

## **IV. SAE J2249: Wheelchair Tiedown and Occupant Restraint Systems**

### ***Organization***

Following the Scope, Reference, and Definitions sections (Sections 1, 2, and 3) , there are three parts of J2249 that contain the primary requirements and provisions of the Recommended Practice. Section 4 contains requirements that address issues of design intent on keeping with basic crashworthiness principles discussed in the previous section, and with regard to good engineering design practice. Section 5 contains requirements for the WTORS manufacturer with regard to written material, such as instructions and manuals, and with regard to labeling of WTORS assemblies and components. Section 6 contains performance requirements for WTORS that parallel requirements of existing federal standards for OEM vehicle restraints, or that reference specific test methods provided in the appendices of J2249. Included are performance requirements for the frontal impact test, or dynamic strength test (hereafter referred to as the dynamic test), the test for partial and ineffective engagement of WTORS components, and the test for webbing slippage at adjustment devices of wheelchair tiedowns.

Appendices A through D provide normative (i.e., required) test methods and procedures to determine compliance with design and performance requirements contained in the body of the standard. Appendix A specifies procedures for setting up and conducting the dynamic test, Appendix B provides methods for determining compliance with restraint system geometry and adjustment lengths, Appendix C sets forth procedures for determining the potential for partial and ineffective engagement of WTORS components, while Appendix D provides methods for testing adjustment devices of strap-type tiedowns for webbing slippage. Appendix E provides requirements for the surrogate wheelchair that is used in the dynamic test of Appendix A, as well as in the occupant restraint tests of Appendix B. Appendix F is an informative (i.e., not required) appendix that contains additional design and performance recommendations for WTORS manufacturers, such as more specific information about preferred fit of occupant restraints that a manufacturer might wish to include in their instructions to installers, and guidelines for installing WTORS anchorages in sheet metal vehicle flooring.

### ***Overview of the Main Provisions of RP J2249***

#### **1. The Scope**

The key elements of the scope of SAE J2249 are as follows:

- It specifies design requirements, test methods, and performance requirements for WTORS, requirements for manufacturer's instructions to installers and users, and requirements for product marking and labeling.
- It specifies test procedures and performance requirements for a 48-kph, 20-g frontal impact.
- It specifies test procedures and performance requirements for webbing slippage at adjustment devices of strap-type wheelchair tiedowns, and for partial but ineffective engagement of wheelchair tiedowns and tiedown components.
- It applies to WTORS used with forward-facing wheelchair-seated adults and children to age six.
- It applies to passengers and drivers of personally licensed motor vehicles as well as to passengers of motor vehicles used in public and school transportation.
- It applies to all types of WTORS, including those that use docking-type wheelchair tiedowns.
- It applies to components and subassemblies of WTORS that manufacturers may want to certify as being in compliance with SAE J2249.

It is important to understand that, while SAE J2249 contains a few requirements that apply only to WTORS with specific types of tiedowns, such as docking devices or four-point strap systems, most of the Recommended Practice applies to WTORS that use all types of tiedown devices, as long as they are designed and intended for use with forward-facing wheelchairs and occupants. The only restriction is that the WTORS must include a belt-type occupant restraint system, which can be either the vehicle three-point restraint provided by the vehicle manufacturer (primarily for the situation of a wheelchair-seated driver), or an occupant restraint system that is provided by the WTORS manufacturer. In the latter case, which is strongly encouraged, both upper- and lower-torso restraints must be included in the complete WTORS system. This is done to provide the user with the option to use, and to encourage the use of, a complete and effective occupant restraint system. Obviously the Recommended Practice does not, and cannot, enforce the use of either by individuals or transportation authorities.

The Recommended Practice also allows a manufacturer to certify parts of a WTORS system as being in compliance with J2249 if tested as part of a complete WTORS and accompanied by appropriate documentation (see 5.5 of J2249). This was done in recognition that some manufacturers currently market components of a complete WTORS, such as anchorage track or strap webbing, to replace components of previously purchased WTORS, or for assembly and installation with other WTORS components by the installer or vehicle modifier.

Unlike the comparable ISO WTORS standard (ISO 10542-1 and -2)<sup>5</sup>, SAE J2249 applies to WTORS that are used with children about six years and older, as well as adults (i.e., with a body mass of 22 kg or greater). In general, however, a WTORS must demonstrate that it is strong enough to perform effectively for adults with potentially high wheelchair and occupant masses, since in public and school transportation, it is almost never possible to control the situations in which a particular WTORS product line will be used. A WTORS designed for use with only lighter-weight child-size wheelchairs and occupants can be tested to J2249 using a specific wheelchair. In this case special marking and labeling (see Section 5.1 of J2249) is required on the WTORS components and in the WTORS literature to indicate these limitations, and to minimize the possibility of misuse.

## 2. References

As is typical in all SAE Recommended Practices, the references are divided into two sections referred to as *Applicable Publications* and *Related Publications*. Applicable publications are referenced in normative sections of the document and are therefore essential to the provisions and requirements of J2249. Related publications are other documents that contain informative material pertinent to the Recommended Practice, or are standards or practices that contain similar provisions.

Applicable Publications are typically divided into *SAE Publications* and *Other Publications*, where, for J2249, *Other* is federal motor vehicle safety standards. In this initial printing of the Recommended Practice, three SAE references were included in Applicable Publications when, in fact, only one reference should be listed. The required reference is SAE J211-2, which gives procedures for filtering transducer signals resulting from the dynamic test of Appendix A. The other two references to J850 and J1834 should be in the Related-Publications section, since they are not referenced in any of the normative parts of SAE J2249. This is being corrected in the 1999 printing of the document.

The two federal standards that are referenced under Applicable Publications are FMVSS 209 and FMVSS 302. The first of these specifies many requirements and associated test methods for *Seat-Belt Assemblies*, such as abrasion resistance of webbing material, belt retractor performance, etc. Those parts of FMVSS 209 that were considered applicable to either occupant restraints or wheelchair tiedowns, or both, are listed in Table 2 of J2249.

The related publications listed in 2.2 of J2249 include numerous SAE publications that deal with crashworthiness design and testing of vehicles and occupant protection systems, as well as closely related standards from the U.S. and other countries, including WTORS and wheelchair standards

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<sup>5</sup> see Appendix A for reference

from Australia, Canada, and ISO. The listing of these related standards and their current status is provided in Appendix H.

### 3. Definitions

While many of the definitions in this part of the RP are self explanatory, several have been specifically and carefully developed to clarify terminology which is unique to the situation of occupant protection systems that provide both wheelchair tiedown and occupant restraint. Key definitions, as they appear in J2249, are provided in the Glossary section (Appendix B) of this guideline document. The rationale for selected key terms and an explanation of their intended usage follows.

In J2249, the term *restraint* is used only in reference to the occupant and not in reference to the wheelchair which is *secured* or tied down, but not restrained. Also, while both wheelchair tiedowns and occupant restraints may include webbing material, the term *belt* is used only in the context of a length of webbing material in an occupant restraint, while the term *strap* is used to refer to a length of webbing material used in a wheelchair tiedown. Thus, it is incorrect to refer to the tiedown *belt*, or to refer to an occupant restraint *strap*.

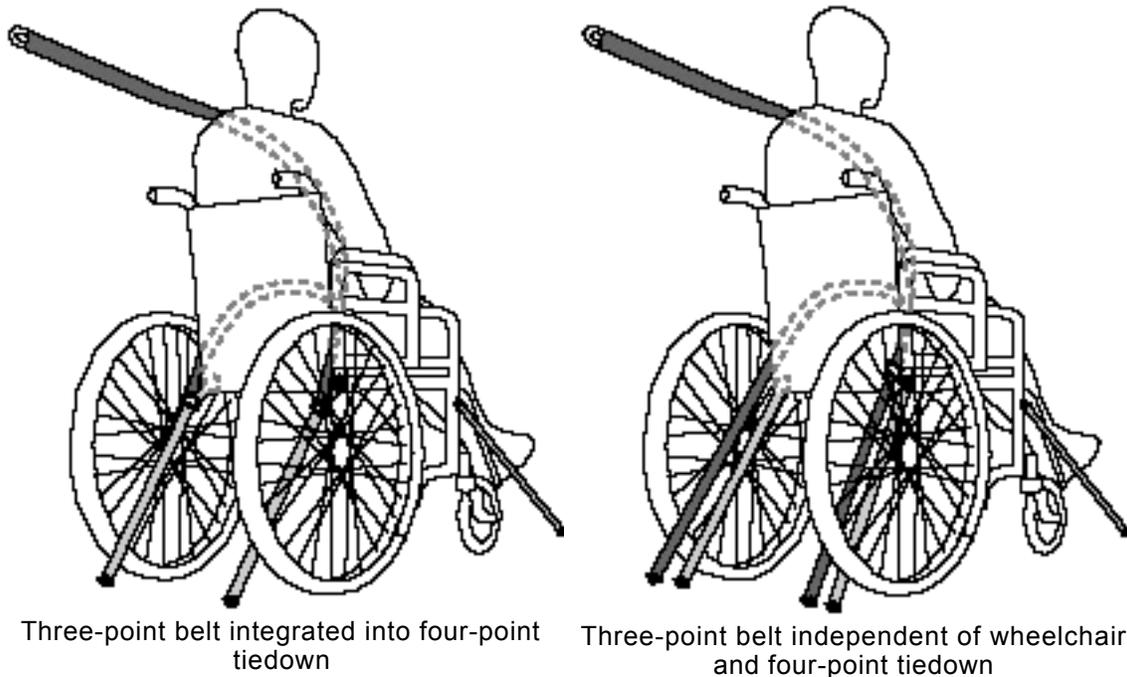
Another set of terms that should be noted are those of *anchor point*, *anchorage*, *securement point*, and *end fitting*. Both anchor point and securement point are points or places to which wheelchair tiedowns and occupant restraints may be attached (i.e., they are both attachment points). However, the term *anchor point* is used exclusively in reference to the points on the vehicle, tiedown hardware, or wheelchair to which the object (e.g., the occupant or wheelchair) is being anchored or fastened. Thus, occupant restraints may be anchored to the wheelchair, to wheelchair tiedown components fastened to the vehicle, or to the vehicle itself. Similarly, a wheelchair is generally secured to anchor points on the vehicle (actually to hardware or anchorages fastened to the vehicle).

In contrast, the term *securement point* (or tiedown point) is reserved exclusively for those points or places on the wheelchair which are "grabbed" by the tiedown device or system in order to anchor or secure the wheelchair to the vehicle. Note that people don't have securement points. Thus, a wheelchair may have four securement points for the case of a four-point tiedown system, or it may have only one or two securement points, in the case of a docking-type tiedown. These points are connected by means of the tiedown system or device to the anchor points. Both anchor points and securement points fall into the general category of *attachment points*.

The term *anchorage* refers to the physical hardware that accomplishes the anchoring or connecting to the anchor point, including the hardware that may be fastened to the vehicle (e.g., the tiedown track), as well as the hardware on the tiedown or restraint system that attaches to the vehicle. The term *end fitting* is more general than the term *anchorage* and refers to

hardware that attaches to an anchorage at the vehicle anchor point, as well as to hardware that attaches to the securement point on the wheelchair. In other words, end fittings are the parts of the tiedown or restraint assembly that connect to the wheelchair that is being secured, and that connect to the object to which the wheelchair tiedown or occupant restraint is being anchored. An anchorage (i.e., hardware component) is an end fitting if it is the part of a tiedown assembly that connects and disconnects to the vehicle anchorage without the use of tools, but an end fitting is not an anchorage if it connects to the securement point on the wheelchair. Also, an anchorage installed in the vehicle is not an end fitting.

The definitions in J2249 include several terms related to occupant restraints, most of which are self explanatory (see Glossary). The terms *independent* occupant restraint and *integrated* occupant restraint have been mentioned previously. Strictly speaking, a fully integrated occupant restraint is one for which the anchor points are on the seat or wheelchair, such that all occupant restraint forces (i.e., upper and lower torso) are transferred to, and through, the wheelchair. Similarly, a partially integrated occupant restraint would be one for which only the pelvic belts are anchored to the wheelchair with the shoulder belt being anchored to the vehicle. However, for purposes of this standard, a more liberal definition has been used. This definition considers an occupant restraint to be integrated if the pelvic belt anchors to tiedown components that are located close to, or attached to, the wheelchair, as is the case with the Q'Straint system and a version of the Kinedyne system.



**Figure 1** - Integrated (left) and independent (right) three-point belt restraint and four-point, strap-type tiedown.

Figure 1 illustrates this more liberal definition of an integrated occupant belt restraint with a four-point, strap-type tiedown compared to an independent occupant restraint that anchors to the vehicle.

The term *test wheelchair* refers to the wheelchair that is used to evaluate the WTORS in the dynamic test of Appendix A and in the seat-belt geometry and adjustment-length tests of Appendix B. In general, the test wheelchair will be the surrogate wheelchair, which is abbreviated as SWC. The surrogate wheelchair is specified in Appendix E as a rigid wheelchair-like structure with a total mass of 85 kg and dimensions and design features as indicated and illustrated in Figure 2. However, as previously indicated, J2249 allows for testing a WTORS that is uniquely designed for, and exclusively to be used with, one particular type or size of wheelchair. In this case, the actual production or prototype wheelchair is used in the tests. Therefore, the term *test wheelchair*, rather than surrogate wheelchair, is needed to generically reference the wheelchair used in the tests of J2249.

At the time the document was written, there were two primary types of WTORS in use in the United States that are considered to provide effective wheelchair securement --those that use four-point strap-type tiedowns and those that use docking-type systems (see Glossary for complete definition). The latter are usually more expensive, but may provide automatic wheelchair tiedown without the need for an attendant or assistant. They are therefore primarily used by wheelchair-seated drivers of vans, but may also be used by transit vehicle passengers to save time on fixed routes. An example of the latter is the experimental docking system developed by Oregon State University in which two U-shaped brackets attached to both sides of the back of the wheelchair dock with two spring-loaded clamps when the wheelchair is backed into a floor-mounted stanchion. However, docking systems have not found wide acceptance in public transit due to the lack of a standardized method for attaching to the wide range of wheelchair sizes and designs in the marketplace.

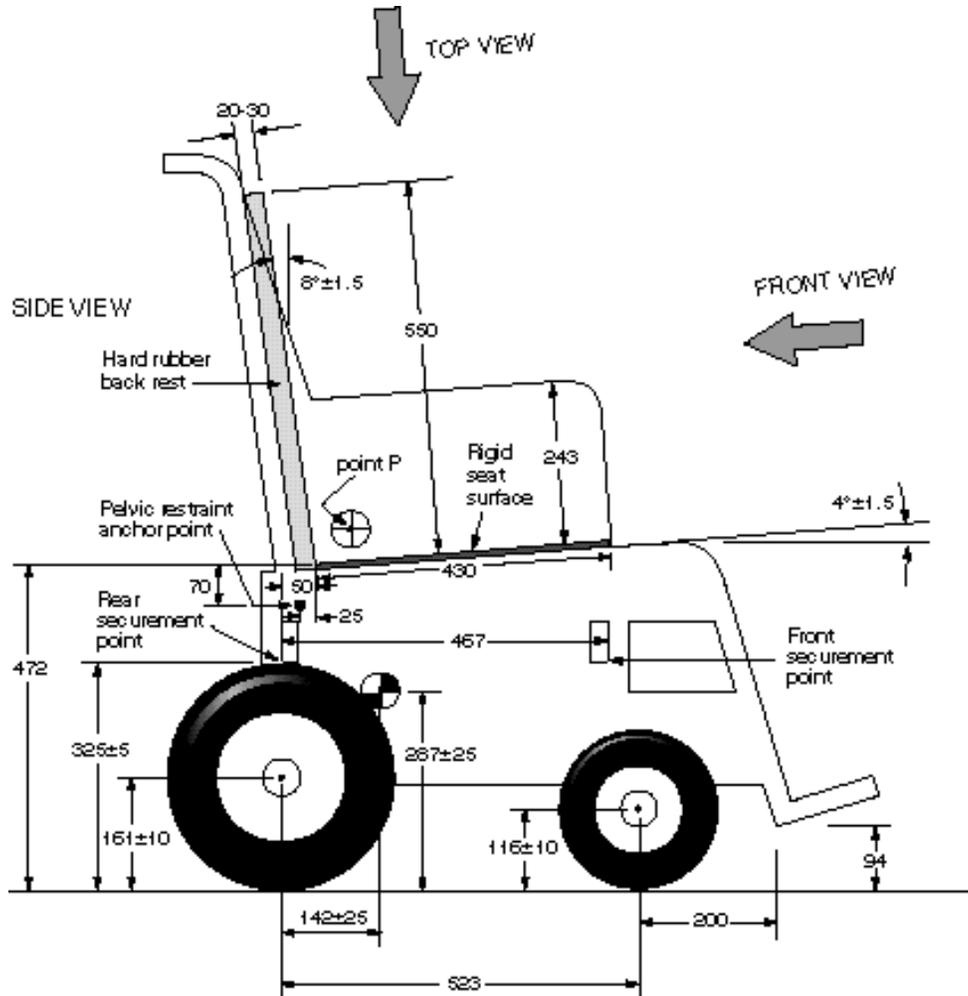


Figure 2 - Side-view illustration of the surrogate wheelchair.

Four-point, strap-type tiedowns are more generally applicable to a range of wheelchair sizes and types without the need for wheelchair add-on brackets, although brackets are a good idea if they improve accessibility to securement points on the wheelchair. In this regard, the strict definition of a four-point tiedown requires four separate securement points on the wheelchair and four separate anchor points on the vehicle and/or on tiedown components fastened permanently, or attached temporarily, to the wheelchair. Therefore, when a four-point strap-type tiedown is used to secure a wheelchair such as a powered scooter, where both front strap assemblies may be attached to the base of the steering tiller, this does not strictly comply with the definition of a four-point tiedown since there are really only three securement points on the wheelchair. Similarly, if two front or two rear strap assemblies anchor to the same anchor point and anchorage hardware on the vehicle, the system is not, strictly speaking, a four-point tiedown system.

#### 4. WTORS Design requirements

Section 4 of J2249 contains requirements for WTORS that address the "design intent" of the WTORS manufacturers. It is in this section that the essential elements of good engineering practice and basic crashworthiness design principles are set forth in the requirements for WTORS. The section is divided into three parts based on whether the requirements apply to both the tiedown and restraint system subassemblies (complete WTORS), to only the tiedowns, or to only the occupant restraints.

##### 4.1 Complete WTORS

As noted previously under Scope, one of the primary goals of J2249 is to encourage the design and marketing of complete WTORS that provide for both wheelchair securement and occupant restraint. The design requirements set forth in J2249 that apply to both the components, separate assemblies, and total assembly of the complete WTORS, are the following:

WTORS shall:

- a) be for use with only one wheelchair and one occupant at a time,
- b) not require components of wheelchair tiedowns and occupant restraints to pass through the wheels of a wheelchair,
- c) provide for release of both the wheelchair and the occupant within sixty seconds by a single attendant or wheelchair user without the use of tools,
- d) not require removal of wheelchair frame material, drilling into the wheelchair frame, deformation of the wheelchair, welding, or the use of an adhesive process, during installation, unless the WTORS is intended for a specific wheelchair and the modifications are approved by the wheelchair manufacturer,
- e) once installed, be operable without tools,
- f) include only hardware and fittings that are permanently connected to the WTORS or a WTORS subassembly,
- g) be designed to prevent unintentional loosening of all threaded fasteners,
- h) include a manual override in case of power failure for any power-operated mechanisms of tiedowns or restraints, and
- i) include anchorage fasteners and hardware, and/or specifications for such hardware, that are based on the material, size, and quantity of anchorage fasteners used in the simulated frontal impact test of Appendix A.

The design requirements of this section are applicable to the complete WTORS or, in other words, to both the tiedown and restraint portions of a WTORS. In general, these requirements are straight forward and do not require further explanation. The intent is to ensure that a WTORS and its various components are available to the user throughout the life of the WTORS, and so that proper use or installation of the system does not compromise the integrity of the wheelchair frame (i.e., by drilling holes in, and thereby weakening frame members). Also, the design intent should include ease of use in securing the wheelchair and restraining the occupant

(i.e., no tools required), and, in the case of power-operated tiedowns, provision for effective emergency release in the event of a vehicle power failure (i.e., engine cutoff and/or dead battery).

#### 4.2 Wheelchair Tiedowns

Design requirements for the wheelchair tiedown components and assemblies are that the tiedown shall:

- a) not depend on the wheelchair brakes,
- b) be designed so that securement of the wheelchair is accomplished by the tiedown only and not by the occupant restraints,
- c) provide a means to eliminate free movement of the wheelchair without the use of tools,
- d) if the WTORS includes a four-point strap-type tiedown, each strap assembly shall provide for manual adjustment in length without the use of tools, such that the adjustment ranges of front and rear straps enable achieving the minimum and maximum lengths indicated in Table 1 (see below), with at least 25 mm of webbing extending from the adjustment mechanisms,
- e) have securement-point end fittings of four-point tiedowns that are compatible with the securement-point opening geometry and the cross section of the securement-point structural member of the surrogate wheelchair illustrated in Figure E.4, and
- f) include a device to indicate, by visual or auditory means, when a docking-type tiedown is properly engaged.

**Table 1**  
**Minimum Adjustment Ranges for Four-Point Tiedown Straps**

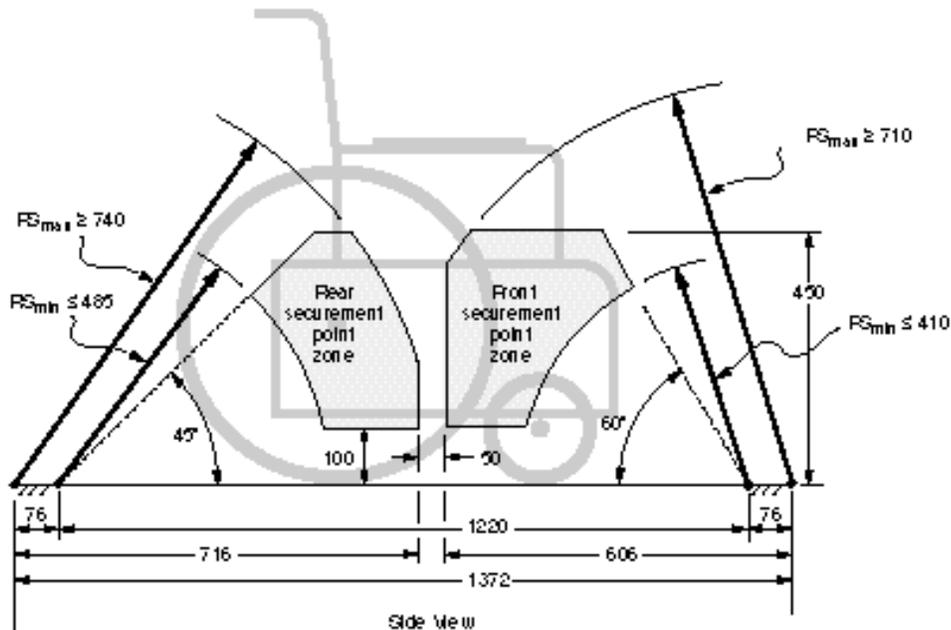
Strap Assembly Location	Minimum Length* mm (in)	Maximum Length* mm (in)
Rear	485 (19)	740 (29)
Front	410 (16)	710 (28)

\* Length is defined as the straight-line distance from the point of intersection of the tiedown end fitting with the wheelchair securement point, to the point at which a straight line along the length of the strap assembly intersects with the wheelchair ground plane when set up as specified in A.6.

+ See F.14 and Figure F.5 of Appendix F for rationale.

Clause (a) states that the wheelchair brakes should not be required for proper functioning of the wheelchair securement device or securement process (e.g., the brakes should not be relied on even to hold the wheelchair in position for docking). This requirement recognizes that braking effectiveness can vary widely across wheelchairs, wheelchair types, and even for the same wheelchair over time, and that brakes do not offer adequate securement in a crash, or even in normal or emergency vehicle maneuvering.

Clause (b) is the very important requirement discussed under *Basic Principles* that wheelchair securement must be achieved independent from occupant restraint, so that the occupant does not experience additional forces due to all, or part, of the wheelchair mass. Clause (c) recognizes that slack or free-play in a system can result in total system or component failure under impact conditions, and therefore must be eliminated in all types of tiedown systems (docking or strap type) if effective securement is to be available when needed. This requirement is necessary since the dynamic test of Appendix A is a single test, at a single setup condition, and will therefore not evaluate this aspect of performance for all possible scenarios of tiedown free-play or slack. In addition, slack or free-play can increase fatigue and discomfort to the wheelchair-seated passenger. Clauses (d) and (e) of this section apply to WTORS that use four-point strap-type tiedowns which, as previously noted, are effective and commonly used in situations where there is a need to secure a range of wheelchair types. If properly designed, these tiedown systems have been demonstrated to be very effective during frontal impact loading with forward-facing wheelchairs. A primary requirement is that such systems provide four adjustable-length tiedown assemblies that can be shortened and lengthened to lower (minimum) and upper (maximum) bounds on strap length. The minimum and maximum lengths for the tiedown assembly specified in Table 1 are based on expected locations of the four securement points on wheelchairs, expected locations (i.e., distances between) of anchor points in vehicles, and maximum and minimum lengths of four-point tiedown assemblies that were considered to be reasonable and acceptable. This is illustrated in Figure 3.



**Figure 3** - Rationale for length adjustment ranges of strap assemblies used in four-point tiedowns.

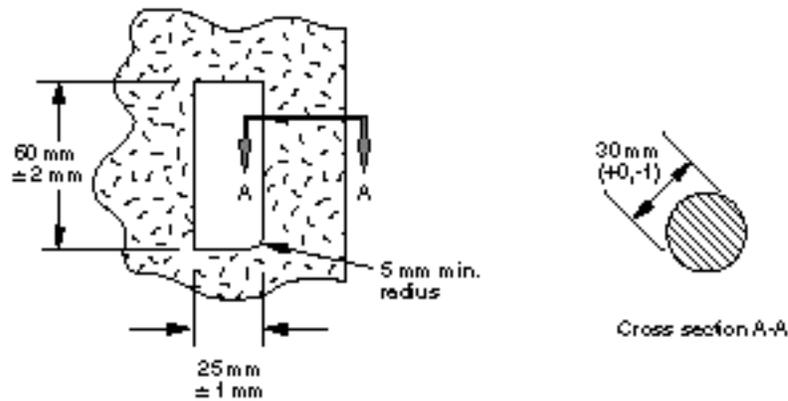
Note: Securement points should be located only on wheelchair frame members and components, and not on wheels or other movable or removable parts of the wheelchair.

The minimum length requirements are based on the consensus of current WTORS manufacturers with regard to a reasonable lower bound for strap assembly length with sufficient strength to pass the frontal impact test of Appendix A, and that include anchorages, hook-type securement-point end fittings, manually operated adjustment and tensioning mechanisms.

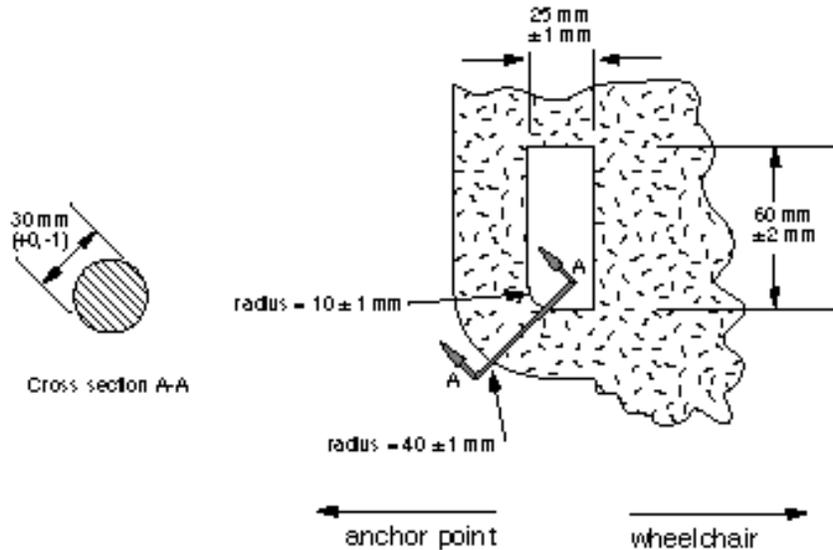
The maximum length requirements are based on manufacturer and transportation personnel consensus with regard to acceptable upper bounds on strap assembly length to minimize cumbersome use in the field (i.e., too much length becomes unwieldy). The requirement is that the strap assemblies of the four-point tiedown system manually adjust in length to achieve the minimum and maximum values in Table 1. A WTORS that provides for adjustment of tiedown assembly lengths beyond the minimum and maximum values given in Table 1 will also comply with this requirement.

In the comparable ISO WTORS standard (ISO 10542-2), four-point, strap-type tiedowns need only have two front or two rear adjustable-length strap assemblies (i.e., two can be fixed in length), as long as there is provision for fore/aft anchor point adjustment (e.g., an anchorage track that runs fore/aft in the vehicle). Such systems are, however, not comparable in their ability to deal with front and rear securement-points in the zones shown in 3. Furthermore, the length requirements for the fixed strap assemblies and the range of fore/aft anchor-point adjustment have not been established. Therefore, such four-point, strap-type tiedown systems are not considered to be in compliance with SAE J2249.

The second requirement of four-point, strap-type tiedowns is that the end fitting of each strap assembly be compatible with the securement points on the surrogate wheelchair. The required geometry is specified in Figure E.4 of J2249 and Figure 4a below. While Figure 4a is in the current version of J2249, it will be replaced by Figure 4b that shows a more appropriate geometry for the securement point. This geometry is based on deliberations in ISO, SAE, and CSA standards development. The opening geometry is a 25 mm by 60 mm slot and is based on the need to attach to wheelchairs using both hook and strap-type end fittings of current four-point tiedown systems. The tiedown end fitting must also effectively engage with the 30-mm diameter structural members of wheelchairs. This dimension is based on the maximum expected cross-section of wheelchair tubing that might serve as a securement point on many wheelchairs. (Note: Since ANSI/RESNA WC/19 specifies a maximum cross-section of wheelchair securement points of 26 mm, future tiedown end fittings will hopefully not be required to engage with the larger 30-mm diameter cross-section. Therefore, this requirement may be modified in future versions of J2249 after most wheelchairs have securement points that comply with ANSI/RESNA WC/19).



**Figure 4a.** Dimensions of wheelchair securement points on the surrogate wheelchair and required engagement geometry for securement-point end-fittings of four-point strap-type tiedowns in current version of J2249.



**Figure 4b.** Modified and improved drawing of surrogate wheelchair securement points to be included in next version of J2249 (from ISO 10542-2).

Clause (f) in this section applies only to docking-type tiedown systems. The requirement is that such devices include a mechanism that indicates when the system is properly engaged, so that the independent wheelchair user knows when the wheelchair is effectively secured. To some extent, the concern about improper or ineffective engagement of a docking-type system is addressed by the Test for Partial Engagement of Appendix C. However, Appendix C simply provides for testing possible and foreseeable scenarios of improper engagement during WTORS testing and evaluation. Whereas Clause f requires an additional method of visual or auditory verification of proper engagement.

### 4.3 Occupant Restraints

The requirements of Section 4.3 apply to the occupant restraint portion of the WTORS, not the wheelchair tiedown. They address several issues related to design intent regarding proper fit of restraint systems to potential users, as well as to accommodating the range of potential occupant sizes who may use the system in a public vehicle.<sup>6</sup>

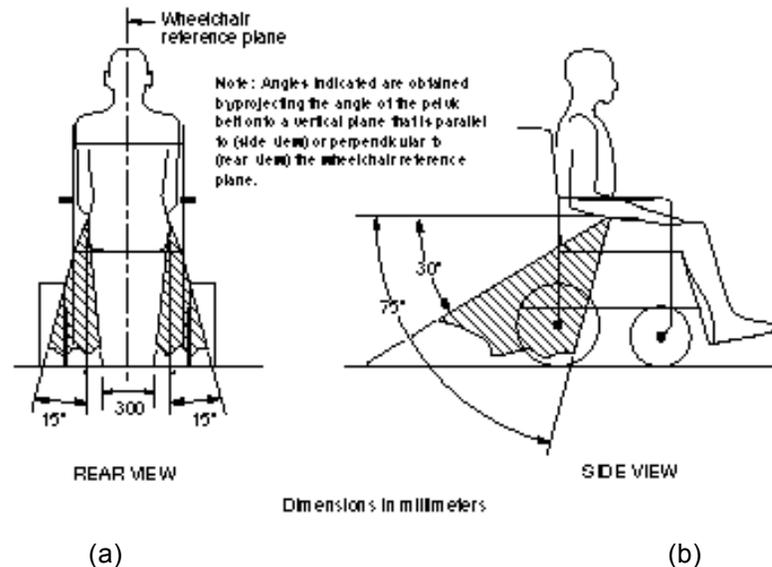
The introductory statement to this section of J2249 allows the WTORS manufacturer to design and market a wheelchair tiedown system with the intention that the wheelchair user will make use of the vehicle manufacturer's three-point belt restraint system. This allowance has been included primarily for the situation of wheelchair-seated drivers, who are currently known to use vehicle-installed restraints, perhaps with some modifications to make the system passive (i.e., automatically in place) and so that the belt will achieve a reasonable fit to the driver seated in a wheelchair. Even in these driver situations, however, it is strongly recommended that the WTORS manufacturer include a specially designed and tested occupant restraint system, so as to better achieve the objectives of effective occupant restraint for a wheelchair-seated driver.

The requirements set forth for occupant restraint systems provided by the WTORS are the following:

- 4.3.1 The occupant restraint portion of the WTORS shall include both pelvic and upper torso restraints.
- 4.3.2 Occupant restraints may be designed to anchor directly to the vehicle, to components of the wheelchair tiedown, or to tiedown components fastened to the wheelchair. Occupant restraints shall not be designed with anchorage's that rely on the transmission of restraint loads through the wheelchair structure unless the WTORS is designed for a specific wheelchair and the WTORS meets the requirements of 6.2 when the combination of wheelchair and WTORS is tested according to Appendix A.
- 4.3.3 The lengths of pelvic and upper torso restraints shall be manually adjustable without the use of tools.
- 4.3.4 When the WTORS is set up and measured as specified in Appendix B, pelvic restraints and, if applicable, their anchor points or guide points, shall:
  - a. achieve side-view projected angles that fall within the zone shown in Figure 5b,
  - b. achieve projected rear-view angles and locations within the zones shown in Figure 5a, and
  - c. provide sufficient length adjustment to allow the pelvic restraint, measured from anchor point to anchor point, to be both increased and decreased by 200 mm with at least 25 mm of webbing extending through the restraint end fittings at all times.

<sup>6</sup> In general, J2249 was written with the assumption that the WTORS manufacturer does not have control on the end use of their product, and that WTORS will be used in situations where a range of user sizes must be accommodated.

- 4.3.5 When the WTORS is set up and measured as specified in Appendix B, upper torso restraints shall provide for sufficient length adjustment to extend an additional 200 mm, and shorten by 300 mm with at least 25 mm of webbing extending through the restraint end fittings at all times.
- 4.3.6 For WTORS that include upper-anchor points or upper-guide support structures for shoulder or harness restraints, the locations of these anchor points or supporting structures shall:
- be sufficiently adjustable in height to be located at or above the shoulder levels of the intended users, or
  - be located at least 1100 mm above the wheelchair ground plane so as to be near or above the shoulder height of wheelchair seated occupants.
- Note 1: The anchor point may be located below 1100 mm if an upper-guide support is located at or above 1100 mm.
- Note 2: Although FMVSS 210 allows for the upper torso restraint anchor points to be located a significant distance below the occupant's shoulder level, such locations are considered to be undesirable and not in compliance with this recommended practice, since they could result in downward loading on the occupant that can produce spinal injuries.
- 4.3.7 The junction of the shoulder and pelvic restraints of three-point restraints shall be located not less than 150 mm from the ATD centerline when installed as specified in Appendix B.
- 4.3.8 An airbag shall be used only as a supplementary occupant restraint in conjunction with a wheelchair tiedown and belt-type occupant restraint that comply with the requirements of this recommended practice.
- 4.3.9 Performance of the WTORS shall not depend on an airbag to comply with this recommended practice.



**Figure 5** - Range of required angles and locations for pelvic restraints and pelvic-restraint anchor points. Note that angles indicated are obtained by projecting the angle of the pelvic restraint onto a vertical plane parallel to the wheelchair reference plane (side view), or onto a vertical plane that is perpendicular to the wheelchair reference plane (rear view).

The first requirement (4.3.1) is a restatement of the fact that both upper- and lower-torso belts are needed to minimize the possibility of occupant contact with interior vehicle components or with other occupants and wheelchairs. The second requirement (4.3.2) is primarily a statement about the locations of the anchor points for which the WTORS is designed. While a belt restraint that anchors to the seat or wheelchair is generally considered to offer improved belt fit for the user, this clause recognizes that most wheelchairs in use today are not designed for, and would not be able to withstand occupant restraint forces. Thus, the requirement states that the design intent of the WTORS must be for a belt-type occupant restraint system to anchor to the vehicle or to tiedown components that may be either fastened to the vehicle or to the wheelchair. Note that the later may be fastened permanently (e.g., bolted) to the wheelchair, or fastened temporarily during transit, as is the case with the Q'Straint system, where the pelvic belt anchors to the rear tiedown straps that are hooked to the wheelchair frame.

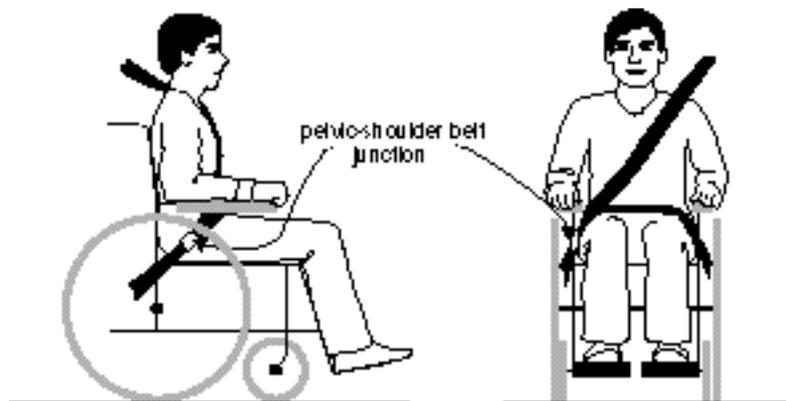
The only exception to this (i.e., to allowing a WTORS to have occupant restraints designed with the intent of anchoring to the wheelchair) is when the WTORS is designed for use with a specific wheelchair and that wheelchair is used as the "test wheelchair" in the frontal impact test of Appendix A. In this case, the frontal impact test is really a systems test (i.e., testing the wheelchair plus the WTORS together. This was done so that compliance with the standard makes a consistent statement about the dynamic strength of a WTORS that complies with the standard -- i.e., that it performed effectively under dynamic loading with an 85-kg wheelchair. The comparable ISO standard (ISO 10542) does not allow such systems tests within Part 1 of the standard, but rather only allows for conducting the frontal impact test with the 85-kg surrogate wheelchair. In ISO, the system test for WTORS that transfer occupant restraint forces to the wheelchair is being accomplished in ISO 10542-5, which is now under development. In either case, the issue comes down to requirements for labeling of WTORS with these types of restraint anchorages, so that they are only used with wheelchairs that have been appropriately tested. Eventually, all wheelchairs that comply with ANSI/RESNA WC 19 will meet this requirement for the pelvic-belt anchor points being on the wheelchair. It will then be possible to modify SAE J2249, to allow testing of all WTORS using the surrogate wheelchair, whether or not they transfer occupant restraint anchorage forces to the wheelchair.

Clauses 4.3.3 through 4.3.7 deal with the fit and accommodation of belt-type occupant restraints to the range of potential users and for the range of foreseeable anchor point configurations in the real world. The first of these (4.3.3) is a requirement that, like all belt restraints installed by vehicle manufacturers, belt restraints of WTORS must be manually adjustable. This requirement is also covered by the fact that restraint systems used in WTORS must comply with FMVSS 209 (see 6.1). The test of Appendix B (4.3.4 and 4.3.5) provides a check on the geometry and adjustment lengths of WTORS for a nominal set of conditions using the

surrogate wheelchair and an adult-size crash dummy or ATD. When setup according to these procedures, the angle of the pelvic belt must fall between 30 and 75 degrees to the horizontal when viewed from the side.<sup>7</sup> The preferred range of pelvic-belt angles is 45 to 75 degrees because steeper angles reduce the probability of occupant submarining under the pelvic belt, a phenomenon that can produce serious and fatal injuries to abdominal organs in a severe frontal crash. However, the standard allows the pelvic belt in these nominal setup condition to be as low as 30 degrees, which is compatible with federal safety standards (i.e., FMVSS 209).

Similarly, the requirement of 4.3.7 that the junction of the shoulder belt with the pelvic belt, illustrated in Figure 6, of three-point restraints be at least 150 from the centerline of the midsize male ATD is related to the concern of the occupant submarining under the lap belt, in this case because of the pelvic belt being pulled off the bony pelvis by upward force from the shoulder belt. The junction of the pelvic and shoulder belts will ideally be near the hip of the occupant, with the shoulder belt fitting properly across both the chest and shoulder, so that the pelvic belt is not pulled upward by the shoulder belt.

Since the junction of the shoulder belt and pelvic belt is usually a fixed distance from the pelvic-belt anchor point, and since a wheelchair station may be used with a range of occupant and wheelchair sizes, it may not be possible to achieve the ideal location of this junction for all users (another good reason for using wheelchair-anchored pelvic restraints that are fit to the individual user). However, the requirement of 4.3.7 provides a check of design intent for a nominal adult configuration. It is generally better if the shoulder-pelvic belt junction point is further from the centerline, and even below the hip, than closer to the centerline, and this will be the case for most occupants if the conditions of the test are met when there is a fixed distance between the pelvic-belt buckle and the shoulder-belt junction.



**Figure 6** - Illustration of pelvic-belt/shoulder-belt junction.

<sup>7</sup> In the current version of SAE J2249, the allowed angle is incorrectly specified as 45 to 75 degrees. This will be corrected in a future edition.

For the pelvic belt, the adjustment length requirement is that the belt assembly be able to lengthen and shorten by 200 mm (about 8 in) from the nominal length when fit to the midsize-male ATD seated in the surrogate wheelchair. These length adjustments are needed because of differences in wheelchair dimensions (e.g., heights of the seat above the ground) and because of differences in occupant size. Since J2249 applies to WTORS that are used with children as well as adults, these should be considered minimum adjustment requirements. Depending on the wheelchair and WTORS designs, a reduction in length of 200 mm may not be sufficient to provide a snug fit to some children. Thus, it may be necessary for WTORS manufacturers to offer additional adjustment range, or special pelvic belt options, when it is known that smaller children need to be accommodated.

For the upper-torso belt adjustment range (4.3.5), the test setup specified in Appendix B requires that the system be installed using upper anchor points or guide points that are located at worst-case positions of the anticipated range of foreseeable anchor-point locations in actual vehicles. For example, this location is representative of an anchor point that is located above and behind the windows of a bus, since this may be the only available place where a suitably strong vehicle structure for the anchor point can be found. The figures in Appendix F of J2249 illustrate expected real-world anchor-point zones, where the worst-case locations are the highest corners in these zones. The requirements are that an additional 200 mm (8 in) of lengthening be provided, primarily to account for occupants who are larger than the average U.S. male (76.3 kg), and that it be able to shorten by 300 mm (12 in) to fit smaller people and for lower anchor points.

For WTORS that provide a structure for the upper-torso anchor point or guide point, such as a triangulated tubular structure that is installed in the vehicle as an after-market component, clause 4.3.6 addresses the height of these anchor points. Ideally, such structures will provide for adjustment of the anchor-point height, so that the anchor point can be established at, or a few inches above, the wheelchair users' shoulders. However, if an upper anchor point provided with the WTORS is at a fixed height, Part b requires that it be located a minimum height of 1100 mm above the vehicle floor or wheelchair ground plane. While this may be significantly higher than the shoulders of some wheelchair-seated occupants, it is better that it be close to, or above, the shoulder height of all wheelchair occupants, than significantly below the shoulders of some users. Based on a database of wheelchair seat heights (not including cushions) and data on seated shoulder heights, it has been estimated that the height of the shoulder of an average size U.S. male will be about 1100 mm above the floor (see Table F2 in Appendix F of J2249).

In reference to this shoulder anchor-point-height requirement, it should be noted that FMVSS210 (seat-belt anchorages) allows the upper anchor

points of upper torso belts to be located so as to produce a downward (to the horizontal) angle of 30 degrees. During the development of J2249, this federal requirement was referenced by one WTORS manufacturer as reason to change or remove the minimum height requirement for fixed after-market anchor points. However, the SAE Task Group considered the federal standard to be outdated in terms of good restraint system design practice, and therefore rejected this more liberal geometry. The concern is that if the upper torso belts are directed downward to their anchor point after passing over the shoulder, this will generate downward forces on the occupant's spine that can produce spinal-cord injury.

The last two requirements of this section address the issue of design intent with respect to the use of airbag restraints. As indicated in the Scope of J2249, a WTORS that complies with J2249 must use, and be impact tested with, a belt-type occupant restraint. Clauses 4.3.8 and 4.3.9 reaffirm this requirement by indicating that an airbag shall not be used without a belt-type occupant restraint, and shall not be used to assist the performance of the belt restraint in the frontal-impact test of Appendix A.

### **5. Requirements for Instructions, Documentation, and Labeling**

Section 5 of J2249 contains requirements for the written documentation that WTORS manufacturers must provide to installers and users about their products, as well as statements and markings that must be included on the WTORS and WTORS component' labels, or in presale literature. More specifically, these requirements encompass:

- identification and labeling of WTORS assemblies and components
- instructions and warnings for installation of the WTORS in a vehicle,
- instructions and warnings to users of the WTORS, and
- requirements for statements in presale literature.

It will be noted that many of the statements that comprise the requirements of this section use the word "should" rather than "shall." For example, 5.20 requires that the WTORS manufacturer provide a statement in the instructions to the installer that "all vehicle padding *should* comply with the flammability requirements of FMVSS 302." The reason for using should instead of *shall* in this statement is that the requirement is for the WTORS manufacturer to provide the statement, not to enforce its implementation, which is obviously impossible and therefore inappropriate to word in a normative manner J2249. Note that the introductory statement to 5.2 says that "Manufacturers of WTORS *shall* provide written instructions for the installer that include:" This is the mandatory part of the requirement.

## 5.1 Identification and Labeling

The requirements in J2249 for product identification and labeling are as follows.

Primary WTORS components and subassemblies shall be permanently and legibly marked with:

- a) manufacturer's name or trademark,
- b) month and year of manufacture with the month indicated by the name or a recognized abbreviation and the year indicated by at least the last two digits,
- c) manufacturer's model and part number or an equivalent identification code,
- d) other information that may be necessary to identify a particular product in the event that a recall or special inspection becomes necessary,
- e) the name and location of each detachable WTORS component (e.g., right-rear tiedown, shoulder restraint, pelvic restraint, etc.), and
- f) the notation that the WTORS complies with SAE J2249, and for WTORS impact tested according to Appendix A with a specific production or prototype wheelchair rather than the 85-kg surrogate wheelchair, the make, model, and name of the specific wheelchair, along with the mass of the wheelchair and ATD used in the test.

These requirements pertain to the labeling or marking of the physical pieces, components, and subassemblies that comprise the WTORS. The manufacturer's name or trademark, date of manufacture, and model plus part number are important for determining the age and source of a WTORS system with regard to potential replacement. These markings will also be useful for identifying WTORS or WTORS components that may need to be recalled in the event of a product defect. However, if, in the judgment of the WTORS manufacturer, these are not sufficient for recall and replacement purposes, 5.1d requires that additional information, such as manufacturer lot number, also be provided.

Statement 5.1e requires that the separate functional components of a WTORS be clearly labeled as to their intended purpose. For example, the separate parts of the occupant restraint should be labeled "pelvic belt (left)", "pelvic belt (right)", and "shoulder belt." Also, for a WTORS that uses a four-point strap-type tiedown system, each strap assembly must be clearly and permanently marked to note its intended position, such as "right-rear tiedown" or simply "rear tiedown" as is important to the performance of the particular system.

Finally, the WTORS needs to be clearly marked to indicate that it is in compliance with J2249, and that it complies with the dynamic strength test performance requirements of 6.2. In general, it is expected that this label will include a statement that the WTORS has been impact tested using the 85-kg surrogate wheelchair and 76.3 kg ATD. However, for WTORS tested with a particular commercial wheelchair for which it has been specifically designed, the labeling must clearly indicated the make, model, name, and mass of the wheelchair and ATD for which the WTORS has been tested and

is to be exclusively used. This information must also be included in the manufacturer's presale literature to warn the potential purchaser that the WTORS has been designed for use with a specific wheelchair and that it has limited application.

## 5.2 Instructions for Installation

- The requirements in J2249 for instructions to WTORS installers are as follows. Manufacturers of WTORS shall provide written instructions for the installer that include:
- a) diagrams showing acceptable methods for fastening WTORS anchorage's to the vehicle,
  - b) a description of how the WTORS is to be used so that the installer may be fully informed regarding the purpose and function of all components and how they should be installed,
  - c) a statement that if a head restraint is anchored to the vehicle, a vehicle-anchored back restraint must be provided to minimize rearward deflection of the wheelchair seatback and thereby prevent neck injury,
  - d) an exploded-view drawing, parts list, or receiving inspection checklist for all components required in the installation,
  - e) if fasteners are not supplied as part of the WTORS assembly, the minimum specifications for all wheelchair tiedown and occupant restraint anchorage fasteners and related components. The specifications shall be based on the material, size, and quantity of anchorage fasteners used in the simulated frontal impact test of Appendix A,
  - f) a statement that vehicle anchor points may require reinforcement, along with a minimum strength recommendation for the vehicle at all WTORS anchor points,
  - g) identification of any components to be permanently fastened to the wheelchair and a description of procedures for attachment,
  - h) a statement of the number of separate packages containing WTORS components,
  - i) a description of the types of anchorage fittings that are suitable for use with the vehicle-installed anchorage's,
  - j) recommended distances between anchor points of four-point wheelchair tiedowns, along with Figures 5 and 6,
  - k) recommended locations, relative to wheelchair tiedown anchor points, for anchor points of pelvic restraints that are intended to anchor directly to the floor of the vehicle, and an explanation that pelvic-restraint anchor points should be selected to achieve side-view projected restraint angles of 30 degrees or greater, and preferably between 45 and 75 degrees, to the horizontal, as shown in Figure 7, in order to reduce the possibility of the pelvic restraint loading the occupant's abdomen,

- l) recommended locations for upper anchor or upper guide support points of shoulder and harness restraints, and an explanation that these points should be positioned so that the belt webbing passes over the midpoint of the occupant's shoulder and at a height that is at or above the level of occupant's shoulders so as not to impose downward loads on the spine,
- Note: See tables and figures in Appendix F for more information on torso belt fit.
- m) a diagram indicating recommended distances between WTORS anchor points and vehicle interior components along with the illustration of Figure 8, indicating that the distances are based upon the desire to maintain clear zones for potential head excursions of occupants provided with both upper and lower torso restraint, or with only a pelvic restraint, as applicable to the particular transportation situation,
  - n) an instruction that, to reduce the possibility of head injury to wheelchair-seated passengers, vehicle components that are inside of the clear zones of Figure 8 should comply with the impact performance requirements of FMVSS 201,
  - o) an instruction that all vehicle padding should comply with FMVSS 302, Flammability of Interior Materials,
  - p) a statement that an airbag shall be used only as a supplementary occupant restraint in combination with a wheelchair tiedown and belt-type occupant restraint system that complies with the requirements of this recommended practice, and
  - q) a statement that airbags should be disconnected if the wheelchair-seated occupant is positioned less than 175 mm from the airbag module, or if any after-market device is installed so as to block or compromise deployment of the airbag.

A well designed WTORS system will not provide effective protection if it is not installed properly. This section of J2249 specifies the *minimum* requirements for written instructions that the WTORS manufacturer must provide to properly and effectively install the system in a vehicle. One of the primary issues addressed is the locations of anchor points to achieve effective performance of the particular type of wheelchair tiedown. For example, for a four-point, strap-type tiedown, the WTORS manufacturer is required to indicate that the system should be installed to achieve angles of rear tiedown straps of 30 to 45 degrees to the horizontal in order to resist both forward and upward movement of the wheelchair during a frontal impact. In many instances, the installer does not have control over these angles, which are dependent on the locations of tiedown or securement points on the wheelchairs, and also on the relative positioning of the wheelchair within that space. However, J2249 requires that the WTORS manufacturer provide this information so that the installer will be knowledgeable of the goals of a good installation and can therefore install the system for optimal performance.

Similarly, the manufacturer must provide installation recommendations for pelvic and shoulder belts (k and l, respectively) in order to achieve a good fit to potential users. For the pelvic belt, the goal is to set the anchor points to achieve a belt angle between 30 and 75 degrees to the horizontal during normal use, and preferably above 45 degrees. Although this may not be realizable for all wheelchair users at a particular station in a public or school transportation vehicle, the information is provided so that the

installer knows the objects of the installation - i.e., to achieve steeper angles rather than shallow angles, since low angles increase the probability of the pelvic bone submarining under the lap-belt webbing and the belt loading and lacerating the abdominal organs, which can lead to serious and fatal injuries.

Several of the requirements in 5.2 require that the WTORS manufacturer instruct the installer as to proper hardware installation techniques, including diagrams (5.2.a), specifications for fasteners (5.2.e), and the need to provide additional reinforcement for some anchor points, such as installation into sheet metal. At one time, the information in F.1.3 and F.1.4 of Appendix F (i.e., recommendation for installing anchorages into structural members and for use of backing plates when installing into sheetmetal) was included in the requirements of 5.2, but these were replaced by the more general statements in Section 5.2, which places the responsibility for the details about effective installation on the WTORS manufacturer.

A WTORS system is only as strong as its weakest link and, if fasteners are not of required hardness, size, or quantity, an otherwise effective WTORS may catastrophically fail when needed in a crash. In this regard, there was considerable discussion during the development of the standard about whether the WTORS manufacturer should be required to provide all fasteners for anchorages with the WTORS. Some manufacturers agreed that this was essential, while others thought that it was inappropriate and unnecessarily costly because the length of the fasteners needed depends on the type of installation and vehicle, making it necessary to include fasteners of different dimensions to cover all possible installation scenarios. The final requirement is that the manufacturer either include the fasteners, or include the minimum specifications for the fasteners, based on the fasteners used in the dynamic test of Appendix A. While not specifically required by J2249, it is recommended that WTORS manufacturers include specifications for fasteners, even when the fasteners are provided with the WTORS, in the event that substitution or replacement is needed.

Clause (c) of this section is a warning to installers who might think it is beneficial to install a vehicle-anchored head restraint to limit rearward head movement and neck bending in rear impacts or on rebound from frontal impacts. The statement tells installers that, if they do this, they must also install an effective vehicle-anchored back support. The reason is that most wheelchair backrests will deform under occupant loading from a rear impact, or during occupant rebound from a frontal impact. If this occurs, but the head is effectively restrained by a vehicle-anchored headrest, serious injury to the neck can occur. It is better for the head and torso to move backward together, perhaps with a head restraint attached to the wheelchair seatback, assuming that the wheelchair backrest deflects rearward but does not totally collapse.

Clauses (b), (d), (g), and (h) address the packaging and identification of the pieces and parts that comprise the WTORS and are self explanatory. Clause (i) requires that the WTORS manufacturer tell the installer about the types of anchorages that will work effectively with the installed anchorages. For example, different types of anchorage track are used with four-point, strap-type tiedowns, and it is important that the installer, as well as the users, understand the types of end fittings that will effectively engage with the particular type of track included in the WTORS kit. Small differences in dimensions or design features between anchorage track from different manufacturers may result in ineffective engagement and performance.

The remaining requirements of this section deal with instructions that address the concern of occupants contacting vehicle components in an impact situation, and concerns about the use of airbags with wheelchair seated occupants. On the first issue, the standard requires that the WTORS manufacturer indicate the need for clear space, both in words and by illustration (Figure 8 of the standard), and the need to place effective, non-flammable padding on vehicle components that may fall within the needed clear space. By "effective" is meant padding that absorbs energy and reduces head accelerations when dynamically tested as specified in FMVSS 201. An example of material that would comply with FMVSS 201 is 19-to-25 mm thick Rubatex R 3901-SV (Rubatex is located in Bedford, Virginia; phone: 1-800 RUBATEX).

With regard to airbags, J2249 requires that the installer be warned by the WTORS manufacturer not to use airbags without an effective belt restraint system (i.e., that airbags are supplementary restraints), and that the installer should call the vehicle manufacturer and/or the National Highway Traffic Safety Administration (NHTSA) if they suspect that an occupant may sit too close to the airbag module, which can result in serious or fatal injury from the energy of the airbag deployment. Just prior to publication, this latter provision specified "too close" as when any part of the wheelchair occupant's body was within 175 mm (about 7 in) of the airbag module. This distance, however, was removed since some WTORS manufacturers may choose to be more conservative (i.e., instruct to disable the airbag if people sit within 200 mm of the module), and since airbag systems may change so as to make a smaller distance acceptable in the future. It should also be noted that, at the time of this publication, the NHTSA was using 250 mm (10 in) as the minimum recommended distance between the airbag module and the occupants during normal vehicle operation.

### **5.3 Advice and Warnings for Installers**

This section of Part 5 contains additional requirements for special "advice" and "warnings" to installers that the manufacturer *must* provide. They are separated from the written requirements of 5.2 to make the point that these statements should be more strongly "flagged" in the installer instructions (e.g., larger, bold, all caps font), although no requirements about font size and type are specified. The requirements are that a

WTORS manufacturer warn the installer by providing:

- a) a statement that the WTORS complies with all applicable requirements of SAE J2249, including a 48-kph, 20-g frontal impact test using either:
  - i) a forward-facing surrogate wheelchair with a mass of 85 kg and an ATD with a mass of 76.3 kg, or
  - ii) a specific production wheelchair and an appropriate size ATD, along with the mass of the test wheelchair and ATD.
- b) a statement that the WTORS should only be installed for forward-facing seating,
- c) advice to have the WTORS installed by an experienced technician,
- d) descriptions of any wheelchair features that are required to allow correct fitting of WTORS components that are to be permanently fastened to the wheelchair,
- e) a general warning to consult the WTORS manufacturer in case of questions as to the method of installation on the wheelchair and/or in the vehicle,
- f) a warning that anchorages should not be installed into unsound materials such as corroded metal, wood, plastic, and fiberglass panels, without additional and suitable reinforcement,
- g) a warning against making alterations or substitutions to the WTORS parts or components without consulting the WTORS manufacturer,
- h) a warning that the equipment has been tested in a configuration similar to that recommended by the manufacturer and that any deviation from the manufacturer's recommendations is the responsibility of the installer, and
- i) a warning to protect webbing from contacting sharp corners and edges

The first requirement is that the manufacturer indicate compliance with SAE J2249 and mention the 48 km/h (30 mph), 20-g dynamic test. In most cases, the manufacturer will have tested with the 85-kg surrogate wheelchair and 76.3 kg adult test device (ATD) and will so indicate, thereby making a statement that the WTORS is suitable for use with essentially all wheelchairs (i.e., wheelchairs of relatively high mass). However, since the standard allows for a WTORS to be tested with a specific wheelchair that may have a lower mass, 5.3.1(b) requires that the WTORS manufacturer indicate the specific type of wheelchair and mass of wheelchair occupants (i.e., as represented by the anthropomorphic test device) for which it was designed and tested.

It is perhaps worth noting again that the main part of the comparable ISO standard (i.e., ISO 10542-1) only allows testing with the 85-kg surrogate wheelchair and 76.3 kg ATD, so that compliance with Part 1 makes a singular statement about the dynamic strength of WTORS that comply. Testing of WTORS designed for use with only a specific, and potentially lower mass wheelchair will be accomplished in a separate part of the ISO

standard that provides for testing a combination of commercial wheelchairs and commercial WTORS (Part 5) and that is still under development at this time. It is still not clear, however, how this separation of testing with lower mass wheelchairs into a separate part of ISO 10542 will accomplish the desired goal, since the distinction between tiedowns tested with the 85-kg surrogate wheelchair and lower mass wheelchair must still be accomplished by labeling on the WTORS equipment.

Clause (b) is a warning to use the WTORS only in the forward-facing mode, and is self explanatory but extremely important, since it is, and has been, common practice to place wheelchairs and their occupants facing toward the aisle of the vehicle (i.e., sideways). This is essentially a restatement of part of the Scope of J2249 which says that J2259 only applies to WTORS designed for use with forward-facing wheelchairs and occupants.

During development of the recommended practice and the comparable ISO 10542, there was considerable discussion over the requirement for the warning in (c) that a WTORS be installed by an "experienced technician." The concern was that there is no objective criteria about what constitutes an experienced technician. Nevertheless, the requirement for this warning was retained in J2249, with the understanding that it does convey a message about using knowledgeable people to install this equipment, while leaving the judgment of what constitutes an experienced technician up to the installer.

#### 5.4 User Instructions

This section requires that a WTORS manufacturer provide the consumer or user of the WTORS (i.e., the person in the wheelchair or the persons responsible for transport of the person in a wheelchair) information about the proper use and maintenance of the wheelchair tiedown and the occupant restraint. These instructions must be provide on a durable instruction sheet that can kept and displayed in the vehicle, and many are similar to the instructions provided to the installer. This instruction sHEET shall include:

- a) a statement that the WTORS complies with all applicable requirements of SAE J2249, including a frontal impact test conducted at 48 kph, 20 g using:
  - 1) a forward-facing surrogate wheelchair with a mass of 85 kg and an ATD with a mass of 76.3 kg, or
  - 2) a specific production wheelchair and an appropriate size ATD, along with the mass of the test wheelchair and ATD.
- b) a statement that the WTORS has been dynamically tested with an anthropomorphic test dummy restrained by both pelvic and upper-torso restraints, and that use of only a pelvic restraint may compromise the performance of the WTORS,
- c) for WTORS designed to transfer loads through the wheelchair, a statement indicating this, along with a description of the specific wheelchair for which the WTORS has been designed and impact tested,
- d) a statement that the WTORS is to be used only with forward-facing wheelchairs,

- e) a description of the types of anchorage hardware that may be used with the vehicle-installed anchorage components,
- f) a description of the features required of a wheelchair for the WTORS securement hardware to effectively attach to it,
- g) a description of the correct positioning of the occupant restraint on the user, including:
  - 1) a statement that the pelvic restraint is designed to bear upon the bony structure of the body and should be worn low across the front of the pelvis with any junctions between the pelvic and shoulder restraints located near the wearer's hip,
  - 2) a statement that the angle of the pelvic restraint should be within the preferred zone of 45 to 75 degrees to the horizontal, or the optional zone of 30 to 45 degrees to the horizontal, as shown in Figure 7,
  - 3) a statement that restraints should not be held away from the body by wheelchair components or parts, such as the wheelchair armrests or wheels, along with the illustration of Figure 8,
  - 4) a statement that occupant restraints should be adjusted as firmly as possible and consistent with user comfort,
  - 5) a statement that upper torso restraints should fit over the shoulder or shoulders, and
  - 6) a statement that restraint webbing should not be worn twisted,
- h) a statement that the WTORS should be used as shown in the manufacturer's instructions,
- i) a statement that all WTORS webbing and components should be inspected, cleaned, and maintained regularly and:
  - 1) that care should be taken to prevent contamination of the webbing with polishes, oils, and chemicals, particularly battery acid,
  - 2) procedures for cleaning webbing,
  - 3) that frayed, contaminated, or damaged webbing should be replaced,
  - 4) that broken and worn parts should be replaced, and
  - 5) that WTORS components, including anchorages, that are suspected to have been in use during an impact from which the vehicle must be towed should be replaced,
- j) a statement that auxiliary wheelchair equipment should be effectively secured to the wheelchair or removed from the wheelchair and secured in the vehicle during transport so as not to break free and cause injury to vehicle occupants in an impact, and
- k) a statement that, whenever possible, items attached to the wheelchair in front of the occupant should be removed and secured separately during transportation to prevent potential injury to the wheelchair occupant.

Since J2249 allows for testing with either the 85-kg surrogate wheelchair and associated 76.3 kg ATD, as well as with a specific wheelchair and the appropriate size ATD that may be of lower mass, the user (as well as the installer) must be informed, as required by (a), of the sizes and masses of wheelchair and dummy used in the dynamic test, since this may have significant implications on its range and limits of application. Note, however, that the mass of the ATD and the mass of the surrogate wheelchair do not, and need not, correspond to the limits of wheelchair and occupant mass in real-world use. The user is also to be instructed (clause d) that the WTORS is intended only for use with forward-facing wheelchairs and occupants, and is to be strongly encouraged in the user instructions to use both the lower and upper torso belt restraints (clause b).

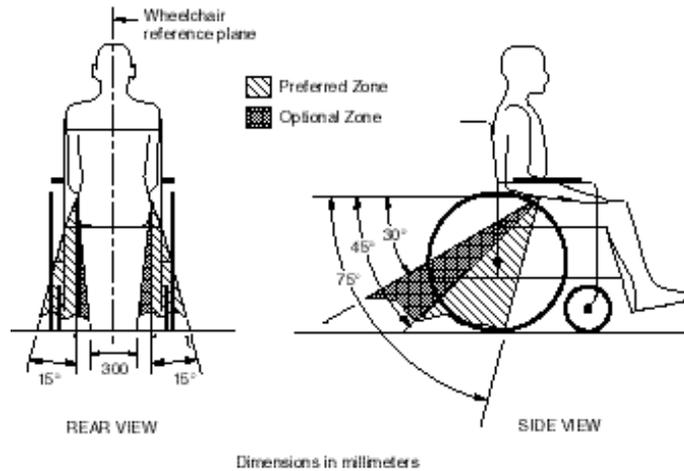


Figure 7 – Preferred and optional angles for pelvic belts.



**Figure 8** - Restraints should not be held away from the body by wheelchair components or parts, such as the wheelchair armrests or wheels.

Although WTORS with four-point, strap-type tiedowns are required to have end fittings that engage with the securement points on the surrogate wheelchair (Figure E4), there are no requirement for attachment hardware of other types of tiedowns at this time. Therefore, the user is to be informed (f) of the wheelchair features (i.e., geometry) required for effective attachment of the tiedown system, both for end fittings that attach temporarily when the wheelchair is in a vehicle, as well as for add-on attachment components that are permanently fastened to the wheelchair.

Similarly, since anchorage end fittings may be disconnected from anchorage hardware fastened to the vehicle and potentially used in other vehicles (e.g., Kinedyne anchorage hardware attached to the strap assembly can be removed from the aluminum tiedown track), the user must be informed (clause e) of the specific type of anchorage hardware that can effectively be engaged with the anchorage components installed in

the vehicle, and visa versa. For example, there are numerous types of aluminum and steel tiedown track that bolt to the floor of the vehicle. However, as indicated previously, there may be small differences in the dimensions of the anchorage track that determine the types and sizes of anchorage components needed for effective performance under impact loading. It is therefore important that the WTORS manufacturer provide information in sufficient detail about key factors that are necessary to ensure proper use of the different separable components of the WTORS, in the event that they become separated or sold separately (see 5.5 below).

Since J2249 allows for WTORS with an occupant restraint that anchors to the wheelchair, and thereby transfers occupant restraint loads directly to the wheelchair (i.e., by dynamically testing with the actual wheelchair), the manufacturer is required in clause (c) to make this limitation clear in the user instructions whenever applicable, and to provide a description of the wheelchair or wheelchairs for which it has been designed and tested. It is hoped, of course, that most wheelchairs will eventually be designed and tested with on-board occupant restraints (i.e., through compliance with ANSI/RESNA WC/19), so that such a statement to the user will not be necessary, but this will not be possible for several years.

Item (g) of this part of J2249 requires the manufacturer to provide information to the user, similar to that provided to the installer in 5.2, on the proper wearing and fit of belt-type occupant restraints to maximize their effectiveness in reducing injuries. In particular, Figure 7 is used to indicate preferred and optional angles for the pelvic belt. Item (i) requires the manufacturer to inform the user about procedures for maintenance and possible replacement of worn or dynamically loaded WTORS. The latter is important since, even if there are no obvious signs of failure, a system may be weakened or, in the case of seat-belt webbing, stiffened, after it is loaded in an impact, thereby changing its potential effectiveness and energy-absorbing properties, should the vehicle be involved in another impact situation.

Finally, items (j) and (k) require that the user be warned about potential problems with auxiliary equipment that may be attached to the wheelchair to serve the needs of the user. Such items can break loose and cause injury to other occupants and should therefore be effectively secured to the wheelchair or detached and stored elsewhere in vehicle. Items placed in front of the wheelchair occupant, such as trays, often have fairly rigid and narrow edges, and the user must be informed of the potential hazard (k) such items can present in a crash environment. Although this is not strictly the WTORS manufacturer's responsibility, since it is not part of the WTORS system, such items can reduce the ability of the WTORS to provide effective occupant protection. Therefore, it was decided that the WTORS manufacturer must at least bring this concern to the user's attention. In many cases, removing items such as trays may not be an acceptable option. In these cases, placing energy-absorbing padding between the

tray and the wheelchair occupant, and/or increasing the space between the occupant and the tray, is recommended.

### **5.5 Instructions for WTORS Components and Subassemblies Sold Separately**

- 5.5.1 Parts and subassemblies of WTORS that are not supplied as parts of complete kits shall be supplied with installation, user, and maintenance instructions that include details of the WTORS devices and components with which they are compatible.
- 5.5.2 A replacement part for WTORS shall include appropriate installation instructions for that part.

Not too many years ago, it was often the case that a wheelchair-seated occupant was provided with some kind of wheelchair tiedown, or some kind of occupant restraint, but not both. For this reason, one of the goals of J2249 is to encourage the marketing and use of complete WTORS systems that include both an effective wheelchair tiedown and a properly designed occupant restraint. However, it was recognized during the development of J2249 that some manufacturers market pieces and components of WTORS that are assembled into a complete system by a third party. An example is the anchorage track sold by Kinedyne, Inc. that is used in WTORS with four-point tiedowns marketed by several different companies.

Thus, while J2249 applies primarily to the companies that assemble and market the final WTORS, this section was included to address the situations where WTORS components and parts are marketed separately, to insure that these parts are in compliance with J2249. Such parts must, of course, be tested to J2249 as part of a complete WTORS, and must be marketed with appropriate documentation required by 5.1 through 5.4, as is appropriate to the particular component. Similarly, 5.5.2 allows all manufacturers to market replacement parts for complete WTORS that are in compliance with J2249, but stipulates that such replacement parts include "appropriate" installation instructions.

### **6. Performance Requirements**

While Section 4 of J2249 contains requirements that address the design intent of the WTORS manufacturer, Section 6 specifies *minimum* performance requirements for WTORS. Except for the first subsection (i.e., 6.1) which requires adherence to selected parts of existing federal motor vehicle safety standards for belt restraint design and materials, specific test methods to determine compliance are provided in Appendices to J2249 as follows:

- Appendix A - Frontal Impact Test (i.e., dynamic test)
- Appendix C - Test for Partial Engagement of WTORS Components

Appendix D - Test for Webbing Slippage at Tiedown Adjustment Devices of Wheelchair Tiedown Straps

**6.1 WTORS Components**

This subsection of performance requirements references applicable parts of FMVSS 209, *Seat Belt Assemblies*, and FMVSS 302, *Flammability of Interior Materials*. While FMVSS 209 applies strictly to belt restraint systems, several parts were also considered applicable to webbing, metal parts, and mechanisms of tiedown assemblies, as noted in the last column of Table 2 reproduced below.

**Table 2 of J2249  
Applicable Subsections of FMVSS 209**

Section	Component	Subject	Tests referenced	Application*
S4.1 (a)	general design	occupancy	-	R
S4.1 (b)	pelvic restraint	design	-	R
S4.1 (c)	upper torso restraint	design	-	R
S4.1 (d)	hardware	burrs & sharp edges	-	R + TD
S4.1 (e)	release mechanism	design	-	R
S4.1 (g)	restraint assemblies	adjustment range	-	R
S4.1 (h)	webbing	unraveling	-	R + TD
S4.2 (a)	webbing	belt width	S5.1(a)	R
S4.2 (b)	webbing	breaking strength	S5.1(b)	R + TD
S4.2 (c)	webbing	elongation	S5.1(c)	R + TD
S4.2 (d)	webbing	abrasion resistance	S5.1(d), S5.3(c)	R
S4.2 (d)	webbing	abrasion resistance	S5.1(d)	TD
S4.2 (e)	webbing	light resistance	S5.1(e)	R + TD
S4.2 (f)	webbing	microorganism resistance	S5.1(f)	R + TD
S4.2 (h)	webbing	stain resistance	S5.1(h)	R + TD
S4.3 (a)	hardware	corrosion resistance	S5.2(a)	R + TD
S4.3 (b)	hardware	temperature resistance	S5.2(b)	R + TD
S4.3 (d)	buckle release	release force	S5.2(d)	R
S4.3 (e)	adjustment device	adjustment force	S5.2(e)	R
S4.3 (f)	tilt-lock devices	locking angles	S5.2(f)	R
S4.3 (g)	buckle latch	separation force	S5.2(g)	R
S4.3 (h)	belt retractor	performance	S5.2(h)	R
S4.3 (i)	belt retractor	performance	S5.2(i)	R
S4.3 (j)	belt retractor	performance	S5.2(j)	R
S4.3 (k)	belt retractor	performance	S5.2(k), S4.4	R
S4.4 (a)	pelvic restraints	performance	S5.3(a)	R
S4.4 (b)	3-pt restraints	performance	S5.3(b)	R

\* R = occupant restraint; TD = wheelchair tiedown.

## 6.2 Frontal Sled Impact Test

This subsection of performance requirements sets forth the criteria for passing the frontal-impact dynamic strength test of WTORS. This is the test that assesses the potential for a WTORS to provide effective wheelchair securement and effective occupant restraint to the wheelchair user in a frontal crash test. These criteria are fundamental to J2249 and require that the WTORS:

- a) retain the ATD in the test wheelchair and on the test sled with the test wheelchair in an upright position,
- b) not show any visible signs of tearing, fragmentation, fracture, or complete failure of any load carrying part, unless that part is designed to tear or fail in a controlled and predictable manner to limit forces on the occupant,
- c) not become detached or separated at anchorages or securement points,
- d) not allow the horizontal excursions of the test dummy and the test wheelchair to exceed the values given in Table 3 (see below),
- e) prevent the wheelchair from imposing forward loads on the occupant as indicated by:

$$X_{knee}/X_{wc} \geq 1.1$$

- f) allow removal of the ATD and the test wheelchair subsequent to the test without the use of tools.

Measurement Point	Excursion Variable	Pelvic & Shoulder Restraint
Test Wheelchair	$X_{wc}$	200
ATD Knee	$X_{knee}$	375
ATD Head	$X_{head}$	650

where,

$X_{wc}$  = the horizontal distance relative to the sled platform between the contrast target placed at or near point P on the test wheelchair at time  $t_0$ , to the point P target at the time of peak wheelchair excursion.

$X_{knee}$  = the horizontal distance relative to the sled platform between the dummy knee-joint target at time  $t_0$ , to the knee joint target at the time of peak knee excursion, and

$X_{head}$  = the horizontal distance relative to the sled platform between the most forward point on the dummy's head above the nose at time  $t_0$ , to the most forward point on the dummy's head at the time of peak head excursion,

The peak ATD and wheelchair forward excursion limits in Table 3 are based on measurements of typical excursions in “successful” tests of WTORS at the time J2249 was written. As improvements in WTORS are achieved, and as more test results with the surrogate wheelchair become available, it is expected that these excursion limits may be decreased in future versions of Recommended Practice.

### **6.3 Partial Engagement of Anchorage and Securement Components**

The performance requirement of this subsection applies to anchorage and securement components of both tiedowns and occupant restraints, and it applies to components of all types of tiedowns, including docking and strap assemblies. The test procedures of Appendix C require that all hardware components that may be manually separated, such as tiedown anchorages of strap assemblies that plug into anchorage track on the vehicle, or components of a docking system attached to the wheelchair that engage with docking hardware anchored to the vehicle, be connected in all possible and foreseeable ways, other than the intended manner for effective lockdown. For each such connection, a force is applied to separate the parts. If the separation force is greater than 22 N (about 5 lb), it is assumed that proper engagement may be erroneously perceived, and the WTORS fails the test. That is, for each improper engagement, components must separate easily so as **not** to give the impression of proper and effective engagement.

### **6.4 Webbing Slippage at Tiedown Adjustment Devices**

When tested as specified in Appendix D, webbing adjustment mechanisms of the wheelchair tiedown system shall not show slippage greater than 25 mm.

## **7. Test Report**

Although this section is titled *Test Report*, its primary purpose is to itemize the documentation that a WTORS manufacturer shall have on file as evidence that the particular WTORS complies with SAE J2249 and is therefore justified in being so labeled. Much of this information would of course be provided in the test report by the test lab that performs the tests. However, many of the tests may be performed by the WTORS manufacturer. The section is essentially a recap of the design and performance requirements set forth in the body of the standard.