

# **SIDE IMPACT TEST PROCEDURES FOR IMPROVED WHEELCHAIR TRANSPORTATION SAFETY**

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16. Abstract  This project developed side impact test procedures for evaluating wheelchairs, wheelchair tiedowns and occupant restraint systems (WTORS), and vehicle-based occupant protection systems for wheelchair seating stations. This document includes the proposed procedures. This document is also included as Appendix E of the project final report.			
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## Introduction

These procedures were developed to provide improved safety in side impact crashes for people who travel while seated in their wheelchairs. The procedures will allow testing and development of:

- Wheelchairs that remain intact and keep the occupant positioned relative to the airbag under lateral loading
- Tiedowns that effectively secure wheelchairs under lateral loading
- Vehicle occupant protection systems for people using wheelchairs as vehicle seating in nearside and farside impact

The test procedures and tools address the different needs of wheelchair manufacturers, wheelchair tiedowns and occupant restraint systems (WTORS) manufacturers, and vehicle manufacturers, while also considering how to maximize both independence and safety of wheelchair users. While wheelchairs are designed for a variety of different user sizes, these initial procedures focus on testing products suitable for use by a midsized male occupant.

The design and performance requirements, and associated test methods, have been adapted from RESNA WC-4:2017 for use under side impact test conditions.

These procedures can be used to evaluate wheelchair performance in a 10-g, 13-mph lateral impact. Figure 1 shows the velocity versus time plot for this crash event. The test fixtures orient the wheelchair and tiedowns 80 degrees laterally (rotated 10 degrees toward frontal from a full 90-degree lateral impact), to account for the frontal component present in most side impact crashes. The test severity was developed by reviewing the FMVSS 214 and US Side NCAP acceleration profiles of passenger vehicles that can be converted for wheelchair use, generally vans, minivans, and SUVs. The profile of the loading wall used during wheelchair evaluation was also derived from these tests to represent the residual deformation seen in side impacts of these types of vehicles.

Three similar but separate procedures have been developed to reflect the different test goals for the three commercial items tested: WTORS, wheelchairs, and vehicle occupant protection systems.

In side impact, the WTORS purpose is to limit motion of the wheelchair and maintain the wheelchair in an upright position while remaining intact and not creating sharp edges or projectiles. WTORS should be tested to determine their strength under lateral loading. This is best accomplished using a sled test without a representation of a lateral wall to maximize the load on the tiedown elements. Since the test is primarily of strength and there are no lateral vehicle elements to interact with, the mass of the ATD is important but its ability to assess injury risk in side impacts is not. To maximize the tiedown loads, a wheelchair-anchored lap belt is used. The commercial WTORS is tested with a surrogate representation of a wheelchair and a mid-size male ATD.

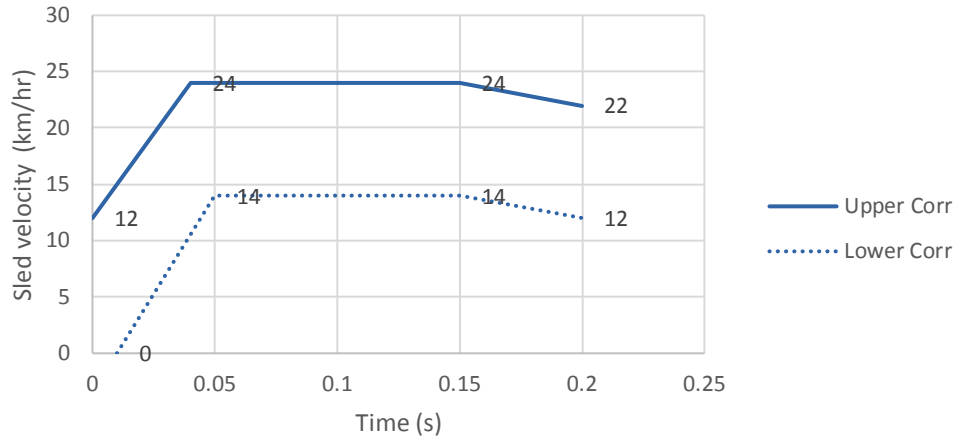


Figure 1. Side impact velocity corridor.

In side impact, the wheelchair should fill the role of a vehicle seat. The wheelchair should maintain the occupant in an upright seated position and maintain its essential size and shape, despite impact with vehicle interior elements. The wheelchair should stay intact and not create dangerous projectiles or sharp edges that can be contacted by vehicle occupants. To assess these qualities, the wheelchair is tested with a sled test that includes a surrogate WTORS and a generic representations of the deformed vehicle sidewall.

Much of the protection afforded to vehicle occupants in side impact comes from the vehicle environment and the built-in occupant protection systems. The anchoring of the occupant belts, characteristics of the vehicle side wall, and deployment parameters of the side airbags are all key factors that are determined by the vehicle manufacturer. These systems should be tested using a fidelic representation of the vehicle, such as sled testing (or simulations) with a body in white or a full vehicle side impact test, per FMVSS 214 or US Side NCAP. In these cases, the vehicle manufacturer may or may not know the characteristics of the WTORS that will be used, but they will need to plan to protect a wide range of occupants using many different wheelchair models. These vehicle systems are best evaluated using either a commercial (if known) or surrogate WTORS, a surrogate wheelchair, and a side impact ATD such as the ES2-re.

To accomplish these three distinct sets of target outcomes, three procedures are proposed.

## **Side Impact Test Procedures for WTORS**

### **Objective**

This procedure describes the tools and methods for sled testing using simulated side impact loading conditions that WTORS would experience in a 10-g, 13-mph side impact event when securing a wheelchair that faces forward in the vehicle (toward the primary direction of vehicle travel). In this procedure, the WTORS is evaluated for dynamic strength, structural integrity, and the system's ability to maintain the wheelchair and occupant in an upright seated position, so the occupant can benefit from vehicle features that mitigate side impact related loading and injury. WTORS that are designed to work with a wide range of wheelchairs are tested with a surrogate wheelchair base and a midsize male ATD. These same procedures can be used with WTORS systems that are designed for use by one specific wheelchair model. In the latter case, the commercial wheelchair could be used for testing.

### **WTORS Test Methods**

#### **Equipment**

The equipment needed to conduct this testing includes:

- A complete commercial WTORS that complies with ANSI/RESNA WC18
- A dynamic sled with a flat rigid mounting surface capable of the 10-g, 13-mph test pulse shown in Figure 1.
- Rigid fixturing where the upper shoulder anchor point can be attached. This anchor point fixture should not have any structural elements that extend into the head excursion area.
- Calibrated instrumentation to verify the tested pulse with a data collection system that complies with SAE J211
- A midsize male ATD
- A surrogate wheelchair base meeting the description found in Annex B of ANSI/RESNA WC20
- Two high speed digital video cameras capable of recording images at 500 fps or higher
- A means to accurately measure back support post angle with respect to vertical, lateral wheelchair and ATD excursions from the recorded video views.

Prior to conducting the test, make sure the sled instrumentation has been calibrated per the manufacturer in the past 12 months. Inspect the ATD for damage and adjust the joints to a resistance of 1 g. Dress the ATD in snug fitting cotton clothing as specified for federal crash testing requirements. Verify that the surrogate wheelchair base is in good working order and the tires are inflated per manufacturer specifications.

#### **Test Procedures**

1. Define a wheelchair station on the sled platform that is at least 76 cm (30 in) wide and 123 cm (48 in) long.
2. Orient the centerline of the wheelchair station so that in the plan (overhead) view, the centerline of the station is rotated 80 degrees clockwise from the primary direction of sled travel, as shown in Figure 2.

3. Install the WTORS per the manufacturer's instructions using the provided commercial anchorages and fasteners. In absence of manufacturer's instructions to the contrary, install the WTORS:
  - a. For strap-type tiedown systems, choose anchor points that are:
    - i. Symmetrically located with respect to the wheelchair center line (aka the wheelchair reference plane).
    - ii. At least 123 cm (48 in) apart from front to rear of the wheelchair
    - iii. Installed so that the rear anchorages are directly behind the wheelchair securement points and the rear tiedown straps are parallel to the wheelchair centerline when viewed from overhead.
    - iv. Installed so that the front tiedown points are outboard of the front wheelchair securement points, but not further apart than 76 cm (30 in).
  - b. For docking systems follow the manufacturers installation instructions.
4. Secure the wheelchair with the WTORS per the manufacturer's instructions.
5. Place the ATD into the wheelchair making sure the ATD is seated symmetrically with the torso upright and the back and legs pushed into and in contact with the wheelchair back support and seat.
6. Position the seat belt on the ATD with the lap belt routed at the junction of the pelvis/thigh and route the shoulder belt so that it diagonally crosses the collarbone, sternum and meets the lap belt at the hip. The shoulder belt anchor point should be located  $300\text{ mm} \pm 15\text{ mm}$  (11.8 in.  $\pm$  0.6 in.) behind the front edge of the ATD shoulder ('clavicle'),  $300\text{ mm} \pm 15\text{ mm}$  (11.8 in.  $\pm$  0.6 in.) lateral from ATD head center, and  $50\text{ mm} \pm 15\text{ mm}$  (6.9 in.  $\pm$  0.6 in.) above the top of the ATD's head.
7. Apply high contrast targets on the front corners of the wheelchair seatpan (to calculate excursion from overhead camera) and at the top and bottom of the seatback centerline (visible from rear camera) to allow calculation of angle.
8. Measure and record the WTORS anchorage locations, tiedown strap angles and seat belt angles.
9. Conduct the sled test.

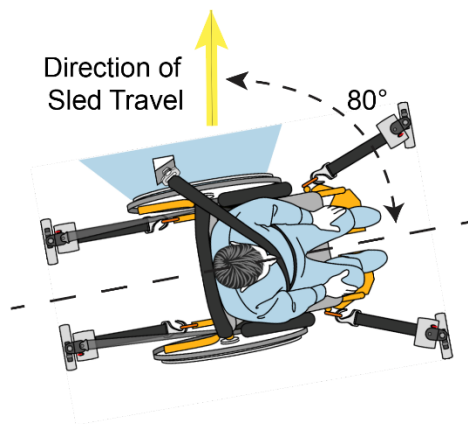


Figure 2. Overhead view of wheelchair station placement.

## **WTORS Performance criteria**

Examine the WTORS, ATD, and test wheelchair, and analyze the test films or videos to determine, measure, and/or calculate compliance with the criteria below:

1. The ATD should be in a seated posture in the wheelchair at the end of the test, with the ATD torso leaning less than 45° from the vertical when viewed from all directions,
2. The test wheelchair shall remain upright on the test platform,
3. Primary load-carrying parts and components of a WTORS shall not completely fail in the absence of a backup component or structural member without signs of failure,
4. Components of the WTORS that may contact the wheelchair-seated occupant or other nearby occupants shall not fragment or separate in a manner that produced sharp edges with a radius of less than 2 mm (0.08 in.),
5. Rigid components of the WTORS greater than 150 g (5.3 oz) shall not completely detach,
6. The wheelchair and ATD can be removed from the tiedown/securement system without the use of tools,
7. The maximum angle of the WC back support posts, relative to the vertical, shall not exceed 12 degrees, and
8. The lateral excursion of the right edge of the wheelchair seatpan near point-P shall not exceed 275 millimeters measured perpendicular to the initial wheelchair centerline.

## Side Impact Test Procedures for Wheelchairs

### Objective

This procedure describes the tools and methods for a sled test to simulated side impact loading conditions that wheelchairs would experience in a 10-g, 13-km/hr side impact event while traveling facing forward in the vehicle (toward the primary direction of vehicle travel). In this procedure, the wheelchair is evaluated for dynamic strength, structural integrity, and the wheelchair's ability to stay upright and maintain the occupant in an upright seated position, so the occupant can benefit from vehicle features that mitigate side impact related loading and injury. A staggered surrogate vehicle sidewall is used to represent the intruding vehicle wall at peak intrusion. This wall allows realistic loading between the vehicle and wheelchair frame. Wheelchairs are tested with a surrogate WTORS, and the procedure is suitable for testing products designed for an occupant the size of a midsized male ATD.

### Wheelchair Test Methods

#### Equipment

The equipment needed to conduct this testing includes:

- A complete commercial wheelchair that complies with ANSI/RESNA WC19.
- A dynamic sled with a flat rigid mounting surface capable of the 10-g, 13-km/hr test pulse shown in Figure 1.
- Rigid fixturing where the upper shoulder anchor point can be attached. This anchor point fixture should not have any structural elements that extend into the head excursion area.
- The side impact wall described in Annex A.
- Calibrated instrumentation to verify the tested pulse with a data collection system that complies with SAE J211
- A midsized male ATD.
- A surrogate WTORS meeting the description of Annex D of ANSI/RESNA WC19.
- Two high speed digital video cameras capable of recording images at 500 fps

Prior to conducting the test, make sure the sled instrumentation has been calibrated per the manufacturer in the previous 12 months. Inspect the ATD for damage and adjust the joints to a resistance of 1 g. Clothe the ATD in snug fitting cotton clothing as specified in federal crash testing standards. Verify that the surrogate wheelchair is in good working order and the tires are inflated per manufacturer's specifications.

#### Test Procedures

1. Define a wheelchair station on the sled platform that is at least 76 cm (30 in) wide and 123 (48 in) long.
2. Orient the centerline of the wheelchair station so that in the plan (overhead) view, the centerline of the station is rotated 80 degrees from the primary direction of sled travel, as shown in Figure 2.
3. Shift and secure the loading wall so it is parallel to the wheelchair centerline and positioned  $50 \pm 1$  cm ( $20 \text{ in} \pm 0.5 \text{ in}$ ) away from the closest point on the wheelchair.



4. The wheelchair should be adjusted to fit the ATD per the manufacturer's instructions and all adjustment mechanisms should be tightened per the user manual.
5. Adjustable elements of the seat (such as tilt and recline) should be in a middle position rather than at the end of adjustment travel.
6. The seat back support angle should be between 5 and 30 degrees from vertical when measured unloaded at the seatback centerline.
7. The seat pan angle should be between 5 and 30 degrees from horizontal when measured unloaded at the seat centerline.
8. Install the SWTORS so that the anchor points are:
  - a. Symmetrically located with respect to the wheelchair center line (aka the wheelchair reference place).
  - b. At least 48 inches apart from front to rear of the wheelchair.
  - c. Installed so that the rear anchorages are directly behind the wheelchair securement points and the rear tiedown straps are parallel to the wheelchair centerline when viewed from overhead.
  - d. Installed so that the front tiedown points are outboard of the front wheelchair securement points, but not further apart than 76 cm (30 in).
9. Secure the wheelchair with the SWTORS.
  - a. While maintaining the wheelchair reference plane within  $3^\circ$  of the centerline of the wheelchair station, adjust the fore/aft position of the wheelchair while tensioning the tiedown straps to between 100 N and 200 N (about 22 lbf and 44 lbf), to achieve a side-view projected angle of the rear tiedown straps of  $45^\circ \pm 3^\circ$  to the horizontal.
  - b. If a rear tiedown-strap angle in this range cannot be achieved with a tiedown-strap length of at least 495 mm (19.5 in.), adjust the length of the rear tiedown strap assemblies to between 495 mm and 508 mm (19.5 in. and 20 in.), and measure the resulting side-view projected angle of the rear tiedown straps.
10. Place the ATD into the wheelchair making sure the ATD is seated symmetrically with the torso upright and the back and legs pushed into and in contact with the wheelchair back support and seat.
11. Position seat belt on the ATD with the lap belt routed at the junction of the pelvis/thigh and route the shoulder belt so that it diagonally crosses the collarbone, sternum and meets the lap belt at the hip. The shoulder belt anchor point should be located  $300 \text{ mm} \pm 15 \text{ mm}$  (11.8 in.  $\pm$  0.6 in.) behind and  $173 \text{ mm} \pm 15 \text{ mm}$  (6.9 in.  $\pm$  0.6 in.) above the top of the ATD's shoulder.
12. Measure and record the SWTORS anchorage locations, tiedown strap angles, seat belt angles, the wheelchair width at the seat rails, the ATD H-point height, wheelchair back support angle, and wheelchair seat pan angle.
13. Conduct the sled test.

## **Wheelchair Performance Criteria**

When tested according to the procedures in this document, the wheelchair should meet the following requirements:

1. The wheelchair securement point structural components shall not fail completely.
2. The wheelchair securement points shall not deform such that the hooks of the four-point, strap-type surrogate tiedown system cannot be disengaged and removed.
3. The wheelchair should be in an upright position at the end of the test.
4. The ATD should be in a seated posture in the wheelchair at the end of the test, with the ATD torso leaning less than 45° from the vertical when viewed from all directions.
5. No rigid components, parts, equipment, or accessories with a mass greater than 150 grams (5.3 oz) should detach from the wheelchair during the test.
6. Wheelchair components that could contact the occupant seated in a wheelchair or nearby occupants should not break or separate in a manner that produces sharp edges with a radius of less than 2 mm (0.08 in.).
7. Locking mechanisms of tilt seating systems shall not have structural components that completely fail during the test. Shifting of seating-system orientation from release or slipping of a friction clamp are allowed if the sideview angle of the seating surface does not rotate below horizontal.
8. At the end of the test, the average height of the left and right ATD H-points relative to the wheelchair ground plane shall not have decreased by more than 20% from the pre-test average height.
9. At the end of the test, the average wheelchair width, measured at the seat rails shall not have decreased by more than 20% from the pre-test width.
10. Seats and back supports shall not separate or detach from the wheelchair or wheelchair frame unless there is a backup at the same point that remains functional.
11. No webbing of the surrogate wheelchair tiedown and occupant restraint system (SWTORS) or commercial WTORS shall completely fail due to interaction with the wheelchair or its components during a test.
12. All securement hooks of the SWTORS or commercial tiedown shall remain attached to the wheelchair securement points throughout the test.
13. Wheelchair-anchored belt restraints shall not become detached at anchorages, disconnected at buckles, or show complete webbing failure.
14. Batteries of power wheelchairs or their surrogate replacement parts shall:
  - i) not move completely outside the wheelchair footprint,
  - ii) remain attached or tethered to the battery compartment throughout the test, and
  - iii) shall not contact the ATD

## **Method for positioning wheelchairs, WTORS, and ATDs for in-vehicle testing and simulation**

These procedures adapt the methods for evaluating wheelchair dynamic performance on a sled using the procedures of WC19 so they can be used to evaluate occupant protection systems in vehicles through computational modeling or vehicle crash testing. The WC19 procedures were inspired by FMVSS 208 seating procedures.

### **Wheelchair Adjustment**

- 1) For wheelchairs with seats that adjust from front-to-back, adjust to the midpoint of the range, or to the location recommended by the wheelchair manufacturer for the size of ATD being tested.
- 2) For wheelchairs with multiple anchor points for belt restraints, choose the midpoint of the range, or the location recommended by the wheelchair manufacturer for the size of ATD being tested.
- 3) If desired, replace electronic components with substitutes having the same dimensions, mass, and center of gravity. For batteries, electrolyte fluid can be replaced with water. Batteries or their substitutes should represent the heaviest allowed for use with the wheelchair.
- 4) Inflate tires to the midpoint of the manufacturer's suggested pressure range.
- 5) If using, install the wheelchair-anchored lap belt or 5-point harness.
- 6) For wheelchairs with reclining seatbacks, adjust the seatback angle to 10 degrees rearward of vertical, measured along the centerline of the unloaded seatback.
- 7) For wheelchairs with adjustable seat cushions, or tilt seating systems, adjust to 10 degrees above horizontal, measured at the centerline of the seat cushion.
- 8) Tighten and lock any adjustments according to manufacturer's directions.
- 9) Apply the wheelchair brakes, if present.

### **Wheelchair Securement**

When securing a wheelchair using commercial tiedowns, follow the WTORS manufacturer's instructions for use. The following directions are for use when securing a wheelchair using four surrogate wheelchair tiedowns, defined in WC19, in a vehicle or simulation.

- 1) Vehicle anchor points should be symmetric about the longitudinal centerline of the wheelchair station. The wheelchair centerline should be aligned with the longitudinal centerline of the wheelchair station within +/- 3 degrees.
- 2) The fore-aft distance between front and rear anchor points should be 1220 +/- 12 mm (48 +/- 0.5 in). An alternative fore-aft distance of 1296 +/- 12 mm (51 in +/- 0.5) is allowed to accommodate larger wheelchairs (or if trying to comply with ISO test procedures).
- 3) Laterally, the rear anchor points should be within +/- 25 mm of the rear securement points on the wheelchair.
- 4) Laterally, the front anchor points should be aligned with or outboard relative to the front securement points on the wheelchair. Lateral distance should range from 300 to 760 mm (12 to 30 in).
- 5) Adjust the surrogate tiedown length to 495 mm (19.5 in). Attach the surrogate tiedowns to the four securement points on the wheelchair. With the rear tiedowns taut, measure the side-

view angle of the rear tiedown straps between the anchor points on the floor and the hooks at the wheelchair.

- a. If the angle is below 45 degrees, the strap adjustment is good.
  - b. If this angle is above 45 degrees, lengthen the rear tiedown straps until the tiedown straps are within 45 +/- 3 degrees when secured to the rear anchor points.
- 6) When the desired length is achieved, tension the front tiedown using the ratchet mechanisms to a tension between 100 and 200 N (22 to 44 lbf).

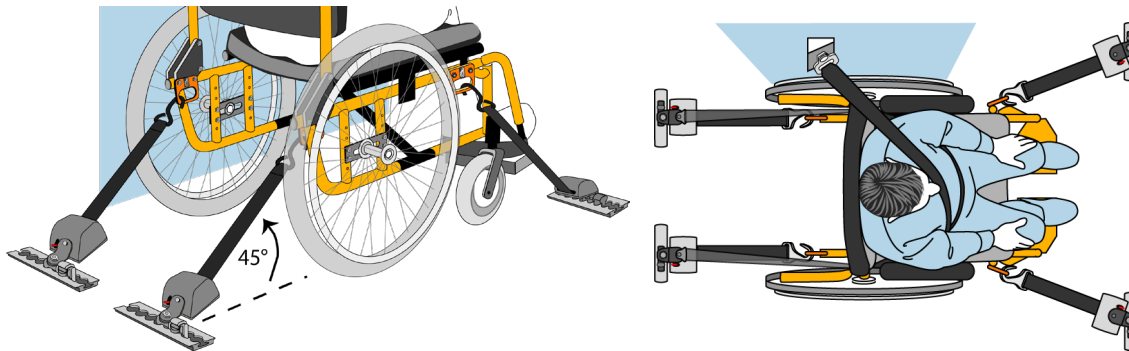


Figure 3. Illustration of ideal sideview tiedown angle between 30-45 degrees and lateral positions of tiedowns.

### **ATD Positioning**

- 1) Adjust joints of ATD to 1 g setting as directed in ATD user's manual. The ATD should wear snug fitting cotton clothing as specified in federal standards for crash testing.
- 2) Position the ATD in the wheelchair sitting upright and symmetrically about the wheelchair longitudinal centerline. The back of the pelvis/buttocks should be as close as possible to the bottom of the back support.
- 3) Position the feet on the footrests.
- 4) Place the elbows on the wheelchair arm supports (if provided) and prop the hands on the ATD thighs, so that the upper torso is supported in an upright position.
- 5) Place high-contrast targets on the ATD's knee joint and head CG.

### **Seatbelt Placement using Add-On Occupant Restraints**

- 1) Attach the floor anchorages of the seatbelt restraint to the floor so that they are located longitudinally between the rear tiedown anchorages and the wheelchair and laterally within 50 mm (2 in) of the wheelchair side frames to achieve sideview pelvic-belt angles between 30° and 75° to the horizontal.
- 2) The lap belt should be placed low across the front of the pelvis on the upper thighs, not on the abdomen. When possible, the lap belt should be angled between 45° and 75° to the horizontal when viewed from the side. Some wheelchair features, like armrests, can interfere with good belt fit. To avoid placing the lap belt over the armrest and to keep the lap belt low on the pelvis, it may be necessary to pivot the armrests out of position, insert the belt between the armrest and the seatback, or through openings between the backrest and seat.

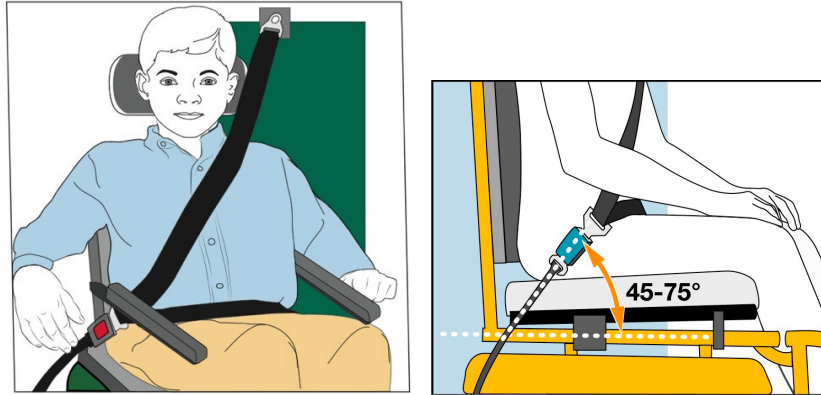


Figure 4. Illustration of recommended belt fit.

- 3) When using adjustable shoulder belt anchor point hardware, the diagonal shoulder belt should cross the middle of the shoulder and the center of the chest, and should connect to the lap belt near the hip of the wheelchair rider. The upper shoulder-belt anchor point or guide should be anchored above and behind the top of the occupant's shoulder, so that the belt is in good contact with the shoulder and chest while traveling. A side-view angle of  $30^{\circ} \pm 5^{\circ}$  is achieved with the anchor point located  $300 \text{ mm} \pm 15 \text{ mm}$  (11.8 in.  $\pm$  0.6 in.) behind and  $173 \text{ mm} \pm 15 \text{ mm}$  (6.9 in.  $\pm$  0.6 in.) above the top of the ATD's shoulder.

## References

1. RESNA WC-4:2017, Section 18: Wheelchair tiedown and occupant restraint systems for use in
2. motor vehicles
3. RESNA WC-4:2017, Section 19: Wheelchairs used as seating in motor vehicles
4. RESNA WC-4:2017, Section 20: Wheelchair seating systems for use in motor vehicles
5. SAE Recommended Practice J211 Instrumentation for impact tests
6. Federal Motor Vehicle Safety Standard 214 (FMVSS 214) 49 CFR Part 571.214 Side impact protection

**Annex A: Drawings of Side Impact Wall Structure**

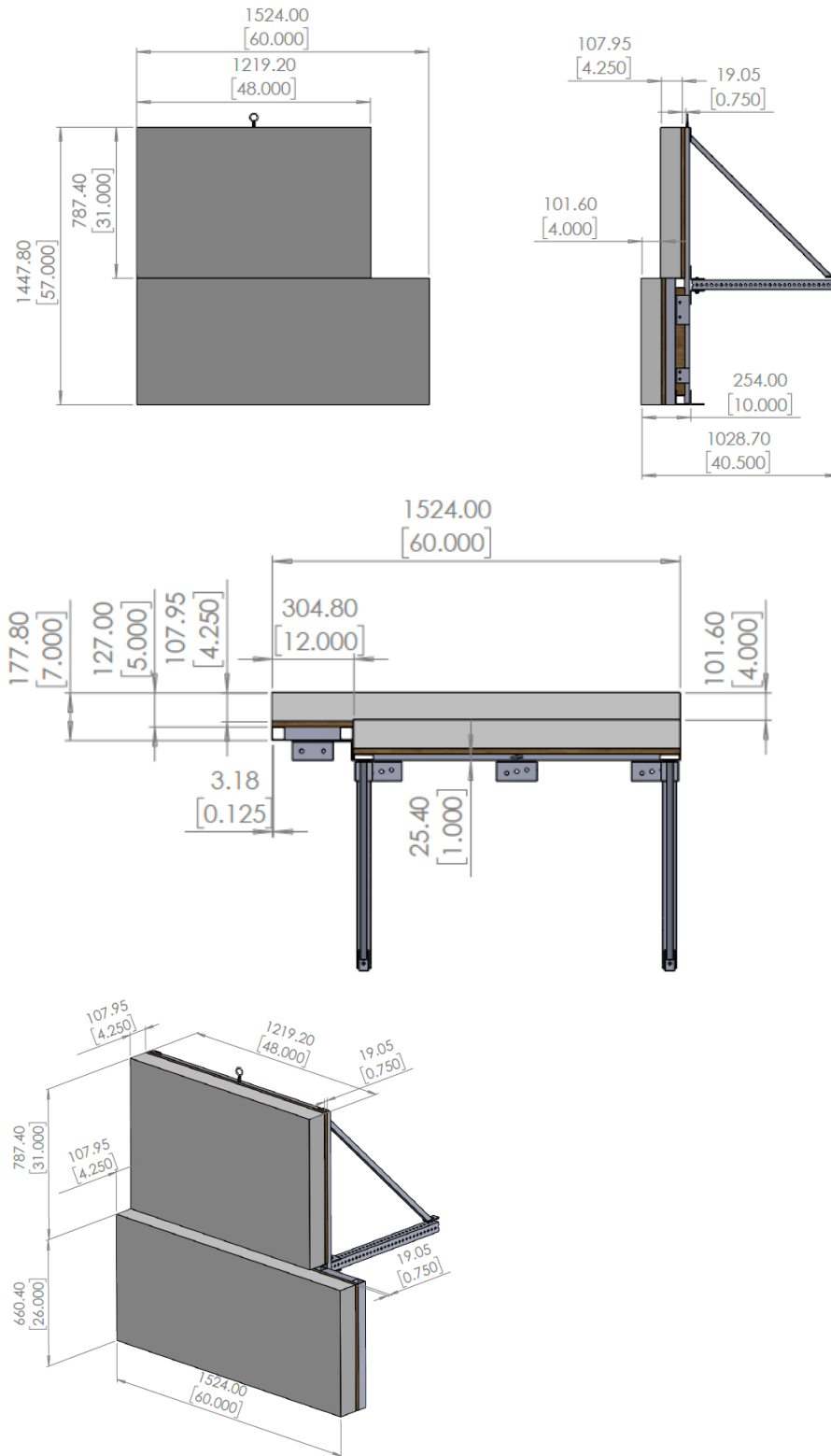


Figure 1. CAD images of side impact testing wall (drawings available to download at <https://wc-transportation-safety.umtri.umich.edu/wheelchair-side-impact-test-procedure/>).



## Annex B: Wheelchair & WTORS Performance Criteria Evaluation Forms

### SUMMARY OF WHEELCHAIR PERFORMANCE IN SIDE IMPACT

#### SLED TEST WX2204 – Q6 Edge 2.0 Power WC + Commercial 4-PT #1 + Wall

Proposed Requirement	Notes	Pass/Fail
Structural components of the WC securement points shall not completely fail	Securement points did not fail.	Pass
Deformation of WC securement points must not prevent disengagement of hook	Securement points did not deform.	Pass
WC upright and on test platform	WC upright	Pass
ATD must be in WC seat with torso leaning not more than 45°	ATD in seat with torso upright	Pass
Detached hardware cannot exceed 150 g	No hardware detached	Pass
WC must not have sharp edges with potential for occupant contact	No sharp edges observed	Pass
Locking mechanisms of tilt seating cannot release or completely fail.	No tilt release.	Pass
Post-test height of ATD H-point shall be $\geq$ 20% of pretest height	Post-test H-pt height did not decrease from pre-test height.	Pass
Average WC width shall not decrease by more than 20% of pretest width	Post-test width did not decrease from pre-test width.	Pass
Seating system cannot break free from WC at any attachment point.	Seating stayed attached	Pass
WC cannot cause complete failure of the surrogate WTORS.	No WTORS failure	Pass
Tiedown hooks of WTORS shall remain engaged with WC securement points.	No tiedown hooks disengaged.	Pass
WC-anchored belt restraints shall not detach or completely fail.	WC-anchored lap belt intact and attached.	Pass
Batteries must be within WC footprint	Batteries remained within footprint	Pass
Batteries must remain attached to battery compartment	Batteries remained attached	Pass
Batteries cannot contact ATD	Batteries did not contact ATD	Pass

**SUMMARY OF WHEELCHAIR PERFORMANCE**  
**SLED TEST WX2206 – Ki Mobility Manual + UDIG + Wall**

<b>Proposed Requirement</b>	<b>Notes</b>	<b>Pass/Fail</b>
Structural components of the WC securement points shall not completely fail	UDIG attachments did not fail	Pass
Deformation of WC securement points must not prevent disengagement of hook	UDIG attachments did not fail and prevent disengagement	Pass
WC upright and on test platform	WC upright	Pass
ATD must be in WC seat with torso leaning not more than 45°	ATD in seat with torso reclined 10 degrees	Pass
Detached hardware cannot exceed 150 g	No hardware detached	Pass
WC must not have sharp edges with potential for occupant contact	No sharp edges observed	Pass
Locking mechanisms of tilt seating cannot release or completely fail.	No tilt release	Pass
Post-test height of ATD H-point shall be $\geq$ 20% of pretest height	Post-test H-pt height did not decrease from pre-test height	Pass
Average WC width shall not decrease by more than 20% of pretest width	Post-test width did not decrease from pre-test width	Pass
Seating system cannot break free from WC at any attachment point.	Seating stayed attached	Pass
WC cannot cause complete failure of the surrogate WTORS.	No UDIG failure	Pass
Tiedown hooks of WTORS shall remain engaged with WC securement points.	NA	NA
WC-anchored belt restraints shall not detach or completely fail.	WC-anchored lap belt intact and attached.	Pass
Batteries must be within WC footprint	NA - no batteries	NA
Batteries must remain attached to battery compartment	NA - no batteries	NA
Batteries must not contact ATD	NA - no batteries	NA

**SUMMARY OF WHEELCHAIR PERFORMANCE**  
**SLED TEST WX2208 – Quickie 2 Manual + SWTORS + Wall**

<b>Proposed Requirement</b>	<b>Notes</b>	<b>Pass/Fail</b>
Structural components of the WC securement points shall not completely fail	Securement points did not fail.	Pass
Deformation of WC securement points must not prevent disengagement of hook	Securement points did not deform.	Pass
WC upright and on test platform	WC upright	Pass
ATD must be in WC seat with torso leaning not more than 45°	ATD in seat with torso reclined 10 degrees	Pass
Detached hardware cannot exceed 150 g	No hardware detached	Pass
WC must not have sharp edges with potential for occupant contact	No sharp edges observed	Pass
Locking mechanisms of tilt seating cannot release or completely fail.	No tilt release	Pass
Post-test height of ATD H-point shall be $\geq$ 20% of pretest height	Post-test H-pt height did not decrease from pre-test height	Pass
Average WC width shall not decrease by more than 20% of pretest width	Post-test width did not decrease from pre-test width	Pass
Seating system cannot break free from WC at any attachment point.	Seating stayed attached	Pass
WC cannot cause complete failure of the surrogate WTORS.	No WTORS failure	Pass
Tiedown hooks of WTORS shall remain engaged with WC securement points.	No hooks detached	Pass
WC-anchored belt restraints shall not detach or completely fail.	WC-anchored lap belt intact and attached.	Pass
Batteries must be within WC footprint	NA - no batteries	NA
Batteries must remain attached to battery compartment	NA - no batteries	NA
Batteries must not contact ATD	NA - no batteries	NA

**SUMMARY OF WHEELCHAIR PERFORMANCE**  
**SLED TEST WX2209 – Q6 Edge 2.0 Power WC + SWTORS + Wall**

<b>Proposed Requirement</b>	<b>Notes</b>	<b>Pass/Fail</b>
Structural components of the WC securement points shall not completely fail	Securement points did not fail.	Pass
Deformation of WC securement points must not prevent disengagement of hook	Securement points did not deform.	Pass
WC upright and on test platform	WC upright	Pass
ATD must be in WC seat with torso leaning not more than 45°	ATD in seat with torso leaning 5 degrees to the left	Pass
Detached hardware cannot exceed 150 g	A plastic cupholder detached but <150g	Pass
WC must not have sharp edges with potential for occupant contact	No sharp edges observed	Pass
Locking mechanisms of tilt seating cannot release or completely fail.	No tilt release	Pass
Post-test height of ATD H-point shall be $\geq$ 20% of pretest height	Post-test H-pt height did not decrease from pre-test height	Pass
Average WC width shall not decrease by more than 20% of pretest width	Post-test width did not decrease from pre-test width	Pass
Seating system cannot break free from WC at any attachment point.	Seating stayed attached	Pass
WC cannot cause complete failure of the surrogate WTORS.	No WTORS failure	Pass
Tiedown hooks of WTORS shall remain engaged with WC securement points.	No hooks detached	Pass
WC-anchored belt restraints shall not detach or completely fail.	WC-anchored lap belt intact and attached.	Pass
Batteries must be within WC footprint	Batteries remained within footprint	Pass
Batteries must remain attached to battery compartment	Batteries remained attached	Pass
Batteries must not contact ATD	Batteries did not contact ATD	Pass

**SUMMARY OF WHEELCHAIR PERFORMANCE**  
**SLED TEST WX2210 – Ki Mobility Manual + UDIG + Wall**

<b>Proposed Requirement</b>	<b>Notes</b>	<b>Pass/Fail</b>
Structural components of the WC securement points shall not completely fail	UDIG attachments did not fail	Pass
Deformation of WC securement points must not prevent disengagement of hook	UDIG attachments did not fail and prevent disengagement	Pass
WC upright and on test platform	WC upright	Pass
ATD must be in WC seat with torso leaning not more than 45°	ATD in seat with torso upright	Pass
Detached hardware cannot exceed 150 g	No hardware detached	Pass
WC must not have sharp edges with potential for occupant contact	No sharp edges observed	Pass
Locking mechanisms of tilt seating cannot release or completely fail.	No tilt release	Pass
Post-test height of ATD H-point shall be $\geq$ 20% of pretest height	Post-test H-pt height did not decrease from pre-test height	Pass
Average WC width shall not decrease by more than 20% of pretest width	Post-test width did not decrease from pre-test width	Pass
Seating system cannot break free from WC at any attachment point.	Seating stayed attached	Pass
WC cannot cause complete failure of the surrogate WTORS.	No UDIG failure	Pass
Tiedown hooks of WTORS shall remain engaged with WC securement points.	NA	NA
WC-anchored belt restraints shall not detach or completely fail.	WC-anchored lap belt intact and attached.	Pass
Batteries must be within WC footprint	NA - no batteries	NA
Batteries must remain attached to battery compartment	NA - no batteries	NA
Batteries must not contact ATD	NA - no batteries	NA

**SUMMARY OF WHEELCHAIR PERFORMANCE**  
**SLED TEST WX2211 – Q6 Edge 2.0 Power WC + Dock #1 + Wall**

<b>Proposed Requirement</b>	<b>Notes</b>	<b>Pass/Fail</b>
Structural components of the WC securement points shall not completely fail	Securement adaptor did not fail.	Pass
Deformation of WC securement points must not prevent disengagement of hook	Dock was able to release	Pass
WC upright and on test platform	WC upright	Pass
ATD must be in WC seat with torso leaning not more than 45°	ATD in seat with torso leaning 40 degrees to the right	Pass
Detached hardware cannot exceed 150 g	No hardware detached	Pass
WC must not have sharp edges with potential for occupant contact	No sharp edges observed	Pass
Locking mechanisms of tilt seating cannot release or completely fail.	No tilt release	Pass
Post-test height of ATD H-point shall be $\geq$ 20% of pretest height	Post-test H-pt height did not decrease from pre-test height	Pass
Average WC width shall not decrease by more than 20% of pretest width	Post-test width did not decrease from pre-test width	Pass
Seating system cannot break free from WC at any attachment point.	Seating stayed attached	Pass
WC cannot cause complete failure of the surrogate WTORS.	No WTORS failure	Pass
Tiedown hooks of WTORS shall remain engaged with WC securement points.	NA	NA
WC-anchored belt restraints shall not detach or completely fail.	WC-anchored lap belt intact and attached.	Pass
Batteries must be within WC footprint	Batteries remained within footprint	Pass
Batteries must remain attached to battery compartment	Batteries remained attached	Pass
Batteries must not contact ATD	Batteries did not contact ATD	Pass

**SUMMARY OF WHEELCHAIR PERFORMANCE**  
**SLED TEST WX2212 – Ki Mobility Manual WC + SWTORS + Wall**

<b>Proposed Requirement</b>	<b>Notes</b>	<b>Pass/Fail</b>
Structural components of the WC securement points shall not completely fail	Securement points did not fail.	Pass
Deformation of WC securement points must not prevent disengagement of hook	Securement points did not deform.	Pass
WC upright and on test platform	WC upright	Pass
ATD must be in WC seat with torso leaning not more than 45°	ATD in seat with torso upright	Pass
Detached hardware cannot exceed 150 g	No hardware detached	Pass
WC must not have sharp edges with potential for occupant contact	No sharp edges observed	Pass
Locking mechanisms of tilt seating cannot release or completely fail.	No tilt release	Pass
Post-test height of ATD H-point shall be $\geq$ 20% of pretest height	Post-test H-pt height did not decrease from pre-test height	Pass
Average WC width shall not decrease by more than 20% of pretest width	Post-test width did not decrease from pre-test width	Pass
Seating system cannot break free from WC at any attachment point.	Seating stayed attached	Pass
WC cannot cause complete failure of the surrogate WTORS.	No WTORS failure	Pass
Tiedown hooks of WTORS shall remain engaged with WC securement points.	No hooks detached	Pass
WC-anchored belt restraints shall not detach or completely fail.	WC-anchored lap belt intact and attached.	Pass
Batteries must be within WC footprint	NA - no batteries	NA
Batteries must remain attached to battery compartment	NA - no batteries	NA
Batteries must not contact ATD	NA - no batteries	NA

**SUMMARY OF WHEELCHAIR PERFORMANCE**  
**SLED TEST WX2302 – Leggero Enzo WC + SWTORS + Wall**

<b>Proposed Requirement</b>	<b>Notes</b>	<b>Pass/Fail</b>
Structural components of the WC securement points shall not completely fail	Securement points did not fail.	Pass
Deformation of WC securement points must not prevent disengagement of hook	Securement points did not deform.	Pass
WC upright and on test platform	WC upright	Pass
ATD must be in WC seat with torso leaning not more than 45°	ATD in seat with torso upright	Pass
Detached hardware cannot exceed 150 g	Front left frame portion detached >150 g	Fail
WC must not have sharp edges with potential for occupant contact	The front left lateral frame broke with a sharp edge exposed.	Fail
Locking mechanisms of tilt seating cannot release or completely fail.	No tilt release	Pass
Post-test height of ATD H-point shall be $\geq$ 20% of pretest height	Post-test H-pt height decreased by 4% from pre-test height	Pass
Average WC width shall not decrease by more than 20% of pretest width	Post-test width did not decrease from pre-test width	Pass
Seating system cannot break free from WC at any attachment point.	Seating stayed attached	Pass
WC cannot cause complete failure of the surrogate WTORS.	No WTORS failure	Pass
Tiedown hooks of WTORS shall remain engaged with WC securement points.	No hooks detached	Pass
WC-anchored belt restraints shall not detach or completely fail.	WC-anchored lap belt intact and attached.	Pass
Batteries must be within WC footprint	NA - no batteries	NA
Batteries must remain attached to battery compartment	NA - no batteries	NA
Batteries must not contact ATD	NA - no batteries	NA



**SUMMARY OF WTORS PERFORMANCE**  
**SLED TEST WX2305 – SWCSI + 4-PT #1**

<b>Proposed Requirement</b>	<b>Notes</b>	<b>Pass/Fail</b>
ATD must be in WC seat with torso leaning not more than 45°	ATD in seat with torso upright	Pass
WC upright and on test platform	WC upright	Pass
Primary load-carrying parts and components of a WTORS shall not completely fail in the absence of a backup component or structural member without signs of failure	No failure of WTORS	Pass
WTORS must not have sharp edges with potential for occupant contact	No sharp edges	Pass
Detached hardware cannot exceed 150 g	No hardware detached	Pass
WC and ATD can be removed from WTORS without the use of tools	No tools needed	Pass
WC point-P excursion cannot exceed 275 mm	270 mm	Pass
WC back support post angle wrt vertical cannot exceed 12°	5°	Pass

**SUMMARY OF WTORS PERFORMANCE**  
**SLED TEST WX2307 – SWCSI + 4-PT #2**

<b>Proposed Requirement</b>	<b>Notes</b>	<b>Pass/Fail</b>
ATD must be in WC seat with torso leaning not more than 45°	ATD in seat with torso leaning 5° to the left	Pass
WC upright and on test platform	WC upright	Pass
Primary load-carrying parts and components of a WTORS shall not completely fail in the absence of a backup component or structural member without signs of failure	No failure of WTORS	Pass
WTORS must not have sharp edges with potential for occupant contact	No sharp edges	Pass
Detached hardware cannot exceed 150 g	No hardware detached	Pass
WC and ATD can be removed from WTORS without the use of tools	No tools needed	Pass
WC point-P excursion cannot exceed 275 mm	239 mm	Pass
WC back support post angle wrt vertical cannot exceed 12°	4°	Pass

**SUMMARY OF WTORS PERFORMANCE**  
**SLED TEST WX2308 – SWCSI + Dock #1**

<b>Proposed Requirement</b>	<b>Notes</b>	<b>Pass/Fail</b>
ATD must be in WC seat with torso leaning not more than 45°	ATD in seat with torso leaning 5° to the left	Pass
WC upright and on test platform	WC upright	Pass
Primary load-carrying parts and components of a WTORS shall not completely fail in the absence of a backup component or structural member without signs of failure	No failure of WTORS	Pass
WTORS must not have sharp edges with potential for occupant contact	No sharp edges	Pass
Detached hardware cannot exceed 150 g	No hardware detached	Pass
WC and ATD can be removed from WTORS without the use of tools	No tools needed	Pass
WC point-P excursion cannot exceed 275 mm	136 mm	Pass
WC back support post angle wrt vertical cannot exceed 12°	14°	Fail

**SUMMARY OF WTORS PERFORMANCE**  
**SLED TEST WX2309 – SWCSI + Dock #2**

<b>Proposed Requirement</b>	<b>Notes</b>	<b>Pass/Fail</b>
ATD must be in WC seat with torso leaning not more than 45°	ATD in seat with torso leaning 10° to the left	Pass
WC upright and on test platform	WC upright	Pass
Primary load-carrying parts and components of a WTORS shall not completely fail in the absence of a backup component or structural member without signs of failure	No failure of WTORS	Pass
WTORS must not have sharp edges with potential for occupant contact	No sharp edges	Pass
Detached hardware cannot exceed 150 g	No hardware detached	Pass
WC and ATD can be removed from WTORS without the use of tools	No tools needed	Pass
WC point-P excursion cannot exceed 275 mm	161 mm	Pass
WC back support post angle wrt vertical cannot exceed 12°	17°	Fail