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ISO 7176-11

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Wheelchairs —

Part 11: Test dummies

Fauteuils roulants —

Partie 11: Mannequins d'essai

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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 7176-11 was prepared by Technical Committee ISO/TC 173, *Assistive products for persons with disability*, Subcommittee SC 1, *Wheelchairs*.

This second edition cancels and replaces the first edition (ISO 7176-11:1992), which has been technically revised.

ISO 7176 consists of the following parts, under the general title *Wheelchairs*:

— *Part 1: Determination of static stability*

— *Part 2: Determination of dynamic stability of electric wheelchairs*

— *Part 3: Determination of effectiveness of brakes*

— *Part 4: Energy consumption of electric wheelchairs and scooters for determination of theoretical distance range*

— *Part 5: Determination of dimensions, mass and manoeuvring space*

— *Part 6: Determination of maximum speed, acceleration and deceleration of electric wheelchairs*

— *Part 7: Measurement of seating and wheel dimensions*

— *Part 8: Requirements and test methods for static, impact and fatigue strengths*

— *Part 9: Climatic tests for electric wheelchairs*

— *Part 10: Determination of obstacle-climbing ability of electrically powered wheelchairs*

— *Part 11: Test dummies*

— *Part 13: Determination of coefficient of friction of test surfaces*

— *Part 14: Power and control systems for electrically powered wheelchairs and scooters — Requirements and test methods*

— *Part 15: Requirements for information disclosure, documentation and labelling*

— *Part 16: Resistance to ignition of postural support devices*

— *Part 19: Wheeled mobility devices for use as seats in motor vehicles*

— *Part 21: Requirements and test methods for electromagnetic compatibility of electrically powered wheelchairs and scooters, and battery chargers*

— *Part 22: Set-up procedures*

— *Part 23: Requirements and test methods for attendant-operated stair-climbing devices*

— *Part 24: Requirements and test methods for user-operated stair-climbing devices*

— *Part 25: Batteries and chargers for powered wheelchairs - Requirements and test methods*

— *Part 26: Vocabulary*

— *Part 28: Requirements and test methods for stair-climbing devices*

A technical report (ISO/TR 13570-1) is also available giving a simplified explanation of the parts of ISO 7176.

Introduction

When testing wheelchairs it is often necessary to simulate a human occupant. Test dummies designed for motor vehicle crash testing are used where it is appropriate to do so, but they are expensive. A need exists for an affordable alternative. The first edition of ISO 7176-11, published in 1992, specified a set of test dummies that would be suitable for most wheelchair tests. The designs were intended to provide an appropriate total load mass, to approximate the mass distribution of a human occupant, to avoid unrepresentative damage to the wheelchair, to be durable and to be inexpensive to manufacture.

Experience of using the first edition of ISO 7176-11 and related test dummy specifications showed that test dummies did not always provide repeatable results, particularly for static and dynamic stability tests. Several areas for improvement have been identified: to extend the mass range, to enable a test dummy of arbitrary mass to be made, to enable verification of the location of the overall centre of mass and to enable adjustment of the position of the overall centre of mass. This second edition of ISO 7176-11 is intended to provide these improvements.

The ability to measure and adjust the location of the overall centre of mass eliminates the need to specify many aspects of test dummy design. It also allows for the mass of a test dummy to be altered as needed.

The formulae provided in this part of ISO 7176 for the location of the overall centre of mass are based on data and research available to date. It is expected that the range of masses and the mass distribution of wheelchair occupants will change over time. Revisions can be made to this part of ISO 7176 to reflect such changes as and when data becomes available.

Wheelchairs —

Part 11: Test dummies

1 Scope

This part of ISO 7176 specifies requirements for test dummies of any mass greater than or equal to 25 kg, to be used in the evaluation of wheelchairs. This part of ISO 7176 provides formulae that specify the location of the overall centre of mass of test dummies, the masses of the segments that comprise the test dummies and the locations of pivots that connect the segments. It also specifies the characteristics of loading pads that support the segments.

The specified location for the centre of mass is approximately the same as that of a human being of the corresponding mass when seated in a wheelchair, and also, for masses up to 100 kg, when in a standing position in a stand-up wheelchair. This part of ISO 7176 does not attempt to represent the mass distribution of a person with limb atrophy or amputation. This part of ISO 7176 is intended to enable the construction of test dummies that will produce comparable results for stability, performance and durability testing of manual wheelchairs and electrically powered wheelchairs, including scooters.

This part of ISO 7176 also includes informative tables of mass and locations of centre of mass, which are derived from the formulae, corresponding to example test dummy masses up to 300 kg in 25 kg increments.

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 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
forward location
distance forward from the back support reference plane, measured perpendicular to it

NOTE For the purposes of this document, the back support reference plane is equivalent to the front surface of the test fixture's back support when the test dummy is fitted in the test fixture (see 5.1).

3.2
height
distance upward from the seat reference plane, measured perpendicular to it

NOTE For the purposes of this document, the seat reference plane is equivalent to the upper surface of the test fixture's seat when the test dummy is fitted in the test fixture (see 5.1).

3.3
loading pad
component, consisting of a loading plate and a foam cushion, intended to transfer the load between a segment of the test dummy and the wheelchair under test

NOTE The foam cushion is the part of the loading pad intended to make contact with the wheelchair.

3.4
loading plate
rigid flat plate for use in a loading pad

3.5
lower leg segment
segment of the test dummy that represents the lower legs and feet of a human being

3.6
overall centre of mass
centre of mass of the whole test dummy

3.7
test dummy
device used to represent the mass and mass distribution of a human being, for the purpose of testing a wheelchair

3.8
thigh segment
segment of the test dummy that represents the upper legs and buttocks of a human being

3.9
torso segment
segment of the test dummy that represents the torso, head and arms of a human being

4 Symbols and abbreviated terms

CoM	centre of mass
m_{dummy}	nominal mass of the test dummy
m_{leg}	mass of the lower leg segment
m_{thigh}	mass of the thigh segment
m_{torso}	mass of the torso segment
l_{thigh}	distance from the hip pivot axis to the knee pivot axis
l_{leg}	distance from the knee pivot axis to the ankle pivot axis
x_{ankle}	forward location of the ankle pivot axis
x_{dummy}	forward location of the overall centre of mass
x_{hip}	forward location of the hip pivot axis
x_{knee}	forward location of the knee pivot axis
x_{leg}	forward location of the CoM of the lower leg segment
x_{thigh}	forward location of the CoM of the thigh segment
x_{torso}	forward location of the CoM of the torso segment
y_{ankle}	height of the ankle pivot axis
y_{dummy}	height of the overall centre of mass
y_{hip}	height of the hip pivot axis
y_{knee}	height of the knee pivot axis
y_{leg}	height of the CoM of the lower leg segment
y_{torso}	height of the CoM of the torso segment
y_{thigh}	height of the CoM of the thigh segment

NOTE In this part of ISO 7176, all linear dimensions are expressed in millimetres and all masses are expressed in kilograms.

5 Test equipment

5.1 Test fixture, for measuring the location of the overall centre of mass. The test fixture shall:

a) conform to the dimensions shown in Figure 1;

b) be constructed so that the seat and back support are perpendicular within ± 0,5°;

c) be constructed so that the foot support and seat are parallel within ± 0,5°;

d) have provision for the height of the foot support to be adjusted within the range shown in Figure 1 or include rigid spacers to be placed on the foot support, such that the upper surface of the uppermost

rigid spacer can be located within the range shown in Figure 1 and such that it is parallel to the seat as specified in b);

e) include means to secure the torso segment and thigh segment so that the torso loading pad and thigh loading pad are in contact with the back support and seat respectively, with the foam cushions compressed;

f) include a means to secure the lower leg segment so that the foot loading pads are in contact with the foot support or uppermost rigid spacer as specified in d);

g) have mass not exceeding 28 kg or 15 % of m_{dummy}, whichever is greater;

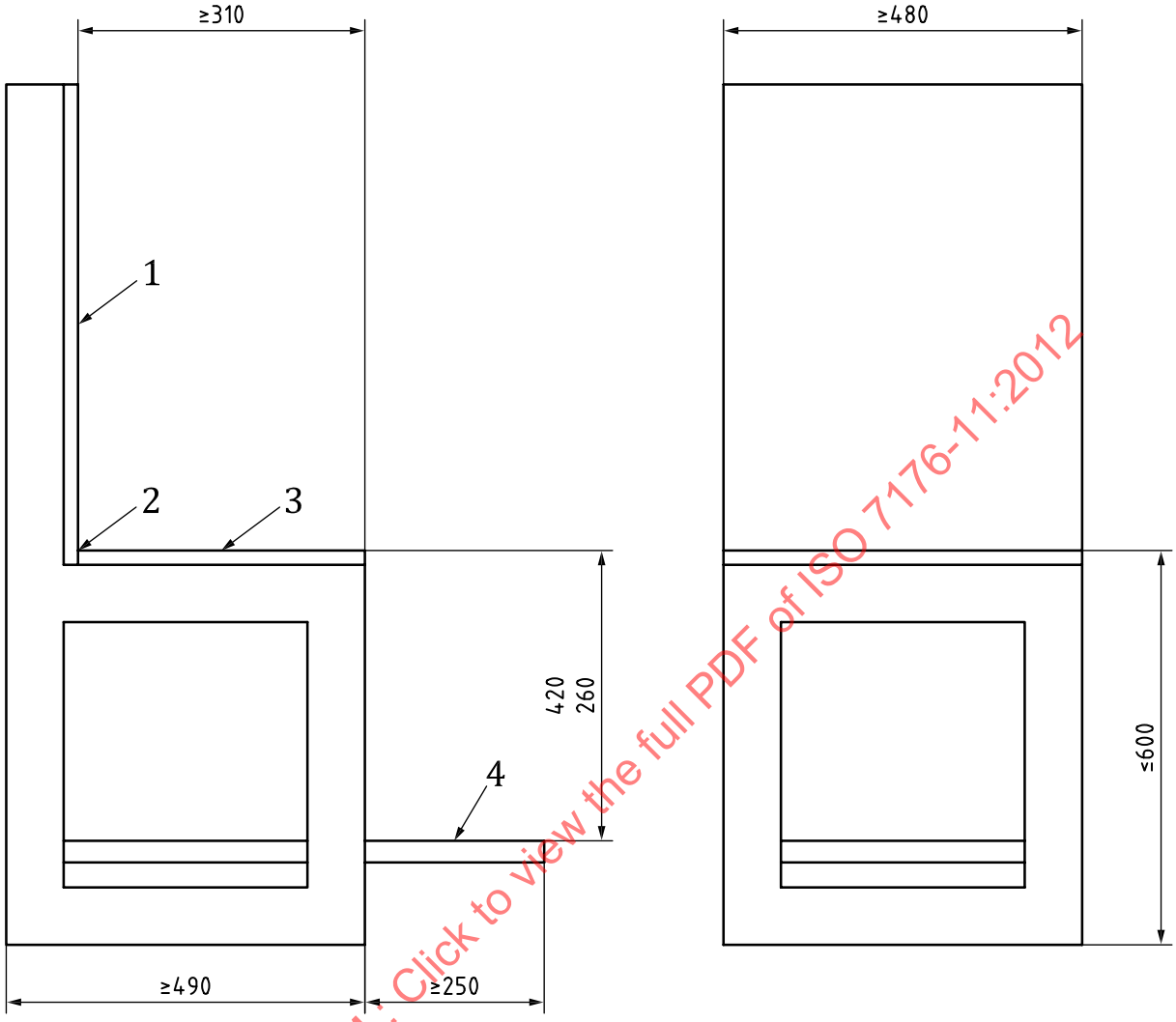
h) be constructed with sufficient stiffness that during use no dimensional change exceeds 5 mm;

i) if necessary, be fitted with means for manual handling, such as handles.

The recommended seat depth is 310 mm for 25 kg test dummies, and 375 mm for test dummies of 50 kg and above.

Plywood specified for structural use in unprotected exterior conditions, of thickness 19 mm, and solid timber specified for structural use, of thickness 60 mm, is suitable for use in the construction of test fixtures for test dummies of 125 kg or less.

Dimensions in millimetres



Key

1 back support
2 seat reference point
3 seat
4 foot support

Figure 1 — Test fixture

5.2 Inclinometer or **plumb line**, for measuring the angle of inclination of the test fixture (5.1) with an uncertainty that does not exceed 0,2°, when using the balance method specified in Annex A.

5.3 Scales, to measure the combined weight of the test fixture (5.1) and the test dummy, with an uncertainty that does not exceed 0,2 kg.

5.4 Test surface, constructed of a hard material, such as a concrete or hardwood platform, which does not deviate from level by more than 2 mm within the area occupied by the test fixture (5.1) when using either method specified in Annex A.

6 Materials

6.1 General

The material and construction of the test dummy shall be selected so that the dummy meets the requirements of mass and mass distribution specified in 7.5 and 7.6 and so that it does not distort beyond the specified limits under the stresses it will encounter during use.

NOTE 1 Steel, nominally 6 mm thick, aluminium, nominally 12 mm thick, and plywood specified for structural use in unprotected exterior conditions, nominally 19 mm thick, have all been used successfully for test dummy segments.

NOTE 2 Plywood, nominally 19 mm thick, has been used successfully for loading plates.

6.2 Rigid spacers

Any material used to position the overall centre of mass shall meet the requirements specified in 6.1.

NOTE Lightweight material, such as expanded polystyrene rigid foam insulation for domestic purposes, has been successfully used for rigid spacers.

6.3 Foam cushions

Foam cushions for loading pads shall be made of material that compresses to (15 ± 3) mm when tested as follows.

Conduct the test at an ambient temperature of (20 ± 5) °C.

Prepare a homogeneous test sample (i.e. one with no surface 'skinning', such as from a manufacturing process) of thickness (30 ± 5) mm, cut to an area of (140 000 ± 4 000) mm^2, with the minimum dimension of its large surface no smaller than 300 mm.

Place the sample with one of its large surfaces on a flat surface. Using a flat plate, apply to the upper surface of the sample a uniformly distributed force of (920 ± 20) N perpendicular to the lower surface of the sample, for (60 ± 10) s.

NOTE 1 The area of the sample corresponds to the area of the thigh loading plate of a 100 kg test dummy. The force applied corresponds to the combined weight of the torso segment and thigh segment of a 100 kg test dummy.

NOTE 2 The test sample may be built up from sheets of foam that are below the required thickness.

NOTE 3 Some closed-cell foam that has an indentation hardness index equal to (750 ± 250) N when measured as specified in ISO 2439, method A (for PVC, polyurethane and latex foams of the open-cell type) is suitable.

7 Specifications

7.1 General

7.1.1 A test dummy consists of three segments: the torso segment, thigh segment and lower leg segment. The segments have associated loading pads and may also have rigid spacers between the segments and loading pads. The lower leg segment may have either one or two leg members. Typically, the torso segment and thigh segment each consists of a frame loaded with weights, which are added, removed or repositioned to adjust the mass and location of CoM of the segment.

The foam cushions of the loading pads should be the only parts of the test dummy that come into contact with the wheelchair under test. The dimensions of the torso, thigh and lower leg segments should be

selected so that they do not project beyond the profile of any loading plate that can be used with them in any way that might cause the segments to come into contact with the wheelchair under test.

NOTE 1 The loading plates specified in this part of ISO 7176 are expected to be suitable for testing most wheelchairs, but might be unsuitable for testing some particular wheelchairs. It is anticipated that a future revision of ISO 7176-22 will deal with these situations by providing instructions for selecting alternative loading plates, from the ones specified in this part of ISO 7176, that are more appropriate.

NOTE 2 The frames of the torso and thigh segments should be of appropriate size to allow final adjustment of the position of the overall centre of mass by adding or removing rigid spacers between the frame and the associated loading plate.

NOTE 3 A suitable depth for the frames of the torso and thigh segments is 100 mm.

7.1.2 The torso segment and thigh segment shall be connected by hip pivots. The thigh segment and lower leg segment shall be connected by knee pivots. The lower leg member(s) and the feet shall be connected by ankle pivots. The pivots shall provide a range of rotation that accommodates all postures likely during use.

7.1.3 When determining the mass and location of CoM of each segment, the mass of the associated loading pad(s) and rigid spacer(s) shall be included. The mass of the hip pivots and knee pivots shall be included in the thigh segment and the mass of the ankle pivots shall be included in the lower leg segment.

7.1.4 If the lower leg segment has two separate lower leg members, the knee pivots for the lower leg members shall rotate independently and allow lateral placement of the lower leg members as necessary to place the foot loading pads on the foot support(s) of the wheelchair under test. Regardless of the number of lower leg members, the lower leg segment shall have two feet.

Unless otherwise specified, a lower leg segment with a single leg member may be used when testing a wheelchair with a one-piece foot support.

7.1.5 The feet of the test dummy consist of the foot loading pads, together with all components connecting the foot loading plates to the ankle pivots. The feet are part of the lower leg segment.

7.2 Location of pivots

NOTE These dimensions are derived from WHO growth charts, DIN 33402-2 and X 35-002.

7.2.1 x_{hip} shall be (78 ± 25) mm.

7.2.2 y_{hip} shall be (78 ± 25) mm.

Where the test dummy is intended to stand, x_{hip} should be equal to y_{hip}.

7.2.3 y_{knee} shall be (78 ± 25) mm.

7.2.4 The nominal value of l_{thigh} shall be as shown in Table 1.

Table 1 — Nominal values of l_{thigh} and l_{leg}

Dummy mass range kg	**l_{thigh} (nominal)** mm	**l_{leg} (nominal)** mm
$25 \leq m_{dummy} < 50$	$4{,}2\ m_{dummy} + 205$[a]	$5{,}2\ m_{dummy} + 160$[a]
$50 \leq m_{dummy}$	415	420

[a] These formulae relate the numerical value of linear dimensions, expressed in millimetres, to the numerical value of dummy mass, expressed in kilograms.

The distance between the knee pivots and the hip pivots shall be adjustable. The range of adjustment shall include the nominal value of l_{thigh} and a value 75 mm greater. If the adjustment is incremental, the increments should not be greater than 15 mm. The means for adjustment shall be locked whenever the test dummy is in use, while allowing the hip pivots and knee pivots to rotate freely.

NOTE The requirement for adjustment is to allow the test dummy to be adjusted to fit a particular wheelchair.

7.2.5 The nominal value of l_{leg} shall be as shown in Table 1.

The distance between the knee pivots and the ankle pivots shall be adjustable to allow the foot loading pads to be positioning on the foot supports of a wheelchair. Provision shall be made to allow the test dummy to be used with the means for adjustment locked or unlocked, while allowing the knee and ankle pivots to rotate freely in either condition.

NOTE The means for adjustment would be locked to allow the lower leg segment to support the mass of the other segments, for example to use the test dummy in a standing position. The means would be unlocked, for example, in wheelchair fatigue testing when the test dummy is used in the seated position.

7.2.6 The forward position of the ankle pivots relative to the rear of the foot loading plates shall be (70 ± 15) mm.

7.2.7 The relative height of the ankle pivots above the bottom of the foot loading plates shall be (60 ± 15) mm.

7.3 Loading pads

7.3.1 Loading pads transmit loads between the test dummy and the wheelchair under test. They are components of the test dummy, but they may be removable.

7.3.2 A torso loading pad shall be fitted at the rear of the torso segment. The foam cushion of the torso loading pad shall have the property specified in 6.3 and shall be of unloaded thickness (30 ± 5) mm.

7.3.3 A thigh loading pad shall be fitted to the underside of the thigh segment. The foam cushion of the thigh loading pad shall have the property specified in 6.3 and shall be of unloaded thickness (30 ± 5) mm.

7.3.4 The distance between the seat reference plane and the lowest point of the torso loading plate shall be between 25 mm and 80 mm.

The distance between the back support reference plane and the rearmost point of the thigh loading plate shall be between 25 mm and 80 mm.

NOTE If the test dummy is to be used in a standing position, it is likely that the positions of the torso and thigh loading plates will be set close to the maximum limits specified in 7.3.4 to avoid the loading plates clashing.

7.3.5 Unless otherwise specified, foot loading plates may be used without foam cushions. Where foam cushions are used, they shall have the property specified in 6.3 or harder, and shall have unloaded thickness not greater than 5 mm.

7.3.6 Dimensions for loading plates are shown in Tables 2 and 3 and Figures 2, 3 and 4. Unless otherwise specified, loading plates shall be selected for the applicable dummy mass in accordance with Tables 2 and 3.

NOTE The figures do not show the foam cushions.

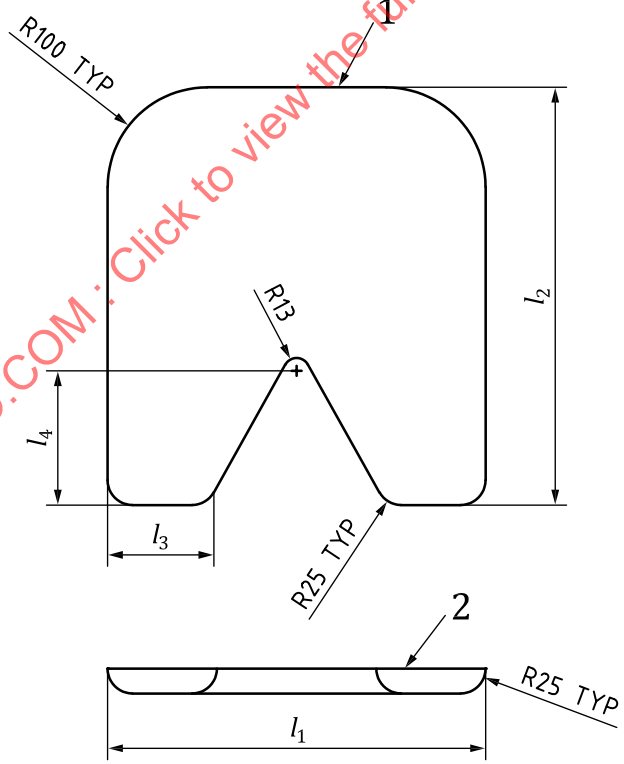
Table 2 — Dimensions of thigh loading plates

Dummy mass range kg	l_1 mm	l_2 mm	l_3 mm	l_4 mm
$25 \leq m_{dummy} < 50$	200	300	80	150
$50 \leq m_{dummy} < 75$	260	350	100	175
$75 \leq m_{dummy} < 100$	320	380	105	160
$100 \leq m_{dummy} < 125$	380	420	110	135
$125 \leq m_{dummy} < 150$	430	440	115	110
$150 \leq m_{dummy} < 175$	480	440	120	100
$175 \leq m_{dummy} < 200$	530	440	120	100
$200 \leq m_{dummy} < 250$	570	440	120	100
$250 \leq m_{dummy} < 300$	630	440	120	100
$300 \leq m_{dummy}$	680	440	120	100

The tolerance for all linear dimensions shall be ± 15 mm.

NOTE The dimensions are derived from seating dimensions typically provided for wheelchairs in each specified occupant mass range.

Dimensions in millimetres



Key

1 rear edge

2 upper face

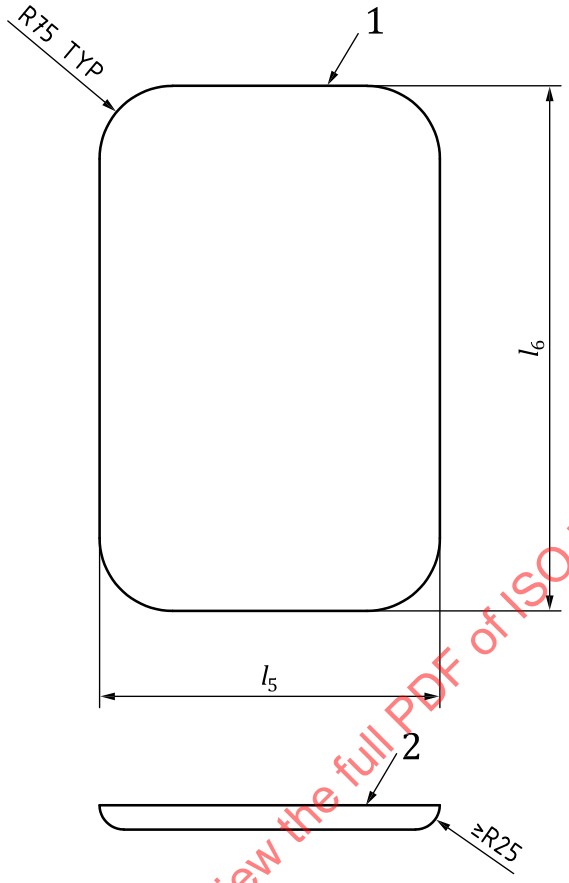
Tolerances on radii shall be ± 5 mm.

Figure 2 — Thigh loading plate

Table 3 — Dimensions of torso and foot loading plates

Dummy mass range kg	Torso loading plate		Foot loading plate	
	l_5 mm	l_6 mm	l_7 mm	l_8 mm
$25 \leq m_{dummy} < 50$	180	380	80	200
$50 \leq m_{dummy} < 75$	230	440	100	300
$75 \leq m_{dummy} < 100$	290	490	100	300
$100 \leq m_{dummy} < 125$	350	540	100	300
$125 \leq m_{dummy} < 150$	400	540	100	300
$150 \leq m_{dummy} < 175$	450	540	100	300
$175 \leq m_{dummy} < 200$	500	540	100	300
$200 \leq m_{dummy} < 250$	540	540	100	300
$250 \leq m_{dummy} < 300$	600	540	100	300
$300 \leq m_{dummy}$	650	540	100	300
The tolerance for all linear dimensions shall be ± 15 mm.				
NOTE The dimensions are derived from seating dimensions typically provided for wheelchairs in each specified occupant mass range.				

Dimensions in millimetres



Key

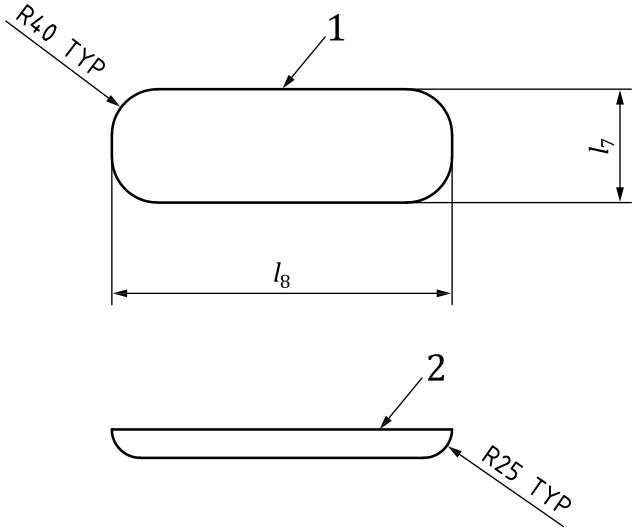
1 upper edge

2 forward face

Tolerances on radii shall be ± 5 mm.

Figure 3 — Torso loading plate

Dimensions in millimetres



Key

1 lateral edge
2 upper face

Tolerances on radii shall be ± 5 mm.

Figure 4 — Foot loading plate

7.4 Adjustment of location of overall centre of mass

7.4.1 For test dummies of mass not greater than 200 kg, one of the procedures specified in Annex A shall be used to verify the location of the overall centre of mass. For test dummies of mass greater than 200 kg, the location of the overall centre of mass shall be verified by using one of the procedures specified in Annex A or by using a suitable alternative method.

NOTE Two alternative methods considered acceptable would be a) using the wheelchair under test instead of the test fixture; b) calculation of the location of the overall CoM based on the measured location of the CoM of a test dummy of mass less than 200 kg, and the location(s) and mass(es) of additional load(s).

7.4.2 The forward location and height of the overall centre of mass may be adjusted using any method such that the test dummy meets the requirements specified in Clause 7.

EXAMPLE Placing a rigid spacer of the necessary thickness between the torso segment and its loading pad to adjust the forward location of the overall CoM, or between the thigh segment and its loading pad to adjust the height of the overall CoM.

7.5 Masses of segments

The masses of the segments shall be as specified in Table 4.

The tolerance for the overall mass of the test dummy shall be $m_{\text{dummy}}\ ^{+5}_{-2}$ kg.

Table 4 — Masses of segments

Masses in kilograms

Dummy mass range	m_{torso}	m_{thigh}	m_{leg}
$25 \leq m_{dummy} < 50$	$(0{,}66\ m_{dummy} - 3) \pm 3$	$(0{,}34\ m_{dummy} - 2) \pm 3$	5 ± 1
$50 \leq m_{dummy} < 100$	$(0{,}66\ m_{dummy} - 5) \pm 3$	$(0{,}34\ m_{dummy} - 3) \pm 3$	8 ± 1
$100 \leq m_{dummy}$	61 ± 3	$(m_{dummy} - 69) \pm 3$	8 ± 1

7.6 Locations of centres of mass

7.6.1 Location of overall centre of mass

7.6.1.1 The overall centre of mass shall not be more than 25 mm from the median plane of the test dummy.

NOTE This may be verified by analysis.

7.6.1.2 When the test dummy is configured as specified in A.1.2, x_{dummy} and y_{dummy} shall be as specified in Table 5 (see also Figure 5). Annex B provides numerical values for these quantities for test dummies up to 300 kg in 25 kg increments.

Table 5 — Location of overall centre of mass

Dummy mass range kg	x_{dummy}[a] mm	y_{dummy}[a] mm
$25 \leq m_{dummy} < 100$	$(0{,}62\ m_{dummy} + 173) \pm 25$	$(0{,}77\ m_{dummy} + 159) \pm 25$
$100 \leq m_{dummy}$	$(0{,}62\ m_{dummy} + 173) \pm 25$	$(-0{,}28\ m_{dummy} + 264) \pm 25$

[a] These formulae relate the numerical value of linear dimensions, expressed in millimetres, to the numerical value of dummy mass, expressed in kilograms.

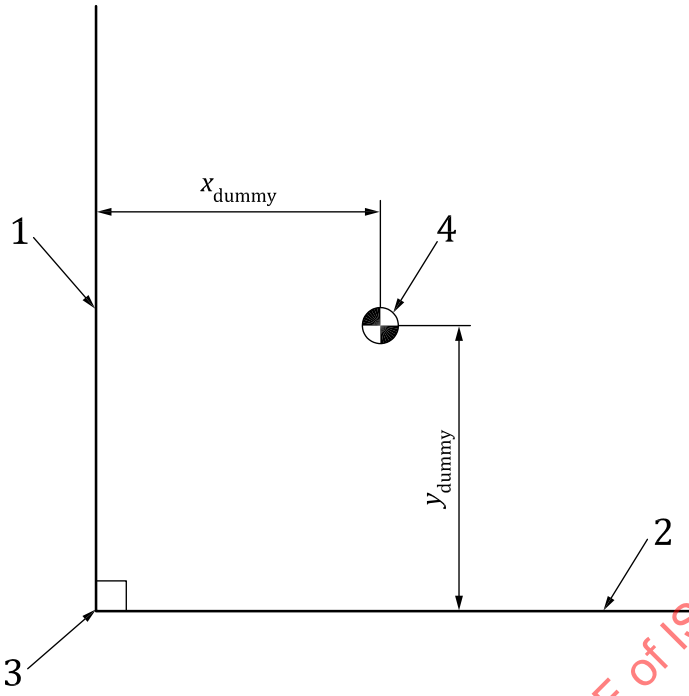
7.6.2 Recommended locations for centres of mass of segments

The recommended locations for the centres of mass of the torso, thigh and lower leg segments, when the test dummy is configured as specified in A.1.2, are given in Tables 6, 7 and 8 (see also Figure 6). Annex C provides numerical values for the nominal mass and recommended locations of centre of mass of the torso, thigh and lower leg segments for test dummies up to 300 kg in 25 kg increments.

NOTE Requirements apply to the location of the overall centre of mass and the masses of the segments. Recommendations are provided for the locations of the centres of mass of the segments to assist test dummy constructors in achieving the required location for the overall centre of mass.

x_{thigh} should not change by more than 5 % when the distance between the knee pivots and hip pivots is adjusted over the range specified in 7.2.4.

The centre of mass of the lower leg segment shall lie within 50 mm of the plane defined by the knee pivot axis and the ankle pivot axis. When the distance between the knee pivots and ankle pivots is adjusted as specified in 7.2.5, any change in y_{leg} should not be greater than the change in l_{leg}.



Key

1 back support reference plane
2 seat reference plane
3 seat reference point
4 overall centre of mass

Figure 5 — Location of overall centre of mass

Table 6 — Recommended location for CoM of torso segment

Dummy mass range kg	x_{torso} mm	y_{torso} mm
$25 \leq m_{dummy} < 100$	$0{,}8\ m_{dummy} + 65$[a]	$m_{dummy} + 240$[a]
$100 \leq m_{dummy}$	145	340

[a] These formulae relate the numerical value of linear dimensions, expressed in millimetres, to the numerical value of dummy mass, expressed in kilograms.

7.7 Test dummies intended for use in a standing position

A test dummy for use in the standing position should be designed to allow the hip and knee pivots to rotate to the standing position, and provide lockable hip, knee and ankle joints. The thigh segment and lower leg segment, together with the hip, knee and ankle joints, will be subjected to greater loads than are applied to the corresponding parts of a test dummy used in the seated position. It is essential that they can withstand these loads. In addition, stronger containment of the mass in the thigh segment might be necessary.

NOTE Subclause 7.7 provides recommendations for test dummies intended to be used only in the standing position. The recommendations might not be sufficient for test dummies intended to move between a sitting position and a standing position when in use.

Table 7 — Recommended location for CoM of thigh segment

Dummy mass range kg	x_{thigh}[a] mm	y_{thigh}[a] mm
$25 \le m_{dummy} < 50$	$\frac{0{,}092\,m_{dummy}^{\,2} + 111{,}5\,m_{dummy} - 1220}{0{,}34\,m_{dummy} - 2}$	$\frac{0{,}11\,m_{dummy}^{\,2} + 16{,}6\,m_{dummy} + 880}{0{,}34\,m_{dummy} - 2}$
$50 \le m_{dummy} < 100$	$\frac{0{,}092\,m_{dummy}^{\,2} + 134{,}1\,m_{dummy} - 3619}{0{,}34\,m_{dummy} - 3}$	$\frac{0{,}11\,m_{dummy}^{\,2} + 5{,}6\,m_{dummy} + 2496}{0{,}34\,m_{dummy} - 3}$
$100 \le m_{dummy}$	$\frac{0{,}62\,m_{dummy}^{\,2} + 173\,m_{dummy} - 12789}{m_{dummy} - 69}$	$\frac{-0{,}28\,m_{dummy}^{\,2} + 264\,m_{dummy} - 19444}{m_{dummy} - 69}$

[a] These formulae relate the numerical value of linear dimensions, expressed in millimetres, to the numerical value of dummy mass, expressed in kilograms.

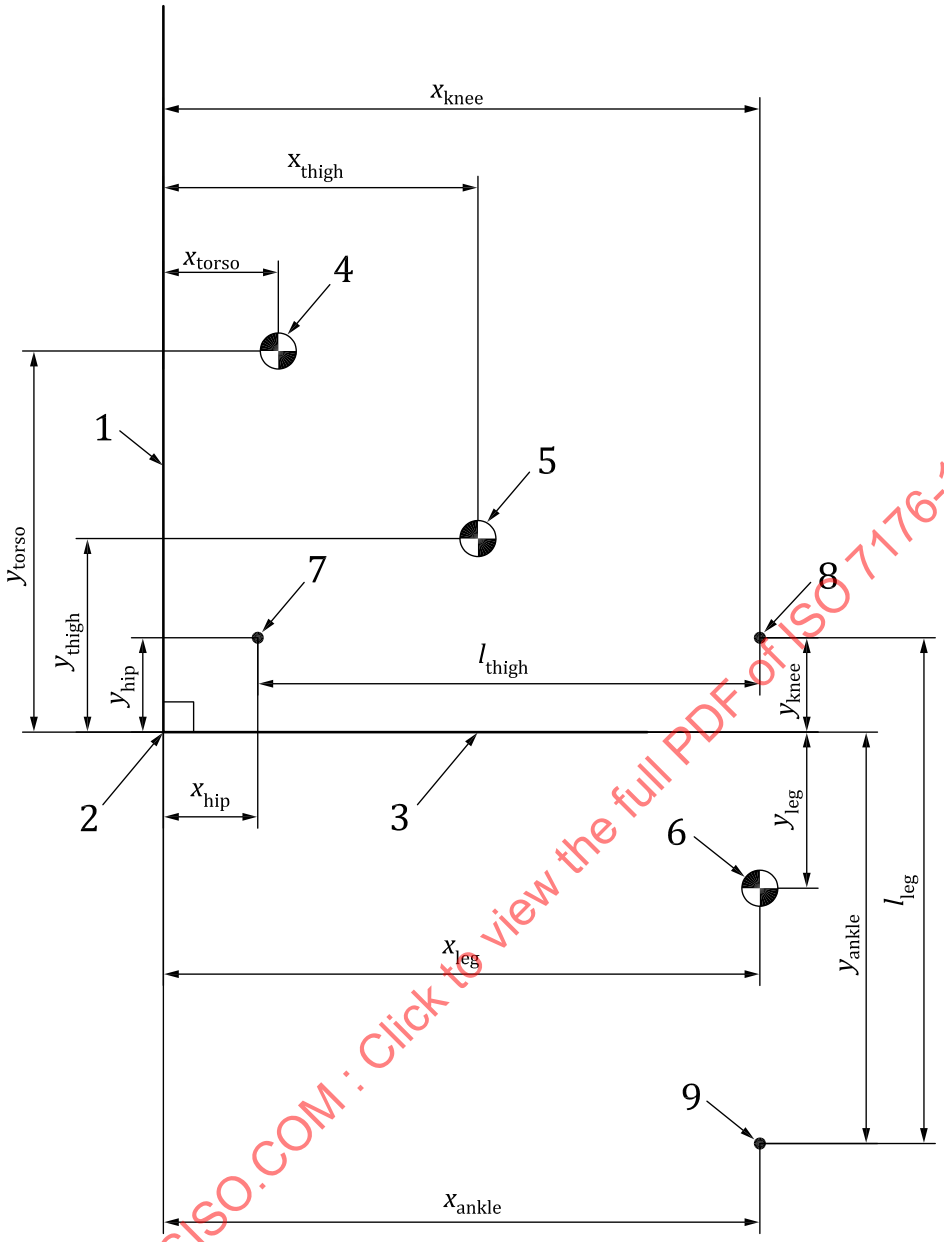
Table 8 — Recommended location for CoM of lower leg segment

Dummy mass range kg	x_{leg} mm	y_{leg} mm
$25 \le m_{dummy} < 50$	$4{,}2\,m_{dummy} + 283$[a]	$-2{,}6\,m_{dummy} - 32$[a]
$50 \le m_{dummy}$	493	-162

[a] These formulae relate the numerical value of linear dimensions, expressed in millimetres, to the numerical value of dummy mass, expressed in kilograms.

7.8 Examples of test dummy construction

Annex D contains illustrations of example test dummy constructions.



Key

1 back support reference plane
2 seat reference point
3 seat reference plane
4 torso segment CoM
5 thigh segment CoM
6 lower leg segment CoM
7 hip pivot axis
8 knee pivot axis
9 ankle pivot axis

Figure 6 — Locations of centres of mass of segments and pivot axes

Annex A
(normative)

Measurement of location of overall centre of mass

WARNING — These tests can be hazardous. It is essential that appropriate safety precautions be taken to protect test personnel.

A.1 Balance method

A.1.1 Principle

The balance method is the referee method for determination of the position of the overall CoM. The location of the centre of mass is determined from two balance points of the test fixture (see 5.1): one with the CoM of the test fixture stabilized above the forward edge of its base, and the other with the CoM stabilized above the rear edge of its base. The mass and location of CoM of the empty test fixture are measured first for reference. The test dummy is then fitted to the test fixture and the composite mass of the test dummy and test fixture, and the location of the composite CoM, are measured. The location of the overall CoM is calculated from the location of the composite CoM, the test dummy mass, and the mass and location of CoM of the empty test fixture.

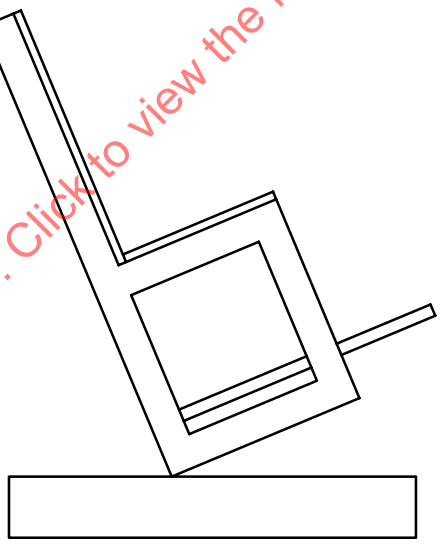


Figure A.1 — Empty test fixture tilted rearward

A.1.2 Procedure

A.1.2.1 Adjust l_{thigh} and l_{leg} to the nominal values ± 15 mm and then lock the means for adjustment. Adjust the height of the foot support or secure the appropriate rigid spacer(s) so that the feet of the test dummy will be supported when the test dummy is fitted to the test fixture as specified in A.1.2.3.

A.1.2.2 Use the procedure specified in A.1.3 to measure the mass and location of CoM of the empty test fixture.

A.1.2.3 Position the test dummy on the test fixture. Secure the test dummy segments so that the thickness of the foam cushions in the loading pads is not greater than half the unloaded thickness, and

so that no part of the test dummy moves relative to the test fixture during the test, other than due to compliance of the foam cushions. After securing the torso and thigh segments, but before securing the lower leg segment, adjust the position of the feet so that x_{ankle} is equal to x_{knee} ± 15 mm.

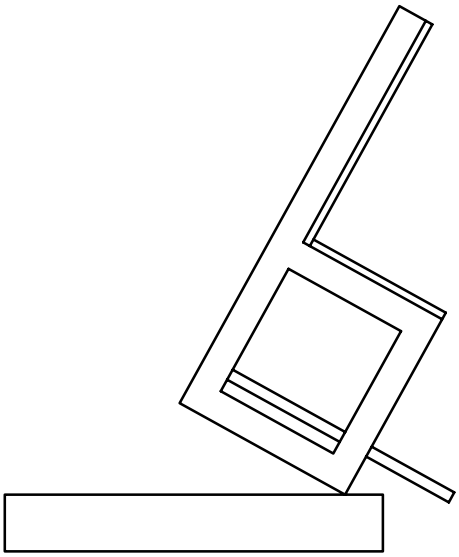


Figure A.2 — Empty test fixture tilted forward

A.1.2.4 Use the method specified in A.1.3 to measure the composite mass and location of CoM of the test dummy and test fixture.

A.1.2.5 Using the dimensions of the test fixture, express the location of CoM of the empty fixture and the location of CoM of the composite fixture and dummy relative to the seat reference point. Calculate the forward location and height of the overall CoM using Formula (A.3) and Formula (A.4).

A.1.3 Determination of CoM location

a) Weigh the test fixture using the scales (see 5.3), with the test dummy if fitted, and record its mass to the nearest 0,2 kg.

b) Place the test fixture on the test surface (see 5.4).

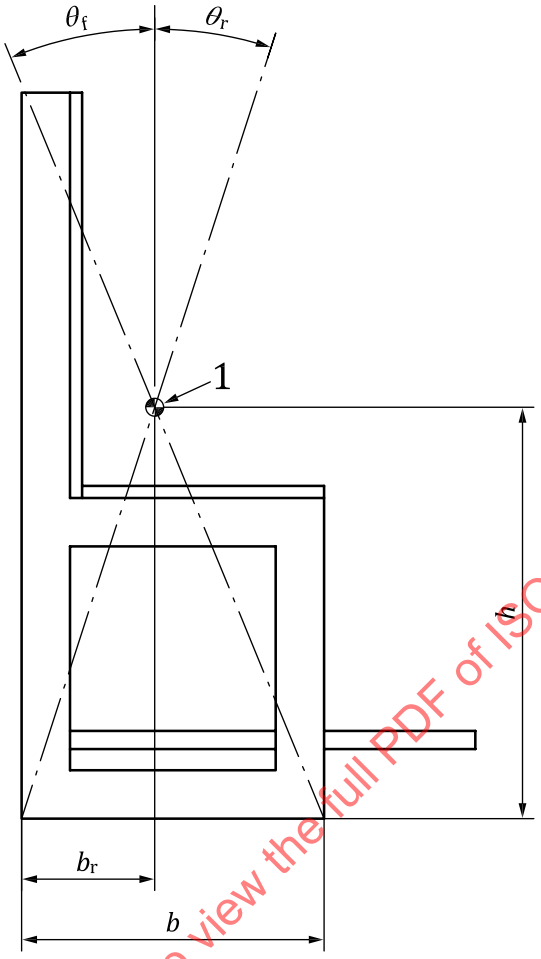
c) Tilt the test fixture rearward and stabilize it balanced on the rear edge of its base (see Figure A.1). Using the inclinometer (see 5.2), measure and record the angle of tilt of the test fixture θ_r to the nearest 0,2° or mark a plumb line on the side of the test fixture that intersects the rear edge of its base. Maintain the balanced position of the test fixture long enough to allow the inclinometer or plumb line to settle. A block or other suitable means for supporting the test fixture may be used.

d) Tilt the test fixture forward and stabilize it balanced on the front edge of its base (see Figure A.2). Measure and record the angle of tilt of the test fixture θ_f to the nearest 0,2° or mark a plumb line on the side of the test fixture that intersects the front edge of its base.

e) If using an inclinometer, repeat c) and d) a further two times and calculate and record the mean values of θ_f and θ_r to the nearest 0,2°.

f) If plumb lines have been marked on the side of the test fixture, the location of the CoM is their intersection.

g) If using an inclinometer, calculate the location of the CoM relative to the base of the test fixture using Formula (A.1) and Formula (A.2) (see also Figure A.3).



Key
1 centre of mass

Figure A.3 — Calculated values for balance method

A.1.4 Formulae

$$h = \frac{b}{\tan\theta_r + \tan\theta_f} \tag{A.1}$$

where

h is the height of the centre of mass relative to the base of the test fixture;

b is the distance between the front and rear edges of the base of the test fixture;

θ_r is the rearward balance angle;

θ_f is the forward balance angle.

$$b_r = h\tan\theta_r \tag{A.2}$$

where

b_r is the forward distance of the centre of mass relative to the rear edge of the test fixture.

$$x_a = \frac{x_c\left(m_a + m_f\right) - x_f m_f}{m_a} \tag{A.3}$$

where

x_a is the measured forward position of the overall centre of mass;

x_c is the measured forward position of the composite centre of mass;

m_a is the measured mass of the test dummy;

m_f is the measured mass of the test fixture;

x_f is the measured forward position of the CoM of the empty test fixture.

$$y_a = \frac{y_c\left(m_a + m_f\right) - y_f m_f}{m_a} \tag{A.4}$$

where

y_a is the measured height of the overall centre of mass;

y_c is the measured height of the composite centre of mass;

y_f is the measured height of the CoM of the empty test fixture.

A.2 Scale method

A.2.1 Principle

The test fixture is supported on two scales. The location of the centre of mass relative to the supporting points is calculated using moments. Since each measurement establishes the location of the centre of mass in one direction, the measurement is made twice, first with the test fixture upright and then with it lying on its back.

The mass and location of CoM of the empty test fixture are measured first for reference. The test dummy is then fitted to the test fixture and the composite mass of the test dummy and test fixture, and the location of the composite CoM, are measured. The location of the overall CoM is calculated from the location of the composite CoM, the test dummy mass, and the mass and location of CoM of the empty test fixture.

A.2.2 Procedure

A.2.2.1 Follow the instructions in A.1.2.1.

A.2.2.2 Use the procedure specified in A.2.3 to measure the mass and location of CoM of the empty test fixture.

A.2.2.3 Follow the instructions in A.1.2.3.

A.2.2.4 Use the method specified in A.2.3 to measure the composite mass and location of CoM of the test dummy and test fixture.

A.2.2.5 Follow the instructions in A.1.2.5.

A.2.3 Determination of CoM location

a) Place the test fixture, with the test dummy if fitted, on two scales (see 5.3) so that the front of the test fixture rests on one scale and the rear of the test fixture rests on the other scale (see Figure A.4). Use suitably narrow means to support the test fixture on the scales so that their centres can be determined to the nearest millimetre.

b) Record the readings of the scales and their sum to the nearest 0,2 kg. Measure the distance between the centres of the supports and record the value to the nearest millimetre.

c) Repeat a) and b), but placing the back of the test fixture on the scales (see Figure A.5).

d) Calculate the location of the CoM relative to the supporting points using Formula (A.5) (see also Figure A.6).

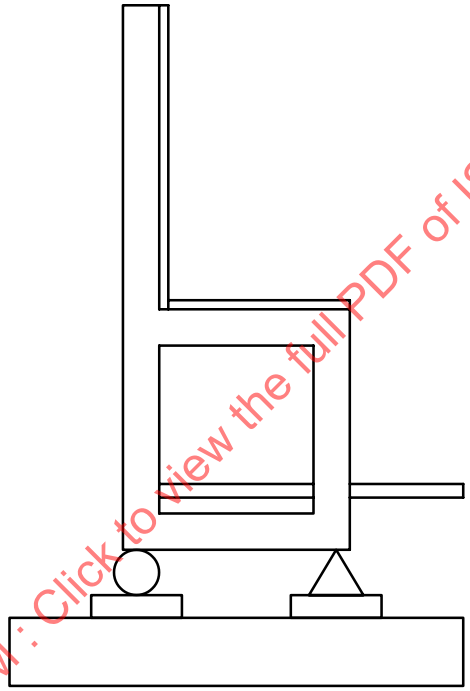


Figure A.4 — Empty test fixture standing on scales

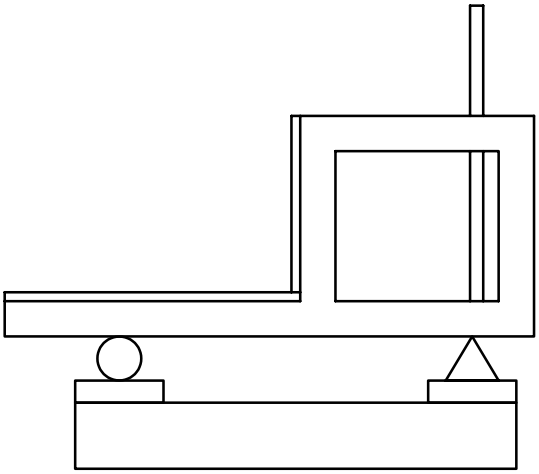
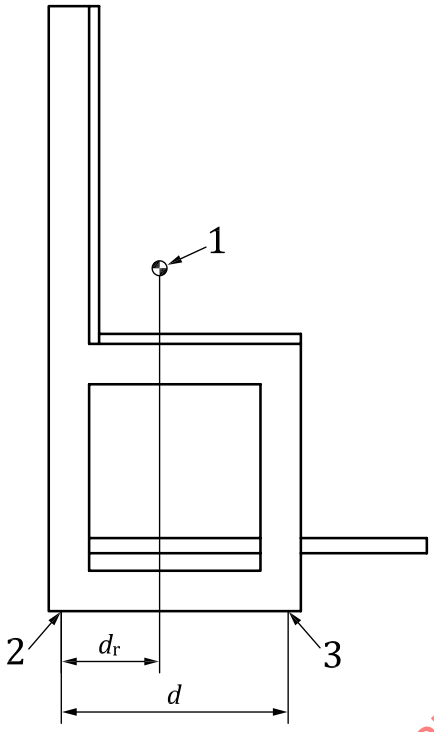


Figure A.5 — Empty test fixture lying on scales



Key

1 centre of mass
2 centre of rear support
3 centre of front support

NOTE The upright orientation of the test fixture is shown as an example.

Figure A.6 — Calculated value for scale method

A.2.4 Formula

$$d_r = \frac{d\,m_f}{m_f + m_r} \tag{A.5}$$

where

d is the distance between the centres of the supports;

d_r is the distance between the rear support and the centre of mass, measured parallel to d;

m_r is the reading of the rear scale;

m_f is the reading of the front scale.