

Guidance document

G185 Interior Crashworthiness and Egress

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1 Purpose

- 1.1 The purpose of this Guidance Document is to define guidance on measures which promote safer London Underground rolling stock interior environments for passengers, train staff and personnel under normal working conditions, and a higher level of protection under collision conditions. Enhanced interior crashworthiness increases the survivability of passengers, train staff and personnel under these conditions and minimises those injuries that may preclude their subsequent escape.
- 1.2 Guidance is also given to encourage design of London Underground rolling stock interiors that provide passengers, train staff and personnel adequate opportunity to evacuate and escape from a vehicle in the event of an emergency.

2 Scope

2.1 General Interior Features

This Guidance applies to the interiors of London Underground rolling stock occupied by passengers or staff, except for rail mounted maintenance machines and replaces G-185 A1. There were no technical changes. However, clarification has been provided around references which have since been superseded.

3 Crashworthiness

3.1 Principles

- 3.1.1 During a collision condition (the primary impact), the deceleration of the vehicle to a stop will cause secondary impacts of passengers and objects as a result of their relative velocity with respect to the vehicle. The profile of this resultant deceleration of the vehicle will depend on the collision conditions, but is variable in magnitude and length of time
- 3.1.2 Due to the likely high deceleration and short time period of a crash pulse on the London Underground, it is important to minimise (as far as this is practicable) injuries due to secondary impacts of passengers with vehicle features.
- 3.1.3 The three main principles are defined in 3.1.4, 3.1.5 and 3.1.6 and should be considered as top-level guidance for passenger carrying vehicles on the London Underground.
- 3.1.4 Compartmentalisation

The design of the interior should have the effect, during an incident of restraining a passenger in their normal seated or standing area such that secondary impacts between passenger and passenger or passenger and interior fittings are reduced as much as is reasonably practicable. Compartmentalisation of passengers should be ensured as far as is reasonably practicable and in such a way that any materials, features or components used are non-aggressive and therefore minimise passenger injury. Compartmentalisation should also be considered for reducing risks due to movement and impacts of wheelchairs and their occupants, as well as luggage where specific luggage locations are provided.

3.1.5 Passenger containment.

The risk of ejection of passengers to the vehicle exterior, either wholly or partially, should be made as low as is reasonably practicable by adopting the principle of passenger containment. This requires that for any foreseeable accident scenario, the vehicle is able to withstand any likely forces, whilst maintaining its structural integrity and ability to contain passengers, so far as is reasonably practicable.

3.1.6 Structural penetration

The vehicle should be designed to withstand any likely forces whilst resisting gross deformation. The risk of foreign objects entering the vehicle interior and impinging on passenger survival space should be made as low as is reasonably practicable.

3.2 General Interior Features

3.2.1 When designing vehicle interiors there are two philosophies that should be adopted to minimise passenger injuries during a crash scenario:

- a) the use of energy absorbing structures and features to reduce injuries to passengers caused by secondary impacts;
- b) prevent excursions leading to passenger to passenger secondary impacts.

3.2.2 Beyond minimising injury due to interaction with vehicle features, passenger-to-passenger interaction should be minimised by compartmentalisation so far as this is reasonably practicable. Risks due to the movement of wheelchairs and luggage should also be minimised by consideration of compartmentalisation

3.2.3 The vehicle interior should provide a safe environment for passengers, train staff and personnel under normal working conditions and a high level of protection under collision conditions.

3.2.4 Crashworthiness performance of vehicles should be such as to minimise those injuries that may prevent subsequent escape of passenger, train staff and personnel.

3.2.5 Surfaces likely to be subjected to impact by persons should be smooth, free of unnecessary protrusions and hard sharp edges or rigid areas and, wherever practicable, should be flat or of generous radius. They should also, where practicable, be capable of absorbing energy due to impact loading in such a way as to minimise the risk of injury.

3.2.6 All equipment housed in the vehicle interior should be stored in flush-fitted cupboards or recesses, where practicable.

3.2.7 All components, including their fixings, which may be subjected to impact by persons, should be designed to maximise energy absorption and deform progressively so as to minimise injury to occupants.

3.2.8 Glass components should be of either the safety glass type or laminated glass, to a recognised national or international standard. Glass components should not fail in a

dangerous manner when impacted. They should provide good properties of containment and compartmentalisation (even after failure of the glazed elements of their construction) where this is desirable.

- 3.2.9 All furniture, fixtures, fittings and equipment, including their attachments, should be securely fixed and be capable of withstanding agreed proof loads and ultimate accelerations. The loading cases should be based on the maximum laden conditions of the items concerned. The weight of a person should be based on the mass of a 95th percentile British adult male. Where wheelchair impacts are likely, the loading cases should be based on the mass of both the wheelchair and its occupant.
- 3.2.10 Materials should be chosen as to avoid, as far as is practicable, the production of sharp edges, projections, or other features that could cause injury when impacted by persons if they are subject to failure. The use of ductile materials wherever practicable is preferred.
- 3.2.11 To minimise injury, the onset of permanent deformations should occur at loads as near as practicable above the specified proof or static loads. Materials should have good post yield plasticity.
- 3.2.12 All forms of aperture covers such as cupboards, access panels and shutters should remain securely attached in the open or closed positions as appropriate, when subjected to the agreed ultimate accelerations.
- 3.2.13 Heavy items of equipment, including emergency equipment, should as far as is practicable, be mounted at low level.
- 3.2.14 Loose items of equipment should be stored to ensure a safe environment under normal working conditions and a high level of protection under collision conditions.

3.3 Guidance

3.3.1 Seats

- 3.3.1.1 All seats should be securely fixed to the vehicle structure. The seats and their fixings should be designed to withstand without significant permanent deformation the agreed static loads, subject to meeting the injury level criteria under dynamic crash simulation. Current injury criteria are defined in AV/ST9001. This will be in accordance with the requirements of a suitably defined crash pulse. In areas where there is doubt or conflict, seating should be considered sacrificial to the safety benefit of the passenger.
- 3.3.1.2 The seats should be designed such that the seat back is not unduly stiff in order to minimise injury levels. This should be done whilst ensuring good ductility and still meeting proof load requirements.
- 3.3.1.3 Transverse Seating
 - 3.3.1.3.1 High backed seats are desirable for occupant protection. The support should be sufficiently close to the head of a normally seated person to prevent unacceptable rotation of the head.
 - 3.3.1.3.2 The seats should be designed such that the seat back is not unduly stiff in order to minimise injury levels. This should be done whilst ensuring good ductility and still meeting proof load requirements.
- 3.3.1.4 Bay Seating
 - 3.3.1.4.1 Consideration should be given to using unidirectional seating rows in preference to the open bay configuration.

3.3.1.4.2 To reduce injuries to lower legs the following options should be considered:

- a) deformable structures at the front edge of the seat pan;
- b) generous cushioning at the front edge of the seat pan.

3.3.1.5 Longitudinal Seating

3.3.1.5.1 To ensure passenger compartmentalisation there should be no more than three seating positions which are not separated from the adjoining seats by means of a grab-pole, draft screen, or similar. The possibility of a person being subjected to long excursions down the vehicle should be as low as is reasonably practicable by implementing this compartmentalisation.

3.3.1.5.2 The seat and supporting structure should withstand the loads without permanent deformation or damage as defined from the agreed crash pulse.

3.3.1.6 Armrests

3.3.1.6.1 From the perspective of crashworthiness an armrest can be used to assist the compartmentalisation of passengers during an incident. Armrests should be positioned at every seating position. The design of an armrest has important effects on the projected trajectory and possible injury of a seated passenger. When considering the design of an armrest to reduce injuries and undesirable trajectories the following parameters should be considered:

- a) **Stiffness** - An armrest should be designed such that it is stiff enough to provide compartmentalisation during a typical crash scenario whilst having suitable ductility to minimise injuries;
- b) **Height** - The position of an armrest in the vertical plane should be low enough to avoid soft tissue intrusion around the abdomen, as far as is practicable, whilst remaining functional as an armrest. Where possible, any force associated with a collision scenario should be transmitted through the pelvis rather than the abdomen;
- c) **Angle of Deflection** - An armrest should exhibit ductile behaviour and should withstand a force exceeding the proof load, applied at the armrest's end. It must display good post yield plasticity.

3.3.1.6.2 Any failure should avoid, as far as is practicable, the production of sharp edges, projections, or other features that could cause injury when impacted by persons.

3.3.1.7 Seats in End Vestibules

The use of vehicle end seats and vehicle perch seats in end vestibules is not preferred due to the increased risk of ejection from the vehicle and uncontrolled excursions in the event of an incident.

3.3.1.8 Wheelchair Locations

Wheelchair locations should be arranged, as far as is practicable, to limit the distance through which the wheelchair and occupant travel before a secondary impact, as a result of a collision. For example, location of a wheelchair facing rearwards against a suitable designed restraint, e.g. bulkhead or partition would minimise excursion of the wheelchair in a longitudinal deceleration.

3.3.2 Partitions and Draft Screens

The design of draft screens has a direct effect on possible injuries sustained by passengers. The weight and stiffness of draft screens are sufficient to cause serious