab rail or other feature.

e) For transverse partitions at least 5 mm, and the exposed edge should have a minimum overall thickness of 20 mm unless the edge is shielded by a grab pole, grab rail or other feature.
(2) Partitions with exposed glass edges should be orientated in a transverse direction. Partitions with exposed glass edges shall not be orientated in a longitudinal direction.

NOTE 1: Shielding provided by a grab pole, grab rail or the use of a resilient edge profile would no longer result in an exposed edge.

(3) Exposed rigid external edges of luggage stacks and exposed rigid external edges on the undersides of overhead luggage racks should have radii of at least 10 mm, subject to the application of the formulae permitted by 6.2.2.3.

(4) Exposed rigid external edges of interior panelling (for example corner joints between walls) should have radii of at least 10 mm, subject to the application of the formulae permitted by 6.2.2.3.

6.2.2.3 Formulae for exposed edge radii for obtuse included angles

(1) Requirements or recommendations for minimum edge radii assume 90 degree external corners. In cases where a minimum radius is specified and the included angle between surfaces is greater than 90 degrees, the minimum radius may be reduced according the method given in 6.2.2.3 (2), as shown in Figure 6.5 and taking values according to Table 1.

![Figure 6.4](image)

Key

\[ \alpha \] Included angle between surfaces

Figure 6.4 Examples of external edge radii for obtuse included angles

(2) For external edges or corners which are partially exposed, only the parts of the edge surface that can be contacted by a 100 mm diameter sphere are considered. The effective included angle for determining the minimum edge radius shall be determined with a 100 mm diameter sphere positioned on the adjacent lower surface or surfaces and taking the included angle between the tangent to the sphere at the point of contact with the edge of the upper surface assuming there is no radius (See figure 6.5.).

NOTE 1: Upper and lower surfaces are relative to the assumed direction of approach by the sphere.
Included angle $\alpha$, degrees | Minimum radius, mm
---|---|---|---
$\alpha \leq 105^\circ$ | 20 | 10 | 5
$105^\circ < \alpha < 120^\circ$ | linearly interpolate between 20 and 15 | linearly interpolate between 10 and 7.5 | linearly interpolate between 5 and 4
$\alpha = 120^\circ$ | 15 | 7.5 | 4
$120^\circ < \alpha < 135^\circ$ | linearly interpolate between 15 and 5 | linearly interpolate between 7.5 and 2.5 | linearly interpolate between 4 and 2.5
$135^\circ \leq \alpha \leq 180^\circ$ | linearly interpolate between 5 and 0 | linearly interpolate between 2.5 and 0 | linearly interpolate between 2.5 and 0

Table 1  Edge radii for obtuse included angles

6.2.2.4  Recesses
(1) In areas potentially impacted by seated occupants, between seat and/or table assemblies and immediately adjacent vehicle interior features:

f) To control the risk of hand entrapment, there should be no gaps or recesses greater than 8 mm and less than 25 mm in width with a depth greater than 20 mm around a seat when installed.

g) To control the risk of foot entrapment beneath seats, gaps or recesses should be either smaller than 100 mm x 50 mm or greater than 300 mm x 150 mm.

6.2.2.5 Projecting items

(1) Wherever possible, concealed fasteners should be used to minimise the risk of injury due to secondary impact. The type and location of fasteners which are flush fitting or which are not concealed (for example countersunk, domed or standard screws or rivets) should be assessed to ensure the risk of secondary impact injuries is controlled.

6.3 Interior doors, glazing and partitions

6.3.1 Proof loads for interior doors and partitions

(1) Interior doors (with the exceptions of hinged doors which do not lock or latch) and partitions, in any areas of such items which are not glazed, shall withstand the following proof loads applied independently:

   a) A concentrated perpendicular load of 2.0 kN applied over a symmetric area of not more than 0.01 m² which may occur at any position on the surface.

   b) A pressure of 2.0 kPa applied over the entire surface.

(2) The positions where the concentrated loads are the most critical shall be determined. The analysis shall consider the maximum stresses in the door structures or partitions due to bending and stresses at mounting points and any other locations where stress concentrations could occur due to local details or changes in shape or form.

(3) The proof loads shall be applied to both sides of interior doors independently.

(4) The proof loads shall be applied to partition faces which are fully or partly exposed to the vehicle interior. Where both faces of a partition are exposed to the vehicle interior the proof loads shall be applied to each face independently.

NOTE 1: The proof load requirements do not apply to areas of partitions which are completely shielded by other items, for example seats or luggage stacks. A partition is required however to withstand any loads transferred to it by such items.

(5) Where partitions are fitted with trim panels, it is permissible for the specified proof loads acting on the trim panels to be considered as ultimate loads for these items.

NOTE 2: Where trim panels are used, the specified loadings are to be treated as proof loads by the underlying structure of the partition assembly. In terms of secondary impact, provided that hard spots or abrupt changes in stiffness can be avoided, the implied panel flexibility would generally be considered beneficial to passengers in the event of a collision.

(6) Where seats are attached directly to partitions or the seat backs are placed sufficiently close to partitions, luggage stacks or other seat backs to allow them to be contacted under proof load conditions, the partition, luggage stacks or adjacent seats shall withstand without significant permanent deformation loads that are transferred from the affected seats when subjected to the specified seat proof loads.

6.3.2 Interior glazing

(1) For interior glazing the objectives are to:
a) Maintain internal containment to minimise the trajectories of people or luggage and therefore the potential for secondary impact injuries.

b) To minimise the spread of glass fragments inside the vehicle with the potential for aggravating or causing injury.

(2) Where glass is used in the vehicle interior, the glass shall be either:

a) Laminated safety glass with material properties in conformity with an applicable Euro norm (EN) or where an EN is not available, conformity with another applicable national or international standard.

or

b) Toughened safety glass with material properties in conformity with an applicable Euro norm (EN) or where an EN is not available, conformity with another applicable national or international standard.

NOTE 1: GB National Technical Rules require laminated safety glass to be used for all glass in the vehicle interior.

(3) Interior doors (with the exception of hinged doors which do not lock or latch) and partitions in any areas which are glazed when installed shall withstand the following ultimate load cases applied independently:

h) A concentrated perpendicular load of 2.0 kN applied over a symmetric area of not more than 0.01 m² which may occur at any position on the surface.

i) A pressure of 2.0 kPa applied over its entire surface.

(4) The positions where the concentrated loads are the most critical shall be determined. The analysis shall consider the maximum stresses in the glass due to bending and stresses at mounting points and any other locations where stress concentrations could occur due to local details or changes in shape or form.

(5) Where laminated safety glass is used it should be constructed using toughened glass and for calculations and/or testing normal room temperature (nominally 20° C) should be assumed.

(6) Where both sides of the glass are accessible by passengers or staff, the load cases shall be applied to both sides independently. The glazing shall remain intact and in position throughout the application and removal of the loads.

(7) Where toughened safety glass is used and containment is required, there shall be included in the item features to provide containment if the glass is broken.

NOTE 2: It is assumed that if laminated safety glass is used the properties of the glass and the interlayer provide an acceptable level of containment when the glass is broken.

NOTE 3: Interior glass in rail vehicles is used for a number of purposes. In this document a distinction is made between:

a) Glass which provides internal containment for passengers and/or their luggage, for example glass partitions or the sides of luggage stacks.

b) Glass used for other purposes for example light diffusers, in luggage racks for visibility of the contents, mirrors or decorative features.

6.3.2.1 Explanatory notes (informative)

(1) Glazing elements could use materials other than glass, subject to the performance requirements being satisfied.
(2) In the event of an accident or collision in addition to direct impact, interior glazing can be broken due to deflection and/or distortion of the primary vehicle structure and the resulting effect on the interior substructures.

(3) Laminated safety glass, in particular in draughtscreens, internal windows and doors, can be effective in limiting the potential trajectories of passengers, luggage or other objects and therefore reduce the risk of injury due to the residual strength provided by the interlayer when the glass is broken. Careful attention to the attachment of the glass to the vehicle structure is necessary to achieve this behaviour. The adhesion of the broken glass to the interlayer also limits the spread of broken glass through the vehicle.

(4) Depending on the details of the glass and interlayer construction, when broken some types of laminated glass can release relatively large amounts of spall and allow sharp edges to be formed on the non-impact side. It is recommended that laminated safety glass is constructed using toughened glass to minimise the amount of spall, to give a more benign surface to the broken glass pane.

(5) When progressively loaded, if, in the installed condition, the laminated glass fractures but the load can be increased up to the specified ultimate loading, then the requirement is satisfied. The loading at which fracturing occurs is then analogous to a proof load condition. Whether this behaviour occurs is dependent on the installation arrangement (the amount of support and the stiffness of the supporting structure) and the construction and geometry of the glass.

(6) Due to the visco-elastic properties of the most frequently used interlayers, the temperature and also the loading duration are important parameters for determining the laminated safety glass construction required for a given application. Standards and codes of practice for buildings should therefore be used with caution, as otherwise an unduly conservative result may be obtained in terms of strength and weight.

(7) Toughened safety glass when initially broken, as well as forming small blunt dice, can sometimes form larger irregular fragments if there are bending or twisting loads acting on the glass. This effect can be mitigated when specifying the post-impact performance of the glass and careful consideration of the mounting scheme to limit the potential for loading passing through from the primary vehicle structure.

(8) Toughened safety glass fragments can reach potentially high velocities from the combination of impact energy and the release of strain energy locked in due to the toughening process. Application of self-adhesive film can eliminate the risk of small high speed fragments but the risks associated with the detachment of the complete item then have to be considered.

6.3.3 Requirements for toughened safety glazing

(1) Solid items should not be secured to toughened safety glass panels unless there is also attachment made to other parts of the interior.

(2) Labels, transfers or stickers should not be applied to toughened safety glass where both faces are exposed to the vehicle interior unless either:

   a) The exposed glass surface is completely covered with a self-adhesive film in accordance with the requirements of 6.3.3.2.

   NOTE 1: If the glass is broken there is the possibility that the entire piece will be detached from its mounting. This will be the case generally where film is applied after installation of the glass for protection against vandalism.

   Or

   b) It can be demonstrated that the disintegration behaviour of the glass when broken is not affected.
(3) To assist the installation and removal of self-adhesive film, a small margin between the edge of the self-adhesive film and the edge of the glass is permissible. It is recommended that this margin is not greater than 2 mm.

6.3.3.1 Explanatory notes (informative)

(1) For items bonded or mechanically fastened to toughened safety glass, if the glass is broken in an accident and there is no other means of attachment to the interior, these will become detached and have the potential to act as hazardous projectiles.

(2) Labels or stickers, typically of relatively high strength vinyl, attached to toughened safety glass partitions or interior door glazing can form jagged projectiles when the glass is shattered.

(3) Application of self-adhesive film, typically used to prevent vandalism or for printed decoration or both, over the exposed surface of existing toughened safety glass partitions or door glazing is considered to be a sufficient safeguard to ensure that if stickers or labels are used the entire piece of glass when broken will remain a single item.

6.3.3.2 Specification for self-adhesive film for application to glass

(1) Where used for the purposes of this document, self-adhesive film should have the following minimum properties at normal room temperature:
   a) Nominal tensile strength of at least 172 N/mm²
   b) Nominal breaking strength of at least 17.5 N per mm of width
   c) Elongation at break of at least 125%
   d) Peel adhesion (180°) shall be at least 1.47 N per mm of width according to the FTM 1 test method.

(2) As an alternative, when the self-adhesive film is applied to 6 mm float glass and pendulum tested according to EN 12600, a classification of at least 2B2 should be achieved.

NOTE 1: The FTM 1 test method is published by FINAT (Fédération Internationale des fabricants et transformateurs d’Adhésifs et Thermocollants sur papiers et autres supports), The Hague, The Netherlands.

6.4 Handrails and hand holds

6.4.1 Handrail design

(1) A design objective for interior passive safety is that handrails (for example in doorways, vestibules or passageways) should not project unnecessarily into the passenger area in order to control to the risk of injury due to secondary impact.

(2) Panel, partition or draughtscreen mounted handrails should not project from surrounding features in excess of any limiting dimensions set out in the PRM TSI.

NOTE 1: This recommendation does not apply to moveable handrails required in universal toilets, longitudinal grab rails fitted to luggage racks or free standing grab poles from floor to ceiling or from seat back to ceiling or ceiling mounted grab rails.

6.4.1.1 Explanatory notes (informative)

(1) The mandatory requirements for persons of reduced mobility are set out in the PRM TSI. When these have been satisfied, the measures defined in this document take effect. For example, if for accessibility of persons of reduced mobility it is required to have a handrail with a diameter of 30 mm to 40 mm, and it is then determined that there is a risk of bodily contact, the larger diameter is recommended to minimise the potential for injury if impacted.
(2) Where handrails are mounted on partitions or draughtscreens without being recessed, the requirements for persons of reduced mobility specify a minimum clearance to any adjacent surface of 45 mm. A handrail will therefore project a minimum of 75 mm to 85 mm from the panel it is attached to. Applying only the requirements for persons of reduced mobility, a greater projection would be permissible which is normally undesirable from an interior passive safety perspective.

(3) If there is a need for a handrail to project further from an adjacent surface, a justification should be made for this. Reasons for this could be due to the local panel contour locally increasing the clearance to a handrail or due to its location in the vehicle, for example being shielded by some other item.

(4) The functional requirements for persons of reduced mobility can be satisfied with abrupt ends to a handrail. The ends should however be radiused and/or blended into the adjacent panel to minimise injury potential.

6.4.2 Handrail and handhold proof loads

(1) Overhead grab rails, mounted from either a luggage rack or from the ceiling shall withstand without significant permanent deformation of the grab rail, attachments or supporting structure a concentrated vertical proof load of 1,7 kN applied anywhere along the grab rail.

(2) All other handrails shall withstand without significant permanent deformation a concentrated proof load of 1,7 kN applied anywhere along the portion or portions intended to be held or gripped. The load shall be applied perpendicular to the longitudinal axis of the portion or portions intended to be held or gripped at any angle around the axis to give the most onerous loading on the handrail, attachments or supporting structure.

(3) Handholds shall withstand without significant permanent deformation a concentrated horizontal proof load of 1,5 kN applied at the centre of the gripping surface acting perpendicular to the handhold face.

6.5 Interior fixtures and fittings

6.5.1 Access panels and cubicle doors

(1) An objective for the interior design should be to avoid access panels in areas where accidental opening could cause injury or block escape routes. The design of access panels should consider the mode of opening, minimise the size and mass of the panels and where possible, eliminate any aggressive features.

NOTE 1: In the event of an accident or collision, access panels, in particular when mounted overhead can be released by deflection or distortion of surrounding structures. Depending on their location, accidentally opened access panels can have the potential to block escape routes or cause injury due to their mass and their shape (edges, sharp corners).

(2) Enhanced locking or a secondary means of retention (for example, safety catches or straps) shall be provided where the following conditions apply:

a) If accidentally opened, access panels that could block an escape route through an internal or external door unless, when such a panel is opened, the internal or external door remains operable and at least 75% of the normal width and height remains available.

b) Where access panels are located above or alongside areas normally used by seated or standing passengers or staff and when accidentally opened they enter the space normally used by passengers or staff and have the potential to cause injury due to their position, size, shape or weight when reviewed in accordance with 6.2.
(3) The space normally used by seated or standing passengers or staff shall be considered to be limited to a maximum height of 1950 mm above floor level in standing areas and up to a maximum height of 1680 mm above floor level in seating areas. In seating areas the assumed seat width shall be at least 450 mm centred relative to each seat. The upper corners of the seated space envelope may be assumed to be radiused to a maximum value of 225 mm.

NOTE 2: These parameters are based on the PRM TSI requirements for headroom in seated areas.

(4) Where access panel hinged joints can be separated by movement beyond their normal opening to allow a panel to be removed, the assembly shall be fitted with restraints to prevent separation after panel opening without an additional operation being required.

NOTE 3: Secondary retention features fulfil this requirement.

(5) An enhanced level of locking may be used by consideration of the amount or type of engagement, if the magnitude of deflection or distortion of surrounding structures can be predicted from the structural collision scenarios set out in EN 15227 or from service experience as an alternative to secondary retention devices.

(6) If secondary retention devices are used, in determining the proof loads to be applied to secondary retention devices, only the loadings in the primary line of action should be considered (for example secondary catches to prevent a ceiling access panel dropping fully open need only be designed for vertical proof loads).

(7) Examples of secondary retention devices include spring release hooks (car bonnet style) or wire straps. Careful consideration should be given to the requirements for the removal and refitting of removable devices such as wire straps.

6.5.2 Wheelchairs

(1) Where provision is made for wheelchairs, the requirements for persons of reduced mobility are applicable. Due to the very wide range of wheelchair types and sizes available, prescriptive requirements in terms of interior passive safety are not possible.

NOTE 1: In collisions, the relationships between the passenger, their seat and any table have been shown to have a significant effect on the likely outcome. Unlike other seated passengers, in the case of a wheelchair user, the design, dimensions and mechanical characteristics of the wheelchair (the seat) are outside the control of the rail vehicle operator. In addition, if not adequately braked, contained or restrained, in the event of a collision, a wheelchair can represent a hazard for other occupants of a rail vehicle.

6.5.3 Ceiling and wall lighting

(1) All breakable lighting sources (for example, fluorescent tubes, and bulbs) shall be shielded by diffusers or similar devices.

6.5.4 Catering equipment

(1) Where mobile catering trolleys are intended to be unattended for all or part of a journey, provision shall be made for the catering trolleys to be securely stowed.

(2) Fixed catering trolleys should be securely located and locked in position.

(3) A secure stowage area or fixed trolley location shall be capable of restraining fully laden catering trolleys against the proof load accelerations specified for equipment attached to the vehicle body set out in 5.3.

NOTE 1: Secure stowage can be achieved using elements of the vehicle structure, partitions and/or a fastening device or devices.

NOTE 2: Catering trolleys can represent a potentially significant hazard in a collision if not adequately restrained. A distinction is made between trolleys providing at-seat service which are intended to be mobile and as a result could be expected to be in a variety of locations during a journey and fixed catering trolleys...
which remain in designated locations throughout a journey (for example as part of a modular catering installation).

(4) Service trolleys should be subject to the same considerations as catering trolleys.

(5) Catering equipment that cannot be permanently secured, such as crockery, tableware and supplies, should be securely stowed or otherwise contained when not in use, to minimise the risk of injury in the event of a collision or derailment, taking account of functional and service requirements.

6.5.5 Security and location of firefighting equipment

(1) Fire extinguishers and other firefighting devices shall be securely located. The location arrangement shall be capable of withstanding the proof load accelerations specified for equipment attached to vehicle bodies set out in 5.3 (and accordingly EN12663-1).

(2) The open or openable face of a fire extinguisher enclosure or fire extinguisher mounting face should not be oriented longitudinally unless located in a doorway, a vestibule or an alternative location which restricts longitudinal movement in the event of the extinguisher breaking free during a collision or derailment.

NOTE 1: Typical doorway or vestibule dimensions will limit longitudinal movement to less than 3 metres. A saloon mounting could give a longitudinal trajectory in excess of 20 m.

(3) Fire extinguishers should be located below window level where practicable.

6.5.5.1 Explanatory notes (informative)

(1) As a removable item, there is inherently less control over the correct installation or placement and therefore the retention of fire extinguishers under extreme conditions. These risks associated with possible incorrect installation or placement are minimised by the recommendations for extinguisher locations.

(2) Locations for fire extinguishing devices should be selected to give the shortest possible free flight trajectory before encountering a restraint or barrier such as a partition, consistent with the devices being readily accessible when required. The low location height specified minimises the risk of head or upper body injury in the event of an extinguisher becoming detached.

(3) The most basic installation method is for a fully exposed extinguisher to be mounted on a location bracket or brackets with a securing strap around the body of the extinguisher. A higher level of security can be achieved for example by an enclosure for the extinguisher body or fully enclosed inside a cupboard with quick release mechanism on the door.

6.6 Luggage stowage

6.6.1 General requirements

(1) An objective for luggage stowage facilities is to ensure that, in the event of an accident or collision, luggage is retained and the risk of injury to passengers from items of luggage in free flight is minimized.

6.6.2 Floor mounted luggage stacks or luggage stowage

(1) If provided in passenger areas, luggage stacks or luggage stowage areas shall retain the stowed items longitudinally.

NOTE 1: This may be achieved by orientation of luggage stacks and luggage stowage areas to give access to stowed items only from the side (i.e. access is only in the transverse direction relative to the vehicle.)

(2) When fully laden with representative items, luggage stacks, luggage stowage areas, shall withstand as proof loads the accelerations specified for equipment attached to vehicle bodies set out in 5.3 (and accordingly EN12663-1).
(3) A fully laden luggage stack or luggage stowage area shall be assumed to have a distributed mass loading of 100 kg/m² on each horizontal surface when subjected to the accelerations specified.

(4) For determining loadings on side or end faces of luggage stacks or luggage stowage areas, luggage shall be assumed to have a density of 250 kg/m³.

(5) Where luggage stowage between or behind seats will place additional loads on seats these potential additional loads shall be taken into account, assuming that the luggage areas are filled, with luggage of a density of 250 kg/m³. Where the mass of the luggage per seat is less than 100kg, the possible effects of additional seat loading may be discounted.

6.6.3 Overhead luggage racks

(1) If provided, overhead luggage racks shall satisfy the following requirements.

(2) Overhead luggage racks shall be orientated longitudinally relative to the vehicle.

(3) Intermediate dividers shall be installed along the length of overhead luggage racks, in order to control longitudinal movement of luggage during a collision or derailment. Dividers shall be spaced no greater than 3 metres apart. An end barrier shall be fitted where an overhead luggage rack does not terminate against a fixed partition.

(4) When subjected to the longitudinal accelerations specified for equipment attached to vehicle bodies set out in 5.3, the dividers or end barriers shall withstand a uniformly applied ultimate load equal to the mass of a luggage load of 100 kg/m in the adjacent section of the overhead luggage rack.

(5) Overhead luggage racks shall withstand the following loads applied simultaneously:

   a) A distributed proof load of 1000 N/m.

   b) A vertical proof load of 850 N positioned anywhere along the front edge of the overhead luggage rack unless a luggage rack handrail is fitted in which case the requirements set out in 6.4 shall apply.

(6) If provided, auxiliary luggage racks shall withstand a distributed downwards proof load of 250 N/m

6.6.3.1 Explanatory notes (informative)

(1) Overhead luggage racks are normally intended for the stowage of items typically considered to be hand luggage. Heavy items are intended to be placed in luggage stacks or other luggage stowage areas. Operational rules and their enforcement are outside the scope of this document.

(2) Overhead luggage rack dividers are not required to be solid barriers blocking the full cross-section. An acceptable solution could be for example a bar across the rack. The objective is to limit the kinetic energy of a racks content, which could occur if allowed to slide over significant distances in a collision.

6.6.4 Bicycle stowage

(1) When fully laden, bicycle stowage facilities (partitions, retention devices, location brackets) shall withstand as proof loads the accelerations specified for equipment attached to vehicle bodies set out in 5.3 (and accordingly EN12663-1)

(2) The number, size and mass of bicycles to be assumed shall form part of the vehicle specification.
(3) It is recommended that surveys are conducted to determine representative values for the size and mass of bicycles to be stowed. As a guideline the following mass values can be assumed:

   a) For a conventional adult bicycle without baskets, carriers or luggage, a mass of up to 16 kg.
   b) For an electric bicycle (e-bike) without baskets, carriers or luggage, a mass of up to 25 kg.
   c) For baskets, carriers or luggage, an additional mass of up to 20 kg.

6.6.5 Coat hooks

(1) Coat hooks shall withstand proof loads of 300 N acting downwards and 250 N acting horizontally.

(2) The shape, form and projection of coat hooks together with their location should be considered to minimise injury potential.
7. Seats for passengers or staff

7.1 Seats for passengers or staff

7.1.1 Objectives and application for seat assessment

(1) For seat assemblies, the principal objective is to ensure that in the event of a collision or accident the risk of injury to passengers and staff is controlled and minimised by satisfying as far as possible the following related objectives:

a. Seat assemblies and seat components remain securely attached.

b. The potential for injury is controlled.

c. Seated passengers or staff are contained in the area where they are seated and residual space is maintained.

NOTE 1: Seats in the driver’s cab are outside the scope of this document, however the requirements for passenger seats can also be appropriate for seats in the driver’s cab.

(2) The requirements are set out as follows:

a. General requirements for seats (7.1.2)

b. Lateral loadings on transverse seats (7.1.3)

c. Seat armrests (7.1.4)

d. Seat back height for transverse passenger seats (7.1.5)

e. If applicable, seat mounted tables (7.2)

f. Dynamic assessment requirements for transverse passenger seats (7.3)

(3) A seat assembly certified as conforming to this standard requires satisfactory assessment results for:

a. Static proof loads (7.1.1, 7.1.2, 7.1.3, 7.1.4)

b. If applicable, seat mounted tables (7.2)

c. Dynamic structural integrity assessment (7.3.2)

d. Injury potential assessment

(4) From the conformity assessment results, an acceptable range of installation pitches are derived (7.3.2.2, 7.3.2.3) and fixation loadings are determined.

(5) A certified seat assembly may then be installed directly in any vehicle subject to:

a. Validation of the structural integrity of the interfaces for the attachment to the vehicle.

b. For unidirectional seating configurations, installation at seat pitches within the limits established from the results of the structural integrity and residual space assessment.

NOTE 2: For what is essentially universal application, a seat assembly can therefore be certified with a proof load assessment, two structural dynamic assessments and one dynamic injury potential assessment.
7.1.2 General requirements for passenger seats

(1) All seat assemblies shall be attached directly or indirectly to the vehicle structure.

(2) The potential for injury shall be reviewed. The results of structural assessments and conformity with geometric requirements may form part of this review. In addition the methods set out in Chapter 9 may be applied.

(3) When not occupied, tip-up seats should be designed to fold away automatically.

(4) For seat assemblies, the predominant radii (i.e. ignoring transition and blending radii) for all exposed rigid edges above the height of the seat cushion base shall be at least 10 mm subject to permitted variations set out in 6.2.2.3.

(5) For seat assembly surfaces below the height of the seat cushion base, there shall be no exposed edges that can be contacted by passengers' legs in either normal use or under impact conditions where the predominant radii (i.e. ignoring transition and blending radii) are less than 5 mm. Contact shall be considered for the outer surfaces of the seat underside, for example any seat support legs, the surfaces orientated towards a seated passenger in a unidirectional layout and the surfaces orientated towards a seated passenger in a bay layout.

NOTE 1: The height of the seat cushion base is defined in Figure 7.1, dimension U.

NOTE 2: Under some circumstances a seated passenger can be projected forwards and their legs attempt to pass underneath the seat in front rather than the passenger directly impacting the seat back. This is often referred to as 'submarining'.

(6) Seat upholstery or trim, when subjected to the static or dynamic loads set out in this document, shall not become detached or displaced to expose sharp edges or sharp points. Any items that become exposed as a result of the static or dynamic loads specified in this document shall be assessed according to the requirements of the secondary impact review (see 6.2.2).

(7) Seats, seat mountings and their fixings through to primary structure shall be designed to withstand without significant permanent deformation the following proof loads:
   a. A vertical load of 1000 N applied downwards over an area of 380 mm wide by 220 mm deep on the leading edge of the seat cushion.
   b. With the exception of tip-up seats, a vertical load of 1200 N applied upwards over an area of 380 mm wide by 220 mm deep below the leading edge of the seat cushion.
   c. With the exception of tip-up seats, longitudinal loads of ±1500 N (relative to the seat) applied over an area of 380 mm wide by 80 mm deep located centrally at the uppermost part of the seat back, up to a maximum value of 580 mm for the upper boundary of the loading area, dimension 'c', determined in accordance with Figure 7.1.
   d. Where seat back hand holds are fitted, the hand holds shall withstand without significant permanent deformation longitudinal proof loads of ±500 N (relative to the seat) applied uniformly over the handgrip area.

NOTE 3: The centre line of the area for application of the longitudinal proof load is 40 mm below the height of the uppermost part of the seat back (as measured or calculated with respect to the floor).

(8) Where there is no clear transition between the seat back and headrest, for example where a separate headrest is not used, the height of the uppermost part of the seat back above floor level shall be determined using Figure 7.1 with a seat back height of 580 mm (Dimension 'c').

(9) For the determination of seat heights and the application of loads, adjustable seat backs shall be in the upright position.
(10) Multiple seats are any group of seats which share common structures, sub-structures or attachments resulting in individual seat loadings acting in combination. For multiple seats, the load cases specified in this sub-clause shall be applied simultaneously on each seat.

![Diagram of seat dimensions with key labels]

**Key**

- **A** Point 50 mm from the front edge on the upholstery contour (uncompressed)
- **A’** Point A, compressed by dimension A-A’
- **B** Foremost point of the backrest (centre of the lumbar support)
- **C** Point of intersection of a 300 mm radius about point B and the contour of the backrest
- **X** Point of intersection of a vertical line positioned 120 mm forward from point B with the contour of the seat cushion upholstery
- **X’** Point X compressed by dimension X-X’
- **U** Height of the seat cushion base. If there is not a clear transition the dimension A – 100 mm shall be used
  - **a** depth of seat cushion
  - **β** angle of backrest inclination from the vertical
  - **h** height of seat cushion
  - **c** height of the backrest without headrest (measured parallel with line B-C at the seat backrest inclination angle β)
  - **d** height of the headrest (measured parallel with line B-C at the seat backrest inclination angle β)
- **A-A’** Compression of the front of the seat when in use; a value of 20 mm shall be assumed or a measured value may be used assuming a loading equivalent to a 95th percentile male ATD
X-X’ Compression of the seat cushion when in use; a value of 30 mm shall be assumed or a measured value may be used assuming a loading equivalent to a 95th percentile male ATD

Figure 7.1 Seat measurement points and geometry

7.1.3 Lateral loadings on transverse seats

(1) For transverse seat assemblies which are wholly or partially attached to the vehicle floor, the seats, seat mountings and their fixings through to primary structure shall be designed to withstand a lateral displacement of the seat assembly as an ultimate load case. The following objectives shall be satisfied:

a) In the event of a significant displacement or deformation of the vehicle side wall, the seat assembly shall not become detached.

b) When the seat assembly is laterally loaded beyond yield, the attachment for at least two points exhibits post-yield plasticity to ensure the location of the seat assembly is maintained.

NOTE 1: For a seat assembly fastened to the bodyside and the floor using a leg or legs, it is acceptable for the leg or legs to break provided that the bodyside connection is maintained and the seat assembly is retained in its position.

NOTE 2: Large bodyside side wall displacements or distortion during a collision or derailment, for example lateral bodyside impacts, can place significant lateral loads on seat assemblies and their mountings with the risk that seats become detached. The lateral loading requirement does not therefore apply to seats which are only mounted from the bodysides, for example using a cantilever arrangement or mounted on the bodyside and suspended from the ceiling.

(2) The seat assembly shall be assessed in accordance with the following method:

a. A lateral force shall be applied to the seat assembly which shall be secured to a rigid fixture using anchorages representative of those used in vehicles in which the seats are intended to be used.

b. The bodyside shall be assumed to be subject to only a lateral translation.

i. For seat assemblies that are attached to the floor and bodyside, it is assumed that the bodyside pushes against the seat assembly bodyside mountings, which may offer additional linear or rotational displacement constraints.

ii. For seat assemblies that are only attached to the floor, it is assumed that the bodyside pushes against the seat assembly, no other linear or rotational displacement constraints shall be assumed.

c. A lateral displacement which is sufficient to demonstrate that the objectives are fulfilled shall be applied up to a maximum displacement of 100 mm.

d. Lateral displacement shall be measured at the side of the assembly adjacent to the bodyside side wall at seat cushion level, height ‘U’ as defined in Figure 7.1.

e. For seat assemblies with bodyside attachments, the force required to achieve the displacement shall be applied at the bodyside attachment points.

f. For seat assemblies that are only attached to the floor, the imposed displacement shall applied as close as practicable to the seat cushion level, height ‘U’ as defined in Figure 7.1.

NOTE 3: This ultimate load case is assessed independently of any other seat assembly requirements.
7.1.4  Seat armrests

(1) Where seat armrests are fitted, they shall withstand:

   a. Static proof loads of ±750 N applied in the transverse direction (relative to the seat) at the free end of the armrest.

   b. A static proof load of 1000 N applied vertically downwards at the free end of the armrest.

(2) It shall be demonstrated that the specified armrest proof loads can be re-acted through the seat frame including the primary seat fixing points.

(3) In the case of multiple seats, the specified transverse proof loads shall be applied simultaneously to the armrests that would be loaded by the seat occupants when subject to a lateral acceleration.

(4) The exposed rigid ends of seat armrests shall have radii of at least 20 mm in plan view (for moveable armrests, when in the deployed position).

7.1.4.1 Explanatory notes (informative)

(1) Seat armrests can be very beneficial in helping to contain passengers in their seats in the event of an accident. It is however not always practical or desirable to fit them due to limitations of saloon width or for high density applications where armrests can impede the safe movement of passengers.

(2) Simultaneous application of the transverse load is intended to represent the loadings from a fully occupied group of seats all subjected to the same acceleration event.

7.1.5  Seat back height for transverse passenger seats

(1) For seating layouts the seat back height shall be sufficient to ensure that containment of passengers within the area of their seats or seat bay is maintained. This shall be determined from the results of the dynamic structural integrity assessment (see 7.3.2).

(2) The seat back support should also be sufficient to control the risk of injury due to rotation of the head when subjected to a rearward acting (relative to the seat) deceleration. This can be achieved by using high-backed seats with the top of the seat or headrest above the compressed seat cushion to give a value of at least 840 mm for Dimension ‘d’ as defined in Figure 7.1.

(3) Adjustable seat backs shall be assumed to be in the fully upright position for consideration of the seat height.

7.1.5.1 Explanatory notes (informative)

(1) The seat back height in transverse seating influences the effect of a deceleration pulse in a collision or accident on the passenger in respect of:

   a. Neck injury and/or whiplash when the passenger has their back to the direction of impact.

   b. Loss of containment by projection over the seat in front when the passenger is facing the direction of impact.

(2) For a passenger with their back to the direction of travel, with a low seat back, the most likely injury mechanism occurs as the head rotates about the neck into or over the seat top and then rotates in the opposite direction as the body rebounds from the seat back. To control the risk of injury due to these movements a minimum seat height is recommended.

(3) For a passenger projected forward in a collision with unidirectional low seat backs there is additionally the risk of passing over the top of the seat in front with the possibility of more serious injuries for themselves and other passengers.
7.2 Seat mounted tables

7.2.1 General requirements for seat mounted tables

(1) Seat mounted tables shall withstand without significant permanent deformation vertical proof loads of 750 N applied downwards at any point along the unsupported table edges.

(2) Where seat mounted tables incorporate an overload protection mechanism, designed to allow the table to fold away downwards or otherwise collapse in a controlled manner at a load lower than 750 N, the vertical proof load requirements shall not apply. The correct functioning of an overload protection mechanism shall be demonstrated by test.

(3) For seat mounted tables, where the seat back facing the user provides a limit on forward movement against the table:

   a) The table edge exposed to a seated occupant's chest or abdomen when in use shall be at least 15 mm thick,

   b) The table shall have edge profile radii of at least 5 mm between the surfaces and the table edge

   c) The table plan view radii closest to the user shall be at least 25 mm.

   d) The edge thickness shall be measured at a plane between 5 and 10 mm inboard from the edge.

   e) For any exposed edges on mounting hinges and fittings between the seat and the table, minimum radii of 5 mm should be used.

![Diagram showing key dimensions for seat mounted table and edge profiles.]

Key
1 Principal surface e.g. table top, partition face
2 Edge profile
A-A Section through edge profile
R₁ Edge profile upper radius
R₂ Edge profile lower radius
R₃ Plan view radius
Offset to thickness measurement plane

Edge thickness

Figure 7.2  Seat mounted table edge profile geometry

7.3  Dynamic assessment requirements for transverse passenger seats

7.3.1  General requirements

(1) A seat assembly is intended to be assessed independently of a specific train or vehicle design. It is however permissible for an assessment to be undertaken for a specific installation.

(2) Seat assemblies for a new installation (for example either a completely new design of seat assembly or a new design of support forming part of the seat assembly) for which a structural integrity assessment has not been undertaken in accordance with this document, shall be dynamically assessed in accordance with 7.3.2.

(3) The forces obtained from the dynamic assessment at the seat assembly fixing points shall be reacted at the corresponding points in the vehicle interior wherever the seat assembly is mounted through to the primary structure.

7.3.2  Dynamic seat assessment for structural integrity and residual space

7.3.2.1  General requirements

(1) Subject to the requirements of 7.3.1, dynamic assessment for structural integrity of seat assemblies shall be undertaken in accordance with 7.3.2.2, 7.3.2.3. These assessments shall be considered equivalent to ultimate load cases.

(2) The dynamic assessment may take the form of physical testing or numerical simulation or a combination of both (See 10.2).

NOTE 1: For the structural assessment of a seat assembly one rearward and one forward dynamic assessment are the minimum necessary.

(3) Successful dynamic assessments shall satisfy the criteria set out in 5.3.

(4) The dynamic assessment results and the residual space requirements set out in Annex F shall be used to determine either:

a) The minimum pitch or pitches at which the seat assembly (the seat assembly and mounting arrangement) may be installed in a unidirectional configuration.

Or

b) At a specified minimum pitch where the residual space requirements are respected for installation in a unidirectional configuration.

(5) For seated occupants, their residual space shall be determined assuming that they are normally seated and sitting on the centre line of the seat.

(6) Where there are variations between seat assemblies which are due to a modular design of support structure, the assembled configuration which represents a worst case in terms of loading and maximum longitudinal seat stiffness under proof load conditions shall be used for assessment.
(7) For seat assemblies where optional features can be added or omitted from a base design, these variations do not need to be considered where the mechanical characteristics and the injury potential are not affected.

NOTE 2: Examples of variations due to modular design are where the position of a floor mounting can be varied laterally on assembly to cater for different keyway spacing or where a single seat is mounted on a truncated version of a double seat sub-frame.

(8) On completion of a successful structural integrity assessment the following data shall be obtained:

a) Dynamic time-history loads at each seat assembly attachment point.

b) The minimum pitch at which the seat can be installed for unconstrained unidirectional seating (see Figure 7.5, Situation A).

c) The minimum pitch at which the seat can be installed for constrained unidirectional seating (see Figure 7.5, Situation B).

d) The maximum pitch (which may be unlimited if the assessment was made using the free-flight impact seat pitch (see 7.3.2.3)).

7.3.2.2 Rearward structural integrity and residual space assessment

(1) A dynamic assessment shall be undertaken to represent the rearward projection of a 95th percentile male passenger or passengers back into their own seats as indicated in Figure 7.4. For multiple seat assemblies all laden seats shall therefore be loaded with a 95th percentile male passenger.

(2) The Dynamic structural integrity assessment shall be:

a) In accordance with Annex A

Or

b) An assessment shall be made in accordance with a procedure which can be demonstrated to be at least equivalent to the requirements of Annex A.

(3) Where a bay seating configuration is formed from pairs of seat assemblies or where a unidirectional layout changes direction using a pair of seat assemblies and the seat assemblies have been assessed for unidirectional installation, an additional rearward dynamic assessment is not required (see Figure 7.5).
For a rearward dynamic structural integrity assessment, the seat deflections throughout the dynamic event shall be used with the residual space envelopes (as defined in Annex F) to determine minimum seat pitch values according to Figure 7.6 for unidirectional seating for the following conditions:

a) Where the movement of the seats is unconstrained (Figure 7.5, Situation A), a residual space envelope corresponding to at least a 5th percentile female shall be provided.

b) Where the movement of the seats is constrained (Figure 7.5, Situation B), a residual space envelope corresponding to at least a 95th percentile male shall be provided.

Residual space shall be determined on the longitudinal-vertical plane passing through the centre-line of the seat or seating position being assessed.

Where the rearward dynamic structural integrity assessment is made using a predetermined seat pitch, the seating layout shall be assessed to determine if any seats behind the seat are constrained or not (Figure 7.5, Situation A or Situation B) and the residual space envelope required (as defined in Annex F and according to Figure 7.6) shall be maintained throughout the dynamic event.

NOTE 1: It is assumed that seats deflected by the 95th percentile males are occupied by 5th percentile females or smaller, and any deflection by them of their seats is very small and therefore discounted. For larger, heavier passengers it is assumed that their seats will also deflect at the same time as the seats deflected by the 95th percentile males, maintaining an acceptable residual space. Where the seats are constrained this sympathetic displacement is prevented and the full residual space for a 95th percentile male is required.

For a rearward dynamic structural integrity assessment of layouts which are exclusively made up of bay seating, it is not required to determine residual space.
Key

A  Situation A - Unconstrained unidirectional seating
B  Situation B - Constrained unidirectional seating
T  Bay seating – No requirements for open bays, see 8.2.2 for table bay requirements.

**Figure 7.5**  Residual space envelope requirements for unidirectional seating layouts

Key

C  Clearance between deflected seat and residual space envelope
P  The seat pitch
R  Required residual space envelope

**Figure 7.6**  Method to determine residual space for a unidirectional configuration

Pass criterion:
\[ C \geq 0 \]
Minimum pitch, \( P_{\text{MIN}} \),
when \( C = 0 \)
NOTE 2: If the minimum pitch for installation in a unidirectional configuration is being determined from the dynamic assessment results and the residual space requirements, as shown in Figure 7.6, it is not necessary to place empty seats behind the seats being assessed.

7.3.2.3 Forward structural integrity and residual space assessment

(1) For unidirectional seating, a dynamic assessment shall be undertaken to represent the forward projection of a 95th percentile male passenger or passengers into the back of the seat or seats in front as indicated in Figure 7.7. For multiple seat assemblies all launch seats shall therefore be loaded with a 95th percentile male passenger.

(2) A final velocity impact should be undertaken to represent the worst case, a forward impact at the maximum free-flight velocity of a seat occupant for the longitudinal collision pulse set out in Annex B. Under these conditions there is no restriction on the installed seat pitch.

(3) The Dynamic structural integrity assessment shall be:

a) In accordance with Annex A

Or

b) An assessment shall be made in accordance with a procedure which can be demonstrated to be at least equivalent to the requirements of Annex A.

Figure 7.7 Configuration of forward dynamic structural integrity assessment

(4) For a final velocity impact assessment, the seat pitch shall be set to give a 250 mm longitudinal spacing between the front of the residual space envelope for a 95th percentile male, as defined in Annex F, and the back of the seat in front of it, as shown in Figure 7.8. The spacing shall be measured at a height equal to dimension YF, as shown in Figure 7.8, using the values defined and set out in Annex F.
The final velocity seat pitch shall be determined on the longitudinal-vertical plane passing through the centre-line of the seat or seating position being assessed.

**NOTE 1:** The final velocity impact seat pitch assumes the final or maximum free-flight velocity calculated from the collision pulse set out in Annex B is reached at the time of first contact to give a worst case condition. The free space required between the ATD and the impact seat is calculated to generate an impact velocity of at least 5 m/s for the initial contact.

(5) As an alternative it is permissible to specify a value for the impact seat pitch. This will place a limitation on the range of seat pitches for installation of the seat assembly in a unidirectional configuration.

![Diagram](image)

Key

1 Launch seat
2 Impact seat
R The residual space envelope for a 95th percentile male.
YF = Y1 − R1, see Annex F, Figure F.1
Y1 Effective thigh height, see Annex F, Figure F.1
R1 0.5 x thigh clearance, see Annex F, Figure F.1

Figure 7.8 Method to determine final velocity impact assessment pitch

(6) When satisfactorily assessed at the final velocity impact seat pitch, there shall be no restriction on the maximum seat pitch for installation in a unidirectional configuration, as the worst-case impact condition has been assessed.

**NOTE 2:** If the final velocity seat pitch is 1000 mm but it is decided to only test at 900 mm then the limitation is that the seat cannot be installed at pitches greater than 900 mm. If the final velocity pitch is used, as this is a worst case (maximum impact speed), there is no limitation of maximum pitch.

(7) For unidirectional seating, to ensure that adequate residual space is maintained after a forward impact there shall be a clearance of at least 183 mm (5th percentile female chest depth, see Annex F, Table F.1) between adjacent seat backs (See figure 7.9) after the dynamic event.
The residual space shall be determined on the longitudinal-vertical plane passing through the centre-line of the seat or seating position being assessed.

**NOTE 3:** It is assumed that the seats impacted by the 95th percentile males are occupied by 5th percentile females or smaller, and that any impact by them against the seat in front will not permanently deform it.

(8) The residual space shall be assessed using a pitch value which shall be either:

a) The minimum pitch or pitches at which the seat assembly (the seat assembly and mounting arrangement) may be installed, determined from the rearward dynamic structural integrity and residual space assessment.

Or

b) A specified minimum pitch.

![Diagram of seat arrangement with key labels](image)

**Key**

1. Impacted seat
2. Empty seat
C. Minimum clearance

**Figure 7.9 Clearance requirements for forward impact**

(9) If the minimum clearance specified cannot be achieved after a forward impact, the pitch value shall be increased to give a new value that ensures the minimum clearance requirement is satisfied.

**NOTE 4:** The minimum pitch values determined from the rearward test for installation in a unidirectional configuration will therefore be modified.
8. Tables for passengers or staff

8.1 Tables

8.1.1 Objectives and application for table assessment

(1) The objectives are that:

a. Tables remain attached to the vehicle structure.

b. The potential for injury is controlled.

c. Residual space for seated passengers is maintained.

(2) The requirements are set out as follows:

a. General requirements for tables (8.1.2)

b. Dynamic assessment requirements for transverse passenger seats (8.2)

(3) A table assembly certified as conforming to this standard requires satisfactory assessment results for:

a. Static proof loads (8.1.3)

b. Dynamic structural integrity assessment (8.2.2)

c. Injury potential assessment

8.1.2 General requirements

(1) A table assembly is intended to be assessed independently of a specific train or vehicle design. It is however permissible for an assessment to be undertaken for a specific installation.

(2) All fixed or side tables shall be attached directly or indirectly to the vehicle structure. Requirements applicable to seat mounted tables are set out in Chapter 7.

(3) The potential for injury shall be reviewed. The results of structural assessments and conformity with geometric requirements may form part of this review. In addition the methods set out in Chapter 9 may be applied.

(4) For seated passengers, where the distance from the seat centre-line to the table lateral edge is greater or equal to 160 mm the table shall be considered to be a side table (See figure 8.1).

![Figure 8.1 – Side table for seated passengers](image)

(5) For seated passengers, where the overlap from the seat centre-line to the end of the table edge facing the user is equal or greater than 160 mm in both transverse directions, the table shall be
considered to fully overlap the seating position (See figure 8.2). Fixed tables which exceed the transverse dimensions of a side table but which are less than a full overlapping table, shall be considered to be partially overlapping tables.

![Figure 8.2 – Fully overlapping fixed table for seated passengers](image)

**NOTE 1:** The transverse dimension of 160 mm relates to the chest breadth of a 50th percentile male ATD. For larger users, for example a 95th male, a small overlap of approximately 25 mm will occur for a centrally positioned user.

(6) Partially overlapping tables are an open point. The requirements for fully overlapping tables can be applied.

(7) Fixed tables and their mountings shall withstand the following static proof loads:

a) 1000 N applied vertically downwards and upwards at any position. The proof load shall be applied in each direction independently. Where hinged elements are used, the upward load shall apply only to the fixed parts of the table.

b) 750 N applied horizontally to the edge of the table, in any direction and at any position on the edge. Where hinged or sliding elements are used, the load shall apply only to the fixed parts of the table.

c) For fixed tables which fully or partially overlap two or more transverse seating positions, a load of 1500 N parallel to the longitudinal axis of the vehicle applied horizontally to the edge of the table on the side accessible to passengers (see Figure 8.3). Where hinged or sliding elements are used, the load shall apply only to the fixed parts of the table. A fixed table partially overlaps a second position when the end of the table extends beyond the second seat centre line or when the dimension from the end of the table to the second seat centre-line is less than 160 mm (see Figure 8.3).

d) For hinged or sliding elements when fully deployed or extended, vertical proof loads of 750 N applied downwards at the centre of the hinged part of the table and at any point along the edge of the hinged or sliding part.
Side tables and their mountings shall withstand vertical proof loads of 750 N applied downwards at any point along the unsupported table edges.

8.1.2.1 Requirements for table edge profiles

1) For fixed tables with rigid edges exposed to a seated or standing occupant’s chest or abdomen, the edges shall be at least 40 mm thick with minimum corner radii of 5 mm between the surfaces and the table edge. The thickness shall be measured at a plane between 5 and 10 mm inboard from the edge (See figure 8.4).

2) For fixed tables with folding, hinged or sliding elements (to facilitate passenger access for example), in the deployed condition rigid, edges exposed to a seated occupant’s chest or abdomen the edges shall be at least 20 mm thick with minimum corner radii of 5 mm between the surfaces and the table edge. The thickness shall be measured at a plane between 5 and 10 mm inboard from the edge (See figure 8.4).

3) When table elements can be folded over completely to give a flat surface, the resulting table edge shall be at least 40 mm thick with minimum corner radii of 5 mm between the surfaces and the table edge (See figure 8.4).

4) Table plan view radii shall be at least 25 mm with the following exceptions:

   a) For table corners mounted adjacent to the bodyside or fixed partitions, the plan view radii may be reduced to 15 mm.
b) For tables with hinged elements, the plan view radii shall not be less than 5mm on all parts. It is recommended, whether the table is folded or unfolded, for table corners that are directly exposed to adjacent passengers or walkways that the plan view radii are at least 25mm where practicable. (See figure 8.4).

(5) Alternative table edge profiles and thicknesses are permissible and shall be supported by suitable data demonstrating that the injury potential for the table is at least equivalent to the requirements set out in this document.

Key
1 Principal surface e.g. table top, partition face
2 Edge profile
A-A Section through edge profile
R₁ Edge profile upper radius
R₂ Edge profile lower radius
R₃ Plan view radius
O Offset to thickness measurement plane
T Edge thickness

Figure 8.4 – Fixed table edge profile geometry

8.2 Dynamic assessment requirements for fixed tables for seated passengers
8.2.1 General requirements

(1) Dynamic assessment is only required for fixed tables used in conjunction with transverse seating. Dynamic assessment may take the form of physical testing or numerical simulation or a combination of both (See 10.2).

(2) Table assemblies for a new installation (for example either a completely new design of table assembly or a new design of supports) for which a structural integrity assessment has not been
undertaken in accordance with this document shall be dynamically assessed in accordance with 8.2.2.

(3) The forces obtained from the dynamic assessment at the table assembly fixing points shall be reacted at the corresponding points in the vehicle interior wherever the table assembly is mounted through to the primary structure.

(4) If a structurally identical table design has been assessed in a specific configuration and met all the requirements of this document, it does not need to be reassessed for a different installation configuration if all of the parameter modifications relative to the seats are within the following tolerance ranges:

a) Any increase in the longitudinal distance (in a horizontal plane) between the front edge of the table top and the seat backs (depicted as dimension “A” and “C” in Figure 8.5) is not greater than 25 mm.

b) The variation in the vertical distance between the underside of the table top and the highest point on the seat bottom cushion (depicted as dimension “B” in Figure 8.5) is within the range of ±25 mm.

Key
A  Horizontal clearance(s) between table edge and launch seat back(s) at the seat centre line
B  Vertical clearance between seat base and table top
C  Horizontal clearance(s) between table edge and facing seat back(s) at the seat centre line
x  Table width
It may be desirable to manufacture a table with slightly different table top geometry for different applications. If minor geometrical changes are made to an otherwise structurally identical table design that has been assessed and met all the requirements of this document, it does not need to be reassessed if geometry changes are within the defined acceptable tolerance range below:

a) The variation in the table lateral dimension is within the range +25/-75 mm (dimension “y” in Figure 8.5).

b) The variation in the table longitudinal dimension is within the range +75/-0 mm (dimension “x” in Figure 8.5).

c) The installed variations relative to the seats are within the defined limits.

### 8.2.2 Dynamic table assessment for structural integrity and residual space

(1) Subject to the requirements of 8.2.1, a dynamic assessment shall be undertaken to represent the forward projection of a 95th percentile male passenger or passengers against the table in front of them. This assessment shall be considered equivalent to an ultimate load case.

(2) Successful dynamic assessments shall satisfy the criteria set out in 5.3.

(3) The Dynamic structural integrity assessment shall be:

   a) In accordance with Annex A.

   Or

   b) An assessment shall be made in accordance with a procedure which can be demonstrated to be at least equivalent to the requirements of Annex A.

(4) The requirements for residual space shall be satisfied.

(5) For tables with sliding elements no dynamic structural assessment shall be required for the extended position if the sliding element slides back to the closed position when subjected to a horizontal force of not greater than 100 N.

(6) On completion of a successful structural integrity assessment the following data shall be obtained:

   a) Dynamic time-history loads at each table assembly attachment point.

   b) The maximum spacing between the table and the laden seat(s) (Figure 8.5, dimension ‘A’).

   c) The spacing between the table and the empty seat(s) (Figure 8.5, dimension ‘C’). This dimension shall always be less than or equal to the spacing between the table and the laden seat(s) (Figure 8.5, dimension ‘A’).

   d) The height from any floor level attachment points and the table top.

   e) The clearance (relative height) between the seat and the table top (Figure 8.5, dimension ‘B’). Dimension ‘B’ shall be measured from point A’ on Figure 7.1.

**NOTE 1:** If the table bay is not symmetric, for example to give priority seating on one side, assessment using the maximum seat back to table spacing (so that A > C) (Figure 8.5) is assumed to give the worst case structurally.
NOTE 2: It is assumed that in practice, due to ergonomic and PRM requirements, there will be limited variation in the absolute table height and the seat to table clearance (dimension B)

f) The table top dimensions (y laterally, x longitudinally)

(7) Where there are variations between table assembly types which are due to a modular design of support structure, the assembled configuration which represents a worst case in terms of maximum longitudinal table stiffness under proof load conditions shall be used for assessment.

NOTE 3: Examples are where the position of a floor mounting can be varied laterally on assembly to cater for different keyway spacing.

NOTE 4: If the minimum pitch is being determined from the assessment results and the residual space requirements, it is not necessary to place empty seats in front of the table being assessed.

(8) For a dynamic structural integrity table assessment, a residual space envelope as defined in Annex F shall be provided on the non-impacted side of the table as set out in Figure 8.6:

a) For Case A (see Figure 8.7), a 5th percentile female residual space envelope.

b) For Case B (see Figure 8.7), a 95th percentile male residual space envelope.

![Figure 8.6 Residual space and clearance requirements for fixed table bays](image_url)

Key
R Residual space envelope

(9) On the impacted side of the table, if the launch seat can be directly impacted from behind (Figure 8.7 Case A) during the same dynamic event that causes the table to be impacted, then after the dynamic event, the clearance shall be determined between launch seat and the table as set out in Figure 8.8. The determination of clearance between seat and table is not required for Case B as shown in Figure 8.7.

(10) Residual space shall be determined on the longitudinal-vertical plane passing through the centre-line of the seat or seating position being assessed.

(11) The same deflection as determined for the forward structural integrity assessment for the seat to be installed with the table shall be assumed (see Figure 7.9 and sub-clause 7.3.2.3).
Figure 8.7 Fixed table bay reference configurations

Key
D  Clearance to fixed table after forward impacts to table and launch seat
S  Residual spacing to table after forward impact to the seat behind the table
R  Residual space envelope

Figure 8.8 Residual space and clearance requirements for fixed table bays (Figure 8.6 Case A)

(12) For installations that correspond to Figure 8.7 Case A:

a) There shall be a clearance of at least 246 mm (95th percentile male chest depth) between the deformed table edge and the deformed seat (Figure 8.8, dimension D).

b) There shall be a clearance of at least 183 mm (5th percentile female chest depth) between the un-deformed table edge and the deformed seat (Figure 8.8, dimension S).

NOTE 5: The seat deflection data to determine D and S is obtained from the certification results for the seats to be installed (See 7.3.2).

a)
9. Dynamic methods for injury potential assessment (Informative)

9.1 Dynamic methods for injury potential assessment

(1) The following method for the assessment of injury potential may be applied. Application of these assessment measures can be considered as part of the overall arrangements for risk management of the rail system on which the vehicles operate and in consideration of national rules.

9.2 Dynamic unidirectional seat assessment for injury potential

9.2.1 Requirements for seat injury potential assessment

(1) A seat assembly for use in a unidirectional seating configuration shall be dynamically assessed to determine its injury potential unless the validity of a previous assessment for a similar seat assembly can be demonstrated according to the following requirements:

a) Where an injury potential assessment has been undertaken for a seat but the seat supporting structure and/or method of attachment to the vehicle structure is of a new design, the dynamic deflections from the old and new dynamic structural integrity assessments shall be used to determine if a new injury potential assessment is required. The dynamic structural integrity assessments to be compared shall both be in accordance with this document.

b) For assessment of the changes in dynamic deflections from the old and new dynamic structural integrity assessments, reference points shall be defined that characterise the impact points for the existing injury potential assessment, typically the base of the seat back and the seat back at the position used for application of the longitudinal proof loads. The reference points used must be located on those parts of the seat assembly which are in common between the old and new dynamic structural integrity assessments.

(2) If the dynamic deflections of the seat assembly from the new dynamic structural integrity assessment are greater than for the old dynamic structural integrity assessment, then an additional (i.e. new) injury criteria assessment is not required.

(3) If for the new dynamic structural integrity assessment the dynamic deflections of the seat assembly are lower than for the old dynamic structural integrity assessment, then a new injury potential assessment is required.

(4) Dynamic assessment may take the form of physical testing or numerical simulation or a combination of both (See 10.2).

9.2.2 Dynamic seat injury potential assessment

(1) When required, injury potential shall be evaluated by either:

a) Dynamic assessment in accordance with Annex A to represent the projection forward of a 50th percentile male passenger into the back of the seat in front to give a satisfactory injury assessment as set out in Annex E.

Or

b) Assessment in accordance with a procedure which can be demonstrated to be at least equivalent to the requirements of Annex A and which results in a satisfactory injury assessment in accordance with Annex E.

(2) The final velocity impact seat pitch defined for dynamic structural integrity assessment shall be used (see 7.3.2.3) or an impact seat pitch shall be specified.
Only one ATD shall be used for the injury assessment. For multiple seat assemblies, the stiffer seat position shall be used for injury assessment (see Figure 9.1). The longitudinal deflection determined under structural dynamic load conditions (see 7.3.2) for the individual seats (for example aisle or window positions) shall be used to determine the relative stiffness’s.

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**Key**

1. Launch seat (directly behind the impact seat)
2. Impact seat (where $\delta_{\text{proof}}$ is the minimum)
1’ and 2’ denote alternative seat positions

$\delta_{\text{proof}}$ Deflection under longitudinal dynamic structural load

**NOTE 1:** The impact seat is determined by the minimum value of $\delta_{\text{proof}}$. The impact seat itself may form part of a seating bay rather than an exclusively unidirectional group of seats

**Figure 9.1 – Dynamic assessment for injury potential**

9.2.3 **Side mounted seat tables, injury potential assessment**

(1) For fold away tables which are directly mounted on a seat at the side of the passenger, a dynamic injury assessment shall be undertaken in accordance with the dynamic assessment requirements for fixed tables (see 9.3).

9.2.4 **Seat back mounted tables, injury potential assessment**

(1) For seat back mounted tables, the risk of chest or abdominal contact in a longitudinal collision shall be assessed using a 50th percentile male ATD.

(2) It is permissible for the seat to be either a numerical model or a real seat, and for the ATD to be either a numerical model or a physical test device.

(3) If the lowered seat back table, when subjected to a horizontal force of 100 N, folds back into the closed position or closes to the point where a securing latch is contacted, no assessment shall be required for the lowered position.
NOTE 1: With the exception of self-weight, no other loadings or external constraints are assumed when the assessment load is applied.

(4) The following method shall be used:

a) The seat back table in front of the seat to be assessed shall be lowered. If the table is intended to be extendable or moveable towards the user, it shall be extended and then pushed back horizontally with a force not greater than 100 N.

b) If required, the seat table may be temporarily fixed in its final position at the end of the load application.

c) For this assessment, the seat for the ATD and the seat on which the seat back table is mounted shall be spaced at a pitch which is sufficient for the table to be lowered without making contact with the ATD.

d) The ATD shall be positioned on the seat with the ATD H-point aligned with the seat H-point within an allowable envelope of ± 10mm in the vertical and horizontal directions (See Annex C).

e) The ATD shall be moved forwards along the seat cushion until the knees contact the seat in front.

f) At this point the upper body shall be rotated forward about the hip joint until head or chest contact is made with the seat in front or until the head or chest of the ATD is prevented from forward movement by the table (See Figure 9.2). For this purpose the neck and head shall be assumed to maintain the same relative orientation relative to the spine.

g) The clearance or overlap between the ATD and the seat back table shall be determined. If the head or chest of the ATD is prevented from contacting the seat in front, the overlap between the table and the ATD shall be determined by comparison with a repeated assessment made with the table folded away.

h) If a physical assessment is undertaken, to determine the overlap, a straight line may be assumed between the lower edge of the chest tangential to the base of the abdomen.

![Diagram of seat back table geometric injury potential assessment](Image)
(5) If the chest or abdomen of the ATD does not contact the seat back table the risk of injury may be discounted.

(6) Where there is contact between the ATD and the seat back table, if the overlap is less than 40 mm between the table and chest or abdomen then, subject to all the other criteria being satisfied for the seat back table (see 7.2.1), the risk of injury may be considered to be acceptable.

(7) Where the overlap between the ATD and the seat back table exceeds 40 mm, a dynamic assessment for injury potential shall be undertaken:

a) The assessment procedure set out in 9.2.2 shall be repeated so that both the fully deployed and fully stowed positions are assessed.

b) If, under dynamic load conditions, the seat back table closes, there shall be no contact between the neck or head of the impacting ATD and the edge of the table unless, where this occurs, it is shown to be acceptable as part of the injury criteria assessment set out in Annex E

9.3 Dynamic table assessment for injury potential

(1) A table assembly for use with transverse seating to a design for which an injury potential assessment has not been undertaken shall be dynamically assessed to assess the injury potential.

(2) Where an injury potential assessment has been undertaken for a table assembly but the supporting structure and/or method of attachment to the vehicle structure is to a new design, the dynamic deflections from the old and new dynamic structural assessments shall be used to determine if a new injury potential assessment is required.

(3) If the dynamic deflections of the table assembly from the new dynamic structural assessment (characterised by the longitudinal deflections of the table at the centre lines of the seats and the dynamic rotation (pitch) of the table top) are greater than for the old dynamic structural assessment then an additional (i.e. new) injury potential assessment is not required.

(4) If for the new dynamic structural assessment the dynamic deflections of the table assembly are lower than for the old dynamic structural assessment then a new injury potential assessment is required.

(5) When required, injury potential shall be evaluated by a dynamic assessment to give a satisfactory injury assessment in accordance with Annex E for the projection forward of a 50th percentile male passenger against the table in front of them.

NOTE 1: Injury criteria that are typically considered the most relevant for a dynamic table injury assessment are those for the chest and abdomen, but the criteria for the head and neck, subject to the detailed design of the table and the envisaged installation can also be significant. For relatively small seat bay configurations (characterised by the sum of A + x + C on Figure 8.5) where relatively narrow tables are used, the occupants legs may strike the opposite seat during the same time period that abdomen or chest contact is made and therefore injury criteria for femur, knee and tibia also become relevant.

(6) The Dynamic injury potential assessment shall be:

a) In accordance with Annex A

Or

b) An assessment shall be made in accordance with a procedure which can be demonstrated to be at least equivalent to the requirements of Annex A.

(7) A single seat position for dynamic assessment shall be selected according to the following assumptions and criteria:
b) For shared tables, the seat position where the local table longitudinal stiffness (measured at the seat centre-line) is greater shall be used. It is acceptable for displacements from longitudinal proof load assessment to be used for this purpose.

c) Where tables are fitted with hinged flaps or moveable elements to permit access to seating, both open and closed cases shall be dynamically assessed for injury potential.

For tables with sliding elements if, when subjected to a horizontal force not greater than 100 N, the sliding elements retract to the closed position, no assessment shall be required for the extended position.

10. Verification

10.1 Demonstration of railway vehicle interior structural integrity

(1) The satisfactory performance of railway vehicle interior structures and structural elements shall be demonstrated by calculation, testing, comparison with documented established practice on other vehicles or a combination of these methods.

(2) In order to allow for uncertainties associated with methods of calculation and also for the consequences of failure, all proof or service load calculations or test results shall achieve the proof and ultimate load safety factors as set out in Chapter 5.

10.2 Dynamic testing, computer simulations and calculations

(1) It is permissible to undertake computer simulations and calculations in place of dynamic testing for seats and tables where it can be demonstrated that the models used are validated against directly comparable test data for a rail vehicle interior. As a minimum, it shall be demonstrated that:

a) Validated computer models of the anthropomorphic test devices (ATDs) are used.

b) The models used for seats, tables or other fixtures are validated by testing or calculation.

c) The results obtained exhibit good correlation with existing test data for equivalent conditions. Measurements of data from the computer models for the determination of injury criteria and deformations shall be within ±20% of comparable physical test results.
Annex A. Dynamic Test Procedures for Passenger Seats or Tables

(Normative)

A.1 Introduction
A.1.1 This Annex sets out the requirements for dynamically testing seats or tables for a longitudinal impact, using anthropomorphic test devices (ATDs).

A.1.2 Where numerical simulations are used instead of physical testing the models used shall demonstrate equivalence with the physical test requirements in this Annex and Annexes B, C and D. For example, a section of a vehicle structure model or a rigid base can be considered equivalent to a testing platform, and pre and post-processor outputs from numerical simulations are equivalent to photographs and video.

A.2 Preparation of seats or tables for dynamic testing
A.2.1 General Requirements
A.2.1.2 The seat or tables to be tested shall be mounted on a testing platform in a manner that is functionally representative of the vehicle interior for the purposes of the dynamic tests to be undertaken.

NOTE 1: In mounting the seats or tables on a given testing platform it is recognised that often it will not be possible to fully replicate the actual vehicle installation and that a number of approximations or simplifications will be necessary.

A.2.1.3 For each test, the seats and tables shall be positioned using the seat pitch, spacing and orientation required. Any additional items identified in determining the critical positions shall be installed in their locations relative to the seats and tables.

A.2.1.4 The seats to be tested shall be complete with all upholstery and accessories. If the seats are fitted with seat back tables, they shall be either in the stowed or fully deployed positions as required.

A.2.1.5 If adjustable, seat backs shall be in the upright position.

A.2.1.6 Seats completing the installation to be tested but which will not be impacted by the ATD shall be the same type as the seat being tested and shall be located in an identical arrangement to that used in vehicles in which the seat is intended to be used.

NOTE 2: Seats which are required to launch an ATD into a table are not required to be identical to the vehicle seats provided that it can be demonstrated that the dynamic test results are not affected in terms of ATD launching, trajectory and any rebound after impact.

A.2.2 Component testing - Representative supports and fixings
A.2.2.1 The anchorages on the testing platform provided for the test seats or tables shall be representative of those used in vehicles in which the seats or tables are intended to be used.

A.2.2.2 Components (e.g. seats and tables) shall be complete assemblies including any supports, plinths, brackets or supporting structures required for their installation into a vehicle.

A.2.2.3 The vehicle primary structure may be assumed to be rigid for the purposes of testing. The vehicle primary structure for the purpose of component tests may be considered to include where relevant intermediate structures between the primary carbody structure and the component e.g. resiliently mounted floor units, partitions or support frameworks for panels.
A.2.2.4 The correct fasteners and/or fittings shall be used between the component and any parts representing the vehicle structure. The fasteners and/or fittings shall be tightened and/or secured in accordance with the installation instructions for the component.

A.2.2.5 Where keyways are used it shall be demonstrated that the directly loaded parts of the keyway do not fail due to the loads applied through the fastenings and associated fittings by fracture or splaying.

A.2.2.6 Where separate keyways are mechanically fastened to the vehicle structure it should be further demonstrated that the keyway fasteners are sufficient in size and quantity to withstand the dynamic loadings.

A.2.2.7 Load data shall be measured to define the structural requirements for the item’s installation, and the required strength of attachment points and fixings.

NOTE 3: For the purposes of testing, where keyways, for example T-slots, are used as the primary anchorages on the vehicle, it is permissible to use alternatives, for example commercially available generic keyway sections, provided that the critical elements of the fastening system are the same.

A.4 Dynamic test

A.4.1 The test environment shall be maintained at a temperature between 19°C and 26°C.

A.4.2 (1) The configuration and arrangement of each test installation shall be recorded, using measurements and photographs to enable the tests to be replicated by repeated testing or computer simulation

(2) ATDs shall be prepared and positioned for testing as set out in Annex C.

(3) The test installation shall be marked up for motion analysis and measured in accordance with Annex D.

(4) Details of the seat type, table type if applicable, build configuration of the seats and tables and details of all mountings and fixings shall be included in the test report.

(5) If the mounting arrangement is configurable on assembly, the configuration shall be included in the test results.

NOTE 1: The intention is that the tests will be documented on a consistent basis at a level of detail sufficient if required to allow the tests to be replicated or simulated at a future date. The data to be recorded will form part of the test report which will form a key part of the technical argument presented to justify the acceptability of a given dynamic test.

A.4.3 The testing platform with ATDs installed shall be subjected to a simulated impact in accordance with the test pulse specified in Annex B.

A.4.4 The dynamic test shall be recorded using high speed cameras or imaging systems recording at a rate of at least 1000 frames per second. The video data shall be sufficient for the dynamics of the test and the interaction of the ATDs with the seats or tables to be determined and as a minimum shall record the test from the side and from above with cameras aligned perpendicularly to the axes of the test platform.

A.4.5 After the dynamic test at least the following items shall be determined and recorded:

b) For each ATD the location of points of impact shall be identified, located and photographed.

c) The maximum dynamic deflection longitudinally and the final position of the seats or tables longitudinally, laterally and vertically shall be measured and recorded.

d) Where parts have been moved or been deformed or damaged the extent of deformation shall be measured, photographed and recorded.
Annex B.  Longitudinal dynamic test pulse

(Normative)

B.1  Introduction

B.1.1  This Annex specifies the dynamic acceleration pulse for a longitudinal impact.

B.1.2  A minimum free flight velocity of 5 m/s and a maximum free flight velocity of 6 m/s shall be attained.

B.1.3  For numerical simulations a rectangular 5g pulse of 100 ms duration may be used.

Figure B.1 Test pulse

<table>
<thead>
<tr>
<th>Point</th>
<th>Time (ms)</th>
<th>Acceleration (g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>0</td>
<td>0.0</td>
</tr>
<tr>
<td>B</td>
<td>10</td>
<td>5.0</td>
</tr>
<tr>
<td>C</td>
<td>90.5</td>
<td>5.0</td>
</tr>
<tr>
<td>D</td>
<td>100</td>
<td>0.0</td>
</tr>
<tr>
<td>E</td>
<td>-20</td>
<td>0.0</td>
</tr>
<tr>
<td>F</td>
<td>0</td>
<td>6.0</td>
</tr>
<tr>
<td>G</td>
<td>105</td>
<td>6.0</td>
</tr>
<tr>
<td>H</td>
<td>140</td>
<td>0.0</td>
</tr>
</tbody>
</table>

Table B.1 Test pulse coordinates
NOTE 1: The test pulse is designed to represent the effect on passenger and crew areas of collision impacts seen by vehicles having energy absorbing properties. Limits are set to reflect the practical limitations of dynamic sled testing.

Annex C. Preparation and Setting Up Procedures for Anthropomorphic Test Devices (ATDs)

(Normative)

C.1 ATDs for dynamic assessment
C.1.1 ATDs for structural assessment shall comply with the requirements of C.2 and shall be prepared and position in accordance with the relevant requirements set out in C.4, C.5, C.6, C.7 and C.8.

C.1.2 If ATDs are used for the evaluation of injury potential, they shall comply with the requirements of C.3 and shall be prepared and position in accordance with the relevant requirements set out in C.4, C.5, C.6, C.7 and C.8.

C.2 ATDs for structural assessment
C.2.1 For the determination of structural integrity, 95th percentile male ATDs shall be used unless otherwise specified in this document.

C.2.2 95th percentile male ATDs shall conform to the dimensions set out in U.S. Department of Transportation 49 CFR 238.5

C.2.3 Un-instrumented 95th percentile male ATDs shall be either Hybrid II or Hybrid III as specified in the dummy manufacturer's user manual.

C.3 ATDs for assessment of injury potential
C.3.1 For the determination of injury criteria, except where permitted by C.2.3, Hybrid III 50th percentile male ATDs shall be used, equipped with sufficient instrumentation to determine the injury criteria required.

C.3.2 Hybrid III 50th percentile ATDs shall conform to U.S. Department of Transportation 49 CFR 572.30 and ECE 94, except for the following modifications and additions:

a) 45 degree dorsi-flexion ankles / feet with rubber bump stops and padded heels shall be fitted.

b) Roller ball-bearing knees, such as those supplied by ASTC, shall be fitted.

C.3.3 Where it is not practicable to measure parameters directly with a standard Hybrid III ATD, it is permissible for data to be used in support of the overall injury criteria assessment that is obtained using:

a) Modified Hybrid III ATDs (for example the Hybrid III RS ATD).

Or

b) Other test devices (for example other types of ATD, for example the THOR ATD, or headform devices).

Or

c) Validated computer simulations.

NOTE 1: For a description and specification of the Hybrid III RS ATD please see RSSB research project T066, particularly the report ‘Hybrid III Rail Dummy Specification’

NOTE 2: When using computer simulations as an alternative to ATDs, software models that represent more completely the human body could be used as these develop and become more widely available. In such cases
the validation should clearly demonstrate the links between physical ATD testing, simulation of the testing and any simulation using alternative models in addition to the validation of the alternative numerical ATD or human body models used.

C.4 Certification and calibration of ATDs

C.4.1 Hybrid III ATDs shall be re-certified after every 10 impact tests according to the certification procedure for the Hybrid III ATDs (see US Department of Transportation 49 CFR 572.30) and Annex 10 of ECE 94.

C.4.2 Where modified ATDs are used, the standard parts of the ATDs shall be re-certified according to C.3.1. Non-standard parts shall be calibrated according to the manufacturer's instructions or a suitable calibration procedure shall be included in the injury criteria assessment.

C.4.3 Where other test devices are used, the devices shall be calibrated according to the manufacturer's instructions or a suitable calibration procedure shall be included in the injury criteria assessment.

C.4.4 Where computer simulations are used, details of the software revision level and publisher shall be included in the assessment report.

C.5 ATD preparation

C.5.1 Each ATD shall be clothed with form-fitting cotton stretch garments with short sleeves and pants which shall not cover the dummy's knees.

C.5.2 Each ATD shall be fitted with shoes equivalent to those specified in MIL-S-13192P (size XW).

C.5.3 Each ATD shall have a stabilised temperature in the range of 19°C to 26°C. This shall be achieved by the following procedure:

a) The ATD shall be heat soaked at the specified temperature range for at least 4 hours prior to the test.

b) The temperature of the ATD shall be measured using a recording electronic thermometer placed inside the dummy's flesh.

c) The temperature shall be recorded at intervals not exceeding 10 minutes.

d) A printout of the temperature readings shall be supplied as part of the standard output of the test.

e) Subject to the ATD remaining within the test environment, it shall not be necessary to repeat the temperature stabilisation procedures set out in C.4.3 a) to d) for a sequence of tests or for repeat testing.

C.5.4 All constant friction joints shall have their 'stiffness' set by the following method:

a) The ATD temperature shall be stabilised in accordance with C.4.3.

b) The tensioning screw or bolt which acts on the constant friction surfaces shall be adjusted until the joint can just hold the adjoining limb in the horizontal. When a small downward force is applied and then removed, the limb shall continue to fall.

c) The ATD joint stiffness's shall be set as close as possible to the time of the test and, in any case, not more than 24 hours before the test.

d) The ATD shall be maintained within the temperature range specified in C.4.3 between the time of setting the limbs and the time of the test.
C.6 Physical ATD positioning

C.6.1 The ATD shall be positioned as follows:

a) Establish the seat H Point by using the SAE J826 procedure

b) The ATD shall be placed on the seat as close as possible to the required position so that its plane of symmetry corresponds to the plane of symmetry of the seating position in question.

c) A small rearwards force shall be applied to the lower torso and a small forwards force to the upper torso to flex the upper torso forwards from the seat back. The torso shall then be rocked left and right four times, going to between 14° and 16° to the vertical.

d) A small rearwards force shall be applied to the upper torso while maintaining the small rearwards force to the lower torso to return the upper torso to the seat back. This force shall be removed slowly.

e) The ATD's hands shall rest on its thighs with its elbows touching the seat back. If seated at a table the ATD's hands shall rest on the table top, with the arms aligned with the longitudinal axis of the dummy, palms down, with the wrist bolt in line with the edge of the table.

f) Where seat footrests are provided and are to be used in the test, the feet should be placed on the footrest with the instep of the shoe located on the footrest bar or platform. The heels shall be adjusted so they have the same X co-ordinate (longitudinally along the length of the vehicle or test platform).

g) Where seat footrests are not provided or not to be used in the test, the legs shall be extended to the maximum and then lowered so the heels shall touch the floor. The feet shall be pushed 10 mm rearward and shall be adjusted so the foot lies flat on the floor. The heels shall be adjusted so they have the same longitudinal position.

h) The separation between the knees shall be 170 mm.

i) The head transverse instrumentation platform shall be horizontal to within 2.5° from the horizontal.

j) Measure the ATD H Point position and compare to the seat H point value obtained following the procedure SAE J826. If the ATD value is outside the tolerance of ±13 mm longitudinally and/or vertically with respect to the seat H-point, adjust the pelvic position until within the tolerance and follow steps e) to i) to reposition the other parts of the ATD.

k) Measure the ATD H Point and check that it's within the tolerance. If necessary repeat the positioning procedure. If it is not possible to position the ATD H Point within the tolerance relative to the seat H point, place the ATD as close as possible and record the position.

C.6.2 If only a physical test is being undertaken and therefore a very precise positioning is not required to allow interchange between physical and simulated tests, steps a), j) and k) may be omitted at the discretion of the test laboratory. Any such omission shall be recorded in the test report.

C.6.3 Where it is not possible to correctly position 95th percentile ATDs for dynamic structural integrity testing, it is permissible to use 50th percentile ATDs which are ballasted to the mass of a 95th percentile ATD.

a) For forward tests, the ballast mass shall be placed in line with the pelvis and the ATD positioned to bring the knees in line with those of the outer ATDs.

b) For rearward tests, the ballast mass shall be placed on the ATD chest.
NOTE 1: The size and relative inflexibility of the 95th percentile ATD means that for some seats, for example triple seats for commuter stock, it is not possible to correctly position the ATDs. When the smaller 50th percentile ATD is used and ballasted to the correct mass, the test objective of applying a dynamic passenger load on the applicable seat structures can be satisfied. There is not known to be a corresponding problem for dynamic testing for injury potential using the 50th percentile ATD.

C.7 Virtual ATD positioning

C.7.1 Where numerical simulations are used instead of physical testing, the ATD models used shall be installed into the overall numerical model so as to achieve equivalence with the physical test positioning requirements set out in C.6 of this Annex.

C.7.2 The ATD H-point shall be determined in the numerical model following the procedure set out in C.5 (See C.5.1).

C.7.3 The data recording the position of each physical dummy in its seat shall be obtained in accordance with Annex D.

C.7.4 In setting up the numerical simulation, each ATD shall be positioned in the seat so that:

a) The ATD H-point is within ± 13 mm longitudinally and/or vertically and ± 0.1 mm laterally

b) Static equilibrium is achieved assuming a self-weight loading under gravity.

c) The status of the contacts between the virtual ATD and the seat can be shown to be within realistic limits at the start of the assessment, consistent with the overall accuracy of the simulation.

C.7.5 The initial posture and positioning of numerical ATDs shall be the same as for a physical test.

C.7.6 The numerical ATD model position relative to its seat when compared to the measured data obtained for the physical dummy shall be within the same tolerance ranges as the H-point position.

C.7.7 Data demonstrating the correct positioning of virtual ATDs shall be included in any report or documentation for the numerical simulation.

C.8 Instrumentation

C.8.1 Measuring instruments and instrumentation cabling shall not in any way affect the movement of the ATD during impact.

C.8.2 The temperature of the system of measuring instruments shall be stabilised before the test and maintained within a range between 19°C and 26°C.
Annex D. Measurements and data requirements for dynamic testing

(Normative)

D.1 General Requirements
   D.1.1 Prior to testing, the test arrangement shall be marked up and measured.
   D.1.2 Where only a single physical test is required, the requirements of sections D.2, D.3, D.5 and D.6 shall be satisfied.
   D.1.3 Where interchange between physical and simulated tests is required, the requirements of sections D.2, D.3, D.4, D.5 and D.6 shall be satisfied.
   D.1.4 Where numerical simulations are used the equivalent data points on the numerical model shall be reported and/or monitored so as to achieve equivalence with the physical test requirements set out in this Annex.

D.2 Motion analysis and contact point markings
   D.2.1 As a minimum, motion analysis target points or strips shall be positioned on each ATD at the following locations:
      a) The ankle, knee, wrist, elbow and shoulder joints.
      b) The H point.
      c) The centre of gravity of the head.
      d) To evaluate axial rotations of the head additional motion analysis targets or strips.
      e) The upper and lower thorax (to have an approximation of torso inclination)
   D.2.2 Anticipated points of contact on the ATD, seats and/or tables shall be marked with a non-permanent, transferable marker (for example a non-setting paint). Each contact marker shall be coloured so as to enable different contacts to be identified.

D.3 Minimum ATD position measurement requirements
   D.3.1 If only a physical test is being undertaken and interchange between physical and virtual tests is therefore not required, the following requirements represent the minimum requirement.
   D.3.2 Using a fixed datum on the fixed seat structure or on the test apparatus, the following ATD reference positions shall be measured and recorded longitudinally, laterally and vertically:
      a) ‘H-Point’ (see Figure D.1).
      b) Head centre of gravity.
   D.3.3 Measurements defining the ATD position relative to the seat shall be made to an accuracy of at least ±5 mm. The datum point shall be recorded.
   D.3.4 The ATD pelvic angle shall be measured relative to the horizontal plane.
D.4 **ATD measurement and data requirements for physical and virtual tests**

D.4.1 Where interchange between physical and simulated tests is required, the following measurements shall be undertaken before testing.

D.4.2 The measurements to be recorded shall be taken with a multi-axis measuring arm as a series of x, y, z coordinates referenced to a datum point on the fixed seat structure or on the test apparatus.

D.4.3 Measurements shall be to an accuracy of at least \( \pm 0.15 \) mm and a repeatability of at least \( \pm 0.15 \) mm.

D.4.4 The following points and/or positions on each ATD shall be recorded:

   a) The position of the H-point derived from the H point manikin
   b) The position of the H-point derived from the ATD
   c) The centre of gravity of the head on its lateral plane
   d) The pelvic angle should be recorded, using the pelvic angle measuring gauge.
   e) The position of the heels of the shoes.
   f) For locations where the feet are on foot rests, the angle of the foot.
   g) The location of the hand and wrist.
   h) The location of the ankle.
   i) The location of all motion analysis targets.
D.5 Seat geometry measurements

D.5.1 The following points and/or positions on the seat assemblies shall be recorded:

a) The height of the top of the seat base cushion from the floor at the front edge of the seat.

b) The lowest most height of the seat shell or supporting structure at the front of the seat from the floor.

c) The angle of the seat base cushion from the horizontal, additionally the length of the cushion from the front of the seat to the intersection point of the back cushion and the base cushion.

d) The angle and length from the top of the seat base cushion at the front of the seat to the underside of the seat pan or supporting structure at the front of the seat (tibia impact when considering open bay seat arrangements).

e) The angle of the seat back cushion to the vertical.

f) The vertical distance from the top of the seat back to the floor.

g) The horizontal distance from the front of the seat base cushion to the rearmost location of the main seat shell or supporting structure (seat footprint).

h) When the seats are located in rows, the distance between seats, measured as the distance from the vertical seat back to the corresponding point on the seat in front.

i) When the seats are arranged in bays, the distance between the seat back, (the top of the seat at the rearmost location of the main seat shell or supporting structure) and the corresponding location of the seat on the other side of the seat bay.

j) When the seats are arranged in bays, the distance between the front edges of the opposing seat base cushions.

k) Where armrests are fitted, the length of the armrest from its fulcrum to the front edge.

D.6 Table geometry (bay or seat back) measurements

D.6.1 The following points and/or positions on the seat assemblies shall be recorded:

a) The height above floor level to the upper surface of any fixed or deployable seat back table, in the deployed position.

b) The height above floor level to the under surface of any fixed or deployable seat back table in the deployed position. This should also include the dimensions of all supporting structure framing members etc., and the profile of the table edge.

c) The table width at the bodyside and any variation in width across the table.

d) The horizontal distance from the vertical edge of the table to the front edge of the seat base cushion under consideration.

e) The horizontal distance between the table edge at the top of the table and the ATD’s abdomen or thorax (as appropriate) at the same table top height.
f) The height from the top of the seat base cushion to the underside of the fixed or deployable table.

g) Where seats are oriented in the vehicle in unidirectional configurations having fixed or deployable seat back tables. Then the width of the table and the distance from the rear edge of the table top to a position on the seat back shell at the same vertical height from the floor.

h) The profile of the table edge.

i) Where appropriate the hinge positions for folding tables.
Annex E. Injury Criteria

(Normative)

E.1 Injury criteria assessment

E.1.1 If ATDs or equivalent devices in accordance with Annex C are used for the assessment of injury potential, the methods and criteria in this Annex shall be applied.

E.1.2 Injury criteria shall be measured according to established European or international standards and testing procedures.

E.1.3 All measurements shall be taken in accordance with the positive sense (acceleration and force directions) and filtering specified in SAE J211-1.

E.1.4 Injury criteria from E.2 to E.6 below shall be selected according to the type of installation being assessed, previous test experience and initial test results or test observations.

E.1.5 The selection of injury criteria should be validated by reference to a previous assessment for an equivalent installation or by a preliminary assessment.

E.1.6 Following a dynamic test (or equivalent simulation) the injury criteria shall be evaluated from the recorded data and an assessment made of the results obtained.

E.1.7 The injury criteria assessment shall:

a) Take into account the test equipment, test conditions, instrumentation characteristics and measurement accuracy and any other relevant parameters.

b) Account for any anomalies observed during testing due to for example loss of containment or unforeseen contact by the ATD against the items forming the test assembly.

c) Conclude if the results obtained are satisfactory or not with respect to the objectives of the test and the injury criteria specified.

E.1.8 The primary objective for chest and abdominal injury assessment is to minimise the risk of injury for impacts against table edges. Where ATDs capable of measuring local chest deflections and abdominal compression are not available then for a dynamic injury potential assessment of tables the following reaction force method may be used with a standard Hybrid III ATD:

a) The object (table or seat with seat mounted table) to be impacted shall be mounted on force measuring load cells or tri-axial accelerometers shall be mounted on the table to derive the forces acting on it by calculation.

b) The peak aggregate longitudinal reaction force acting on the object struck during the assessment shall not exceed:

   For an impact to the abdomen, 6.7 kN.

   For an impact to the chest (ribs), 13.0 kN.

   d) The table assembly shall exhibit a progressive deformation characteristic for forces in excess of the specified proof loads.
NOTE 1: Table impact injury risk can be reduced by either minimising the impact velocity determined by the spacing between seat and table and the specified crash pulse (Annex B) and/or by controlling the dynamic local and global stiffness of the table and its mass.

E.2 Head injury criteria

E.2.1 Head injury criteria shall be determined in accordance with the requirements of E.1.3.

E.2.2 The head injury criterion (HIC) shall not exceed a value of 500 over any time interval of up to 15 ms. The HIC shall be calculated using the following formula:

$$\text{HIC} = (t_2 - t_1) \left[ \int_{t_1}^{t_2} A_R \, dt \right]^{2.5}$$

Where

- $t_1$ represents the start of the time interval
- $t_2$ represents the end of the time interval.

$\text{HIC}_{15}$ is the maximum value of HIC for $(t_2 - t_1) \leq 15 \text{ ms}$

$A_R$ is the resultant acceleration

And

$$A_R = \sqrt{A_X^2 + A_Y^2 + A_Z^2}$$

Where $A_X$, $A_Y$, $A_Z$ represent the accelerations in the X, Y, and Z directions.

NOTE 1: Note that the European Directive 96/79/EC refers to this parameter as the Head performance criteria (HPC). The calculation is the same.

NOTE 2: The limit value of 500 is considered to be sufficient for passengers to be able to evacuate a vehicle unassisted after a collision or derailment if required.

NOTE 3: The 15 ms time window relates to the original biomechanical testing used to establish the HIC as an injury criterion commonly accepted for impacts against fixed surfaces.

E.2.3 The maximum acceleration of the head shall not exceed 80 g for more than 3 ms

NOTE 4: The 80 g maximum acceleration criterion is derived from biomechanical test data and relates to a 20% risk of skull fracture.

E.3 Neck injury criteria

E.3.1 Neck injury criteria shall be determined in accordance with the requirements of E.1.3.

E.3.2 The bending moment of the neck in flexion ($M_Y$) shall not exceed 310 Nm.

E.3.3 The bending moment of the neck in extension ($M_Y$) shall not exceed 135 Nm.

E.3.4 The peak tensile force on the neck ($F_Z$) shall not exceed 4170 N.

E.3.5 The peak compressive force on the neck ($F_Z$) shall not exceed 4000 N.

E.3.6 At any point in time the neck injury criterion ($N_i$) shall not exceed 1.0. The $N_i$ shall be calculated using the following formula:

$$N_i = (F_Z/F_{ZC}) + (M_Y/M_{YC})$$

Where $F_{ZC}$ is 6806 N when $F_Z$ is tensile

$F_{ZC}$ is 6160 N when $F_Z$ is compressive
$M_{VC}$ is 310 Nm when $M_Y$ is in flexion

$M_{VC}$ is 135 Nm when $M_Y$ is in extension.

E.4 **Upper chest (thorax) injury criteria**

E.4.1 Thoracic injury criteria shall be determined in accordance with the requirements of E.1.3.

E.4.2 The maximum resultant chest acceleration ($A_{max}$) shall not exceed 60 g over any 3 ms interval.

E.4.3 If a standard ATD is used (a single chest deflection measurement), it is permissible to use the reaction force method set out in E.1.8 instead of making an assessment against E.4.5 and E.4.6.

**NOTE 1:** Localised chest (rib) deflection, required to evaluate the maximum chest deflection or the viscous criterion or the CTI, cannot be reliably measured using standard Hybrid III instrumentation. Localised loading to the lower ribs due to for example a table edge can actually give measurements indicating chest expansion. Where this criterion is critical it is recommended that a more applicable test device is used (see Appendix C.1.4).

E.4.4 The maximum chest deflection ($D_{max}$) shall not exceed 63 mm.

E.4.5 The viscous criterion ($V^*C$) at any time $t$ shall not exceed 1.0 m/s. The $V^*C$ shall be calculated using the following formula:

$$V^*C = 1.3 \times V(t) \times C(t)$$

Where $V(t)$ is the instantaneous chest velocity (m/s)

$C(t)$ is the instantaneous chest compression

And $C(t) = D(t) / 229$

Where $D(t)$ is the instantaneous chest deflection in mm.

E.4.6 The combined thoracic index (CTI) shall not exceed a value of 1.0. The CTI shall be calculated using the following formula:

$$CTI = (A_{\text{max}} / A_{\text{int}} + D_{\text{max}} / D_{\text{int}})$$

Where $A_{\text{int}}$ is 90 g

$D_{\text{int}}$ is 103 mm

$A_{\text{max}}$ is defined in C.4.2

$D_{\text{max}}$ is defined in C.4.3.

E.5 **Lower chest (abdomen) injury criteria**

E.5.1 Abdomen injury criteria shall be determined in accordance with the requirements of E.1.3.

E.5.2 If a standard ATD is used (no measurement of instantaneous abdominal deflection), the following assessment methods are permissible:

Either

The ATD is fitted with a frangible abdomen device to measure the maximum compression

Or

The reaction force method set out in E.1.8 is followed.
E.5.3 If a frangible abdomen device is used, in conjunction with a standard Hybrid III ATD, the peak abdominal compressive deflection shall not exceed 40 mm.

E.5.4 Where instantaneous abdominal deflection is measured, the peak abdominal compressive deflection shall not exceed 67 mm.

E.5.5 If instantaneous abdominal deflection and velocity are measured, using an alternative test device as permitted by C.1.4, the viscous criterion, $V^*C$, at any time $t$ shall not exceed 1.98 m/s. The $V^*C$ shall be calculated using the following formula:

$$V^*C = V(t) \times C(t),$$

Where

$V(t)$ is the instantaneous abdominal velocity (m/s)

$C(t)$ is the instantaneous abdominal compression.

And

$$C(t) = \frac{D(t)}{D_{AB}}$$

Where

$D(t)$ is the instantaneous abdominal deflection

$D_{AB}$ the depth of the uncompressed abdomen test device.

E.6 Leg injury criteria

E.6.1 Leg injury criteria shall be determined in accordance with the requirements of E.1.3.

E.6.2 The tibial index (TI) shall be calculated using the following formula:

$$TI = \left| \frac{M(t)}{M_C} \right| + \left| \frac{F(t)}{F_C} \right|$$

Where

$M_C$ is 240 Nm

$F_C$ is 12 kN

$M(t)$ is the instantaneous resultant tibial bending moment

$F(t)$ is the instantaneous tibial compressive force

E.6.3 The maximum tibial compressive force shall not exceed 8 kN.

E.6.4 The peak femur compressive force shall not exceed 4.3 kN and the TI at any time $t$ shall not exceed a value of 1.3. It is permissible for the femur compressive force to exceed 4.3 kN up to a maximum value of 5.7 kN subject to the maximum permissible TI value linearly decreasing from 1.3 to 1.0 over the range 4.3 to 5.7 kN (see Figure E.1).

E.6.5 The maximal knee displacement shall not exceed 16 mm.
**Figure E.1 Leg injury criteria**

**NOTE 1:** The objective in setting leg injury criteria is for the femur and tibia injury criteria to be set at a level where the passenger is considered to be still able to leave the vehicle with little or no assistance.

**NOTE 2:** The limiting values have been derived from recent sled test results and from an understanding of what is practical and achievable for railway seats using existing technologies. It is however considered desirable for future designs that the femur load is limited to 4 kN and the TI to 1.0 which is considered to correspond to a ‘Moderate’ injury (20% risk of AIS 2+, where AIS 2 represents an injury requiring brief hospitalisation but no long term effects).

**NOTE 3:** The 4.3 kN femur axial load threshold represents the failure load at the hip (mean – 1 standard deviation) and 5.7 kN the mean value (Rupp et al 2002). For comparison, 6 kN is the corresponding axial failure load for the femur (mean – 1 standard deviation), 7.6 kN the mean (Rupp et al 2002).

**NOTE 4:** Revised intercept values for the TI are specified, $M_C = 240 \text{ Nm}$ and $F_C = 12 \text{ kN}$ (Schreiber et al, 1997). The TI was formerly calculated using $M_C = 225 \text{ Nm}$ and $F_C = 35.9 \text{ kN}$. The more significant change is in the value of $M_C$ since for railway applications the tibial axial force levels seen are generally very low.

**NOTE 5:** A direct shin load is not measurable using current instrumentation and where the ATD legs make direct contact with a seat base the TI could, in some circumstances, be misleading. Test experience however shows that a high TI is indicative of a high probability of injury and an unsatisfactory design.
Annex F. Residual space

(Normative)

F.1 Introduction

F.1.1 Residual space shall be determined with the objective that a minimum space envelope is maintained that can accommodate any passenger in the range between a 5th percentile female and a 95th percentile male.

F.2 Residual space envelopes for seated passengers

F.2.1 Reference residual space envelopes shall be constructed according to the dimensions set out in Figure F.1 and using the data given in Table F.1.

Key

- a  Seat depth (see Figure 7.1)
- h  Seat height (see Figure 7.1)
- β  Seat back angle (see Figure 7.1)
- X1 Maximum of Buttock to knee length (K); a + (K) - Buttock Popliteal Length (N)
- X2 Chest depth (O)
- Y1 Maximum of h + Thigh clearance (F); Popliteal height (L) + (F)
- Y2 Shoulder pivot height (B) + 50 mm
- Y3 Total sitting height (A)
R1 0.5 x Thigh clearance (F)

ATD dimensions denoted using bracketed letters, e.g. (Z). See Table F.1 for values

Figure F.1 – Reference residual space envelopes

<table>
<thead>
<tr>
<th>ATD Dimension</th>
<th>Designation letter</th>
<th>95th percentile Male</th>
<th>5th percentile Female</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total sitting height</td>
<td>A</td>
<td>935</td>
<td>787</td>
</tr>
<tr>
<td>Shoulder pivot height</td>
<td>B</td>
<td>549</td>
<td>445</td>
</tr>
<tr>
<td>Thigh clearance</td>
<td>F</td>
<td>168</td>
<td>127</td>
</tr>
<tr>
<td>Buttock to knee length</td>
<td>K</td>
<td>638</td>
<td>533</td>
</tr>
<tr>
<td>Popliteal height</td>
<td>L</td>
<td>470</td>
<td>366</td>
</tr>
<tr>
<td>Buttock Popliteal Length</td>
<td>N</td>
<td>503</td>
<td>427</td>
</tr>
<tr>
<td>Chest depth</td>
<td>O</td>
<td>246</td>
<td>183</td>
</tr>
</tbody>
</table>

Table F.1 – ATD dimensions for construction of residual space envelopes

**NOTE 1:** For a 95th percentile male ATD, if the minimum PRM TSI seat height of 430 mm is assumed, Y1 will be the sum of the popliteal height and the thigh clearance, 470 + 168, giving 638 mm. For a 5th percentile female ATD, for the same seat, Y1 will be the sum of the seat height and the thigh clearance, 430 + 127, giving 557 mm.

**F.3 Determination of residual space for seated passengers**

**F.3.1** Where it is required to maintain a residual space envelope, this shall be demonstrated by either:

a) From analysis of dynamic assessment data, determining the minimum seat spacing or pitch required to ensure that the residual space envelope required can be maintained throughout the dynamic event.

Or

b) For a predetermined seat layout, demonstrating that the residual space envelope is maintained throughout the dynamic event (using for example film analysis and marked limits or measurements).

**F.3.2** Where it is not possible to demonstrate that the residual space envelopes defined can be maintained under dynamic conditions using the methods set out in E.3.1, it is permissible to use one of the following methods or a combination of these to determine that sufficient residual space is maintained:

a) By including a 95th percentile male ATD or dimensionally equivalent dummy in a rearward dynamic test. After testing it shall be demonstrated that:

i) The dummy has not been compressed or penetrated by any adjacent parts.

ii) The dummy can be removed by hand without removing seats, tables or other items.

b) By including a 5th percentile female ATD or dimensionally equivalent dummy in a rearward dynamic test. After testing it shall be demonstrated that the dummy has not been compressed or penetrated by any adjacent parts.

c) By measurement, simulation or calculation using the true geometry of the ATD corresponding to the envelope required.

**NOTE 1:** Residual space is defined in this Annex primarily in the context of the dynamic seat and table testing measures set out in Chapters 7 and 8. EN 15227:2008 sets out more general residual space criteria for passenger areas relating to permissible levels of deformation in the primary structure. There should be no conflict between these ‘global’ requirements and the ‘local’ requirements set out in this Annex.
Bibliography


