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**Wheelchair containment and occupant retention systems for accessible transport vehicles designed for use by both sitting and standing passengers —**

Part 1:

**Systems for rearward-facing wheelchair-seated passengers**

*Produits d'assistance pour personnes en situation de handicap et systèmes d'immobilisation de fauteuil roulant, et de retenue des occupants pour les passagers assis sur les fauteuils roulants dos à la route —*

*Partie 1. Systèmes pour passagers en fauteuil roulant assis dos à la route*



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Published in Switzerland

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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 10865-1 was prepared by Technical Committee ISO/TC 173, *Assistive products for persons with disability*, Subcommittee SC 1, *Wheelchairs*.

ISO 10865 consists of the following parts, under the general title *Wheelchair containment and occupant retention systems for accessible transport vehicles designed for use by both sitting and standing passengers*:

— *Part 1: Systems for rearward-facing wheelchair-seated passengers*

The following parts are under preparation:

— *Part 2: Systems for forward-facing wheelchair-seated passengers*

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## Introduction

Providing safe transportation for wheelchair-seated passengers in motor vehicles usually requires installation of aftermarket equipment to secure the wheelchair and provide passenger restraint during emergency vehicle manoeuvres and crash conditions that are appropriate to the size and travel conditions of the vehicle. ISO 10542-1<sup>[15]</sup> establishes design and performance requirements and associated test methods for wheelchair tiedown and occupant restraint systems (WTORS) intended for use by forward-facing wheelchair-seated passengers in all types of motor vehicles that have been modified for use by people seated in wheelchairs. The provisions of ISO 10542-1 were based on the belief that WTORS manufacturers are not able to control the types of vehicles and travel modes in which most of their products are installed and used. Therefore ISO 10542-1<sup>[15]</sup> requires frontal sled-impact testing of WTORS to nominal worst-case crash conditions of smaller vehicles, such as full-size vans and minivans, using a simulated crash acceleration/deceleration pulse that results in a change in sled speed ( $\Delta V$ ) of 48 km/h.

While this one-size-fits-all approach to WTORS crashworthiness testing is appropriate for equipment intended for general use in all types of motor vehicles, it generally leads to products that are over designed for use in larger and heavier vehicles used primarily in low-speed intra-city transportation. This is particularly the case for larger accessible transit vehicles in which passengers are allowed to travel sitting as well as standing, hereafter referred to as accessible transit vehicles-sitting and standing, or ATV-SS.

Recognizing these different and significantly lower transportation safety requirements for ATV-SSs in a new standard can be expected to result in alternative solutions for safely transporting wheelchair-seated passengers in these vehicle environments. These solutions are more compatible with operational needs (e.g. fixed-route schedules) of these transportation services and offer wheelchair users a greater level of usability and independence than is achieved with WTORS designed to comply with 48 km/h crash conditions. More specifically, accident/injury data for ATV-SSs indicate that the frequencies of occupant fatalities and serious injuries per million passenger kilometres travelled are significantly lower than for smaller vehicles that travel at much higher speeds<sup>[1]</sup>. In fact, analysis of data from police reports of accidents involving fixed-route intra-city buses indicates that the likelihood of a collision event for these vehicles is sufficiently rare to justify basing performance requirements for safety equipment installed in these vehicles on accelerations and decelerations that occur during non-crash conditions, such as emergency vehicle manoeuvres, including sudden stopping, rapid acceleration, and turning corners at excessive speeds. Several studies have clearly demonstrated that ATV-SS accelerations that may result from such emergency manoeuvres are all below  $1g$ <sup>[2][3]</sup>.

Recognizing the different safety needs of ATV-SS passenger environments in the early 1990s, many European countries<sup>[4][5][6]</sup>, as well as Canada and Australia<sup>[7]</sup>, began implementing rearward-facing wheelchair passenger stations (RF-WPS) for use by wheelchair-seated passengers travelling in these vehicles. In practice, the RF-WPS concept has been well received by both wheelchair users and transit providers because of increased passenger independence, significantly reduced driver involvement and reductions in schedule delays<sup>[7][8]</sup>. However, from an injury-risk perspective, the concept is not ideal in several important ways. For example, some wheelchairs do not have brakes or may have defective brakes, allowing the wheelchair to have excessive movement. Also, some aisle-side barriers do not work effectively with some types of wheelchairs, such as scooters, and allow tipping or swerving of wheelchairs into the centre aisle during vehicle turning. Attempts to resolve these deficiencies by some transporters have resulted in the addition of various types of auxiliary wheelchair securement straps that require driver intervention<sup>[7][9]</sup>. This nullifies a main advantage of the RF-WPS-independent vehicle access by the wheelchair user. Furthermore, many countries have no national standards for the design, testing and installation of a RF-WPS, therefore misapplication of the rearward-facing concept may readily occur in practice.

The purpose of this part of ISO 10865 is to establish minimum design and performance requirements for RF-WPS and to establish test methods for the performance requirements. This will provide wheelchair-seated passengers using RF-WPS with a reasonable level of transportation safety while maintaining a high level of usability and independence during travel in ATV-SS.

A fundamental principle behind the concept of an RF-WPS in ATV-SS is that correctly designed passive containment (which does not require the physical attachment of securement devices by the wheelchair user or vehicle operator) of an occupied wheelchair during normal travel and emergency vehicle manoeuvres is sufficient to provide a reasonable level of transportation safety to wheelchair-seated passengers. This level of safety is comparable to that provided to other vehicle occupants, including standing passengers, who hold

onto stanchions and straps to resist movement during vehicle accelerations and decelerations. In this regard, a primary feature of RF-WPS required by this part of ISO 10865 is a forward excursion barrier (FEB) against which the wheelchair passenger backs their wheelchair upon entering the RF-WPS. The primary function of the FEB is to prevent forward movement of the wheelchair during vehicle decelerations of normal or emergency braking. However, if the wheelchair backrest and the back of the head of the wheelchair user are in close proximity to the FEB, this structure may also limit forward movement of the wheelchair passenger beyond that provided by the wheelchair backrest during emergency braking, or even in the rare event of a frontal collision. With regard to the latter, while the primary performance requirements for wheelchair containment set forth in Annex B are for non-collision vehicle accelerations and decelerations of less than 1g, Annex C specifies strength testing of the FEB structure based on 3g wheelchair-plus-occupant loading.

Lateral displacement, rotation or tipping of occupied wheelchairs in an RF-WPS are typically limited in one direction by the vehicle sidewall. Lateral displacement, rotation or tipping of the wheelchair into the centre aisle are typically limited by a physical barrier, such as a vertical stanchion or horizontal padded arm or bar, referred to as a lateral excursion barrier, or LEB. However, in an effort to avoid being unnecessarily design restrictive, this part of ISO 10865 does not require or specify any particular structure to limit displacement, rotation or tipping of the wheelchair toward the vehicle aisle. Rather, this part of ISO 10865 establishes performance requirements and associated test methods to assess whether the features of the RF-WPS sufficiently limit lateral wheelchair movement and tipping in this direction.

Wheelchair movement toward the rear of the vehicle is limited in the passive mode by requiring minimum friction properties for the vehicle floor within the RF-WPS that generate friction forces on the tyres of wheels that have been locked by applying the wheelchair brakes or by the drive train of powered wheelchairs for which the power has been turned off during travel. Active resistance to rearward wheelchair movement may also be provided by implementing vehicle-anchored occupant retention and/or wheelchair containment devices, such as a pivoting padded bar, and/or by the wheelchair user grabbing a handhold within the RF-WPS that complies with geometry and location specifications of this part of ISO 10865. Use of a handhold and/or an active occupant retention device will also help limit rearward movement of the wheelchair passenger relative to the wheelchair seat during vehicle accelerations. If a specific RF-WPS design requires active application of an occupant retention and/or wheelchair containment device to pass the rearward wheelchair containment test of Annex B, it is important that a warning to use this device be clearly displayed in the RF-WPS.

As indicated above, this part of ISO 10865 assumes that retention of the occupant in their wheelchair, which is important to minimize the risk of serious injuries, even in low-g non-crash events, depends largely on retention features provided by, and on, the wheelchair. The wheelchair backrest will generally provide sufficient retention during vehicle braking but, as previously noted, the FEB can further reduce forward occupant movement in the vehicle when the back and head of the wheelchair passenger are in close proximity to the FEB. Retention of the wheelchair passenger during lateral accelerations caused by vehicle turning is generally provided by wheelchair armrests and lateral torso postural supports that are customized components of the wheelchair seat, but may be augmented by LEBs. The use of wheelchair-mounted postural belts are important for passive occupant retention during vehicle accelerations and this practice is therefore encouraged by requirements for user warnings displayed in the RF-WPS. In addition, as noted above, this part of ISO 10865 allows RF-WPS to provide active vehicle-anchored passenger retention and wheelchair containment devices that can be easily implemented by the wheelchair user or driver, and it specifies design and location requirements for handholds that can be used by capable wheelchair-seated passengers to augment containment of the wheelchair and enhance retention and stability of the wheelchair passenger. In addition, a vehicle-mounted lap belt or some other retention device is required in order to prevent an otherwise unrestrained occupant from falling out of their wheelchair during unexpected vehicle manoeuvres.

Informative design guidelines are provided in Annex E to aid manufacturers in designing RF-WPS that conform with the requirements of this part of ISO 15608. An RF-WPS may also be equipped with WTORS for use by forward-facing wheelchair users, but requirements and specifications for these systems are not within the scope of this part of ISO 10865.

# Wheelchair containment and occupant retention systems for accessible transport vehicles designed for use by both sitting and standing passengers —

## Part 1: Systems for rearward-facing wheelchair-seated passengers

### 1 Scope

This part of ISO 10865 is applicable to wheelchair passenger spaces (RF-WPSs) intended for use by rearward-facing wheelchair-seated occupants, with a body mass greater than 22 kg, when travelling in accessible transport vehicles. It is applicable to systems for use in vehicles used mainly on fixed route services when operated under normal and emergency driving conditions, where passengers are allowed to travel both sitting and standing. It assumes that the maximum acceleration imparted to the vehicle in any direction during emergency driving manoeuvres will not exceed 1g.

This part of ISO 10865 specifies design and performance requirements and associated test methods, requirements for manufacturer instructions and warnings to installers and users as well as requirements for product labelling and disclosure of test information.

The primary purpose of this part of ISO 10865 is to limit those movements of a rearward-facing wheelchair, including scooters with three or more wheels, that can result in hazardous contact with the vehicle interior or injury to other passengers.

The provisions of this part of ISO 10865 apply primarily to a complete RF-WPS, but subsets of the provisions can be applied to components and subassemblies sold separately, as appropriate to the specific functions of the components and/or subassemblies they are intended to replace.

### 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 3795, *Road vehicles, and tractors and machinery for agriculture and forestry — Determination of burning behaviour of interior materials*

ISO 7176-11, *Wheelchairs — Part 11: Test dummies*

ISO 7176-13, *Wheelchairs — Part 13: Determination of coefficient of friction of test surfaces*

ISO 7176-26, *Wheelchairs — Part 26: Vocabulary*

### 3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 7176-26 and the following apply.

#### 3.1

##### **ambulatory passengers**

passengers who do not require the use of a wheelchair

- 3.2**  
**forward excursion barrier**  
**FEB**  
padded structure designed to limit forward movement relative to the vehicle of a rearward-facing wheelchair and its occupant
- 3.3**  
**gross vehicle weight rating**  
**GVWR**  
maximum total weight, as determined by the vehicle manufacturer, at which the vehicle can be safely and reliably operated for its intended purpose
- 3.4**  
**handhold**  
grab bar  
handrail  
any device on board a transport vehicle that is designed to allow passengers to use their hand grip to manoeuvre through the vehicle or provide passengers with a more stable ride while on board the vehicle
- 3.5**  
**accessible transport vehicle for sitting and standing passengers**  
**ATV-SS**  
a motor vehicle, designed and manufactured to provide transport service for primarily seated and standing passengers, with provision for the needs of persons with physical disabilities
- 3.6**  
**lateral excursion barrier**  
**LEB**  
structure or device to the right and/or left of the occupied wheelchair, designed to prevent the wheelchair from tipping, rotating or sliding into the centre aisle or vehicle wall during transport
- NOTE The LEB can be padded to reduce or cushion the impact of any accidental contact.
- 3.7**  
**occupant retention device**  
system or device used to retain the occupant of the wheelchair in a low-*g* environment
- 3.8**  
**passive securement system**  
method of preventing undesirable wheelchair movement (containment) that does not require the physical attachment of securement devices by the wheelchair user or vehicle operator
- 3.9**  
**rearward-facing wheelchair passenger space**  
**RF-WPS**  
location in a large transport vehicle that limits movement of an occupied rearward-facing wheelchair through the use of structures and devices that do not require the physical attachment of wheelchair securement devices by the wheelchair user or vehicle operator
- 3.10**  
**rearward excursion barrier**  
**REB**  
structure or device designed to limit rearward movement, relative to the vehicle, of a rearward-facing wheelchair
- 3.11**  
**seat bight height**  
vertical distance from the floor to the intersection of the seat and back planes of a wheelchair

**3.12****surrogate wheelchair****SWC**

reusable device, which conforms to Annex D, that is used to simulate a production wheelchair for the purpose of Annex B containment testing

**3.13****wheelchair reference plane**

vertical plane in the longitudinal centre line of the wheelchair

**4 Design requirements**

**4.1** A rearward-facing wheelchair passenger space (RF-WPS) shall:

- a) comply with the dimensional and clear space requirements specified in Annex A;
- b) be fitted with
  - 1) a FEB that limits the wheelchair's movement toward the front of the vehicle,
  - 2) a handrail or handhold to facilitate wheelchair occupant stability during transport,
  - 3) a means to limit lateral tipping, sliding and rotational movement of the wheelchair,

NOTE The vehicle wall can be the means to limit movement in one direction.

  - 4) an occupant retention device for optional use by the wheelchair occupant,
  - 5) a means to limit rearward motion, relative to the vehicle, sliding or tipping of the wheelchair, and

NOTE The occupant retention device or an auxiliary securement strap may be such a means.

  - 6) a device affixed within the wheelchair passenger space, located as specified in Annex A, that allows the wheelchair passenger to request a normal stop to egress from the vehicle;
- c) be ready for use (access for a wheelchair is unobstructed and any flip-down seats are in the up position) when entered by a wheelchair user;
- d) be usable by other passengers (sitting or standing) when no wheelchair user is present;
- e) have components or structures that may contact the wheelchair occupant or other passengers during emergency driving manoeuvres covered by energy absorbing materials that conform to the performance specifications of FMVSS 201 or ECE R 21;
- f) have components that are smoothly finished without sharp (radius <2 mm) edges, burrs or irregularities.

**5 Performance requirements****5.1 Static strength of wheelchair passenger space components****5.1.1 Forward excursion barrier**

When tested in accordance with C.5.1, the FEB shall:

- a) not fracture or expose sharp structures with a radius of <2 mm;
- b) not permanently deform by >15 mm from the pre-test configuration;
- c) not have adjustable components that will move by >15 mm from their original position.

### 5.1.2 Lateral excursion barrier(s)

If provided, the LEB shall be tested in accordance with C.5.2 and shall:

- a) not fracture or expose sharp structures with a radius of <2 mm;
- b) not permanently deform by >15 mm from the pre-test configuration;
- c) not have adjustable components that will move by >15 mm from their original position.

### 5.1.3 Rearward excursion barrier(s)

If provided, the REB shall be tested in accordance with C.5.3 and shall:

- a) not fracture or expose sharp structures with a radius of <2 mm;
- b) not permanently deform by >15 mm from the pre-test configuration;
- c) not have adjustable components that will move by >15 mm from their original position.

## 5.2 Wheelchair movement

When tested in accordance with Annex B, the wheelchair passenger space shall prevent:

- a) lateral tipping of the wheelchair to an angle of >10°;
- b) rearward tipping of the wheelchair (i.e. forward tipping relative to vehicle) to an angle of >10°;
- c) translation of the wheelchair in any direction by >50 mm;
- d) lateral rotation (about a vertical axis) of the wheelchair reference plane by >15° in either direction from the longitudinal reference axis of the RF-WPS.

## 5.3 Coefficient of friction of floor material

When tested in accordance with ISO 7176-13, the RF-WPS floor surface material shall have a coefficient of friction in the range of 0,65 to 0,8.

## 6 Information, identification and instruction requirements

### 6.1 Identification and labelling of RF-WPS components and subassemblies

#### 6.1.1 Permanent labelling of components

Permanently installed and replacement parts shall be permanently and legibly marked with:

- a) the manufacturer's name or trademark;
- b) the month and year of manufacture, and any other identification necessary to clearly identify an assembly or subassembly in the event of a product recall;
- c) a mark showing that the device conforms to this part of ISO 10865.

#### 6.1.2 Identification

Primary components and subassemblies shall be accompanied by information that includes:

- a) the manufacturer's model and part number or an equivalent identification code;
- b) the name and intended use of each component.

### 6.1.3 Information for RF-WPS users

The RF-WPS shall contain a readable sign affixed in the wheelchair area instructing that:

- a) the rearward-facing wheelchair and occupant should be positioned as close as possible to the barrier;

NOTE To allow closer body contact to the barrier, removal of large items on the wheelchair seat back is recommended.

- b) the power should be turned off and the brakes applied, if applicable;
- c) an occupant retention device should be used at all times while the vehicle is in motion.

In addition, a pictogram as illustrated in Figure 1, shall be installed to show that the wheelchair faces toward the rear of the vehicle.

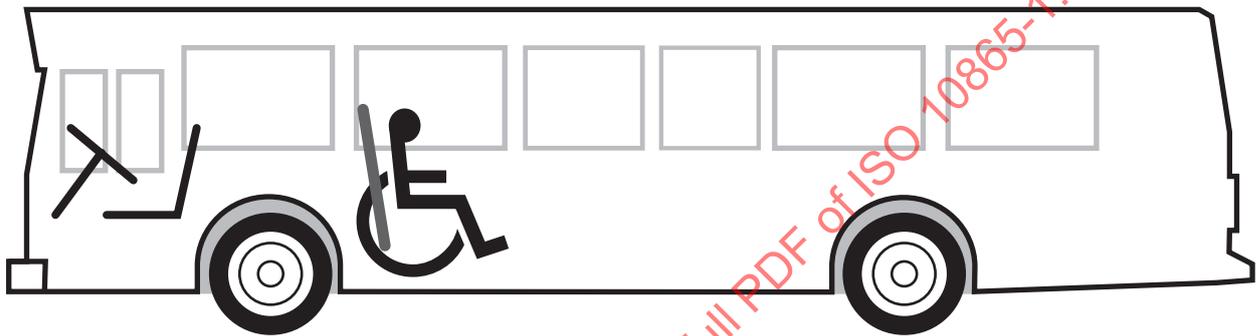


Figure 1 — Pictogram for wheelchair passenger space showing the wheelchair facing the rear of the vehicle

## 6.2 Instructions for installers

### 6.2.1 General

6.2.1.1 Manufacturers of RF-WPS components shall provide written instructions for the installer in the principal language(s) of the country in which it is marketed.

6.2.1.2 The instructions shall include statements that:

- a) indicate that the components of the RF-WPS shall be installed for use by rearward-facing wheelchair passengers;
- b) indicate the type and number of separate components that comprise a complete RF-WPS;
- c) indicate the minimum specifications for all structural parts, anchorage fasteners and related components used in an installation.

### 6.2.2 Installation Instructions

The instructions shall include descriptions of:

- a) how the RF-WPS is to be used, so that the installer may be fully informed regarding the purpose and function of all components;
- b) how the RF-WPS is to be installed, including minimum specifications for anchorage fasteners and related components;
- c) a method for attachment of the RF-WPS to the vehicle structures (floor, walls, ceilings) that reflects the strength conditions under which successful testing was conducted in Annex C.

### 6.2.3 Diagrams, drawings and signs

The instructions shall include diagrams that illustrate:

- a) if applicable, acceptable methods for fastening the RF-WPS or RF-WPS components to the vehicle;
- b) an exploded view drawing for all components required in the RF-WPS installation;
- c) a diagram showing the dimensional layout of the RF-WPS, including the location of any structural components intended to come in contact with the wheelchair or its occupant.

### 6.2.4 Warnings

The instructions shall include warnings that:

- a) the RF-WPS should be installed by an experienced technician;
- b) vehicle anchor points can require reinforcement;
- c) if used, additional vehicle interior padding should have a burning rate that does not exceed 100 mm/min when tested in accordance with ISO 3795;
- d) the RF-WPS manufacturer should be consulted in case of questions as to the method of installation;
- e) alterations or substitutions to the RF-WPS components should not be made without consulting the RF-WPS manufacturer.

### 6.3 Instructions for vehicle operators

The instructions shall state:

- a) how the RF-WPS is to be used, so that the vehicle operator is fully informed regarding the purpose and function of all components;
- b) that the wheelchair shall be in the rearward-facing orientation when using the RF-WPS, except in cases where the space has been equipped for additional use with forward-facing wheelchairs;
- c) that the wheelchair should be positioned as closely as possible (ideally in direct contact with) to the FEB, the brakes applied and power turned off, if applicable;
- d) that the wheelchair user should use either their wheelchair-mounted lap belt or the vehicle-mounted retention device at all times while in the RF-WPS;
- e) that the RF-WPS should not be used for rearward-facing wheelchair-seated passengers when the operation of the vehicle does not allow standing passengers.

## 7 Documentation of compliance

7.1 The following shall be included in each test report of one or more tests conducted in accordance with this part of ISO 10865:

- a) a reference to this part of ISO 10865, i.e. ISO 10865-1:2012;
- b) the name and address of the testing institution;
- c) the date of the test;
- d) a unique test report number shown on each numbered page;
- e) the manufacturer, product and serial number, if applicable;
- f) the product type and designation;

- g) the name and address of the manufacturer;
- h) a photograph of the test set-up.

**7.2** The manufacturer shall maintain statements and evidence on file as to whether the RF-WPS and its contained components have met the design requirements specified in Clause 4.

**7.4** The manufacturer shall maintain statements and evidence on file as to whether the RF-WPS and its contained components have met the performance requirements contained in 5.1 to 5.3.

**7.3** The manufacturer shall maintain statements and evidence on file as to whether the information, identification and instruction requirements contained in 6.1 to 6.3 have been met.

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## Annex A (normative)

### Specifications for dimensions and clear spaces for a rearward-facing wheelchair passenger space (RF-WPS)

#### A.1 General

To facilitate access and ease of independent use by a majority of wheelchair users, the RF-WPS shall comply with critical space dimensions based on the sizes and manoeuvring capabilities of larger size wheelchairs that are typically transported on ATV-SSs. Also, to prevent excessive forward wheelchair movement and to provide occupant injury protection, the RF-WPS shall be fitted with a FEB that is securely mounted to the vehicle. The dimensions and location of the FEB, relative to other vehicle structures, are important considerations in the event that unexpected forces act on the contained wheelchair and its occupant. In addition, the incorporation of structures or devices designed to prevent excessive lateral or rearward longitudinal wheelchair movement become important safety considerations. Clear spaces need to be specified in and around the RF-WPS, in which wheelchair passengers are prevented from coming into contact with injury-producing vehicle structures. Similarly, injury protection of other passengers, sitting or standing, in close proximity to the occupied wheelchair is important. Therefore, the main purpose of this annex is to specify the critical dimensions of an RF-WPS and the location and dimensions of its required components, the FEB, passenger handhold and stop request activator.

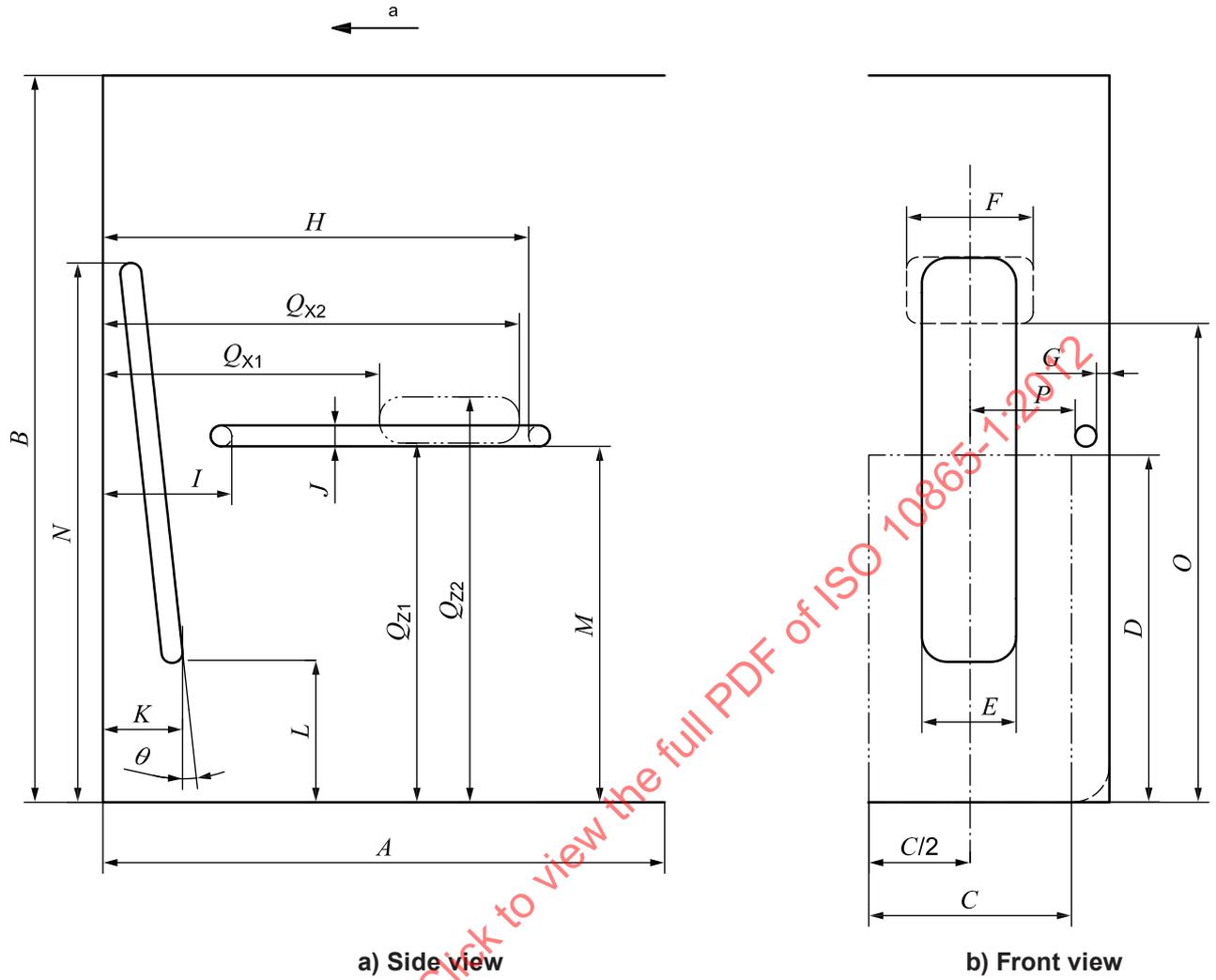
#### A.2 Principle

The specified RF-WPS dimensions and clear spaces are based on the principle of passive wheelchair containment (no physical attachment of securement devices required). This means that, as far as possible, the wheelchair user should be afforded the same degree of independent use of the transport vehicle as all other passengers, and the physical intervention of the operator should be minimized. Figure A.1 and Table A.1 provide the dimensions for the RF-WPS space envelope, as well as the critical dimensions of the FEB and other components that are required in order to provide an acceptable level of injury protection and independence for rearward-facing wheelchair passengers while travelling in an ATV-SS.

Annex E provides further explanation and rationale for the dimensions given in this annex, as well as other factors intended for use by the RF-WPS designer.

#### A.3 Dimensional specifications

A wheelchair passenger space (WPS) and its contained FEB for use in an ATV-SS shall have dimensions as specified in Figure A.1 and Table A.1.



a Front of vehicle.

Figure A.1 — Specifications for dimensions and clear spaces for a WPS

Table A.1 — Dimensions of a WPS

Dimension	Description	Value
<i>A</i>	WPS length	≥1 400 mm
<i>B</i>	WPS height	≥1 500 mm
<i>C</i>	Width of unobstructed wheelchair clear space at floor level extending vertically to a height 50 mm below the minimum height of the handrail (dimension <i>M</i> )	≥750 mm
<i>D</i>	Height of unobstructed wheelchair clear space	750 mm
<i>E</i>	Width of FEB	250 to 280 mm
<i>F</i>	Width of head support	≥300 mm
<i>G</i>	Handrail to nearest obstruction	≥45 mm
<i>H</i>	Horizontal distance to front handrail attachment	≥1 000 mm
<i>I</i>	Horizontal distance to rear handrail attachment	≤ 300 mm
<i>J</i>	Handrail cross section	30 to 35 mm
<i>K</i>	Horizontal distance to front of FEB	375 mm
<i>L</i>	Height to lower FEB	425 to 480 mm
<i>M</i>	Height to lower handrail	800 to 900 mm
<i>N</i>	Height to top of FEB	≥1 400 mm
<i>O</i>	Height to bottom of head support	≥1 200 mm
<i>P</i>	Inside handrail to centreline FEB	≥375 mm
<i>Q<sub>x1</sub></i>	Minimum horizontal dimension to stop request activation zone	600 mm
<i>Q<sub>x2</sub></i>	Maximum horizontal dimension to stop request activation zone	900 mm
<i>Q<sub>z1</sub></i>	Minimum vertical dimension to stop request activation zone	800 mm
<i>Q<sub>z2</sub></i>	Maximum vertical dimension to stop request activation zone	925 mm
<i>θ</i>	Recline angle of FEB from the vertical	0° to 4°

NOTE The handrail shall have a circular cross section with a diameter of not less than 30 mm and not more than 35 mm, or an oval cross section, the maximum section of which is not more than 35 mm and not less than 30 mm, and the minimum section of which is not less than 20 mm.

## Annex B (normative)

### Test for wheelchair containment

#### B.1 General

Research has shown that emergency braking and evasive manoeuvring of an ATV-SS produces accelerations within the RF-WPS in the range of  $0,25g$  to  $0,8g$ <sup>[10][11]</sup>. In general, the RF-WPS concept uses passive structures or barriers to limit the movement of the rearward-facing wheelchair, thereby not requiring the physical attachment of securement devices to the wheelchair by an attendant or vehicle operator. A FEB limits the forward movement of the wheelchair and its occupant and absorbs loads on the occupant from rapid vehicle decelerations. Laterally mounted passive devices or structures (LEBs) are typically used to limit movement or tipping of the wheelchair and its occupant into the vehicle aisle due to lateral forces caused by rapid vehicle turning. Brakes on the wheelchair, when working effectively in combination with high friction force between the wheelchair wheels and the vehicle floor, are intended to prevent rearward movement during vehicle accelerations and/or when ascending steep hills.

The purpose of this annex is to evaluate the ability of the RF-WPS and its installed components to limit the movement of the wheelchair to within specified maximum limits when subjected to the maximum loads that can be expected under emergency driving conditions, while seated in a rearward-facing wheelchair aboard an ATV-SS.

#### B.2 Principle

To safeguard other passengers and provide the wheelchair-seated occupant with a comfortable ride, a wheelchair passenger station (RF-WPS) shall limit movement of a wheelchair relative to the vehicle interior during normal and emergency driving manoeuvres. This normative annex specifies the equipment, test conditions and procedures for measuring the potential for undesirable lateral, forward, rearward and rotational movement of an occupied wheelchair. This is done by simulating the maximum horizontal forces that can act on an occupied wheelchair during emergency driving manoeuvres, and then measuring the wheelchair movement that has occurred. To assess the performance of the RF-WPS, independently of variations in wheelchair structures, the location of the wheelchair and variable centres of gravity, the tests are conducted using two types of SWC occupied by a 75 kg test dummy. The tests may be conducted either on an RF-WPS installed in a vehicle or in a laboratory that has simulated the vehicle installation intended by the RF-WPS manufacturer. Since this part of ISO 10865 does not require the use of an LEB or an REB, these might or might not be present in a specific installation that is being tested.

In order to reduce costs and to maintain consistency across test facilities, the 75 kg test dummy specified in ISO 7176-11 was chosen as the surrogate occupant. Although it would have been desirable to use a production wheelchair in lieu of the two specified surrogate wheelchairs, it was agreed that testing using the surrogates specified in Annex D would improve the test repeatability and objectivity. Therefore, their use is required in order to be in compliance with Annex B.

The test loads have been derived from research data referenced above, to which a nominal safety factor of 1,2 has been added. The test force (resulting from the specified deceleration) applied longitudinally towards the FEB is the force resulting from a  $1g$  deceleration and the test force applied away from the FEB (towards the rear of the vehicle) is the force resulting from  $0,3g$  deceleration. The test force applied laterally (towards the vehicle aisle or wall) is the force resulting from a  $0,75g$  deceleration. Since the actual test load is dependant on the combined mass of the occupied SWC being used, the minimum test load values have been computed accordingly in kiloNewtons (kN) for each surrogate type and are provided in Table B.1.

All tests in this annex are conducted under two conditions: brakes applied (locked) and brakes not applied (unlocked).

### B.3 Equipment to be tested

A complete unused commercial or prototype RF-WPS and its contained components, complete with a floor surface with a coefficient of friction that meets the requirements of 5.3.

### B.4 Test apparatus

**B.4.1 Means to locate a longitudinal reference line (LRL)** on the RF-WPS floor surface, which specifies the mid-plane of the RF-WPS.

**B.4.2 Manual surrogate wheelchair (MSWC)** meeting the specifications of Annex D.

**B.4.3 Scooter surrogate wheelchair (SSWC)** meeting the specifications of Annex D.

NOTE A single surrogate device that is configurable to meet the specifications of both the manual and scooter wheelchair, as specified in Annex D, is acceptable.

**B.4.4 Test dummy**, with a mass of 75 kg, as specified in ISO 7176-11.

NOTE ISO 7176-11:1992 specifies the use of 30 mm thick foam inserts under the thigh and behind the torso sections of the dummy. If it is decided not to use the inserts, in order to achieve better positioning of the dummy in the MSWC and SSWC, then redistribution of the dummy mass will be required in order to retain the specified centre of gravity (CG) location of the dummy.

**B.4.5 Means to apply a horizontal load**, of at least 3 kN, through the combined CG of the SWC and test dummy in the longitudinal and lateral directions, respectively.

**B.4.6 Measuring device** to measure the lateral, longitudinal and rotational movements of the SWC to an accuracy of  $\pm 3$  mm and  $\pm 1^\circ$ , respectively.

### B.5 Test procedures

#### B.5.1 General

Perform the following steps in the order indicated, first with one surrogate wheelchair then the other.

#### B.5.2 Pretest set-up

- a) Designate fore and aft reference points on the SWCs for measuring movement in the following locations:
  - 1) the rear reference point (RRP), located on a rearward structure of the SWC that intersects with the SWC reference plane, and
  - 2) the forward reference point (FRP), located on a forward structure of the SWC that intersects with the SWC reference plane, most likely between the footrests.
- b) Check all tyres on the SWC. If pneumatic, ensure inflation in accordance with the wheel manufacturer's instructions.
- c) If conducted in a laboratory setting, mount the RF-WPS on the test surface in accordance with the manufacturer's instructions.
- d) Locate the occupied SWC in the RF-WPS so that the SWC reference plane coincides with the mid-plane of the test surface. Back the SWC against the FEB with the caster wheels trailing in the direction of the rear of the vehicle.
- e) Position the front wheel axle(s) of the SWC perpendicular to the wheelchair reference plane. Do not lock the wheels to prevent their rotation from the reference plane during testing.

### B.5.3 Longitudinal movement tests

#### B.5.3.1 Brakes unlocked, force applied towards FEB

- a) Position the rearward-facing, occupied SWC against the FEB as described in B.5.2 and mark its initial position.
- b) With the brakes unlocked, apply a longitudinal horizontal force, as specified in Table B.1, through the combined CG of the SWC and test dummy in the direction of the front of the vehicle (towards the FEB).
- c) Hold the test load for a minimum of 3 s.
- d) While maintaining the test load within  $\pm 5$  % of its nominal value, measure and record the longitudinal movement of the SWC from the initial position, including rolling or sliding, to an accuracy of  $\pm 3$  mm.
- e) Note any tipping (tipping is defined as any vertical lifting of any SWC wheel from the test surface more than 10 mm from its pre-test position).
- f) Return the SWC to the initial position.
- g) Repeat a) to f) two more times, and record the average of the three trials.

#### B.5.3.2 Brakes locked, force applied towards FEB

- a) Apply the brakes on the SWC.
- b) Repeat B.5.3.1 with the exception that b) shall be performed with the brakes locked.
- c) Record the average of the three trials.

#### B.5.3.3 Brakes unlocked, force applied away from FEB

- a) Position the rearward-facing, occupied SWC against the FEB as described in B.5.2 and mark its initial position.
- b) With the brakes unlocked, apply a longitudinal horizontal force, as specified in Table B.1, through the combined CG of the SWC and test dummy in the direction of the rear of the vehicle (away from the FEB).
- c) Hold the test load for a minimum of 3 s.
- d) While maintaining the test load within  $\pm 5$  % of its nominal value, measure and record the longitudinal movement of the SWC from the initial position, including rolling or sliding, to an accuracy of  $\pm 3$  mm.
- e) Note any tipping.
- f) Return the SWC to the initial position.
- g) Repeat a) to f) two more times, and record the average of the three trials.

#### B.5.3.4 Brakes locked, force applied away from FEB

- a) Apply the brakes on the SWC.
- b) Repeat B.5.3.3 with the exception that b) shall be performed with the brakes locked.
- c) Record the average of the three trials.

### B.5.4 Lateral movement tests

#### B.5.4.1 Brakes unlocked

- a) Position the rearward-facing, occupied SWC against the FEB as described in B.5.2 and mark its initial position.

- b) With the brakes unlocked, apply a horizontal lateral force, as specified in Table B.1, through the combined CG of the SWC and test dummy, at 90° to the SWC reference plane.
- c) Hold the test load for a minimum of 3 s.
- d) While maintaining the test load within ±5 % of its nominal value, measure and record
  - 1) the lateral movement of the SWC from the initial position, including rotation to an accuracy of ±2°,
  - 2) sliding to an accuracy of ±3 mm, and
  - 3) the tipping angle to an accuracy of ±2°, whereby the tipping angle is defined as the change in angle between the wheelchair reference plan and the mid-plane of test surface.
- e) If the installation is intended to have aisles on both sides, the test shall be applied separately on each side of the SWC.
- f) Return the SWC to the initial position.
- g) Repeat a) to f) two more times, and record the average of the three trials.

**B.5.4.2 Brakes locked**

- a) Apply the brakes on the SWC.
- b) Repeat B.5.4.1 with the exception that b) shall be performed with the brakes locked.
- c) Record the average of the three trials.

**Table B.1 — Test force and direction of application**

Direction	Applied force on the MSWC <sup>a</sup>	Applied force on the SSWC <sup>b</sup>
	kN	kN
Longitudinal towards FEB	1,1	1,7
Longitudinal away from FEB	0,34	0,5
Lateral (sideways)	0,84	1,2
<sup>a</sup> Manual surrogate wheelchair as specified in D.3.1. <sup>b</sup> Scooter surrogate wheelchair as specified in D.3.2.		

## Annex C (normative)

### Static strength tests for wheelchair containment barriers

#### C.1 General

Research has indicated that a frontal 48 km/h collision of a typical stationary ATV-SS and average size automobile generates peak accelerations within the ATV-SS in the range of 2,75g to 3g<sup>[5]</sup>. Although this part of ISO 10865 assumes that the chance of a wheelchair user being in frontal collision while riding in ATV-SS is very small, the possibility does exist. Since the strength of the RF-WPS components do not negatively affect the ease of use (usability) of the device by the wheelchair user, it was agreed that the static strength requirements of the FEB would be based on forces that may occur during a 3g frontal impact. Although the real-world loads applied to the structures are dynamic, for reasons of cost and simplicity, it was agreed that static testing, which includes a 1,2 safety factor, would be used to provide strength validation. Therefore, the purpose of this annex is to provide a means of testing the strength performance of critical RF-WPS structures to ensure that they meet minimum strength requirements and therefore will withstand the forces that can occur in a real-world driving event.

#### C.2 Principle

The design requirement of Clause 4 requires the installation of a FEB. The primary purpose of the FEB is to limit excessive forward movement of the wheelchair and its occupant during braking events. In addition, as indicated, the strength of the FEB should be able to withstand a 3g frontal collision event. Therefore, the specification of the total mass that will simulate a worst-case occupied wheelchair becomes important. In general, electrically powered wheelchairs are much heavier than manual wheelchairs. All electrically powered wheelchairs, including scooters, have brakes that automatically lock the drive wheels when the wheelchair is stopped. However, it is unknown if the brake mechanism will withstand a 3g impact, and therefore it shall be assumed for the purposes of this test that the full mass of an occupied nominal powered wheelchair will impact on the FEB during a frontal 3g impact event. In several countries, a combined occupant and wheelchair mass of 272,7 kg is used for the test load for their wheelchair lift standards. Assuming a 3g worst-case longitudinal loading and a 1,2 safety factor, this results in a static test load for the FEB of 9,6 kN.

Conformance testing involves the application of the test load on the front of the FEB at a point that is 600 mm above the floor, and then, upon removal of the test force, measuring and recording any permanent deformation of the FEB structure. To conform, the FEB structure shall not have permanently deformed by more than 15 mm or show evidence of structural failure, in accordance with C.5.1.

The RF-WPS shall also restrict movement in the lateral direction. If a lateral excursion barrier or device is used to restrict lateral movement in the RF-WPS installation, it shall be tested in accordance with C.5.2. Using the same rationale as above and a 0,5g maximum lateral load condition under emergency turning manoeuvres, this results in a nominal lateral static test load of 1,6 kN.

The RF-WPS shall also restrict movement in the rearward (relative to vehicle) direction. If a rearward excursion barrier or device is used to restrict rearward movement it shall be tested in accordance with C.5.3. Using the same rationale as above and a 0,3g maximum rearward load condition under emergency turning manoeuvres, the nominal rearward static test load is 962 N.

The tests can be conducted either in a vehicle or in a laboratory. If conducted in a laboratory, the vehicle attachment structures (configuration and components) as specified by the manufacturer shall be simulated in order to confirm that the vehicle-to-RF-WPS attachment(s) will withstand the specified test forces.

### C.3 Equipment to be tested

The following devices or structures shall be tested:

- a) the FEB intended to prevent forward (relative to the vehicle) movement or to absorb energy of forward movement of an occupied wheelchair;
- b) any device or structure intended to prevent lateral (angular or longitudinal) movement of an occupied wheelchair (LEB);
- c) any device or structure intended to prevent rearward (relative to the vehicle) movement of an occupied wheelchair (REB).

### C.4 Test apparatus

**C.4.1 Test machine**, capable of applying and monitoring the static loads of at least 5,0 kN for a period of not less than 1,5 s.

**C.4.2 Test bed**, capable of securing devices or structures as they would be mounted in a vehicle RF-WPS installation.

**C.4.3 Means of applying the test load through a rigid force applicator** with an application area of 200 mm x 200 mm.

**C.4.4 Measuring device**, capable of measuring structural deformation to an accuracy of  $\pm 2$  mm.

### C.5 Test procedures

#### C.5.1 FEB

Perform the following steps in the order indicated.

- a) Fix the FEB to the test bed in accordance with the manufacturer's instructions using the fixing points supplied for the usual attachment to the vehicle structure.
- b) Identify the force application point (FAP) as a point on the vertical mid-plane on the wheelchair-contact surface of the FEB, located 600 mm  $\pm 10$  mm above the floor.
- c) Set up the test machine so that a horizontal test force will be applied through the FAP.
- d) Measure and record the position of the FAP in such a manner that a permanent change in the position of the FAP in the longitudinal plane of the test bed can be measured and recorded.
- e) Using the rigid force applicator, apply a horizontal test load of 9,6 kN  $\pm 10$  N for a period of not less than 1,5 s.
- f) After relieving the load, measure and record the longitudinal position of the FAP.
- g) Record any difference between the two recordings in d) and f) to an accuracy of  $\pm 2$  mm.
- h) Visually inspect the FEB to determine whether any structural damage has occurred that would render the FEB non-functional or prevent removal of the wheelchair from the RF-WPS, or whether it has any exposed sharp surfaces that could injure a nearby person.

#### C.5.2 LEB

If an LEB is provided, perform the following steps in the order indicated.

- a) Install the LEB on the test bed in accordance with the manufacturer's instructions using the fixing points supplied for the intended attachment to the vehicle structure.

- b) Determine the location of the LEB support structure that will generate the largest destructive moments when a horizontal lateral force is applied and mark it as the FAP.
- c) Record the position of the FAP in such a manner that a permanent change in its horizontal position can be measured and recorded to an accuracy of  $\pm 2$  mm.
- d) Set up the test machine so the force applied will pass through the FAP in a horizontal plane in the lateral (aisle) direction, as when mounted in a vehicle.
- e) Apply a horizontal test load of  $1,6 \text{ kN} \pm 10 \text{ N}$  in the lateral direction ( $90^\circ$  to the reference plane of the FEB) through the FAP for a period of not less than 1,5 s.
- f) After removal of the test load, measure the lateral position of the FAP, compare it to the original position and record any difference to an accuracy of  $\pm 2$  mm. Visually inspect the LEB to determine whether any structural damage has occurred that would render the LEB non-functional or prevent removal of the wheelchair from the RF-WPS, or whether it has any exposed sharp surfaces that could injure a nearby person.

### C.5.3 REB

If an REB is provided, perform the following steps in the order indicated.

- a) Install the REB on the test bed in accordance with the manufacturer's instructions using the fixing points supplied for the intended attachment to the vehicle structure.
- b) Determine the location on the REB support structure that will generate the largest destructive moments when a horizontal rearward force is applied and mark it as the FAP.
- c) Record the position of the FAP in such a manner that a permanent change in the horizontal position of the FAP can be measured and recorded to an accuracy of  $\pm 2$  mm.
- d) Set up the test machine so the force applied will pass through the FAP in a horizontal plane in the rearward direction, as when mounted in a vehicle.
- e) Apply a horizontal test load of  $962 \text{ N} \pm 10 \text{ N}$  in the rearward direction (parallel to the REB reference plane) through the FAP for a period of not less than 1,5 s.
- f) After removal of the test load, measure the longitudinal position of the FAP, compare it to the original position and record any difference to an accuracy of  $\pm 2$  mm. Visually inspect the rearward excursion barrier to determine whether any structural damage has occurred that would render the rearward excursion barrier non-functional or prevent removal of the wheelchair from the RF-WPS, or whether it has any exposed sharp surfaces that could injure a nearby person.

## Annex D (normative)

### Specifications for surrogate wheelchairs

#### D.1 General

The wheelchair movement tests in Annex B require testing using both a surrogate wheelchair and surrogate scooter that conform to the specifications in this annex. The design of the surrogates is based on the principle that the Annex B movement testing will be done using a worst-case occupied surrogate. All other types and sizes of wheelchairs and scooters will therefore have greater stability or better resistance to movement and, consequently, less potential for undesirable movement. One worst-case wheelchair type is a lighter-weight manual adult-size wheelchair with a small wheelbase area, but with a seat wide enough to accommodate a large, tall adult. The other potentially highly unstable situation in an ATV-SS is a mid-sized three-wheeled scooter, occupied by a larger adult. Both research and in-vehicle observations support this need for safety testing.

When compared to occupants of heavier powered wheelchairs, occupants of lower mass manual wheelchairs have reduced tipping stability due to the higher combined CG of the wheelchair and occupant. Also, an adult-sized manual wheelchair with a smaller (narrower) track has decreased lateral tipping stability, especially if occupied by a user with a relatively high CG. The three-wheeled scooter has a wheelbase that is inherently less stable than a four-wheeled powered wheelchair. Since a scooter's mass is on the low end of the range of powered wheelchairs, the stabilizing friction force on the floor will be comparatively reduced. Therefore, undesirable longitudinal or rotational movement is more likely to occur with a three-wheel scooter than with heavier powered wheelchairs.

The use of the adult dummy (75 kg) that can be accommodated in the wheelchair seat increases the vertical height of the combined CG, when compared to using a smaller size dummy. This means that any object with a higher CG, given that all other factors are equal, is more susceptible to tipping than one with a lower CG. For similar reasons, the surrogate scooter seat height design specifications were derived from production samples set at their maximum seat height adjustments.

The purpose of this annex is to establish the design specifications for the Annex B surrogate bases which are representative of a range of production adult manual wheelchairs and mid-sized three-wheeled scooters that would most likely be the least stable (tipping, rotating or sliding) when used as a seat in a ATV-SS. Also, specifying surrogate bases that meet specific design parameters, in contrast to using typical production wheelchairs or scooters as surrogates, means that the test results will be more consistent across test facilities. Since there is no destructive testing, the surrogate wheelchair does not need to be as robust as a surrogate used in crash testing.

#### D.2 Principle

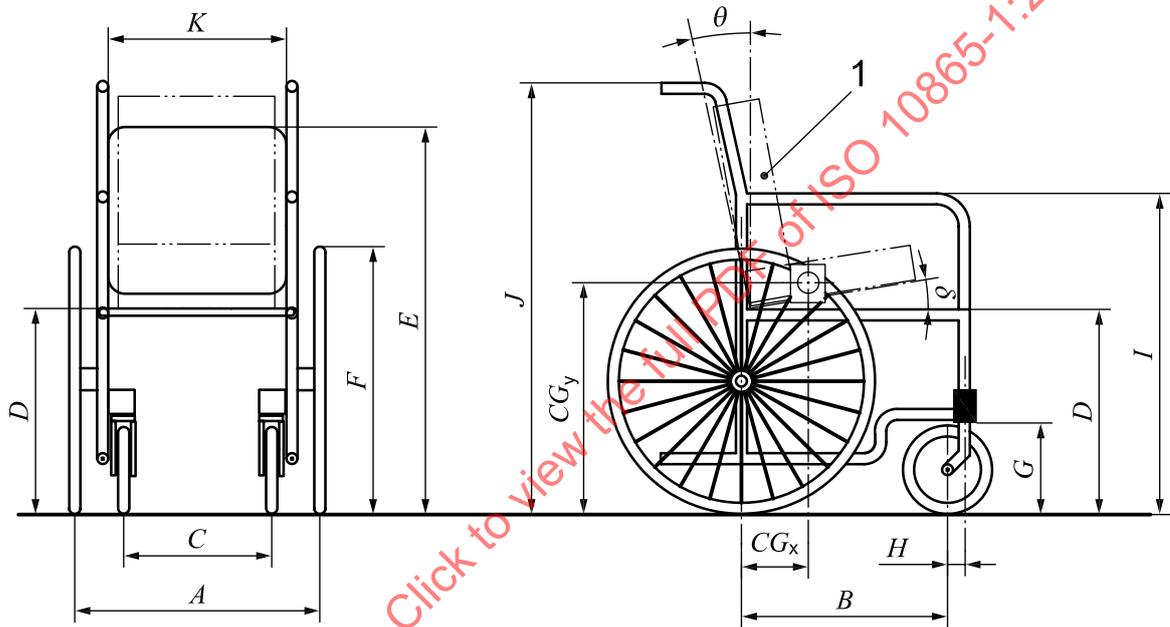
Based on the principles of physics indicated above, the critical wheelchair and scooter parameters that affect the sliding, tipping or rotation tests of Annex B were identified. Integration of databases of manual wheelchair and scooter dimensions and CG locations allowed for the determination of a range of values for the critical design parameters, deemed to be the more unstable. In general, these critical values are based on adult manual wheelchairs and scooters with a shorter wheelbase, narrower rear wheel track, and higher seat heights. When a 75 kg male test dummy is added to the surrogate seat, the higher location of the combined CG, plus the relatively smaller wheeled support base, creates the scope for reduced stability typical of what can occur in the real world. Therefore, a successful Annex B test using the surrogate bases and a 75 kg male dummy occupant that meets the specifications of this annex, should provide reasonable assurance that all occupied wheelchairs and scooters on ATV-SSs, when subjected to maximum destabilizing forces, will not cause injury to either wheelchair occupants or nearby standing passengers due to uncontrolled movement.

### D.3 Specifications

#### D.3.1 Specifications for a manual surrogate wheelchair (MSWC)

A MSWC shall:

- have a rigid seat and backrest to facilitate repeatability of dummy placement;
- have front wheels that are castored;
- have rear wheel parking brakes equivalent to commercial products;
- meet the specifications in Table D.1.



1 ISO 75kg dummy

Figure D.1 — Critical MSWC specifications

Table D.1 — Specifications for MSWCs

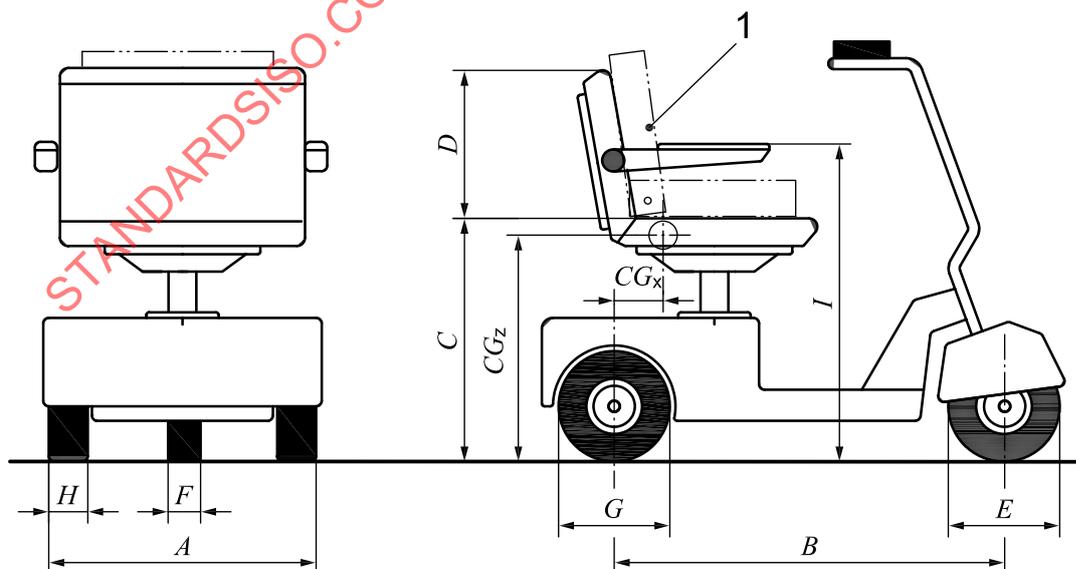
Designation	Feature	Values <sup>a</sup>
—	Mass	20 kg ± 0,2 kg
<i>A</i>	Rear wheel track	465 mm
<i>B</i>	Wheelbase (measured with castors trailing rearward as shown)	360 mm
<i>C</i>	Front wheel track	275 mm
<i>D</i>	Seat bight height	530 mm
<i>E</i>	Top of backrest to floor	800 mm
<i>F</i>	Rear wheel diameter	609 mm
<i>G</i>	Castor wheel diameter	178 mm
<i>H</i>	Castor trail	45 mm
<i>I</i>	Arm rest height	720 mm
<i>J</i>	Push handle height	950 mm
<i>K</i>	Push handle inside width	325 mm
$\delta$	Seat surface angle (from horizontal)	5° to 10°
$\theta$	Back rest angle (from vertical)	10°
$CG_x$	forward location of the combined CG	115 mm ± 10 mm
$CG_z$	vertical location of the combined CG	600 mm ± 10 mm

<sup>a</sup> Tolerances are ±5 mm or ±1° unless otherwise specified.

D.3.2 Specifications for the scooter surrogate (SSWC)

A surrogate scooter shall:

- a) have a rigid seat and backrest to facilitate repeatability of dummy placement;
- b) have only three wheels with the front wheel used for manual tiller-type steering;
- c) meet the specifications in Table D.2.



1 ISO 75kg dummy

Figure D.2 — Critical surrogate scooter specifications

Table D.2 — Specifications for a surrogate scooter

Designation	Feature	Values <sup>a</sup>
—	Mass	68 kg ± 0,2 kg
<i>A</i>	Rear wheel outside width	565 mm
<i>B</i>	Wheelbase	800 mm
<i>C</i>	Seat bight height	625 mm
<i>D</i>	Back rest height (above seat bight)	356 mm
<i>E</i>	Front wheel diameter	203 mm
<i>F</i>	Front wheel width	69 mm
<i>G</i>	Rear wheels diameter	228 mm
<i>H</i>	Rear wheel width	76 mm
<i>I</i>	Arm rest height	853 mm
$\delta$	Seat surface angle from horizontal (not shown)	3°
$\theta$	Back rest angle from vertical (not shown)	5°
$CG_x$	Forward location of combined CG	205 mm ± 10 mm
$CG_z$	Vertical location of combined CG	536 mm ± 10 mm

<sup>a</sup> Tolerances are ±5 mm or ±1° unless otherwise specified.