SAE The Engineering Society For Advancing Mobility Land Sea Air and Space®
INTERNATIONAL
400 Commonwealth Drive, Warrendale, PA 15096-0001

SURFACE VEHICLE RECOMMENDED PRACTICE

SAE J2249 | ISSUED OCT96

Issued 1996-10

Submitted for recognition as an American National Standard

WHEELCHAIR TIEDOWN AND OCCUPANT RESTRAINT SYSTEMS FOR USE IN MOTOR VEHICLES

Foreword—For people with disabilities who are unable to transfer from their wheelchairs when traveling in motor vehicles, the wheelchair must serve as the vehicle seat. This usually means that the occupant restraint system installed by the vehicle manufacturer cannot be used to provide protection in a crash. In addition, the wheelchair must be secured to the vehicle so that it does not impose forces on its occupant and/or become a hazard to other vehicle occupants in a collision or sudden vehicle maneuver. Providing occupant protection for the wheelchair-seated occupant, therefore, requires that aftermarket equipment be installed to secure the wheelchair and restrain the wheelchair user.

This SAE Recommended Practice applies to the design and performance of motor-vehicle adaptive equipment referred to as wheelchair tiedown and occupant restraint systems or WTORS. It is the purpose of this document to encourage the design, testing, installation, and use of WTORS equipment that will provide effective wheelchair securement and occupant restraint in a frontal collision, and that will be comparable in crash performance to seat securement and occupant restraint systems provided by the vehicle manufacturer. While the primary concern is to reduce the potential for injury to wheelchair-seated occupants involved in a frontal vehicle crash, it is anticipated that achievement of improved occupant protection will also result in increased driver and passenger safety and comfort during normal travel. The provisions of this document should not be used to discourage people with disabilities from using motor vehicle transportation or to limit access to, and availability of, motor vehicle transportation to wheelchair users.

Since manufacturers of WTORS are generally not able to control or specify the end use of their products, the 48-km/h, 20-g sled impact test specified in Appendix A is intended to qualify WTORS for use in vehicles with a gross vehicle weight of less than 7000 kg. In larger vehicles, it may be possible to provide safe transportation using WTORS that do not comply with the level of crash severity used in this document.

As with any vehicle seat, the wheelchair is an important component of the occupant protection system, and also contributes significantly to the stability and comfort of the wheelchair-seated occupant during normal travel. Design and performance of wheelchairs used as seats in motor vehicles is addressed in a separate, but related, ANSI/RESNA Standard now under development.

QUESTIONS REGARDING THIS DOCUMENT: (412) 772-8512 FAX: (412) 776-0243
TO PLACE A DOCUMENT ORDER; (412) 776-4970 FAX: (412) 776-0790

TABLE OF CONTENTS

1. ***Scope***—This SAE Recommended Practice applies to WTORS comprised of a system or device for wheelchair tiedown and a system or device for restraining the wheelchair-seated occupant. 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. This document places particular emphasis on design requirements, test procedures, and performance requirements for the dynamic performance of WTORS in a 48-km/h, 20-g frontal impact. It also 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 that could be perceived to be effectively engaged. Appendix F includes additional recommendations for WTORS that will enhance the design, performance, installation, and use of WTORS, but which are not, at this time, required for compliance with this document.

The contents of this document apply to WTORS used with forward-facing wheelchair-seated children and adults, and apply to passengers and drivers of personally licensed motor vehicles as well as to passengers of motor vehicles used in public and school transportation. While much of the focus of this document is on WTORS that use four-point wheelchair tiedown systems, unless otherwise specified, the provisions of this document are applicable to all types of WTORS, including those that use docking-type wheelchair tiedowns.

While the primary focus of this document is a WTORS that is packaged by the manufacturer as a complete system or kit, it is recognized that a significant portion of the WTORS market consists of separate WTORS components and subassemblies, such as anchorage track that is sold to the bus manufacturer, or securement and restraint assemblies that are sold to the transit provider. Manufacturers of such WTORS components and subassemblies may certify their equipment as being in compliance with this document provided that:

a. The subassemblies and components intended to be used together to create a WTORS meet all the appropriate requirements of this document, and
b. The separately sold components and subassemblies are provided with instructions in accordance with 5.5, where the word "compatible" means tested together to comply with this document.

2. *References*

2.1 Applicable Publications—This document contains provisions which reference the following documents. At the time of publication, the indicated editions of these references were valid. Since all publications are subject to revision or deletion, users of this document are encouraged to refer to the most recent published editions of these referenced documents.

2.1.1 SAE PUBLICATIONS—Available from SAE, 400 Commonwealth Drive, Warrendale, PA 15096-0001.

SAE J211-2—Instrumentation for Impact Test
SAE J850—Fixed Rigid Barrier Collision Tests
SAE J1834—Seat Belt Comfort, Fit, and Convenience

2.1.2 FEDERAL PUBLICATIONS—Available from the Superintendent of Documents, U.S. Government Printing Office, Washington, DC 20402.

FMVSS 209—Seat Belt Assemblies, Part 571.209
FMVSS 302—Flammability of Interior Materials, Part 571.302

2.2 Related Publications—The following publications are provided for information purposes only and are not a required part of this document.

2.2.1 SAE PUBLICATIONS—Available from SAE, 400 Commonwealth Drive, Warrendale, PA 15096-0001.

SAE J128—Occupant Restraint System Evaluation
SAE J140a—Seat Belt Hardware Test Procedure
SAE J141—Seat Belt Hardware Performance Requirements
SAE J383—Motor Vehicle Seat Belt Anchorage Design Modifications
SAE J2094—Terminology Report for Vehicle and Control Modifications for Drivers with Physical Disabilities
SAE J2252—Surrogate Wheelchair Drawing Package and Maintenance Manual

2.2.2 ADA PUBLICATION—Available from Available from the Superintendent of Documents, U.S. Government Printing Office, Washington, DC 20402.

PL 101-336—Americans with Disabilities Act, Part IV, Transportation for Individual with Disabilities, SN 869-010-0096-1, US Code Citation: 42 USC 12101

PL 101-476—Individuals with Disabilities Act (IDEA), 1990, US Code Citation: 20 USC 1400

2.2.3 AUSTRALIAN STANDARD—Available from Standards Association of Australia, Head Office: Standards House, 80 Arthur Street, North Sydney, P.O. Box 458, North Sydney, 2060 Australia.

AS 2942-1994—(Australian) Standard for Wheelchair Occupant Restraint Assemblies for Motor Vehicles, 2nd edition

2.2.4 CANADIAN STANDARDS ASSOCIATION PUBLICATIONS—Available from Canadian Standards Association, 178 Rexdale Boulevard, Etobicoke, Ontario, Canada M9W1R3.

CAN-D409-M84—Motor Vehicles for the Transportation of Physically Disabled Persons, ISSN 0317-5669, April 1994
CSA Z604—Transportable Mobility Aids for Occupancy in Moving Vehicles
CSA Z605—Mobility Aid Securement and Occupant Restraint Systems for Motor Vehicles

2.2.5 DIN PUBLICATION—Available from ANSI, 11 West 42nd Street, New York, NY 10036-8002.

DIN 75 078 Teil 2—Motor Vehicles for Transportation of Handicapped Persons—Restraint Systems—Concepts, Requirements, Testing

2.2.6 FMVSS PUBLICATIONS—Available from the Superintendent of Documents, U.S. Government Printing Office, Washington, DC 20402.

FMVSS 201—Occupant Protection in Interior Impacts, 49CRF Part 571.201 Amended August 18, 1995
FMVSS222—School Bus Passenger Seating and Crash Protection, Federal Register, Vol 58, No. 10, January 15, 1993

2.2.7 ISO PUBLICATIONS—Available from ANSI, 11 West 42nd Street, New York, NY 10036-8002.

ISO 7176/19—Requirements and test methods for transportation—Wheelchairs for use in motor vehicles
ISO 7193—Wheelchairs—Maximum overall dimensions, 1st edition, 1985-12-1
ISO 10542-1 and 2—Wheelchair tiedown and occupant restraint systems for use in motor vehicles

3. ***Definitions***—For the purposes of this document, the following definitions apply:

3.1 Anchorage—An assembly of hardware and fittings by which loads are transferred directly from the wheelchair tiedown to the vehicle or from the occupant restraint to the vehicle, wheelchair, wheelchair tiedown, or vehicle seat base.

3.2 Anchor Point—A point (area) on a vehicle, wheelchair, wheelchair tiedown, or vehicle seat base to which an anchorage is attached.

3.3 ANSI—Abbreviation for American National Standards Institute.

3.4 Anthropomorphic Test Device (ATD)—An articulated analog of the human body used to simulate a motor-vehicle occupant in a crash environment.

3.5 Automatic-Locking Retractor—A retractor incorporating adjustment by means of a positive self-locking mechanism which is capable, when locked, of withstanding restraint forces (from SAE J1834).

3.6 Back Restraint—A device or system intended to limit rearward movement of the occupant by providing support to the back of the torso.

3.7 Belt—A length of energy-absorbing webbing material used as part of an occupant restraint.

3.8 Docking-Type Tiedown—A wheelchair securement device whose engagement is initiated as a result of the wheelchair rolling into the proper position.

3.9 Emergency-Locking Retractor—A retractor incorporating adjustment hardware by means of a locking mechanism that is activated by vehicle acceleration, webbing movement relative to the vehicle, or automatic action during an emergency, and that is capable, when locked, of withstanding restraint forces (from SAE J1834).

3.10 End Fitting—Anchorage and securement hardware to which tiedown and occupant restraint webbing is fastened and which attaches directly to the anchor points and securement points on the wheelchair, tiedown system, or vehicle.

3.11 Fasteners—Devices used to secure, by mechanical means, other components or parts in place.

NOTE— These include, but are not limited to: bolts, nuts, screws, pins, rivets, and clamps.

3.12 Forward Facing—Orientation in which the wheelchair-seated occupant faces the front of the vehicle with the wheelchair reference plane within 10 degrees of the longitudinal axis of the vehicle.

3.13 Four-Point Tiedown—A wheelchair tiedown system that attaches to the wheelchair frame at four separate points and anchors to the vehicle at four separate anchor points.

NOTE— The typical four-point tiedown system uses four tiedown straps, with two attached to the front portion of the wheelchair and two attached to the rear portion.

3.14 Harness—An occupant restraint consisting of at least one belt designed to provide pelvic restraint and two shoulder or torso belts that apply forces to both shoulders.

3.15 Head Restraint—A device intended to limit rearward displacement of the occupant's head.

3.16 Impact Simulator—A device for accelerating, decelerating, or a combination of decelerating and accelerating, a section of a vehicle or simulated vehicle structures, including instrumentation for measuring pertinent data (from SAE J850).

3.17 Impact Sled—That part of an impact simulator on which components can be mounted for impact testing.

3.18 Independent Occupant Restraint—An occupant restraint that anchors directly to the vehicle or vehicle anchored components that are separate from the wheelchair and wheelchair tiedown.

NOTE— This is also known as a parallel restraint system.

3.19 Integrated Occupant Restraint—An occupant restraint for which the anchor points for the pelvic-restraint, or both pelvic- and shoulder-restraints, are located on the wheelchair, or on tiedown components not fastened to the vehicle.

3.20 Occupant Restraint Anchorage—An assembly of hardware and fittings by which loads are transferred directly from the occupant restraint to the vehicle, wheelchair, wheelchair tiedown, or vehicle seat base.

3.21 Occupant Restraint—A system or device for restraining the occupant in a vehicle to prevent or minimize contact with the vehicle interior components, and to prevent ejection during a crash (from SAE J2094).

3.22 OEM—Abbreviation for Original Equipment Manufacturer.

3.23 Pelvic Restraint—That portion of a seat-belt assembly intended to limit movement of the pelvis.

NOTE— Other terms with similar meaning are lap belt, lap restraint, and lower torso restraint.

3.24 Point P—A reference point that lies at the cross-sectional center of a 100 mm diameter disc positioned with the longitudinal axis perpendicular to the wheelchair reference plane, such that the curved surface of the disc contacts with the backrest and the upper surface of the seat Figure 1.

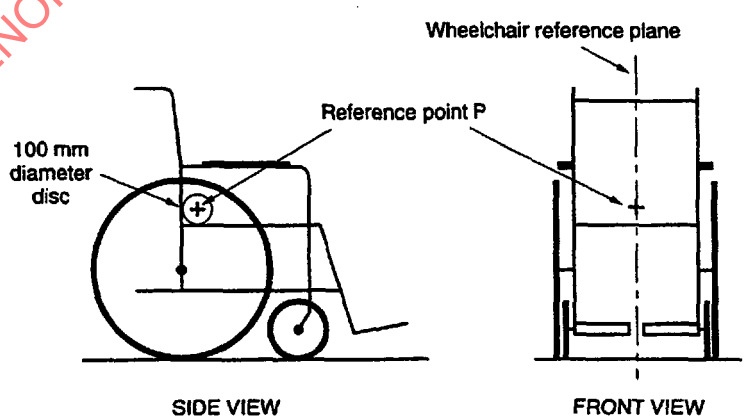


FIGURE 1—WHEELCHAIR REFERENCE POINT P AND WHEELCHAIR REFERENCE PLANE

3.25 Postural Support—A component used to support a person in a desired position, but that is not usually intended to provide occupant restraint in a vehicle impact.

3.26 Securement Hardware—End fittings of a wheelchair tiedown system that connect to the wheelchair.

3.27 Securement Point—Location on the wheelchair frame to which a wheelchair tiedown end fitting connects.

3.28 Strap—A length of webbing material used as a part of a wheelchair tiedown.

3.29 Surrogate Wheelchair—A rigid, reusable device used to simulate a wheelchair for the purpose of testing a WTORS.

3.30 SWC—Abbreviation for surrogate wheelchair.

3.31 Test Wheelchair—A production, prototype, or surrogate wheelchair used to conduct tests specified in this document.

3.32 Three-Point Restraint—An occupant restraint assembly combining both a pelvic belt and diagonal shoulder belt that connect near the hip of the user (see Figure 2).

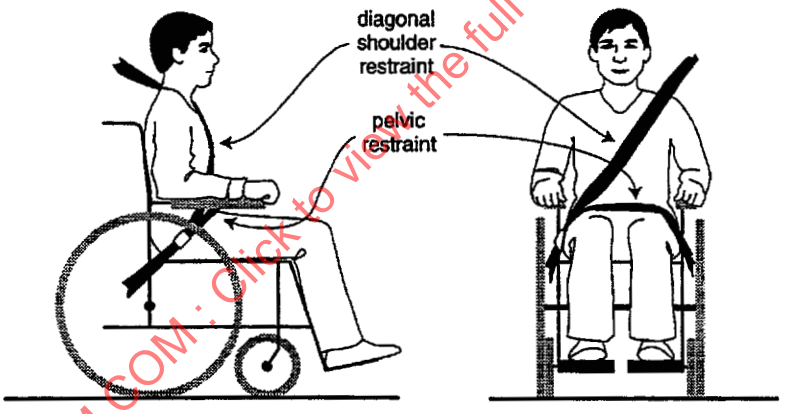


FIGURE 2—THREE-POINT OCCUPANT RESTRAINT. A WHEELCHAIR TIEDOWN IS ALSO REQUIRED BUT IS NOT SHOWN

3.33 Two-Point Restraint—An occupant restraint assembly consisting of a single length of webbing and related components that anchors at two separate points (see Figure 3 for examples).

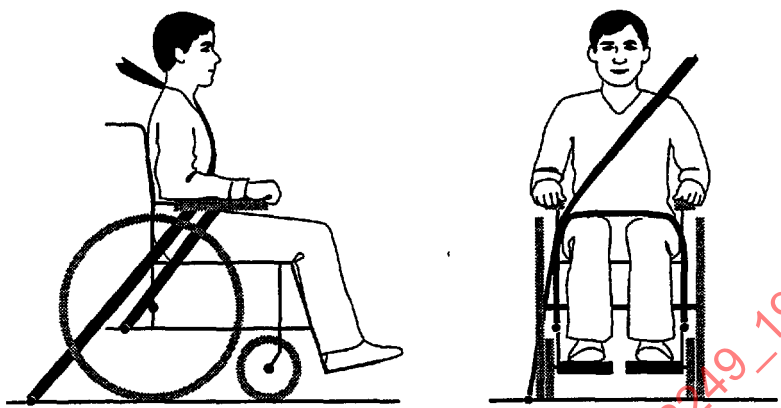


FIGURE 3—TWO-POINT VEHICLE-ANCHORED SHOULDER RESTRAINT WITH TWO-POINT WHEELCHAIR-ANCHORED PELVIC RESTRAINT. WHEELCHAIR TIEDOWN IS ALSO REQUIRED BUT IS NOT SHOWN

3.34 Upper Torso Restraint—A portion of a seat-belt assembly intended to restrain movement of the chest and shoulder regions (SAE J140 and J141).

3.35 Wheelchair—A seating system comprised of a frame, a seat, and wheels that is designed to provide support and mobility for persons with physical disabilities.

NOTE— The term encompasses standard manual wheelchairs, powered wheelchairs, power-based wheelchairs, three-wheel scooter-type wheelchairs, and specialized seating bases.

3.36 Wheelchair Reference Plane—The vertical plane of symmetry in the longitudinal centerline of the wheelchair (see Figure 1).

3.37 Wheelchair Tiedown and Occupant Restraint System (WTORS)—A complete restraint system for wheelchair-seated occupants comprised of a system or device for wheelchair tiedown as well as a system for restraining the occupant.

NOTE— A complete WTORS includes all anchorage hardware and anchorage fasteners, or specifications for anchorage fasteners, required for installing and using the system in a vehicle. Complete WTORS may be designed with the intention of using the vehicle OEM occupant restraint system.

3.38 Wheelchair Tiedown—A device or system designed to secure a wheelchair in place in a motor vehicle.

NOTE— Synonymous terms include wheelchair hold-down, wheelchair lock-down, wheelchair restraint, and wheelchair securement.

3.39 Wheelchair Tiedown Anchorage—An assembly of hardware and fittings by which loads are transferred directly from the wheelchair tiedown to the vehicle.

3.40 WTORS—Abbreviation for wheelchair tiedown and occupant restraint system.

4. *Design Requirements*

4.1 Complete WTORS—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 60 s 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
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

4.2 Wheelchair Tiedowns—Wheelchair tiedowns and tiedown components 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, with at least 25 mm of webbing extending from the adjustment mechanisms.

TABLE 1—MINIMUM ADJUSTMENT RANGES FOR FOUR-POINT TIEDOWN STRAPS(1)

Strap Assembly Location	Minimum Length(2) mm (in)	Maximum Length mm (in)
Rear	485(19)	740 (29)
Front	410 (16)	710 (28)

1. See F.14 and Figure F5 of Appendix F for rationale.
2. 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.6.4.

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 E4.
f. Include a device to indicate, by visual or auditory means, when a docking-type tiedown is properly engaged.

4.3 **Occupant Restraints**—WTORS shall either be designed to use the vehicle OEM passenger or driver restraint, or shall include an occupant restraint that complies with the following requirements:

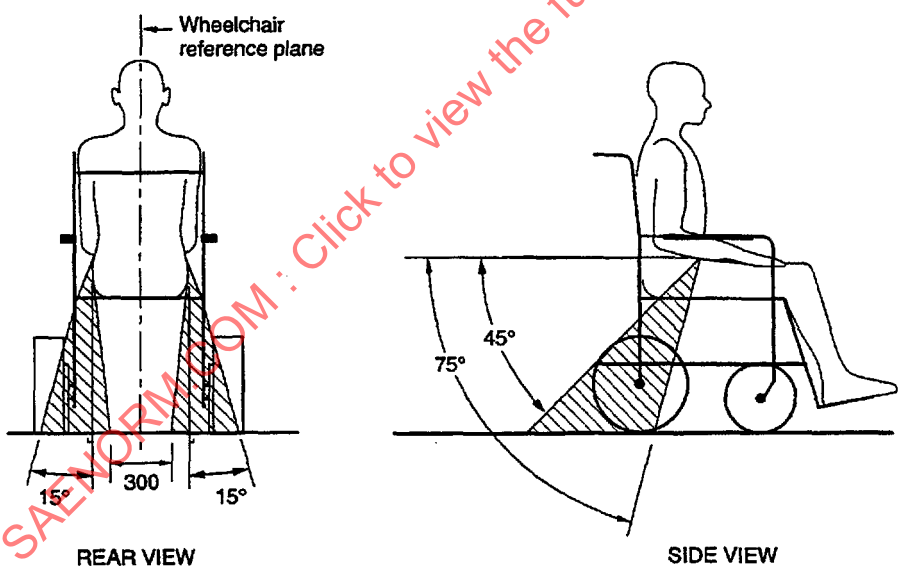
4.3.1 The occupant restraint portion of the WTORS shall include both pelvic and upper torso restraints.

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 anchorages 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 4b
b. Achieve projected rear-view angles and locations within the zones shown in Figure 4a
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



NOTE— 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).

FIGURE 4—RANGES OF REQUIRED ANGLES AND LOCATIONS FOR PELVIC RESTRAINTS AND PELVIC-RESTRAINT ANCHOR POINTS

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:

a. Be sufficiently adjustable in height to be located at or above the shoulder levels of the intended users, or
b. 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 undersirable and not in compliance with this document 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 restrains 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 document.

4.3.9 Performance of the WTORS shall not depend on an airbag to comply with this document.

5. Identification, Labeling, and Instruction Requirements

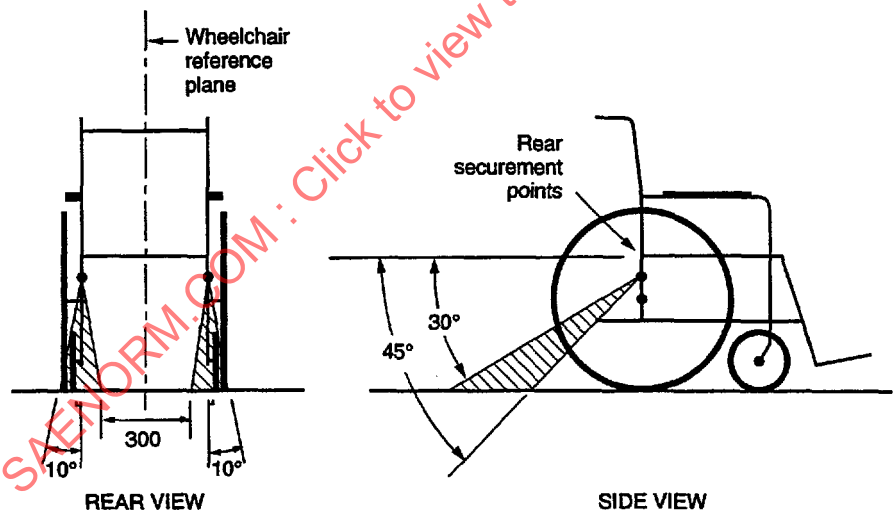
5.1 Identification and Labeling—Primary WTORS components and subassemblies shall be permanently and legibly marked with:

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.)
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

NOTE— The information of 5.1.f shall also be included in the manufacturer's presale literature.

5.2 **Instructions for Installation**—Manufacturers of WTORS shall provide written instructions for the installer that include:

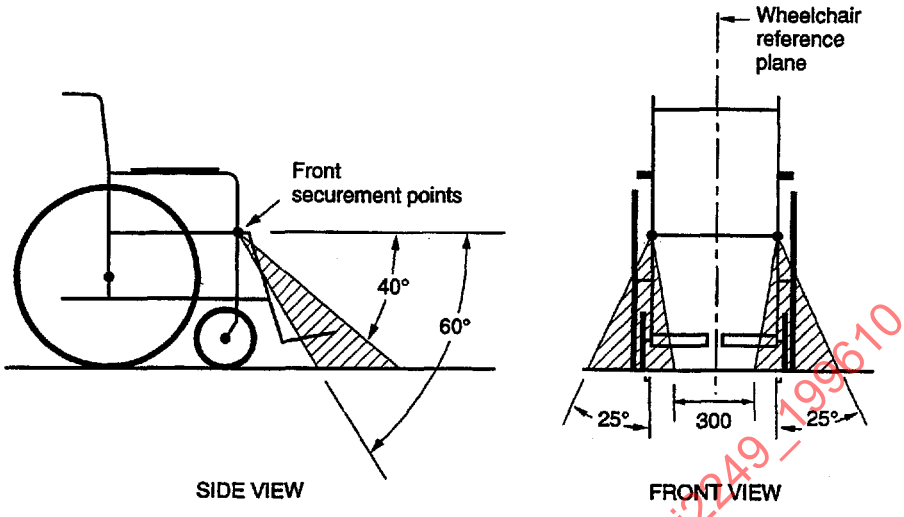
a. Diagrams showing acceptable methods for fastening WTORS anchorages to the vehicle.
b. A description of how the WTORS is to be used so that the installer may be fully informed regarding the purpose and function of all components and how they should be installed.
c. A statement that if a head restraint 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 anchorages.
j. Recommended distances between anchor points of four-point wheelchair tiedowns, along with Figures 5 and 6.



Dimensions in millimeters

NOTE— Note that angles indicated are obtained by projecting the angle of each tiedown strap 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).

FIGURE 5—PREFERRED ANGLES AND LOCATIONS OF REAR WHEELCHAIR TIEDOWN STRAPS AND VEHICLE ANCHOR POINTS



NOTE— Front tiedowns should be angled out for lateral stability when possible. Note that all angles indicated are obtained by projecting the angle of each tiedown strap 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 (front view).

FIGURE 6—PREFERRED ANGLES AND LOCATIONS OF FRONT TIEDOWN STRAPS AND VEHICLE ANCHOR POINTS

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 or 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.

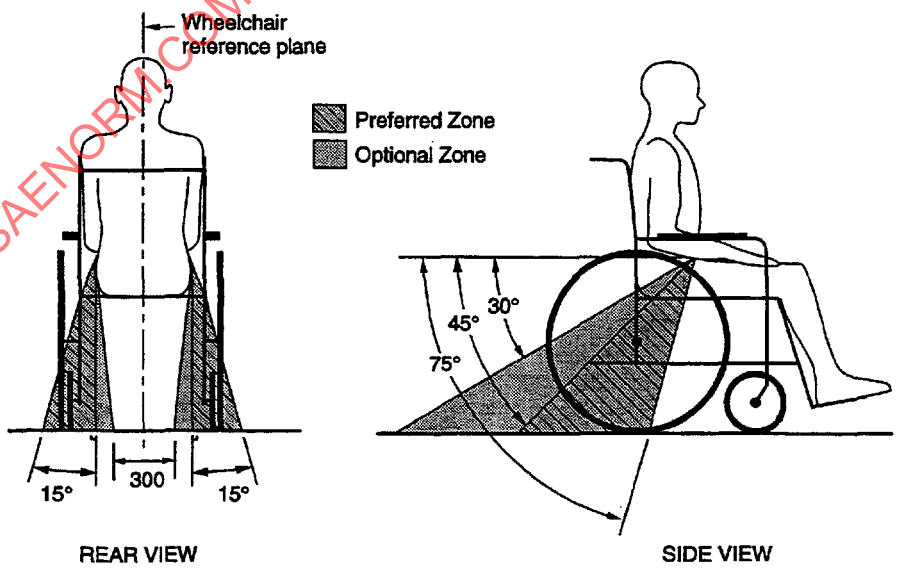


FIGURE 7—PREFERRED AND OPTIONAL ANGLES FOR PELVIC RESTRAINTS

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.

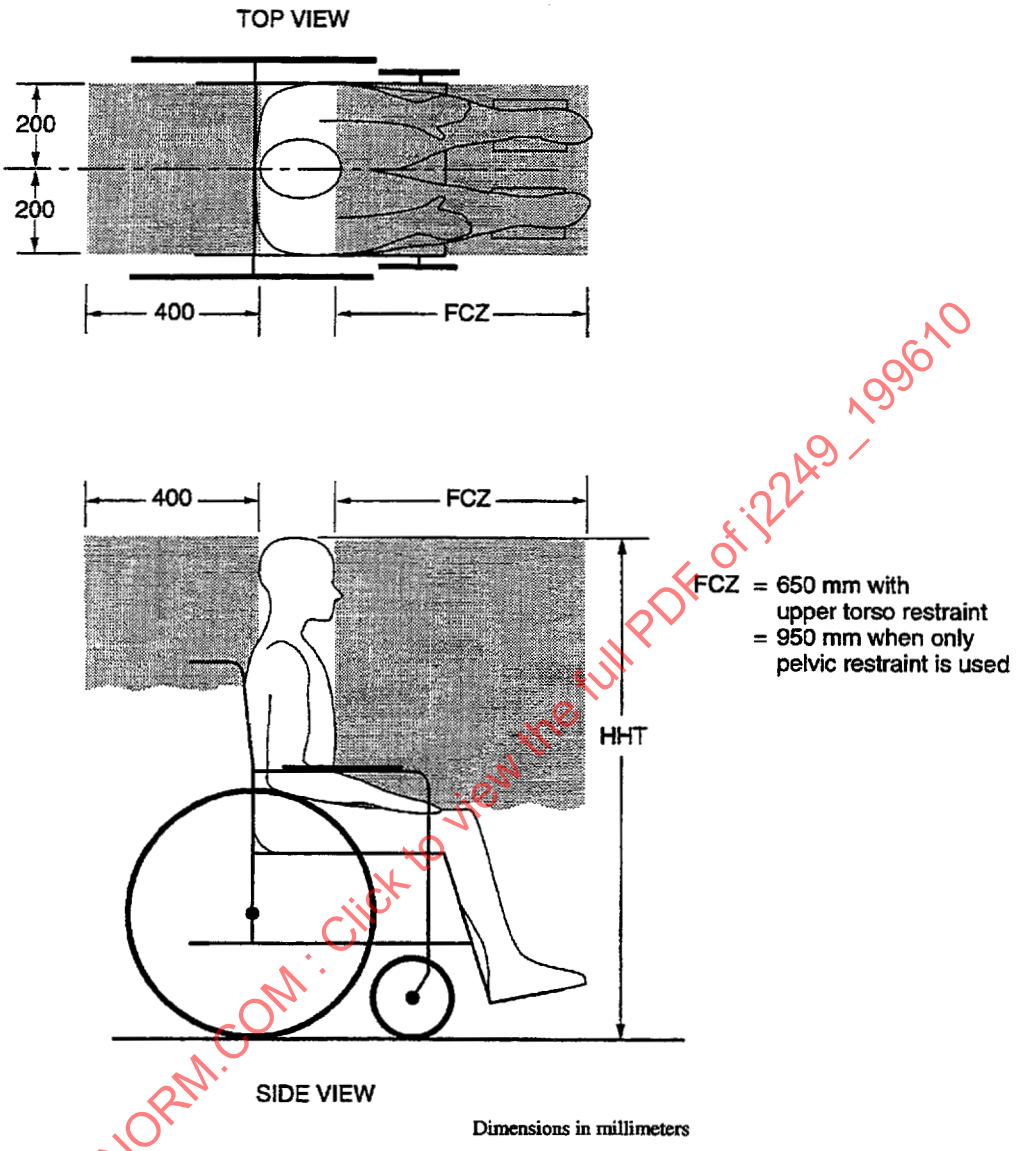
m. A diagram indicating recommended distances between WTORS anchor points and vehicle interior components along with the illustration of Figure 8, indicating that the distances are based upon the desire to maintain clear zones for potential head excursions of occupants provided with both upper and lower 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 the flammability requirements of FMVSS 302.
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 comply with the requirements of this document.
q. A statement that cautions installers that airbags can cause serious injury if a wheelchair-seated occupant sits too close, and to contact the vehicle manufacturer or the National Highway Traffic Safety Administration for advice about disabling the airbag.

5.3 **Advice and Warnings for Installers**—The WTORS manufacturer shall also provide written advice and warnings to the installer that include:

a. A statement that the WTORS complies with all applicable requirements of SAE J2249, including a 48-km/h, 20-g frontal impact test using either:

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 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.
i. A warning to protect webbing from contacting sharp corners and edges.



NOTE— Seated head height (HHT) ranges from as low as 1000 mm for a 6-year-old child to 1550 mm for a tall adult.

NOTE— It is strongly recommended that both pelvic and upper torso restraints be used to reduce the possibility of head and chest impacts with vehicle components. The frontal clear zone (FCZ) may not be achievable with wheelchair-seated drivers.

FIGURE 8—RECOMMENDED CLEAR ZONES FOR WHEELCHAIR-SEATED OCCUPANTS

5.4 **User and Maintenance Instructions**—User and maintenance instructions shall be provided with each WTORS. In addition, a durable instruction and maintenance sheet shall be provided for permanent display in the vehicle. The 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 km/h, 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 end fitting 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 an illustration similar to that of Figure 9.
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.
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, along with statements that:

1. Care should be taken to prevent contamination of the webbing with polishes, oils, and chemicals, particularly battery acid.
2. Describe procedures for cleaning webbing.
3. Frayed, contaminated, or damaged webbing should be replaced.
4. Broken and worn parts should be replaced.
5. 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.

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.

FIGURE 9—RESTRAINTS SHOULD NOT BE HELD AWAY FROM THE BODY BY WHEELCHAIR COMPONENTS OR PARTS, SUCH AS THE WHEELCHAIR ARMRESTS OR WHEELS

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.

6. Performance Requirements

6.1 WTORS Components

6.1.1 All webbing, metal parts, buckles, release mechanisms, and adjustment mechanisms of wheelchair tiedown and occupant restraint systems shall comply with applicable subsections of FMVSS 209 as indicated in Table 2.

TABLE 2—APPLICABLE SUBSECTIONS OF FMVSS 209

Section	Component	Subject	Test Referenced	Application[1]
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	micro 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	tempt. 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-put restraints	performance	S5.3 (b)	R

1. R = occupant restraint; TD = wheelchair tiedown.

6.1.2 Any webbing material used in WTORS shall comply with the flammability requirements of FMVSS 302.

6.2 Frontal Sled Impact Test—When tested as specified in Appendix A, the WTORS shall:

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.

TABLE 3—HORIZONTAL EXCURSION LIMITS (mm)

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_o, to the point P target at the time of peak wheelchair excursion.

X_{knee} = the horizontal distance relative to the sled platform between the ATD knee-joint target at time t_o, 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 ATD's head above the nose at time t_o, to the most forward point on the ATD's head at the time of peak head excursion.

e. Prevent the wheelchair from imposing forward loads on the occupant as indicated by:

$$X_{knee}/X_{wc} \leq 1.1 \quad \text{(Eq. 1)}$$

f. Allow removal of the ATD and the test wheelchair subsequent to the test without the use of tools.

6.3 Partial Engagement of Anchorage and Securement Components—When WTORS anchorage and securement components are tested as specified in Appendix C, all improper and partial engagements shall separate with a force of less than 22 N.

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—The WTORS manufacturer shall have documentation on file and available that includes:

7.1 Statements concerning compliance of the WTORS with the Design Requirements of 4.2 through 4.3 including:

a. Minimum and maximum tiedown strap lengths of four-point strap tiedowns in comparison to the requirements of Table 1.
b. Whether the end-fitting geometry of four-point tiedowns is compatible with the end-fitting geometry of Figure E4.
c. The angle of pelvic restraints when setup according to Appendix B.
d. The range of length adjustment in the pelvic restraint when set up and measured as specified in Appendix B.
e. The range of length adjustment in the upper-torso restraints when set up and measured as specified in Appendix B.
f. The height or height-adjustment range of upper-torso restraint upper-anchor upper-guide support points provided with the WTORS, and a statement of whether the height complies with 4.3.6.
g. The distance of the pelvic/shoulder restraint interface of three-point restraints from the ATD centerline when set up and measured according to Appendix B.

7.2 Statements concerning compliance with the requirements of:

a. FMVSS 209 as specified in Table 2.
b. FMVSS 302 concerning flammability of WTORS webbing material.

7.3 Statements concerning compliance with the Frontal Impact Test of Appendix A, including:

a. A description of the test facility, including the type of impact simulated, instrumentation and signal processing techniques, the frame speed for each film and/or video produced, methods for measuring sled velocity change and deceleration, methods used to measure ATD and test wheelchair excursions, and the accuracy of excursion measurements.
b. A statement of whether the sled deceleration pulse complied with A.4.3 and Figure A1, including the duration of the pulse, and the number of cumulative milliseconds that the deceleration exceeded 15 g and 20 g.
c. The measured or calculated value of the test delta V.
d. A full identification of the WTORS, anchorage fasteners, test wheelchair, and ATD used.
e. Pretest measurements documenting the locations of all WTORS anchorages relative to point P of the test wheelchair.
f. The side-view, front-view, and rear-view projected angles of all tiedown straps and pelvic restraints relative to the horizontal or vertical, as appropriate.
g. A description of the test setup including a statement about any parts or fasteners used in the test that were not provided by the WTORS manufacturer.
h. Whether the ATD remained in the test wheelchair.
i. Whether the test wheelchair remained on the test platform.
j. The change in the orientation of the test wheelchair reference plane, if measurable, in comparison with the initial test orientation.
k. Identification of any WTORS load-carrying parts that showed visible signs of tearing, fragmentation, fracture, or complete failure, that were not designed to tear or fail in the manner noted.
l. The peak horizontal excursions specified in 6.2.d, and whether any of the excursions exceeded the limits in Table 3 of this document.
m. A statement as to whether the ATD and test wheelchair could be released from the WTORS without the use of tools.
n. A statement as to whether the ATD was loaded by the test wheelchair based on the results of the calculation in 6.2.e.

7.4 Statements concerning compliance of appropriate WTORS components with the Test for Partial Engagement of Appendix C, including:

a. Full identification of the WTORs system and the securement and anchorage components tested.
b. A description, including photographs if necessary, of the manner of each partial engagement tested.
c. A description of the procedure used to apply the separating force.
d. The results of each test, i.e., the securement or anchorage mechanism either separated or remained engaged.

7.5 Statements concerning compliance of any strap assemblies of wheelchair tiedowns with the Test for Webbing Slippage at Adjustment Devices of Appendix D, including:

a. Full identification of the WTORS system, type of webbing, and each adjustment device tested.
b. A description of the test apparatus and procedure.
c. The amount of webbing slippage at each adjustment device tested.
d. A statement as to whether the 25 mm limit was exceeded for each adjustment device tested.
e. A statement as to whether all adjustment devices of the wheelchair tiedown portion of the WTORS passed the test.

PREPARED BY THE SAE ADAPTIVE DEVICES STANDARDS COMMITTEE

APPENDIX A

(NORMATIVE)
FRONTAL IMPACT TEST

A.1 ***Scope and Purpose***—This appendix specifies equipment, conditions, and procedures for conducting a sled impact test to simulate the dynamic loading that WTORS components used with forward-facing wheelchairs and occupants can be expected to experience in a 48-km/h frontal impact. The test applies to all types of WTORS, including those with strap-type and docking-type tiedowns. For WTORS designed for use with a range of wheelchair types and sizes, the test procedures specify use of a rigid, reusable surrogate wheelchair (SWC) that complies with the specifications documented and illustrated in Appendix D. For WTORS designed only for use with a specific wheelchair having unique design features or components required by the WTORS, the test procedures provide for conducting the test with the appropriate production or prototype wheelchair. The surrogate, production, or prototype wheelchair is referred to as the test wheelchair.

A.2 ***Equipment to be Tested***—A complete, unused WTORS, including all fittings, anchorages, fasteners, and instructions for installation and use, shall be provided for testing. If a WTORS is designed to use the OEM vehicle restraint system, the WTORS manufacturer shall provide a representative vehicle restraint system for testing. If modifications to the WTORS are necessary to interface with the test wheelchair, or if changes from recommended installation geometry and/or hardware are required in order to interface with the sled platform, such modifications shall be made or approved by the WTORS manufacturer and shall not affect the basic structural design and dynamic strength of the WTORS.

For WTORS designed to be used with a specific wheelchair, or for WTORS designed to rely on the wheelchair structure to transfer occupant restraint loads to the vehicle, a production or prototype wheelchair of the type and model required shall be provided for each test, weighted with actual or simulated components such as batteries, motors, and electronic components, as is appropriate to the style of wheelchair.

A.3 ***Test Equipment***—The frontal impact test shall be performed with impact simulator equipment that includes:

a. An impact sled with a flat, structurally rigid platform, suitably reinforced to accept WTORS anchorages, and capable of producing the impact conditions specified in A.4.
b. A rigid structure for anchorage of upper restraint hardware.
c. A track or guide path to permit only linear movement of the sled during the impact event.
d. A Hybrid II or Hybrid III anthropomorphic test dummy (ATD) with a total mass of 76.3 kg ± 1 kg.

NOTE 1—For tests involving a specific production or prototype wheelchair intended for use by children, an appropriate size ATD of the Hybrid II or Hybrid III type may be used (e.g., 6-year old or small female).

NOTE 2—ATDs can be purchased from First Technology Safety Systems, Inc., in Plymouth, Michigan, or Vector Research, Inc., in Milan, Ohio.

e. A test wheelchair consisting of either a surrogate wheelchair that complies with the specifications of Appendix E, or a production or prototype wheelchair required for a specific WTORS design.
f. High-speed film or video equipment for recording and measuring, to an accuracy of ±5 mm, the horizontal excursions of the ATD and test wheelchair at a minimum rate of 500 frames per second.
g. A means to process the sled accelerometer signals as specified in A.4.2 in order to measure and record the acceleration-time history of the sled platform in the direction of sled travel during the impact event to an accuracy of ±0.5 g.
h. A means to measure the horizontal velocity change (delta V) during the impact deceleration/acceleration event to an accuracy of ±0.5 km/h.

A.4 Test Conditions and Signal Processing

A.4.1 Subject the sled platform with WTORS, test wheelchair, and ATD installed as described in Section A.6 to a horizontal velocity change of 48 km/h (+2/–0) in the direction of impact using a sled acceleration/deceleration pulse that complies with A.4.3.

A.4.2 Process the sled accelerometer signal according to SAE J211 by:

a. Prefiltering to Channel Class 1000 (–4 dB at 1650 Hz).
b. Digitizing at 10 000 Hz
c. Filtering the digitized signal to Channel Class 60 (–4 dB at 100 Hz)

A.4.3 The processed sled deceleration-time pulse shall:

a. Fall within the shaded corridor of Figure A1.
b. Exceed 20 g for a cumulative time period of at least 15 ms.
c. Exceed 15 g for a cumulative time period of at least 40 ms.
d. Have a duration of at least 75 ms from t_0 to t_f.

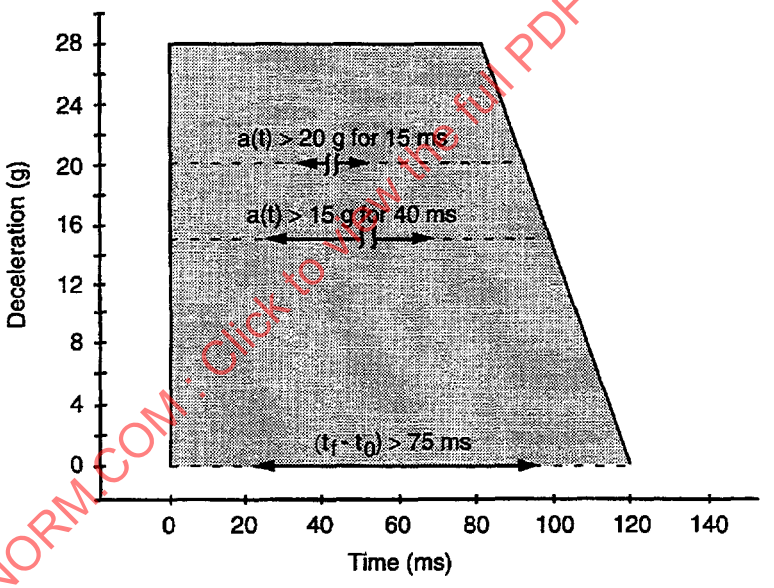


FIGURE A1—DECELERATION PULSE CORRIDOR FOR A 48 (+2/–0) km/h DELTA V

A.5 Preparation and Calibration of Test Equipment—Prior to conducting the test:

A.5.1 Check to make sure that the sled accelerometer has been calibrated as specified by the accelerometer manufacturer.

A.5.2 Calibrate the signal processing system for the sled accelerometer.

A.5.3 Inspect the ATD to ensure that all primary components are intact and functioning.

A.5.4 Adjust the ATD to achieve a static resistance of 1 g at each joint, indicated by just-noticeable movement from the weight of the distal body segment.

A.5.5 Place snug-fitting cotton clothing on the pelvis, thighs, and torso of the ATD.

A.5.6 If the surrogate wheelchair is used:

a. Modify the surrogate wheelchair as needed to accommodate the tiedown system to be tested while maintaining the wheelchair specifications within the tolerances specified in Appendix E.
b. Inflate the rear tires to 414 kPa ± 69 kPa and inflate the front tires to 759 kPa ± 69 kPa, with the wheelchair unoccupied and resting on a horizontal surface.
c. Inspect the sidewalls of the tires for abrasion and/or cracking and replace tires if worn.
d. Inspect the seat plate and plate-support structures and replace if deformed.
e. Inspect all frame joints and components and repair if there are signs of fatigue or deformation.

A.5.7 If the test involves use of a production or prototype wheelchair:

a. Inspect and adjust the wheelchair condition according to the manufacturer's instructions.
b. Either replace battery acid with water or replace the batteries with a surrogate of the same dimensions and mass as the batteries (±2%).
c. Replace electronic components and motors with equivalent masses, if desired.

A.6 Setting Up and Conducting the Test—Perform the following in sequence:

A.6.1 Set up the high-speed film or video system to record a lateral view of the test sled, test wheelchair, and ATD during the impact event.

A.6.2 Fasten any wheelchair add-on components to the test wheelchair, modifying the WTORS components as necessary and as specified by the WTORS manufacturer, to achieve compatibility with the WTORS add-on hardware and the surrogate wheelchair structure.

A.6.3 Position the test wheelchair facing forward on the sled with the wheelchair reference plane parallel to the direction of sled travel.

A.6.4 Install the wheelchair tiedown anchorages on the sled platform in accordance with the manufacturer's instructions, selecting anchor points for four-point tiedowns that:

a. Are symmetric about the intended wheelchair reference plane.
b. Are located 1300 mm ± 20 mm from the front anchor point to the rear anchor point.
c. Have a lateral distance between front and rear anchor points equal to the lateral distance between rear securement points of the test wheelchair, ±25 mm.
d. Have a lateral distance between front anchor points of 300 mm to 810 mm, as is appropriate to the test wheelchair and specified by the manufacturer.

NOTE 1—If fasteners provided with the WTORS are incompatible with the sled platform, replacement fasteners shall be of the same thread size and specification. The anchor bolt may also be fastened directly into a tapped hole in the sled platform.

NOTE 2—For purposes of locating the anchor points, the front-to-back location of an anchor point is the location of the primary fastener that secures the anchorage to the test platform or, in the case of multiple fasteners, the center of these fasteners. The lateral location of an anchor point is considered to be the center of the location where the tiedown end fitting contacts the anchorage hardware attached to the test platform.

NOTE 3—When a range of installation dimensions are specified for WTORS that do not use a four-point tiedown, use the midpoint of the range.

A.6.5 Secure the test wheelchair in accordance with the WTORS manufacturer's instructions and, for four-point tiedowns, to achieve lengths of the rear tiedown strap assemblies of 495 to 533 mm, measured from the interface of the tiedown end fitting and the securement point on the wheelchair to the anchor point.

NOTE— For purposes of measuring the rear tiedown length, the anchor point is considered to be the point at which a straight line along the length of the strap assembly intersects with the wheelchair ground plane.

A.6.6 Tension any tiedown straps to the manufacturer's specifications, making sure that the test wheelchair reference plane remains aligned within ±3 degrees of the direction of sled travel.

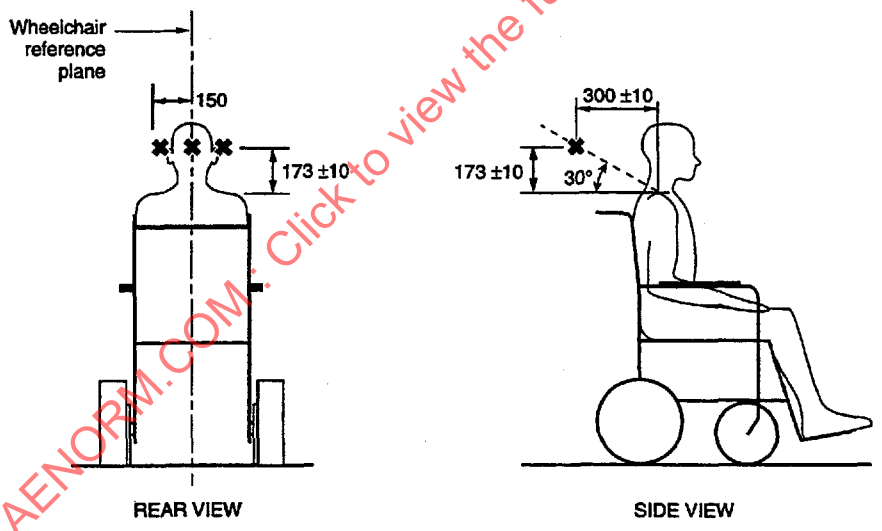
A.6.7 Position the ATD in the test wheelchair sitting upright and symmetrically positioned about the wheelchair midline, with the pelvis and elbows as close to the seatback of the test wheelchair as possible.

A.6.8 Install the pelvic restraint in accordance with the manufacturer's instructions, selecting anchor points at the midpoint of the recommended zones, if applicable.

NOTE 1—If the manufacturer of an independent pelvic restraint does not specify the anchor points, install the pelvic restraint anchorages at or near the same front/back location as the rear tiedown anchor points.

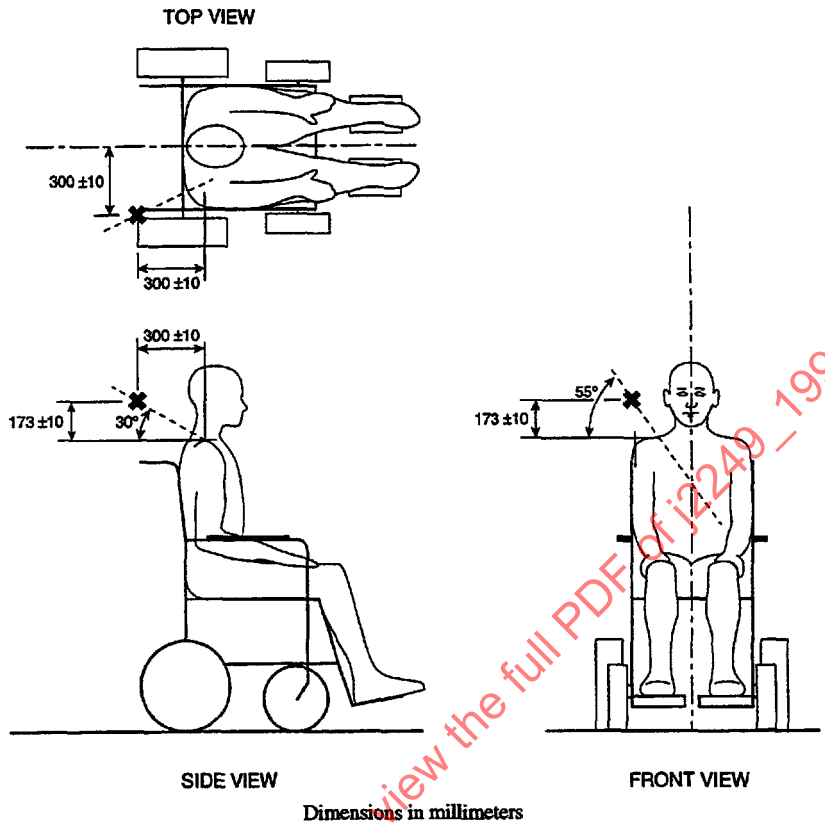
NOTE 2—If fasteners provided with the WTORS are incompatible with the sled platform, replacement fasteners shall be of the same thread size and specification. The anchor bolt may also be fastened directly into a tapped hole in the sled platform.

A.6.9 For WTORS that do not include upper-anchor or upper-guide support points for shoulder or harness restraints, install the upper-torso restraint anchorage or guide at the point or points marked by a **bold X or Xs** in Figures A2 or A3, as applicable, to achieve a good fit across the ATD shoulders and chest.



NOTE: For tests involving other sizes of ATDs, adjust the anchor point location accordingly to give a good fit to the ATD's chest and shoulders.

FIGURE A2—TEST LOCATIONS FOR UPPER ANCHOR POINT(S) OF CENTER-ANCHORED AND TWO-POINT ANCHORED HARNESSES WHEN USING THE MIDSIZE-MALE ATD IN THE SURROGATE WHEELCHAIR OF APPENDIX E



Dimensions in millimeters

NOTE: For tests involving other sizes of ATDs, adjust the anchor point location accordingly to give a good fit to the ATD's chest and shoulders.

Anchor point may be located on either side of wheelchair and ATD.

FIGURE A3—TEST LOCATION FOR UPPER ANCHOR POINT OF SHOULDER RESTRAINT WHEN USING THE MIDSIZE-MALE ATD IN THE SURROGATE WHEELCHAIR OF APPENDIX E

NOTE 1—Use the upper-torso restraint anchorage and fastener hardware if supplied as part of complete WTORS by the manufacturer.

NOTE 2—When an upper-torso restraint guide is provided, the guide shall be located so that the interface between the restraint webbing and the guide is at the intended anchor-point location.

A.6.10 For WTORS that include components for upper-torso restraint upper anchor points or upper-guide supports, install the upper-torso restraint anchorages or guides as specified by the manufacturer to achieve a good fit to the ATD's shoulders and chest.

A.6.11 Adjust the tension in the pelvic restraint as follows:

a. If an emergency-locking or automatic-locking retractor is provided, adjust the pelvic restraint for minimum slack over the ATD's pelvis.
b. If no emergency-locking or automatic-locking retractor is provided, adjust the tension of the pelvic restraint to a snug fit over the ATD's pelvis.

A.6.12 Adjust the shoulder restraint as follows:

a. If an emergency-locking or automatic-locking retractor is provided, adjust the shoulder belt for minimum slack across the ATD's chest.
b. If no emergency-locking or automatic-locking retractor is provided, adjust the shoulder belt to a snug fit with a 75 x 75 x 75 mm block placed between the belt and the ATD's sternum.

A.6.13 Position high-contrast targets on the sides of the ATD and test wheelchair in view of the high-speed recording equipment at:

a. The lateral aspect and center of the ATD's knee joint.
b. The point P of the surrogate wheelchair (see Figure 2), or a point on the side of the seatback of a production or prototype wheelchair that is as close to the wheelchair point P as possible.

A.6.14 Verify that the test wheelchair reference plane is aligned within ±3 degrees of the direction of sled travel.

A.6.15 Record the locations of all WTORS anchor points relative to the test wheelchair and the projected angles of all tiedown straps and pelvic restraints relative to the horizontal longitudinal axis of the sled platform.

A.6.16 Conduct the impact test.

A.7 Measurement and Calculation of Test Results—After the test:

A.7.1 Examine the test wheelchair, ATD, and WTORS components to determine and/or measure:

a. Whether the ATD remained in the test wheelchair
b. Whether the test wheelchair remained on the test platform
c. Any change in orientation of the test wheelchair reference plane relative to the direction of sled travel
d. Whether any load-carrying parts became separated, fragmented, or showed any signs of failure
e. If the ATD and test wheelchair could be released from the WTORS without the use of tools

A.7.2 Analyze the high-speed films or video recordings to determine the following excursions with an accuracy of ±5 mm:

a. X_{head}
b. X_{knee}
c. X_{wc}

NOTE— See Table 3 for definitions of variables.

A.7.3 Calculate the ratio: X_{knee}/X_{wc}.

APPENDIX B

(NORMATIVE)
PROCEDURES FOR MEASURING GEOMETRY AND ADJUSTMENT LENGTHS OF OCCUPANT RESTRAINTS

B.1 ***Purpose***—This appendix sets forth procedures for setting up the WTORS to determine compliance with the design requirements in Section 4.2 and Section 4.3. These procedures apply to WTORS designed for general use by different size occupants and provide a nominal set of test conditions, based on the midsize-male ATD seated in the surrogate wheelchair, for checking:

a. The angle of pelvic restraints
b. The range of length adjustment in pelvic restraints
c. The range of length adjustment in upper-torso restraints
d. The height of upper-torso restraint upper-anchor, or guide-support points if provided with the WTORS
e. The location of pelvic/shoulder restraint junctions relative to the ATD centerline

B.2 ***Principle***—In order for restraint systems to be usable by the range of wheelchair occupant sizes and the range of vehicle installation geometries, it is important to provide adequate length adjustment in the restraint belt assemblies. In addition it is important that:

a. The pelvic restraint be designed to fit low over the wheelchair occupant's pelvis and thighs with a relatively steep angle to the horizontal in order to reduce the potential for abdominal loading and injury.
b. That the junction of the pelvic and shoulder restraints be located away from the midline of the occupant so that the shoulder belt does not pull up on the pelvic restraint.

B.3 ***Test Setup***

B.3.1 Secure the surrogate wheelchair to a flat, horizontal, and rigid platform using the wheelchair tiedown portion of the WTORS as specified by the manufacturer. If the wheelchair tiedown consists of a four-point system, secure the wheelchair by selecting anchor points as specified in Section A.6.4 and position the wheelchair as specified in Section A.6.5 and Section A.6.6.

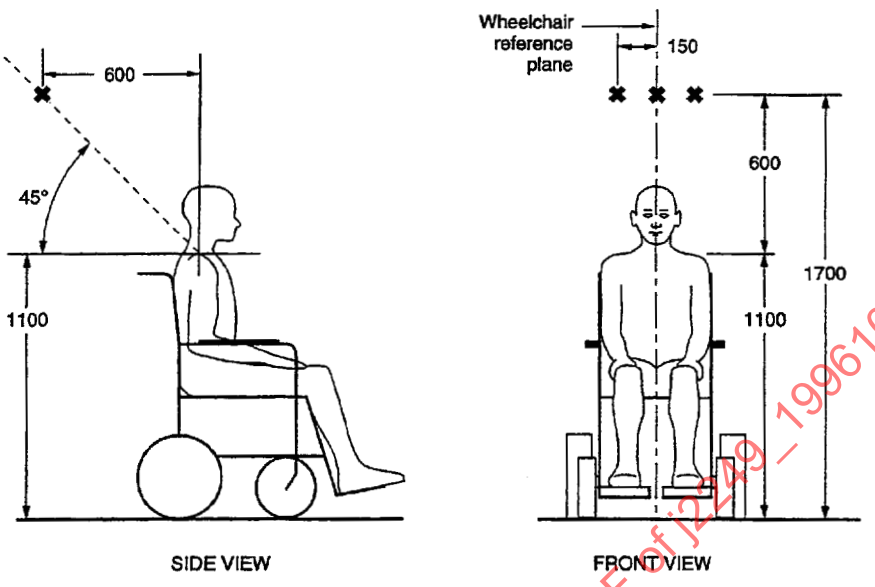
B.3.2 Position a midsize-male Hybrid II or Hybrid III ATD symmetrically in the surrogate wheelchair with the buttock and pelvis against the backrest and the arms positioned on the armrests.

B.3.3 Install the pelvic restraint in accordance with the manufacturer's instructions, selecting anchor points at the midpoint of the recommended zones, if applicable.

NOTE— If the manufacturer of an independent pelvic restraint does not specify the anchor points, install the pelvic restraint anchorages at or near the same front/back location as the rear tiedown anchor points.

B.3.4 Install the upper-torso restraint as follows:

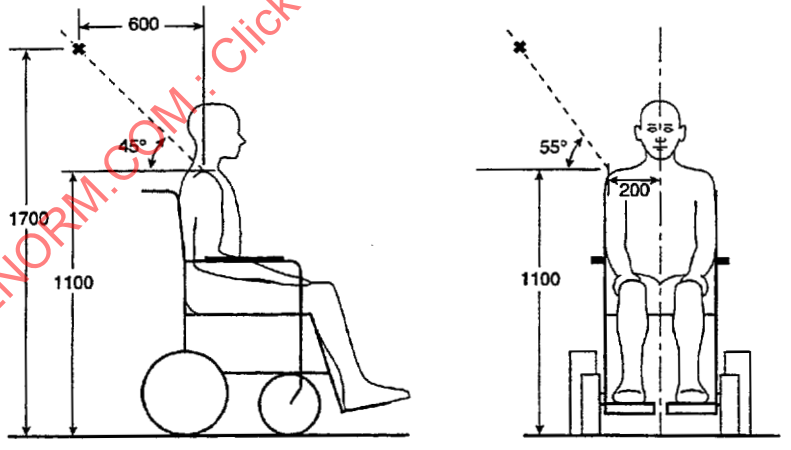
a. For WTORS that do not include upper-anchor points or upper-guide supports for shoulder or harness restraints, install the upper-torso restraint upper-anchor point or guides support at the point or points marked by a **bold X or Xs** in Figures B1 or B2, as applicable, using the upper-torso restraint anchorage hardware if supplied as part of a complete WTORS by the manufacturer.
b. For WTORS that include components for upper-torso restraint upper-anchor points or guide supports, install the upper-torso restraint anchorages or guide supports as specified by the manufacturer.



Dimensions in millimeters

NOTE: BOLD X indicates the upper-anchor point location.

FIGURE B1—ANCHOR-POINT LOCATIONS FOR TEST SETUP WITH CENTER-ANCHORED OR TWO-POINT ANCHORED HARNESS USING A MIDSIZE-MALE ATD SEATED IN THE SURROGATE WHEELCHAIR SPECIFIED IN APPENDIX E



Dimensions in millimeters

NOTE: BOLD Xs indicate the upper-anchor point locations.
Shoulder restraint may be anchored to either side of wheelchair.

FIGURE B2—ANCHOR-POINT LOCATION FOR TEST SETUP WITH THREE-POINT RESTRAINT USING A MIDSIZE-MALE ATD SEATED IN THE SURROGATE WHEELCHAIR SPECIFIED IN APPENDIX E

B.3.5 Adjust the tension in the pelvic restraint as follows:

a. If an emergency-locking or automatic-locking retractor is provided, adjust the pelvic restraint for minimum slack over the ATD's pelvis.
b. If no emergency-locking or automatic-locking retractor is provided, adjust the tension of the pelvic restraint to a snug fit over the ATD's pelvis.

B.3.6 Adjust the shoulder restraint as follows:

a. If an emergency-locking or automatic-locking retractor is provided, adjust the shoulder belt for minimum slack across the ATD's chest.
b. If no emergency-locking or automatic-locking retractor is provided, adjust the shoulder belt to a snug fit over the ATD's sternum.

B.4 Measurements

B.4.1 Measure the projected side-view angle of the pelvic restraint relative to the horizontal to the nearest degree.

B.4.2 Measure the distance from the centerline of the ATD along the arc of the belt to the center of the junction of the upper-torso restraint and the pelvic restraint.

B.4.3 Mark the location of the webbing in the upper-torso restraint adjusters. Disconnect the upper-torso restraint at one anchor point and measure the total length of restraint lengthening and shortening provided, while checking to make sure that at least 25 mm of webbing extends through the restraint end fittings at all times.

B.4.4 Mark the location of the webbing at the pelvic restraint adjusters with the pelvic belt on the ATD as described in Section B.3. Unbuckle the pelvic belt and measure the total length of belt lengthening and shortening provided (including both sides of the pelvic belt if applicable), while checking to make sure that at least 25 mm of webbing extends through the restraint end fittings at all times.

APPENDIX C

(NORMATIVE)
TEST FOR PARTIAL ENGAGEMENT OF WTORS COMPONENTS

C.1 ***Scope and Purpose***—This appendix sets out a method for determining the potential for partial and ineffective engagement of WTORS components that could be erroneously perceived to be effectively engaged. The test applies to engagement of anchorage hardware of wheelchair tiedowns and occupant restraints with vehicle-installed anchorage components, of securement-point end fittings with wheelchair securement points, and of wheelchair-installed components of docking-type tiedowns with vehicle installed hardware.

C.2 ***Principle***—A separating force is applied between the separate WTORS components that have been engaged in any condition other than complete and proper engagement. If the components do not disengage, a potential for partial engagement is demonstrated.

C.3 ***Test Equipment***—The following equipment is required:

a. A new WTORS system.
b. A means of applying a separating force of 22 N between the separate components of each anchorage mechanism, or between the securement-point end fittings and the wheelchair securement points.
c. A means of measuring the applied force to an accuracy of ±5%.

C.4 ***Test Procedure***—Identify all reasonably foreseeable ways that the separate components of a securement or anchorage mechanism can be engaged other than complete engagement. For each of these ways, perform the following:

a. Engage the separate components of a securement or anchorage mechanism in any manner other than complete engagement.
b. Record the manner of apparent engagement, including photographs, if necessary, to fully describe the condition.
c. Apply a separating force of 22 N between the components of the securement or anchorage mechanism.
d. Record the result, i.e., the components separated or remained engaged.

APPENDIX D

(NORMATIVE)
TEST FOR WEBBING SLIPPAGE AT ADJUSTMENT DEVICES OF WHEELCHAIR TIEDOWN STRAPS

D.1 ***Scope and Purpose***—This appendix describes a method to determine the potential for webbing slippage at adjustment devices of strap-type wheelchair tiedown assemblies during normal vehicle operation and maneuvering.

D.2 ***Principle***—The webbing and adjustment device of a wheelchair tiedown assembly are subjected to cyclical loading for 1000 cycles and the webbing slippage at the adjustment device is measured. If the webbing slippage at the adjustment device during the cyclical loading exceeds 25 mm, the potential for the tiedown straps to become slack during normal vehicle travel is demonstrated.

D.3 ***Test Equipment***—The equipment and setup shown in Figure D1 is required. This consists of:

a. A mass of 5 kg.
b. A means of applying an up/down motion to the 5-kg mass with a peak-to-peak amplitude of 300 mm ± 20 mm at a frequency between 0.5 Hz and 0.75 Hz.
c. A roller arrangement, if desired, to change the direction of motion.

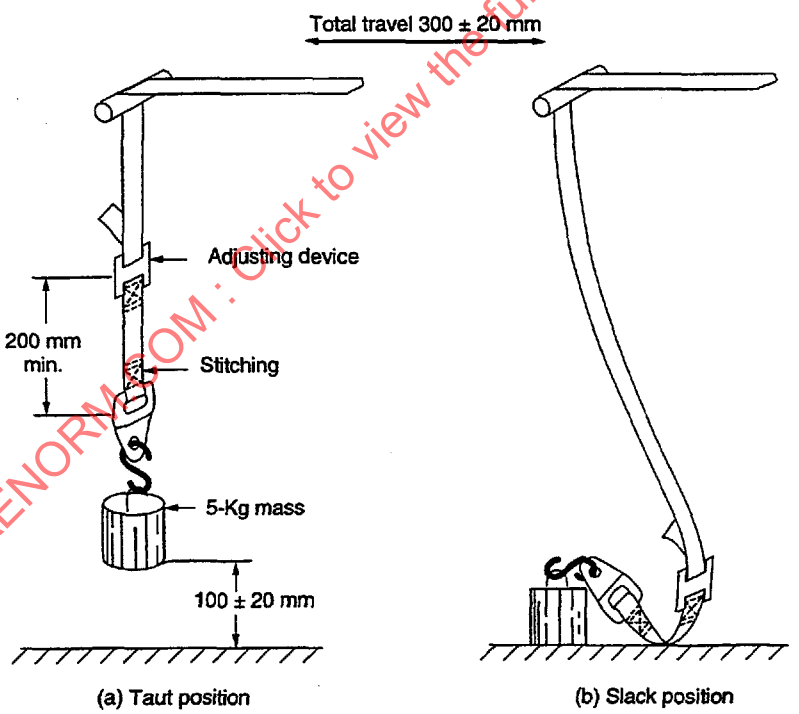


FIGURE D1—TEST SETUP FOR WEBBING SLIPPAGE AT ADJUSTMENT DEVICES

D.4 ***Pretest Storage Conditions***—Store the WTORS components to be tested at a temperature of 20 °C ± 5 °C and a relative humidity of 65% ± 10% for 24 h prior to testing.

D.5 Test Procedure—Conduct the test at room temperature between 15 °C and 30 °C as follows:

a. Arrange the webbing and adjustment device to be tested in the test apparatus with the adjustment device not less than 200 mm from the end fitting as shown in Figure E1.
b. Attach a 5-kg mass to the end fitting.
c. Adjust the height of the bottom of the mass to be 100 mm ± 20 mm off the resting surface when the movement mechanism is at maximum upward travel.
d. Guide the 5-kg mass to prevent the load from swaying and rotating during the test.
e. Apply an up/down oscillating motion with an amplitude of 300 mm ± 20 mm to the adjustment device by raising and lowering the webbing in the test fixture and continue for 20 or more cycles to ensure that the test equipment is operating correctly. On the downward stroke, the webbing shall descend in a concave curve when the mass is contacting the resting surface.
f. Mark the webbing position at the adjustment device.
g. Repeat the up/down oscillating motion as specified in D.3.b and continue for 1000 cycles at a frequency between 0.5 and 0.75 Hz.
h. Measure any movement of the mark on the webbing at the adjustment device after the test and record as the amount of webbing slippage.

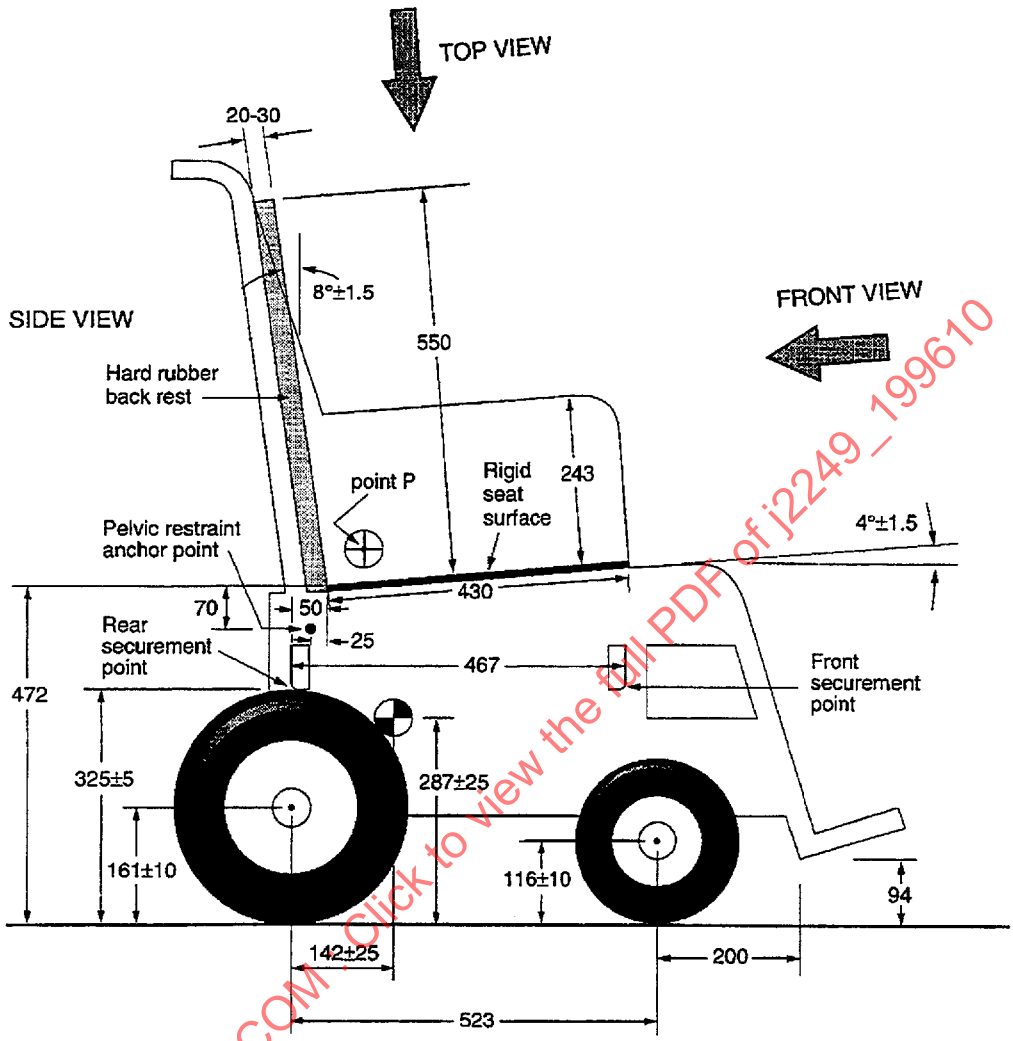
APPENDIX E

(NORMATIVE)
SPECIFICATIONS FOR THE SURROGATE WHEELCHAIR

E.1 ***Scope and Purpose***—This appendix provides design, dimensional, material, and performance specifications for the surrogate wheelchair (SWC) referenced in the design requirements and tests of this document. These specifications are intended to provide a repeatable and reusable device that represents a typical adult-sized power wheelchair for evaluating the frontal impact performance of WTORS comprised of either strap-type or docking-type wheelchair tiedown systems using the procedures of Appendix A. The SWC is not intended to represent the design of the ideal wheelchair for use in a motor vehicle.

E.2 ***Specifications***—Details for the design, fabrication, and maintenance of the surrogate wheelchair are provided in SAE J2252. The surrogate wheelchair has been designed with the features, dimensions, and specifications shown in Figures E1 through E4 and listed as follows:

a. Be of rigid durable construction, such that there is no permanent deformation of the frame, seat surface, or seatback in a 48-km/h, 20-g frontal impact test with a midsize-male, 76.3-kg ATD positioned and restrained in the SWC.
b. Have a total mass of 85 kg ± 1 kg.
c. Comply with the dimensions of Figures E1 through E4.
d. Have a lower frame design that can be modified to be compatible with WTORS components of docking-type wheelchair tiedowns with little or no modification to those components.
e. Have a center of gravity located 142 mm ± 25 mm forward of the rear axle and 287 mm ± 25 mm above the ground plane for the range of frame-to-floor clearance adjustments allowed.
f. Provide two front securement points and two rear securement points for four-point tiedowns at the locations indicated in Figure E1 and with the geometry specified in Figure E4.
g. Provide accessible and rigid attachment points located 250 mm ± 10 mm above the ground plane at the rear portions of each side of the surrogate wheelchair, for attachment of two horizontal steel bars oriented perpendicular to the wheelchair reference plane so as to simulate the axle securement points of a standard welded-frame power wheelchair.
h. Provide pelvic restraint anchor points on both sides of the surrogate wheelchair located so that the angle of a pelvic restraint anchored to these points, and placed snugly over the pelvis of a midsize-male ATD seated in the surrogate wheelchair, is between 45 and 75 degrees to the horizontal.
i. Have a rigid, flat seat surface with dimensions shown in Figure E3 that is oriented at an angle of 4 degrees ± 1.5 degrees to the horizontal (front end up) when the SWC tires are inflated as specified in (m) and (n) and are resting on a flat horizontal surface.
j. Have a rigid seatback with height and width dimensions indicated in Figure E2 that is oriented at 8 degrees ± 1.5 degrees to the vertical when the inflated tires of the SWC are inflated as specified in (m) and (n) and are resting on a flat horizontal surface.
k. Have a 20 to 30-mm thick firm (i.e., not deflecting under ATD loading) rubber pad with height and width dimensions indicated in Figures E1 and E2 fixed to the front surface of the rigid seatback.
l. Have a detachable but rigid mounting plate for placement of a side-view contrast target at the location of reference point P outboard of tiedown and restraint system components on either side of the SWC.
m. Have pneumatic front tires that, when inflated to 760 kPa ± 15 kPa with the unoccupied surrogate wheelchair resting on a flat horizontal surface, have a diameter of 230 mm ± 10 mm, a width of 75 mm ± 5 mm, and a sidewall height of 54 mm ± 5 mm.
n. Have pneumatic rear tires that, when inflated at 415 kPa ± 15 kPa with the unoccupied surrogate wheelchair resting on a flat horizontal surface, have a diameter of 325 mm ± 10 mm, a width of 100 mm ± 10 mm, and a sidewall height of 70 mm ± 5 mm.



NOTE: Securement-point locations shown on the surrogate wheelchair are not intended to imply recommended locations for securement points on production wheelchairs.

FIGURE E1—SIDE-VIEW DRAWING OF THE SURROGATE WHEELCHAIR