9. APTA SS-C&S-016-99, Rev. 1 Standard for Row-to-Row Seating in Commuter Rail Cars

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Abstract: This standard contains design guidelines, recommendations and requirements for the procurement, design, strength and testing of Passenger Seating Equipment for use in commuter rail.

Key Words: ATD, crashworthiness, injury, seat, seating

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1. Overview

This standard gives design guidelines, recommendations and requirements for passenger seating equipment to be installed into commuter passenger rail cars that are part of the general railroad system of transportation.

This standard is intended to be used for the procurement of passenger seating equipment for new commuter passenger rail cars, and generally describes the qualifying processes, reviewing and submittal requirements and documentation associated with the procurement process.

1.1 Purpose

The purpose of this standard is to:

– Provide background information and design guidelines

– Provide nomenclature and definitions associated with passenger rail seating

– Establish minimum requirements for seat attachment strength

– Establish human injury criteria associated with seat design and application

– Specify minimum flame and smoke standards

– Specify minimum reporting requirements to demonstrate compliance with this standard.

The intent for complying with this standard is to provide and maintain an appropriate level of safety for commuter passengers, for that component of safety influenced by the seating. Due diligence to meet the intent of this standard shall be maintained.

1.2 Scope

This standard is intended to provide guidance for the design, manufacture and testing of passenger seating in passenger commuter rail cars. Portions of this standard are intended to provide details for meeting the requirements of *49 CFR Part 238.233 for Tier I Passenger Seating Equipment.*[1]

[1] For references in Italics, see Section 2.

1.3 Limitations of this standard

This standard is intended to apply to seating that is transversely mounted and facing in the same direction in the rail car such that the occupant faces the back of another seat as shown in Figure 1 and Figure 4.

Structural testing of seating and seating attachments are specified and recommended in this standard. In most cases, the standard refers to the attachment of the seat to the car structure. Where practical, a simulated section of a car structure should be used as a test fixture. Where it is not practical to provide a simulated car structure for testing, compliance for the car structure may be demonstrated by analysis or separate testing.

2. References

This standard shall be used in conjunction with the following publications. When the following standards are superceded by an approved revision, the revision shall apply.

49 CFR Parts 37, Transportation Services for Individuals with Disabilities (ADA)

49 CFR Parts 38, Americans with Disabilities Act (ADA) Accessibility Specifications for Transportation Vehicles

49 CFR Part 572, Anthropomorphic Test Devices

49 CFR Part 238, Federal Railroad Administration Passenger Equipment Safety Standards, October 2000

49 CFR Part 216 et al, Passenger equipment Safety Standards, Proposed Rule September 23, 1997

APTA RP-I&M-002-98, “Development Model for Rail Car Technical Documentation”

APTA SS-PS-004-99, Rev.1 “Standard for Low-Location Exit Path Marking”

FMVSS 208 Final Rule for Federal Motor Vehicle Safety Standard (FMVSS) 208 – Occupant Crash Protection

Mil-Std 1472E, Human Engineering Design Criteria for Military Systems, Equipment and Facilities

SAE AS8049, Performance Standards for Seats in Civil Rotorcraft and Transport Airplanes

SAE ARP750, Passenger Seat Design Commercial Transport Aircraft

SAE J 899, Operator’s Seat Dimensions for Off Road Self-Propelled Work Machines

SAE J 826, Devices for Use in Defining and Measuring Vehicle Seating Accommodation

SAE J 1454, Dynamic Durability Testing of Seat Cushions for Off-Road Work Machines

Technical Data Sheet, First Technology Safety Systems, 1992 for Models H3-5F-R, H3-50, and H3-95-R

2.1 Procurement specifications

This standard is intended to be supplemented by procurement specifications prepared by the Purchaser and directed to the Seat Manufacturer. These procurement specifications should, as a minimum, include:

- Expected environmental operating conditions and standards against which measurable results should be specified for conditions such as temperature ranges, humidity, salt atmosphere, ultra-violet radiation, static electricity and vibration.

- Normally used cleaning agents.

- Requirements for Aesthetic features such as:

  a) Fabric types and colors

  b) Finishes

- Format for Parts, Service and Maintenance Manual (see APTA RP-I&M-002-98 titled "Development Model for Rail Car Technical Documentation")

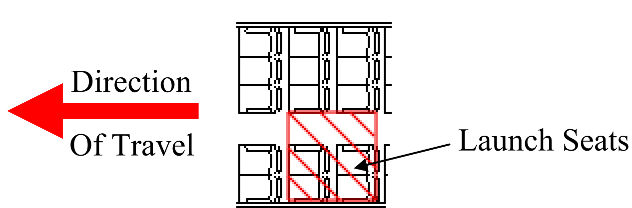
The procurement specifications may, at the option of the Purchaser, modify the requirements of this standard where special conditions make such modifications reasonable and do not unduly or unreasonably alter the intent of this standard with respect to the crashworthiness design of the seat and the safety and comfort of the occupant.

3. Definitions, abbreviations and acronyms

For the purpose of this standard the following terms and definitions apply:

3.1 Definitions

3.1.1 compartmentalization: A strategy for seat design in which the seat provides enough stiffness to absorb all or a substantial portion of the kinetic energy of a passenger thus preventing a tertiary impact. An occupant is compartmentalized when the torso is confined within the perimeter defined by the front edge of the front row seat pan, the full width of the aisle, and the seat back surface of the launch seat. Compartmentalization is defined by the shaded area in the illustration below.



3.1.2 facing seats: Seats which are mounted in the car such that occupants face one another.

3.1.3 fixed seat: Seat which cannot be rotated, and not of the walkover type design. These seat types can only face in the direction at which they are mounted.

3.1.4 flip seat: Seats that have bottom cushions that can be flipped up to provide additional space. Flip seats are often used in areas of a car to provide wheelchair parking space.

3.1.5 g, G: An acceleration equal to 32.2 ft/sec^2 (9.8 m/sec^2)

3.1.6 H-Point: Hip Point location on the seated occupant as measured according to SAE J 826.

3.1.7 HIC: Head Injury Criterion – calculated according to the following:

$$HIC = \left[(t_2 - t_1)\left[\frac{1}{t_2 - t_1}\int_{t_1}^{t_2} a(t)dt\right]^{2.5}\right]_{\max}$$

where:

t_1, t_2 = Any two points in time during the head impact, in seconds

a(t) = The resultant head acceleration during head impact, in multiples of g’s.

3.1.8 High Performance Photo-Luminescence: A material that is capable of emitting fluorescent and/or phosphorescent light at a high rate and for an extended period of time after absorption of light radiation from an external source by the process of photon excitation. Reference APTA SS-PS-004-99.

3.1.9 hip to knee space: A horizontal dimension from the back rest of a seat to the back of the next seat. This dimension is measured along the centerline of an occupant placement in a horizontal plane tangent to the top of the bottom cushion. See Figure 1.

3.1.10 ingress/egress space: Space available for passengers to occupy or leave an occupant space. This has importance for both normal passenger seating and also for emergency exit considerations. See Figure 2

3.1.11 lateral crash pulse: A time based acceleration curve, triangular and symmetrical in shape and having a 250 millisecond base and a 4g peak. A lateral crash pulse is in the horizontal direction and perpendicular to the normal direction of travel of the car.

3.1.12 left hand and right hand seats: Seat handedness is most easily defined by sitting in the seat. If the seat is a transverse seat and the window is on the left hand, then it is a left hand seat assembly.

3.1.13 left hand and right hand seat components: Handedness of seat components are also defined by sitting in the seat. If an armrest, for example is on the left side of the seat, then it is a left hand armrest. Seat components that are not symmetrical and only one of which can be supplied with the seat, carry the same handedness name as the seat assembly. See Figure 3 and Figure 4 for illustrations.

3.1.14 longitudinal: Descriptive of a direction parallel to the normal direction of car travel.

3.1.15 longitudinal crash pulse: A time based acceleration curve, triangular and symmetrical in shape and having a 250 millisecond base and an 8g peak. A longitudinal crash pulse is in the direction parallel to the normal direction of travel of the car.

3.1.16 Low-Location Exit Pathway Marking: Evacuation guidance for passengers and crewmembers when normal and emergency sources of illumination are obscured or inoperative. Reference APTA SS-PS-004-99.

3.1.17 occupant: A seated passenger occupying a seat placement in a normal manner.

3.1.18 occupant placement: That portion of a seat assembly that is normally occupied by a seated passenger. For example, a two passenger seat assembly has two occupant placements.

3.1.19 passenger: A person who is within the occupied volume of a passenger rail car, whether seated or not.

3.1.20 primary impact: During a car crash, primary impact refers to the impact of the car itself.

3.1.21 purchaser: The agency or organization (transit authority or carbuilder) responsible for the acquisition of seating equipment.

3.1.22 row-to-row seating: Seating arrangement such that each row of seats face the same direction as illustrated in Figure 4. Also known as theater style seating.

3.1.23 seat pitch: The distance between like features on seats facing the same direction, as illustrated in Figure 1

3.1.24 seat manufacturer: The agency or company responsible for the design, specification compliance and warranty of the seat and its design.

3.1.25 shall: Practices directed by shall are required or standard practices.

3.1.26 secondary impact: During a car crash, secondary impact refers to the impact of passengers to features on the car or other passengers.

3.1.27 should or may: Practices directed by should or may are recommended practices

3.1.28 tertiary impact: Passengers who have undergone a secondary impact and have glanced off of that object to impact another object in the car.

3.1.29 tier I: Rail Equipment operated at speed not exceeding 125 mph (200 k/h) as defined in 49 CFR Part 238.

3.1.30 transverse: Descriptive of a direction perpendicular to the normal direction of car travel.

3.1.31 walkover seat: A particular type of seat design in which the seat back and bottom cushion are articulated such that the direction that occupants face can be reversed by moving the seat back longitudinally

3.2 Abbreviations and acronyms

ADA	Americans with Disabilities Act
ASME	American Society of Mechanical Engineers
ATD	Anthropomorphic Test Device (also referred to as crash test dummy - see 49CFR Part 572)
CFR	Code of Federal Regulations
FMVSS	Federal Motor Vehicle Safety Standard
HPPL	High Performance Photo-Luminescence
LLEPM	Low-Location Exit Pathway Marking
MIL-STD	Department of Defense Military Handbook
SAE	Society of Automotive Engineers
SRP	Seat Reference Point as given by SAE AS8049

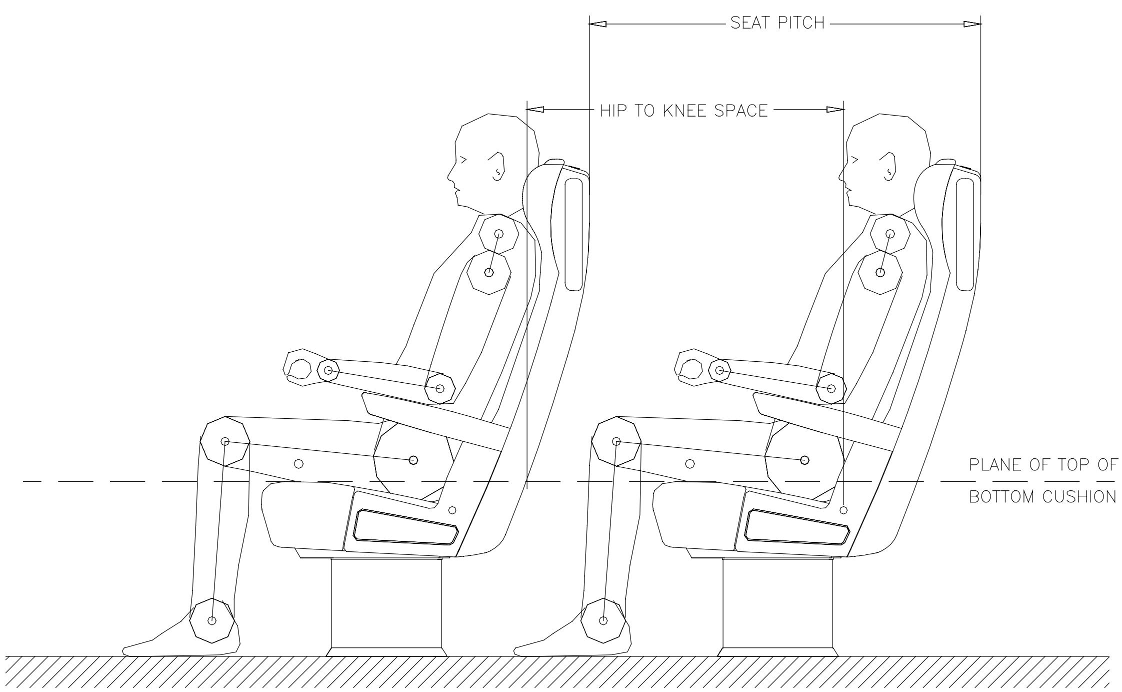


Figure 1 – Hip to Knee Space and Seat Pitch

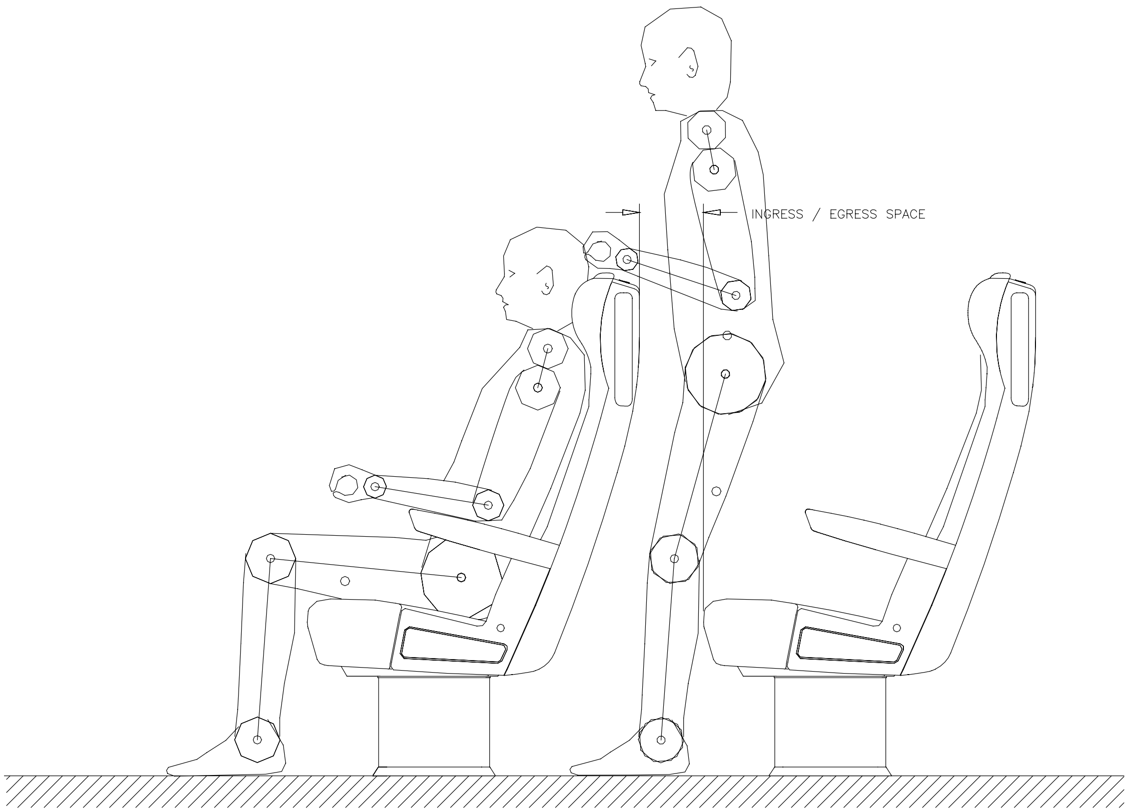


Figure 2 – Ingress/Egress Space

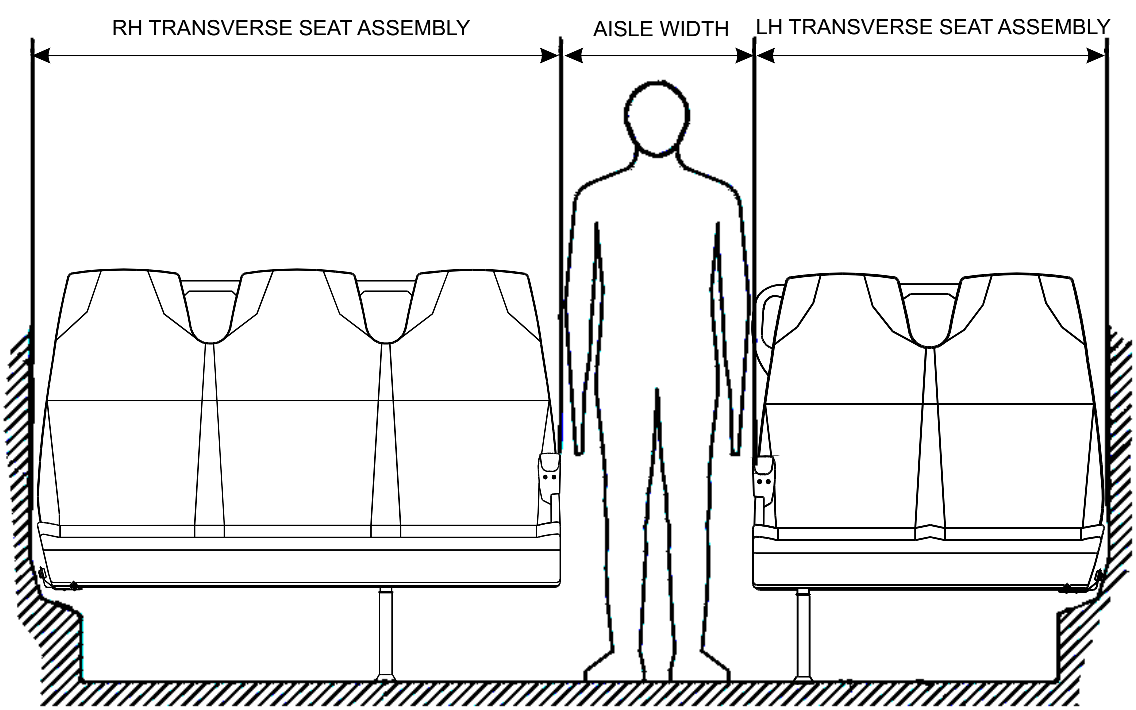


Figure 3 – Cross Section Through 3+2 Seating

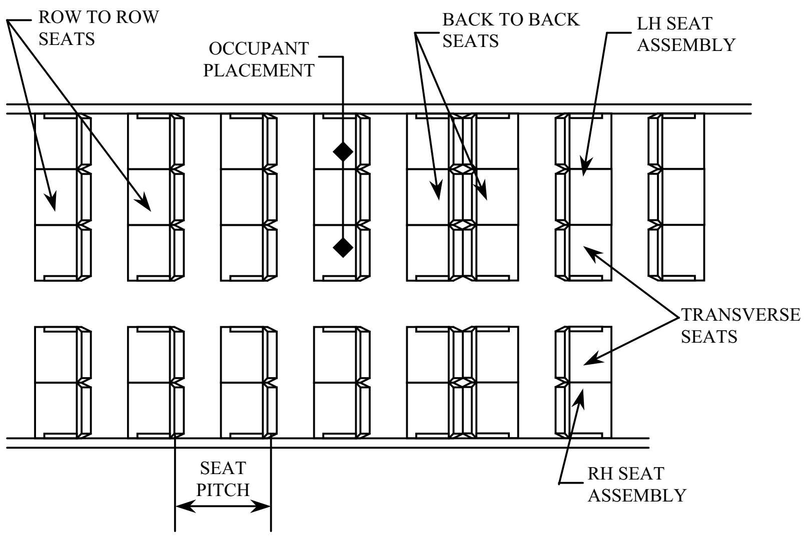


Figure 4 – Seat Arrangement and Nomenclature

3.3 Anthropomorphic test devices (ATD's)

Reference is made in this standard to a series of Anthropomorphic Test Devices (ATD's) that are designed to represent the 5^{th}-percentile female occupant, the 50^{th}-percentile male occupant, and the 95^{th}-percentile male occupant.

A table of available ATD's and their typical weights as used in testing to represent these occupant populations is given below for reference:

Table 1 – Typical Weights of ATDs

ATD	WEIGHT	
Hybrid III 5^{th} female	110.2 lb	50 kg
Hybrid III 50^{th} male	172.3 lb	78.2 kg
Hybrid II 50^{th} male	168 lb	76.2
Hybrid III 95^{th} male	223.4 lb	101.3 kg

Reference: First Technology Safety Systems, Technical data sheet, 1992 for Models H3-5F-R, H3-50, H2-50 and H3-95-R.

4. Seat design features

This section is intended to provide guidelines, recommendations and requirements regarding features commonly found on passenger rail seating equipment.

4.1 Materials and workmanship

Seating should be made of materials suitable for use in the railroad environment. All materials should be new. The seat shall be free of protrusions, sharp edges or corners that could cause injury, catch or damage the clothing of passengers or crew members. The seat should be free of rattles or loose joints that could create noise or vibration during normal operation. All parts of the seat should be interchangeable with parts of like seats. No unusual adjustments or procedures such as grinding or bending of materials should be required to replace parts that are designed to be replaced. The use of exposed fasteners should be minimized.

4.2 Industrial design

To provide a pleasing and coordinated environment within the car interior, the seat manufacturer should participate with the purchaser in a comprehensive Industrial Design Program. As part of this program the seat manufacturer should submit decorative samples of materials that form the finished exterior of the seating equipment. Human factors addressing such issues as accessibility, emergency exits, use by the elderly, hearing and sight impaired should be part of the Industrial Design Program.

Seating should be designed to comfortably accommodate the range of passengers anticipated, from the 5th percentile female to the 95th percentile male. Adequate hip to knee space should be provided for the 95th percentile male. To document the ergonomic aspects of the seat design the purchaser should ask that the seat manufacturer prepare an Ergonomic Analysis and Report as part of its work for the supply of seating equipment. Contents of the Ergonomic Analysis should address issues such as seat comfort, hip to knee space, cushion contours, armrest height, lateral passenger space, ingress-egress space, effort required to adjust and operate various seat features, and other issues involving the use of the seating equipment by passengers.

4.3 Cushions and upholstery

Cushions should be contoured to provide optimal occupant retention and comfort during normal use. Cushioning material should be durable and should be capable of passing the cushion life test described herein.

4.4 Walkover seats

Walkover seats, if provided, shall be fitted with a locking mechanism designed to prevent the seat back from moving from one extreme seating position to the other during the crash pulse shown in Figure 12. Adequacy of the lock mechanism shall be demonstrated as part of the Dynamic Sled Test given in Section 5.2. The purchaser may require additional testing of the lock mechanism according to test procedures agreed to by the purchaser and the seat manufacturer. The lock mechanism should not require any maintenance over the life of the seat.

4.5 Recline

Recline mechanisms, if provided, should meet the requirements of this section. Seat back should recline according to the dimensions specified in the Procurement Specification. Recline control should provide for infinite adjustment through the range specified. Recline mechanism design should be such that activation of the recline control does not allow a sudden change in back rest position. Reclining seat backs should return to the up position in a controlled, damped manner. Care should be taken so that reclined seats do not present obstructions for emergency egress.

4.6 Armrests

Armrests, if provided should be optimally positioned to support the range of occupants specified. The top of the armrests should be covered with a durable material as provided for in the Procurement Specifications. Armrests shall be capable of passing the Armrest Strength Test given in Section 5.1.4.

4.7 Rotation

Seat rotation, if provided should be 180 degrees. A lock capable of passing the anti-rotation test described in Section 5.3.1 shall be provided in both extreme positions. The rotation mechanism should operate smoothly. Lateral offset of the rotation mechanism or seat mounting geometry should be sufficient to allow two passenger seats to be placed close to the wall for maximum aisle width. Single passenger seats may be mounted some distance from the wall to provide rotation clearance and may not have an offset feature as part of the rotation mechanism.

5. Seat testing

Seating equipment shall be subjected to a series of static, dynamic and durability tests to verify that the requirements given in this section are met. Testing shall be conducted on seat assemblies or components that are representative of seating equipment to be delivered.

5.1 Static strength testing

The purpose of static seat strength testing is to verify that the seat structure and its components meet the various loading conditions that are expected in commuter passenger rail operation. The testing should be conducted on representative samples of various configurations of the seats supplied. For example, if the supply of seating includes one, two and three passenger seats then each should be tested. Where, however, sufficient similarity between seat types exist, the purchaser and manufacturer may jointly agree to apply the results of testing to various seat types.

In general, static testing can be performed on the structural parts of a seat assembly, usually the seat frame, pedestal and other mounting equipment and hardware. Where concern exists that non-structural components can be damaged by the stresses and flexing of structural components, they may be included in the testing.

Seat frames and components shall be designed and tested to meet the individually applied static load requirements given below with no yielding of structural materials, loss of function or change in appearance of the seat or component. A small amount of yielding due to relieving of trapped manufacturing stresses (welding, forming, etc.) shall be permissible. Seats to be tested should be mounted on a simulated car structure and all components comprising the attachment to the car shall be included. Where it is not feasible to use a simulated car structure, a rigid base may be used.

5.1.1 Backrest strength test

The purpose of this test is to establish the strength of the seat back for durability, especially against the effect of a passenger sitting behind this seat pushing his/her feet against the top of the seat back. Therefore, a load of 300 lb. (136 kg) per occupant shall be applied to the upper back of the seat frame at the midpoint of each seat back and at an elevation 3 inches (76 mm) below the top of the seat back and in a direction perpendicular to the seat back (reference Figure 5). This load is to be distributed across the seat back. Reclining seats shall be in the full upright position. A fixture may be used to distribute the load across the seat frame members. Load shall be applied for a minimum of 5 seconds. This test shall be repeated in both horizontal directions, from the back of the seat and from the front of the seat.

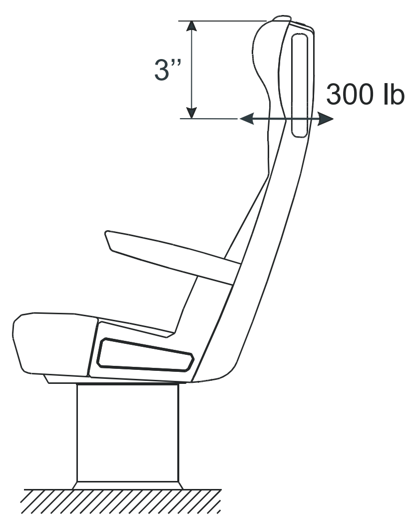


Figure 5 – Backrest Strength Test Loading Conditions

5.1.2 Grab handle strength test

A 300 lb. (136 kg) load shall be applied to the grab handle at a point near the middle of the grab handle in a longitudinal direction (reference Figure 6). Load shall be applied for a minimum of 5 seconds. This test shall be repeated in both longitudinal directions. A fixture may be used to insure that the load is properly applied and distributed onto the grab handle.

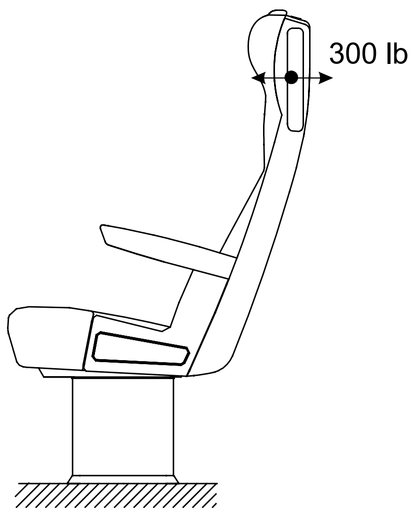


Figure 6 – Grab Handle Strength Test Loading Conditions

5.1.3 Vertical seat strength

A load of 450 lb. (204 kg) per occupant shall be applied on the seat frame near the front edge of each occupant placement in a vertical downward direction at the midpoint of each occupant position (reference Figure 7). The contact area of the applied load shall not exceed 4 square inches (26 square centimeters). The load shall be applied for a minimum of 5 seconds.

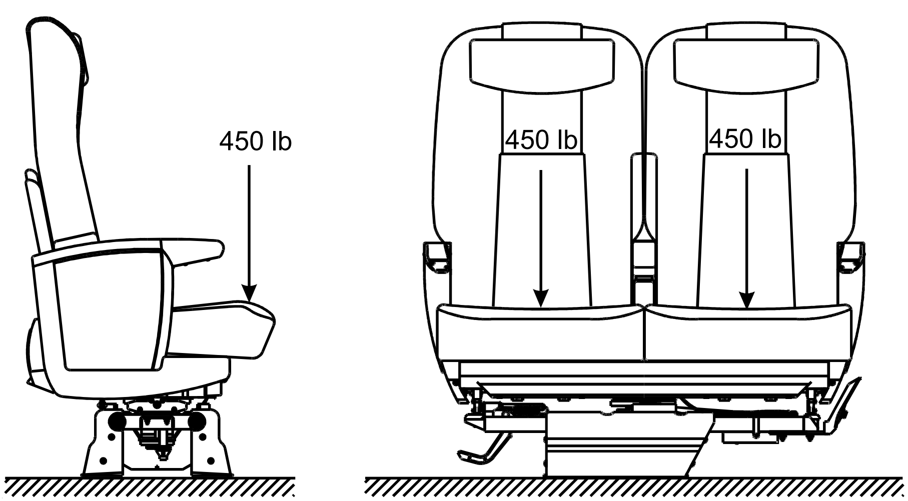


Figure 7 – Vertical Seat Strength Test Loading Conditions

5.1.4 Armrest strength

A load of 250 lb. (113 kg) shall be applied to the horizontal member of the armrest structure at a point that produces maximum stress in the member (reference Figure 8). A fixture may be used to properly apply and distribute the load. The contact area of the applied load shall not exceed 4 square inches (26 square centimeters). The load shall be applied for a minimum of 5 seconds. This test shall be repeated for the two horizontal conditions (toward the aisle and toward the wall side of the seat) and then vertically downward.

For seats with folding center armrests, the folding armrest shall be tested by applying a vertical 150 lb. (68 kg) load as near as practical to the end of the armrest. Separately, a horizontal 150 lb. (68 kg) load shall be applied as near as practical to the end of the armrest. The horizontal load test shall be repeated for both directions. The contact area shall not exceed 4 square inches (26 square centimeters) in all cases.

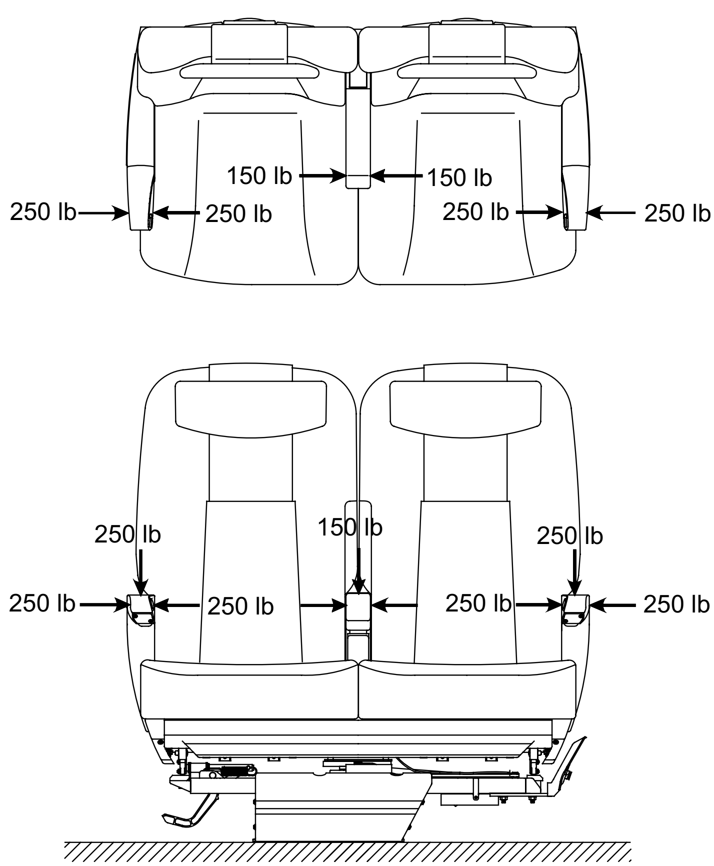


Figure 8 – Armrest Strength Test Loading Conditions

5.1.5 Footrest test

With footrest deployed in the most nearly horizontal position, a 400 lb. (180 kg) load shall be placed on the diagonal center of the footrests surface (reference Figure 9).

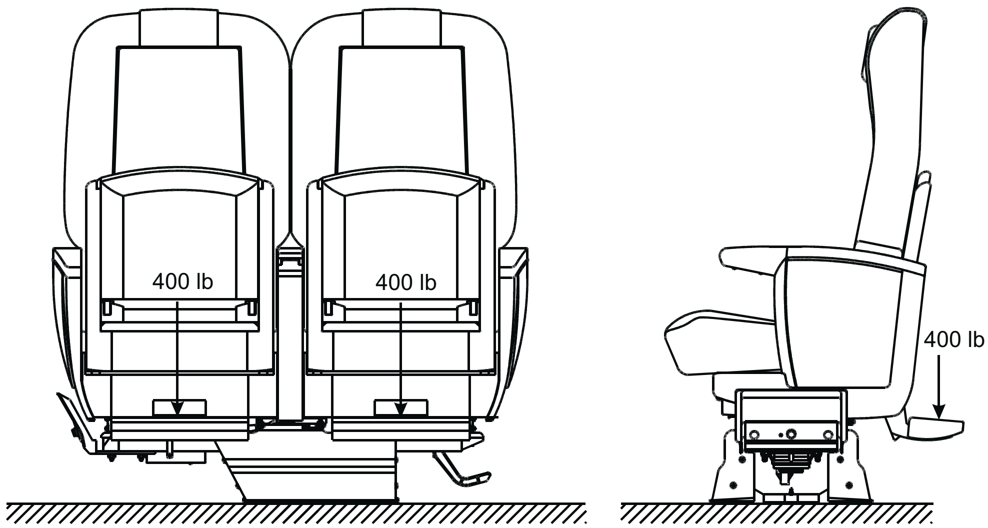


Figure 9 – Footrest Strength Test Loading Conditions

5.1.6 Legrest test

With the legrest assembly in the most nearly horizontal position, place a 65 lb. (30 kg) load distributed over an area of 25 square inches (160 square centimeters) on the diagonal center of the legrest cushion (reference Figure 10). This test is intended for footrests that have a load limiting feature to prevent passengers from using it as a step stool. Overloading of these types of footrests shall not result in structural failure or sudden drop of the load.

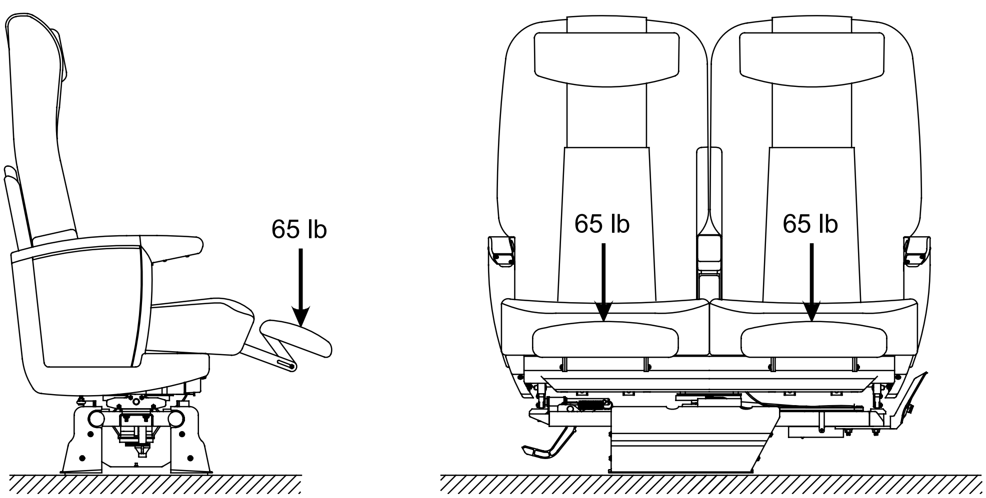


Figure 10 – Legrest Strength Test Loading Conditions

5.1.7 Tray table test

With the tray table mounted to the seat in deployed and extended position, place a 5 lb. (2.2 kg) load distributed over an area of 25 square inches (160 square centimeters) upon the diagonal center of the tray and let it remain for 10 seconds to determine the pre-load height from a reference location (reference Figure 11). Add an additional 17 lb. (7.7 kg) to the 5 lb. pre-load and let it remain for 10 minutes. The maximum temporary deflection from the reference position should not exceed 1 inch (19 mm).

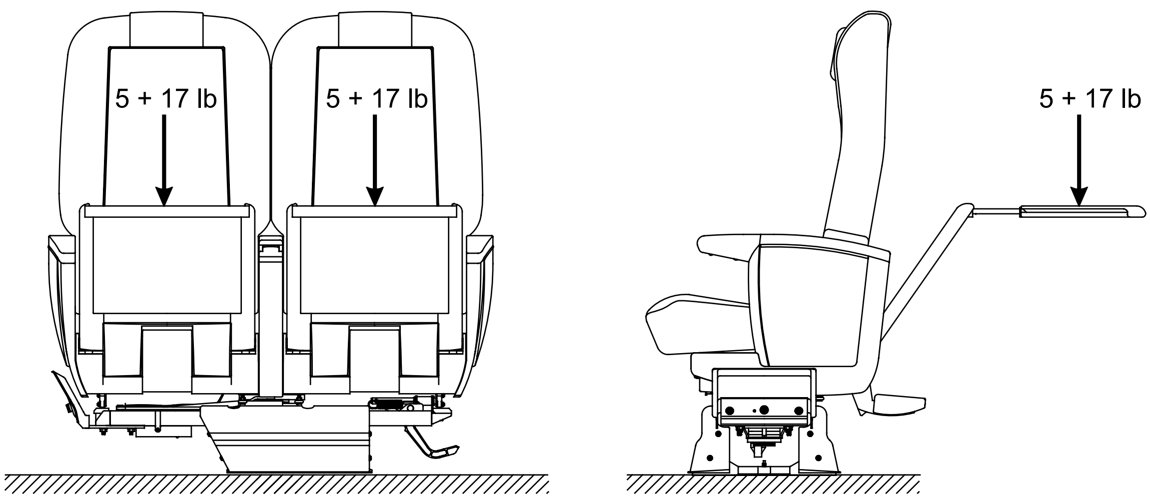


Figure 11 – Tray Table Strength Test Loading Conditions

5.2 Dynamic sled testing

The primary objectives of the dynamic sled testing is to simulate a rail car crash and verify the following:

- That seat assemblies remain attached to the car
- That seat components remain attached to the seat assembly
- That the seat effectively compartmentalizes the occupants
- That the seat does an effective job of minimizing human injury

There are two dynamic sled tests prescribed to measure these objectives. One consists of forward-facing row-to-row seats with ATDs that will be used to simultaneously measure the seat's structural strength and human injury potential; the second test will consist of one aft-facing seat to measure seat structural strength in that direction.

If a seat of largely similar design to the subject seat has been previously subjected to these prescribed dynamic sled tests, then the manufacturer may provide data from these previous tests to satisfy the corresponding portion of these requirements, for approval of the subject seat by the purchaser. Due diligence to meet the intent of this standard shall be maintained.

5.2.1 Forward-facing seat attachment and human injury test

This test shall use two transversely mounted rows of seats so that occupants are facing seat backs and facing the direction of travel. If seats contain adjustable features such as recline, tray tables, footrests, these should be placed in the upright and stowed positions.

The ATD's shall meet the standards and requirements needed to comply with *48 CFR Part 572, Subparts B*[2]. The adjustment, positioning, and care of all ATD's used in the testing processes shall be in accordance to the standards and requirements needed to comply with SAE AS8049.

Each ATD shall be clothed in a form fitting, cotton stretch garment with short sleeves, and mid-thigh-length bottoms. The ATD's shall also be fitted with shoes. Each ATD shall be seated in the center of the occupant placement, in as nearly symmetrical a position as possible and in a uniform manner so as to obtain reproducible test results. The following ATD components shall be positioned as follows:

- Back shall be placed against the seat back without clearance.
- Knees shall be separated by four inches.
- Hands shall be placed on the top of the upper legs, just behind the knees.
- Feet shall be placed flat on the floor and so that the centerlines of the lower legs are approximately parallel.
- Lower legs shall be placed as close to vertical as possible.

The ATD's may be tethered to the sled, however tethering shall not restrict ATD's such that evaluation of compartmentalization is impeded.

Seats shall be subject to the following test:

- Two rows of seating shall be tested with the rear row of seats fully occupied by 50th percentile male ATD's, one ATD per seating position. All the ATD's shall be instrumented with head, chest and femur transducers.
- Seats shall be mounted on a rigid test fixture or simulated car mounting and at the predominant seating pitch for the seat's application.
- Seats shall be subjected to an 8g, 250 millisecond crash pulse as shown in Figure 12.
- High-speed photography shall record the occupant kinematics and assess compartmentalization effectiveness.

[2] For references in Italics, see Section 2

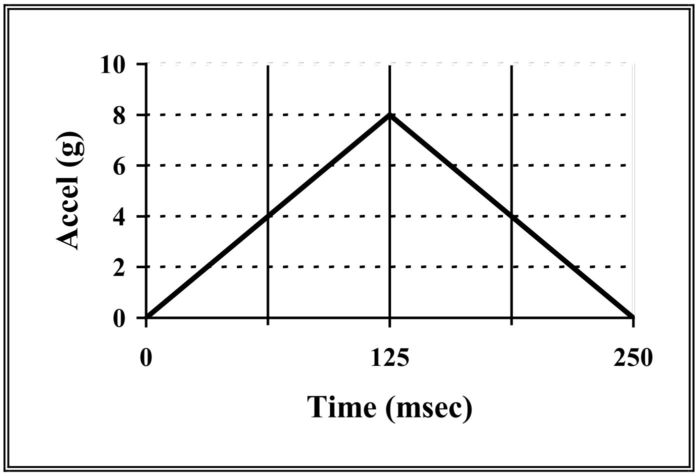


Figure 12 - Longitudinal Crash Pulse

Seat structural assessments shall include: Seats may deform but shall not tear loose from their mountings. Seat components shall not tear loose and become separated from the seat assembly such that the components become projectiles.

Human injury assessments shall include observing the compartmentalization capability of the seat back. The seat back shall compartmentalize the ATD's. After testing, the seat backs shall not be collapsed to such an extent that they present an impediment to emergency egress.

Human injury measurements shall not exceed the head, chest and femur injury criteria listed for the 50th-percentile ATD in Table 2.

Table 2 – Human Injury Limits for 50th-percentile Male ATD

Criterion[3]	Maximum Value
HIC_{36}	1000
Chest acceleration	60g over 3ms
Axial Femur load	2,250 lb. (1020 kg)

(These numbers may be revised based on future research)

5.2.2 Rearward-facing seat attachment test.

The second test shall use one transversely mounted seat row on a rigid fixture and arranged so that occupants are facing backwards. The seat shall be fully occupied by 50th percentile male ATD's; they need not be instrumented. The seat shall be subjected to an 8g, 250 millisecond crash pulse as shown in Figure 12.

- The seat shall be mounted on a rigid test fixture or simulated car mounting.
- High-speed photography shall record the occupant kinematics and assess compartmentalization effectiveness.

Seat structural assessments shall include: Seats may deform but shall not tear loose from their

3 ;*Reference FMVSS 208 – Final Rule for Federal Motor Vehicle Safety Standard – Occupant Crash Protection*

mountings. Seat components shall not tear loose and become separated from the seat assembly such that the components become projectiles.

5.3 Additional dynamic testing

5.3.1 Anti-rotation test

On seats equipped with rotation, an anti-rotation test shall be performed to insure that during a simulated car crash, the seat does not rotate inadvertently. All rotating seats shall pass an “anti-rotation” test composed of the following criteria:

– Use a complete double seat assembly.

– Load each seat with 185 lb. (84 kg) of bulk lading.

– A pendulum shall be swung such that the combined height and weight of the pendulum deliver a total kinetic energy of 1850 foot pounds (2508 joules) of kinetic energy to the seat at impact.

– Contact points shall be the center of each seat back, at a point 1 inch (25 mm) above the bottom plane of the rotating seat frame assembly.

The locking device shall retain the seat in its locked position after attempts have been made to drive the seat in the clockwise, then counterclockwise directions via the test described above. Permanent deformation of the rotating frame and seat back are acceptable. Additionally, the seat pedestal and sidewall mounting system (including fasteners) shall survive without failure in the above test.

As an option to pendulum testing, the purchaser and seat manufacturer may jointly agree to conduct sled tests to meet this requirement. The sled tests shall be conducted using the procedure given in Section 5.2.1, except the seat shall be occupied by one 95th male ATD placed in the seating position that maximizes the load on the locking mechanism. A minimum of two sled tests shall be conducted, one tending to drive the seat in the clockwise direction and the other tending to drive the seat in the counter clockwise direction.

5.3.2 Lateral and vertical strength tests

The objective of these tests is to insure that seat assemblies remain attached to the car structure when subjected to vertical and lateral forces resulting from a simulated rail car crash. The intent of these tests is to insure that the seat remains attached to the car structure when subjected to accelerations of 4g in the vertical direction and separately 4g in the horizontal direction. These tests can be performed statically as described below.

As an alternative and as agreed to by the manufacturer and purchaser, these tests may be performed dynamically using sled tests or by analysis. If sled tests are used, the seats should be subjected to a 4g, 250 millisecond triangular crash similar in shape to the crash pulse shown in Figure 13.

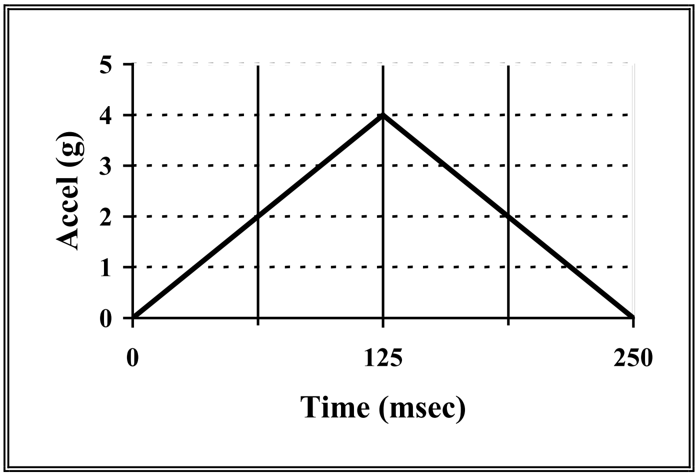


Figure 13 – Lateral and Vertical Crash Pulse

5.3.2.1 Lateral strength test

With a seat assembly mounted in a rigid test fixture or simulated car structure, a horizontal load equal to four times the weight of the seat assembly shall be applied at a point on the seat structure located at the same elevation as the center of gravity of the seat. Seat attachments (pedestals, wall brackets, etc.) shall be included in the load. The load shall be applied in at least one of the two lateral directions. Depending on the structural details of the seat mounting, the Purchaser or the Seat Manufacturer may perform this test in the opposite direction on a new assembly. The seat may suffer permanent deformation but shall remain attached to the test base or simulated car structure.

5.3.2.2 Vertical strength test

A vertical load equal to four times the weight of the seat assembly shall be applied at a point on the seat structure located at the same horizontal dimensions as the center of gravity of the seat. Seat attachments (pedestals, wall brackets, etc.) shall be included in the load. The load shall be applied in at least the vertically upward directions. Depending on the structural details of the seat mounting, the purchaser or the seat manufacturer may perform this test in the vertical downward direction on another seat assembly. The seat may suffer permanent deformation but shall remain attached to the test base or simulated car structure.

6. Seat durability testing

Seating and seating components should be designed to provide an optimal life as specified by the purchaser and used in the environment defined by the purchaser.

6.1 Mechanisms

Moving components and adjustment mechanisms should be tested to verify their durability. These components and mechanisms include:

- Recline
- Rotation and rotation locks
- Walkover
- Flip up Seats
- Tray Tables
- Fore/Aft Adjustment
- Other moving parts

The purchaser and seat manufacturer should jointly determine a test plan for life cycle testing of these components and mechanisms.

6.2 Cushions and upholstery

This accelerated life test is intended to simulate the wear and tear on seating upholstery. A cushion durability should be performed using SAE J 1454 as a guide. Tests should be performed on both bottom and back cushion. Test should consist of an automotive "jounce and squirm" test using a "jounce and squirm" machine similar to that shown in Figure 14. Each cushion should be subjected to the following:

- 200,000 jounce cycles @ 100 cycles per minute
- 4,000 squirm cycles @ 4 cycles per minute
- 180 lb. (82 kg.) load on bottom cushion
- 110 lb. (50 kg.) on back cushion

Jounce and squirm cycles should be applied simultaneously, although motions should be independent. Thigh and torso forms should be employed to transmit the motions to the cushions. Forms should be located as would a seated passenger, using the procedure given in SAE J 826.

As a result of testing, cushions should not show undue wear or signs of failure. Cushion upholstery should show no signs of tearing or ripping and should remain attached to the cushion pans or structure. Upholstery stitching should show no signs of unraveling or breakage. Cushion foam should show no signs of tearing, shearing or significant loss of height.

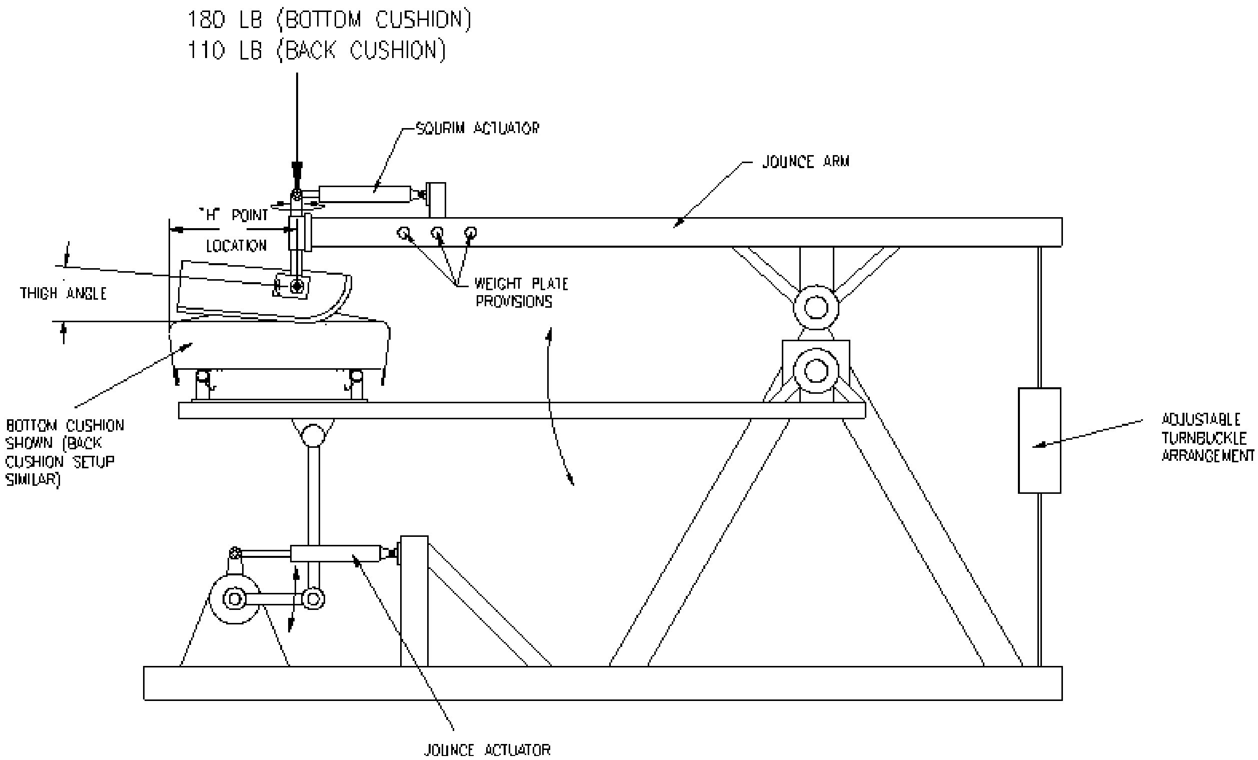


Figure 14 – Jounce and Squirm Test Machine

7. Maintainability

The seat should be easy to maintain and clean and should require no unscheduled adjustments or lubrication for the specified life of the seat. Design of the seat should be such that parts can be replaced with the use of standard hand tools. Components of like seats should be interchangeable. Pockets where dirt and debris can collect should be minimized.

8. Test plan, procedures and reports

All seat testing performed by the seat manufacturer shall be documented with a test plan, test procedures and test reports. This shall include the procedures and reports for Static Load Tests, Seat Attachment Tests, Cushion Durability Tests and Service Life Cycle Tests.

Test plan and procedures should be submitted and approved by the purchaser prior to actual testing. Tests should be scheduled to allow the purchaser to, at his or her option, witness the testing. The purchaser may elect to accept existing test reports and procedures provided the seat to be purchased is demonstrated to be identical to that tested and the test reports and procedures meet the requirements listed below.

8.1 Test plan

Prior to seat testing, a test plan should be submitted by the seat manufacturer to the purchaser. The final test plan shall be reviewed and approved by the purchaser. The test plan shall identify the seating to be tested and the tests to be performed in order to qualify the seat design for delivery and installation into the cars.

8.2 Test procedures

Test procedures for those tests not defined by recognized standards shall be prepared by the seat manufacturer and submitted for approval to the purchaser. The test procedures shall as a minimum include:

- Test Objective
- Complete Description of Item to be tested
- Pass / Fail criteria
- List of Test Equipment
- Descriptions and/or drawings of Test Setup
- Description of Test Personnel Required
- Scheduled Time and Location of Tests
- Sequential, Step by Step Test Procedure
- Test Data Sheets (for recording data during testing)

8.3 Test reports

Test Reports shall as a minimum include:

- A copy of the test procedure meeting the requirements listed above
- Text or cover letter which gives a summary of the test results, the date and location of the test, and includes the signature of the person or person(s) responsible for conducting the test and writing the report.
- Calibration data for all test measuring equipment
- Pre and post test measurements (dimensions, adjustment activation force, etc.)
- Filled-in Test Data Sheet
- Photos of test set-up and results

9. Flammability and smoke emission

Materials used in seat construction shall meet the requirements given in *CFR Part 238, Appendix B*[4], including notes. A test report for each combustible material tested shall be submitted by the Seat Manufacturer to the Purchaser. Testing shall be performed by an independent qualified testing facility. Test reports shall be prepared by the test facility.

In certain instances, materials used in seat construction can not be configured in the sizes required for test samples. For such materials, Seat Manufacturer shall submit a waiver request from testing of this material. The waiver request shall be submitted in writing and shall include the total weight of the material to be used, the location and distribution of the material in the seat and any previous test reports available.

As part of its work for the supply of seating equipment, the Seat Manufacturer should prepare and submit to the Purchaser a Combustible Content Matrix. The matrix should include total weight of each combustible material, where used, supplier's name, flammability and smoke emission, test identity, test facility, test requirements, test results, nature and quantity of the products of combustion, and heating value in BTU/lb. (joule/kg.) and BTU/hr. (joule/hr.) should be submitted by the Seat Manufacturer.

10. Parts, service and maintenance manuals

When not superseded by the requirements of the purchaser's own specifications, as part of its work the seat manufacturer shall provide a set of manuals. The manual(s) shall:

- Provide seat specifications and application data (such as weight, envelope dimensions, ranges of motion, mounting dimensions, mounting bolt sizes, grade and torque requirements, etc.)
- Provide installation and removal information
- Provide assembly and disassembly instructions and data
- Provide a list of replacement parts with part numbers and ordering information
- Provide exploded views of the seat assembly and its components
- Provide scheduled and unscheduled maintenance instructions and data, such as the periodic checking of fasteners (including torque values), lubrication instructions and cleaning instructions

Format and size of manual(s) shall be as agreed to by purchaser and seat manufacturer.

11. Engineering drawing

As part of its work and prior to the supply of seats, the seat manufacturer shall submit an engineering drawing for approval. The drawing shall, as a minimum, include the following:

[4] For references in Italics, see Section 2.

- Overall dimensions and tolerance of the seat assembly
- Weight and location of the center of gravity of the seat assembly
- Depictions of the range of motions of all adjustments and tolerances in the range of motions
- Mounting requirements including hole sizes, recommended bolt sizes and torque requirements and recommended grade of bolts to be used for mounting
- Location and operation of all seat controls and adjustments
- Forces required to operate the seat controls during normal use
- Description of materials including cushion and fabric as well as colors and model number.

12. Submittals for approval

Prior to acceptance of the seat by the purchaser, the seat manufacturer shall submit documentation listed below.

Table 3 - Submittals

Submittal	**Reference Standard Section**
Decorative Samples	4.2
Ergonomic Analysis and Report	4.2
Static Seat Strength Test Reports	5.1
Horizontal Seat Attachment Test	5.2.1 & 5.2.2
Human Injury Test Report	5.2.1
Anti Rotation Test (if applicable)	5.3.1
Lateral and Vertical Seat Attachment Tests	5.3.2
Mechanism Life Test Report(s)	6.1
Cushion and Upholstery Life Tests	6.2
Test Plan	8.1
Test Procedures	8.2
Test Reports	8.3
Flammability and Smoke Emission Report(s)	9
Combustible Content Matrix	9
Engineering Drawings	11

As an option, submittals from previous seating supply can be submitted to satisfy this requirement as negotiated by the purchaser and seat manufacturer. Timing of submittals of Manuals (Section 10) shall be as negotiated between the purchaser and seat manufacturer, but should be in a timely enough manner so as to serve as a reference and guide during installation of seating equipment into cars.

Annex A Bibliography

Document	Title
SAE ARP750	Passenger Seat Design Commercial Transport Aircraft
SAE J 899	Operator's Seat Dimensions for Off Road Self-Propelled Work Machines
Mil-Std 1472E	Human Engineering Design Criteria for Military Systems, Equipment and Facilities
49CFR Part 216 et al.	Passenger equipment Safety Standards, Proposed Rule September 23, 1997
49CFR Parts 37 and 38	Americans with Disabilities Act
Volpe Contract DAAD01-98-C-0010	Commuter Rail Seat Testing and Analysis, Final Report, Document Number TR99008, Simula Technologies, Inc.
National Academy Press, Transportation Research Record No. 1989, July 1995	''Evaluation of Selected Crashworthiness Strategies for Passenger Trains.'' D. Tyrell, K. Severson-Green, & B. Marquis
American Society of Mechanical Engineers, AMD–Vol. 210/BED–Vol. 30, pp. 539–557, 1995	''Analysis of Occupant Protection Strategies in Train Collisions.'' D. Tyrell, K. Severson, & B. Marquis
DOT/FRA/ORD–96/08—DOT–VNTSC–FRA–96–11, October 1996	''Crashworthiness Testing of Amtrak's Traditional Coach Seat.'' D. Tyrell K. Severson
DOT–VNTSC–FRA–96–5, September 1996	"Crashworthiness of Passenger Trains.''
FMVSS 208	Final Rule for Federal Motor Vehicle Safety Standard (FMVSS) 208 – Occupant Crash Protection

Annex B

(informative)

(The information in this Annex is for informational purposes only and is not required for compliance with this standard.)

B.1 Background on seat safety and crashworthiness

Passenger seating in rail cars can either improve the safety environment within the car interior or can be a hazard, depending on the details of seating design, its arrangement in the car and the strength of its attachment to the car structure.

Seating can become a hazard when:

– Seats and parts of seats tear loose from the seat or its mounting during an accident and become projectiles, cause injuries and become impediments to timely evacuation of a car after an accident.

– Seat backs that are too flimsy or too short and fail to contain the occupant and thus fail to prevent the occupant from impacting with another, possibly less friendly object in the interior.

– Seats that have hard surfaces in the wrong places, or have sharp corners and edges can contribute to injury, even in moderate accidents.

Seating can help improve the interior safety of a passenger rail car when:

– Seats and parts of seats are designed to stay attached during an accident or collision and reduce the hazard associated with loose objects during an accident.

– Seat backs are designed to mitigate injuries by containing a passenger within a defined space during a collision and absorb some of the energy that would otherwise contribute to injury.

– Seats are designed to mitigate injuries and contribute to the timeliness and efficiency of emergency evacuation efforts by increasing the likelihood that passengers can exit with little or no aid from emergency personnel.

– Seats are designed with appropriate padding and rounded corners.

During most train collisions, passenger cars are decelerated to reduce their forward speed. In such train collisions (primary impact), passengers in forward-facing seats and longitudinally mounted seats, in the absence of any restraining devices, gain a velocity relative to the car and its interior features. The magnitude of this relative velocity depends on the distance through which passengers travel before colliding with another feature or passenger within the car interior (secondary impact) and is given by:

$v = \sqrt{2as}$, where v is the relative passenger velocity, a is the deceleration of the car, if constant, and s is the distance through which the passenger travels.

The severity of the secondary impact for passengers in forward-facing and longitudinally mounted seats depends, among other things, on the relative velocity of the passenger at impact. An important fact stemming from the physics is that the kinetic energy reduction required to decrease the passengers' speed to that of the car increases as the relative velocity increases. It is the dissipation of this kinetic energy during impacts that is the source of injury for passengers in forward-facing seats. In general, this kinetic energy is dissipated by passengers colliding with features in the interior of the car

Another consideration is the possibility of passengers colliding with an object close by, such as a seat back, glancing off that object, and then proceeding to impact with another object farther away. This is known as tertiary impact, and can be a primary contributor to serious injuries.

One strategy for reducing the likelihood and severity of tertiary impacts is called "compartmentalization". According to D. Tyrell et al., (AMD-Vol.210/BED-Vol.30, "Crashworthiness and Occupant Protection in Transportation Systems", ASME 1995), "The principle objectives of this strategy are to limit the occupant's range of motion and to ensure that the interior surfaces are designed to limit injury during occupant impact."

Passengers in rear-facing seats remain compartmentalized if the seat remains attached while the car decelerates. Because there is no time delay between the primary impact and occupant-seat contact, the initial deceleration peak is higher for rear-facing occupants than it is for forward-facing occupants. The chance of injury to rear-facing occupants increases if the seat fails at its floor attachment and compartmentalization is no longer provided.

There are also issues associated with human tolerance to impact. In any discussion of overall survivability of accidents, one must take into account a passenger's ability to respond to emergency personnel, find and open emergency exit and evacuate the car and surrounding area. Often, the time associated with post-accident activities is critical. Thus, it is obvious that the fewer debilitating injuries suffered by a passenger, the higher the chances of surviving any post-accident hazards. And it follows that any overall plan to improve emergency preparedness would be more effective if passengers themselves were more capable of participating in post accident activities.

Although there is some disagreement with exact levels of human tolerance to impacts, many other transportation industries place limits on certain measurements related to criteria that have been associated with human injuries or fatalities. Anthropomorphic dummies have been refined to a remarkable level of physical resemblance to human bodies and are available in a range of sizes and with high levels of instrumentation to record forces and accelerations on the human form. Test sleds and highly sophisticated facilities are readily available to simulate certain crashes and record anticipated human responses. In addition, computer programs such as MADYMO are available to aid in the design process and have been validated against simulated crashes (see USDOT/FRA "Crashworthiness Testing of Amtrak's Traditional Coach Seat" by D. Tyrell and K. Severson, Volpe Center, for validation of MADYMO as a predictive tool). In short, there are many tools available to the designer of seating for commuter cars to help mitigate the effects of occupant impacts with seating.

All of the discussion above leads to some guidelines for passenger rail seating. These are given below and apply (1) to transverse seats arranged so that passengers face the back of another seat and (2) to transverse, aft-facing seats. They are presented in order of importance:

1. Seats, seat components and the attachment of the seat to the car structure are to be strong enough to prevent the seat and its parts from tearing loose during a crash.

2. The seat back is to be strong enough to prevent occupants who strike the seat back from behind or are pressed against the seat back in a backward-facing seat, from completely collapsing the seat back.

3. The seat back is to be appropriately compliant, energy-absorbing and/or padded in such a way as to mitigate human injury.

B.2 Effects of seating arrangement

Another issue affecting the crashworthiness of seating is that of arrangement in the car. Most commuter passenger rail cars have the seats generally arranged transversely such that occupants are facing the back of another seat. In some places, however, occupants face one another or face a bulkhead wall. There are also situations where occupants are in longitudinally mounted seats facing the center of the car. Figure 15 illustrates many of these different seating arrangements.

Although seating arrangement issues often involve considerations for quality of service and optimizing the seating capacity in cars, the designer should be aware of the effects of arrangement on crashworthiness.

In general, the most crashworthy arrangement is when seats are arranged transversely such that occupants face another seat back. When it is necessary to arrange seats differently, there are certain things that can be done to improve the crashworthiness of the arrangement.

Facing seats could have a table, with a relatively thick and rounded edge, between the occupants. The table and its attachment to the car structure should be strong enough to withstand the impact of passengers during a crash. While it appears logical that a table would enhance the compartmentalization of occupants seated facing each other, it is not yet obvious that a rigidly-mounted table would not seriously cause abdominal injuries. Additional research is needed to determine the affect of a rigidly-attached table, both adverse and effective, on occupants.

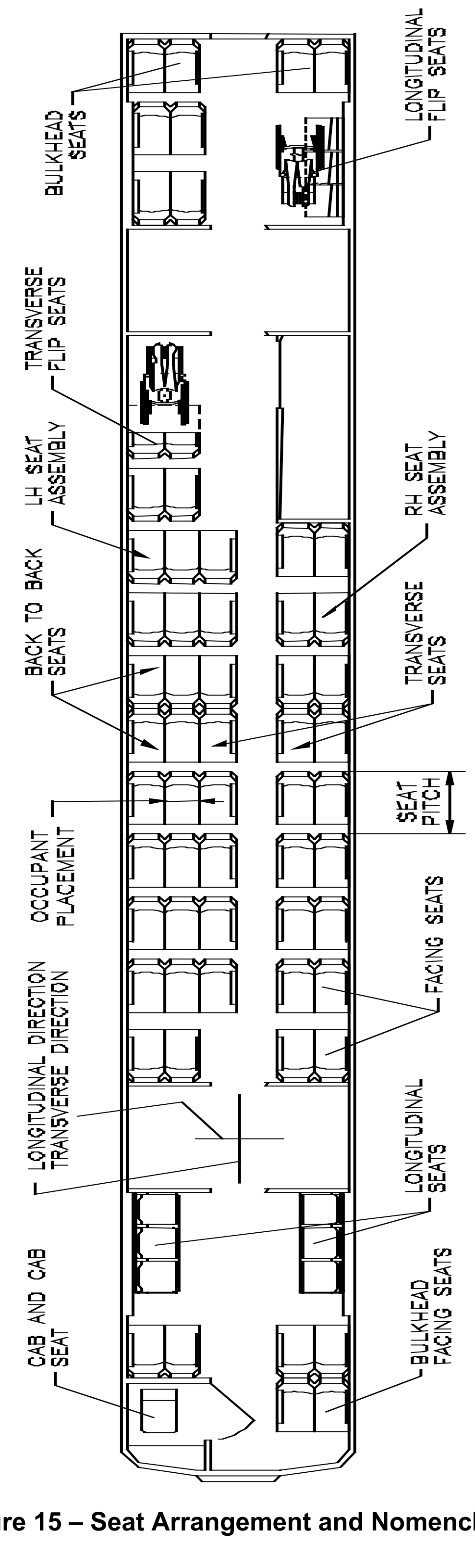


Figure 15 – Seat Arrangement and Nomenclature

In certain types of seating (such as walkover and rotating seats) the seats can be adjusted so that they face one another. When this is the situation, some Transit Authorities may want to consider having the mechanism providing the adjustment (rotation or walkover mechanism) be designed such that control of the adjustment is done by the Transit Authority, rather than the passenger depending on the type of service they wish to provide.

If seats face a bulkhead, the bulkhead should be padded or otherwise provide protection for the occupant(s) during a crash. If longitudinal seating is used, the range of motion of an occupant during a crash should be limited by placing features along the length of the seat. These features should be padded or otherwise provide protection for the occupant during a crash.

Wheelchair parking areas should be oriented so that occupants are facing in the direction (or opposite direction) of car travel The range of motion of a wheelchair and its occupant should be limited by another feature in the car, such as a windscreen, bulkhead wall or seat. In all cases, seating arrangement should meet the requirements of the *49CFR Parts 37 and 38 (Americans with Disabilities Act).*[5]

B.3 Derivation of crash pulse

Figure 16 is taken from The FRA's Notice of Rulemaking 49 CFR Part 216 et al., published in the Federal Register on September 23, 1997. According to the notice, the peak deceleration of passenger rail coach equipment was 8g's for a head on collision during a train-to-train collision at 70 mph. For the purposes of testing, this crash pulse was idealized to the one shown in this standard. Results from recently-conducted research, particularly involving full scale crash tests, as discussed below, have shown that the measured occupant deceleration environment during a collision is different then the originally approximated. The crash pulse used in the standard and the measured occupant deceleration environments from three different full scale tests are shown in Figure 17. The computed secondary impact velocities of a forward facing unrestrained occupant for each crash pulse from Figure 17 are shown Figure 18. An ongoing study of these results is considering if the current crash pulse should be modified.

[5] For references in Italics, see Section 2.

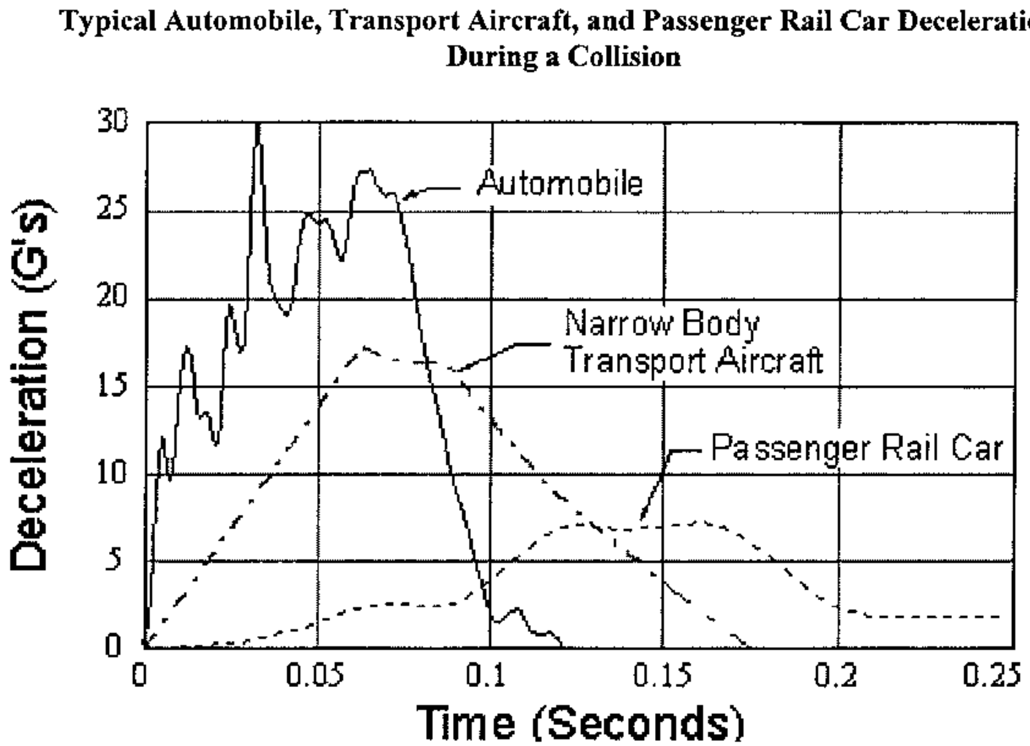


Figure 16 – Typical Decelerations During a Collision

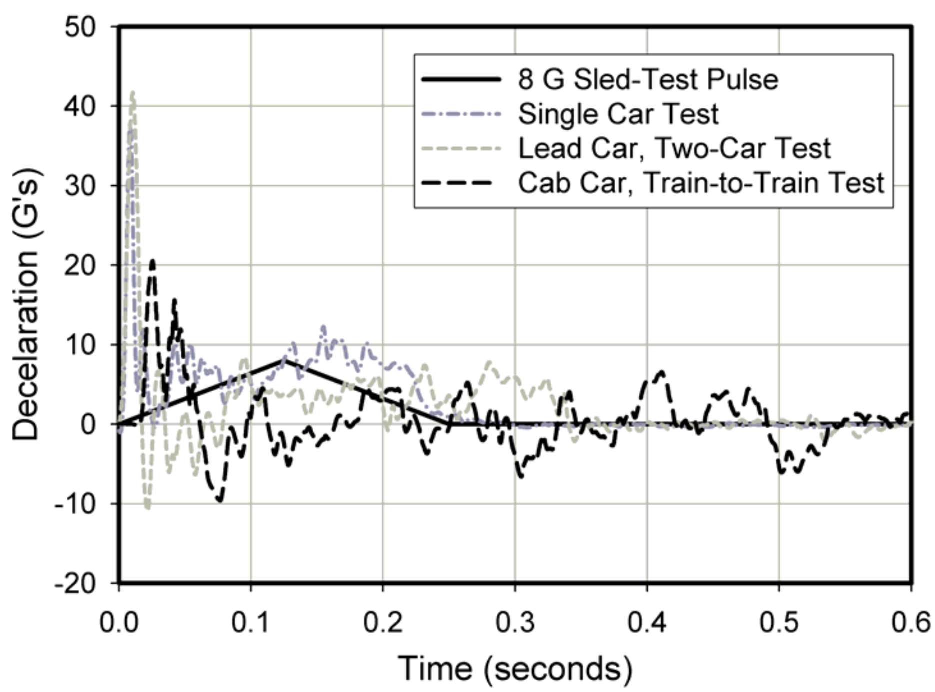


Figure 17 – Actual Decelerations Measured During Full Scale Tests

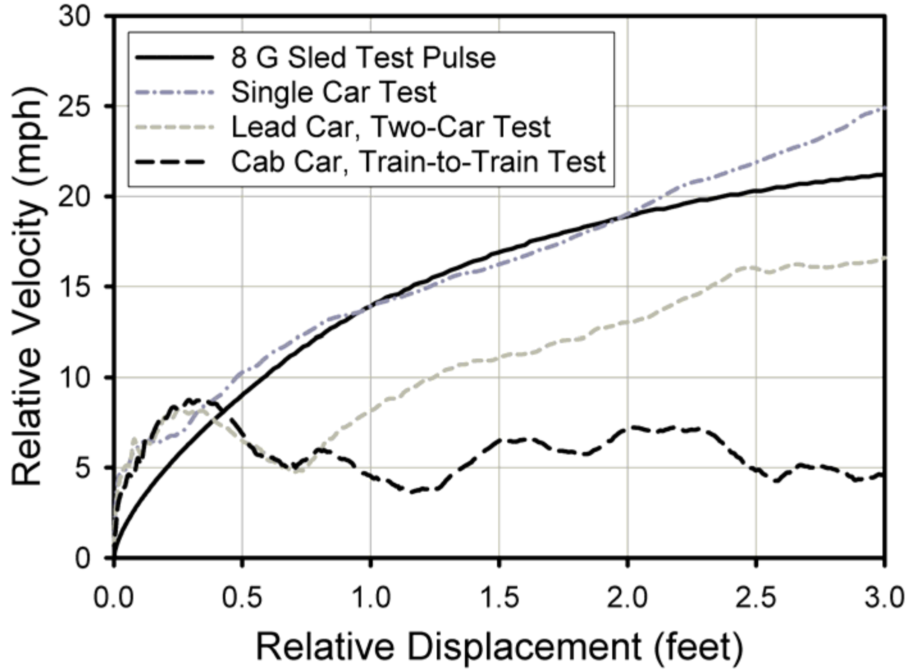


Figure 18 – Secondary Impact Velocity During Full Scale Tests

B.4 Research programs

Simultaneous to the development of this standard, the FRA embarked on a comprehensive Rail Crashworthiness Research Program which included a series of dynamic sled tests and full-scale collision testing. At the onset, and particularly as part of the development of this standard, APTA, together with the Volpe Center (FRA) conducted analyses and a series of sled tests on representative commuter seating at Simula, Inc. in Phoenix, AZ.

B.4.1 Dynamic sled testing program

The intent of the dynamic sled testing was to provide a better understanding of how traditional commuter seating behaves in a crash environment in terms of both the seat and dummy response.

Two test programs have been conducted. One program tested three types of row-to-row commuter seats as shown in Figure 19, and the other program tested a typical facing seat system. Table 4 below is information about the application of these seats:

Table 4 – Description of Seats Used in Test Program

Seat Tested	Comments
2 Passenger LIRR C-3 Seat	This seat was selected because it represents the only cantilever mount commuter seat configuration in current use. Pedestal mount versions of this seat are also to be placed in service during 1999 at PCJPB and NVTC.
3 Passenger Walkover Seat	Used be NJT. Two passenger versions used by METRA and PCJPB.
3 Passenger M-Style Seat	Used in various configurations by Metro-North, LIRR, SEPTA, MBTA, NICTD, MARC and others.
2 Passenger Facing Seat	Manufactured by Bombardier for their bi-level commuter train. Other properties are preparing to install the facing configuration in their cars: San Diego, Vancouver, Florida, SCRRA, Dallas, Seattle.

Prior to testing, a series of analyses was conducted using MADYMO models of each seat. To help develop the models of the seats, each seat was subjected to static loads across the seat backs to determine the stiffness of the seat backs. Evaluations were made by placing different size occupants in different locations in the seats. As expected, this resulted in different dummy responses depending on the mix of dummies in the seat and the location of the dummies. The analysis on the facing seats included variations with and without a table between the seats.

After seat testing, comparisons were made between test data and the values predicted by the modeling. In general, seat/occupant computer models correlate well with the test results and showed that using a tool like MADYMO can reasonably predict the response of seating and occupants during sled testing.

All of the seat frame structures remained attached to the test fixtures. Cushion detachment during dynamic testing proved to be the primary source of flying objects in the row-to-row series of seat tests and was especially noted on the M-Style seat. In the facing seat testing, the upper part of the seatback (the headrest) typically fractured due to the impacting dummy. This seat failure did not occur when the table was installed between the seats.

The stiffer LIRR C-3 rail seat showed improved passenger compartmentalization and cushion attachment, but, because of the increased stiffness, showed an increased likelihood of neck injuries caused by the dummies impacting the seat in front.

The more compliant seat(s), the M-Style and Walkover seats, increased the risk of passengers ejecting from the seats, but reduced the risk of injuries caused by the dummies impacting the seats in front. Thus the testing showed that to optimize passenger safety, seat backs need to be designed to be stiff enough to provide effective compartmentalization, but not so stiff as to increase the likelihood of injury. The results for the facing seats are similar. Placement of a table between the seats also proved to be an effective method of compartmentalizing occupants if the table remains attached.

The seats and table were all rigidly attached to the test fixture in an effort to eliminate an unpredictable variable during testing, i.e., the rail car floor or wall strength. The consequence of rigid seat attachment was a more repeatable test, however, the tests could not account for any energy that may be absorbed by the rail car floor or wall structure.

All row-to-row seat tests were conducted under conservative spacing conditions; specifically a 32-in. seat pitch. However, commuter seats in the field are typically attached with a 33-in. to 34-in. seat pitch. The computer seat models were all run with a 32-in and a 33-in. seat pitch to compare the difference in occupant injury data. The results suggest that the difference is very slight. Computer results did show that as seat pitch increased to 48 in. the predicted injury loads increased. Therefore, injury outcomes identified from these tests will likely become worse as the seat pitch increases. The facing seat tests were conducted with a 65-in spacing between the seats. Test dummies were not seated in the aft-facing seat during testing. Computer modeling and/or additional testing should be conducted to determine the ramifications of occupants facing each other.

B.4.2 Full-scale rail collision testing

In addition to the commuter seat sled testing and analysis programs, a series of full-scale commuter rail collision test programs has been in progress. To date, three tests have been conducted:

1. a single car traveling at 35 mph into a rigid barrier

2. two coupled cars traveling at 26 mph into a rigid barrier.

3. a train-to-train test involving a cab-car led, 4-car consist trailed by a locomotive colliding at 30 mph into a stationary locomotive coupled with two ballasted freight cars.

In all three of these tests, a series of seat/occupant experiments were installed inside the railcars to compare with the outcomes of the dynamic sled tests. In each full-scale test, one or more ATDs measured neck load(s) that exceeded the neck injury criteria and in all but the train-to-train test, one ATD in each full-scale test measured femur loads that exceeded the femur criterion. None of the head and chest accelerations exceeded injury criteria. These results suggest that it would be reasonable to add the neck injury criteria as a requirement in this standard.

In addition to providing data for the seat/occupant response to the impact forces of a train collision, these full-scale tests provide realistic crash pulse data that may be used to update the current crash pulse described in this standard.

The crash pulse defined in this standard and used in the seat testing described above (250 msec, triangular pulse with 8G peak) was originally derived from computer analyses by the Volpe center. While this pulse appears to produce reasonable seat/occupant responses, it will eventually be validated with the crash pulse data produced through full-scale passenger rail car crash testing. Some features of the crash pulses produced to date from full-scale crash testing, and not currently described by the derived crash pulse, include an initial high peak longitudinal acceleration approximately 25 G followed by an average constant acceleration of approximately 5 G, plus an additional vertical acceleration pulse and possibly a lateral acceleration pulse, see Figure 17 for the crash pulses obtained from the recent full scale testing..

B.4.3 Neck Injury Criteria

During all these research programs, the ATD neck loads have been recorded along with head, chest and femur loads. It is quite noteworthy that neck loads are the predominant measurements recorded that exceed the given injury criteria. Despite this observation, neck loads are not yet included as a requirement in this standard. First, Hybrid II dummies are preferred for rail seat testing because of their straight spine, however they are not equipped to record neck loads. Hybrid III dummies, on the other hand, contain provisions for measuring neck loads, but they have curved spines that, while suitable for the semi-reclined position in automotive seating, provide a less natural seating position than the Hybrid II dummies do for rail seating. Second, no other industry has required neck injury criteria until recently when the automotive industry adopted the requirement to include neck injury criteria (Nij) to certify their automobiles, specifically for airbag deployment safety (Reference FMVSS 208). This new rule will be phased in starting on September 1, 2003 and could propel other industries, including the rail industry, to comply with neck injury criteria as well. Results from ongoing research by the FRA in their Rail Crashworthiness Research Program will be used to make a final determination about incorporating neck injury criteria as a requirement in this standard.

Despite these reasons for not yet including neck injury criteria as a standard requirement, it is highly recommended that the neck injury loads be recorded during testing and that they do not exceed the comparative neck injury criteria listed in Table 5:

Table 5 – Human Injury Limits for 50th-percentile Male ATD

<table>
<tr><th>Criterion</th><th>Maximum Value</th><th>Nij Criteria</th></tr>
<tr><td>HIC_{36}</td><td>1000</td><td>N/a</td></tr>
<tr><td>Chest acceleration</td><td>60g over 3ms</td><td>N/a</td></tr>
<tr><td>Axial Femur load</td><td>2250 lb. (1020 kg)</td><td>N/a</td></tr>
<tr><td>Neck Fx</td><td>+/- 697 lb (316 kg)</td><td>N/a</td></tr>
<tr><td>Neck Fy</td><td>+/- 697 lb (316 kg)</td><td>N/a</td></tr>
<tr><td>Neck Fz</td><td>+742/-900 lb
(+337 kg/-408 kg)</td><td rowspan="2">Nij ≤ 1.0

(CFC 600)</td></tr>
<tr><td>Neck My</td><td>+140/-42 ft-lb
(+63.5 kg/-19 kg)</td></tr>
</table>

The following related reports and papers describing the testing are available through the FRA website:

Tyrell, D., Severson, K., Perlman, A.B., March, 2000, "Single Passenger Rail Car Impact Test Volume I: Overview and Selected Results, " U.S. Department of Tranportation, DOT/FRA/ORD-00/02.1.

VanIngen-Dunn, C., March 2000, "Single Passenger Rail Car Impact Test Volume II: Summary of Occupant Protection Program," U.S. Department of Tranportation, DOT/FRA/ORD-00/02.2.

Tyrell, D., Severson, K., Perlman, A.B., Brickle, B., VanIngen-Dunn, C., "Rail Passenger Equipment Crashworthiness Testing Requirements and Implementation," Presented at the 2000 International Mechanical Engineering Congress and Exposition, November 6, 2000, Orlando, Florida.

Tyrell, D., Zolock, J., VanIngen-Dunn, C., "Rail Passenger Equipment Collision Tests: Analysis of Occupant Protection Measurements," presented at the 2000 International Mechanical Engineering Congress and Exposition, November 6, 2000, Orlando, Florida.

VanIngen-Dunn, C., Tyrell, D., Occupant Protection Experiments for the Federal Railroad Administrations' Single-car and Two-car Passenger Rail Impact Tests, Final Report, Volpe National Transportation Systems Center, Cambridge, MA, Contract No. DAAD01-99-C-0012, Simula Technologies, Inc. Phoenix, Arizona, September 8, 2000.

Commuter Rail Seat Testing and Analysis, Final Report, USDOT, Volpe National Transportation Systems Center, Contract No. DAAD01-98-C-0010, Simula Technologies, Inc., Phoenix, Arizona, April 6, 1999.

A report on the analysis and testing of facing seats is yet to be released by the FRA:

Commuter Rail Seat Testing and Analysis for Facing Seats, Final Report, USDOT, Volpe National Transportation Systems Center, Contract No. DTR S57-99-D-00096/TO3, Simula Technologies, Inc., Phoenix, Arizona, December 2000.

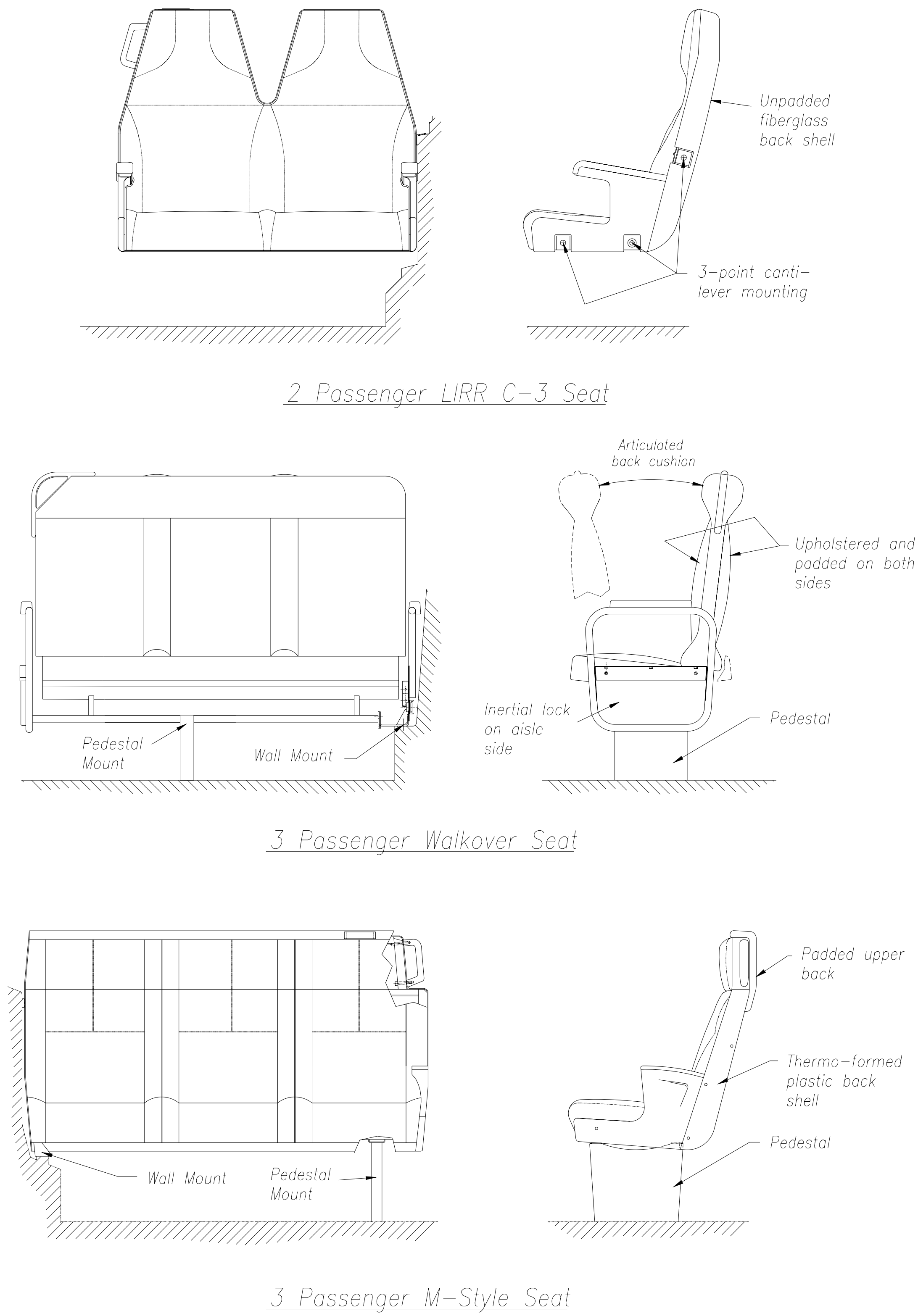


Figure 19 – Seats Tested