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PRESS Construction and Structural Working Group

# Passenger Seats in Passenger Railcars

**Abstract:** This rail standard specifies minimum strength, crashworthiness, and fire safety requirements for the design and procurement of passenger seats for use in passenger railcars that are operated on the general railroad system of transportation, regardless of Tier of operation.

**Keywords:** anthropomorphic test device (ATD), crashworthiness, injury criteria, seat, seating

**Summary:** This standard specifies minimum strength, crashworthiness and fire safety requirements for revenue passenger seating equipment installed in cars operated on the general railroad system of transportation, regardless of Tier of operation. This standard applies to passenger seating equipment in all new car procurements and generally describes the test conditions, measurements and performance requirements necessary to demonstrate compliance. Seating equipment in compliance with Revision 2 of this standard is acceptable for retrofits and refurbishments of existing railcars. This standard becomes effective on the date of authorization stated on the title page.

**Scope and purpose:** Compliance with this standard will provide and maintain an appropriate level of safety for rail passengers, for that component of safety attributed to the seating. The purpose of this standard is to establish minimum requirements for seat attachment strength; establish minimum human injury criteria associated with dynamic seat testing; specify minimum flame and smoke standards; specify minimum reporting requirements to demonstrate compliance with this standard; provide background information; and provide nomenclature and definitions associated with passenger seating.

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## Introduction

*This introduction is not part of APTA PR-CS-S-016-99, Rev. 3, "Passenger Seats in Passenger Railcars."*

This standard applies to all:

1. Railroads that operate intercity or commuter passenger train service on the general railroad system of transportation; and
2. Railroads that provide commuter or other short-haul rail passenger train service in a metropolitan or suburban area, including public authorities operating passenger train service.

This standard does not apply to:

1. Rapid transit operations in an urban area that are not connected to the general railroad system of transportation;
2. Tourist, scenic, historic, or excursion operations, whether on or off the general railroad system of transportation;
3. Operation of private cars, including business/office cars and circus trains; or
4. Railroads that operate only on track inside an installation that is not part of the general railroad system of transportation.

# Passenger Seats in Passenger Railcars

## 1. Overview of requirements

### 1.1 Applicability

The intent of this standard is to demonstrate that passenger seats in passenger railcars comply with minimum strength and crashworthiness requirements. The requirements in this standard shall apply to all passenger seats in all classes, i.e., first, business, coach, etc., in all cars. Computer analysis shall not be allowed as a substitute for any testing requirements. Computer analysis may be used to determine the worst case configuration to be dynamically tested.

Except as specified below, each seat type (i.e., one-, two-, or three-passenger seats) and class (i.e., first, business, coach) shall be tested.

- Dynamic testing shall be completed using the largest seat pitch for a given configuration, which can be used to validate seating configurations with smaller pitches.
- Open bay seating does not need to be tested in accordance with Sections 3.2 and 3.3.4 in the open bay configuration unless more than 50% of a car's passenger seating is configured as open bay seating.
- Seating types/classes that represent less than 5% of a car's passenger seating do not need to be tested in accordance with Section 3.2.
- Tier III trainsets that comply with 49 CFR Part 238.735 (a)(2) do not need to comply with the requirements in this standard.

For static testing, where sufficient structural similarity exists between seat types, and the test results are comparable to the numerical analyses, the purchaser and manufacturer may jointly agree to apply the results of testing to various seat types.

At a minimum, at least one seat configuration shall be tested in accordance with the requirements in Sections 3.2 and 3.3.4 in this standard.

The dynamic test requirements in Sections 3.2 and 3.3.4 of this seating standard do **not** apply to non-revenue seating in food service or lounge cars, or to any seating in sleeping cars, or to any flip-up seats or longitudinally-oriented seats that face the center aisle or side windows, or to fixed bulkhead-facing seating or other seating arrangements for which there is an impact surface other than a seat. The attachment strength requirements of 49CFR Part 238.233 and the static load requirements in section 3.1 in this standard shall still apply to these other types of seating arrangements.

Walkover and rotating seats shall be tested in the row-to-row configuration. These seats do not need to be tested in the open bay configuration, provided that the operator intends to position the seats in the row-to-row configuration in service. If the operator intends to use walkover or rotating seats in the open bay configuration, then they should be tested as open bay seats based on the guidance in this section. Walkover and rotating seats at the end of a row may be positioned in the open bay configuration by the operator without the need for testing in the open bay configuration.

At the time of publication, compliance with Revision 2 of this standard is required by regulation in *49 CFR Appendix G to Part 238—Alternative Requirements for Evaluating the Crashworthiness and Occupant Protection Performance of a Tier I Passenger Trainset*, and *49 CFR Part 238.735 for Seat Crashworthiness (Passenger and Cab Crew).* Portions of this standard are intended to provide details on how to demonstrate compliance with the requirements of *49 CFR Part 238.233 for Tier I Passenger Seating Equipment,* which apply to every seat type and class.

## 1.2 Crashworthiness of open bay seat configuration

The open bay seat configuration, in which two rows of seats are positioned such that passengers face one another, without a table between the facing seats, is common in passenger trains. There is mounting evidence, however, from computer analyses,[1] dynamic sled tests[2] and accident investigations[3], that open bay seats do not provide the same level of occupant protection during an accident as row-to-row seats that face the same direction. Fixed workstation tables that are designed to absorb an occupant's kinetic energy during a collision have been shown to mitigate hazards associated with open bay seats.[4,5] Facing seats with intervening workstation tables are allowed, and preferred over open bay seats, provided that the tables meet the requirements in APTA PR-CS-S-018-13, "Fixed Workstation Tables in Passenger Rail Cars."

Open bay seating in railcars should be limited to the extent practical, unless the configuration complies with all the requirements in this standard. Open bay seats used at the end of a row to prevent seats from facing a bulkhead wall, windscreen, vestibule wall or similar structure are considered an acceptable justification for the use of open bay seats. In addition, open bay seats positioned to accommodate access to emergency egress windows as required by 49 CFR 238.113(a) are considered an acceptable justification for the use of open bay seats. To compromise on operators' desire to use unlimited open bay seats, up to 50 percent of a car's seating capacity may be open bay seats without conducting the forward-facing ATD sled tests in the open bay configuration. Unlimited open bay seats may be used if the seats comply with all the requirements in this standard, including the forward-facing ATD sled tests, in the open bay configuration.

## 1.3 Anthropomorphic test devices

Reference is made in this standard to a series of anthropomorphic test devices (ATDs) designed to represent the 50th-percentile male occupant and the 95th-percentile male occupant. The ATDs used to meet the test requirements specified in this standard must be compliant with 49 CFR Part 572.

A table of available ATDs and their typical weights as used in testing to represent these occupant populations is given below for reference in **Table 1**.

1. Tyrell, D.C., Severson, K.J., and Marquis, B.J., "Analysis of Occupant Protection Strategies in Train Collisions," American Society of Mechanical Engineers, AMD-Vol. 210, BED-Vol. 30, pp. 539-557, 1995.
2. VanIngen-Dunn, C., "Commuter Rail Seat Testing and Analysis of Facing Seats," U.S. Department of Transportation, DOT/FRA/ORD-03/06, December 2003.
3. Accident of Metrolink passenger train #111 on Sept. 12, 2008, in Chatsworth, California; and accident of Metrolink passenger trains #100 and #901 on Jan. 25, 2005, in Glendale, California.
4. Severson, K., and Parent, D., "Train-to-Train Impact Test of Crash Energy Management Passenger Rail Equipment: Occupant Experiments," American Society of Mechanical Engineers, Paper No. IMECE2006-14420, November 2006.
5 Luebke, W., "Development of an APTA Compliant Energy Absorbing Workstation Table," Passive Safety of Rail Vehicles 11th International Symposium, Berlin, Germany, March 2017.

**TABLE 1**
Typical Weights of ATDs

| ATD | Weight | |
|---|---|---|
| Hybrid III 50th-percentile male | 172.3 lb | 78.2 kg |
| Hybrid III 95th-percentile 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.

# 2. Seat design features

This section provides requirements regarding features commonly found on passenger seating equipment.

## 2.1 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 9**. Adequacy of the lock mechanism shall be demonstrated as part of the dynamic sled test given in Section 3.2. The purchaser may require additional testing of the lock mechanism according to test procedures agreed to by the purchaser and the seat manufacturer. The seat back on walkover seats shall be adequately fastened to the seat base such that it will not become separated from the seat base during the dynamic tests described in sections 3.2 and 3.3.

## 2.2 Rotation

Seat rotation, if provided, shall be 180 deg. A lock capable of passing the anti-rotation test described in Section 3.3.1 shall be provided in both extreme positions. A seat securement system is required to prevent the disengagement and undesired rotation of seats. The system shall have a positive seat securement indicator that makes clear to rail operators that the rotating seat is in a locked and secured position.

# 3. Seat testing

Seating equipment shall be subjected to a series of static and dynamic 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 the seating equipment to be delivered. If a structurally identical seat has met all the requirements in the current version of this standard, then the manufacturer may provide data from the previous tests to satisfy the corresponding portion of this standard, for approval of the subject seat by the purchaser.

> **NOTE:** Although durability tests are not required to demonstrate compliance with this standard, Appendix C contains a limited set of durability tests that are provided as information only.

## 3.1 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 expected in rail operations. Seats to be tested are outlined in Section 1.1 of this standard.

In general, static testing is performed on the structural parts of a seat assembly, usually the seat frame, pedestal and other mounting equipment, and hardware.

Seat frames and components shall be designed and tested to meet the individually applied static load requirements given in this section (if optional components are present), with minimal permanent yielding of structural materials (limits specified herein), loss of function, or change in appearance of the seat or component. Prior to static testing, it is permissible to apply and remove a 100 percent preload to relieve any manufacturing pre-stresses that may be present. A small amount of permanent deformation measured post-test (less than $^{1}/_{8}$ in.) shall be permissible.

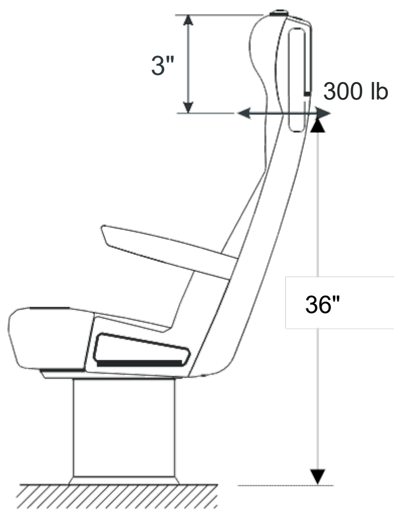
There are no maximum temporary deflection limits imposed on the seating components during static testing.

Not all static tests need to be performed using a single test specimen. It is permissible to use different but identical seats for different tests.

### 3.1.1 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 or her feet against the seat back. Therefore, a load of 300 lbf (1334 N ) per occupant shall be applied to the upper part of the seat back at the lateral midpoint of each seat back and at an elevation of 36 in. (914 mm) above the floor, or 3 in. (76 mm) below the top of the seat back, whichever is lower, and in a direction perpendicular to the seat back (reference **Figure 1**). 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 back members. Load shall be applied for a minimum of 5 s. This test shall be repeated in both longitudinal directions, i.e., load is applied to the back of the seat and the front of the seat.

**FIGURE 1**
Backrest Strength Test Loading Conditions

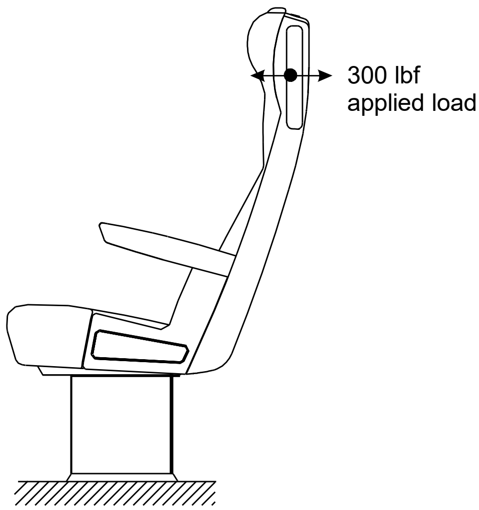



### 3.1.2 Grab handle strength test (if equipped)

A 300 lbf (1334 N) load shall be applied to the grab handle (if present) at a point near the middle of the grab handle in a longitudinal direction (reference **Figure 2**). Load shall be applied for a minimum of 5 s. This test shall be repeated in both longitudinal directions. A fixture may be used to ensure that the load is properly applied and distributed onto the grab handle.

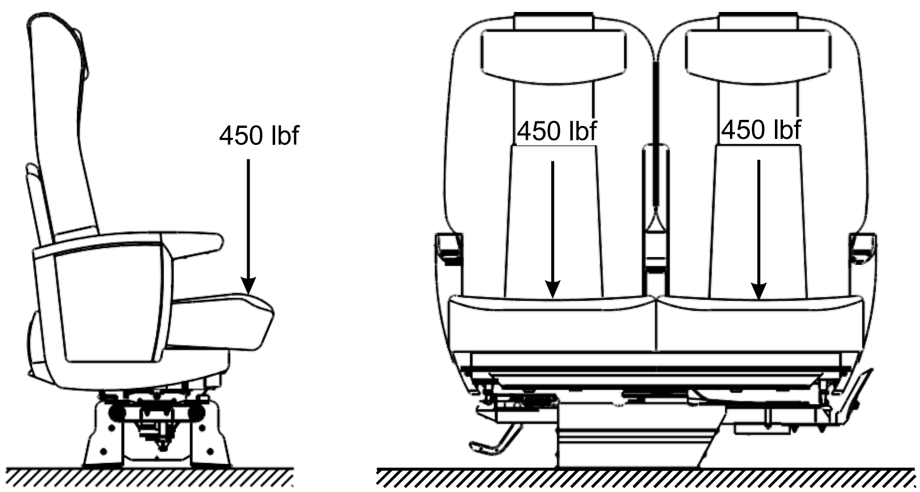
**FIGURE 2**
Grab Handle Strength Test Loading Conditions




### 3.1.3 Vertical seat strength

A load of 450 lbf (2002 N) per occupant shall be applied to the seat bottom cushion near the front edge of each occupant placement in a vertical downward direction at the midpoint of each occupant position (reference **Figure 3**). The contact area of the applied load shall be 5 by 5 in. (13 by 13 cm). The load shall be applied for a minimum of 5 s.

**FIGURE 3**
Vertical Seat Strength Test Loading Conditions



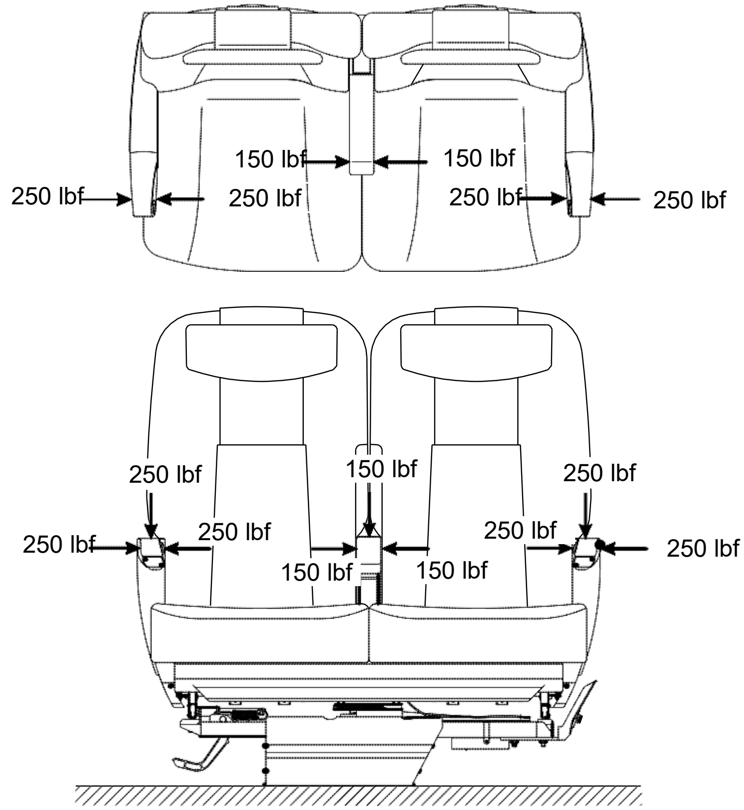

### 3.1.4 Armrest strength

A load of 250 lbf (1112 N) shall be applied to the horizontal member of the fixed armrest structure (if present) at a point that produces maximum stress in the member (reference **Figure 4**). A fixture may be used to properly apply and distribute the load. The contact area of the applied load shall not exceed 2 by 2 in. (5 by 5 cm). The load shall be applied for a minimum of 5 s. This test shall be repeated for the two lateral conditions (toward the aisle and toward the wall side of the seat) and then vertically downward.

For seats with folding armrests, the folding armrest shall be tested by applying a 150 lbf (667 N) vertically downward load as near as practical to the end of the armrest. Separately, a lateral 150 lbf (667 N) load shall be applied as near as practical to the end of the armrest. The contact area shall not exceed 2 by 2 in. (5 by 5 cm) in all cases. The load shall be applied for a minimum of 5 s. The lateral load test shall be repeated for both directions.

**FIGURE 4**

Armrest Strength Test Loading Conditions

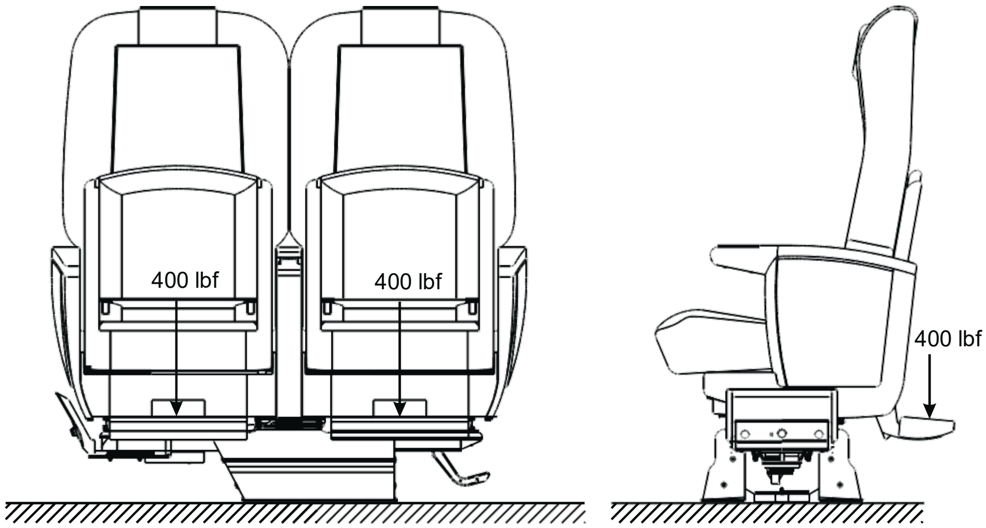



## 3.1.5 Footrest test (if equipped)

With footrest deployed in the most nearly horizontal position, a 400 lbf (1779 N) load shall be placed at the center of the footrest surface (reference **Figure 5**). The load shall be applied over an 8 in. ±0.25 in. (20 cm ±0.64 cm) length, over the full depth of the footrest, centered on the footrest surface. The load shall be applied for a minimum of 5 s.

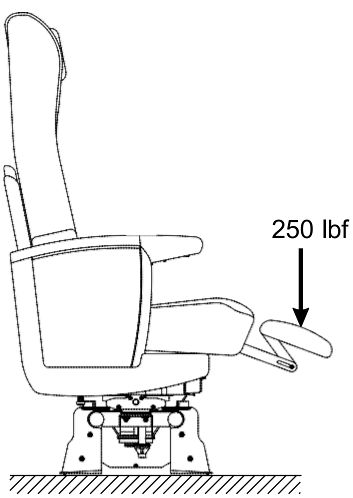
**FIGURE 5**
Footrest Strength Test Loading Conditions




## 3.1.6 Leg rest test (if equipped)

With the leg rest assembly in the most nearly horizontal position, place a 250 lbf (1112 N) load distributed over an area of 5 by 5 in. (13 by 13 cm) at the center of the leg rest cushion (reference **Figure 6**). The load shall be applied for a minimum of 5 s.

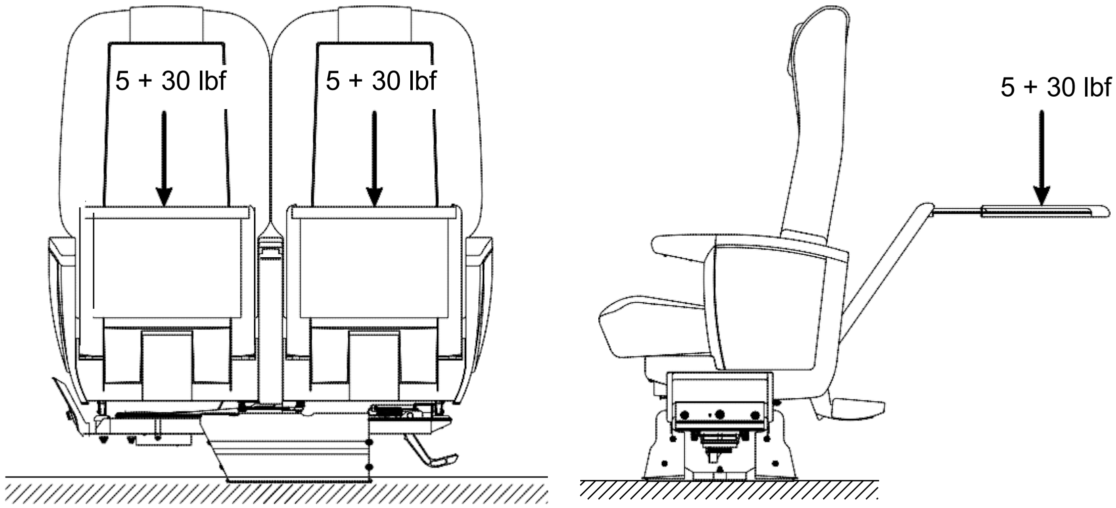
**FIGURE 6**
Leg Rest Strength Test Loading Conditions




## 3.1.7 Tray table test (if equipped)

With the tray table mounted to the seat in the deployed and extended position, place a 5 lbf (22 N) load distributed over an area of 5 by 5 in. (13 by 13 cm) upon the center of the tray, and let it remain for 10 s to determine the preload height from a reference location (reference **Figure 7**). Add an additional 30 lbf (133 N) to the 5 lbf (22 N) preload and let it remain for 10 min.

**FIGURE 7**
Tray Table Strength Test Loading Conditions




## 3.2 Dynamic sled testing

The primary objectives of the dynamic sled tests in this section are to simulate a railcar crash and verify the following:

- Seat assemblies remain attached to the car.
- All seat components, including cushions, remain attached to the seat assemblies.
- The seat assemblies effectively compartmentalize the occupants.
- Human injury criteria do not exceed prescribed limits.

There are two dynamic sled tests prescribed in this section to evaluate compliance with these objectives. Each test uses instrumented Hybrid III 50th percentile male ATDs to simultaneously measure the seat's structural strength and human injury potential. In one test the seats and ATDs will be forward-facing. In the other test the seats and ATDs will be rear-facing. Refer to Section 1.1 to identify the configuration(s) to be tested.

The ATDs shall comply with 49 CFR Part 572, Subpart E. The adjustment, positioning and care of all ATDs used in the testing processes shall be in accordance with SAE AS8049.

Each ATD shall be clothed in a form-fitting, cotton stretch garment with short sleeves and mid-thigh-length bottoms. The ATDs 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 comparable test results. The following ATD components shall be positioned as follows:

- Back shall be placed against the seat back without clearance.
- The center lines of the knees shall be separated by 6.7 ± 0.4 in. (170 ± 10 mm) for 50th-percentile male ATDs, and 7.5 ± 0.4 in. (190 ± 10 mm) for 95$^{th}$ percentile ATDs. The intent is for the ATD's thighs to be approximately parallel.
- 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.

Apply different-colored chalk to face, chest and knees of each ATD in order to aid in interpretation of test results.

The ATDs may be tethered to the sled; however, tethering shall not restrict the motion of the ATDs such that evaluation of compartmentalization is impeded.

The dynamic sled tests in this standard that utilize ATDs are intended to simulate the ATD-to-floor interface, which shall include the finished floor material (carpet, rubber flooring, composite resin, etc.) intended for use in service. Should a qualified seating system be used on another program, or undergo a refurbishment at a later date with a different floor covering chosen, a repeat test is not required, solely on the basis of a different floor covering.

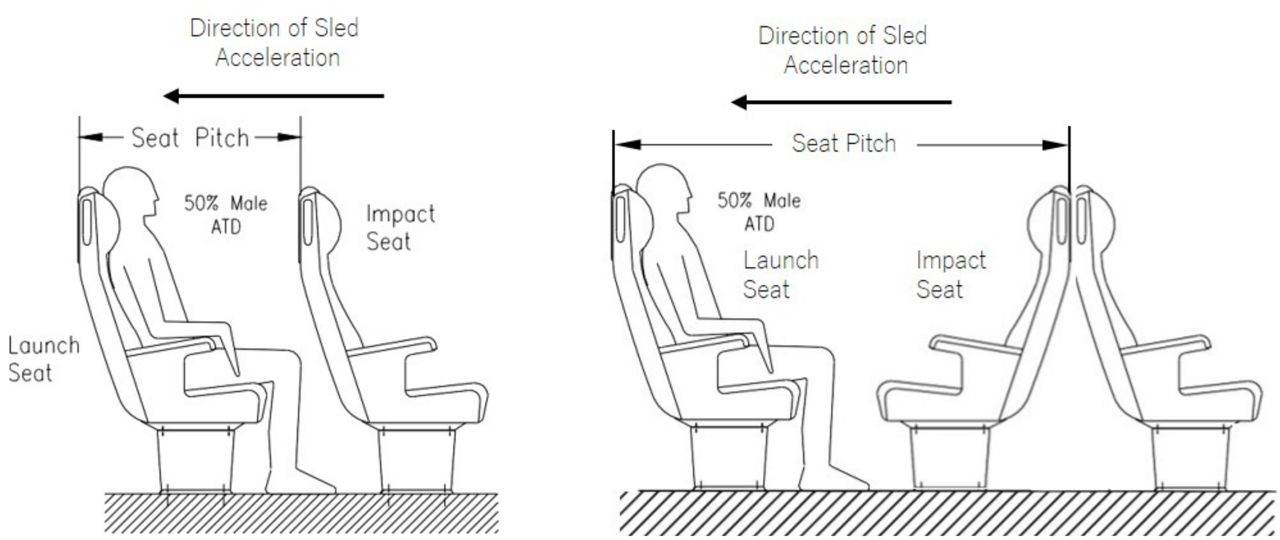
### 3.2.1 Forward-facing human injury test

### 3.2.1.1 Test conditions

This test shall use two transversely mounted rows of seats so the ATDs are facing the opposing row of seats and facing the direction of travel (reference **Figure 8**). If seats contain adjustable features such as recline, tray tables and footrests, then these shall be placed in the stowed positions.

**FIGURE 8**

Schematic of Forward-Facing Human Injury Test for Row-to-Row and Open Bay Seating




Seats shall be subject to the following test:

- Two rows of seating shall be tested with one row of seats fully occupied by Hybrid III 50th percentile ATDs, one ATD per seating position. Obstructions in the dominant open bay seat configuration that may affect the seat performance e.g. adjacent seats, partitions, etc shall be represented in the test setup. The two rows of seats shall face the same direction if testing the row-to-row configuration, or the seats shall face one another if testing the open bay configuration. The ATDs shall be positioned to face the direction of travel with respect to the crash pulse, regardless of seating configuration. The ATDs shall be instrumented with head, chest, neck, and femur transducers.
- Seats shall be mounted on a simulated car structure representative of the intended installation, using the same fasteners or attachment mechanism(s) used in service (bolts, screws, seat track, tapping plate, welds, etc.) and at the largest seat pitch for the seat’s application. The test procedures document

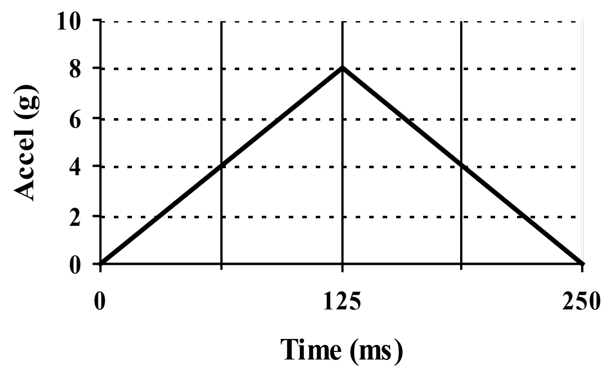
 

shall describe the method of seat attachment to the test fixture, including drawings with details regarding welds, fasteners, etc.

- The test sled shall be subjected to an 8g, 250 ms crash pulse as shown in **Figure 9**. The crash pulse shall be in a direction such that the ATDs impact the seat back of the opposing row of forward-facing seats or the front of a facing row of seats. The crash pulse shall comply with the requirements established in SAE AS8049, Section 5.3.9.2 and Appendix A. Sled braking forces on acceleration-type sleds shall be kept as low as possible to minimize the sled deceleration after the 250 ms crash pulse to prevent damage to the launch seat caused by the rebounding ATDs.

For the human injury tests, a peak sled deceleration that is within 2 percent less than the 8g peak will be permissible, provided that the change in velocity associated with the measured sled deceleration pulse is at least 5 percent above the required minimum of 21.95 mph, and that the derived human injury criteria are all at least 5 percent below the allowable limits. This deviation from the requirements in SAE AS8049 is provided to account for variables that influence the crash pulse, such as seat stiffness.

**FIGURE 9**
Longitudinal Crash Pulse




## 3.2.1.2 Test measurements and documentation

The following forces, displacement and accelerations shall be measured for each ATD in accordance with SAE J211/1:

- triaxial head acceleration-time history
- triaxial chest acceleration-time history
- axial left and right femur force-time history
- upper neck extension/flexion bending moment ($M_y$)
- upper neck axial force ($F_z$)
- upper neck shear force ($F_x$)
- axial acceleration-time history of the test sled

The following injury criteria shall be computed for each ATD in accordance with 49 CFR 571.208, where applicable:

- HIC15
- chest deceleration criterion (i.e., 3 ms chest g's)
- axial femur load
- peak upper neck axial tension/compression forces
- Nij

Unless otherwise indicated, instrumentation for data acquisition, data channel frequency class and moment calculations are the same as given for the 49 CFR Part 572, Subpart E Hybrid III test dummy.

The test shall be captured using high-speed video cameras providing an overhead view (plan view) and a side view (elevation view) that encompasses the motion of the ATDs for the duration of the test. Lighting shall be sufficient for high-quality analysis of the recording.

Pre- and post-test still digital photographs of the test configuration shall be taken. At a minimum, pre- and post-test photographs of the test sled shall be taken from all four sides, as well as close-up photographs of the seats to document seat mounting condition and any seat damage

#### 3.2.1.3 Performance requirements

For a successful test, the following requirements must be met:

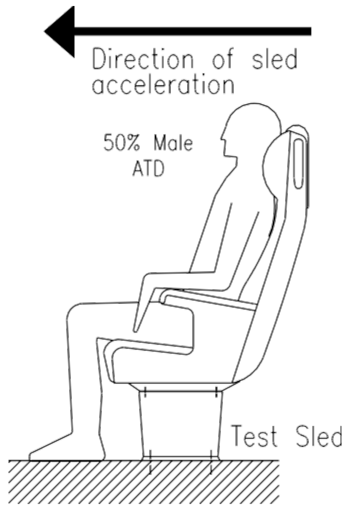
- Seats may deform but shall not tear loose from their mountings.
- Seat components shall not tear loose and become completely separated from the seat assembly.
- The ATDs shall be compartmentalized between rows of seats, per the definition of "compartmentalization" in Definitions. After testing, the seats shall not be deformed to such an extent that they present an impediment to emergency egress.
- All injury measurements computed in Section 3.2.1.2 must meet the following criteria, which are defined in CFR 49 Part 571, Standard No. 208, "Occupant Crash Protection." The injury criteria shall be calculated from test data that have been filtered in accordance with SAE J211/1, Table 1.
    - Head injury criteria, HIC15, must not exceed 700.
    - Neck injury criteria, Nij, must not exceed 1.0.
    - Neck axial tension, $F_z$, must not exceed 938 lbf (4170 N).
    - Neck axial compression, $F_z$, must not exceed 899 lbf (4000 N).
    - Chest deceleration must not exceed 60g over a 3 ms clip.
    - Axial femur load must not exceed 2250 lb (10,000 N).
- If the tested seats are rotating seats, then the anti-rotation lock mechanism shall not fail, and the seat shall be retained in the locked position.
- It is permissible for tray tables to deploy during the dynamic tests, provided they can be moved out of the way for egress.

### 3.2.2 Rearward-facing seat attachment and human injury test

#### 3.2.2.1 Test conditions

The rearward-facing test is similar to the forward-facing test described in Section 3.2.1, except that the seat is accelerated in the opposite direction, and it is not mandatory to have more than one row of seats for the test. See schematic in **Figure 10**.

**FIGURE 10**
Schematic of Rearward-Facing Seat Attachment and Human Injury Test




The ATDs shall be positioned in the same manner as described in Section 3.2.1 and subjected to the following test:

- The seat shall be fully occupied by Hybrid III 50th-percentile male ATDs, one ATD per seat position. All the ATDs shall be instrumented with head, chest and neck transducers.
- The seat shall be mounted on a simulated car structure representative of the intended installation, using the same floor covering (linoleum, carpet, etc.), and the same fasteners or attachment mechanism(s) used in service (bolts, screws, seat track, tapping plate, welds, etc.). The test procedures document shall describe the method of seat attachment to the test fixture, including drawings with details regarding welds, fasteners, etc.
- The test sled shall be subjected to an 8g, 250 ms crash pulse as shown in **Figure 9**. The crash pulse shall be in a direction such that the seated occupants are accelerated into their seat backs. The crash pulse shall comply with the requirements established in SAE AS8049, Section 5.3.9.2 and Appendix A.

### 3.2.2.2 Test measurements and documentation

The following forces, displacement and accelerations shall be measured for each ATD in accordance with SAE J211/1:

- triaxial head acceleration-time history
- triaxial chest acceleration-time history
- upper neck extension/flexion bending moment ($M_y$)
- upper neck axial force ($F_z$)
- upper neck shear force ($F_x$)
- axial acceleration-time history of the test sled

The following injury criteria shall be computed for each ATD in accordance with 49 CFR 571.208, where applicable:

- HIC15
- chest deceleration criterion (i.e., 3 ms chest g's)
- peak upper neck axial tension/compression forces
- Nij

Unless otherwise indicated, instrumentation for data acquisition, data channel frequency class, and moment calculations are the same as given for the 49 CFR Part 572, Subpart E, Hybrid III test dummy.

The test shall be captured using high-speed video cameras providing an overhead view (plan view) and a side view (elevation view). Lighting shall be sufficient for high-quality analysis of the recording. Pre- and post-test still digital photographs of the test configuration shall be taken. At a minimum, pre- and post-test photographs of the test sled shall be taken from all four sides, as well as close-up photographs of the seats to document seat mounting condition and any seat damage.

#### 3.2.2.3 Performance requirements

For a successful test, the following requirements must be met:

- The seat may deform but shall not tear loose from its mountings.
- Seat components shall not tear loose and become completely separated from the seat assembly.
- The ATDs shall be compartmentalized in the aft direction, per the definition of "compartmentalization" in Definitions. After testing, the seats shall not be deformed to such an extent that they present an impediment to emergency egress.
- All injury measurements computed in Section 3.2.2.2 must meet the following criteria, which are defined in CFR 49 Part 571, Standard No. 208, "Occupant Crash Protection." The injury criteria shall be calculated from test data that have been filtered in accordance with SAE J211/1, Table 1.
    - Head injury criteria, HIC15, must not exceed 700.
    - Neck injury criteria, Nij, must not exceed 1.0.
    - Neck axial tension, $F_z$, must not exceed 938 lbf (4170 N).
    - Neck axial compression, $F_z$, must not exceed 899 lbf (4000 N).
    - Chest deceleration must not exceed 60g over a 3 ms clip.
- If the tested seats are rotating seats, then the anti-rotation lock mechanism shall not fail during the test, and the seat shall be retained in the locked position.
- It is permissible for tray tables to deploy during the dynamic tests, provided they can be moved out of the way for egress.

## 3.3 Additional dynamic testing

### 3.3.1 Anti-rotation test

For rotating seats, an anti-rotation test shall be performed to ensure that during a simulated car crash, the seat does not unintentionally rotate. All rotating seats shall pass an "anti-rotation" test.

Two sled tests shall be conducted using the procedures given in Section 3.2.1 and 3.2.2, except that the seat shall be occupied by one uninstrumented 95th percentile HII or HIII male ATD placed in the seating position that maximizes the moment on the locking mechanism. The forward-facing test in Section 3.2.1 will tend to drive the forward seat in the clockwise direction. The rear-facing test in Section 3.2.2 will tend to drive the occupied seat in the counterclockwise direction.

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 (in a horizontal plane) via the testing 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.

The test shall be captured using high-speed video cameras providing an overhead view (plan view) and a side view (elevation view). Lighting shall be sufficient for high-quality analysis of the recording. Pre- and post-test still digital photographs of the test configuration shall be taken. At a minimum, pre- and post-test photographs of the test sled shall be taken from all four sides, as well as close-up photographs of the seats to document seat mounting condition and any seat damage.

### 3.3.2 Lateral seat attachment test

The objective of this test is to ensure that seat assemblies remain attached to the car structure when subjected to lateral forces resulting from a simulated railcar crash. The intent of this test is to satisfy the requirements described in CFR 49, Part 238, Section 233, and to ensure that the seat remains attached to the car structure when subjected to an acceleration of 4g in the lateral direction toward the aisle acting on the mass of the seat. ATDs are not used in this test. This test must be performed dynamically as described in this section.

- The seat shall be mounted on a simulated car structure representative of the intended installation, using the same fasteners or attachment mechanism(s) used in service (bolts, screws, seat track, tapping plate, welds, etc.), as shown in **Figure 11**.
- The seat shall be subjected to a 4g, 250 ms triangular crash pulse as shown in **Figure 12** in a direction tending to drive the seat into the aisle. The crash pulse shall comply with the requirements established in SAE AS8049, Section 5.3.9.2 and Appendix A.
- The test shall be captured using high-speed video cameras providing an overhead view (plan view) and a side view (elevation view). Lighting shall be sufficient for high-quality analysis of the recording. Pre- and post-test still digital photographs of the test configuration shall be taken. At a minimum, pre- and post-test photographs of the test sled shall be taken from all four sides, as well as close-up photographs of the seats to document seat mounting condition and any seat damage.

Seats may deform but shall not tear loose from their mountings. Seat components shall not tear loose and become completely separated from the seat assembly.

**FIGURE 11**
Seat Orientation for Lateral Seat Attachment Test

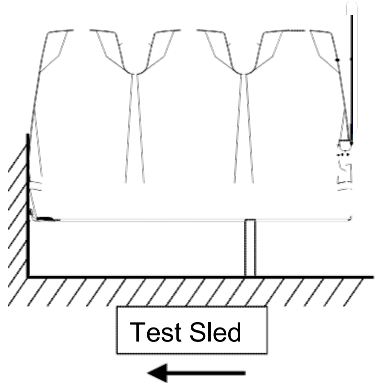
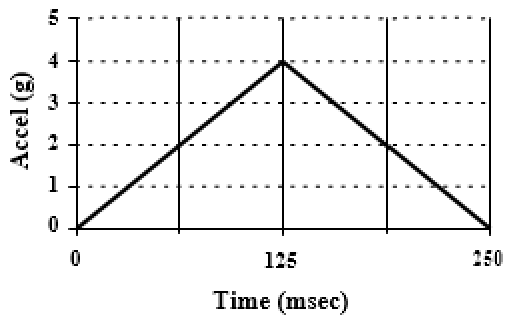



**FIGURE 12**
Lateral and Vertical Crash Pulse



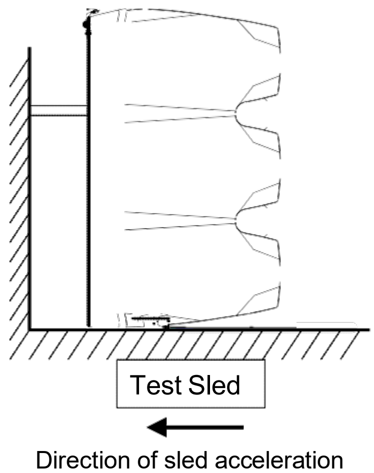

### 3.3.3 Vertical seat attachment test

The objective of this test is to ensure that seat assemblies remain attached to the car structure when subjected to vertical upward forces resulting from a simulated railcar crash. The intent of this test is to satisfy the requirements described in CFR 49, Part 238, Section 233, and to ensure that the seat and seat components remain attached to the car structure when subjected to accelerations of 4g in the vertical upward direction acting on the mass of the seat. ATDs are not used in this test. This test must be performed dynamically as described in this section.

- The seat shall be mounted on a simulated car structure representative of the intended installation, using the same fasteners or attachment mechanism(s) used in service (bolts, screws, seat track, tapping plate, welds, etc.), as shown in **Figure 13**.
- The seat shall be subjected to a 4g, 250 ms triangular crash pulse as shown in **Figure 12**, directed so as to drive the seat away from the floor. The crash pulse shall comply with the requirements established in SAE AS8049, Section 5.3.9.2 and Appendix A.
- The test shall be captured using high-speed video cameras providing an overhead view (plan view) and a side view (elevation view). Lighting shall be sufficient for high-quality analysis of the recording. Pre- and post-test still digital photographs of the test configuration shall be taken. At a minimum, pre- and post-test photographs of the test sled shall be taken from all four sides, as well as close-up photographs of the seats to document seat mounting condition and any seat damage.

Seats may deform but shall not tear loose from their mountings. Seat components shall not tear loose and become completely separated from the seat assembly.

**FIGURE 13**
Seat Orientation for Vertical Seat Attachment Test




### 3.3.4 Forward-facing seat attachment test

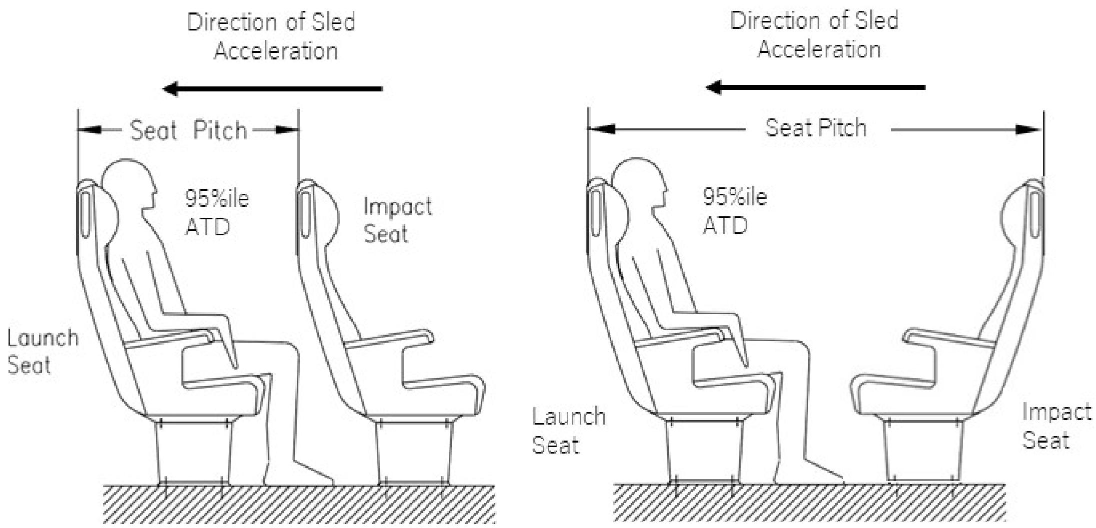
The objective of this test is to ensure that the seat and seat components remain attached to the car structure under the following test conditions. See schematic of test setup in **Figure 14**. The intent of this test is to satisfy the requirements described in CFR 49, Part 238, Section 233. This test must be performed dynamically as described in this section.

- Two rows of seats shall be tested, with the rear row of seats fully occupied by Hybrid III 95th-percentile male ATDs, one ATD per seating position. If Hybrid III 95th-percentile ATDs are not available, Hybrid II 95th-percentile ATDs may be used. The ATDs shall be forward-facing. The ATDs do not need to be instrumented.
- The seats shall be mounted on a simulated car structure representative of the intended installation, using the same fasteners or attachment mechanism(s) used in service (bolts, screws, seat track, tapping plate, welds, etc.), the same floor covering (linoleum, carpet, etc.) and at the predominant seating pitch for the seat's application.
- Seats shall be subjected to an 8g, 250 ms crash pulse as shown in **Figure 9**. The crash pulse shall comply with the requirements established in SAE AS8049, Section 5.3.9.2 and Appendix A.
- The test shall be captured using high-speed video cameras providing an overhead view (plan view) and a side view (elevation view). Lighting shall be sufficient for high-quality analysis of the recording. Pre- and post-test still digital photographs of the test configuration shall be taken. At a minimum, pre- and post-test photographs of the test sled shall be taken from all four sides, as well as close-up photographs of the seats to document seat attachment condition and any seat damage.

Seats may deform but shall not tear loose from their mountings. Seat components shall not tear loose and become completely separated from the seat assembly. The ATDs shall be compartmentalized between rows of seats, per the definition of "compartmentalization" in Definitions. After testing, the seats shall not be deformed to such an extent that they present an impediment to emergency egress. If the tested seats are rotating seats, then the anti-rotation lock mechanism shall not fail during the test, and the seat shall be retained in the locked position.

**FIGURE 14**
Schematic of Forward-Facing Seat Attachment Test for Row-to-Row and Open Bay Seating




# 4. 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, and flammability and smoke emissions tests.

Test plans and procedures shall be submitted and approved by the purchaser prior to actual testing. Tests shall be scheduled to allow the purchaser the option to witness the testing. The purchaser may elect to accept existing test reports and procedures, provided the seat to be purchased is demonstrated to be structurally identical to a previously tested seat and that the test reports and procedures meet the requirements listed in this section.

## 4.1 Test plan

Prior to seat testing, a test plan shall 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 to demonstrate compliance with the requirements of this standard.

## 4.2 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 test
- sequential, step-by-step test procedure
- test data sheets (for recording data during testing)

## 4.3 Test reports

Test reports shall as a minimum include:

- a copy of the test procedure meeting the requirements listed in Section 4.2
- a cover letter that gives a summary of the test results, the date and location of the test, and includes the signature of the person or people 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/videos of test setup, pre- and post-test conditions and results

# 5. Flammability and smoke emission

Materials used in seat construction shall meet the requirements given in CFR Part 238, Appendix B, 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 cannot be configured in the sizes required for test samples. For such materials, the 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 shall prepare and submit to the purchaser a combustible content matrix. The matrix shall 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).

# 6. 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 the following:

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

# 7. Engineering drawings

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

- 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 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

## 8. Submittals for approval

Prior to acceptance of the seat by the purchaser, the seat manufacturer shall submit documentation listed in **Table 2**.

**TABLE 2**
Submittals

| Submittal | Reference Standard Section |
|---|---|
| Static Seat Strength Test Report | 3.1 |
| Dynamic Seat Test Report | 3.2.1, 3.2.2, 3.3.1, 3.3.2, 3.3.3 and 3.3.4 |
| Test Plan | 4.1 |
| Test Procedures | 4.2 |
| Test Reports | 4.3 |
| Flammability and Smoke Emission Report(s) | 5 |
| Combustible Content Matrix | 5 |
| Engineering Drawings | 6 |

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 8) shall be as negotiated between the purchaser and seat manufacturer, but shall be in a timely enough manner so as to serve as a reference and guide during installation of seating equipment into cars.

## Related APTA standards

**APTA SS-PS-004-99, Rev. 1,** “Low-Location Exit Path Marking”
**APTA PR-CS-S-018-13, Rev 2**, “Fixed Workstation Tables in Passenger Rail Cars.”

## References

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

Code of Federal Regulations:
- 49 CFR Part 571, Federal Motor Vehicle Safety Standards 49 CFR Part 572, Anthropomorphic Test Devices
- 49 CFR Part 238, Federal Railroad Administration Passenger Equipment Safety Standards
- 49 CFR Part 37, Transportation Services for Individuals with Disabilities (ADA)
- 49 CFR Part 38, Americans with Disabilities Act (ADA) Accessibility Specifications for Transportation Vehicles

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

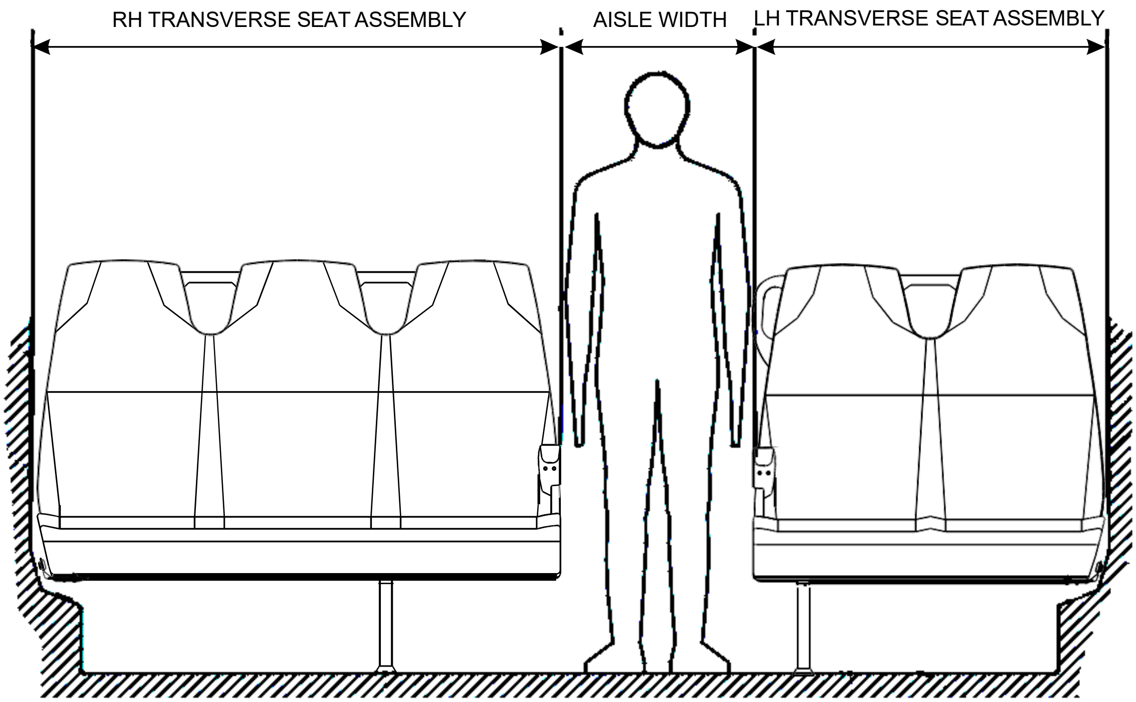
SAE International standards:
- SAE AS8049, “Performance Standards for Seats in Civil Rotorcraft and Transport Airplanes”
- SAE J826, “Devices for Use in Defining and Measuring Vehicle Seating Accommodation”
- SAE J1454, “Dynamic Durability Testing of Seat Cushions for Off-Road Work Machines”
- SAE J211/1, “Surface Vehicle Recommended Practice”

United States Military Standards:
- MIL-STD-1472G, Human Engineering Design Criteria for Military Systems, Equipment and Facilities

## Definitions

**aisle width:** See schematic in **Figure 15** for illustration.

**FIGURE 15**
Aisle Width




**anthropomorphic test device (ATD):** Also known as a crash test dummy, a biofidelic representation of a human body, built to the requirements in 49 CFR 572 and used to assess the risk of injury under simulated collision conditions.

**chest deceleration criterion:** The resultant chest deceleration, filtered at CFC180, shall not exceed 60g, except for intervals whose cumulative duration is not more than 3 ms.

**compartmentalization:** A seat design strategy that aims to contain occupants between rows of seats during a collision, preventing occupants from traveling over the tops of seat backs and impacting other more hostile objects. During sled testing, ATD compartmentalization is evaluated until the point of maximum forward motion of the ATD. The ATD's torso must be confined between the seat backs (which may be potentially deformed) of consecutive rows of seats until the point of maximum forward progress.

**facing seats:** Transverse seats mounted in the car such that occupants face one another.

**fixed seat:** Seat that cannot be rotated, or flipped up/down, and not of the walkover-type design. These seat types face only in the direction at which they are mounted.

**flip-up seat:** Seats that have bottom cushions that can be flipped up to provide additional floor space. Flip-up seats are often used to accommodate wheelchair parking space(s).

**g:** An acceleration equal to 32.2 $ft/s^2$ (9.8 $m/s^2$).

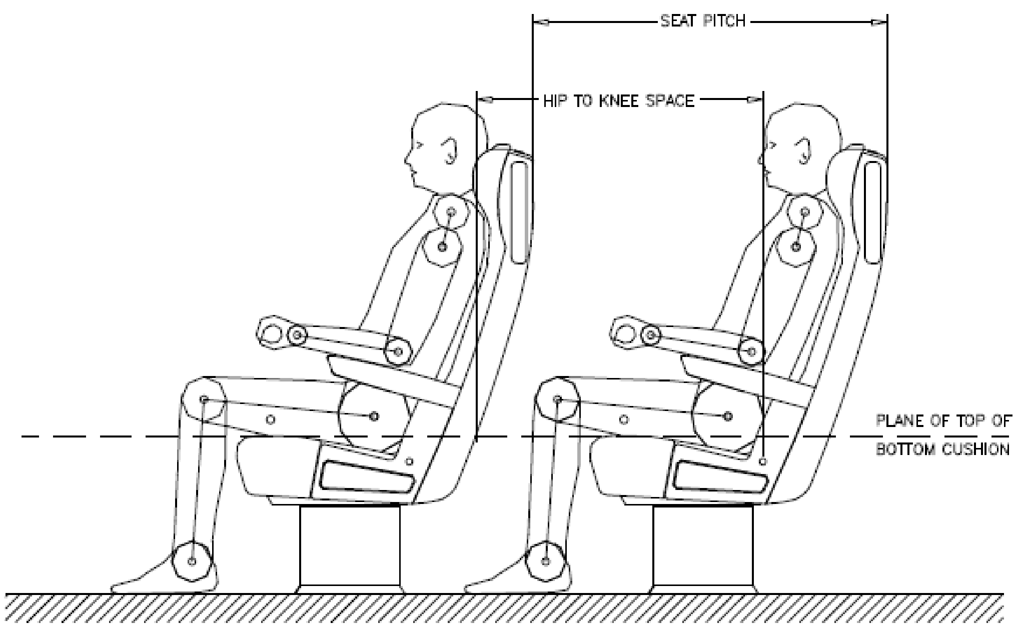
**head injury criterion (HIC15):** Calculated according to the following:

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

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, (g)
The subscript indicates that the time interval between $t_1$ and $t_2$ is limited to 0.015 s

**hip-to-knee space:** A horizontal dimension from the backrest 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 16**.

**FIGURE 16**
Hip-to-Knee Space and Seat Pitch

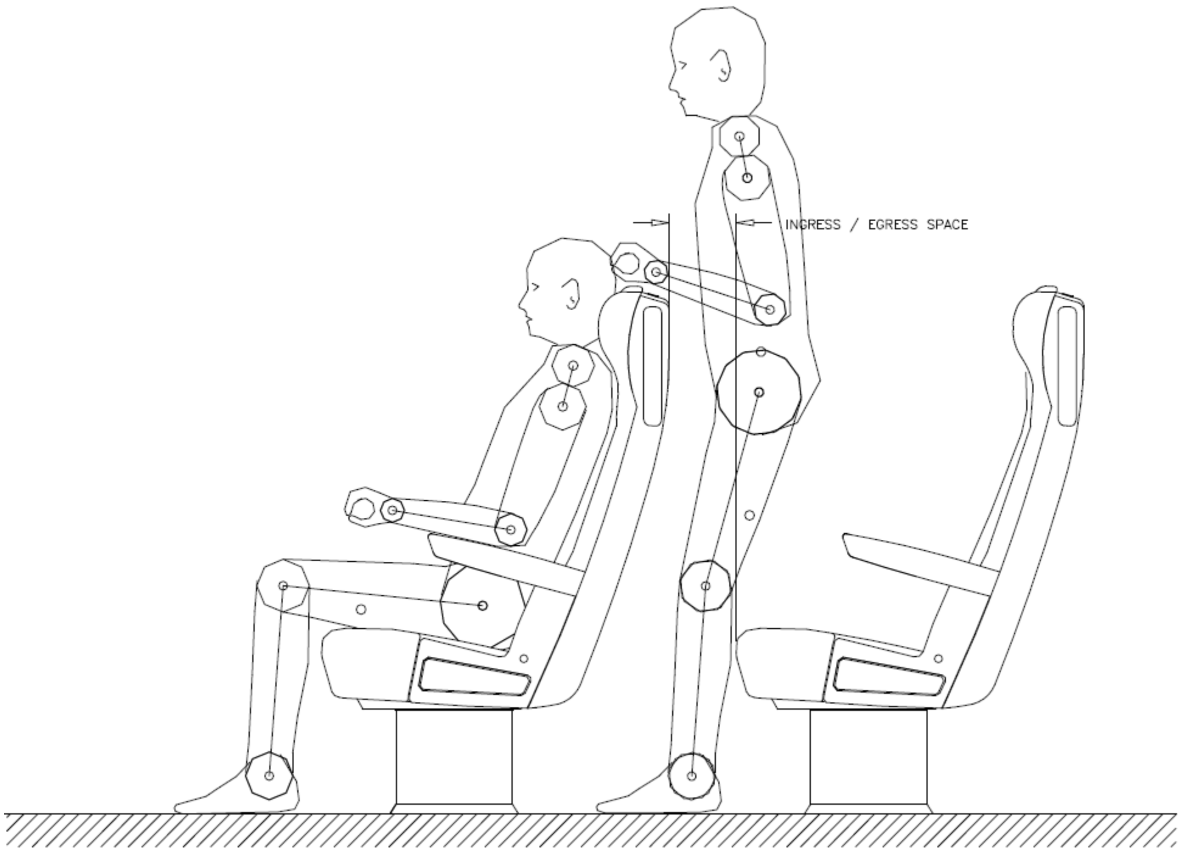



**impact seat:** The forward-most seat in two rows of seats (facing seats or row-to-row seats) that are impacted by ATDs in the testing described in sections 3.2 and 3.3.

**ingress/egress space:** Space available for occupants to occupy or leave an occupied space. This has importance for both normal passenger seating and also for emergency exit considerations. See **Figure 17**.

**FIGURE 17**
Ingress/Egress Space




**lateral crash pulse:** A time-based acceleration curve, triangular and symmetrical in shape, and having a 250 ms 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.

**launch seat:** The rearmost seat of two rows of seats, initially containing ATDs, in the testing described in sections 3.2.1 and 3.3.4.

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

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

**longitudinal seating:** Seats that face the center aisle or side window, perpendicular to the direction of travel.

**neck axial compression criterion:** Peak compressive axial ($F_z$) load measured at the upper neck load cell, filtered at CFC1000.

**neck axial tension criterion:** Peak tensile axial ($F_z$) load measured at the upper neck load cell, filtered at CFC1000.

**Nij (neck injury criterion):** A value calculated according to the following formula:

$$N_{ij} = \frac{F_z}{F_{\text{int}}} + \frac{M_y}{M_{\text{int}}}$$

where:

$F_z$ = axial upper neck load-time history, filtered at CFC600

$F_{int}$ = critical values used for normalization, 1530 lbf (6806 N) in tension, and 1385 lbf (6160 N) in compression

$M_y$ = flexion/extension neck bending moment-time history at the occipital condyle, filtered at CFC600

$M_{int}$ = critical value used for normalization, 229 lbf-ft (310 Nm) in flexion, and 100 lbf-ft (135 Nm) in extension

$F_x$ = shear upper neck load-time history, used to compute the neck bending moment, *M*, about the occipital condyle, filtered at CFC600

$N_{ij}$ shall not exceed 1.0 for each of the four loading conditions in any ATD

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

**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.

**open bay seats:** Transverse seats that are mounted in the car such that occupants face one another, with no intervening table between the seats.

**passenger:** A person within the occupied volume of a railcar, whether seated or not.

**primary impact:** The impact between the railcar and an object, such as another railcar, during a collision.

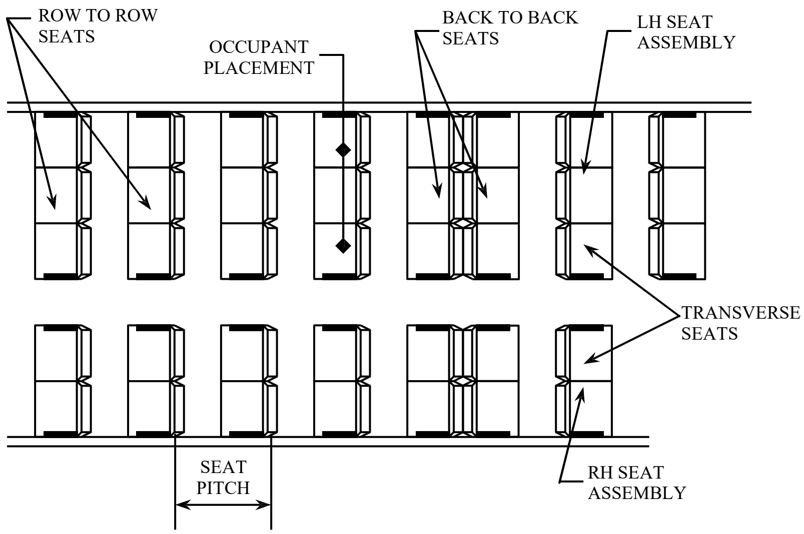
**purchaser:** The agency or organization (transit authority or car builder) responsible for the acquisition of seating equipment.

**rotating seats:** Seats that are transversely mounted and can be rotated to face the front or back of a railcar.

**row-to-row seating:** Seating arrangement such that adjacent rows of seats face the same direction, as illustrated in **Figure 15**. Also known as theater-style seating.

**seating arrangement and nomenclature:** See schematic in **Figure 18** for illustration.

**FIGURE 18**
Seating Arrangement and Nomenclature




**seat class:** For the purpose of this standard, class of service as it applies to the seat: first-class seat, business-class seat, coach-class seat, etc.

**seat configuration:** For the purpose of this standard, the relative orientation of transverse seats with respect to one another: open bay seating, row-to-row seating or facing seats with tables.

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

**seat pitch:** The distance between like seat features on seats facing the same direction, as illustrated in Figure 15. As used in this standard, the seat pitch is defined as the distance from the back of the headrest on one seat to the back of the headrest on the adjacent seat.

**seat type:** For the purpose of this standard, seat occupancy: one-passenger seat, two-passenger seat, three passenger seat, etc.

**shall:** Practices directed by "shall" are required.

**secondary impact:** The impact of passengers with interior structures during a collision.

**should or may:** Practices directed by "should" or "may" are recommended.

**tertiary impact:** Another impact with the interior subsequent to a secondary impact during a collision. For example, a passenger may experience a secondary impact with a seat back and then a tertiary impact with another object in the car.

**Tier I:** Rail equipment operated at a speed not exceeding 125 mph (200 k/h), as defined in 49 CFR Part 238.

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

**transverse seating:** Seats oriented perpendicular to the normal direction of car travel. Occupants in transverse seating may be rear-facing or forward-facing with respect to the direction of travel.

**walkover seat:** A 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.

## 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 49 CFR Part 572) |
| **CEM** | crash energy management |
| **CFR** | Code of Federal Regulations |
| **FMVSS** | Federal Motor Vehicle Safety Standard |
| **FRA** | Federal Railroad Administration |
| **MIL-STD** | United States Military Standard |
| **NATSA** | North American Transportation Services Association |
| **SAE** | Society of Automotive Engineers |
| **SIV** | secondary impact velocity |
| **USDOT** | United States Department of Transportation |

## Summary of document changes

### Revision 2

- Defined and required HIC15.
- Added explicit reference to walkover seat back attachment requirement in Section 2.1.
- Added requirement for positive seat securement indicator for rotating seats in Section 2.2.
- Added neck injury criteria for forward-facing ATDs in dynamic sled tests described in Section 3.2.
- Added the same test requirements for rear-facing dynamic test as for forward-facing dynamic test in Section 3.2, including head, chest, femur and neck injury criteria.
- Required Hybrid III anthropomorphic test devices for dynamic tests described in Section 3.2 in order to measure neck forces and moments.
- Required lateral and vertical attachment strength tests to be conducted dynamically, not statically or analytically, in Section 5.3.
- Added reference to SAE AS8049 for acceptable crash pulse tolerance.
- Added a forward-facing seat attachment strength test using un-instrumented 95th-percentile male ATDs in Section 3.3.4, which is intended to satisfy the requirements of CFR 49, Part 238, Section 233.
- Modified scope in Section 1.1 to reflect inclusion of all classes of passenger seating (coach, first, business, etc.) and specify dynamic testing of predominant seat variation.
- Modified "Limitations of this standard" in Section 1.3 to specifically exclude seating in food service cars, lounge cars and sleeping cars, as well as flip-up seats and longitudinal seats that face the center aisle or window.
- Added selected test results from CEM train-to-train full-scale tests to Appendix B.
- Specified that mounting attachments in tests must use the same fasteners or attachment method used in service and that reaction loads shall be measured with load cells, at the request of the purchaser, if seats are mounted to a rigid test fixture.
- Disallowed analysis as a substitute for any testing requirements.
- Modified definition and evaluation of ATD compartmentalization.

**Revision 3**

- Moved durability requirements that are not related to crashworthiness or safety to an appendix.
- Modified text to address all transversely mounted seats, including forward-facing and rear-facing row-to-row seats and open bay seats. Up to 50 percent of all revenue seat positions in a car may be open bay seats, without conducting the two forward-facing dynamic sled tests. Additional open bay seats may be used, if the seats comply with the forward-facing sled test requirements in addition to all other requirements in this standard.
- Specified minimal yielding of $^{1}/_{8}$ in. following static tests.
- Removed any maximum temporary deflection limits under static loads, which may be detrimental to human injury levels measured in the dynamic tests.
- Adjusted some of the load and surface area requirements in the static tests.
- Deleted option to mount seats to a rigid test fixture for all dynamic tests.
- Allowed the use of Hybrid II 95th-percentile male ATDs if Hybrid III 95th-percentile male ATDs are not available for the forward-facing seat integrity test.
- Made additional edits for clarification.

## Document history

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| First published | — | — | — | March 4, 1999 | March 17, 1999 |
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## Appendix A: Bibliography

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14. Tyrell, D., and Martinez, E., "A Train-to-Train Impact Test of Crash Energy Management Passenger Rail Equipment," 6th International Symposium on the Passive Safety of Rail Vehicles, Berlin, Germany, December 2006.
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# Appendix B: Informative

*(This appendix 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 railcars 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 during an accident and become projectiles, cause injuries and become impediments to timely evacuation of a car after an accident.
- Seat backs are too flexible or too short and fail to contain the occupant, thus failing to prevent the occupant from impacting with another, possibly less friendly, object in the interior.
- Seats have hard surfaces in the wrong places or have sharp corners and edges that can contribute to injury, even in moderate accidents.

Seating can help improve the interior safety of a railcar 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, such that an occupant is compartmentalized between rows of seats, 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 an in-line train collision, the cars generally decelerate. The 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
$s$ 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 [principal] 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 an 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. 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 railcars to help mitigate the effects of occupant impacts with seating.

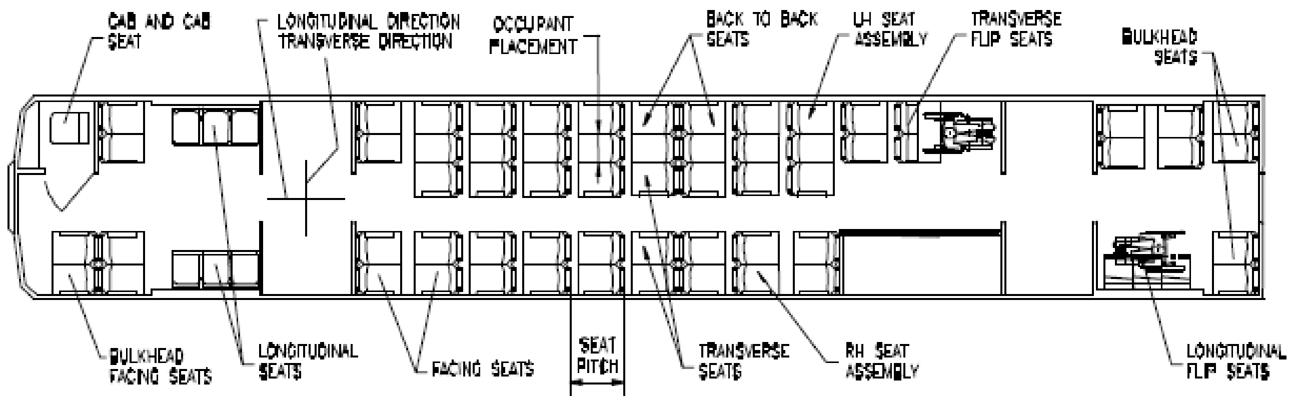
All the discussion above leads to some guidelines for transversely mounted passenger seats. These are presented here in order of importance:

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 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 railcars generally have the seats 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 face the center of the car in longitudinally mounted seats. **Figure 19** illustrates many of these different seating arrangements.

**FIGURE 19**
Seat Arrangement and Nomenclature




In the event of a collision, the railcar decelerates rapidly while the occupants continue to travel at the speed prior to impact, until the occupants strike some part of the interior. The later impact is termed the secondary impact. The severity of the secondary impact is a function of the secondary impact velocity (SIV) and the stiffness of the impacted object. The SIV generally increases with travel distance; i.e., the longer the travel distance, the higher the SIV. Therefore, secondary impact severity can be minimized by reducing travel distance and providing compliant impact surfaces, such as seats and tables that deform plastically under impact loading conditions.

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 strategies available to improve the crashworthiness of the arrangement.

It is recommended that facing seats have an energy-absorbing table positioned between the seats. Crashworthy tables have been shown to enhance the compartmentalization of occupants seated facing one another and mitigate occupant injury.[6,7] APTA safety standard APTA PR-CS-S-018-13 specifies minimum crashworthiness requirements for workstation tables in railcars.

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 it wishes to provide.

If seats face a bulkhead, then the bulkhead should be padded or otherwise provide protection for the occupant(s) during a crash. If longitudinal seating is used, then the range of motion of an occupant during a

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6 Parent, D., Tyrell, D., Rancatore, R., and Perlman, A.B., "Design of a Workstation Table with Improved Crashworthiness Performance," American Society of Mechanical Engineers, Paper No. IMECE2005-82779, November 2005.
7 Severson, K., and Parent, D., "Train-to-Train Impact Test of Crash Energy Management Passenger Rail Equipment: Occupant Experiments," American Society of Mechanical Engineers, Paper No. IMECE2006-14420, November 2006.

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 an occupant can maneuver a wheelchair into a rear-facing position, with the back of the wheelchair up against a reinforced windscreen or bulkhead wall to minimize the travel distance prior to secondary impact. In all cases, accessible seating arrangements shall meet the requirements of 49 CFR Parts 37 and 38 (Americans with Disabilities Act).

## B.3 Derivation of crash pulse

**Figure 20** is taken from the FRA's Notice of Rulemaking 49 CFR Part 216 et al., published in the Federal Register on Sept. 23, 1997. According to the analysis, the peak car deceleration was 8g for a head-on train-to-train collision at 70 mph. For the purpose of testing, this crash pulse was idealized to the 8-g 250-ms crash pulse used in this standard. Results from full scale train-to-train impact testing of equipment using crash energy management (CEM) has shown that the secondary impact velocities (SIVs) calculated from test measurements are similar to the SIV associated with the 8 g crash pulse. The secondary impact velocity for a forward-facing unrestrained occupant associated with the crash pulse used in this standard and associated with the measured crash pulses from the leading cab and 1st coach in the full scale CEM train-to-train test are shown **Figure 21**. See Section B.4.2 for subsequent full-scale test results using equipment modified to incorporate crash energy management (CEM).

**FIGURE 20**
Typical Decelerations During a Collision

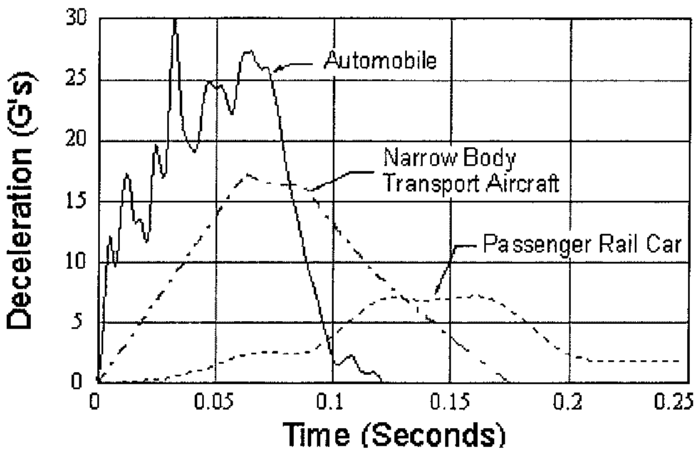
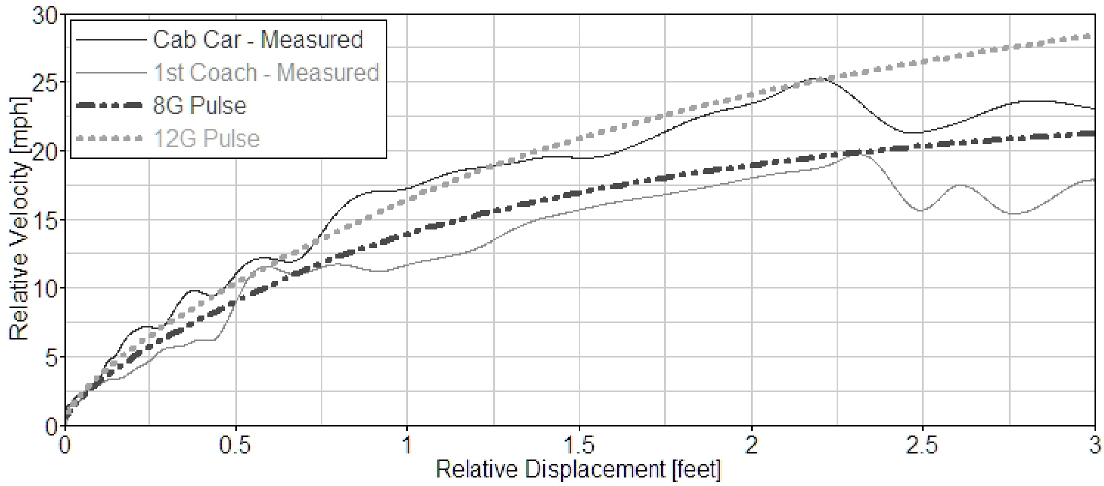


**FIGURE 21**
Secondary Impact Velocity During CEM Full-Scale Train-to-Train Test




## B.4 Research programs

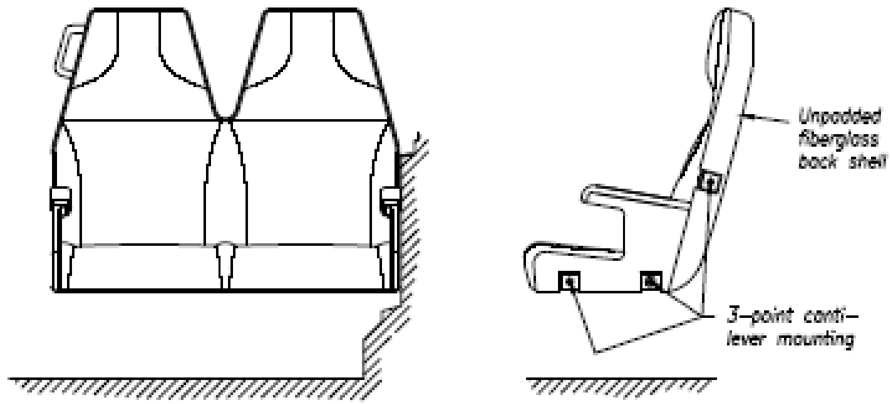
Simultaneous to the development of this standard, the FRA embarked on a comprehensive Rail Crashworthiness Research Program, which included a series of dynamic sled tests and full-scale collision testing. At the onset, and particularly as part of the development of this standard, APTA, together with the Volpe Center, 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

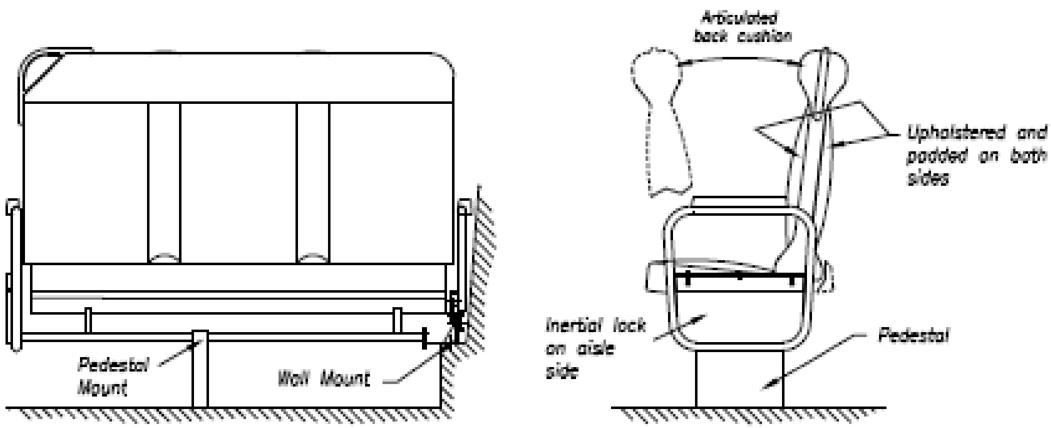
The intent of the dynamic sled testing was to provide a better understanding of how traditional commuter seating behaves in a crash environment in terms of both the seat and dummy response.

Two test programs have been conducted. One program tested three types of row-to-row commuter seats as shown in **Figure 22**, and the other program tested a typical facing seat system. **Table 3** contains information about the application of these seats:

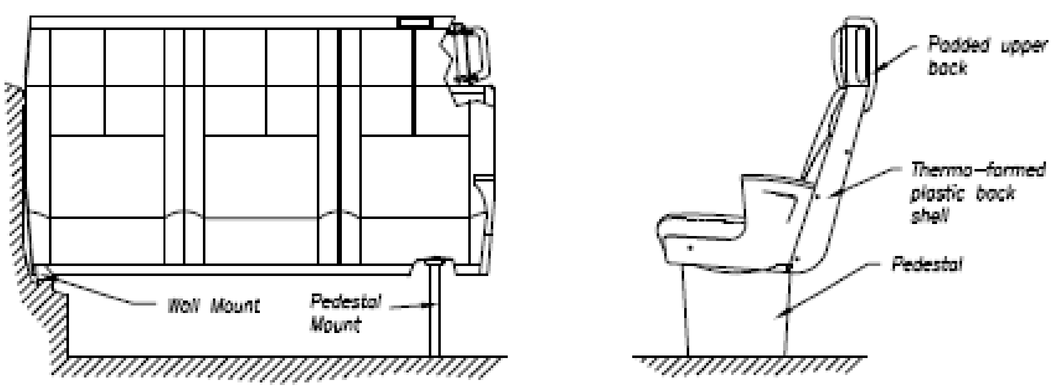
## FIGURE 22
Seats Tested




2 Passenger LIRR C-3 Seat




3 Passenger Walkover Seat




3 Passenger M-Style Seat

**TABLE 3**
Description of Seats Used in Test Program

| Seat Tested | Comments |
|---|---|
| Two-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 were placed in service in 1999 at PCJPB and NVTC. |
| Three-passenger walkover seat | Used by NJT. Two passenger versions used by METRA and PCJPB. |
| Three-passenger M-style seat | Used in various configurations by Metro-North, LIRR, SEPTA, MBTA, NICTD, MARC and others. |
| Two-passenger facing seat | Manufactured by Bombardier for its bilevel commuter train. Other properties that have installed the facing seat configuration in their cars: San Diego, Vancouver, Florida, SCRRA, Dallas and Seattle. |

Prior to testing, several analyses were 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 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 seat back (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 seats, 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 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, e.g., the railcar 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 railcar 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 to 34 in. seat pitch. The computer seat models were all run with a 32 and 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, five tests have been conducted with occupant experiments:

1. A single conventional car traveling at 35 mph into a rigid barrier in November 1999.
2. Two coupled conventional cars traveling at 26 mph into a rigid barrier in April 2000.
3. A conventional train-to-train test involving a cab-car led, four-car consist trailed by a locomotive colliding at 30 mph into a stationary locomotive coupled with two ballasted freight cars in January 2002.
4. Two coupled CEM cars traveling at 29 mph into a rigid barrier in February 2004.
5. A CEM train-to-train test involving a cab car, four coach cars and a locomotive in push mode colliding at 31 mph into a stationary locomotive coupled with two ballasted freight cars in March 2005.

In all five of these tests, a series of seat/occupant experiments were installed inside the railcars to evaluate the crashworthiness of commuter seats and intercity seats under realistic collision conditions. The first three tests involved existing, conventionally designed cars. The last two tests involved existing cars that had been modified to incorporate CEM end structures that were designed to absorb collision energy, while preserving the integrity of the occupant volume.

In the first two full-scale tests, five out of nine ATDs instrumented to measure neck load(s) exceeded at least one neck injury criterion. Two out of nine ATDs instrumented to measure femur loads exceeded the femur load criteria. None of the five ATDs instrumented to measure head and chest acceleration exceeded the respective criteria. These results suggest that it would be reasonable to add the neck injury criteria as a requirement in this standard.

In the conventional train-to-train test, all ATDs met all injury criteria. It must be noted that the leading cab car overrode the standing locomotive in this test, resulting in about 50 ft of crush to the cab car and a loss of survival space in this region. Because the car provided little crush resistance, the crash pulse for each car in the moving train was relatively benign.

The last two tests that used CEM equipment resulted in a more severe acceleration environment for the ATDs. In two experiments, the commuter seats collapsed or separated from the car structure, resulting in a loss of occupant compartmentalization. In the two commuter seat experiments in which the seats remained attached, the injury criteria were met.

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 support the 8g crash pulse described in this standard.

The crash pulse defined in this standard and used in the seat testing described in Section 3.3—triangular pulse with 8g peak and 250 ms duration—was originally derived from computer analyses by the Volpe Center.

Some features of the crash pulses produced from full-scale crash testing include an initial high peak longitudinal acceleration of approximately 25g followed by an average constant acceleration of approximately 5g. (See **Figure 20** and **Figure 23** for the crash pulses obtained from the conventional and CEM full-scale tests, respectively.) The plots of secondary impact velocity that correspond to these crash pulses are shown respectively in **Figure 21** and **Figure 24**.

The plots of crash pulses and secondary impact velocity indicate a wide range of collision environments. The leading car in both the CEM equipment tests experienced an acceleration environment that was comparable to a 12g, 250 ms crash pulse, as shown by the SIV plots in **Figure 24**. Trailing cars in the CEM train-to-train test experienced a collision environment approximated by the 8g, 250 ms crash pulse.

**FIGURE 23**
Actual Decelerations Measured During CEM Full-Scale Tests

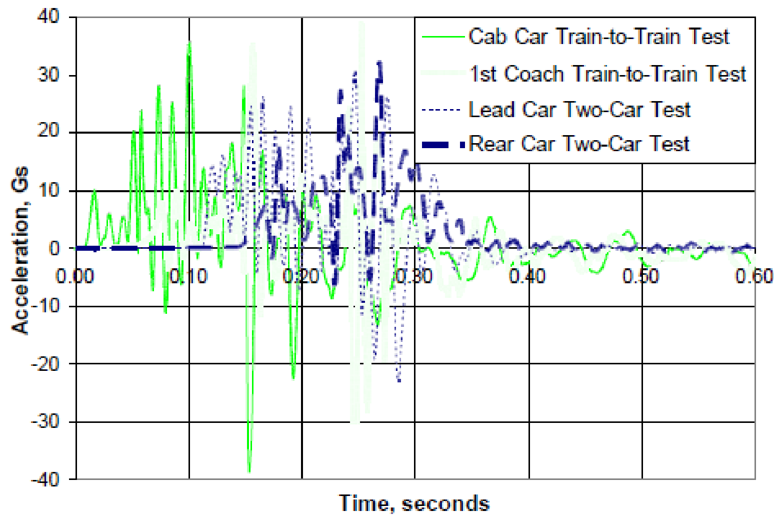
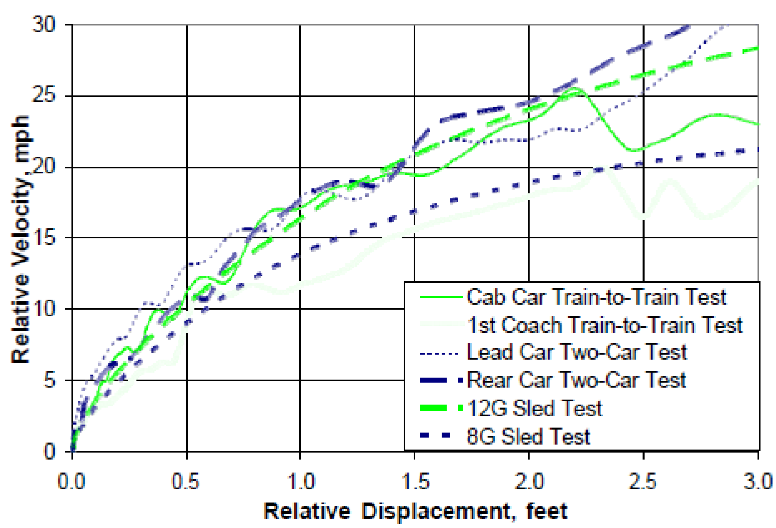



**FIGURE 24**
Secondary Impact Velocity During CEM Full-Scale Tests



### B.4.3 Discussion of crash pulse used

There has been some discussion about the crash pulse to be used in sled testing specified in this standard. Based on the full-scale test data, the 8g crash pulse appears to be a reasonable representation of a moderately severe rail vehicle collision. Some equipment tested has experienced a more benign crash pulse, and other equipment tested experienced a more severe crash pulse. At this point, there is no clear reason to deviate from the existing 8g crash pulse. Unless further research provides new evidence to justify a change in the crash pulse, the existing 8g pulse will continue to be used in sled testing of commuter rail passenger seats.

### B.4.4 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. Based on research results from the FRA Rail Crashworthiness Research Program, discussion within the C&S Subgroup, and changes adopted by the automotive industry, neck injury criteria established by NHTSA in FMVSS 208 (10-1-04 edition) were added to this standard in Revision 2, as shown in **Table 4**.

Nij is a criterion to assess neck injury, where "ij" represents indices for the four injury mechanisms; namely NTE, NTF, NCE and NCF. The first index, i, represents the axial load (tension or compression), and the second index, j, represents the sagittal plane bending moment (flexion or extension). The criterion can be written as the sum of the normalized loads and moments, where $F_z$ is the axial neck load, $F_{int}$ is the corresponding critical value of axial load used for normalization, $M_{ocy}$ is the flexion/extension bending moment computed at the occipital condyle, and $M_{int}$ is the corresponding critical intercept value for bending moment used for normalization. $M_{ocy}$ is computed using the measured neck bending moment, $M_y$, and the measured upper neck shear load, $F_z$.

**TABLE 4**

Neck Injury Limits for Hybrid III 50th-percentile Male ATD

| Criterion | Maximum Value |
|---|---|
| Axial Neck Load, $F_z$ | +937/−899 lbf<br>(+4170 N/−4000 N) |
| Nij, where:<br>$F_{int}$ (critical intercept values) are +1530/−1385 lbf (−6806/−6160 N)<br>$M_{int}$ (critical intercept values) are +229/−100 ft-lbf (+310/−135 Nm) | 1.0 |

# Appendix C: Recommended testing, maintenance and guidelines

The tests, guidelines and/or recommendations specified in this appendix are not required for compliance with this standard; they are specified for the convenience of a seat purchaser and may be referenced in a technical specification if desired.

## C.1 Seat design features

This section is intended to provide guidelines and recommendations regarding features commonly found on passenger seating equipment. They are specified for the convenience of a seat purchaser and may be referenced in a technical specification if desired. They are not required for compliance with this standard.

### C.1.1 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 or 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.

### C.1.2 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; and 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.

### C.1.3 Cushions and upholstery

Cushions should be contoured to provide optimal occupant retention and comfort during normal use. Cushioning material should be durable and capable of passing the cushion life test described in Section C.2.2.

### C.1.4 Recline

Recline mechanisms, if provided, should meet the requirements of this section. The 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 backrest position. Reclining seat backs should return to the upright position in a controlled, damped manner. Care should be taken so that reclined seats do not present obstructions for emergency egress.

### C.1.5 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 3.1.4.

## C.2 Seat durability testing

The guidelines and tests specified in this section are not required for compliance with this standard. They are specified for the convenience of a seat purchaser and may be referenced in a technical specification if desired.

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.

### C.2.1 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.

### C.2.2 Cushions and upholstery

This accelerated life test is intended to simulate the wear and tear on seating upholstery. A cushion durability test should be performed using SAE J1454 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 25**. One passenger seat position should be subjected to the following:

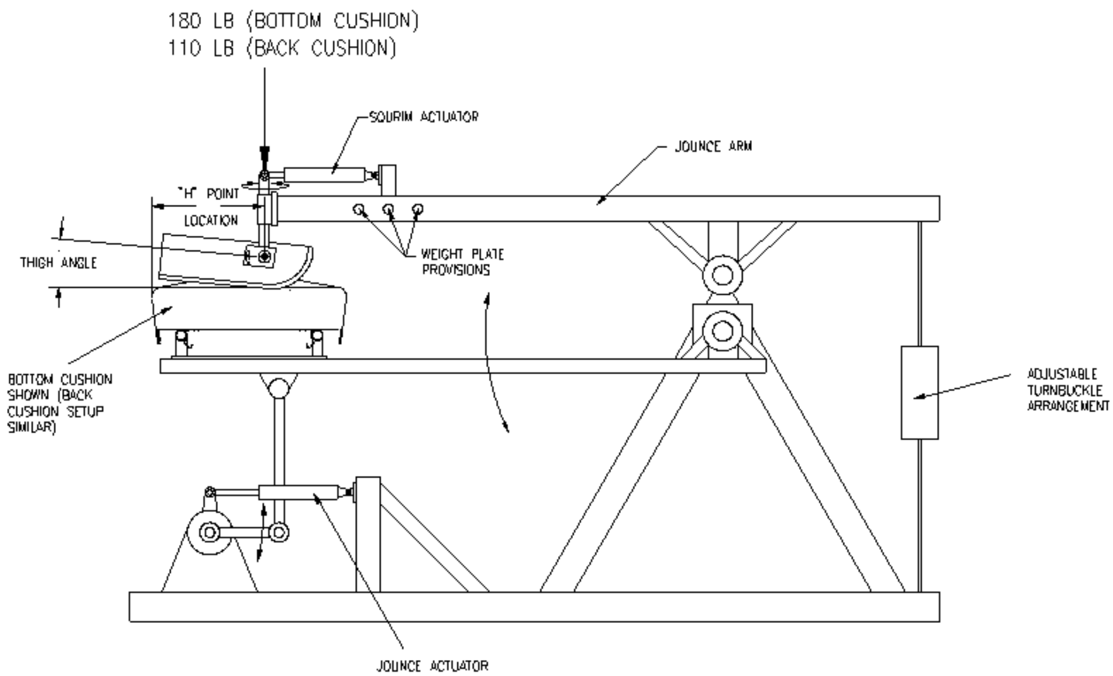
- 200,000 jounce cycles at 100 cycles per minute
- 4000 squirm cycles at two cycles per minute
- 180 lb (82 kg) load on bottom cushion
- 110 lb (50 kg) load on back cushion

Jounce and squirm cycles should be applied simultaneously, although the 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 J826.

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 25**

Jounce and Squirm Test Machine




## C.2.3 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.