INTERNATIONAL STANDARD

ISO 10865-1

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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

Reference number
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Foreword

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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.

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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*

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[15] 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[15] 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[1]. 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 $1g$[2][3].

Recognizing the different safety needs of ATV-SS passenger environments in the early 1990s, many European countries[4][5][6], as well as Canada and Australia[7], 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[7][8]. 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[7][9]. 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.

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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.

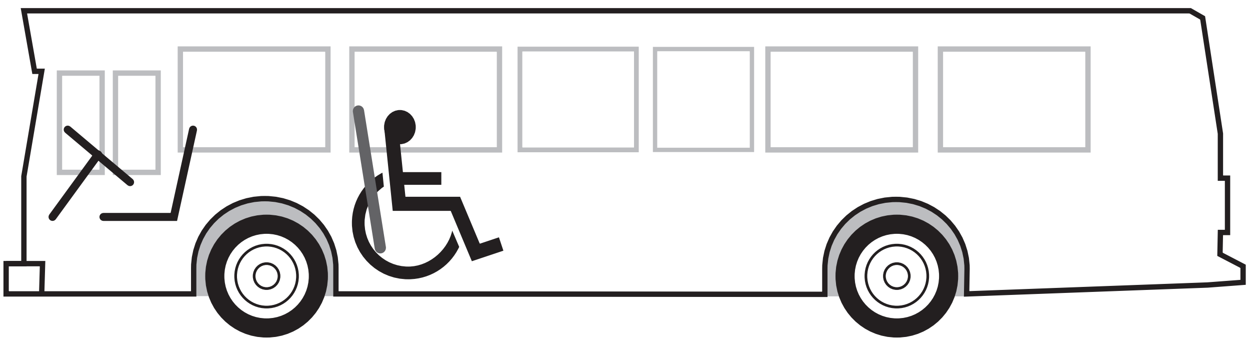

Figure 1 — Pictogram for wheelchair passenger space showing the wheelchair facing the rear of the vehicle

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;

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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.

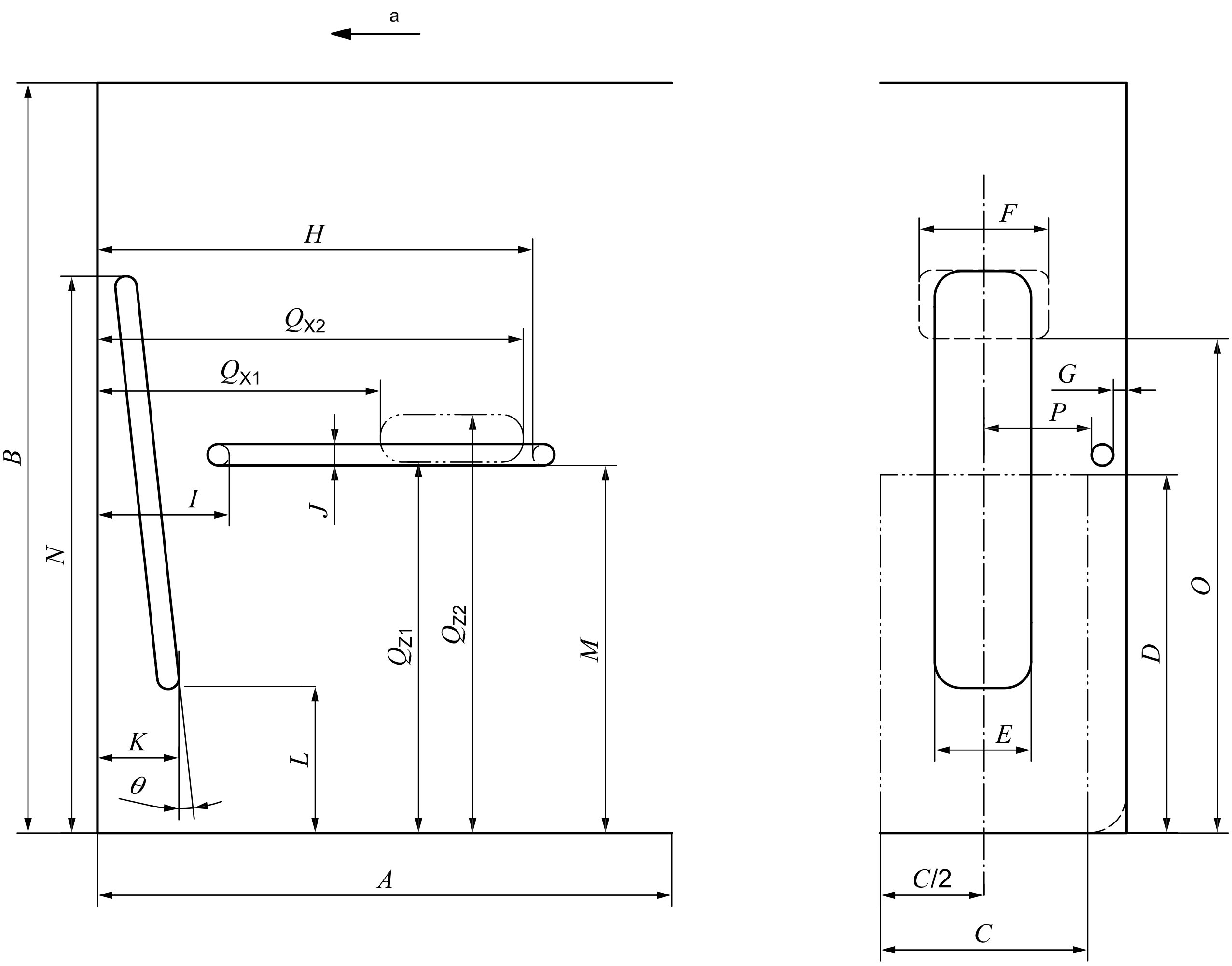
A.2 Principle

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) Side view

b) Front view

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
A	WPS length	≥1 400 mm
B	WPS height	≥1 500 mm
C	Width of unobstructed wheelchair clear space at floor level extending vertically to a height 50 mm below the minimum height of the handrail (dimension *M*)	≥750 mm
D	Height of unobstructed wheelchair clear space	750 mm
E	Width of FEB	250 to 280 mm
F	Width of head support	≥300 mm
G	Handrail to nearest obstruction	≥45 mm
H	Horizontal distance to front handrail attachment	≥1 000 mm
I	Horizontal distance to rear handrail attachment	≤ 300 mm
J	Handrail cross section	30 to 35 mm
K	Horizontal distance to front of FEB	375 mm
L	Height to lower FEB	425 to 480 mm
M	Height to lower handrail	800 to 900 mm
N	Height to top of FEB	≥1 400 mm
O	Height to bottom of head support	≥1 200 mm
P	Inside handrail to centreline FEB	≥375 mm
Q_{x1}	Minimum horizontal dimension to stop request activation zone	600 mm
Q_{x2}	Maximum horizontal dimension to stop request activation zone	900 mm
Q_{z1}	Minimum vertical dimension to stop request activation zone	800 mm
Q_{z2}	Maximum vertical dimension to stop request activation zone	925 mm
θ	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[10][11]. 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 ±3 mm and ±1°, 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 ±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 ±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 ±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 ±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[a] kN	Applied force on the SSWC[b] kN
Longitudinal towards FEB	1,1	1,7
Longitudinal away from FEB	0,34	0,5
Lateral (sideways)	0,84	1,2

[a] Manual surrogate wheelchair as specified in D.3.1.

[b] 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[5]. 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 that 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 ±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 ±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 ± 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 ±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 ±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 kN ± 10 N in the lateral direction (90° 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 ±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 ±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 N ± 10 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 ±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.

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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)

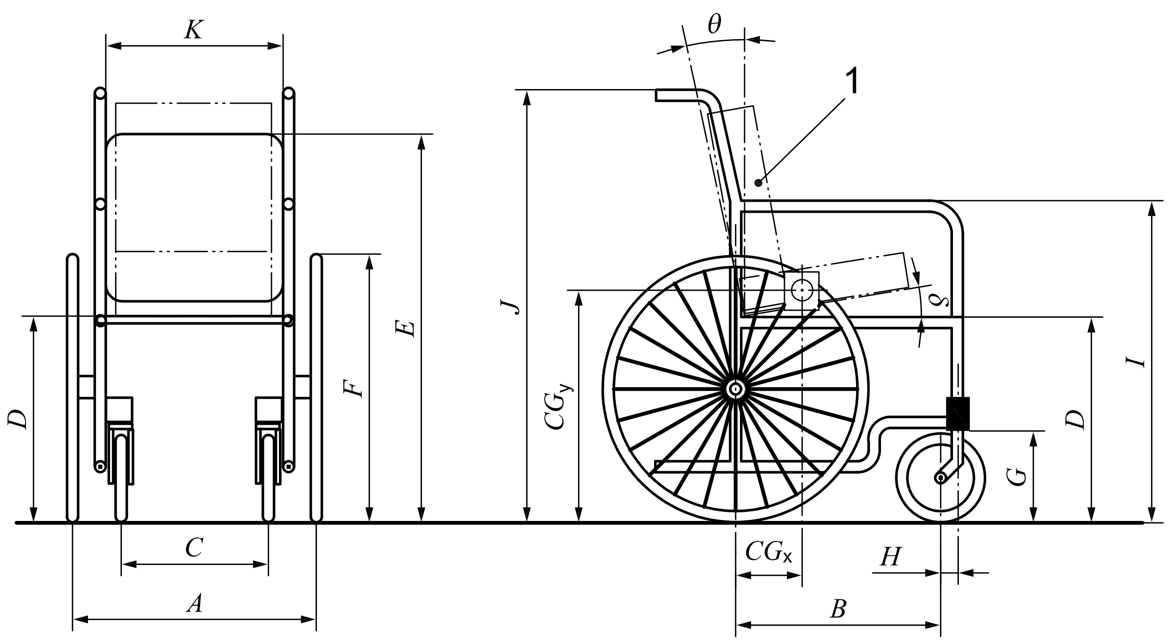
A MSWC shall:

a) have a rigid seat and backrest to facilitate repeatability of dummy placement;

b) have front wheels that are castored;

c) have rear wheel parking brakes equivalent to commercial products;

d) 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[a]
—	Mass	20 kg ± 0,2 kg
A	Rear wheel track	465 mm
B	Wheelbase (measured with castors trailing rearward as shown)	360 mm
C	Front wheel track	275 mm
D	Seat bight height	530 mm
E	Top of backrest to floor	800 mm
F	Rear wheel diameter	609 mm
G	Castor wheel diameter	178 mm
H	Castor trail	45 mm
I	Arm rest height	720 mm
J	Push handle height	950 mm
K	Push handle inside width	325 mm
δ	Seat surface angle (from horizontal)	5° to 10°
θ	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

[a] Tolerances are ±5 mm or ±1° unless otherwise specified.

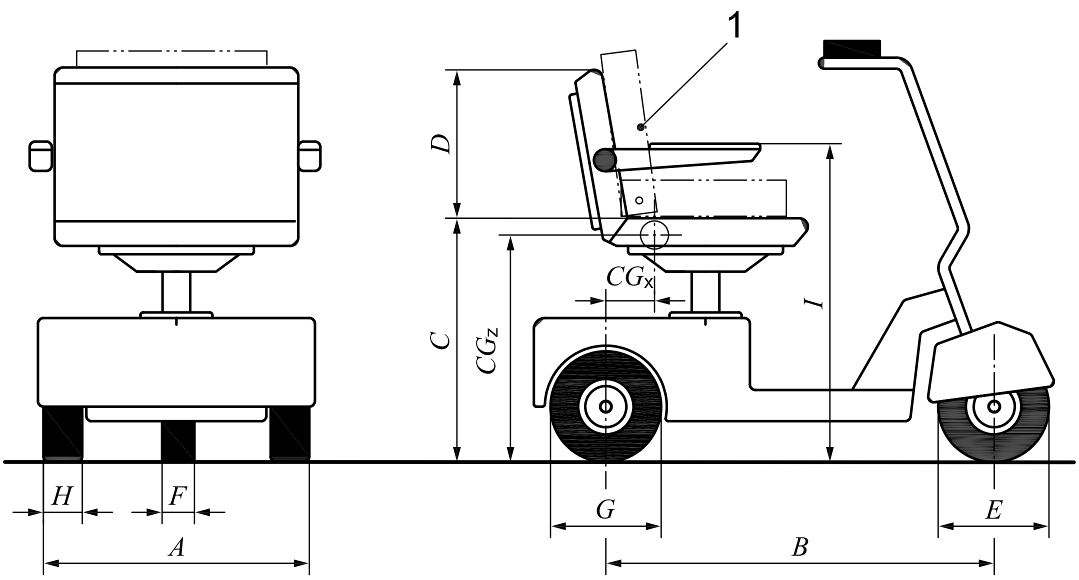
D.3.2 Specifications for the scooter surrogate (SSWC)

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[a]
—	Mass	68 kg ± 0,2 kg
A	Rear wheel outside width	565 mm
B	Wheelbase	800 mm
C	Seat bight height	625 mm
D	Back rest height (above seat bight)	356 mm
E	Front wheel diameter	203 mm
F	Front wheel width	69 mm
G	Rear wheels diameter	228 mm
H	Rear wheel width	76 mm
I	Arm rest height	853 mm
δ	Seat surface angle from horizontal (not shown)	3°
θ	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

[a] Tolerances are ±5 mm or ±1° unless otherwise specified.

Annex E
(informative)

Design guidelines

E.1 General

E.1.1 Rationale, principles and guideline objectives

The overriding goal of the RF-WPS is to provide easier access to large transport vehicles (ATV-SSs) for wheelchair users and reduce the time and demands on the vehicle operator while providing wheelchair transport. Increased efficiency is particularly important for transport authorities running fixed route operations in large urban areas where bus rapid transit (BRT) is a major objective. The majority of wheelchair users are also supportive of any on-board system that will render a level of independence and safety in travel that is available to all other passengers.

The concept of a wheelchair passenger travelling without the need for the direct application of wheelchair securement devices (passive containment) began in Germany in the early 1990s[4][5]. Those studies, in essence, verified that a person could be safely transported using passive containment provided that a number of critical biomechanical safety criteria are met. First, the wheelchair user should be in a large transit vehicle that is operated primarily in a fixed route urban environment where the maximum speeds are relatively low, the comparative mass of the vehicle is high, meaning the chances of a high g frontal impact event is extremely low. If you are willing to accept the risk of never having a frontal collision event, then the design of the passive containment system only needs to address the maximum forces that might result during an emergency or more extreme driving events (maximum braking, rapid swerving and maximum uphill accelerations). Many subsequent studies have confirmed that no emergency or evasive driving event in an ATV-SS generates accelerations greater than1g[2][3][10][11].

The second criterion is that the occupied wheelchair should be orientated facing the rear of the vehicle and positioned against a padded barrier (FEB) that will prevent forward movement of the wheelchair during a maximum braking event. This type of braking event generates a maximum acceleration in the range of 0,75g to 0,85g. Also, the wheelchair should be positioned as close as possible to the FEB to prevent excessive forward head and neck (hyper-extension) movement of the occupant. The wheelchair brakes (if present) should be locked to prevent longitudinal movement of the wheelchair towards the rear of the vehicle during forward vehicle accelerations, especially up inclines.

A hand-hold should also be provided to allow those users with sufficient upper body function to assist in the prevention of excessive movement of their wheelchair or their upper bodies, particularly during emergency driving events.

Finally, there should also be a means to prevent the wheelchair from sideways (lateral) tipping, rotating or sliding during rapid turns of the vehicle. Industry attempts to meet this need have been in the form of a floor-to-ceiling stanchion or flip-down horizontal barrier, which are intended to prevent the wheelchair from rotating, sliding or tipping into the central aisle. The vehicle wall is usually relied upon to prevent wheelchair movement in the wall direction.

In practice, these lateral barriers have been only partially effective in controlling the undesired lateral movement. In some cases, application of auxiliary securement straps by the driver has been necessary in order to prevent excessive wheelchair motion. However, this nullifies one of the main advantages of the passive containment approach. Permanently mounted floor-to-ceiling stanchions also impede access to and from the RF-WPS. Furthermore, most FEBs currently on the market are poorly designed in that they do not allow the head and neck of the occupant to be positioned in close proximity to the FEB. Brakes on many wheelchairs are ineffective in preventing wheelchair rearward movement, especially during rapid uphill accelerations. Hand-holds tend to be poorly located or are non-existent.

Since the wheelchair brakes are intended to contribute an important element in limiting excessive wheelchair movement, the friction force developed between the wheelchair wheels and the vehicle floor becomes an important additional factor. Therefore, the selection of floor covering materials that meet minimum coefficient of friction requirements is essential.

In summary, the objective of these design guidelines is to help manufacturers design and test products that will conform to this part of ISO 10865, thereby providing an improved level of usability and safety for wheelchair-seated passengers who use a rearward-facing wheelchair passenger space in a ATV-SS.

E.1.2 Layout requirements of the rearward-facing wheelchair station

The space available for wheelchair passenger accommodation in ATV-SSs is always limited. Internal vehicle width limitations can be a major factor because maximum overall vehicle width is carefully controlled by federal authorities in most countries. Annex A contains the range of dimensions that allows a larger sized wheelchair and user to manoeuvre into the RF-WPS and back as closely as possible to the required FEB, which is located as far forward as possible in the specified minimum overall space (length, width and height) envelope of the rearward-facing wheelchair passenger station. In general, if a large powered wheelchair should need to reverse in the vehicle for entry or egress, a floor space with a turning circle with a minimum diameter of about 1 500 mm should be available. The actual turning space required for a specific wheelchair is dependent on the length of the wheelchair and the type of powered drive and control system it uses. The skill of the operator can also be a factor. Within the RF-WPS, in addition to the FEB, there should be a means of controlling undesirable lateral and rearward wheelchair movement. Dimensional, layout and performance specifications are provided for the FEB in Annex A. It was agreed that this was necessary because extensive knowledge of wheelchair types and sizes is required in order to design and install an FEB that will safely accommodate the wide range of wheelchairs and users that use public transport. By contrast, only performance specifications are provided for the lateral or rearward movement-limiting devices, thereby completely opening the possible design solutions to the ingenuity of the designer. However, all movement control structures or devices, if provided, should meet the movement control tests specified in Annex B.

E.2 Design of the FEB

Again, the main function of the FEB is to provide a reliable wheelchair forward movement stop in the event of a rapid vehicle braking event. The second purpose is to provide a padded barrier closely behind the upper body of the wheelchair occupant that will prevent excessive head and neck forward movement. This can be achieved in a transport environment in which the injury-producing accelerations are not expected to exceed 1*g*. Table E.1 contains Table A.1 specifications, with an explanation added for each dimension.

Table E.1 — Dimensions of a WPS with the addition of explanatory statements

Dimension	Description	Value mm	Explanation
A	WPS length	≥1 400	ISO 7193[14] stipulates 1 200 mm for maximum wheelchair length; manoeuvring space required
B	WPS height	≥1 500	95 % head height for 75 % of males in a wheelchair is 1 475 mm
C	Width of unobstructed wheelchair clear space at floor level extending vertically to a height 50 mm below the minimum handrail height (dimension *M*)	≥750	ISO 7193 stipulates 700 mm for maximum wheelchair width; manoeuvring space also required
D	Height of unobstructed wheelchair clear space	750	Define upper dimension of space that allows unobstructed wheelchair access
E	Width of FEB	250 to 280	Allow FEB to pass between large rear wheels of child-sized wheelchairs
F	Width of head support	≥300	Ensure a head rest is present even if the wheelchair is located off-centre

Table E.1 *(continued)*

Dimension	Description	Value mm	Explanation
G	Handrail to nearest obstruction	≥45	Ensure there is sufficient space for handrail grasping
H	Horizontal distance to front handrail attachment	≥1 000	Ensure sufficient length of handrail for use by all passengers
I	Horizontal distance to rear handrail attachment	≤300	Ensure sufficient length of handrail for use by all passengers
J	Handrail cross section	30 to 35	Ensure ergonomically appropriate grasp diameter for average sized hand
K	Horizontal distance to front of FEB	375	Ensure sufficient longitudinal unobstructed space for components on lower rear of powered wheelchairs
L	Height to lower FEB	425 to 480	Ensure sufficient vertical unobstructed space for components on lower rear of powered wheelchairs
M	Height to lower handrail	800 to 900	Ensure that the lower handrail is above 95 % of the height of the wheelchair armrests
N	Height to top of FEB	≥1 400	Ensure a head restraint is available for taller wheelchair passengers
O	Height to bottom of headrest	≥1 200	Ensure a head restraint is available for shorter wheelchair adult passengers
P	Inside handrail to centreline FEB	≥375	Ensure there is sufficient wall-side space for a larger wheelchair to be positioned on the FEB centreline
Q_{x1}	Minimum horizontal dimension to stop request activation zone	600	Ensure the stop request is accessible to the majority of wheelchair passengers
Q_{x2}	Maximum horizontal dimension to stop request activation zone	900	Ensure the stop request is accessible to the majority of wheelchair passengers
Q_{z1}	Minimum vertical dimension to stop request activation zone	800	Ensure access to the stop request button is above the wheelchair armrest but still reachable by the majority of wheelchair passengers
Q_{z2}	Maximum vertical dimension to stop request activation zone	925	Ensure access to the stop request button is above the wheelchair armrest but still reachable by the majority of wheelchair passengers
θ	Angle of FEB	0° to 4°	Accommodate some wheelchair seat back recline angle, but keep the upper FEB as close to the upper torso and head of the wheelchair occupant as possible

It should be noted that there is no requirement that FEBs be designed to provide one continuous flat plane. For example, the head rest could be further forward than the trunk support component. The trunk support section could be segmented to better accommodate backpacks or other wheelchair-mounted obstructions that often inhibit close proximity positioning between the occupant and the FEB. Ideally, the lower aspect of the FEB should serve as the wheelchair stop by contacting a rear seat structure during forward wheelchair motion. In this contact position, the upper components of the FEB should be in close proximity to the occupant's upper torso and head. Of course, this is difficult to achieve in all cases since the variability of users and wheelchair types is high. However, any design efforts to achieve the ideal will afford greater safety for larger numbers of wheelchair-seated passengers in an extreme braking event.

The location and type of the stop request button is another import design consideration. Given that many powered wheelchair users have limited hand and arm function, access to a single location button can be difficult or impossible, even if it is relatively large. Therefore, it is recommended that a strip-type switch design be used that extends over at least the forward 75 % of the horizontal (x) dimension of the stop button zone. The height of the strip switch itself, within the specified zone, should be at least 50 mm.

E.3 Design of REBs

Again, the purpose of this optional barrier or device is to prevent or limit uncontrolled movement of the occupied wheelchair towards the rear of the vehicle as a result of maximum accelerations in the range of 0,25g to 0,3g. Recent research has shown that these forces can be as high as 0,4g, as a result of the vehicle suspension rebound after an extreme forward driving braking event[5]. These forces are high enough to cause all manual wheelchairs and many lighter weight powered wheelchairs to roll or slide towards the rear of the vehicle, even with the brakes locked. If these events were to occur on an inclined road, the likelihood of rearward movement is increased. Also, many rearward-facing wheelchair passengers who lack an occupant retention device are at increased risk of falling forward out of their wheelchair. Passengers standing in the RF-WPS, in front of the wheelchair, will be contacted by the rearward-moving wheelchair and injury could very well occur. The intent is to design a passive structure or active device that will prevent or limit this undesirable rearward movement to 50 mm or less. Also, the design should not obstruct the use of RF-WPS by other passengers or inhibit access or egress by the wheelchair user.

A vehicle-mounted occupant retention device is one such device that, if designed and installed properly, will most likely result in the RF-WPS passing the longitudinal movement test specified in B.5.3. However, the design challenge with this approach is to provide an occupant retention device that can be independently used (easy to reach and apply) by the majority of wheelchair users, thereby adhering to the overriding objective of high user independence and minimal operator intervention.

E.4 Design of LEBs

Again, the purpose of this optional barrier or device is to prevent or limit uncontrolled sideways (lateral) movement (rotating, sliding or tipping) of the occupied wheelchair towards the centre aisle of the vehicle as a result of maximum lateral destabilizing accelerations in the range of 0,5g. These destabilizing forces most often occur as a result of rapid swerving events that can occur during fixed route operation. Also, lateral destabilizing forces can occur when the rear wheel of the vehicle accidentally strikes a kerb during a routine cornering event. In most installations it is assumed that the vehicle wall will prevent lateral wheelchair movement in the wall direction. However, if the RF-WPS design is intended to be located away from either side-wall of the vehicle, then the LEB should be designed to limit movement in both lateral directions, and should be tested accordingly in Annex B.

E.5 Maximizing the stabilizing contribution of braked wheelchair wheels

The RF-WPS designer has no control over the combined mass, effectiveness of brakes, or tyre materials of wheelchairs that use an RF-WPS on a public transport vehicle. The designer does have control over the type of material used for the floor covering of the WPS. The friction force generated by the braked wheelchair is directly related to the coefficient of friction between the wheelchair tyre material and the selected floor material. In 5.3 it is stipulated that the floor material should have a coefficient of friction in the range of 0,65 to 0,8. Materials with a higher coefficient will generate higher stabilizing forces at the wheel-floor interface. While the designer can maximize the movement-resisting (stabilizing) forces through a wise choice of slip-resistant floor materials, other structures or devices can also help to prevent undesirable movement of the occupied wheelchair.

E.6 Surrogate test bases

Annex D contains the design specifications for both a surrogate manual wheelchair and a surrogate scooter. Annex B movement tests should be done using both Annex D surrogate bases using a 75 kg male dummy that conforms to ISO 7176-11. The surrogate bases can be designed as two separate bases or as a single base that is configurable into either of the two bases. In both cases, the surrogate bases should comply with the critical specifications contained in D.3.1 and D.3.2.

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E.7 Other injury prevention

All components of the RF-WPS that might come into contact with the wheelchair user or other sitting or standing passengers should be covered by impact absorbing materials as specified in 4.1 e).

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Bibliography

[1] BLOWER, D., WOODROOFFE, J. and SCHNEIDER, L.W., (2005) *Characterization of Transit-Bus Accidents Resulting in Passenger Injuries for Use in Developing Alternative Methods for Transporting Wheelchair-Seated Travelers*. Proceedings of the 2005 International Truck & Bus Safety & Security Symposium

[2] ZAWORSKI, K., ZAWORSKI, J., Assessment of Rear Facing Wheelchair Accommodation on Bus Rapid Transit, Transit IDEA Project 38, Transportation Research Board, National Academies, Washington D.C., January, 2005

[3] RUTENBURG, U. et al., Assessment of Low-floor Transit Bus G Forces on Rearward-facing Wheelchair Securement Systems, Transportation Development Centre, Transport Canada, March 2005

[4] GLAESER, K., Rollstuhle in gebremsten Transportmitteln—grenzen für Kippen oder Rutschen, *Die Sicherung Von Rollstuhlfahrern In Linienbussen Und Behindertentransportwagen*, Bundesminister Für Verkehr Von Der Bundesanstalt Für Strassenwesen, Heft 88, 1992, pp. 23-30

[5] KASTEN, P., Fahrgastfreundliche und behindertengerechte Linienbusse — Beschleunigungsmessungen an Rollstühlen in Linienbussen, *Die Sicherung Von Rollstuhlfahrern In Linienbussen Und Behindertentransportwagen*, Bundesminister Für Verkehr Von Der Bundesanstalt Für Strassenwesen, Heft 88, 1992, pp. 31-66

[6] European Community CO-operation for Science and Techniques (COST), Low-Floor Buses, Final Report COST 322, Report No. EUR 16707 EN, Brussels, Belgium, 1995

[7] Transportation Research Board, Transit Cooperative Research Program, TCRP Synthesis Report, Use of Rearward-facing Position for Common Wheelchairs on Transit Buses, Washington, DC, 2003

[8] Cost Action 349, Accessibility of Coaches and long Distance Buses for People with Reduced Mobility, Final Scientific Report, European Cooperation in the field of Scientific and Technical Research (COST), October 2005

[9] UK Department of Transport, TRL Report: The safety of wheelchair occupants in road passenger vehicles, 2003

[10] MERCER, W., Demonstration of Dynamic Response of Passengers, Personal Mobility Devices, and Their Riders in a Low Floor Bus, Ministry of Transportation of Ontario, Toronto, Ontario, Canada, 1995

[11] Cleveland Clinic, Progress Report: Personal mobility aid securement and passenger restraint on transit vehicles. 1994, The Cleveland Clinic Foundation, Invacare Corporation: Cleveland

[12] ECE R 21, Uniform provisions concerning the approval of vehicles with regard to their interior fittings, Revision 2 (+ Amendment 2), 25 March 2003

[13] FMVSS 201, Occupant protection in interior impact, Federal Motor Vehicle Safety Standards, 49 CFR part 571.201, 1 October 2004

[14] ISO 7193, *Wheelchairs — Maximum overall dimensions*

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

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