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Wheelchair seating —

Part 4: Seating systems for use in motor vehicles

Sièges de fauteuils roulants —

Partie 4: Systèmes d'assise dans les véhicules à moteurs

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

ISO 16840-4 was prepared by Technical Committee ISO/TC 173, *Assistive products for persons with disability*, Subcommittee SC 1, *Wheelchairs*.

ISO 16840 consists of the following parts, under the general title *Wheelchair seating*:

— *Part 1: Vocabulary, reference axis convention and measures for body segments, posture and postural support surfaces*

— *Part 2: Determination of physical and mechanical characteristics of devices intended to manage tissue integrity — Seat cushions*

— *Part 3: Determination of static, impact and repetitive load strengths for postural support devices*

— *Part 4: Seating systems for use in motor vehicles*

Introduction

Transportation safety research has demonstrated that the design of the vehicle seat, the occupant restraints and seat compartment in motor vehicles play a vital role in protecting the occupant in the event of a crash. For some wheelchair users, it is not feasible to transfer to the seat provided by the vehicle manufacturer and they must remain seated in their wheelchair while travelling in a vehicle. ISO 7176-19 provides a means of evaluating the design and frontal crashworthiness performance of complete wheelchairs when used as forward-facing seats in motor vehicles. However, it is common practice that a seating system from one manufacturer and a wheelchair base from another manufacturer be used to form the complete wheelchair. Wheelchair seating systems may also be intended for use on multiple models of wheelchair bases. For this reason, there is a need to be able to evaluate the design and performance of wheelchair seating systems independent of the commercial wheelchair bases on which they may be installed. This part of ISO 16840 provides a means of assessing frontal impact crashworthiness of seating systems without the host wheelchair by using a surrogate wheelchair base.

Manufacturers may choose to not test customized variations of a given seating system. The manufacturer may test a representative variation of the seating system and it is for the manufacturer to document how the results of this test would apply to the limitations in use and instructions for use supplied with the product.

This part of ISO 16840 is intended to encourage safer motor vehicle transportation of wheelchair users by increasing the availability of wheelchair seating systems that comply with basic principles of occupant protection. This part of ISO 16840 should not be used to deny or limit wheelchair user access to motor vehicle transportation.

Currently this part of ISO 16840 addresses only complete wheelchair seating systems and the test requirements are representative of frontal impact conditions. However, future versions may address testing of the individual components of the seating system as well as other directions of impact such as side or rear.

Wheelchair seating —

Part 4:
Seating systems for use in motor vehicles

1 Scope

This part of ISO 16840 specifies test methods and requirements for design and performance, for instructions and warnings and for product marking and labelling of seating systems intended to be used as a forward-facing seat in a motor vehicle when fitted to a manual or powered wheelchair. It evaluates the frontal crashworthiness performance of complete seating systems for occupancy by adults or children of mass equal to or greater than 22 kg.

This part of ISO 16840 only applies to complete wheelchair seating systems including attachment hardware, designed to be used with a wheelchair base tested as part of a wheelchair system that conforms to ISO 7176-19 performance requirements and that has securement points for use with four-point, strap-type tiedowns.

This part of ISO 16840 applies to seating systems designed to be used with occupant restraints that anchor either to the vehicle, the tiedown system, the seating system or the wheelchair base.

Seating systems that are intended only for use with a specific wheelchair base should be tested to ISO 7176-19 using the specifically intended wheelchair base.

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 898-7, *Mechanical properties of fasteners — Part 7: Torsional test and minimum torques for bolts and screws with nominal diameters 1 mm to 10 mm*

ISO 6487, *Road vehicles — Measurement techniques in impact tests — Instrumentation*

ISO 7176-19:2008, *Wheelchairs — Part 19: Wheeled mobility devices for use as seats in motor vehicles*

ISO 10542-1:2001, *Technical systems and aids for disabled or handicapped persons — Wheelchair tiedown and occupant-restraint systems — Part 1: Requirements and test methods for all systems*

ISO 10542-2, *Technical systems and aids for disabled or handicapped persons — Wheelchair tiedown and occupant-restraint systems — Part 2: Four-point strap-type tiedown systems*

FMVSS 201, *Standard No. 201, Occupant protection in interior impact. (Federal Motor Vehicle Safety Standards), 49 CFR 571.201*

ECE Regulation 21, *Uniform provisions concerning the approval of vehicles with regard to their interior fittings, Revision 2, Amendment 2*

ASTM E527-83 (2003), *Standard Practice for Numbering Metals and Alloys (UNS)*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

3.1
adult
person having a mass equal to or greater than 43 kg

3.2
anchor point
location on a vehicle interior component, floor, wall, wheelchair, or wheelchair tiedown, to which an **anchorage** (3.3) is attached

3.3
anchorage
assembly of components 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 interior component

3.4
anthropomorphic test device
ATD
articulated physical analogue used to represent a wheelchair occupant in a test

3.5
attachment hardware
mechanical means of attaching a seating system to the wheelchair frame

EXAMPLE Metal or plastic hooks, nuts or bolts.

3.6
back support angle
angle of the back support reference plane with reference to a vertical plane

NOTE Measurement method specified in ISO 7176-7.

3.7
back support surface
component of seating system intended to support the posterior surface of the sacral, lumbar and/or thoracic segments of the trunk

3.8
back support reference plane
plane associated with the back support of the wheelchair, which is referenced to make measurements

NOTE Method for determining the location of this reference plane specified in ISO 7176-7.

3.9
belt
length of webbing material used as part of an occupant restraint or postural support

3.10
child
person having a mass equal to or greater than 22 kg and less than 43 kg

3.11
custom contoured
uniquely shaped to match the wheelchair occupant

3.12
excursion
horizontal movement of an **ATD** (3.4) or wheelchair during a test relative to its initial position on an impact sled

3.13
forward facing
orientation in which the wheelchair-seated occupant faces the front of the vehicle, with the reference plane within ten degrees of the longitudinal axis of the vehicle

3.14
four-point tiedown
wheelchair tiedown that attaches to the wheelchair frame at four separate securement points and also attaches to the vehicle at four separate anchor points

3.15
four-point strap-type tiedown
four-point tiedown (3.14) that uses four strap assemblies to secure the wheelchair in the vehicle

3.16
H-point
point located on the left and right side of the pelvic region of an **ATD** (3.4) that represents the approximate location of the human hip joint centre in the side view, as specified by the ATD manufacturer

3.17
head support
postural aid to support the head of a wheelchair occupant, not designed or intended to provide head restraint in a vehicle impact

3.18
head restraint
device intended to limit rearward excursion of the wheelchair occupant's head in a vehicle impact

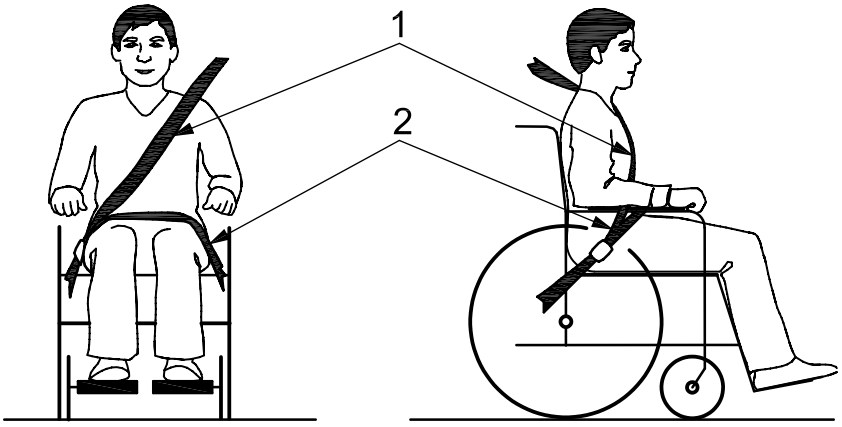
3.19
impact simulator
device for applying a programme of acceleration and deceleration modes to a section of a vehicle or simulated vehicle structures, including instrumentation for measuring data required by this part of ISO 16840

3.20
impact sled
part of an **impact simulator** (3.19) on which components can be mounted for impact testing

3.21
occupant restraint
system or device intended to restrain a motor vehicle occupant during impact in order to prevent ejection, and prevent or minimize contact with the vehicle interior components and other occupants

3.22
pelvic-belt restraint
lap-belt restraint
portion of the occupant restraint intended to limit movement of the pelvis by application of restraint forces to the pelvis

See Figure 1.



Key

1 shoulder-belt restraint

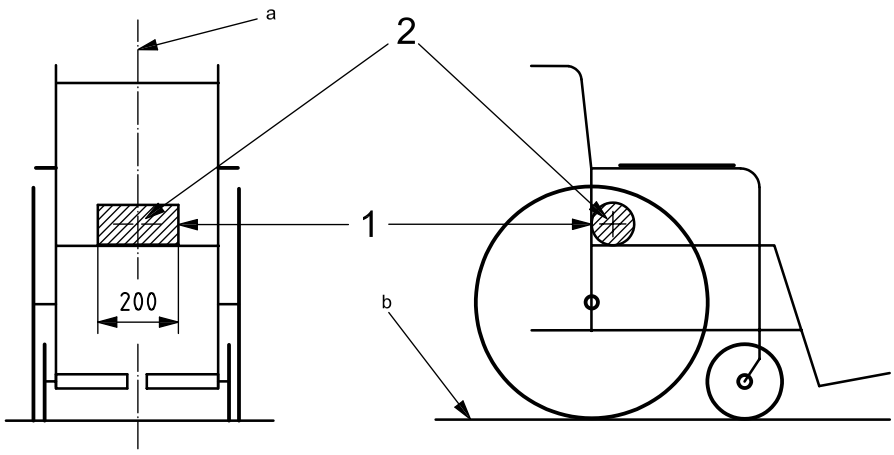
2 pelvic-belt restraint

Figure 1 — Three-point-belt restaint comprised of a pelvic-belt restraint and a shoulder-belt restraint that connect together near the hip of the occupant

3.23
point P
side-view projection of a point on the seating system which lies at the cross-sectional centre of a 100 mm diameter, 200 mm long, cylinder with a maximum weight of 0,5 kg positioned with the longitudinal axis perpendicular to the wheelchair reference plane, such that the curved surface of the cylinder is in contact with the seat and back support surfaces

See Figure 2.

Dimensions in millimetres



Key

1 cylinder, diameter 100 mm

2 point P

a Wheelchair reference plane.

b Wheelchair ground plane.

Figure 2 — Seating system reference point P and wheelchair reference and ground planes

3.24
postural support device
component and/or belt used to support a person in a desired seated position during normal wheelchair use

NOTE Postural support devices are not designed or intended to provide occupant restraint on vehicle impact.

3.25
seat plane angle
angle of **seat reference plane** (3.27) with reference to a horizontal plane

NOTE Measurement method specified in ISO 7176-7.

3.26
seat support surface
component of seating system intended to support the inferior surface of the buttocks and thighs

3.27
seat reference plane
plane associated with the seat of the wheelchair, which is referenced to make measurements

NOTE Methods for determining the location of this reference plane are specified in ISO 7176-7.

3.28
seating system
seat and back support surfaces and their attachment hardware

3.29
securement points
points on the wheelchair to which wheelchair tiedowns are connected

3.30
shoulder-belt restraint
upper torso restraint
portion of the occupant restraint intended to limit movement of the upper body by application of restraining forces to either or both clavicles

See Figure 1.

3.31
strap
length of webbing material used in a wheelchair tiedown

3.32
support surface
part of the seating system that is intended to contact the wheelchair occupant

3.33
surrogate wheelchair base
SWCB
re-usable device that conforms to the requirements of Annex B, used to simulate a wheelchair base for the purpose of testing seating systems

3.34
three-point-belt restraint
three-point restraint
occupant restraint assembly with three anchorages comprised of both a pelvic-belt restraint and a diagonal shoulder-belt restraint that connect together near the hip of the occupant.

See Figure 1.

3.35
wheelchair base
portion of the wheelchair consisting of the wheels and **wheelchair frame** (3.36)

3.36
wheelchair frame
portion of the wheelchair consisting of the members that make up the supporting structure

3.37
wheelchair ground plane
plane representing the surface on which the wheelchair rests

See Figure 2.

3.38
wheelchair reference plane
vertical plane in longitudinal centreline of the wheelchair

See Figure 2.

3.39
wheelchair tiedown
wheelchair securement system
device or system designed to secure a forward-facing wheelchair in place in a motor vehicle

3.40
wheelchair tiedown and occupant restraint system
WTORS
complete restraint system for wheelchair-seated occupants comprised of equipment for wheelchair tiedown and a belt-type occupant restraint

4 Design requirements

NOTE It can be beneficial for some users to have a head restraint as a part of their seating system.

4.1 Reduction of sharp edges

Webbing shall be protected from contacting sharp corners and edges. If the edge of a rigid component of a seating system has a radius less than 2,0 mm, it shall be covered with padding capable of absorbing energy to reduce the likelihood of injuries to wheelchair users and other vehicle occupants during a vehicle impact. Energy-absorbing padding should conform to the requirements of FMVSS 201 and/or ECE Regulation No. 21.

4.2 Accommodation of vehicle-anchored occupant restraints

The seating system shall be constructed in such a way that any part of the system (e.g. frame, hip or thigh supports, etc) will not hold a lap-belt or shoulder-belt restraint away from a seated user's pelvis or upper torso.

5 Performance requirements

NOTE Informative Annex C provides manufacturers with a preliminary means to evaluate the performance of their seating system using low cost static tests. It is important to note that static testing results may not be equivalent to dynamic test performance.

5.1 Frontal impact test

5.1.1 General

The wheelchair seating system shall be tested in accordance with Annex A using the surrogate wheelchair base, as specified in Annex B, secured by a four-point strap-type tiedown that complies with ISO 10542-1 and ISO 10542-2. The requirements of 5.1.2 and 5.1.3 shall be met during and after the conducted test.

5.1.2 During the frontal impact test

When tested in accordance with Annex A, the following requirements shall be met during the test.

a) The horizontal excursions of the ATD and the seating system shall not exceed the values given in Table 1.

NOTE Excursion limits are based upon prevention of occupant secondary impact with vehicle interior.

b) Except when the test has been conducted using a wheelchair base or seat-anchored pelvic-belt restraint or a completely wheelchair base or seat-anchored occupant restraint system, the knee excursion, X_{knee}, shall exceed the point P excursion, X_{ss}, as follows.

$$X_{\text{knee}}/X_{\text{ss}} \geqslant 1{,}1$$

Refer to Table 1 for definitions of X_{knee} and X_{ss}.

NOTE Conformity with this requirement reduces the potential for the seating system to apply loads to the wheelchair occupant.

c) The seating system shall not separate from the surrogate wheelchair base at any attachment point.

5.1.3 After the frontal impact test

When tested in accordance with Annex A, the following requirements shall be met at the end of the test.

a) The ATD shall be retained in the seating system in a seated posture, as determined by the ATD torso being oriented at not more than 45° to the vertical when viewed from any direction.

NOTE The angle of the ATD torso can be estimated by aligning the edge of an inclinometer with a line drawn connecting the centre of the ATD's shoulder and the ATD's hip.

b) The load-carrying components of seating system and attachment hardware shall not show visible fractures or deformation that prevent it from supporting the mass of the ATD.

c) Components, fragments or accessories of the seating system with a mass greater than 0,1 kg shall not have completely separated from the seating system.

d) Rigid seating system components that may contact the occupant shall not fragment or separate in a manner that produces sharp edges with a radius of less than 2,0 mm.

e) The post-test height of the average of left and right ATD H-points relative to the wheelchair ground plane shall not change by more than 20 % from the pre-test height.

Table 1 — Horizontal excursion limits

Dimensions in millimetres

Measurement point	Excursion variable	6-year old child ATD	10-year old child ATD	Small adult female ATD	Midsize and large adult ATD
Point P of seating system	X_{ss}	150	175	200	200
ATD knee centre	X_{knee}	300	325	375	375
ATD front of head	X_{headF}	450	500	550	650
ATD back of head	X_{headR}	−350	−400	−400	−450

X_{ss} is the forward horizontal distance relative to the sled platform between the point P target on the seating system at time t_0, to the point P target at the time of peak seating system excursion.

X_{knee} is the horizontal distance relative to the sled platform between the ATD knee joint target at time t_0, to the knee-joint target at the time of peak knee excursion.

X_{headF} is the horizontal distance relative to the sled platform between the most forward point on the ATD's head above the nose at time t_0, to the most forward point on the ATD's head at the time of peak head excursion.

X_{headR} is the horizontal distance relative to the sled platform between the most rearward point on the ATD's head at time t_0, to the most rearward point on the ATD's head at the time of peak head excursion.

NOTE 1 Refer to Table A.1 for appropriate ATD selection.

NOTE 2 Positive limit values indicate forward excursions, while negative values indicate rearward excursions.

5.2 Accommodation of vehicle-anchored occupant belt restraints

The wheelchair seating system shall be tested for accommodation of vehicle-anchored occupant restraint systems in accordance with Annex D and the resulting rating shall be reported in the product presale literature.

6 Identification, labelling, user instructions, warning and disclosure requirements

6.1 Identification and labelling

The wheelchair seating system shall be permanently marked with:

a) the manufacturer's name;

b) the month and year of manufacture;

c) a unique serial number;

d) a statement that the seating system meets the requirements of ISO 16840-4:2008;

e) a statement that any postural support device not intended for use as occupant restraint in motor vehicle transport may not provide occupant protection in a vehicle impact;

f) the maximum occupant mass;

g) an indication that each component of the system that functions as a postural support conforms to requirements of ISO 16840-4:2008.

6.2 Pre-sale literature

The seating system manufacturer's presale literature shall include:

a) a statement that the seating system is intended only for use with wheelchair bases tested as part of a complete wheelchair system that conforms to the performance requirements of ISO 7176-19;

b) a statement that the seating system must be used on a wheelchair base that provides securement points that conform to the design requirements of ISO 7176-19;

c) a description of the seating system including the components that are intended for use during motor vehicle transport;

d) a statement that the seating system is designed to be forward facing when used with a wheelchair base in a motor vehicle;

e) a description of the WTORS to be used;

f) the overall score and rating of the seating system (i.e. A, B or C)[1)] with regard to accommodating vehicle-anchored occupant restraints, and an explanation of the different ratings based on the test methods of Annex D.

6.3 User instructions

User instructions shall be provided with each seating system in the official languages of the countries in which the product is marketed, and shall include:

a) a statement that the seating system meets the requirements of ISO 16840-4:2008 and that it is suitable for use as a motor vehicle seat when used with an appropriate wheelchair base;

b) a statement describing assembly, use, maintenance and any limitations in using the seating system with a wheelchair base in a motor vehicle;

c) in cases of custom-contoured seating systems, a statement that custom contoured seating systems may require a qualified professional to configure and install the seating system;

d) a statement that both a pelvic-belt restraint and shoulder-belt restraint should be used.

6.4 User warnings

The seating manufacturer shall provide the following warnings in the user instructions using 12-point or larger **bold** font:

a) the seating system shall only be used with wheelchair bases that were tested as part of a wheelchair system that conforms to ISO 7176-19 performance requirements and that has securement points for use with four-point, strap-type tiedowns;

b) the seating system shall only be used for forward-facing seating in motor vehicles;

c) the seating system shall only be used as indicated in the manufacturer's instructions;

d) wheelchair-mounted trays not specifically intended to be used in transport shall:

   1) be removed and secured separately in the vehicle or

   2) be secured to the wheelchair but positioned away from the wheelchair-seated occupant with energy-absorbing padding placed between the tray and the occupant;

1) A = good; B = acceptable; C = poor.

e) postural support devices that are not labelled as conforming to ISO 16840-4 may be used when in a vehicle, but should not be relied on for occupant restraint;

f) alterations or substitutions shall not be made to the seating system structure, parts or components, without consulting the manufacturer;

g) both pelvic-belt and shoulder-belt restraints as a part of a complete WTORS which meets ISO 10542-1 shall be used to achieve effective occupant restraint and optimum protection in a vehicle impact; the belt restraints should be fitted to the user in accordance with WTORS manufacturers' instructions;

h) children whose mass is less than 22 kg should be transferred from their seating system into appropriate child restraint systems intended for use in motor vehicles.

NOTE See also E.2 c).

7 Documentation of compliance

7.1 General

The wheelchair manufacturer shall maintain documentation, including test reports, that provide evidence of compliance to the design and performance requirements of this part of ISO 16840. This documentation shall include the information listed in 7.2 to 7.4.

7.2 Test report

The following shall be included in the report of each test conducted in accordance with this part of ISO 16840:

a) reference to this part of ISO 16840, i.e. ISO 16840-4:2008;

b) the name and address of the test institution;

c) the date of test;

d) a unique test report number shown on each numbered page;

e) the name and address of the manufacturer;

f) product type, designation and serial number of the seating system;

g) a list of individual components and their designation, including postural supports and attachment hardware, tested as a part of the seating system;

h) photographs of the seating system, once test set-up procedures have been completed, before testing and after testing;

i) photographs of the seating system attachment hardware, once test set-up procedures have been completed, before testing and after testing;

j) photographs of the side and frontal view of the test setup before and after testing;

k) a description of any postural support devices used in the test.

7.3 Frontal impact test

The test report for the frontal impact shall also include:

a) the measured or calculated value of the sled velocity change, ΔV, during the impact event;

b) a graph of the impact sled deceleration plotted against time and the specified acceleration/deceleration requirements described in A.4.1 g) and Figure A.1;

c) a description and the total mass of the ATD used in the test;

d) a statement as to whether or not the seating system met the requirements of 5.1 and any other relevant observations.

7.4 Design, labelling and literature requirements

The seating system manufacturer shall maintain statements and evidence on file as to:

a) whether the seating system meets the requirements specified in 4.1, 4.2, 5.1 and 5.2;

b) whether the seating system, its components and related literature are in accordance with the requirements of 6.1, 6.2, 6.3 and 6.4.

Annex A
(normative)

Test method for frontal impact test

A.1 General

This annex specifies apparatus, conditions and procedures for conducting a sled impact test to simulate the dynamic loading on complete wheelchair seating systems, including attachment hardware, during frontal impact. A complete wheelchair seating system shall be evaluated forward facing, using a 48 km/h, 20 g frontal impact.

A.2 Principle

The principle of this test method is to evaluate the performance of a wheelchair seating system, including attachment hardware, occupied by an ATD, independent of a specific wheelchair frame, when subjected to frontal impact. Test procedures specify the use of a surrogate wheelchair base (SWCB) described in Annex B to represent a commercial wheelchair frame. Observations and measurements are made to determine whether the seating system strength and performance are satisfactory under these test conditions.

A.3 Test sample

This comprises a complete seating system, consisting of an unused seating system, attachment hardware, and any postural support devices typically supplied with the seating system and instructions for their installation and use. Obtain instructions from the manufacturer for mounting attachment hardware to the SWCB support structure. This will ensure that the SWCB seat support structure will be compatible with the attachment hardware.

NOTE The SWCB seat support structure is replaceable so that the cross section of the members are compatible with the seating system attachment hardware.

A.4 Test apparatus

A.4.1 An impact simulator, including the following:

a) an impact sled equipped with a flat, horizontal, structurally rigid platform on which the surrogate wheelchair base can be mounted, and to which the wheelchair tiedown can be anchored;

b) a horizontal track or guide path to provide unidirectional movement of the sled during the impact event;

c) a means of driving the impact sled through a change in velocity of 48 km/h + 2 km/h − 0 km/h;

d) a rigid structure attached to the impact sled to which the upper anchorage of the shoulder-belt restraint can be anchored as specified in A.5.9;

e) a wheelchair tiedown that conforms with the dynamic performance requirements specified in 6.2 of ISO 10542-2:2001 and that secures the surrogate wheelchair base by the method specified by the manufacturer;

f) a vehicle-anchored three-point-belt restraint or a wheelchair base anchored lap-belt restraint with a vehicle anchored shoulder-belt restraint that conforms to the requirements of ISO 10542-1;

g) a means of accelerating and/or decelerating the impact sled and test set-up such that the processed sled acceleration- and/or deceleration-time pulse:

   1) falls within the shaded area of Figure A.1,

   2) exceeds 20 g for a cumulative time period of at least 15 ms,

   3) exceeds 15 g for a cumulative time period of at least 40 ms and

   4) has a duration of at least 75 ms from t_o to t_f where t_o is the time at the beginning of the deceleration and t_f indicates the time at the end of the deceleration pulse;

h) an ATD selected from Table A.1 which is representative of the upper size range of users for which the seating system is designed;

i) a surrogate wheelchair base that complies with the specifications of Annex B.

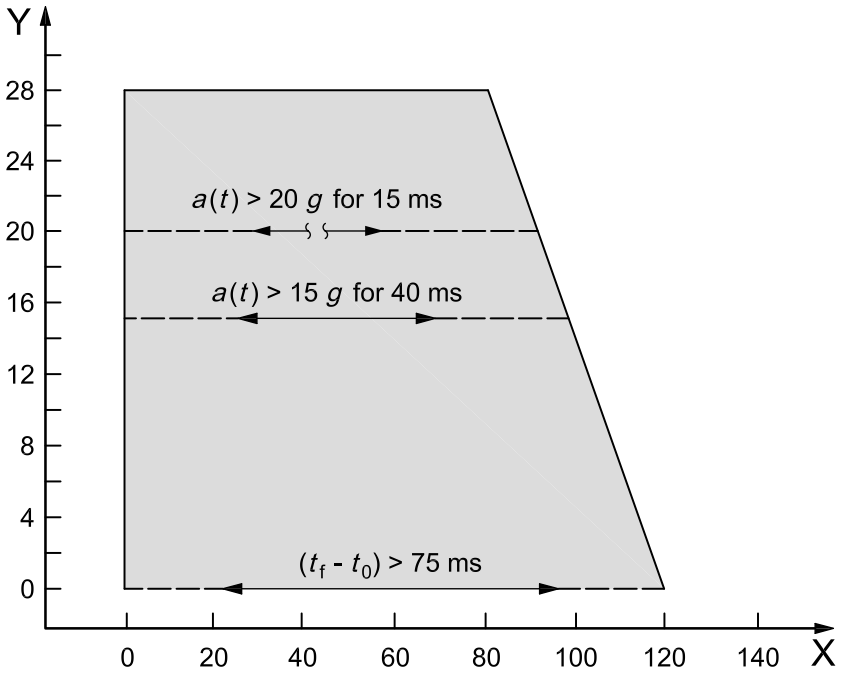
Table A.1 — ATDs[a] for seating system testing

Occupant weight range kg (lb)	ATD Size	Approximate mass of ATD kg (lb)
> 18 to 27 (> 40 to 60)	6-year-old child	22,5 (50)
> 27 to 43 (> 60 to 95)	10-year-old child	35 (76)
> 43 to 57 (> 95 to 125)	Small adult female	47,0 (104)
> 57 to 75 (> 125 to 165)	Small adult female, weighted [b]	59,0 (130)
> 75 to 136 (> 165 to 300)	Midsize adult male	76,3 (170)
> 136 (> 300)	Large adult male	102,0 (225)

[a] The midsize male ATD shall be a Hybrid II or Hybrid III type.

The other sizes of ATDs may be Hybrid II, Hybrid III, VIP, P series or Q series types.

[b] The ATD mass may be increased by attaching weighted material, such as lead sheeting, to the exterior of the ATD.



Key

X time in milliseconds

Y deceleration in g force

NOTE The acceleration/deceleration of the impact sled shall stay within the shaded area and exceed the indicated levels for the specified continuous (unbroken arrows) and cumulative (broken arrows) time period.

Figure A.1 — Acceleration/deceleration requirements for the 48 km/h (+2 km/h – 0 km/h) ΔV impact test

A.4.2 A high speed film or **video system**, capable of recording at a minimum frame rate of 500 frames/sec, to measure the ATD and SWCB horizontal excursions specified in 5.1 and Table 1 to an accuracy of ± 5 mm.

A.4.3 A means of measuring the horizontal acceleration and/or **deceleration of the impact sled in the direction of travel**, at a sampling rate in accordance with ISO 6487, and with a precision of ± 0,5 g.

Impact sled accelerometers shall be calibrated once per year in conformance with ISO 6487.

A.4.4 A means of measuring the horizontal velocity change, ΔV, during the impact with a precision of ± 0,5 km/h.

A.4.5 Provision to filter analog transducer signals, using a low-pass filter in accordance with ISO 6487, including

a) pre-filtering of all transducer signals to Channel Class 1 000 (–4 dB at 1 650 Hz) prior to digitizing at 10 000 Hz,

b) filtering of the digitized accelerometer and load-cell signals to Channel Class 60 (–4 dB at 100 Hz).

A.5 Test preparation and procedure

A.5.1 Set up the surrogate wheelchair base and seating system in accordance with the following.

a) Select and install the appropriate surrogate wheelchair base cross brace frame which matches the seat system width.

b) Select and install seat rails and, where applicable, seatback posts having a cross section or cross sections that are compatible with the attachment hardware.

NOTE For seating systems having an integral seat frame, seatback posts might not be necessary.

c) Install deformable castor elements and, where applicable, the deformable seatback post elements.

d) Fasten the seat and back support surfaces as applicable with the provided attachment hardware to the surrogate wheelchair base seat and back structure in accordance with the manufacturer's instructions.

e) Fasten any additional postural support devices or components to the seating system in accordance with the manufacturer's instructions.

f) If specific instructions are not provided by the manufacturer, tighten bolts and screws to the minimum torque specified in ISO 898-7.

g) For seating systems having an integrated tilting frame, remove the surrogate wheelchair base seatback post elements and mount seating system frame to surrogate wheelchair base.

h) For seating systems with independently reclining back support surfaces, adjust the back support angle to 10° relative to the vertical without the ATD seated in the wheelchair.

NOTE Back support angle measurement method specified in ISO 7176-7.

i) For seating systems with independently adjustable seat support surface angles, adjust the seat plane angle to a maximum incline angle of 10° relative to the horizontal without the ATD seated in the wheelchair.

NOTE Seat plane angle measurement method specified in ISO 7176-7.

j) For seating systems having an integrated tilting frame, adjust the seat plane angle to a maximum of 30°, relative to the horizontal, without the ATD in the wheelchair or a position selected by the manufacturer.

NOTE Seat plane angle measurement method specified in ISO 7176-7.

k) Adjust the horizontal and vertical footrest extension bars to accommodate the selected ATD.

l) Record the pre-test settings, including seatback support surface angle relative to vertical and seat support surface angle relative to horizontal, of the seating system components. Any adjustable seating components shall be set to manufacturer's recommended position or the mid-position of recommended range.

A.5.2 Set up the high-speed film or video system (A.4.2) to record a lateral view of the test sled platform, surrogate wheelchair base with seating system and ATD during the impact event and during ATD rebound.

A.5.3 Position the SWCB with seating system facing forward on the sled platform with wheelchair reference plane parallel to the direction of sled travel.

A.5.4 Install the wheelchair tiedown anchorages on the sled platform, selecting anchor points for four-point tiedowns that:

a) are symmetric about the intended wheelchair reference plane;

b) are located 1 300 mm ± 20 mm from the front anchor point to the rear anchor point;

c) have a lateral distance between rear anchor points equal to the lateral distance between rear securement points of the test wheelchair base, ± 25 mm;

d) have a lateral distance between front anchor points of 508 mm to 660 mm, as is appropriate to the test wheelchair base.

A.5.5 Using the lower rear securement point of the SWCB, secure the SWCB with four-point tiedowns to achieve lengths of the rear tiedown strap assemblies of 495 mm to 533 mm, measured from the interface of the tiedown end fitting and the securement point on the SWCB to the anchor point.

NOTE The upper rear securement point of the SWCB may be used to evaluate wheelchair seating system performance under differing rear securement conditions but is not required by this part of ISO 16840.

A.5.6 Tension any tiedown straps to the manufacturer's specifications, making sure that the SWCB reference plane remains aligned within ± 3° of the direction of sled travel.

A.5.7 Position the ATD selected from Table A.1 in the seating system sitting upright and symmetrically positioned about the wheelchair reference plane, with the pelvis and elbows as close to the seatback of the surrogate wheelchair base or seating system as possible.

A.5.8 Install the pelvic-belt restraint. For vehicle-anchored or SWCB-anchored pelvic-belt restraints, select anchor points within the recommended zones as specified in Figure 5 of ISO 10542-1:2001. For seating system-anchored pelvic-belt restraints, utilize anchor points provided on the seating system.

A.5.9 Install the shoulder-belt restraint anchorage and/or guide on a rigid structure at the point marked by a bold **X** in Figure A.2 for a mid-sized male; to achieve belt restraint, fit across the ATD's shoulder and chest as shown. For tests involving other sizes of ATDs, adjust the anchor point location accordingly to give a good fit to the ATD chest whilst maintaining the angles shown for a mid-sized male ATD in Figure A.2.

A.5.10 Adjust the tension in the pelvic-belt restraint as follows.

a) If an emergency locking or auto-locking retractor is provided, adjust the pelvic-belt restraint for minimum slack over the ATD’s pelvis.

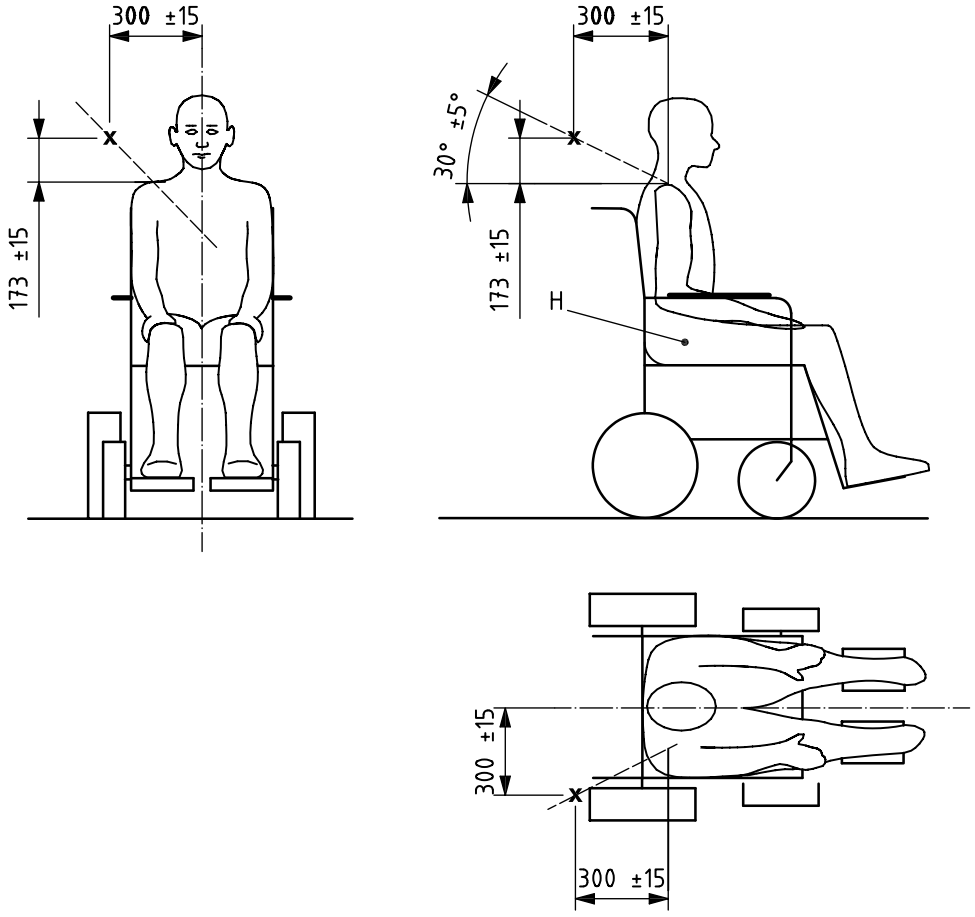
b) If no emergency-locking or auto-locking retractor is provided, remove all belt restraint slack and adjust the tension of the pelvic-belt restraint to a snug fit over the pelvis.

A.5.11 Adjust the tension in the shoulder-belt restraint as follows.

a) If an emergency locking or auto-locking retractor is provided, adjust the shoulder-belt restraint for minimum slack over the ATD’s chest.

b) If no emergency-locking or auto-locking retractor is provided, remove all shoulder-belt restraint slack and adjust the tension of the shoulder-belt restraint to a snug fit with a 75 mm × 75 mm × 75 mm block placed between the shoulder-belt restraint and ATD sternum. Remove the block before conducting the test.

Dimensions in millimetres



NOTE Anchor point **X** can be located on either side of wheelchair and ATD.

Figure A.2 — Test location for upper anchor point of shoulder-belt restraint when using the midsize-male ATD in the surrogate wheelchair base

A.5.12 Position high-contrast markers on the sides of the dummy and test wheelchair in view of the high-speed recording equipment (A.4.2) at:

a) the lateral aspect and centre of the ATD's knee joint;

b) the lateral aspect and centre of the ATD’s hip joint (H-point);

c) the lateral aspect and centre of the ATD’s shoulder joint (acromium process);

d) the point P (see Figure 2), or a point on the seating system that is as close to the point P as possible;

e) the most forward point and most rearward point of the ATD’s head.

NOTE Visual contrast between the ATD and background may improve clarity in determining position of the ATD markers during testing.

A.5.13 Verify that the surrogate wheelchair base reference plane is aligned to within ± 3° of the direction of sled travel.

A.5.14 Measure and record the horizontal and vertical distance from the mid-point of the rear edge of the seat support surface to the rear wheel hub and from the mid-point of the bottom edge of the back support surface to the rear wheel hub.

A.5.15 Measure and record the seat plane angle and back support angle.

NOTE Measurement methods for seat plane angle and back support angle specified in ISO 7176-7.

A.5.16 Measure and record the height (± 5 mm) of the ATD's left and right H-points vertically from the sled platform.

A.5.17 Conduct the impact test.

A.6 Post-test measurements

A.6.1 After the test, inspect the surrogate wheelchair base, seating system, postural supports when present, ATD and WTORS to determine whether the seating system meets the requirements of Clause 5.

A.6.2 Determine peak excursions X_{ss}, X_{knee}, X_{headF} and X_{headR} as defined in 5.1.2 to an accuracy of ± 5 mm.

A.6.3 Measure the height of the left and right H-points of the ATD above the wheelchair ground plane to an accuracy of ± 5 mm (i.e., the raised platform) and calculate the average H-point change in height from the pre-test position.

A.6.4 Use an inclinometer to estimate the maximum angle of the ATD's torso relative to the vertical when viewed from any direction.

A.6.5 Release the occupant restraint, remove the ATD, and record whether wheelchair seating system deformation hinders removal of the ATD from the wheelchair.

A.6.6 Measure and record the movement of seating system components from their pre-test settings.

Annex B
(normative)

Specifications for the surrogate wheelchair base used for impact testing of a seating system

B.1 General

This annex provides design, dimensional, mass and performance specifications for the surrogate wheelchair base (SWCB). These specifications are intended to provide a repeatable and re-usable device that represents a typical, adult-sized wheelchair base for evaluating the frontal impact performance of wheelchair seats, back supports and their attachment hardware.

B.2 Specifications

The surrogate wheelchair base shall be fabricated with the features, dimensions, and specifications shown in Figures B.1 to B.4. The SWCB shall:

a) be of rigid durable construction with deformable, replaceable elements, such that it can withstand repeated use, in a 48 km/h, 20 g frontal impact test with an ATD weighing up to 125 kg that is positioned and restrained in the surrogate wheelchair base;

b) have a total mass of 48 kg $\pm$ 3 kg;

c) comply with the dimensions of Figures B.1 to B.4;

d) have a centre of gravity located 245 mm $\pm$ 10 mm forward of the rear axle and 264 mm $\pm$ 10 mm above the ground plane;

e) have interchangeable cross-brace frames to vary the overall width of the SWCB as indicated in Figures B.1 and B.2;

f) provide two front securement points and two rear securement points for four-point tiedowns at the locations indicated in Figure B.1;

g) provide pelvic-belt restraint anchor points on both sides of the surrogate wheelchair base;

h) have a replaceable seat support structure consisting of two rails that are oriented at an angle of 4° $\pm$ 1,5° to the horizontal (front end up) when the SWCB tyres are inflated as specified in j) and k) and are resting on a flat horizontal surface;

NOTE Seat and back support structures should be of a geometrical cross section that is compatible with seating system hardware. Multiple seat and back support structures with varying geometrical cross sections might be required to interface with various types of attachment hardware.

i) have a removable back support structure consisting of two elements that are oriented at 8° $\pm$ 1,5° to the vertical relative to the transverse plane (90° from wheelchair reference plane) when the tyres of the SWCB are inflated as specified in j) and k) and are resting on a flat horizontal surface; the support structure accommodates the back support surface and associated attachment hardware to be evaluated;

j) have pneumatic front tyres that, when inflated to 320 kPa ± 30 kPa with the unoccupied surrogate wheelchair base resting on a flat horizontal surface, have a diameter of 230 mm ± 20 mm, a width of 75 mm ± 10 mm, and a sidewall height of 54 mm ± 5 mm;

k) have pneumatic rear tyres that, when inflated to 415 kPa ± 15 kPa with the unoccupied surrogate wheelchair base resting on a flat horizontal surface, have a diameter of 325 mm ± 20 mm, a width of 100 mm ± 10 mm, and a sidewall height of 70 mm ± 5 mm;

l) have a deformable back support structure consisting of two ASTM E527-83 Aluminium 6061T6 rods of diameter shown in Figure B.3;

NOTE The deformable structure allows for forward and rearward seatback deflection.

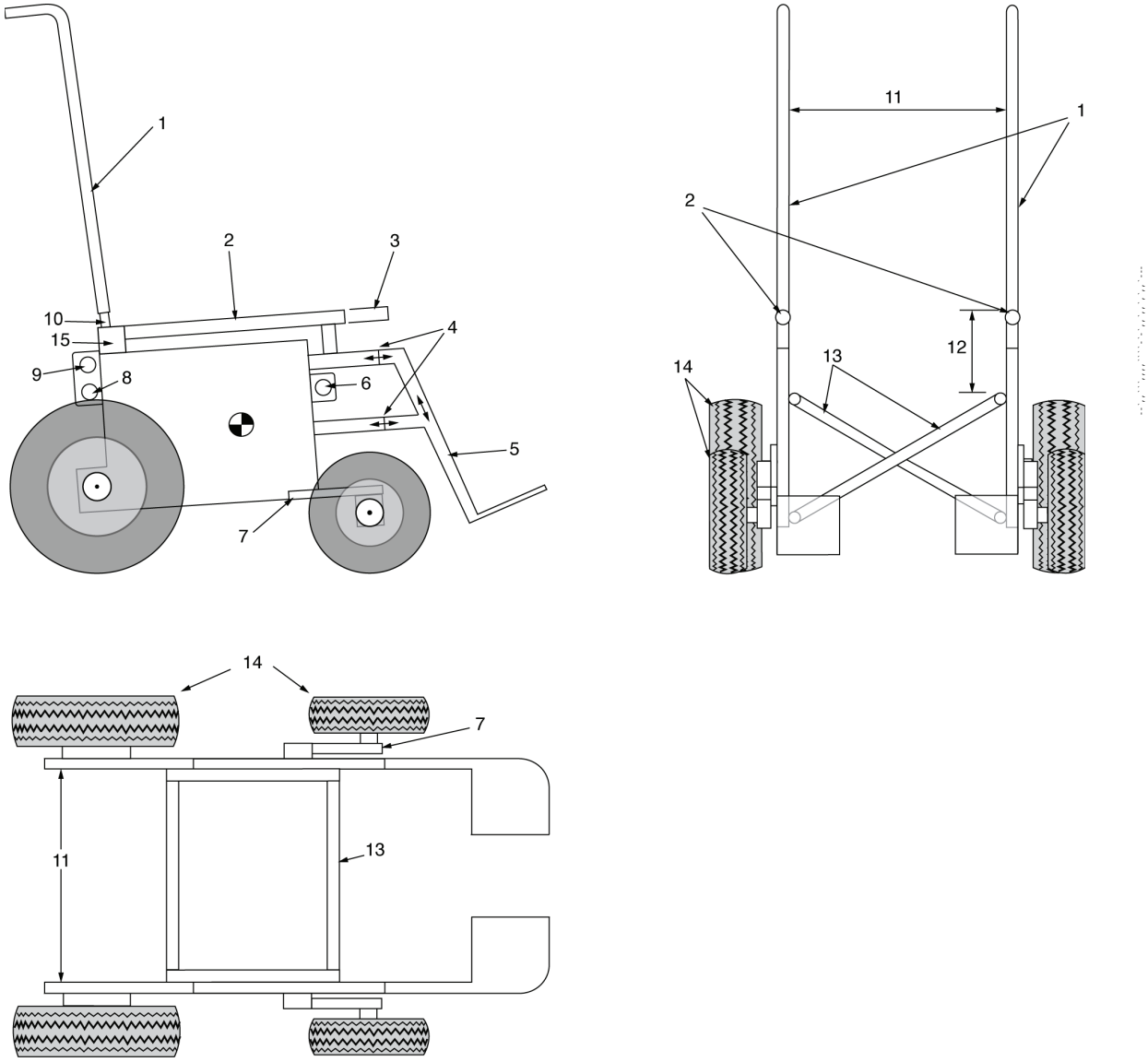
m) have deformable ASTM E527-83 Aluminium 6061T6 castor mounting elements as shown in Figure B.4;

NOTE The deformable elements allow for wheelchair frame and castor downward deflection.

n) have horizontally and vertically adjustable position foot supports that may be detached if required.

B.3 Maintenance and inspection

The surrogate wheelchair base shall be inspected before and after each test to verify that unintended permanent deformation or component failure has not occurred during testing. When failure or permanent deformation is present, the affected components must be repaired or replaced to restore the surrogate wheelchair to its original unused condition.



Key

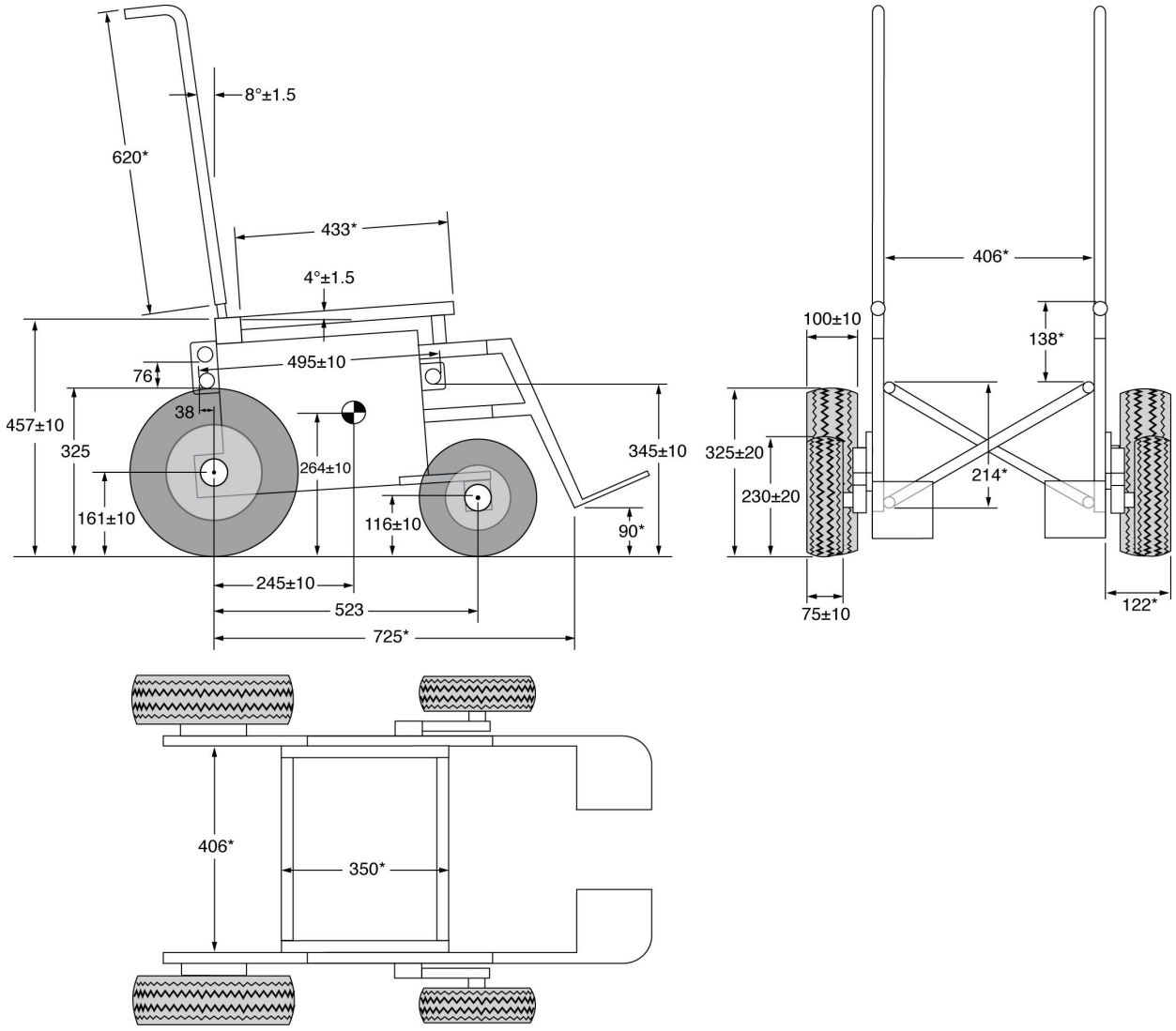
1 optional back support structure
2 replaceable seat support structure
3 optional seat support structure extensions
4 horizontally adjustable footrest length
5 adjustable footrest length
6 front securement point
7 deformable castor mounting bars
8 primary rear securement point
9 optional rear securement point
10 deformable seatback rods
11 adjustable width
12 clear space under seat
13 interchangeable cross-brace frame to adjust width
14 pneumatic tyres
15 pelvic-belt restraint anchor points

NOTE 1 Seat and back tubing: outside diameter 25,4 mm ± 0,2 mm with 3,175 mm ± 0,2 mm wall thickness.

NOTE 2 All other frame tubing: outside diameter 22 mm ± 0,2 mm with 3,048 mm ± 0,2 mm wall thickness.

Figure B.1 — Overall drawing of the surrogate wheelchair base

Dimensions in millimetres

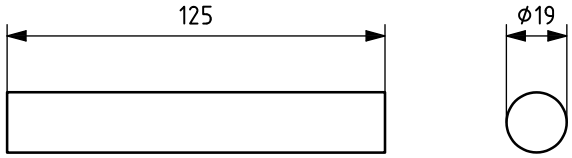


NOTE 1 Tolerances are ± 4 mm unless specified.

NOTE 2 Asterisks indicate dimensions that may vary due to component adjustability.

Figure B.2 — Detailed drawing of the surrogate wheelchair base

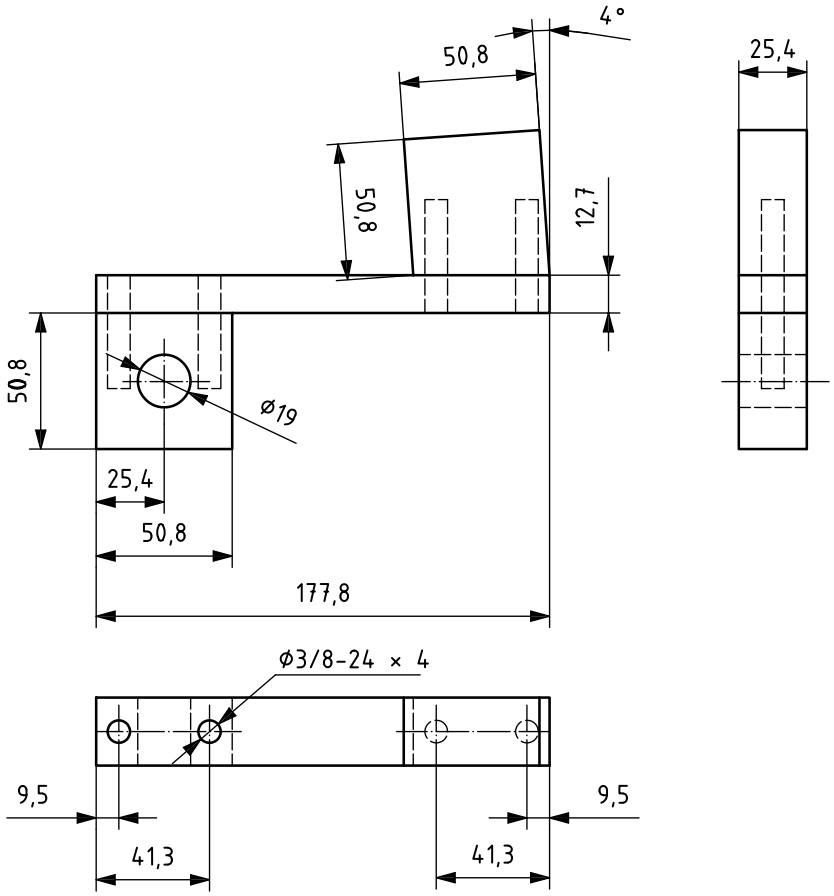
Dimensions in millimetres



NOTE 1 All dimensions have tolerances of ± 0,2 mm unless specified.

Figure B.3 — Deformable seat back support element

Dimensions in millimetres



NOTE 1 All dimensions have tolerances of ± 0,2 mm unless specified.

NOTE 2 Castor mounting structure attaches to SWCB using 3/8-24 × 4 grade 8 bolts.

Figure B.4 — Castor mounting structure including deformable castor element

Annex C
(informative)

Wheelchair seating system — Static test method

C.1 General

C.1.1 Scope

This annex is intended to provide guidance to seating system manufacturers as a part of their design process before carrying out dynamic crash testing. Apparatus, preparations, and procedures for conducting a static test are specified to simulate wheelchair seating system loading during a frontal impact. Conformity with the criteria of this static test does not assure conformity with the dynamic test specified in Annex A, nor does it assure crashworthiness. Criteria for the static test were based upon the following.

C.1.2 Back support and related attachment hardware testing

The wheelchair back support and attachment hardware are evaluated based upon an estimated load associated with the rebound phase of a 48 km/h, 20 g frontal impact.

C.1.3 Seat and related attachment hardware testing

The seat and attachment hardware shall be evaluated based upon an estimated load associated with a 48 km/h, 20 g frontal impact.

This test applies to all types of seating systems and associated components, including drop seats, seat inserts, seat and back support attachment hardware, and sling seats and backs.

C.2 Test sample

The test sample shall consist of an unused seating system or seating system component (seat, back support, attachment hardware), along with instructions for their use and installation. If a wheelchair seat or back support is provided with its attachment hardware as a complete system from a manufacturer, then they shall be tested together as a unit. Otherwise, surrogate attachment hardware shall be used to test the seat or back support, and surrogate support surfaces shall be used to test seat or back support attachment hardware.

C.3 Test apparatus

C.3.1 A compression and **tension loading machine**, to apply a static load to the seating system. The loading machine should be capable of applying a load ranging from 10 000 N to 17 000 N at a rate of 8 000 N/sec.

C.3.2 A rigid test fixture simulating a wheelchair frame, for mounting a seating system or seating system component to be tested.

An example of a rigid test structure is shown in Figure C.1.

The rigid test fixture shall be designed to interface with the attachment hardware cross-sectional geometry. Furthermore, the rigid test fixture shall be designed to accommodate the width of the seat support and/or back support.

C.3.3 Rigid surrogate attachment hardware, to test a seat or back support.

An example of surrogate attachment hardware is shown in Figure C.2.

C.3.4 A rigid surrogate seat/back support, to mount seat or back support attachment hardware to be tested.

An example of a surrogate seat support is shown in Figure C.3.

C.3.5 ISO 7176-7 reference loader gauge (RLG) seat unit and **back unit**, to apply a distributed load over the test support surface.

ISO 7176-7 RLG is shown in Figure C.4.

C.3.6 A means to measure the applied load, to an accuracy of ± 20N.

C.3.7 A means of measuring the displacement of the seat or **back support surface during the test**, to an accuracy of ± 1 mm.

C.4 Preparation and calibration of test apparatus

Prior to conducting the test, prepare and calibrate the test apparatus as follows.

a) Mount the rigid test fixture simulating a wheelchair frame on to the loading machine.

b) Inspect and adjust the seating system according to the manufacturer's instructions.

c) For the back support test, determine the distance between the top edge of the back support and the top edge of the back unit of the RLG, indicated as D in Figure C.6, so that it simulates the condition of a 50th percentile male with his posterior torso positioned against the back support.

d) Assure that the means of measuring the applied load has been calibrated as specified by the manufacturer.

C.5 Test methods

C.5.1 General

Set up the test sample and apparatus as shown in Figure C.5.

Perform the applicable tests in the sequence given in C.5.2 to C.5.7.

C.5.2 Back support with manufacturer provided attachment hardware

a) Mount the back support to the rigid test fixture using the attachment hardware in accordance with the manufacturer's instructions.

b) Place the back unit of the RLG on the back support to be tested as shown in Figure C.6. The position of the back unit of the RLG, distance, D, should be determined as specified in C.6.

c) Apply a downward force perpendicular (± 2°) to the back support surface at a magnitude of 10 188 ± 20 N to the back unit of the RLG through the centre of mass of the complete RLG.

The centre of mass of the complete RLG is shown on Figure C.4.

d) Perform the load cycle as follows:

1) apply the test load within 5 s;

2) hold the load for 2 s;

3) release the load.

C.5.3 Back support without manufacturer provided attachment hardware

a) Mount the surrogate attachment hardware to the back support. The distance between top and bottom surrogate attachment hardware shall be 152 mm ± 5 mm.

b) Mount the back support to the rigid test fixture using the surrogate attachment hardware.

c) Perform C.5.2 b) to C.5.2 d).

C.5.4 Back support attachment hardware

a) Mount the back support attachment hardware to the surrogate seat/back support. The distance between the centres of the top and bottom surrogate attachment hardware shall be 152 mm ± 5 mm.

b) Mount the surrogate seat/back support to the rigid test fixture frame using the back support attachment hardware.

c) Perform C.5.2 b) to C.5.2 d).

C.5.5 Seat with manufacturer-provided attachment hardware

a) Mount the seat to the rigid test fixture using the attachment hardware provided by the manufacturer in accordance with the manufacturer's instructions.

b) Place the seat unit of the RLG on top of the seat to be tested. Place the back edge of the seat unit of the RLG in line with the back edge of the seat support surface as shown in Figure C.7.

c) Apply a 16 680 N ± 200 N downward force to the seat unit of the RLG through the centre of mass of the complete RLG.

The centre of mass of the complete RLG is shown in Figure C.4.

d) The load cycle shall be the same as C.5.2 d).

C.5.6 Seat without manufacturer-provided attachment hardware

a) Mount the surrogate attachment hardware to the seat. The distance between top and bottom surrogate attachment hardware shall be 279 mm ± 5 mm.

b) Mount the seat to the rigid test fixture using the surrogate attachment hardware.

c) Perform C.5.5 b) to C.5.5 d).

C.5.7 Seat attachment hardware

a) Mount the seat attachment hardware to the surrogate seat/back support. The distance between the centres of the top and bottom surrogate attachment hardware shall be 279 mm ± 5 mm.

b) Mount the surrogate seat/back support to the rigid test fixture frame using the seat attachment hardware.

c) Perform C.5.5 b) to C.5.5 d).

In Figure C.1, support rails shall be of a cross-sectional geometry that interfaces with attachment hardware. Spacing of rails shall accommodate the width of the seat and/or back support.

Dimensions in millimetres

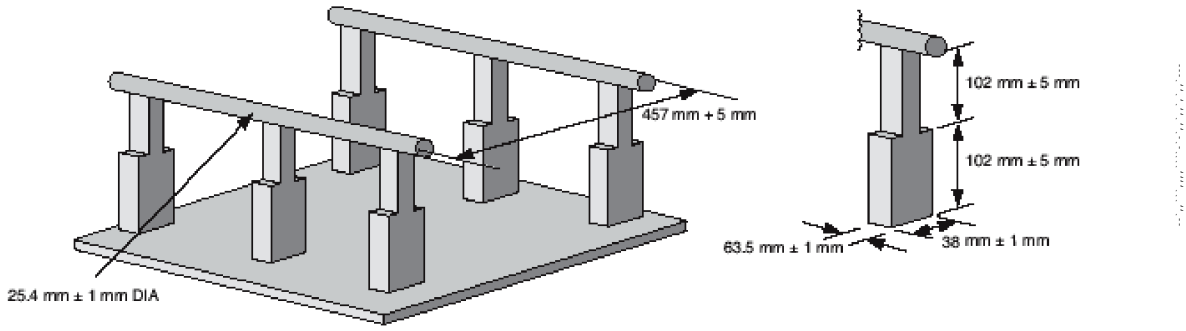


Figure C.1 — An example of a rigid test fixture to simulate a wheelchair frame

Dimensions in millimetres

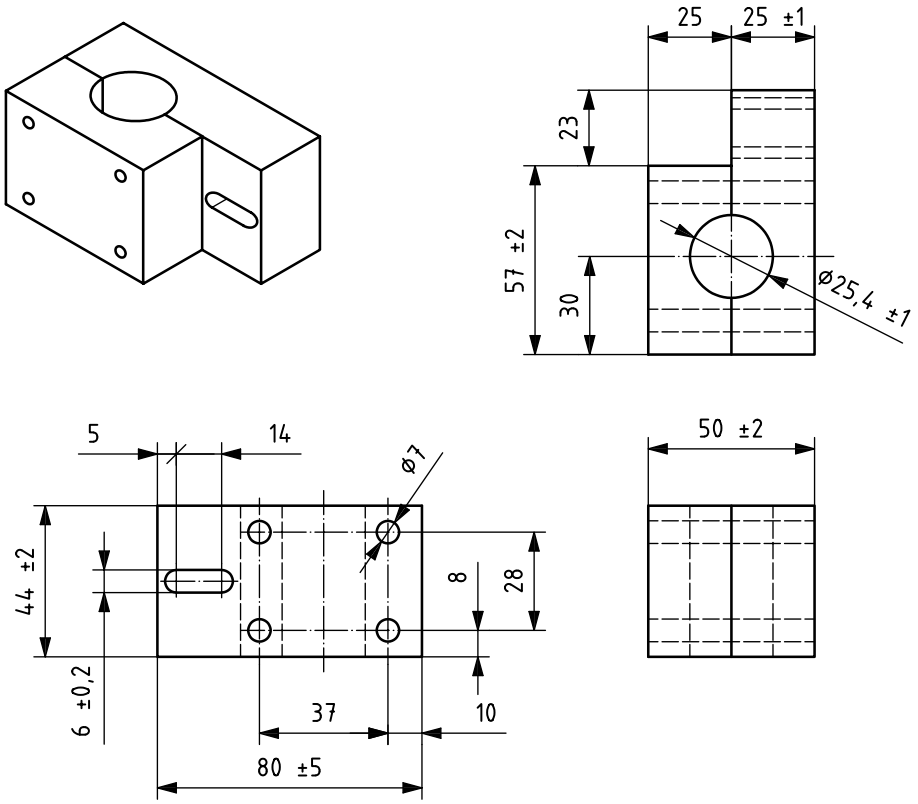
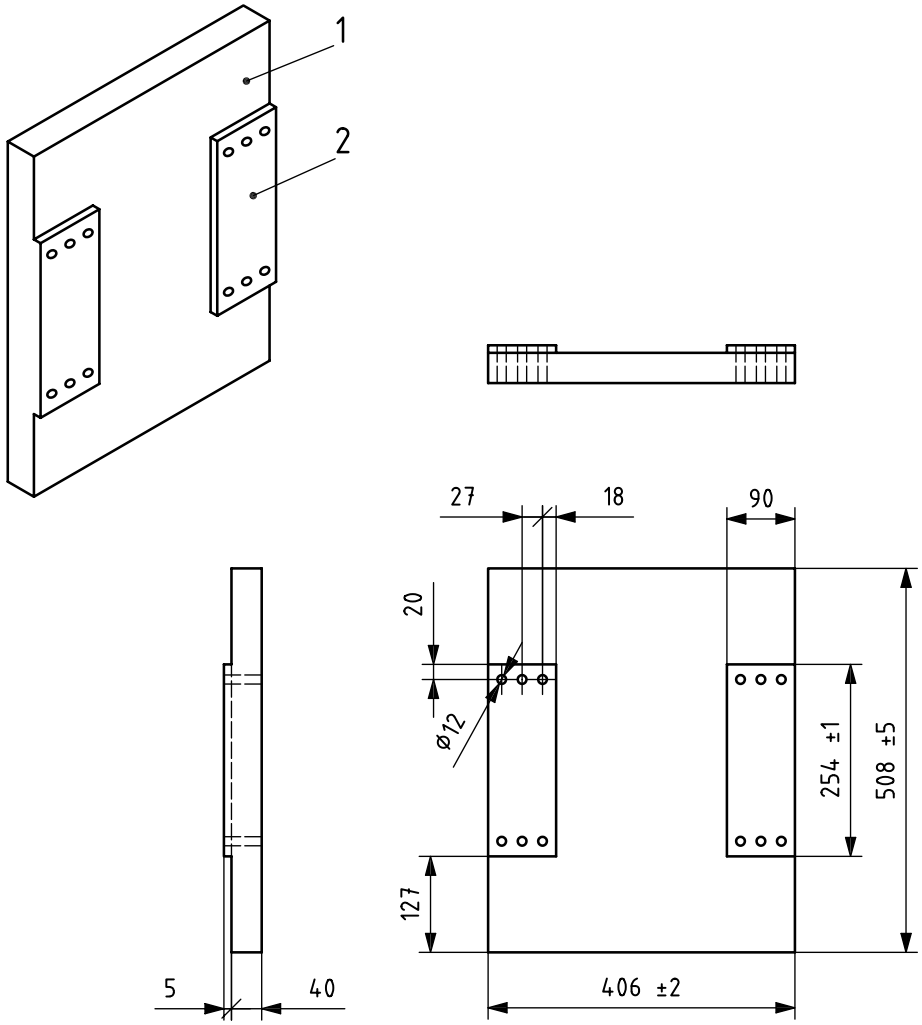


Figure C.2 — An example of surrogate attachment hardware

Dimensions in millimetres



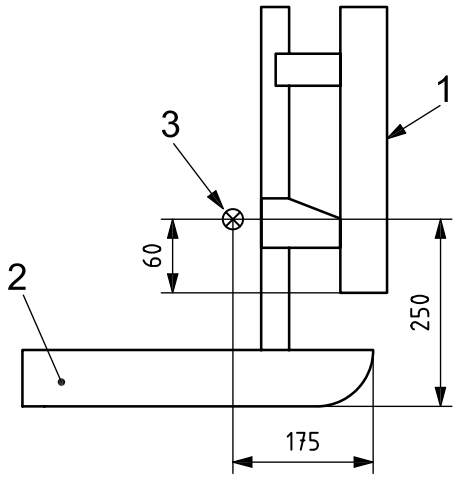
Key

1 40 mm ± 2 mm thickness laminated plywood

2 5 mm ± 1 mm thickness plate steel

Figure C.3 — An example of a surrogate seat/back support surface

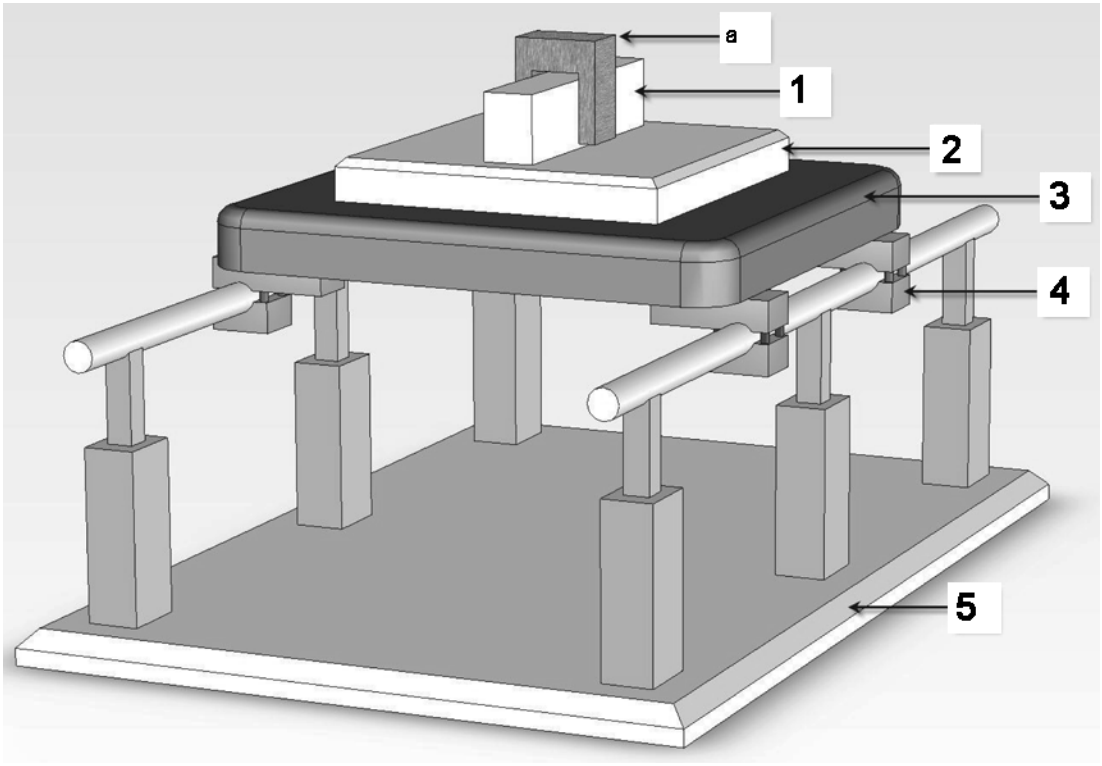
Dimensions in millimetres



Key

1 back unit
2 seat unit
3 centre of mass

Figure C.4 — ISO 7176-7 Reference loader gauge



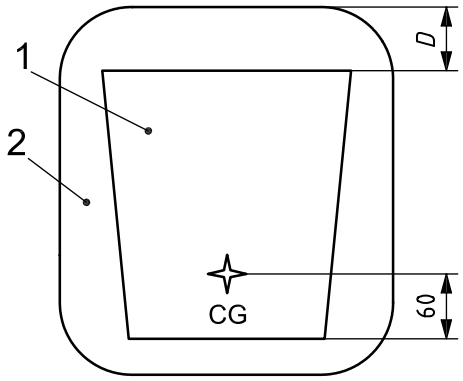
Key

1 load cell
2 ISO reference loader gauge (RLG)
3 WCSS to be tested
4 surrogate attachment hardware
5 test fixture

[a] Downward loading applied by loading device.

Figure C.5 — Example of Static Loading Test Set-up

Dimensions in millimetres



Key

1 back unit of the RLG

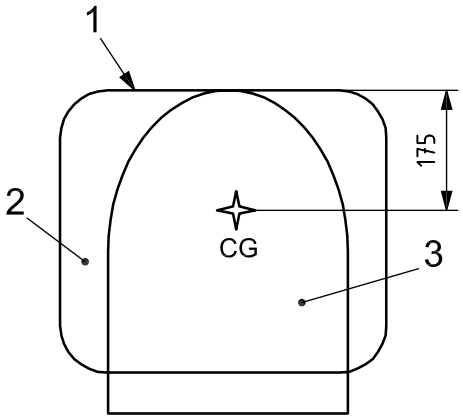
2 wheelchair back support mounted to the test fixture

D edge of back support to edge of RLG back unit – set so as to represent seated shoulder height of 50th percentile male

NOTE Dimension D may vary depending upon the manufacturer's recommended position of the upper edge of the back support relative to the seated shoulder height of a 50th percentile male.

Figure C.6 — Top view of the position of RLG on back support

Dimensions in millimetres



Key

1 rear edge of the seat unit of the RLG and the seat

2 wheelchair seat mounted to the test fixture

3 seat unit of the RLG

Figure C.7 — Top view of the position of RLG on seat support

C.6 Test results

After each test, visually examine the test specimen in order to:

a) determine whether the RLG remained on the tested support surface;

b) determine whether the tested WCSS remained on the frame of the rigid test fixture;

c) determine whether the attachment hardware shows any visible signs of failure or became separated from the frame of the test fixture at any point;

d) determine whether the tested seat or back support shows any visible signs of failure or became separated from the test fixture or the attachment hardware at any point;

e) determine whether the RLG can be released from the WCSS in accordance with the WCSS manufacturer's instructions for removing a user from the WCSS;

f) record the peak load applied to the WCSS and/or WCSS component.

Annex D
(normative)

Test method for rating the seating system's accommodation of vehicle-anchored belt restraints

D.1 Rationale

It is important that wheelchair seating systems intended for use in a motor vehicle are designed to allow easy use and proper fit of vehicle-anchored three-point occupant restraint systems. This annex establishes a test method for rating a wheelchair seating system with regard to:

a) the ease of positioning vehicle-anchored belt restraints on the wheelchair occupant;

b) the fit and contact of vehicle-anchored shoulder-belt and pelvic-belt restraints to the wheelchair occupant;

c) the potential for contact of belt-restraint webbing with sharp edges on the seating system.

D.2 Principle

The seating system is installed on the surrogate wheelchair base (SWCB) specified in Annex B, which is secured on a test platform using a four-point strap-type tiedown system that conforms to ISO 10542-2. The ATD used in the frontal-impact test of Annex A is seated in the seating system in accordance with the procedures of Annex A. A vehicle-anchored three-point-belt restraint that conforms to ISO 10542-1 is installed and positioned on the ATD. The ease of belt restraint placement, the locations and degree of belt webbing contact with the ATD, the angles and paths of the belt restraint webbing to the anchor points, and the proximity of belt restraint webbing to sharp edges are evaluated. Numerical scores of 0 (poor), 1 (acceptable), and 2 (good) are assigned for each of eight performance measures. If all of the performance scores are non-zero, the scores for all the measures are added together to determine whether the seating system is rated A (good) or B (acceptable).

D.3 Test sample

A prototype or production seating system in the appropriate size for installation on the surrogate wheelchair base as configured for the frontal-impact test described in Annex A shall be used in the testing.

D.4 Test apparatus

D.4.1 A surrogate wheelchair base, that conforms to the specifications of Annex B and configured for the frontal-impact test described in Annex A.

D.4.2 A WTORS, consisting of a four-point, strap-type tiedown and vehicle-anchored three-point-belt restraint that complies with ISO 10542-1 and ISO 10542-2.

D.4.3 A test platform, with adjustable anchor points for wheelchair tiedown straps and pelvic-belt and shoulder-belt restraint anchorages.

D.4.4 An ATD, used in the frontal impact test described in Annex A.

D.5 Test method

D.5.1 Install the seating system on the SWCB and then secure the SWCB to the test platform using a four-point, strap-type wheelchair tiedown system and the set-up procedures as specified in A.5.3 to A.5.6.

D.5.2 Fasten the floor anchorages of the three-point-belt restraint to the test platform, selecting anchor points for the pelvic-belt restraint that are 0 mm to 100 mm forward of, and within ± 100 mm lateral to, the rear tiedown anchor points.

NOTE The actual location of the pelvic-belt restraint anchor points depends on the space available between the rear tiedown anchor points and the surrogate wheelchair base.

D.5.3 Place the ATD used in the frontal impact test of Annex A in the wheelchair seating system with the pelvis firmly against the back support.

D.5.4 Locate the upper shoulder-belt restraint anchor point or guide point according to the procedure specified in A.5.9 and as shown in Figure A.2.

D.5.5 Install and position the three-point-belt restraint on the ATD while attempting to achieve optimal fits of the pelvic-belt restraint across the lower pelvis and thighs and the shoulder-belt restraint across the middle of the shoulder and chest.

NOTE ISO 10542-1 contains information on optimal belt-restraint fit.

D.5.6 Score the performance of the seating system during and after the belt-restraint installation process based on the criteria specified in Tables D.1 to D.8.

D.5.7 Determine the overall rating of the seating system with regard to its accommodation of the proper placement of vehicle-anchored belt restraints in accordance with D.6.

NOTE The scores in Table D.1 are based on attempts to achieve optimal belt restraint placement for the wheelchair being tested. The scores in Tables D.2 to D.8 are assessed after achieving optimal placement.

Table D.1 — Overall ease of belt restraint positioning

Rating	Description	Score
Poor	Requires threading belt restraint and/or hardware through any openings, such as openings between the lower part of the back support and the seat cushion, or requires forcing belt webbing into narrow gaps of less than 25 mm.	0
Acceptable	Requires inserting of belt restraint into gaps between seating system components but webbing fits easily into gap and threading of webbing and/or hardware through openings is not required. If there is a narrow gap (less than 25 mm) between seating system components, rating will be acceptable due to extra step required for application.	1
Good	Gaps for inserting restraint between seating components are greater than 25 mm, or provision is made for positioning belt webbing on the occupant without placing it into gaps. Threading of webbing and/or hardware through openings is not required.	2

Table D.2 — Pelvic-belt restraint contact area

Rating	Description	Score
Poor	Belt restraint is held completely away from ATD pelvis because of seating system components	0
Acceptable	Belt restraint makes less than 50 % contact across the full breadth at the front of the ATD and does not contact the ATD H-points	1
Good	Belt restraint makes greater than 50 % contact across the full breadth at the front of the ATD and does contact the ATD H-points	2

Table D.3 — Shoulder-belt restraint contact area

Rating	Description	Score
Poor	Belt restraint is held away from ATD's chest and shoulder because of seating system components	0
Acceptable	Belt restraint makes less than 50 % contact across the thoracic section of the ATD and touches the ATD sternum	1
Good	Belt restraint makes greater than 50 % contact across the thoracic section of the ATD and contacts the sternum and anterior curve of the shoulder	2

Table D.4 — Pelvic-belt restraint contact location

Rating	Description	Score
Poor	Belt restraint contacts the ATD above the pelvis and on the abdomen	0
Acceptable	Belt restraint contacts the ATD on the upper part of pelvis	1
Good	Belt restraint contacts the ATD low on the pelvis near or at the thigh-abdominal junction	2

Table D.5 — Shoulder-belt restraint contact location

Rating	Description	Score
Poor	Belt restraint passes lateral to and off of the ATD's shoulder	0
Acceptable	Belt restraint contacts the ATD's neck	1
Good	Belt restraint crosses near the middle of ATD's shoulder	2

Table D.6 — Pelvic-belt restraint angle

Rating	Description	Score
Poor	Projected sideview angle is less than 30° or greater than 75° to the horizontal	0
Acceptable	Projected sideview angle is between 30° and 45° to the horizontal	1
Good	Projected sideview angle is between 45° and 75° to the horizontal	2
NOTE 1	Use an inclinometer to estimate the projected sideview angle of the pelvic belt after installation on the ATD.	
NOTE 2	See Figure E.1 for preferred pelvic-belt restraint angles.	

Table D.7 — Pelvic-belt restraint clear paths to anchor points

Rating	Description	Score
Poor	Belt restraint makes contact with seating system components resulting in a change in belt angle greater than 15°	0
Acceptable	Belt restraint makes contact with seating system components resulting in a change in belt angle of less than 15°, but greater than 5°	1
Good	Belt restraint makes no contact with seating system components, or resulting in a change in belt angle of less than 5°	2
NOTE	See Figure E.1 for preferred pelvic belt angles.	

Table D.8 — Belt restraint proximity to sharp edges

Rating	Description	Score
Poor	Belt restraint makes contact with sharp edges on the seating system that could cause wear of belt material over time and/or failure of webbing during impact loading	0
Acceptable	Belt restraint does not contact but comes within 25 mm of sharp edges of the seating system	1
Good	Belt restraint does not come within 25 mm of any sharp edges on the seating system	2
NOTE	Sharp edge is defined as an edge of less than 2 mm radius (ISO 7176-19:2008, 5.2.2.d).	

D.6 Overall rating of belt restraint accommodation

D.6.1 If the score for one or more of the tests obtained from Tables D.1 to D.8 is zero, an overall rating of "C" or "poor" should be recorded.

D.6.2 If none of the scores is zero, add the scores for Tables tests D.1 to D.8 inclusive and assign a belt-restraint accommodation rating to the seating system as shown in Table D.9.

Table D.9 — Overall seating system accommodation rating

Total score	Alphanumeric rating	Rating
12 to 16	A	Good
8 to 11	B	Acceptable
$\leqslant 7$	C	Poor

Annex E
(informative)

Recommended user instructions and user warnings

E.1 Purpose and scope

This annex contains additional information which manufacturers may consider including in their user instructions and user warnings.

E.2 User instructions

The following user instructions should be provided with each seating system in the official languages of the countries in which the product is marketed, and should include:

a) a statement that wheelchair users should transfer to the vehicle seat and use the vehicle-installed restraint system wherever possible;

b) a description of the correct positioning of occupant restraint belts on the user, including statements that:

   1) the pelvic-belt restraint should be worn low across the front of the pelvis, so that the angle of the pelvic-belt restraint is within the zone of 30° to 75° to the horizontal, as shown in Figure E.1;

   2) wheelchair and seating components, such as the wheelchair armrests or wheels, should not prevent belt contact with the body, as shown in Figure E.2

   3) shoulder-belt restraints should fit over the shoulders with the shoulder-belt restraint midway between the shoulder and neck;

   4) occupant restraints should be adjusted as firmly as possible, consistent with user comfort;

   5) belts should not be twisted when in use;

c) the overall rating (A, B or C as determined in accordance with D.6) of the seating system with regard to accommodating use and fit of vehicle-anchored occupant restraints, along with an explanation of the meaning of the different ratings based on the test methods of Annex D.

E.3 User warnings

The seating manufacturer should provide the following warnings in the user manual:

a) Clear zones for occupants restrained by both pelvic-belt and shoulder-belt restraints, as shown in Figure E.3 and a statement that frontal clear zones (FCZ) need to be larger when shoulder-belt restraints are not used.

NOTE Clear zones are areas free of interior vehicle components and allow for forward and rearward excursion of the head without impact.

b) It is strongly recommended that both pelvic and upper torso belts be used.

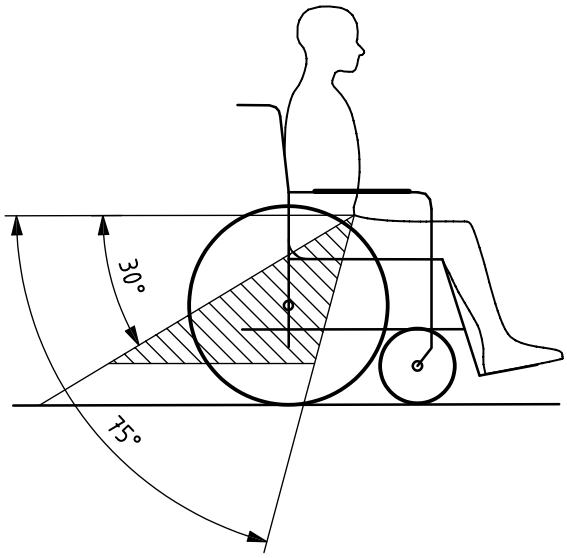
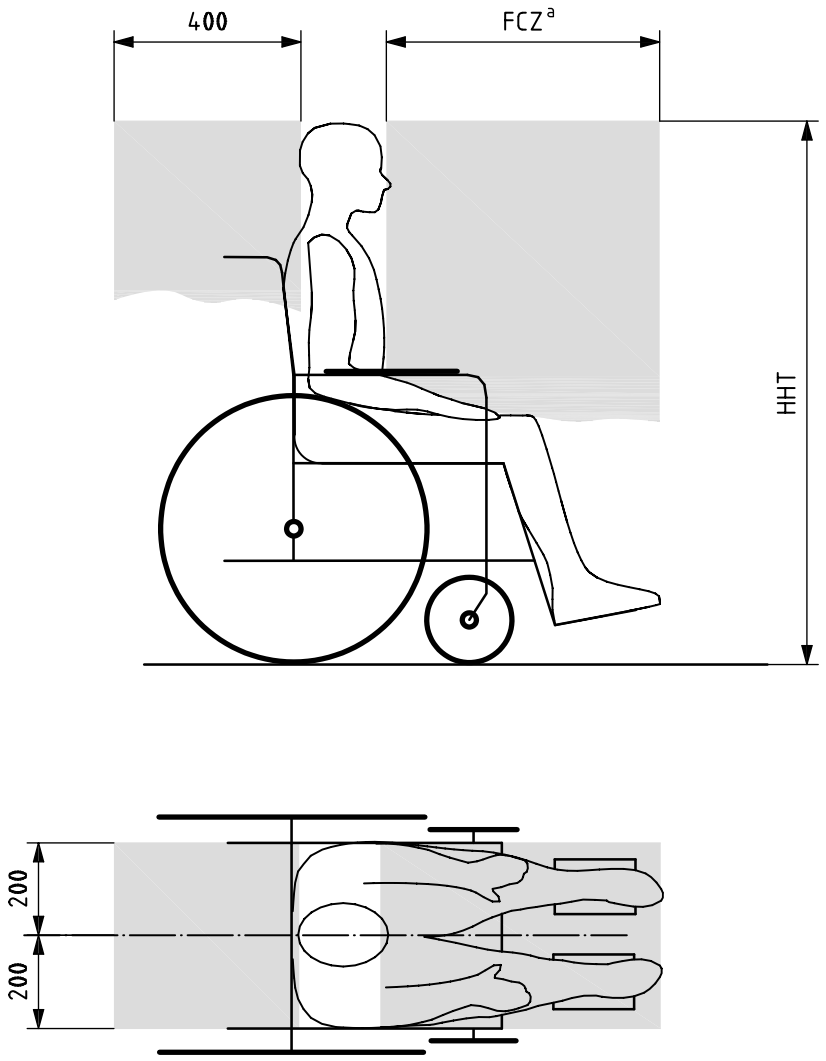


Figure E.1 — Pelvic-belt restraint angle zone

Figure E.2 — Example of warning label indicating improper positioning of occupant restraints

Dimensions in millimetres



a FCZ = 650 mm.

NOTE 1 Rear clear zone is measured from the initial rearmost point on an occupant's head. The front clear zone is measured from the initial frontmost point on an occupant's head.

NOTE 2 HHT is estimated seated height of the occupant from the wheelchair ground plane to the top of the wheelchair-seated occupant's head. HHTs range from 1 200 mm for a small adult female to about 1 550 mm for a tall adult male. HHT can vary depending upon seat heat and occupant stature.

NOTE 3 The frontal clear zone might not be achievable for wheelchair-seated driver.

Figure E.3 — Clear zones for wheelchair-seated occupants

Bibliography

[1] ISO 7176-7, *Wheelchairs — Part 7: Measurement of seating and wheel dimensions*

[2] ISO 7176-15, *Wheelchairs — Part 15: Requirements for information disclosure, documentation and labelling*

[3] ISO 10542-5, *Technical systems and aids for disabled or handicapped persons — Wheelchair tiedown and occupant-restraint systems — Part 5: Systems for specific wheelchairs*

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