DRAFT Rear Impact Evaluation 2.0 Test Protocol

Version I

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OVERVIEW

Purpose

This document outlines the methods for the Insurance Institute for Highway Safety (IIHS) evaluation of seats, head restraints and occupant restraint systems in rear impact crashes. In this evaluation, vehicle seats and relevant restraint systems are replicated in a sled environment to simulate a rear impact crash with a BioRID IIg anthropomorphic test device (ATD) as the human surrogate. The test isolates each restraint system (seat, head restraint and seat belt) from the vehicle and exposes it to the same acceleration pulse, facilitating a comparative assessment of the effectiveness of vehicle restraint systems in rear impact crashes.

This is the first IIHS vehicle ratings program to include computer simulations in the assessment. The computer simulations will replicate the seat, restraints and BioRID dummy and calculate their motion to predict the same outputs as the physical test. Automaker simulations will help IIHS address safety for more occupants and more impact scenarios without increasing the testing burden. Following the IIHS protocol, automakers will provide either simulation results or physical test results for two load cases (16 km/h and 24 km/h delta V pulses, initially). IIHS will audit one of the two tests and ensure that the results align with IIHS physical tests. If the results do align, both automaker tests will be accepted as part of the evaluation.

This current update to the rear impact protocol adds only one evaluation pulse (24 km/h) to the original (16 km/h) crash pulse introduced in 2004 (IIHS, 2019). With future updates, we plan to increase the value of our physical audit tests by adding more occupant sizes and impact scenarios using computational model simulations. These tools will help us build assessments to encourage robust seat and restraint designs that can protect more occupants.

Workflow

1. IIHS notifies automakers of intent to test make/model
2. (Within 3 months of notification) IIHS receives seat and target seat points (bolt locations, center-recliner and head-restraint post points, etc. in IIHS Rear Impact Seat Information__.xlsx template) from automaker. IIHS measures the seat with the H-point manikin according to section 1.3.2, using the center-recliner and head-restraint-post points provided by the automaker to set the seatback. If the torso angle is within 24°-26°, the H-point, torso angle, head point and head-restraint point are collected.
3. From step 2, IIHS provides automaker with:
    - Manikin points (H-point, back of head, torso angle)
    - Seat setup points (center recliner, head restraint post, backset measurement point on head restraint, highest point on head restraint, heel point)
    - Head restraint horizontal and vertical adjustment position (i.e., notch location)
    - BioRID (physical) certification report for scheduled test
    - Audit test date
4. Automaker prepares verification data for submission using one of the following methods:
    - Physical test data (both 16 km/h and 24 km/h results)
    - Simulation test data (both 16 km/h and 24 km/h results)
    - Both simulation and physical test data (must have both pulses for each). Only one pair (simulations or physical tests) must pass the audit to be used for assessment (e.g., if the 24 km/h gets audited and the physical test results from the automaker pass the audit but the

simulations do not, then the physical tests from the automaker can still be used as part of the assessment).

5. (Within 5 months of notification) Automaker submits results for the 16 km/h and 24 km/h tests. For simulation, since pulse variability can affect test outcomes, IIHS is recommending that automakers submit multiple simulations for each load case that span that range of variability observed for the IIHS sled. IIHS will provide these pulses. Using the methods in section 9, IIHS will choose the submission with the pulse closest to audit test for the audit approval.
6. Audit testing
   - IIHS randomly selects audit test (16 km/h or 24 km/h)
   - IIHS conducts physical test using seat and manikin targets from Step 3 of the workflow
   - IIHS compares automaker physical or simulation verification test data against IIHS physical test data using the methods outlined in the *Auditing Methods* section of this document.
   - The workflow optimizes the automaker's ability to pass the audit test by providing the automaker with the targets used by IIHS before the automaker runs simulations or physical tests and by allowing the submission of multiple pulses. Resubmission of verification data after the audit has been conducted will not be allowed.

Definitions

For the purpose of this procedure, the following definitions shall apply:

Head restraint means a device designed to reduce the risk of injury to the cervical vertebrae in the event of a rear impact by supporting an occupant's neck and head so they can be accelerated together with the torso as the seat and head restraint are driven forward.

Integrated head restraint or ***fixed head restraint*** means a head restraint formed by the upper part of the seatback, or a head restraint that is not height adjustable and cannot be detached from the seat or the vehicle structure except using tools or by partially or totally removing the seat furnishings.

Adjustable head restraint means a head restraint that is capable of being positioned to fit the morphology of the seated occupant. The device may permit horizontal displacement, known as tilt adjustment, and/or vertical displacement, known as height adjustment.

Active head restraint means a device designed to improve head restraint geometry during an impact.

Automatically adjusting head restraint means a head restraint that automatically adjusts the position of the head restraint when the seat position is adjusted.

Locking refers to the process of fitting an adjustable head restraint with a device that prevents users from inadvertently moving it from its adjusted position, such as when a rear seat occupant uses a front seat head restraint as a handhold when getting in or out of the vehicle. A locking device may be fitted to both the horizontal and vertical adjustments of the head restraint. A locking device must incorporate a mechanism that requires intervention to allow head restraint adjustment, after which the mechanism should reset automatically.

H-point manikin means the device used for the determination of "H" points and actual torso angles. (SAE, 2021).

HRMD (Head Restraint Measuring Device) means a separate head-shaped device used with the H-point manikin to measure the static geometry of a vehicle head restraint. It was developed under the sponsorship of the Insurance Corporation of British Columbia (ICBC). (SAE paper 1999-01-0639). The HRMD is equipped with two probes to measure head-restraint height and backset. The height probe projects horizontally, level with the top of the head, to provide a reference line for the vertical measurement to the top of the restraint. The backset probe simulates the rear profile of the head and neck and projects horizontally to provide the horizontal measurement to the restraint.

Head Restraint ***Height*** is defined as the measurement between the top of the head restraint and the calculated top of the head point or the height probe of the HRMD.

Head Restraint ***Backset*** is defined as the measurement between the rearmost surface of the HRMD head and the front surface of the head restraint

Head Restraint Measurement Positions
Down is defined as the lowest possible position of an adjustable head restraint.
Up is defined as the highest possible position of an adjustable head restraint.
Back is defined as the rearmost possible position of an adjustable head restraint.
Forward is defined as the forwardmost possible position of an adjustable head restraint.

Verification data is test data from either simulation or physical tests that an automaker provides to IIHS to be used for a safety assessment.
Certification is the process for approving a physical entity (e.g., BioRID II) for use in a safety assessment.
Computer Aided Engineering (CAE) model is a simulation of a physical entity (e.g., BioRID, vehicle seat) that computationally approximates the static geometry and dynamic behaviors of the physical entity, using equations for the physics of motion, materials and contacts.
Qualification is the process for approving a (CAE) model for use in a safety assessment

Seat selection

The seat content selection for physical testing will be defined by the seat in the vehicle with the highest volume take rate for each make/model. If a make/model is new and does not have historical volume take rates, either the previous generation or the automakers prediction can be used.
Seat content (e.g., lumbar adjuster) for automaker seat models do not have to identically match the physically tested seat. It is up to the automaker's discretion how to build their model to best match the physical test outcomes.
IIHS will purchase or acquire seats directly from the automaker and/or their suppliers and take responsibility for shipping costs.

TEST METHODS

1 IIHS physical test procedure

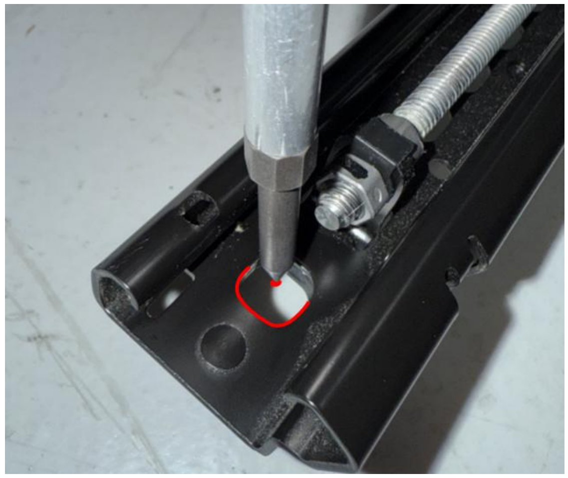
1.1 General test requirements

1.1.1 Coordinate system

The cartesian coordinate reference frame for measurements is as follows: +X forward (i.e., direction of sled motion), +Y right, +Z down

IIHS will collect the left front seat bolt hole (LFSBH) (Figure 1) as a local reference point for the seat. This point can be used for conversion between different coordinate systems.

Figure 1
Left front seat bolt hole (LFSBH) measurement location



1.1.2 Videography

1. A lateral left view (orthogonal to the plane of motion) that captures the entire event from the onset of acceleration to 100 ms past the end of head contact time.
2. A lateral right view (orthogonal to the plane of motion) that captures the entire event from the onset of acceleration to 100 ms past the end of head contact time.
3. A lateral right view following the sled reference frame (orthogonal to the plane of motion) that captures the entire event from the onset of acceleration to 100 ms past the end of head contact time.

1.2 Sled and vehicle environment

Tests are run with production seats in a simulated vehicle environment on a dynamic test sled.

1.2.1 Acceleration sled

The dynamic test is intended to simulate a typical rear crash in which the struck vehicle is initially stationary or moving forward very slowly. Consequently, an acceleration sled is required for these tests. To accommodate different sled types and different relationships between sled motion and the recording of test data, test time will be indexed using the sled acceleration as described in Section 1.3.6 *Instrumentation, data acquisition and processing*.

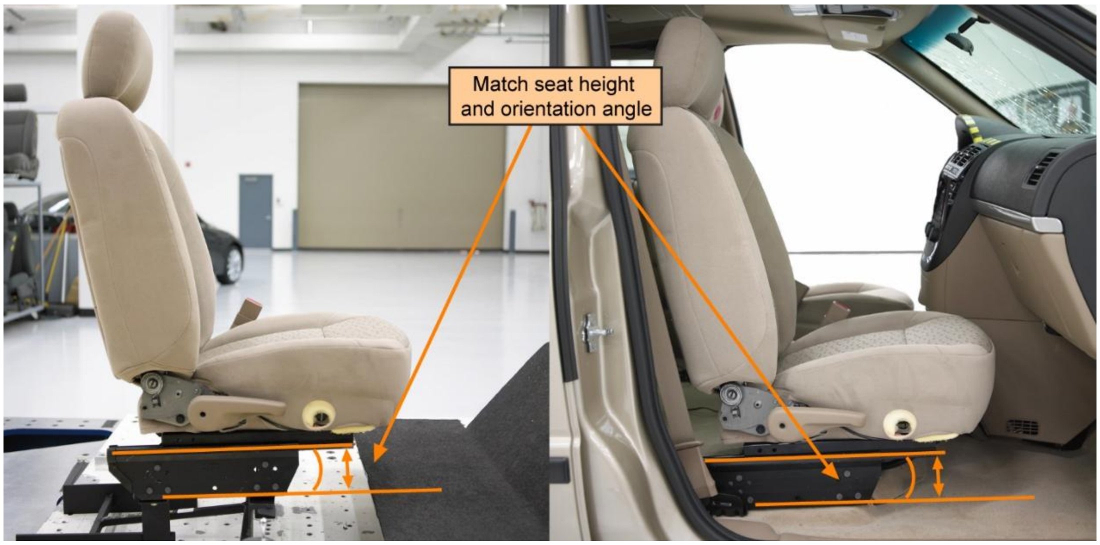
1.2.2 Laboratory environment

The temperature in the test laboratory should be 22.5 ± 3 degrees Celsius (67-78 degrees Fahrenheit) with a relative humidity of 10%-70%. The BioRID test dummy and seat being tested shall be maintained at this temperature at least 3 hours prior to the test.

1.2.3 Attachment of seat/head restraint to sled

The seat, including all of the adjustment mechanisms and hardware that normally connect it to the vehicle floor (e.g., longitudinal adjustment rails), should be securely fastened to the test sled platform. The attachment should be made so that the seat's orientation relative to horizontal is the same as it would be in its intended vehicle. The actual height of the seat from the sled platform may be different from its height above the vehicle floor. A simulated floor and toepan, consisting of a horizontal section sufficiently large to rest the dummy's feet and connected to a section oriented 45 degrees from horizontal and at least 30 cm long, are attached to the sled platform. Both surfaces should be covered with short-piled carpet. The horizontal floor portion should be mounted at the same height relative to the seat bolts/rails as the heel rest point (section 1.2.4). The fore/aft position of the toepan should be adjustable. Figure 2 shows an example seat both in the vehicle and mounted on the sled platform.

Figure 2
Attachment of seat to test sled compared with vehicle installation



1.2.4 Determine heel rest point location

The heel rest point is defined in the vehicle (with removable floor mats removed) by using the accelerator pedal as follows.
Find the geometric center point of the accelerator pedal contact surface (laterally and vertically). Place a straight edge between the accelerator pedal and the fixed carpeting on the vehicle floor so that the straight edge is tangential to the accelerator pedal surface at the center point. The heel rest point location is then the contact point of the straight edge on the vehicle floor (Figure 3).

Figure 3
Heel rest point location

1.2.5 Restraints

1.2.5.1 Seat belts

A three-point lap/shoulder belt should be used during the test. If possible, any belt hardware integrated with the seat should be utilized (e.g., buckle or integrated shoulder belt). The belt should be placed across the dummy's torso, clavicle and pelvis and be routed above the pelvis angle gauge (if equipped).

1.2.5.2 Activation for active elements

For each seat, the automaker should provide information on the presence of active elements (e.g., head restraints, seat belts) that would be expected to activate in a real crash of the same severity and would affect test outcomes. For each element that requires a trigger, time-to-fire (TTF) should be specified by the vehicle manufacturer. Supporting data will be requested.

1.2.6 Set seat adjustments

The seat adjustments should be set according to the following instructions. Prior to setting seat adjustments, the seat shall be bolted to the sled in its position for testing, and the sled brakes should be engaged, if available. Otherwise, the sled should have its movement restrained for the duration of setting up the seat, installing the H-point manikin, installing the dummy, and collecting all necessary measurements. Because the settings of some adjustments may affect the ranges of other adjustments, the seat should be set according to the order of the procedural steps outlined here. An initial seatback angle will be set in section 1.2.6.8 based on target values from the automaker; the final setting will be established in section 1.3.2. Head restraint position (manually, electrically or automatically adjusting) should be set according to the instructions in section 1.2.6.9.

1.2.6.1 Initial seat adjustments

All seat adjustments should be set initially as follows. Appendix A provides more detailed descriptions and illustrations of these adjustments.

- **Seat track** should be in its rearmost position.
- **Seat height** should be set to its lowest position.

- **Seat tilt** should be set to the extreme of its range that puts the cushion angle closest to zero (horizontal). Section 1.2.6.2 describes the method for measuring the cushion angle.
- **Cushion height** should be set to its lowest position.
- **Cushion tilt** should be set to the extreme of its range that puts the cushion angle closest to zero (horizontal). Section 1.2.6.2 describes the method for measuring the cushion angle.
- **Lumbar support** should be set to its rearmost or least prominent position.
- **Upper seatback**, if separately adjustable from the lower portion, should be rotated fully rearward.
- **Cushion extension** should be set to its rearmost or least extended position.
- **Side bolsters** should be set to the widest position.

1.2.6.2 Measure seat cushion angle

Locate and mark a point on the forward edge of the top surface of the seat cushion and midway between the right and left edges of the cushion. Locate, mark, and record a second point that is 400 mm rearward along a line parallel to the direction of the sled movement (Figure 4) with a coordinate measurement machine (CMM). The sine of the cushion angle is the difference in the Z-coordinates (in mm) of these two points (first minus the second) divided by 400 mm.

Figure 4
Seat Cushion Angle (400 mm measurement)

1.2.6.3 Set seat track adjustment to midrange

Mark a hard point on the seat and record its location with a CMM. Move the seat to its most forward adjustment position and record the position of the marked hard point. Move the seat rearward until the marked hard point is midway between the two previously recorded hard point locations. The final position will depend on whether the seat track adjusts continuously or incrementally.

Continuously adjusting seat track – The mark on the seat support structure should align (± 2 mm) with the midtrack mark. Alternatively, the hard point should have an X-coordinate that is midway (± 2 mm) between the X-coordinates of the most forward and most rearward adjustment positions.

Incrementally adjusting seat track – If the midrange adjustment does not correspond to an indexed adjustment position (± 2 mm), then the seat should be set to the first indexed position rearward of the calculated midpoint.

1.2.6.4 Set seat height adjustment to midrange

Mark two hard points on the side of the seat on components that are attached to and move with the cushion frame — one near the front of the cushion and one near the rear. Record the locations of both points with a CMM or measure the vertical heights of the points relative to a fixed reference with a measuring tape. Use the seat height adjustment control(s) to move the seat to its highest position. If the front and rear seat heights are adjusted separately (dual control), then make sure that both the front and rear of the seat are raised to their highest positions. Record the locations of the two hard points with the CMM or measure the vertical heights of the points relative to a fixed reference with a measuring tape. Then lower the seat until both hard points are midway between their highest and lowest positions. The final position will depend on the type of control used to adjust the seat height.

Single control seat height adjustment – The final position of the seat will depend on whether seat height adjusts continuously or incrementally.

> *Continuously adjusting seat height* – The rear hard point should be ± 2 mm of the calculated midpoint.
>
> *Incrementally adjusting seat height* – If the midrange adjustment does not correspond to an indexed adjustment position (± 2 mm), then the seat height should be set to the first indexed position below the calculated midpoint.

Dual control seat height adjustment – If the front and rear seat heights are adjusted separately, then lower the front hard point using the front adjustment control and lower the rear hard point using the rear adjustment control. The final position will depend on whether seat height adjusts continuously or incrementally. Note that the front and rear seat height adjustments may need to be iterated to achieve the calculated midpoints.

> *Continuously adjusting seat height* – Both the front and rear hard points should be within ± 2 mm of the calculated midpoints. If this is not possible, then the rear hard point should be within ± 2 mm of the calculated midpoint and the front hard point as close as possible to the calculated midpoint.
>
> *Incrementally adjusting seat height* – If either the front or rear midrange adjustment does not correspond to an indexed adjustment position (± 2 mm), then the seat height should be set to the first indexed position below the calculated midpoint for the corresponding seat hard point.

1.2.6.5 Set seat cushion height adjustment

The cushion height adjustment uses the points marked on the top surface of the cushion in step 1.2.6.2.

Single control seat cushion height adjustment – Raise the cushion to its highest position and record the location of the rear cushion point (400 mm behind the front edge point). Lower the seat cushion to its midrange position. The final position of the seat will depend on whether the seat cushion height adjusts continuously or incrementally.

Continuously adjusting seat cushion height – The rear cushion point should have a Z-coordinate midway (± 2 mm) between the lowest (initial) and highest positions.

Incrementally adjusting seat cushion height – If the midrange adjustment does not correspond to an indexed adjustment position (± 2 mm), then the seat cushion height should be set to the first indexed position below the calculated midpoint.

Dual control seat cushion height adjustment – Raise the rear of the cushion to its highest position using the rear adjustment control and record the location of the rear cushion point (400 mm behind the front edge point). Lower the rear of the cushion using the rear adjustment control so that the rear cushion point is midway between the lowest (initial) and highest positions. Raise the front of the cushion using the front adjustment control until the cushion angle matches the angle recorded in step 1.2.6.2. The final position will depend on whether seat cushion height adjusts continuously or incrementally.

Continuously adjusting seat cushion height – The rear cushion point Z-coordinate should be ± 2 mm of the calculated midpoint, and the cushion angle should match (± 0.5 degrees) the angle recorded in step 1.2.6.2.

Incrementally adjusting seat cushion height – If the rear midrange adjustment does not correspond to an indexed adjustment position, then the rear cushion height should be set to the first indexed position below the calculated midpoint. Likewise, if the cushion angle in step 1.2.6.2 cannot be matched (± 0.5 degrees) with the front midrange adjustment at an indexed position, then the front cushion height should be set to the next lowest indexed position.

1.2.6.6 Adjust upper seatback angle

Measure the angle relative to vertical of the head restraint support post or some flat part of the seatback frame. Without changing the adjustment of the lower seatback, move the upper seatback to its most forward position and measure the angle at the same location as the initial measurement. Adjust the upper seatback rearward until the angle is midway (± 0.5 degrees) between the most rearward and most forward angles.

1.2.6.7 Other seat adjustments

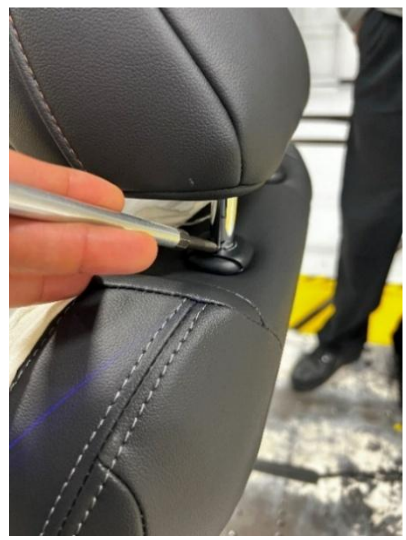
Any seat adjustments not specified in steps 1.2.6.2 through 1.2.6.6 should remain in their initial adjustment positions as described in step 1.2.6.1. If the seat is equipped with a movable armrest, it should be raised or placed in its stored position; adjustable lumbar supports should be fully retracted, adjustable cushion extension should be fully retracted, and adjustable lateral thigh supports and seatback supports (bolsters) should be set open or as wide as possible.

1.2.6.8 Set initial seatback angle

Once all other seat adjustments have been made, use the values supplied by the automaker for the position of the center of the head restraint post (CHRP) relative to the center of the recliner pivot (CoRP) of the seat (Figure 5) to set the initial seatback angle of the unweighted seat. This initial seatback angle will be maintained as long as the manikin torso angle is within 25±1 degrees after following steps in section 1.3.3.

Figure 5
Center of recliner pivot and center of head restraint post measurement examples

(A) Center of recliner pivot (CoRP)



(B) Center of head restraint post (CHRP)

1.2.6.9 Head restraint test position

The head restraint, if equipped with locking vertical and horizontal positions, should be set in a position closest to the midrange vertically and midrange horizontally. Thus, the test position for the restraint depends on whether it is fixed or adjustable and, if adjustable, whether the adjustments lock. Automatically adjusting head restraints are tested as if they are fixed restraints, and the seat adjustments are set according to section 1.2.6.

Fixed head restraint
No adjustment of the restraint is possible.

Nonlocking adjustable head restraint
Restraint is adjusted to its lowest vertical adjustment position and/or most rearward horizontal adjustment position.

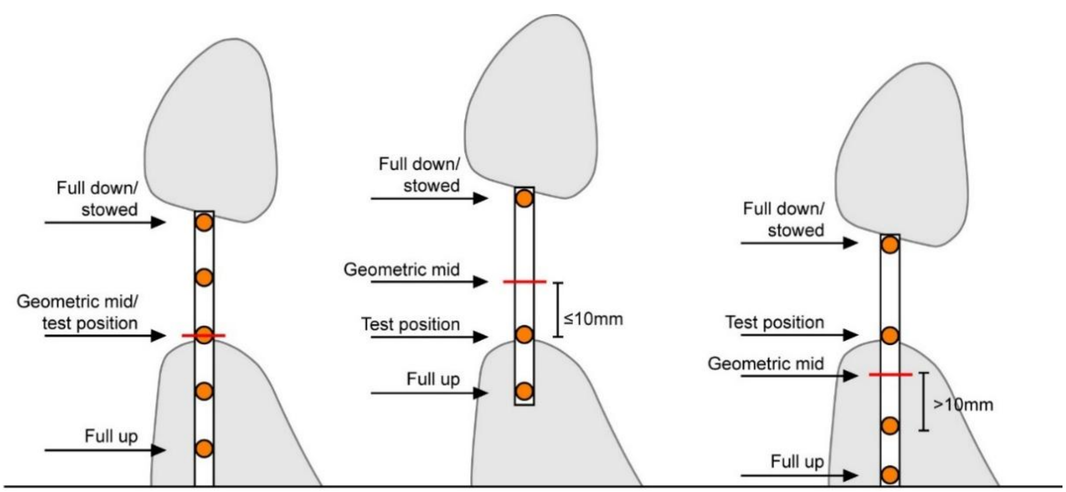
Locking adjustable head restraint
Restraint is adjusted to the midrange of its vertical and/or horizontal adjustment positions. Only locking adjustments are set to the midrange positions. For example, a restraint with locking height adjustment and nonlocking horizontal adjustment would be set to its midrange vertical position and most rearward horizontal position.

Midrange height position is determined by calculating the geometric midpoint between the lowest (locking or nonlocking) and highest locking vertical adjustments, considering only the vertical component of measurement. Similarly, midrange tilt position is determined by calculating the geometric midpoint between the rearmost and forwardmost locking horizontal adjustments, considering only the horizontal component of measurement. (Figure 6). The test position will then be selected based on the following conditions:

- Place the head restraint at the geometric midpoint if a locking position exists there (Figure 6A).
- If there is no locking position at the geometric midpoint, raise the head restraint by up to 10 mm (Figure 6B). If a locking position exists within this 10mm of travel, that position will be the test position.
- If there is no locking position within 10 mm above the geometric midpoint, lower the head restraint to the next lowest locking position (Figure 6C), that position will be the test position.

Once the vertical test position has been determined, the procedure should be repeated for locking horizontal adjustments moving the restraint forward instead of upward and rearward instead of downward.

Figure 6
Examples of Adjustment Positions for Head Restraints with Locking Height (locking positions indicated in orange)



Example A (Locking position at geometric midpoint) | Example B (Locking position up to 10 mm above geometric midpoint) | Example C (Locking position more than 10 mm above geometric midpoint)

Seating Adjustments: Seats with Automatically Adjusting Head Restraints

The BioRID used in these dynamic tests represents an average-size adult male driver or vehicle occupant. Consequently, seats equipped with head restraints that automatically adjust depending on other seat adjustments (e.g., seat track or height) should be set to a position that most likely would accommodate a seat occupant of the same size. The procedure described in *Guidelines for Using the UMTRI ATD Positioning Procedure for ATD and Seat Positioning (Version VI)* (IIHS, 2022) should be followed for seat positioning only. The UMTRI ATD positioning procedure must be conducted with the seat installed in a vehicle. Then the seat adjustments recorded are transferred to the test seat on the sled. The automaker can provide the CoRP and CHRP for this position (Figure 5), if applicable. If it is not possible to employ the UMTRI procedure to determine the appropriate seat position for an average-size male seat occupant, then the seat should be set to the middle of its fore/aft adjustment range (see step 1.2.6.3). Regardless of which method is used to determine the head restraint test position, the seat should be moved rearward from the most forward position to the test position because the starting position can affect the final position of the head restraint.

1.3 Dummy and seating procedures

The dummy is positioned using targets determined in step 2 of the workflow. Section 1.2 is used to define the position of the seat. Automaker-provided CoRP and CHRP points are used to set the seatback for an H-point manikin torso angle of 25°. Section 1.3.2 is used to seat the H-point manikin and collect the H-point and torso angle. Section 1.3.3 is used to calculate the head location and backset targets.

1.3.1 BioRID

These tests should be conducted with a BioRID IIg or later revision dummy. The dummy should comply with both spine stature and dynamic response specifications before the test.

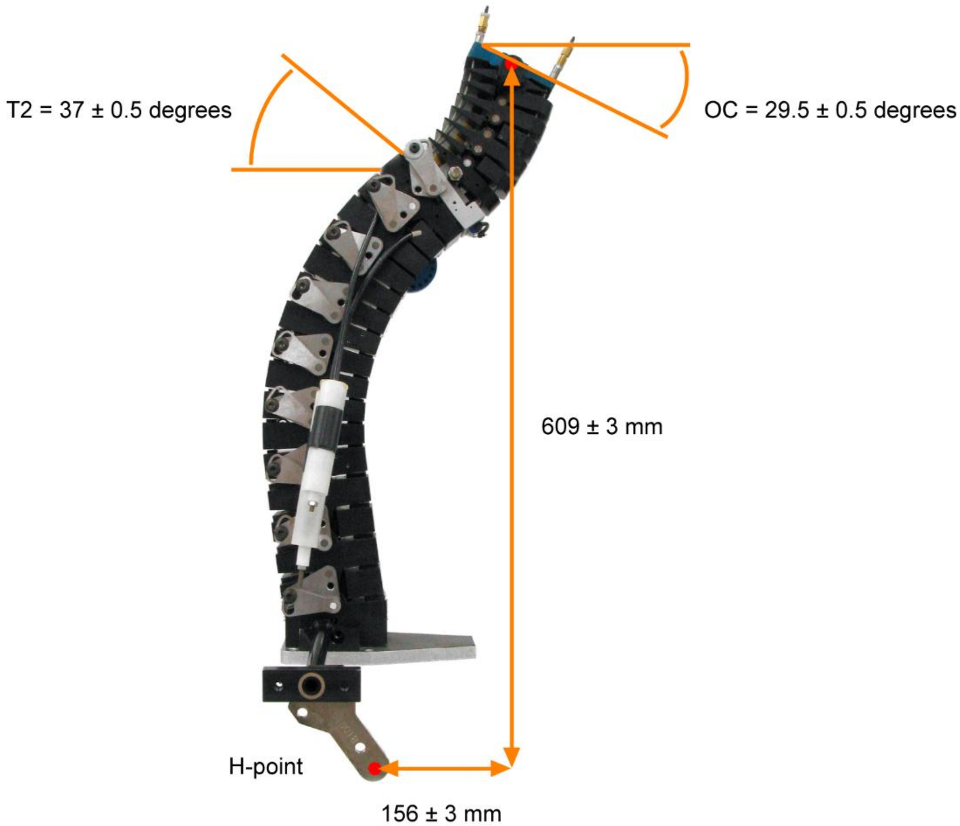
1.3.1.1 Spine Curvature Check

With the pelvis adapter plate placed on a level surface with the occipital condyle (OC) angle at 29.5 ± 0.5 degrees, the T2 angle at 37 ± 0.5 degrees, and the neck plate laterally level ± 0.5 degrees, the distance (X) between the H-point and OC pin should be 156 ± 3 mm, and the distance (Z) between the H-point and OC pin should be 609 ± 3 mm (Table 1 and Figure 7).

Table 1
BioRID IIg Spine Curvature Specifications

Measurement	Specification
Angle of occipital interface plate relative to horizontal	29.5 ± 0.5 degrees
Angle of T2 vertebra relative to horizontal	37.0 ± 0.5 degrees
Angle of neck plate (lateral)	0 ± 0.5 degrees
H-point indicator to occipital condyle pin (horizontal)	156 ± 3 mm
H-point indicator to occipital condyle pin (vertical)	609 ± 3 mm

Figure 7
BioRID IIg Spine Curvature Check



1.3.1.2 Certification

The BioRID dummy should comply with the BioRID dummy jacket validation test, lower torso validation test and dummy certification test outlined the United Nations Mutual Resolution No. 1 - Addendum 1 - *Specifications for the Construction, Preparation and Certification of the 50th percentile male Biofidelic Rear Impact (BioRID-II UN) anthropomorphic test device.*

1.3.1.3 Clothing

The dummy should be dressed in two pairs of close-fitting, knee-length, spandex (e.g., lycra) pants and two close-fitting, short-sleeved spandex shirts. The under layer of clothes should be worn with the shiny/smooth side of the fabric facing out and the outer layer should be worn with the shiny/smooth side against the underclothes (i.e., dull side facing out). The dummies feet should be shod with size 11 (45 European or 27.9 cm) Oxford-style, hard-soled work shoes (e.g., MIL-S-13192P).

1.3.2 H-point manikin installation

Using an H-point manikin that has been calibrated according to SAE J826 (SAE, 2021), follow these steps:

1.3.2.1 Adjust the torque of the manikin H-point locking nuts to set the frictional resistance so that approximately 1 g is required to move the back pan relative to the seat pan. The back pan should retain its position relative to the seat pan without assistance at 90° but move with only the force of gravity at all other positions. For the manikin IIHS uses for rear impacts, this torque value is 18 inch-pounds.

1.3.2.2 The seat shall be covered with a cotton cloth large enough to cover both cushions and seatback.

1.3.2.3 The cloth shall be tucked into the seat joint by an amount sufficient to prevent hammocking of the material.

1.3.2.4 The manikin seat pan and back pan shall be installed in the seat.

1.3.2.5 The lower legs shall be adjusted to the 50th percentile leg length setting, and the upper legs shall be adjusted to the 10th percentile leg length setting; these are the manikin settings closest to the FMVSS 208 requirement.

1.3.2.6 The legs shall be attached to the manikin and set to the 5th position (no.5) on the knee joint T-bar, which places the knees 25 cm apart.

1.3.2.7 With the legs attached and the back pan tilted forward, the manikin shall be positioned in the seat such that its central sagittal plane coincides with the longitudinal centerline of the seat.

1.3.2.8 The back pan shall be straightened to conform to the vehicle seatback.

1.3.2.9 The feet shall be placed as far forward as possible, with the heels on the floor and the soles not in contact with the simulated toepan.

1.3.2.10 The lower leg and thigh weights shall be attached to the manikin and the machine shall be levelled.

1.3.2.11 The back pan shall be tilted forward and the manikin assembly pushed rearward until the seat pan contacts the vehicle seatback. While tilting the back pan forward, a horizontal rearward load of 100N shall be applied using the plunger if present or using a force gauge pressed against the hip angle quadrant structure.

1.3.2.12 The load application shall be repeated and, while keeping the pressure applied, the back pan shall be returned to the vehicle seatback and the pressure then released. Once the back pan has been returned to the vehicle seatback, one hand should be kept on the T-bar with light pressure for the duration of the following installation to make sure the manikin does not move.

1.3.2.13 A check shall be made to determine that the manikin is level, facing directly forward, and located in the centerline of the seat.

1.3.2.14 After checking the position of the manikin in the seat at the seatback position established in section 1.2.6.8, the right and left buttock weights shall be installed. The eight chest weights shall be installed by alternating left to right.

1.3.2.15 Tilting the back pan forward to a vertical position, the assembly shall be rocked from side to side over a 10-degree arc – 5 degrees in each direction. This rocking shall be repeated for a total of three complete cycles while preventing any horizontal translation of the manikin seat pan.

1.3.2.16 The back pan shall be returned to the vehicle seatback, and the manikin shall be levelled again as in 1.3.2.10. To ensure the back pan is stable in the seat, apply and release a horizontal rearward load (**≤ 10N**) to the back pan approximately at the center of the torso weights. Ensure no exterior downward or lateral loads are applied to the manikin at this time.

1.3.2.17 The feet shall be positioned as follows: each foot shall be alternately lifted off the floor via the instep, until no additional forward foot movement is available.

1.3.2.18 When each foot is placed back in the down position, the heel shall be in contact with the floor. The sole should not be in contact with the simulated toepan.

1.3.2.19 If the manikin seat pan is not level after the feet have been repositioned, a sufficient load shall be applied to the top of the seat pan to level it on the vehicle seat.

1.3.2.20 If the measured torso angle is not 25±1 degrees as measured on the flat portion of the left (calibrated) torso weight hanger bar that is welded to the back pan, record the values for the position of the CoRP and CHRP when weighted by the manikin and readjust the seatback to match the reference values provided by the automaker for the weighted CoRP and CHRP. After adjusting the seat to match the weighted CoRP and CHRP points, remove the weights from the chest and buttocks and repeat the steps to position the manikin, beginning with tilting the back pan forward and pushing the manikin rearward as in 1.3.2.11.

1.3.2.21 If the measured torso angle is still not 25±1 degrees after the described readjustment of the seatback in 1.3.2.20, then further readjustment must be made to achieve a measured torso angle in this range. Once further readjustment has been completed, remove the chest and buttocks weights and repeat the steps to position the manikin again. If more than three drops of the manikin are necessary to achieve a measured torso angle in range, the manikin should be fully removed from the seat after the third drop for 15 minutes to allow the seat to recover.

1.3.2.22 For seats with indexed manual seatback adjustment, if there is no adjustment position that places the measured torso angle between 24 and 26 degrees, place the seatback in the most reclined position that supports a torso angle less than 24 degrees for testing.

1.3.2.23 The torso angle, H-points (left/right), and seat setup points shall be recorded when it falls within the allowed range.

1.3.3 Calculation of BioRID targets from manikin position

The BioRID test position is based on reference measurements made with the H-point manikin and calculated values for the back of the head position of the HRMD. In these steps, the HRMD is not installed on the manikin, rather, the location of the HRMD backset probe is simulated using calculations based on the rigid geometry of the manikin and the H-point and torso angle for a given manikin measurement. This method yields the same results for backset as the measurements from the physical HRMD. The determination of these calculated values will be described in this section.

1.3.3.1 Record the vertical and horizontal location of H-point manikin's H-point marker on both the left and right sides using a CMM.

1.3.3.2 Average the collected position values for the right and left side H-point markers.

1.3.3.3 Calculate the location of the horizontal and vertical position of the point on the back of the head of the HRMD (this is a virtual point that corresponds to the screw on the center of the rear surface of the HRMD backset probe) relative to the H-point. Calculate the <u>horizontal position</u> of the back of the head using Equation 1, where θ is the measured torso angle. Calculate the <u>vertical position</u> of the back of the head using Equation 2, where θ is the measured torso angle. To locate these points in the global coordinate system, add them to the H-point marker average point from 1.3.3.2.

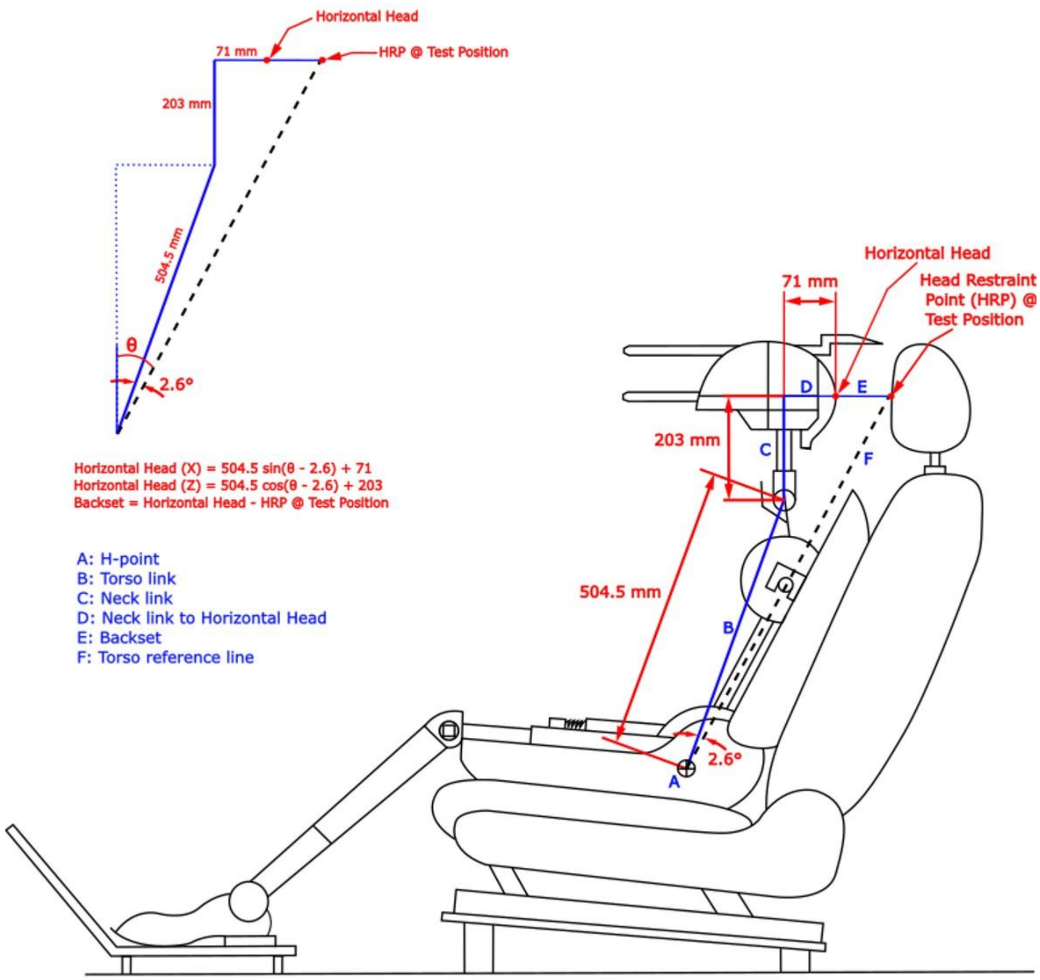
$$Horizontal\ head\ point\ (x) = 504.5 * \sin(\theta - 2.6°) + 71 \qquad \text{Equation 1}$$

$$Horizontal\ head\ point\ (z) = 504.5 * \cos(\theta - 2.6°) + 203 \qquad \text{Equation 2}$$

1.3.3.4 Calculate the vertical position of the top of the head using Equation 3.

$$Vertical\ head\ point\ (z) = Horizontal\ head\ point\ (z) + (-92) \qquad \text{Equation 3}$$

Figure 8
Calculated HRMD Back-of-Head Measurements



(A) H-point from 1.3.3.2
(B) With the HRMD installed, the “torso link” linear distance from the H-point marker to the neck link pivot is 504.5 mm.
(C) With the head of the HRMD leveled, the vertical neck link distance from center of the pivot to the point where the back of the head is measured is 203 mm.
(D) The horizontal distance from the head pivot point to the back of the head is 71 mm.
(E) The backset is the horizontal distance between the Horizontal head point (1.3.3.3) and Head restraint point @ test position(1.3.3.6).
(F) The torso reference line represents the plane where the torso angle is measured

1.3.3.5 Set the head restraint to the test position described in section 1.2.6.9.

1.3.3.6 Mark and record an identifiable point (Head restraint point @ test position) on vertical centerline of the head restraint that corresponds to the Horizontal head point (z) found in 1.3.3.3.

1.3.3.7 Measure and record the reference backset (E) as shown in Figure 8. This is the horizontal distance between Horizontal head point (x) from 1.3.4.3 and the Head restraint point @ test position (x) from 1.3.3.6. The reference backset value (E) cannot be smaller than 0 mm; any calculated value less than 0 mm should be set to 0 mm.

1.3.4 BioRID Positioning

1.3.4.1 Allow the seat to recover for 15 minutes with nothing in it before installing the BioRID.

1.3.4.2 Align the BioRID's midsagittal plane with the centerline of the seat.

1.3.4.3 Adjust the BioRID's midsagittal plane to be vertical; the instrumentation platform in the head should be laterally level.

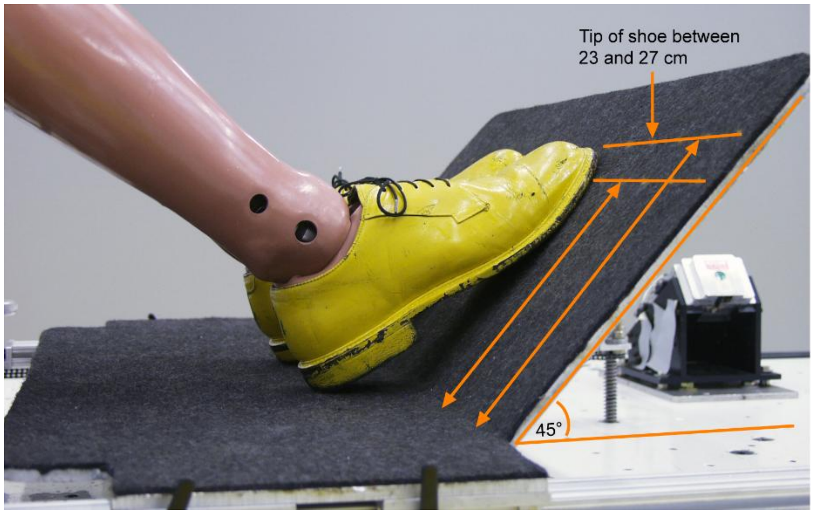
1.3.4.4 Adjust the BioRID's pelvis angle to 26.5 ± 2.5 degrees from horizontal.

1.3.4.5 Position the H-Point 20 ± 10 mm forward of the location recorded in step 1.3.3.2. Position the H-Point the same vertically ± 10 mm as the location recorded in step 1.3.4.2, while keeping the pelvis angle at 26.5 ± 2.5 degrees. Note: It is recommended that the dummy be positioned as close as possible to the nominal target values; the tolerance window should be used only if there is difficulty achieving the required H-point target or backset value.

1.3.4.6 Adjust the spacing of the BioRID's legs so that the centerlines of the knees and ankles are 200 ± 10 mm apart.

1.3.4.7 Adjust the BioRID's feet and/or the adjustable toeboard so that the heels of the dummy's shoes are resting on the simulated vehicle floor and the tips of the shoes are resting on the toeboard 23-27 cm from the intersection of the heel surface and toe board, as measured along the surface of the toe board (Figure 9). Note: If it is not possible to achieve the toe position as specified above, the feet should be positioned with the heels of the dummy's shoes resting on the simulated vehicle floor and the tips of the shoes resting on the toeboard keeping the following in mind. The foot position should be set so that no joint of the BioRID leg or foot is at its endstop, the heel of the BioRID is not positioned in the intersection of the heel surface and toe board, and the pelvis location found in step 1.3.4.5 is not altered by the position of the leg and foot.

Figure 9
Proper BioRID Feet Positioning



1.3.4.8 Position the BioRID's arms so that the upper arms contact the seatback and the elbows are bent so that the small fingers of both hands contact the top of the vehicle seat cushion with the palms facing the dummy's thighs.

1.3.4.9 Level the instrumentation plane of the head (front/rear and left/right directions) to within ± 0.5 degrees.

1.3.4.10 Measure the BioRID's backset (distance between the front of the head restraint and the back of the dummy's head) as follows:

A) Record the most rearward point on the centerline of the dummy's skullcap. (NOTE: If using a measuring tape that contours to the shape of the skullcap, then this point is 9.5 cm from the top edge of the skullcap along the midsagittal plane of the skull.)

B) The BioRID backset is the horizontal distance between the rearmost point on the dummy's head and the head restraint point @ test position marked in step 1.3.3.6 (Figure 10).

Figure 10
Measuring BioRID Backset

1.3.4.11 If the BioRID backset is different from the reference backset (step 1.3.3.7) plus 15 ± 5 mm, then do the following:

A) Tip the head fore/aft no more than ± 0.5 degrees from level to meet the backset requirement.

B) If the BioRID backset still cannot be brought closer to the reference backset plus 15 mm, adjust the pelvis angle and H-point position within their respective tolerance bands, then begin with step 1.3.4.4 and adjust the BioRID position accordingly.

C) If the above iterations still do not allow the backset to come within the specified tolerance for backset target and the H-point position is as far forward as the tolerance allows, then move the H-point forward of the allowed position the smallest distance that allows the backset requirement to be met.

1.3.5 Instrumentation, data acquisition and processing

The instrumentation required to conduct an IIHS rear impact evaluation is listed in Table 2. BioRID IIg includes a loadcell (or structural replacement) at the T1 vertebra; output of this sensor may be recorded at the tester's discretion. It is not recommended that sensors or a sensor mounting block be attached to the C4 vertebrae because of the potential for unintended interaction with the head skin that could affect the spine response. The measurement data shall be recorded according to SAE J211-1. Table 2 specifies the channel frequency classes for each necessary measurement. Measurement data shall be considered for evaluation until the point in time at which the head rebounds from the head restraint or at 300 ms after T = 0, whichever occurs first.

Table 2
BioRID and sled instrumentation and filters

Measurement Location	Measurement	Sensor Type	Channel frequency class (CFC) filter
Back of head	Time of head contact with head restraint	Switch to indicate contact with head restraint	None

Upper neck	A-P and L-M shear force and axial force	Loadcell (R.A. Denton model 4985J)	CFC 1000
Upper neck	A-P moment	Loadcell (R.A. Denton model 4985J)	CFC 600
Head COG	Triaxial linear acceleration	Endevco 7264B-500 or similar	CFC 1000
T1 vertebra – left side	Biaxial linear acceleration (A-P and I-S)	Endevco 7264B-500 or similar	CFC 60
T1 vertebra – right side	Uniaxial linear acceleration (A-P)	Endevco 7264B-500 or similar	CFC 60
L1 vertebra – left side	Biaxial linear acceleration (A-P and I-S)	Endevco 7264B-500 or similar	CFC 60
Pelvis	Triaxial linear acceleration	Endevco 7264B-500 or similar	CFC 60
Sled acceleration	Uniaxial linear acceleration (longitudinal)		CFC 60 (CFC 180 for integration for delta V)

1.3.5.1 Time indexing for all channels

To align sled accelerations and occupant sensors, all channels for a 16 km/h test should be reindexed with the value from 1.4.1.5 and all channels for a 24 km/h test should be reindexed with the value from 1.4.2.5.

1.3.5.2 Variable head contact adjustment (16 km/h and 24 km/h)

Sled accelerations meeting the specified corridors may have different timing that can lead to differences in head contact times recorded on identical seats tested at different labs. To eliminate variation in head restraint contact times between labs, the recorded head contact time must be adjusted to reflect the contact time that would be expected if the exact target pulse was achieved. The procedure for adjusting recorded head contact time is described as follows:

Note: All data referred to in this section must already be time indexed as described in section 1.4.1 or 1.4.2. See Appendix B for an example of how to adjust the head contact time.

1.3.5.2.1 Using the sled filtered acceleration (CFC 180), integrate the data from the last time the acceleration passes through zero at the beginning of the trace until the first time the acceleration passes through zero at the end of the trace. Convert to m/s by multiplying by 9.81.

1.3.5.2.2 (For 16 km/h pulse) Find the time in milliseconds at which the recorded sled velocity change reaches <u>4.0 m/s</u> and use the next highest whole number. For example, both 61.3 ms and 61.8 ms should be converted to 62 ms. If the exact value is a whole number (e.g. 60.0 ms) no adjustment is necessary.

1.3.5.2.3 (For 24 km/h pulse) Find the time in milliseconds at which the recorded sled velocity change reaches <u>4.62 m/s</u> and use to the next highest number.

For example, both 61.3 ms and 61.8 ms should be converted to 62 ms. If the exact value is a whole number (e.g. 60.0 ms) no adjustment is necessary

1.3.5.2.4 Subtract the time recorded in step 1.3.5.2.2 or 1.3.5.2.3 from 70 ms. Add the difference to the time indexed head contact time from step 1.4.1.5 (16 km/h) or 1.4.2.5 (24 km/h). The resulting value will be the official head contact time used for evaluation.

1.4 Crash pulse

The target sled acceleration and pulse specifications are given for the 16 km/h delta V pulse in Figure 11 and Table 3, respectively. The target sled acceleration and pulse specifications are given for the 24 km/h delta V pulse in Figure 12 and Table 4, respectively. Sled accelerations should be measured by an appropriate accelerometer attached to the sled platform and recorded according to the Society of Automotive Engineers Standard J211-1 (SAE, 2022) . Prior to establishing conformance with the acceleration pulse specification, any quiescent signal bias should be removed from the acceleration measurement. Conformance with pulse duration, peak acceleration and timing are done with the signal filtered to channel frequency class (CFC) 60. Velocity change (delta V) is judged using velocity calculated from a CFC 180 signal. For delta V calculation, integrate the sled acceleration data from the last time the acceleration passes through zero at the beginning of the trace until the first time the acceleration passes through zero at the end of the trace. Figure C-1 shows the typical variation in accelerations for the 16 km/h delta V pulse from 50 tests conducted on the IIHS sled, and Figure C-2 shows the typical variation in accelerations for the 24 km/h delta V pulse from 40 tests conducted on the IIHS sled.

1.4.1 Test time indexing (16 km/h)

To normalize the time index among sled laboratory protocols with different T = 0 trigger levels, the time of the occurrence of the maximum acceleration is used as the reference for indexing time. The procedure is described as follows:

1.4.1.1 Record the X-acceleration of the sled in accordance with SAE J211-1 (SAE, 2022).

1.4.1.2 Remove data channel DC bias by subtracting the average of the first 100 samples of the quiescent data channel signal from every test measurement.

1.4.1.3 Filter the sled acceleration to CFC 60 as defined by SAE J211-1 (SAE, 2022).

1.4.1.4 Find the measurement that corresponds to the maximum sled acceleration and note the time it occurs.

1.4.1.5 Subtract 27 ms from the time noted in step 1.4.1.4 and use the resulting difference to re-index the time. If the difference is positive (>0), then measurements recorded at the original T = 0 will now occur before T = 0. If the difference is negative (<0), then measurements recorded at the original T = 0 will now occur after T = 0. The peak sled acceleration (filtered data) should occur at exactly 27 ms.

Figure 11
16 km/h Delta V – Target sled acceleration and specification corridors

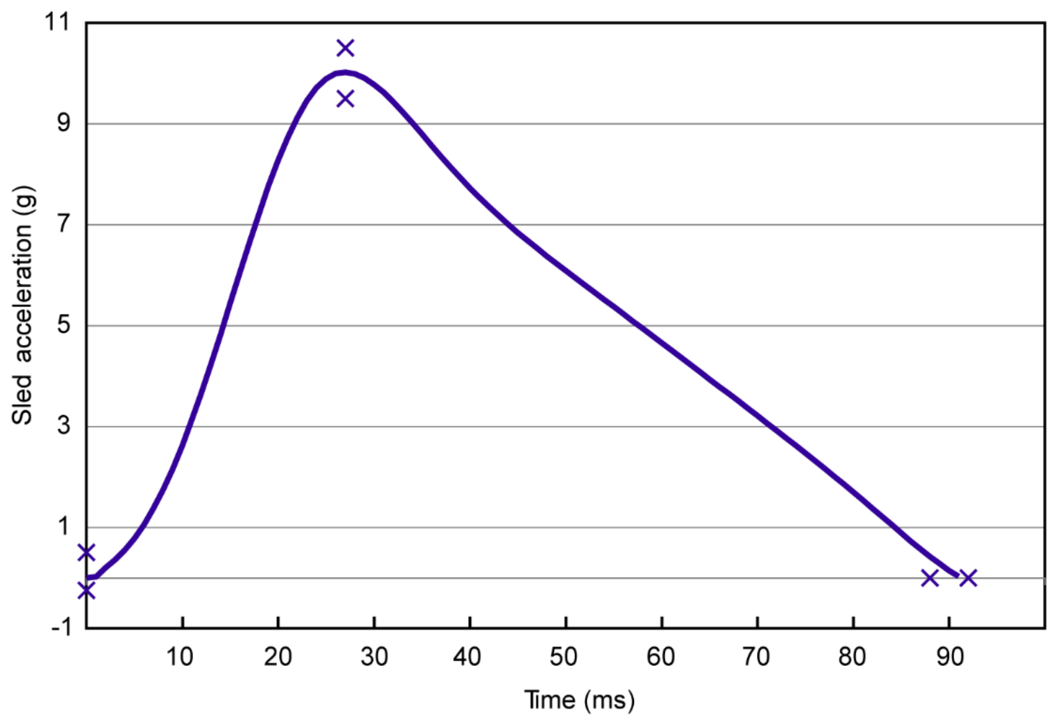


Table 3
16 km/h Delta V - Sled Acceleration Pulse Specifications

Acceleration Pulse Characteristic	Minimum	Maximum
Acceleration at time = 0 ms	-0.25 g	0.50 g
Acceleration at time = 27 ms	9.5 g	10.5 g
Time that sled acceleration returns to 0 g	88 ms	94 ms
Velocity change (delta V)	14.8 km/h	16.2 km/h

1.4.2 Test time indexing (24 km/h)

To normalize the time index among sled laboratory protocols with different T = 0 trigger levels, the time of the occurrence of 1 g acceleration is used as the reference for indexing time. The procedure is described as follows:

1.4.2.1 Record the X-acceleration of the sled in accordance with SAE J211-1 (SAE, 2022).

1.4.2.2 If necessary, remove any data channel DC bias. Typically, the value of the average measurement over 100 samples of the quiescent data channel signal is subtracted from every test measurement.

1.4.2.3 Filter the sled acceleration to CFC 60 as defined by SAE J211-1 (SAE, 2022).

1.4.2.4 Find and note the time that corresponds to the 1 g sled acceleration.

1.4.2.5 Subtract 3.7 ms from the time noted in step 1.4.2.4 and use the resulting difference to re-index the time. If the difference is positive (>0), then measurements recorded at the original T = 0 will now occur before T = 0. If the difference is negative (<0), then measurements recorded at the original T = 0 will now occur after T = 0.

Figure 12
24 km/h Delta V – Target sled acceleration and specification corridors

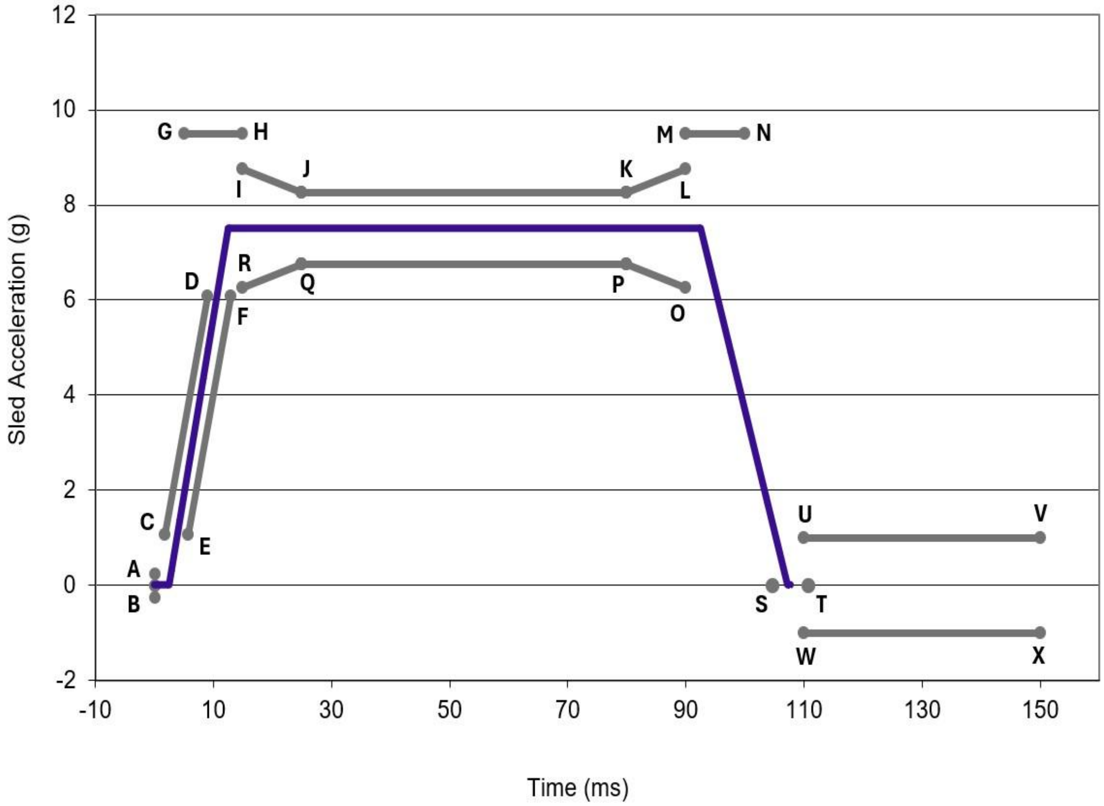


Table 4
24 km/h Delta V – Sled acceleration pulse specifications

Parameter	Target	Minimum	Maximum
Velocity Change	24.45 km/h	23.25 km/h	25.65 km/h
Mean Acceleration	6.44 g	5.94 g	6.94 g
Maximum Acceleration	7.50 g	6.75 g	8.25 g

	Time (ms)	Acceleration (g)		Time (ms)	Acceleration (g)
A	0	0.25	M	90	9.50
B	0	-0.25	N	100	9.50
C	1.8	1.0714	O	90	6.25
D	9	6.0880	P	80	6.75
E	5.8	1.0714	Q	25	6.75
F	13	6.0880	R	15	6.25
G	5	9.50	S	104.7	0.00
H	15	9.50	T	110.7	0.00
I	15	8.75	U	110	1.00
J	25	8.25	V	150	1.00
K	80	8.25	W	110	-1.00

2 Physical test procedure for verification data submission

Physical tests conducted for submission to IIHS as verification data should comply with section 1 (IIHS physical test procedure) with targets provided by IIHS as described in the following steps.

2.1 General test requirements

General test requirements should comply with section 1.1.1 of the IIHS physical test procedure.

2.2 Sled and vehicle environment

- The sled and vehicle environment should comply with section 1.2.1 – 1.2.5 of the IIHS physical test procedure.
- The seat adjustments should be set according to section 1.2.6, ensuring that the CoRP point (X and Z) relative to the left front seat bolt attachment hole (LFSBH) of the unweighted seat aligns (± 5 mm) of the point located by IIHS in step 2 of the workflow. The vertical distance between the heel point and left front seat bolt attachment hole (LFSBH) should be within ± 5 mm of the target used by IIHS in step 2 of the workflow.
- The seatback angle should be set using the CHRP relative to CoRP (Figure 5) horizontal and vertical distances (± 5 mm) for an unweighted seat provided by IIHS after the completion of step 2 of the workflow. Larger tolerances may be accepted for manually adjustable seatbacks.
- The head restraint should be set to match the position provided by IIHS after the completion of step 2 of the workflow. After the head restraint is positioned, the Head Restraint Point (HRP) @ Test Position should be located on the front surface of the head restraint at centerline within ± 5 mm of the vertical distance relative to the CoRP provided by IIHS after the completion of step 2.

2.3 Dummy and seating procedure

The dummy and seating procedure should comply with section 1.3 of the IIHS physical test procedure, except that targets for H-point and backset should be those provided by IIHS after the completion of step 2 of the workflow. The BioRID H-point should be 20 ± 10 mm forward of the manikin location provided by IIHS. BioRID's backset to the Head Restraint Point (HRP) @ Test Position should be the manikin backset provided by IIHS plus 15 ± 5 mm.

2.4 Crash pulse

The crash pulse used should comply with section 1.4 of the IIHS physical test procedure.

3 Simulation procedure for verification data submission

3.1 General simulation requirements

The simulation should replicate the occupant positions and the initial and boundary conditions from the physical test protocol and meet the requirements described in this simulation procedure.

3.1.1 Solver requirements

Simulation result submissions must have originated from (or been successfully traced back to) a Finite Element Model Explicit Solver (e.g., LS-DYNA). The solver software and version will be reported to the IIHS using the *IIHS Rear Impact SIMULATION Data Submission Template.xlsx* template.

3.1.2 Hourglass energy

Automakers will self-report to verify that the hourglass energy of each part of the model remains below 5% of its internal energy at all times.

IIHS will use the submitted global hourglass and internal energy time-histories to verify the hourglass energy rate is correct for the model as a whole.

3.1.3 Added mass

Automakers will self-report to verify that the added mass of each part of the model remains below 5% of the physical mass of its corresponding deformable elements at all times.

IIHS will use the submitted added mass time-history and the reported physical mass of the model to verify the added mass ratio is correct for the model as a whole.

3.1.4 Simulation setup

Simulations must be run at least until the end of head contact time with the head restraint plus 10 ms.

3.1.5 Dummy sensor coordinate systems

The results of each channel must be reported in the coordinate systems in accordance with SAE J211 (SAE, 2022).

3.1.6 Reporting

Automakers will report on all fields indicated in the *IIHS Rear Impact SIMULATION Data Submission Template.xlsx* template and the “data submission” section of this protocol. The template requests information about:

- Solver version
- Model units
- Orientation of the global coordinate system
- Mesh quality
- Model mass
- Time step
- Dummy model
- Seat model
- Seating procedure
- Time-history outputs

3.2 Dummy model

3.2.1 Qualification

Only simulations conducted using pre-approved dummy models will be accepted for assessment. IIHS will determine whether to accept simulations after evaluating the evidence regarding model validity. Appendix D includes a list of all pre-approved dummy models for use in the assessment. Automakers using additional commercially available dummy models or modified versions thereof must seek IIHS approval before submitting results for virtual assessment.

A qualification procedure for rear impact human surrogates is under consideration for future revisions to the protocol.

3.2.2 Seating procedure

Automakers are free to choose the most convenient seating procedure (e.g., settling by gravity, forcing position, etc.) provided that the simulation complies with the following position requirements until Time = 10 ms (with time zero defined based on the pulse shift described in section 1.4):

- The deviation between the midsagittal plane of the dummy and the centerline of the seat must remain below 2 degrees.
- The dummy's midsagittal plane must remain within ±2 degrees of the vertical direction.
- The head frontal, sagittal, and coronal planes must remain within ±2 degrees of the corresponding seat planes.
- The H-point position must remain 20±10 mm forward of the H-point manikin settling location provided by IIHS, understood as the absolute geometric location rather than the location relative to the seat.
- The pelvis angle must remain at 26.5±2.5 degrees from horizontal.
- The centerlines of the dummy knees and ankles must remain 200±10 mm apart.
- The backset must remain 15±5 mm forward of the H-point manikin calculated backset (horizontal distance between Horizontal head point (x) from 1.3.4.3 and the Head restraint point @ test position (x) from 1.3.3.6) provided by IIHS. Unlike the other requirements, this condition only needs to be maintained until Time = 5 ms.

3.3 Sled and vehicle environment

3.3.1 Model details and modifications

The automaker is responsible for modeling the vehicle environment (e.g., seat) with sufficient detail to accurately predict the response observed in the physical test.

Different vehicle environment models (e.g., material characteristics) may be used for the different load cases if it leads to improvements in the prediction of the physical test, except otherwise noted in this document.

3.3.2 Seatbelt model

The automaker should ensure the seatbelt retractor mechanisms represent their physical counterparts as utilized in the physical tests, where relevant for rear impact crashes.

3.3.3 Seat and seatbelt position

The vertical distance between the center of the seat recliner (Figure 5A) and the center of the left front attachment point hole (Figure 1) must remain within ±5 mm of the manikin drop value provided by IIHS until time > 5 ms (with time zero defined based on the pulse shift described in section 1.4).

The angle between the seat recliner and the lateral head restraint post (measured at its intersection with the seatback) must remain within ±0.5 degrees of the manikin drop value provided by IIHS until time > 5 ms (with time zero defined based on the pulse shift described in section 1.4).

- The geometric location of the physical seatbelt anchors, buckle, and D-rings relative to the physical seat shall be preserved in the simulation model.

3.3.4 Sled model

The seat and seatbelt model (when applicable) must be attached to the sled (either rigidly or using a realistic bolt representation) at their corresponding attachment points.

The sled must be represented as a rigid body (even if limited to four nodes at the attachment points) and driven using prescribed motion.

The use of gravitational fields (i.e., body loads) to represent the pulse is not permitted.

3.4 Crash pulse

IIHS will provide automakers with:

1. An average pulse for each load case
2. A range of feasible non-average pulses for each load case

Automakers will be asked to:

1. Use the average pulses provided by IIHS for their simulation submissions.
2. (optionally) Submit simulation results using any or all of the non-average pulses provided by IIHS. These data will be used to identify the simulation result with the pulse most closely matching the physical test for audit purposes.

DATA SUBMISSION

4 General data submission

Data submission formats and methods are under review and still in development. The methods and formats for data exchange described in this document will be used until formats can be finalized and submission tools developed.

5 Physical test-specific data submission

5.1 Test data

Seat and dummy setup information and test outputs should be reported using the *IIHS Rear Impact PHYSICAL TEST Data Submission Template.xlsx.* All fields must be completed unless specified. Time-history data should have a minimum frequency of 10,000 Hz and at least 100 ms of data before sled trigger.

5.2 Video

1. A lateral left view (either stationary following the sled reference frame) (orthogonal to the plane of motion) that captures the entire event from the onset of acceleration to 100 ms past the end of head contact time.
2. A lateral right view (orthogonal to the plane of motion) that captures the entire event from the onset of acceleration to 100 ms past the end of head contact time.

Timestamp – Video must be timestamped in milliseconds aligned with RAW data
Format - .mp4 or .avi
Codec - H.264
Collection frame rate minimum – 500 fps
Replay frame rate – 10 fps

6 Simulation-specific data submission

6.1 General data

All points described in section 3 *Simulation procedure for verification data submission* should be provided in binary format or reported in the *IIHS Rear Impact SIMULATION Data Submission Template.xlsx* provided by IIHS unless otherwise noted as optional. Time-history data should be provided from time zero to 10 ms after the end of head contact time and should have a minimum frequency of 10,000 Hz.

6.2 Video

The following videos should be provided from simulations:

1. A lateral left view of the animation (filename: "Year_Make_Model_[16 or 24]_left.[ext]")
2. A lateral left view of the animation following on the sled reference frame (filename: "Year_Make_Model_[16 or 24]_left_follow.[ext]")
3. A lateral right view of the animation (filename: "Year_Make_Model_ [16 or 24]_right.[ext]")
4. A lateral right view of the animation following on the sled reference frame (filename: "Year_Make_Model_ [16 or 24]_right_follow.[ext]")
5. A frontal view of the animation (filename: "Year_Make_Model_ [16 or 24]_frontal.[ext]")
6. A rear view of the animation (filename: "Year_Make_Model_ [16 or 24]_rear.[ext]")
7. A top-down view of the animation (filename: "Year_Make_Model_ [16 or 24]_top.[ext]")
8. A bottom-up view of the animation (filename: "Year_Make_Model_ [16 or 24]_bottom.[ext]")

All videos must:

- Originate from a simulation output (e.g., d3plot) with a frequency of at least 1 step/ms.
- Be framed and adjusted so that the view is maximized while ensuring that the entire model is visible from beginning to end.
- Be taken from time zero to at least end of head contact time with the head restraint plus 10 ms.
- Meet the following specifications:

  Timestamp – Video must be timestamped in milliseconds aligned with RAW data
  Format - .mp4 or .avi
  Codec - H.264
  Replay frame rate – 10 fps
  File size – 1-10 MB

AUDITING METHODS

7 Load case audit

After receiving the corresponding physical tests or simulations for verification, IIHS will select one of the two load cases at random (i.e., either the 16- or the 24-kph case) to audit the submitted data. IIHS will then conduct a physical test for the selected audit load case and determine whether the submitted data for that case successfully represents the physical test, based on the criteria described in Section 10. If the audited data meets said criteria, the submitted results for both load cases will be accepted for assessment.

In the near term, if the audited data fails to meet the requirements of the audit, IIHS will conduct an in-house physical test of the unaudited load case to complete the assessment and allow the vehicle to be eligible for the IIHS TSP award. The automaker will be responsible for providing the additional seat. IIHS will only conduct a physical test on the unaudited load case if the automaker has made a good faith effort to complete the verification data submission in accordance with the IIHS Rear Impact Evaluation 2.0 protocol.

8 Data processing at IIHS

- The test data will be debiased according to 1.4.1.2.
- The time-history data provided by the automaker will be filtered before determining its acceptability using the CFC filters defined in Table 6**.**
- The time vector will be indexed using the methods described in section 1.4.
- The debiased (when applicable), filtered, and zeroed individual components of head, L1, and pelvis accelerations will be used to calculate the resultant accelerations of the corresponding bodies.
- The debiased (when applicable), filtered, and zeroed individual components of left T1 accelerations will be used to calculate the T1 resultant acceleration.
- The pelvis displacement metric will be calculated with the sled x direction pointing forward using Equation 4 for test data and Equation 5 for simulation data.
- For test data, the sagittal velocity components of the head and pelvis will be calculated by integrating the corresponding accelerations using Equation 6 and Equation 7. For simulation data, the velocity components will be obtained directly from the model output. In both cases, the resultant velocity in the sagittal plane will be calculated using Equation 8.
- The head-to-pelvis relative velocity metric will be calculated using Equation 9.
- NKM will be calculated using Equation 10 and Equation 11.
- The simulation head contact time will be defined as the first time of non-zero contact force between the head and the head restraint.
- The simulation end of head contact time will be defined as the step after the last time of non-zero contact force between the head and the head restraint.

Table 5
Table of equations for calculated metrics

Test type	Calculation	Equation number

Physical test	$\text{Pelvis displacement} = \min\left(\iint a_{pelvis_x} dxdx - \iint a_{sled_x} dxdx\right)$	Equation 4
Simulation	$\text{Pelvis displacement} = \min\left(\int v_{pelvis_x} dx - \int v_{sled_x} dx\right)$	Equation 5
Physical test	$v_{region_x} = \int a_{region_x} dx$	Equation 6
Physical test	$v_{region_z} = \int a_{region_z} dz$	Equation 7
Simulation	$v_{region} = \sqrt{{v_{region_x}}^2 + {v_{region_z}}^2}$	Equation 8
Physical test and simulation	$\text{Head-to-pelvis relative velocity} = \min(v_{head} - v_{pelvis})$	Equation 9
Physical test	$OCmoment = Upper\ y\ moment\ -\ Upper\ x\ force\ *\ .01778$	Equation 10
Physical test and simulation	$NKM = \frac{Fx(t)}{Fint} + \frac{Mocy(t)}{Mint}$	Equation 11

Table 6
Time-history data and filters for calculating ISO scores and peak absolute error

Time-history data	CFC Filter
Head acceleration (all components)	180
Head velocity (all components)*	180
T1 left acceleration (all components)	180
L1 acceleration (all components)	180
Pelvis acceleration (all components)	180
Pelvis velocity (all components)*	180
Upper neck force X	600
Upper neck force Z	600
Upper neck moment Y	600
Head-to-headrest contact (all components)*	N/A

*only applicable to simulation data

9 Pulse selection

IIHS will provide three pulses for each load case that fall within the corridors for pulse acceptance but span the range of variability observed in the IIHS sled. Appendix C and the *IIHS rear impact sled pulses.xlsx* spreadsheet contain the pulses that will be accepted. IIHS suggests that automakers submit a simulation for each (three for 16 km/h and three for 24 km/h) to improve their likelihood of passing the audit. After the audit test is complete, the pulse that aligns most closely with the delta V of the IIHS sled pulse will be chosen to compare with the IIHS physical test. The unaudited test will use the standard pulse.

Note: The IIHS acceleration sled is being replaced fall 2025. After this is complete, the additional pulses will be provided based on the output variability of the new sled.

10 Test and simulation acceptance

IIHS will consider the submitted test or simulation accepted for assessment if:

1. All the points in Sections 2 or 3 have been followed for both load cases
2. The data corresponding to the audited load case meets the criteria outlined in Section 10.1

10.1 Acceptance criteria

- IIHS will audit time-history and peak metric data to determine data acceptance.
- For the submitted data to pass the audit, both the time-history and peak metric criteria as described in Sections 10.1.1 and 10.1.2 must be met.

10.1.1 Time-history data

- The ISO score for the head, T1, L1, and pelvis resultant accelerations will be calculated using the submitted data with the results of the audit test as reference.
- The corridor, magnitude, and phase scores will be calculated using the time-histories filtered as described in Table 6.
- An additional CFC60 filter will be applied to the time-histories before calculating the slope component of the ISO score to reduce artefacts derived from signal noise.
- The window for the ISO score will span from time zero to end of head contact time plus 10 ms in the reference test.
- The ISO score will be calculated using the parameters in Table 7.
- The submitted data will be considered to have met the time-history acceptance criterion if the ISO score is greater or equal to 0.7 for the time-histories indicated in the first point.

Table 7
ISO scoring parameter values

Parameter	**Value**
Exponent factor for calculating the corridor score between the inner and outer corridors (k_Z)	2.0
Relative half width of the inner corridor (a_0)	0.05
Relative half width of the outer corridor (b_0)	0.5
Exponent factor for calculating the phase score (k_P)	1
Maximum allowable percentage of time shift (ε^*_P)	0.2
Exponent factor for calculating the magnitude score (k_M)	1
Maximum allowable magnitude error (ε^*_M)	0.5
Maximum allowable slope error (ε^*_S)	2.0
Weighting factor of the corridor score (w_Z)	0.4
Weighting factor of the phase score (w_P)	0.2
Weighting factor of the magnitude score (w_M)	0.2
Weighting factor of the magnitude score (w_S)	0.2

10.1.2 Peak metric data

- The absolute error between the submitted data and the audit test results will be calculated for the metrics used for rating and normalized using the corresponding normalization factors (Equation 12).
- The submitted data will be considered to have met the peak metric acceptance criterion if the normalized absolute error is lower than 1 for all peak metrics.

$$Normalized\ absolute\ error = \frac{\left|Result_{audit\ test} - Result_{verification}\right|}{Normalization\ factor} \qquad \text{Equation 12}$$

Note: At a minimum, all peak metrics used for rating will be subject to the peak metric acceptance criterion. Normalization factors for these metrics will be published with the rating guidelines.

REFERENCES

Economic Commission for Europe. (2022) Inland transport committee. World forum for harmonization of vehicle regulations. Mutual resolution No. 1 (M.R.1) of the 1958 and 1998 Agreements. Concerning the description and performance of test tools and devices necessary for the assessment of compliance of wheeled vehicles, equipment and parts according to the technical prescriptions specified in Regulations and global technical regulation. Amendment 3. Addendum 1. ECE/TRANS/WP.29/1101/Amend.3. https://unece.org/sites/default/files/2023-06/ECE-TRANS-WP.29-1101-Amend.3e.pdf

Gane, J. (1999). Measurement of vehicle head restraint geometry (No. 1999-01-0639). SAE Technical Paper.

Insurance Institute for Highway Safety. (2019). Vehicle Seat/Head Restraint Evaluation Protocol, Dynamic Criteria (Version V).

Insurance Institute for Highway Safety. (2022). Guidelines for using the UMTRI ATD positioning procedure for ATD and seat positioning (Version VI).

International Organization for Standardization (ISO). (2024). Road vehicles – Objective rating metric for non-ambiguous signals. ISO/TS 18571:2024

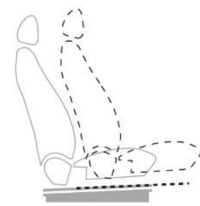
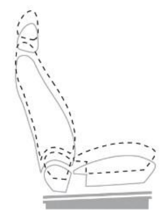
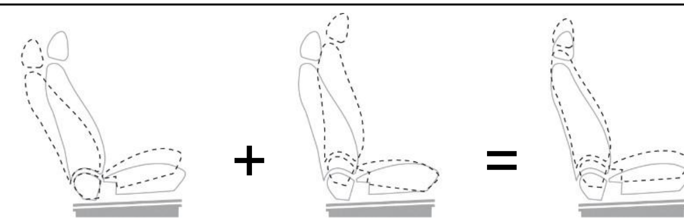
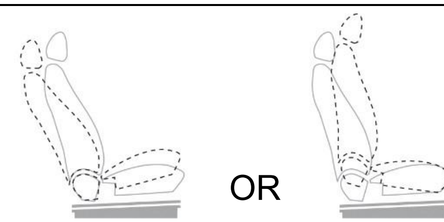
Society of Automotive Engineers. (2022). Surface vehicle recommended practice J211/1; Instrumentation for impact test, Part 1: Electronic instrumentation.

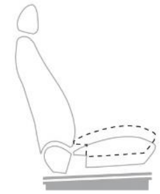
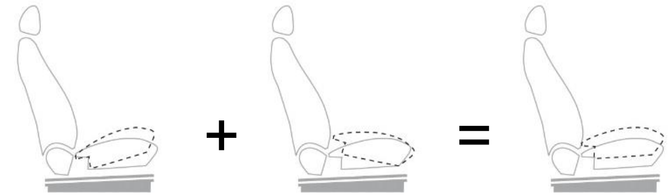
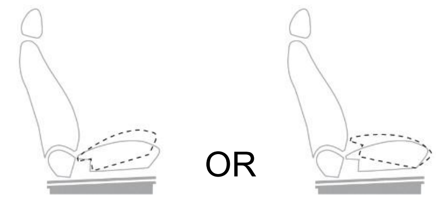
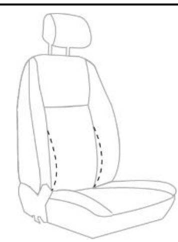
Society of Automotive Engineers. (2021). Standard J826; Devices for use in defining and measuring vehicle seating accommodation.

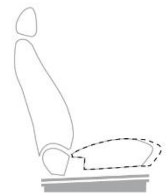
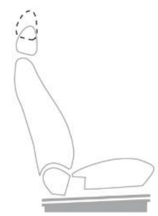
Society of Automotive Engineers. (2015). Surface vehicle recommended practice J1727; Calculation guidelines for impact testing.

Society of Automotive Engineers. (2018). Surface vehicle information report J1733; Sign convention for vehicle crash testing.

Appendix A – Seat adjustment definitions

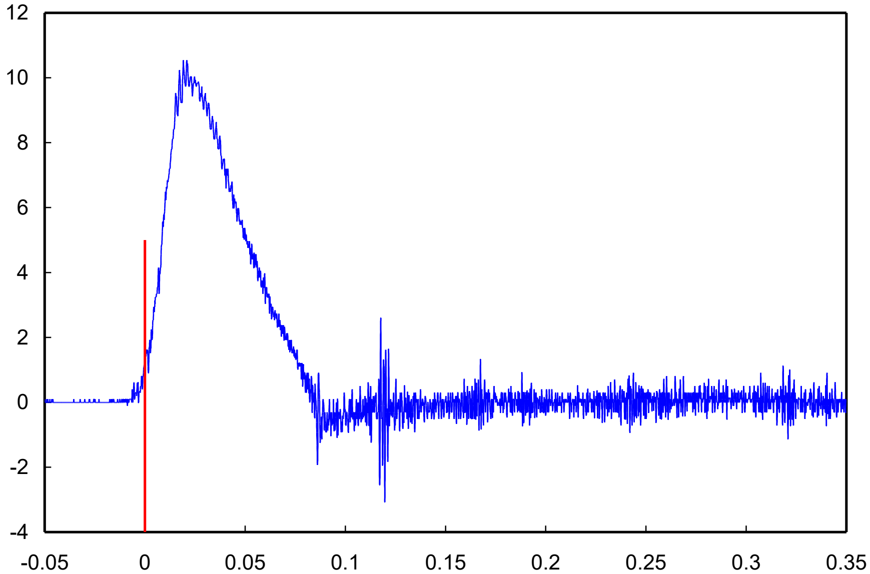
Definition	Image	Additional Images
Seat Track – An adjustment that moves the entire seat (seat cushion and seatback) in the fore and aft directions.		
Seatback – An adjustment that rotates the entire seatback, independently of the seat cushion, from a pivot at the seatback/seat cushion joint, therefore, changing the angle of the seatback relative to the seat cushion.		
Seat Height – An adjustment that moves the entire seat vertically (seat cushion and seatback in unison). This adjustment must keep the angle of the seat cushion the nearly the same relative to the ground. This can be one control (two-way) that moves the whole seat in unison or a combination of controls (four-way – a toggle or multiple knobs) that, when used together, keep the angle of the seat cushion nearly the same relative to the ground.	 Two-way (one control)	 Four-way (toggle or multiple knobs) NOTE: It is not possible to have four-way seat height AND seat tilt
Seat Tilt – An adjustment that rotates the entire seat (seat cushion and seatback in unison). This adjustment rotates a seat in such a way to significantly change the angle of the seat cushion, relative to the ground, from its full-down position. This adjustment can move either the front or rear of the seat to change the angle.		

Definition	Image	Additional Images
Seat Cushion Height – An adjustment that moves the seat cushion vertically, independent of the seatback, while keeping angle of the seat cushion nearly the same relative to the ground. This can be one control (two-way) that moves the whole seat cushion in unison or a combination of controls (four-way – a toggle or multiple knobs) that, when used together, keep the angle of the seat cushion nearly the same relative to the ground.	 Two-way (one control)	 Four-way (toggle or multiple knobs) NOTE: It is not possible to have four-way seat cushion height AND seat cushion tilt
Seat Cushion Tilt – An adjustment that moves the seat cushion, independent of the seatback, in such a way to significantly change the angle of the seat cushion, relative to ground, from its full-down position. This adjustment can move either the front or rear of the seat cushion to change the angle.		
Lumbar Support – An adjustment that causes the lower center portion of the seatback to protrude to provide support to the lumbar section of an occupant's spine.		
Upper Seatback – An adjustment that rotates only the upper portion of the seatback about a pivot point in the seatback. This adjustment will change the angle of the upper seatback relative to the lower portion of the seatback.		

Definition	Image	Additional Images
Cushion Extension – An adjustment that moves or extends a portion of the seat cushion forward so that the overall length of the cushion can be increased.		
Side Bolsters – An adjustment the moves the sides of the seatback or seat cushion so that the contour of the seat can be changed.		
Head Restraint Height – An adjustment that moves the head restraint vertically.		
Head Restraint Tilt – An adjustment that moves the head restraint horizontally.		

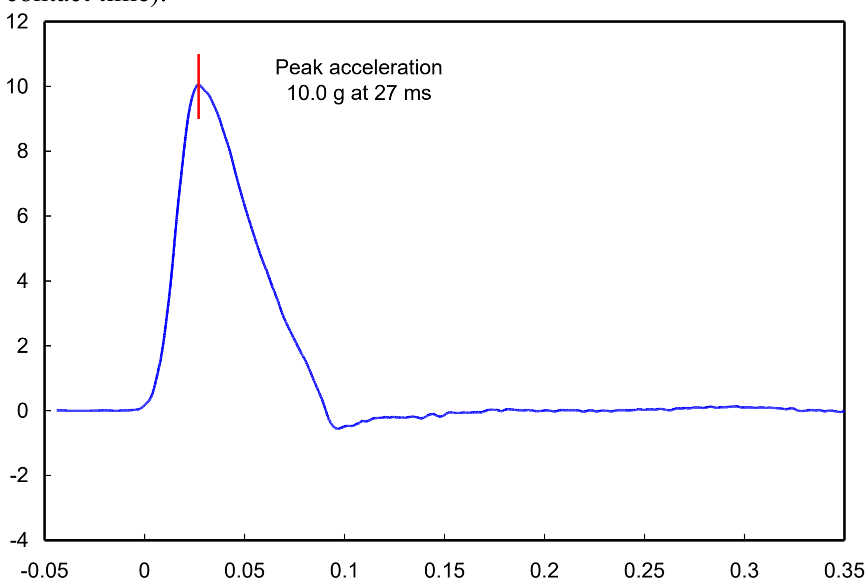
Appendix B – Example Head Contact Adjustment (16 km/h)

Step 1. Record sled acceleration.

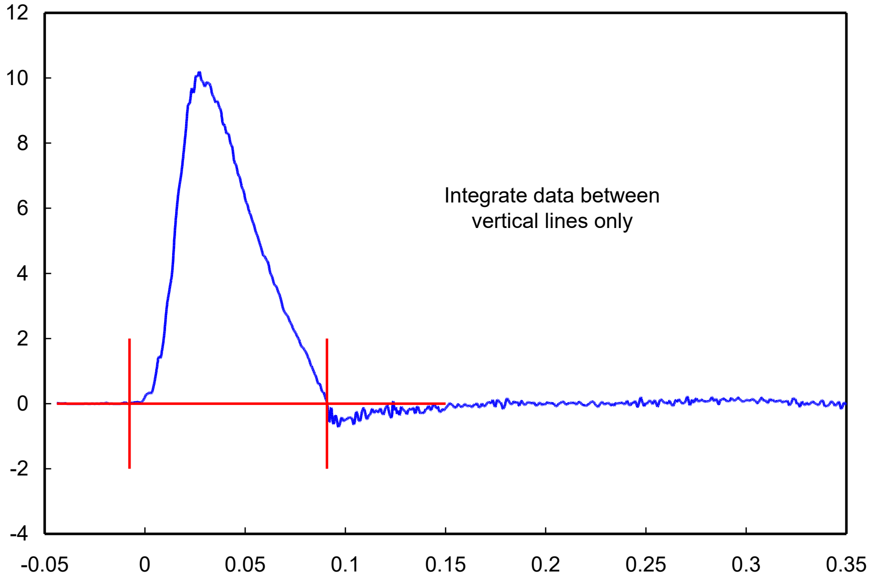


Step 2. Remove signal bias.

Step 3. Filter sled acceleration to CFC 60 to determine time shift and time shift all data (including head contact time).

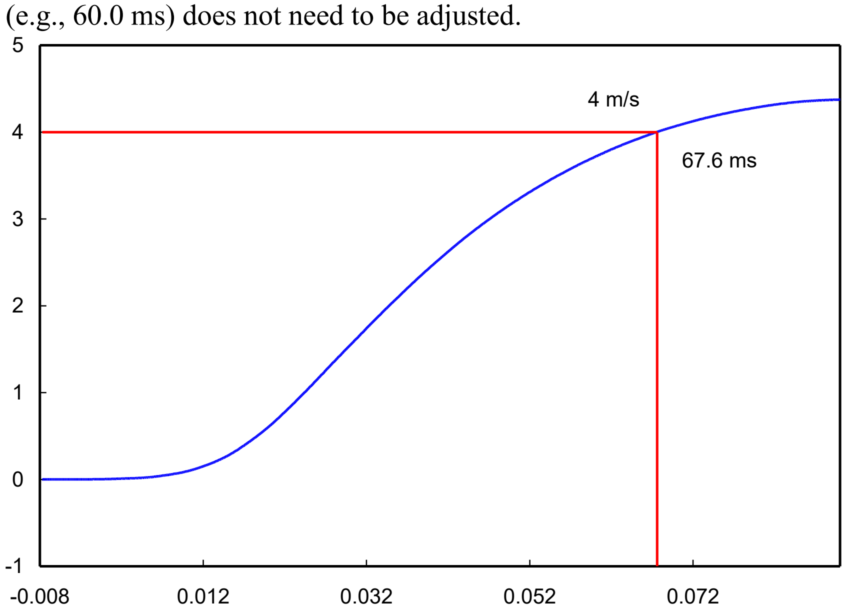


Step 4. Filter sled acceleration data to CFC 180. Integrate from the last time the acceleration passes through zero at the beginning of the trace until the first time the acceleration passes through zero at the end of the trace.

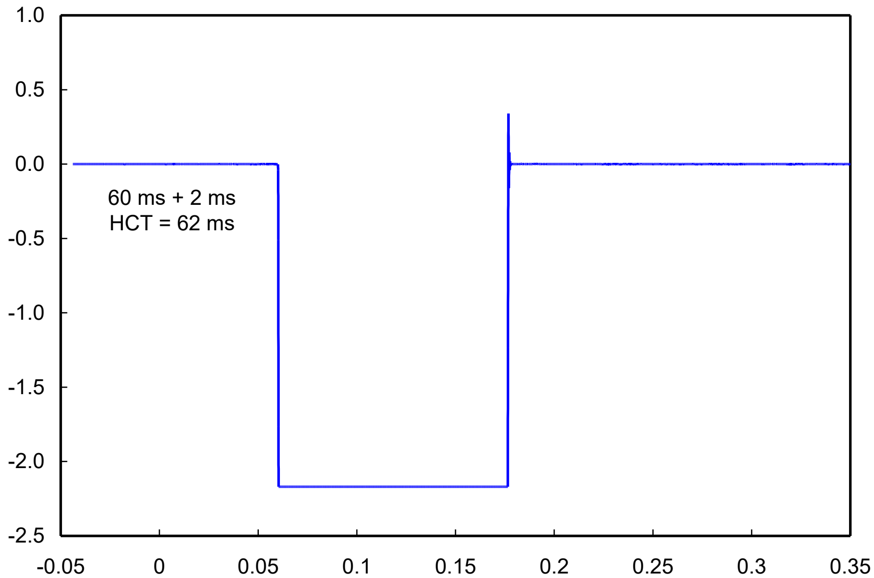


Step 5. Convert from g to m/s by multiplying by 9.81.

Step 6. Find the time at which the velocity change reaches 4 m/s and use the next highest whole number. For example, for both 61.3 ms and 61.8 ms a value of 62 ms should be used. An exact value recorded (e.g., 60.0 ms) does not need to be adjusted.



Step 7. Subtract the time recorded in step 6 from 70 ms. Add the difference to the time indexed head contact time from step 3. The resulting value will be the official head contact time (HCT) used for evaluation.



Appendix C – Crash Pulses

Figure C-1

16 km/h Delta V – Target sled acceleration and specification corridors

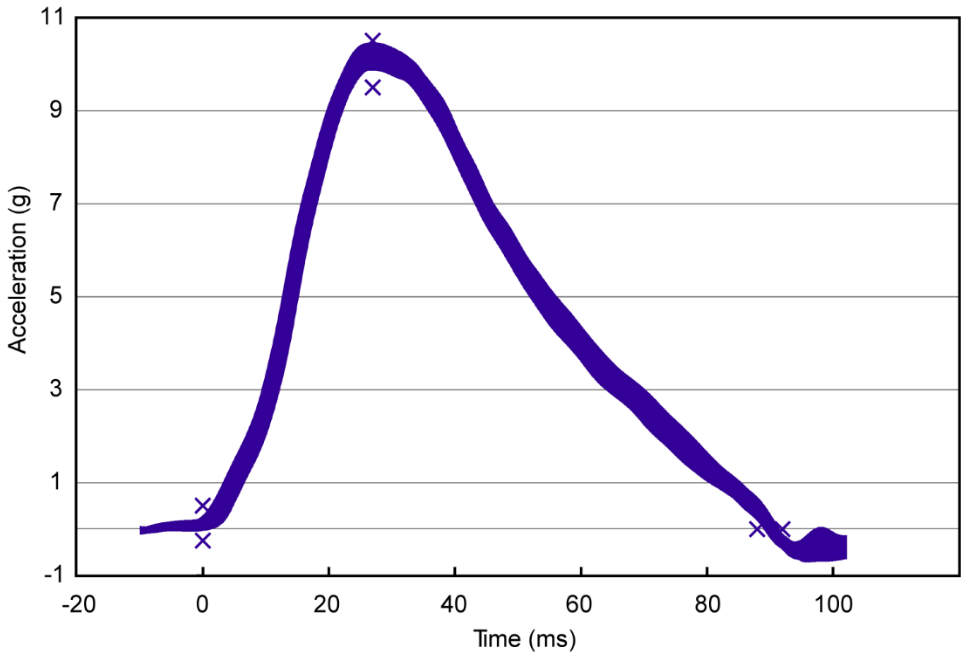


Figure C-2
24 km/h Delta V – Target sled acceleration and specification corridors

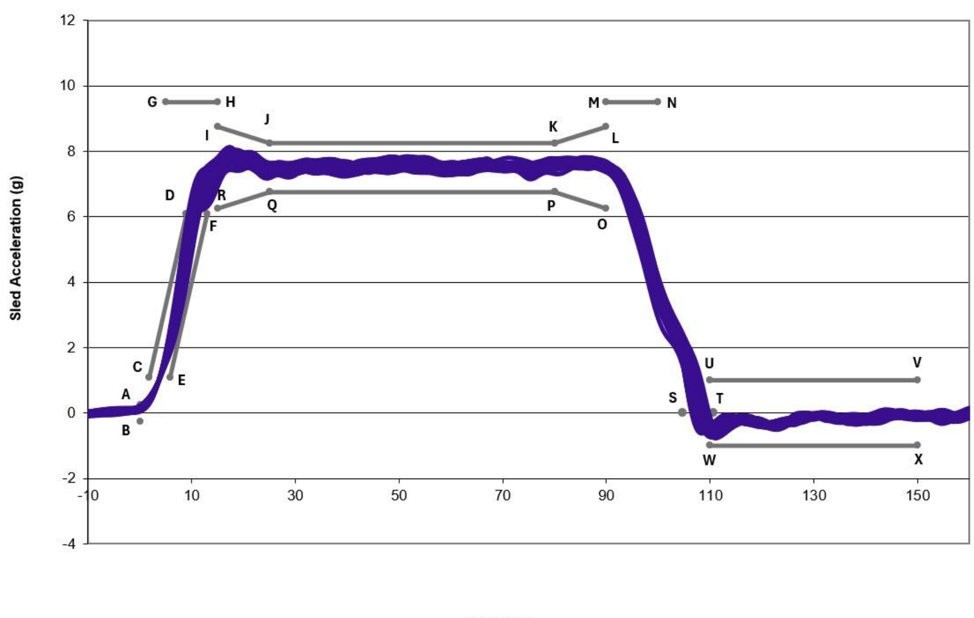


Figure C-3

16 km/h Delta V Crash pulses for simulation

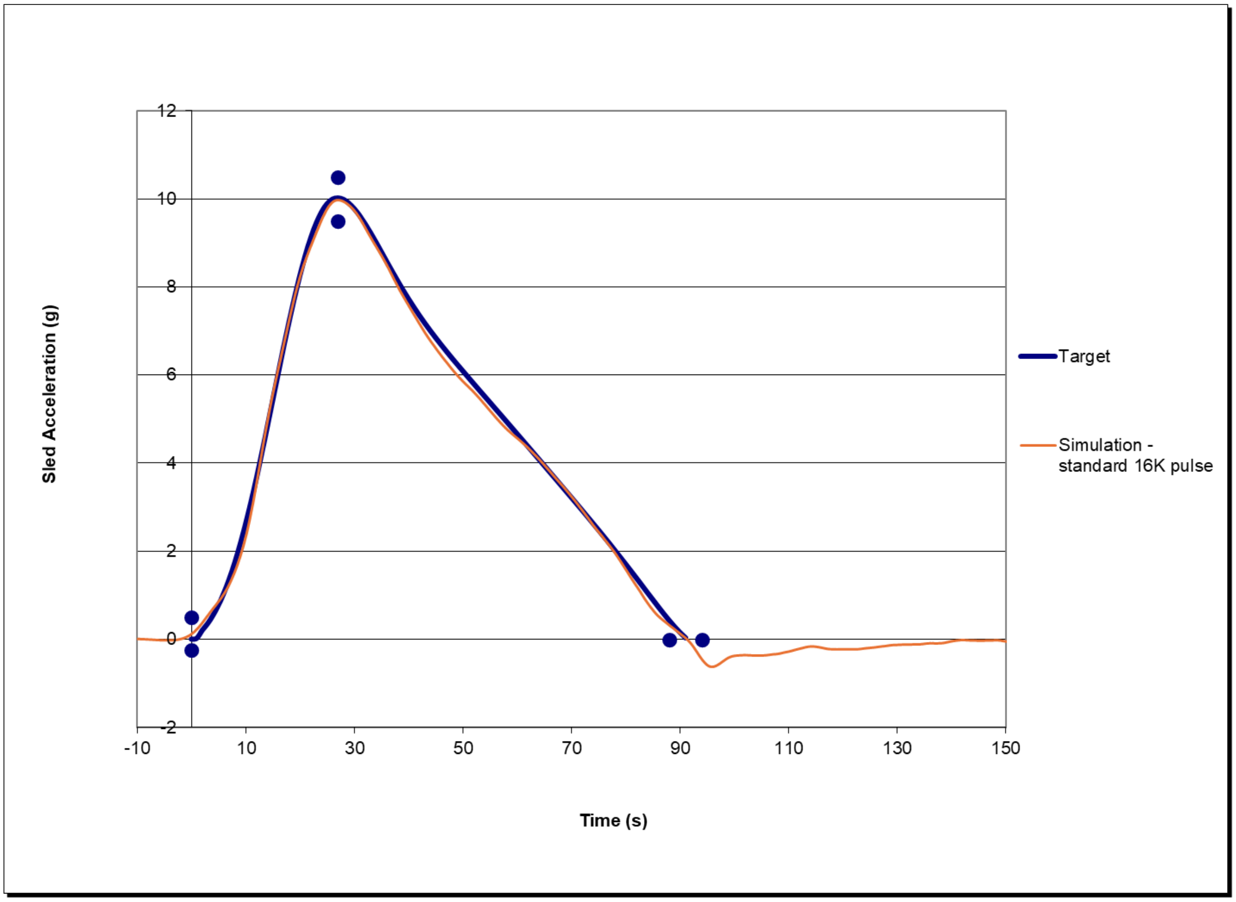


Table C-1
Parameters of the standard 16 km/h pulse for simulation (T0-Zero cross)

Acceleration pulse parameters	Target	16 km/h standard
Acceleration at time = 0 ms	0.125 g ± 0.375 g	0.12 g
Acceleration at time = 27 ms	10.0 g ± 0.5 g	10.0 g
Time that sled acceleration returns to 0 g	91 ms ± 3.0 ms	91 ms
Velocity change (delta V)	15.5 km/h ± 0.7 km/h	15.4 km/h

Figure C-4

24 km/h Delta V Crash pulses for simulation

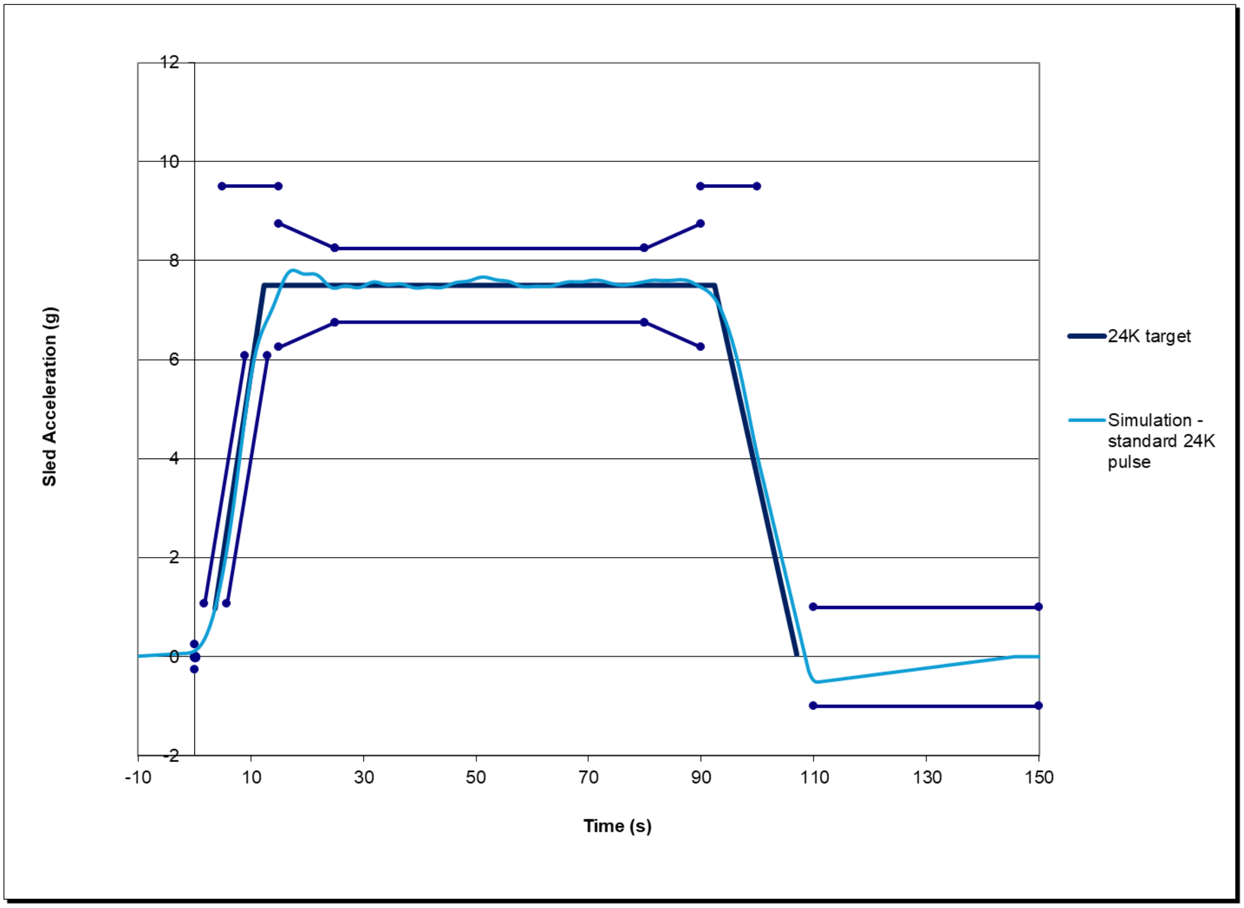


Table C-2

Parameters of the standard 24 km/h pulse for simulation (T0-Zero cross)

Acceleration pulse parameters	Target	24 km/h standard
Velocity Change	24.45 km/h	24.7 km/h
Mean Acceleration	6.44 g	6.5 g
Maximum Acceleration	7.50 g	7.8 g

Appendix D - List of approved dummy models

- DYNAmore GmbH LS-DYNA BioRID-II - Version 3.9 or newer
- PAM-SAFE BioRID FE model – Version 4.0 or newer (In review)

Appendix E - List of templates and their use

IIHS Rear Impact Seat Information.xlsx - is used by IIHS to receive seat setup information and manikin targets from automakers

{testId} Dummy Seating Form.xlsm – is used by IIHS to collect measurement from the seat, manikin and BioRID during the workflow and testing procedure. This sheet (incomplete) will be provided in step 3 of the workflow and then again (complete with dummy setup information) after the completion of the physical audit test in step 6 of the workflow.

IIHS Rear Impact PHYSICAL TEST Data Submission Template.xlsx – is used by automakers to provide verification test data from physical tests to IIHS

IIHS Rear Impact SIMULATION Data Submission Template.xlsx – is used by automakers to provide verification simulation data to IIHS

Rear impact pulse summary.xlsx – provides time-history information for the accepted pulses for the 16 km/h and 24 km/h load cases. There is currently only one pulse for each load case. The IIHS acceleration sled is being replaced fall 2025. After this is complete, the additional pulses will be provided based on the output variability of the new sled.