
Wheelchair seating —

Part 2:

**Determination of physical and
mechanical characteristics of seat
cushions intended to manage tissue
integrity**

Sièges de fauteuils roulants —

*Partie 2: Détermination des caractéristiques physiques et mécaniques
des coussins d'assise et dispositifs de répartition de pression*



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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.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

For an explanation on the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT) see the following URL: www.iso.org/iso/foreword.html.

This document 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 16840-2:2007), significant elements of which has been technically revised.

A list of all the parts of ISO 16840 can be found on the ISO website.

Introduction

Wheelchair seating is a sub-speciality of rehabilitation services involving the selection and provision of wheelchair seating products that provide improved body support and injury prevention to the wheelchair user. Seating products are designed and manufactured to meet the needs of persons with varying types and degrees of disability. Some products, such as wheelchair cushions, are designed to manage tissue integrity for persons who are at risk or have pressure ulcers.

The tests described herein are intended to differentiate performance characteristics between cushions and are not appropriate for ranking or scoring cushions or for directly matching these characteristics with the requirements of individual users. The link to clinical efficacy, although implied, has not been validated. It is intended that this document will evolve when the evidence of clinical relevance is confirmed. This document specifically describes test methods that characterize the physical and mechanical properties of seat cushions. Test conditions simulate a symmetric anatomy and posture. The loads used in this document are based on the 50th percentile wheelchair user and are not intended to characterize any cushion properties under bariatric loading conditions or to assess the weight capacity of a cushion. [Annex B](#) provides typical ranges for the values measured. Flammability testing is subject to either ISO 7176-16 or, for postural support devices intended to manage tissue integrity, ISO 16840-10.

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Wheelchair seating —

Part 2:

Determination of physical and mechanical characteristics of seat cushions intended to manage tissue integrity

1 Scope

This document specifies apparatus, test methods and disclosure requirements for wheelchair seat cushions intended to maintain tissue integrity and prevent tissue trauma. Test conditions simulate a symmetric anatomy and posture and do not represent cushion performance for specific individual users. Loads are intended to represent those seen under the pelvis of a 50th percentile wheelchair user and are not intended to assess the weight capacity of the cushion or to characterize the cushion under bariatric loads. It is possible that not all test methods apply to existing and future cushion technologies. It does not include test methods or requirements for determining the fire resistance of cushions.

This document can also be applicable to tissue integrity management devices used as other support systems, as well as to cushions used in situations other than a wheelchair.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements 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 1302:2002, *Geometrical Product Specifications (GPS) — Indication of surface texture in technical product documentation*

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

ISO 9073-8, *Textiles — Test methods for nonwovens — Part 8: Determination of liquid strike-through time (simulated urine)*

ISO 10993-1, *Biological evaluation of medical devices — Part 1: Evaluation and testing within a risk management process*

ISO 16840-1, *Wheelchair seating — Part 1: Vocabulary, reference axis convention and measures for body segments, posture and postural support surfaces*

ISO/IEC Guide 98-3, *Uncertainty of measurement — Part 3: Guide to the expression of uncertainty in measurement (GUM:1995)*

FMVSS 209, *Standard No. 209; Seat Belt Assemblies. Federal Motor Vehicle Safety Standards, 49 CFR part 571.209, 1 October 1992*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 7176-26, ISO 16840-1 and the following apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at <https://www.iso.org/obp>

— IEC Electropedia: available at <http://www.electropedia.org/>

3.1 cushion loading indenter

CLI

apparatus that is used to apply indentation forces to a seat cushion to determine its support characteristics

Note 1 to entry: A cushion loading indenter can be comprised of loading components that are compliant or rigid.

3.1.1 loaded contour indenter

LCI

CLI ([3.1](#)) representing the ischial tuberosities and trochanters that is used to measure the ability of a seat cushion to contour under load

3.1.2 rigid cushion loading indenter

RCLI

CLI([3.1](#)) with a rigid exterior surface contour

3.1.2.1 impact damping rigid cushion loading indenter

IDRCLI

RCLI ([3.1.2](#)) that is instrumented and used to apply loads rapidly to the cushion to determine its capacity to absorb impact

3.2 base-points

most inferior points on the surface of a RCLI ([3.1.2](#)) when positioned for use

Note 1 to entry: The base-points on the RCLI represent the ischial tuberosities of the human pelvis.

3.3 loaded contour depth

maximum vertical change in shape arising from a load on a cushion's surface at the place designed for buttock loading

4 Symbols and abbreviated terms

a acceleration

5 Apparatus

5.1 Loading rig

A means of applying a vertical load of up to 830 N to a seat cushion and with the ability to measure displacement to ± 1 mm to the reference plane surface of the RCLI as specified in [Figure 1](#) so that the load remains normal to the reference plane throughout the test.

NOTE Use of an actuator to apply the load is not necessary to perform the recovery test ([Clause 10](#)). A vertical load may be applied to the RCLI with free weights for this test.

- a) The load is applied at the anterior-posterior location of load as specified in [Table A.1](#) in the range 0 N to 830 N as shown in [Figure 1](#).

NOTE The load accuracy required is specified in each test method.

- b) The seat cushion is supported on a rigid horizontal surface such that the base of the cushion does not flex during loading.

5.2 Rigid cushion loading indenter (RCLI)

A means of loading a cushion with a rigid exterior surface contour, which shall:

- a) be manufactured from a rigid material such as wood or fibreglass;
- b) meet the requirements specified in [Annex A](#).

5.3 Impact damping rigid cushion loading indenter (IDRCLI)

A means of loading a cushion using an RCLI with a uniformly distributed weight of $500 \text{ N} \pm 10 \text{ N}$ with an accelerometer attached to the reference plane at the location specified in [5.6 d\)](#) to measure the deceleration of the indenter as it suddenly loads the cushion.

5.4 Force application rig

A means of applying a vertical load in the range of 0 N to $225 \text{ N} \pm 5 \text{ N}$ to the loaded contour indenter.

5.5 Displacement gauge

A means of measuring the vertical displacement of the top surface of the RCLI during loading to an accuracy of $\pm 1 \text{ mm}$ in the range 0 mm to 200 mm .

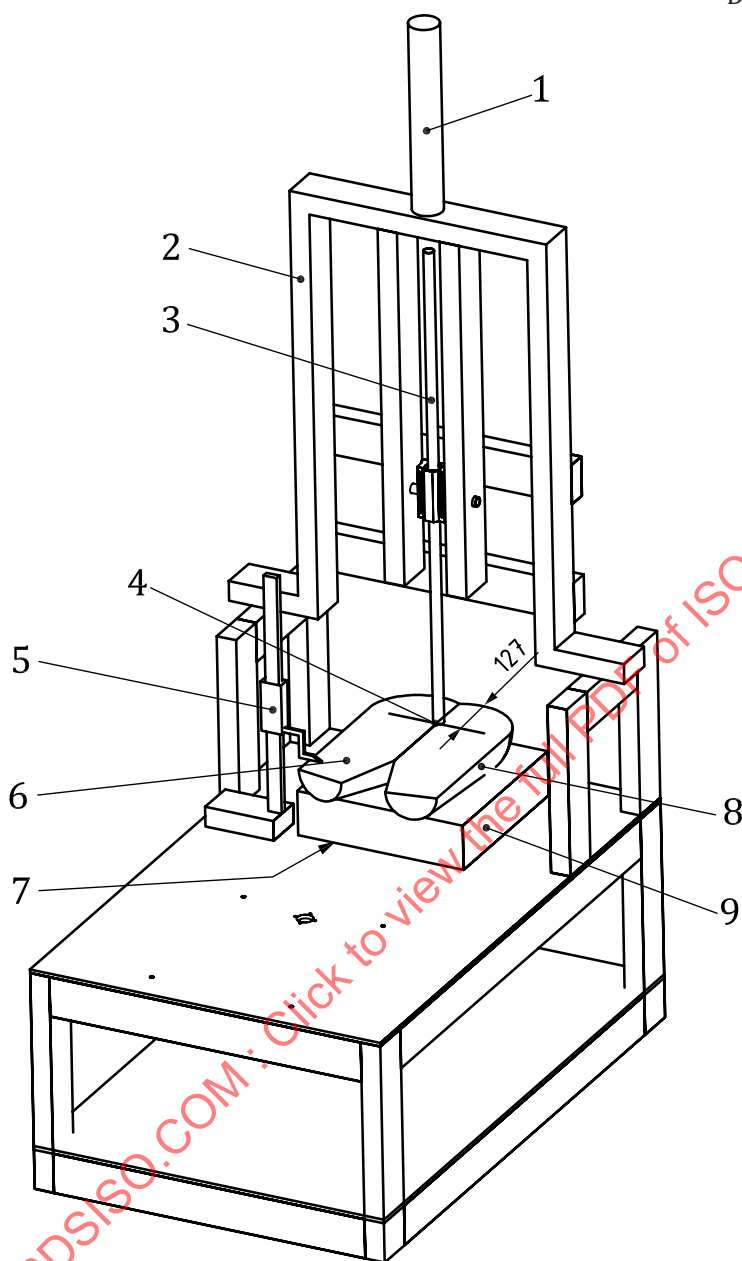
5.6 Impact damping rig

A means of measuring the dissipation of impact loading to the seat cushion:

- a) comprising a rigid hollowed shell representing the outer contour of a RCLI,
- b) with filling to achieve a total weight of the IDRCLI of $500 \text{ N} \pm 10 \text{ N}$.
 NOTE This can be achieved by placing metal spheres into the bottom of the RCLI and fixing them in position (gluing or melting).
- c) capable of applying an impact load to the cushion using the IDRCLI as shown in [Figure 2](#);
- d) capable of recording acceleration in at least one axis, oriented to measure normal to the surface of the IDRCLI in the range -100 ms^{-2} to 100 ms^{-2} with a sampling frequency of at least 30 Hz incorporating an appropriate anti-aliasing filter; accelerometer shall be fixed to the top surface of the IDRCLI on the centre line, $127 \text{ mm} \pm 2 \text{ mm}$ forward of the rear edge of the IDRCLI;
- e) including a rigid plate (plywood or equivalent) measuring $(500 \pm 5) \text{ mm} \times (500 \pm 5) \text{ mm} \times (15 \pm 1) \text{ mm}$ and hinged at one edge providing a means of supporting the cushion and IDRCLI at an angle of $10^\circ \pm 1^\circ$;
- f) including two $25 \text{ mm} \pm 5 \text{ mm}$ diameter rubber cylindrical stops located with their centres at the corners of the rigid plate, 25 mm from the front and lateral edges of the plate, with a hardness of Shore A 60 ± 5 supporting the edge of the plate opposite the hinge such that it is horizontal when resting on the stops;
- g) including a block to support the rigid plate at an angle of $10^\circ \pm 1^\circ$ to the horizontal which can be removed in less than $0,1 \text{ s}$ resulting in the plate falling to horizontal;
- h) capable of consistent placement of IDRCLI relative to the rigid plate.

NOTE This can be accomplished with the use of an alignment rig during placement of the IDRCLI on the test cushion.

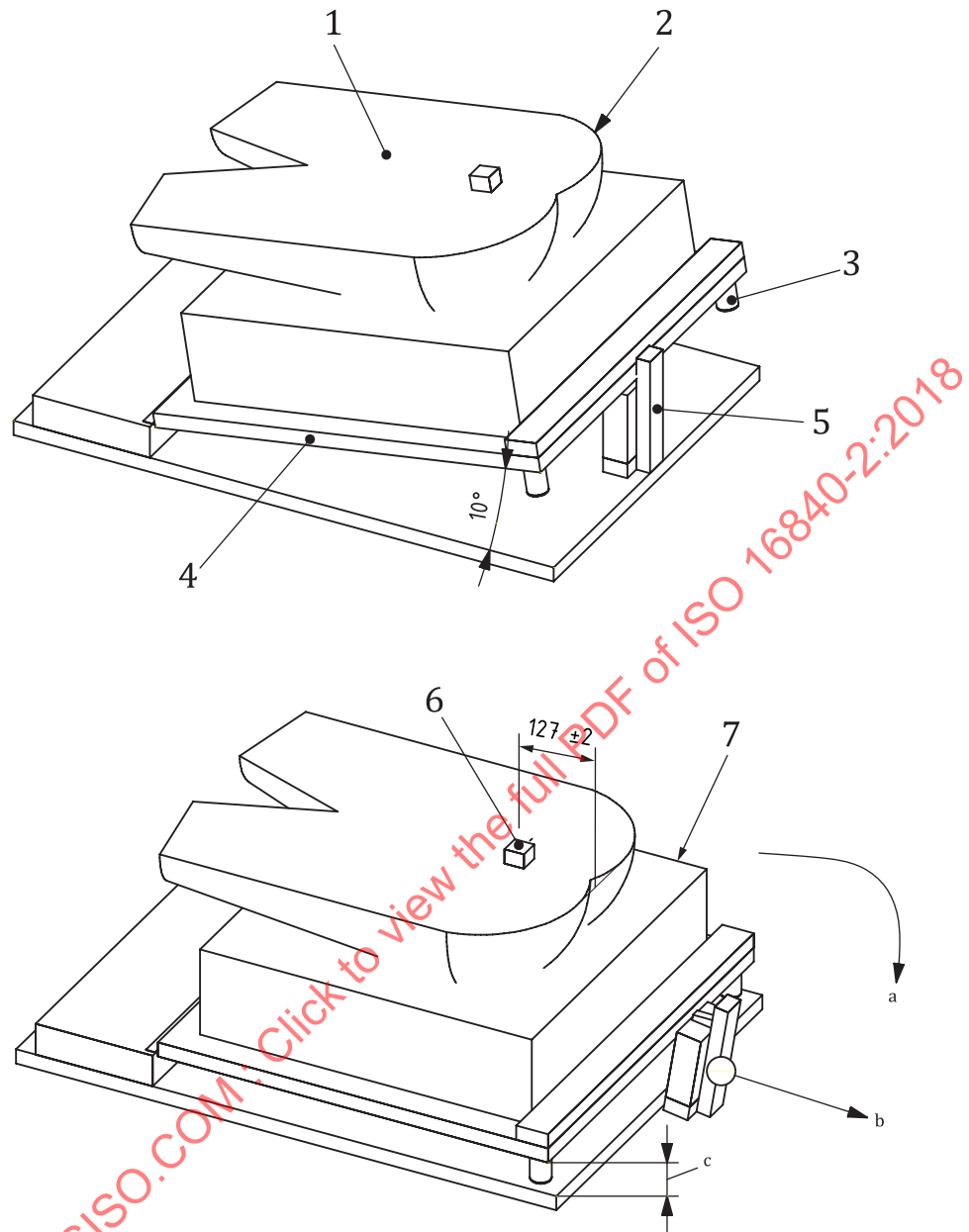
Dimensions in millimetres



Key

- 1 actuator to apply load
- 2 frame
- 3 solid rod
- 4 point of application of load
- 5 displacement gauge
- 6 reference plane
- 7 method of restraint under cushion
- 8 RCLI
- 9 cushion

Figure 1 — Loading rig showing the reference plane on the top surface of the RCLI in plain view and a displacement gauge



Key

- 1 top surface
- 2 IDRCLJ
- 3 stop
- 4 rigid plate
- 5 support block
- 6 accelerometer
- 7 cushion
- a Direction of fall.
- b Direction of pull.
- c Boards are parallel.

Figure 2 — Impact damping rig

5.7 Loaded contour indenter (LCI)

A CLI representing the ischial tuberosities and trochanters as follows and as illustrated in [Figure 3](#).

- a) Two 50 mm $\pm$ 2 mm diameter indenters, centres spaced 120 mm $\pm$ 5 mm apart, representing ischial tuberosities.
- b) Two 25 mm $\pm$ 1 mm diameter indenters, centres spaced 380 mm $\pm$ 10 mm apart, representing the trochanters.
- c) A rigid bar 400 mm $\pm$ 20 mm long.
- d) A 50 mm $\pm$ 2 mm wide webbing as specified in FMVSS 209 attached to the bar at 380 mm $\pm$ 10 mm centres using threaded mounting bolts to sandwich the belt between the 25 mm $\pm$ 1 mm diameter indenters and the bar. The webbing is secured to the bar so that it runs over the 50 mm indenters and under the 25 mm indenters.

NOTE Dimensions have a tolerance of ± 5 % unless specified otherwise.

5.8 Seat cushion thickness measurement rig

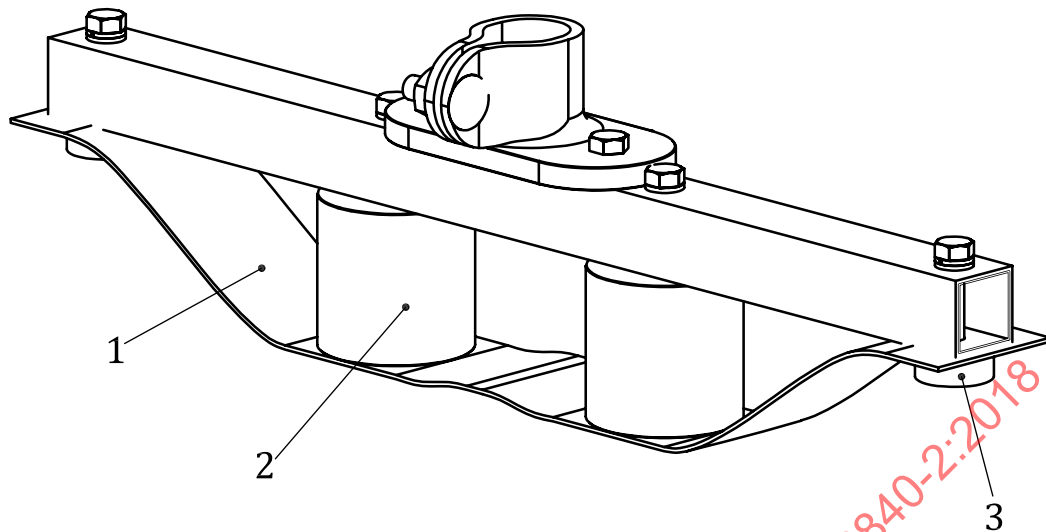
A means to measure the thickness of a cushion at a defined location which:

- a) employs a 50 mm $\pm$ 2 mm diameter circular platen, attached to a displacement gauge mounted on a loading rig with a rigid coupling;
- b) allows vertical displacement of the circular platen;
- c) is capable of applying 3 N $\pm$ 1 N vertical load to the cushion;
- d) can be positioned over the test cushion located 125 mm $\pm$ 2 mm forward of the rear edge of the seat cushion and 55 mm $\pm$ 2 mm lateral to the midline.

NOTE It might be desirable to design this rig so that the circular platen can be placed at other points on the top surface of the seat cushion.

5.9 Test environment

An environment with an ambient temperature of 23° C $\pm$ 2° C and relative humidity 50 % $\pm$ 5 %, which can be determined as specified in ISO 554.



Key

- 1 50 mm wide mesh webbing
- 2 50 mm × 50 mm diameter indenters
- 3 10 mm × 25 mm diameter outside-loading indenters

Figure 3 — Loaded contour indenter

6 Preparation of test cushion

6.1 Choice of cushion

Obtain an unused sample seat cushion for testing with a width and length of 400 mm to 425 mm. If a cover is provided, ensure that it is fitted to the cushion in the orientation specified by the manufacturer.

NOTE A cushion with a 400 mm to 425 mm width and length is the appropriate size for the indenter specified in normative [Annex A](#). Indenters for testing alternative cushion sizes are specified in informative [Annex D](#).

6.2 Preconditioning the cushion

Perform the following:

- a) condition the cushion, unloaded in the test environment for at least 12 h, at an ambient temperature of $(23^{\circ}\text{C} \pm 2^{\circ}\text{C})$ and $50\% \pm 5\%$ relative humidity;
- b) if indicated by the manufacturer, adjust the cushion to accommodate an $830\text{ N} \pm 10\text{ N}$ load applied using the RCLI;
- c) apply $830\text{ N} \pm 10\text{ N}$ using the RCLI for a minimum of 120 s to a maximum of 180 s;
- d) unload and allow the cushion to recover for no more than 120 s;
- e) repeat steps c) and d) for a total of 2 repetitions;
- f) allow cushion to recover for a minimum of 5 min to a maximum of 60 min.

6.3 Setup

Perform the following, prior to performing a test method on a cushion.

- a) If the manufacturer specifies adjusting the cushion to the shape of the user, adjust the cushion using the intended indenter to accommodate the intended test load.
- b) If the cushion contains a material that remains displaced after loading, reset the cushion to the manufacturer's specifications.
- c) Allow the cushion to recover for 5 min to 60 min.

7 Sequence of testing

Conduct the tests specified in [Clauses 8](#) to [14](#) in any sequence.

8 Frictional properties

8.1 Rationale

Some cushions are designed for ease of transfer and others to contain the subject. This clause calls for measurements that provide an indication of the slipperiness of the cushion cover. Work is continuing to define the relevant properties of a cushion (that include the coefficient of friction of the fabric) that impact the sliding resistance of the cushion. The sliding resistance test in [C.3](#) of informative [Annex C](#) was designed to reflect the surface and bulk characteristics of the wheelchair cushion and may provide additional information.

8.2 Test method

Using a standardized test method, determine the coefficient of friction of the surface of the fabric(s) that will be in contact with the occupant.

EXAMPLE BS 3424-10 is an acceptable standardized means of determining fabric coefficients of friction.

8.3 Test report

Provide details of the standardized test utilized to determine the coefficient of friction and the test results.

9 Impact damping under normal loading conditions

9.1 Rationale

This test measures the characteristics of a wheelchair cushion that indicate its ability to reduce impact loading on tissues and help to maintain postural stability. The cushion's ability to absorb impact decreases peak pressures associated with impact loading such as rolling off a kerb or other obstacle. Impact damping is related to hysteresis (see [Clause 14](#)).

9.2 Test method

Prepare cushion as specified in [6.2](#) and [6.3](#) and conduct the following tests in the sequence specified below.

- a) Place the block under the rigid plate so there is an angle of $10^\circ \pm 1^\circ$ between the horizontal testing surface and the rigid plate.

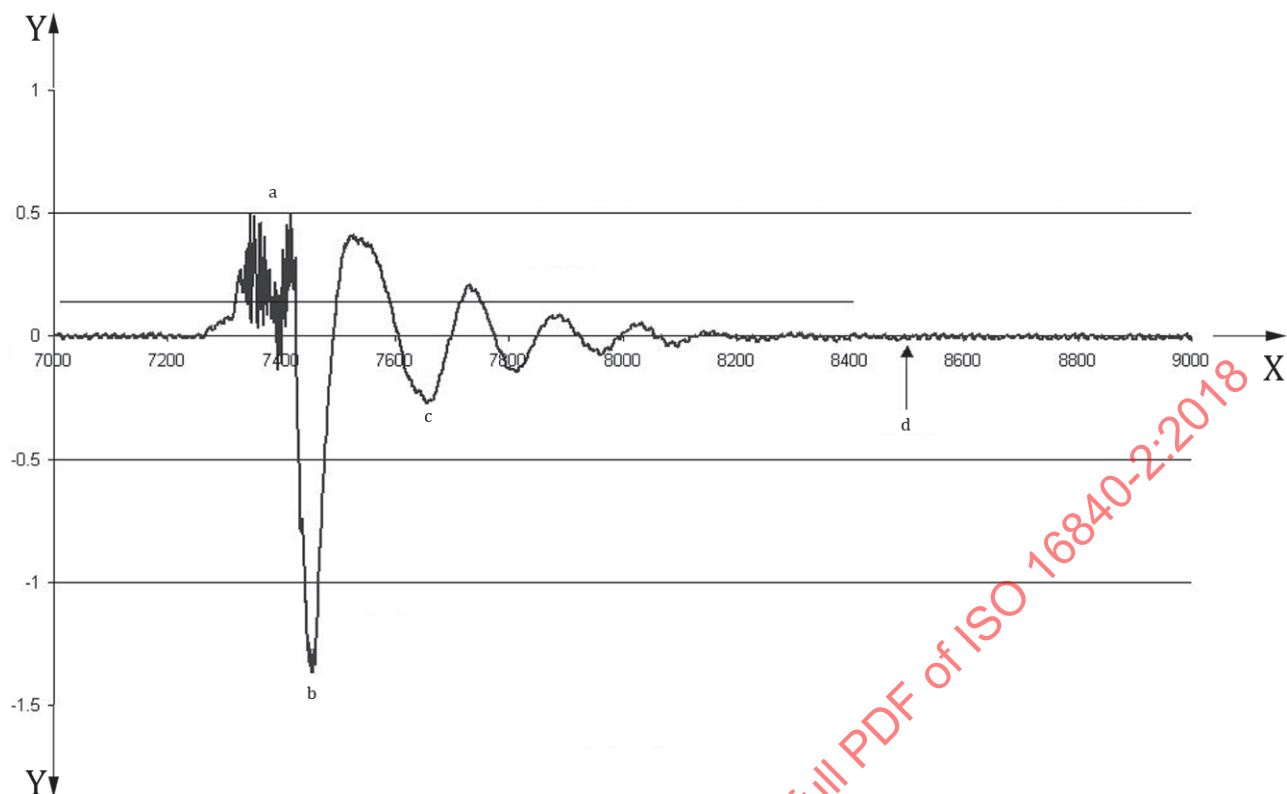
- b) Place the IDRCLI and cushion in the impact damping rig such that the front edge of the IDRCLI is aligned with the hinged edge of the rigid plate and the base points of the IDRCLI are positioned at the location intended by the manufacturer.

NOTE 1 On flat cushions the position of the base points of the IDRCLI is $125 \text{ mm} \pm 10 \text{ mm}$ forward of the back edge of the cushion.

NOTE 2 To ensure repeatable results the accelerometer on the IDRCLI is located a consistent distance from the hinged edge of the rigid plate, as specified in 5.6 d).

- c) Start recording the acceleration of the IDRCLI prior to dropping the plate in the next step, d).
- d) $180 \text{ s} \pm 10 \text{ s}$ after placement of IDRCLI on the cushion, slide the block away in less than 0.1 s , allowing the rigid plate to drop on to its rubber stops.
- e) Stop recording after acceleration has diminished to 1 % of the maximum.
- f) Remove load and allow $300 \text{ s} \pm 10 \text{ s}$ between tests, resetting the cushion as specified in 6.3 b).
- g) Repeat steps c) to f) two more times. This will give a total of three repetitions.

A typical result is shown in Figure 4 with the vertical axis representing the acceleration of the IDRCLI in m/s^2 and the horizontal axis representing time in milliseconds.



Key

- X time in milliseconds
- Y acceleration normalized to gravity (9,81 m/s²)
- a Block removal and free-fall.
- b First impact.
- c Second impact.
- d Baseline.

NOTE The “ragged” higher frequency components in the acceleration signal in this example are typical, reflecting vibration in the system.

Figure 4 — Typical result for impact damping test, plotting acceleration against time in milliseconds

9.3 Method of calculation

The collected data should be smoothed using a 3rd order low pass Butterworth filter or similar filter that has a cut-off frequency of 0,25 Hz. The filtered data are used to calculate the following parameters:

- a) magnitude of the initial impact (Impact 1) for each repetition (m/s²);
- b) magnitude of the 2nd impact (Impact 2) for each repetition (m/s²);
- c) mean values of Impact 1 and Impact 2 across all three repetitions (m/s²);
- d) ratio of Impact 2 to Impact 1 as a percentage.

9.4 Test report

- a) Report the average of Impact 1 across all trials and the average ratio across all trials of Impact 2 to Impact 1 as a percentage.

- b) Include a plot of smoothed acceleration against time in milliseconds as depicted in [Figure 4](#).

10 Recovery

10.1 Rationale

The recovery characteristic of a seat cushion indicates the ability of the cushion to return to its pre-loaded shape and dimensions following a period of loading. Recovery may be associated with repeated loading of the cushion and may be indicative of fatigue. A further part of ISO 16840 is being planned to address changes in cushion properties with use, such as recovery. Alternatively, some seat cushions are designed to mould to the shape of the user employing visco-elastic material properties and take significant time to return to their original shape. In some cases seat cushions employ materials with fluidic components that readily conform to the user and require manipulation to recover their original shape.

10.2 Test method

The following method should be performed without moving the cushion during testing. If movement of the cushion for thickness measurements is unavoidable, a note shall be made in the test report and the disturbances should be minimized. Ideally, the seat cushion thickness measurement rig in [5.8](#) is placed within the loading rig in [5.1](#) when thickness measurements are needed and removed when loading with the RCLI.

- a) Precondition and set up the cushion as specified in [6.2](#) and [6.3](#).
- b) Place the RCLI in the loading rig as specified in [5.1](#).

NOTE An actuator to apply the load is not necessary to perform this test. A vertical load can be applied to the RCLI with free weights.

- c) On the test cushion, mark the base points line, a straight line in the anterior-posterior (A-P) plane joining the two most inferior points of the RCLI defined such that these base-points of the RCLI are aligned with the analogous portion of the cushion; if no conforming location is clearly defined by the cushion's contour, place the base points line 125 mm $\pm$ 10 mm from the rear edge of the cushion.
- d) On the test cushion, mark a reference point defined by the intersection of the base points line, defined in c), and a line parallel to the centreline and located at half the distance of the base-point spacing of the RCLI.
- e) Without the cushion in place, bring the circular platen of the seat cushion thickness measurement rig in contact with the horizontal plane with a contact load of 3 N $\pm$ 1 N and record the vertical distance to the nearest 1 mm from a reference plane (measurement A).
- f) With the cushion in place, bring the circular platen of the seat cushion thickness measurement rig in contact with the cushion such that it is centred within a 2 mm radius of the reference point marked on the cushion. Apply a 3 N $\pm$ 1 N contact load and record the vertical distance to the nearest 1 mm from the reference plane (measurement B).
- g) Place the cushion in the loading rig such that the base-points of the RCLI are aligned with the base points line on the cushion and the centre lines of the RCLI and cushion are aligned $\pm$ 10 mm.
- h) Apply a load of 500 N $\pm$ 10 N with the RCLI within 5 s to 10 s and hold for 1 200 s $\pm$ 60 s.
- i) Remove the load.
- j) 25 s $\pm$ 2 s after load removal, bring the circular platen of the seat cushion thickness measurement rig in contact with the cushion such that it is centred within a 2 mm radius of the reference point marked on the cushion; apply a 3 N $\pm$ 1 N contact load and record the vertical distance to the nearest 1 mm from the reference plane (measurement C).
- k) Remove the circular platen from the cushion surface.

- l) 1 200 s ± 60 s after load removal, bring the circular platen of the seat cushion thickness measurement rig in contact with the cushion such that it is centred within a 2 mm radius of the reference point marked on the cushion; apply a 3 N ± 1 N contact load and record the vertical distance to the nearest 1 mm from the reference plane (measurement D).
- m) Repeat steps e) to l) two more times for a total of three repetitions, resetting the cushion between measurements as specified in 6.3 b).

10.3 Test report

In addition to the information required as specified in [Clause 16](#), report the following:

- a) the two-dimensional location of the reference point on the test cushion relative to the mid-line and back of the cushion;
- b) whether the cushion was moved during testing to make measurements with the seat cushion thickness measurement rig;
- c) the average original thickness of the cushion at the base-point location of the RCL (B-A);
- d) the average ratio of the recovery thickness at 25 s to the original thickness at the base-point location of the RCL:

$$\frac{\text{thickness}_{25\text{ s}}}{\text{original thickness}} = \frac{C - A}{B - A}$$

- e) the average ratio of the recovery thickness at 1 200 s to the original thickness at the base-point location:

$$\frac{\text{thickness}_{1\,200\text{ s}}}{\text{original thickness}} = \frac{D - A}{B - A}$$

11 Loaded contour depth and overload deflection

11.1 Rationale

The ability of a cushion to maintain tissue integrity relates to its ability to envelop the pelvis. It is also important for the user to maintain a margin of safety in the cushioning effect. The overload test measures the amount of deflection resulting from increases in load of 33 % and 66 % over the nominal test load. A cushion that has been loaded beyond the margin of safety is identified when an increase in load does not produce a commensurate increase in deflection. Cushions with higher deflections in the overloaded conditions have higher margins of safety against bottoming out conditions.

This test characterizes two cushion capabilities:

- a) the ability to contour, taking into account the initial contour and contouring produced by loading;
- b) the ability of the cushion to withstand overloading conditions.

11.2 Test method

- a) Prepare the cushion for testing as specified in [6.2](#) and [6.3](#).
- b) Place the test cushion on a flat, horizontal surface.
- c) Measure the cushion thickness (L_{th}) in relation to the horizontal supporting surface to the nearest 1 mm at a location from the rear border of the cushion analogous with the distance of the manufacturer's intended positioning of the ischial tuberosities of a pelvis from the rear of the

cushion while applying $1,5 \text{ N} \pm 0,5 \text{ N}$ using the seat cushion thickness measurement rig; contoured cushions are measured at the lateral edge and convex or flat cushions are measured at midline.

NOTE For convex or flat cushions, measure the cushion thickness $125 \text{ mm} \pm 10 \text{ mm}$ forward of the rear border of the cushion.

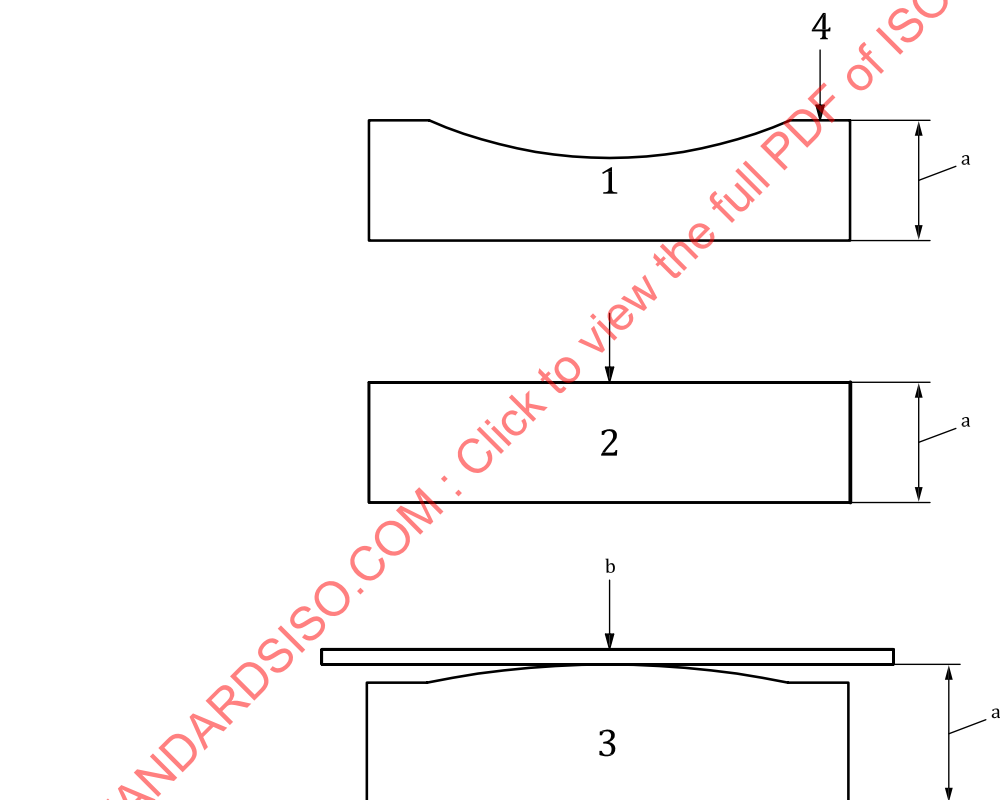
- d) Repeat step c) two times for a total of three repetitions and determine the average cushion thickness, L_{th} , to the nearest 1 mm.

NOTE 1 A rigid sheet of material of known thickness can be used to ensure a consistent thickness measurement without material deflection; this plank thickness is subtracted before recording cushion thickness.

NOTE 2 Figure 5 illustrates locations of measurement as described.

- e) Place the LCI in the force application rig in contact with the cushion so that its base points are positioned at the location intended by the manufacturer.

NOTE On flat cushions the position of the base points of the LCI is $125 \text{ mm} \pm 10 \text{ mm}$ forward of the back edge of the cushion.



Key

- 1 contoured cushion
- 2 flat cushion
- 3 convex cushion
- 4 lateral border
- a Unloaded thickness.
- b Support surface thickness measured after placement of plank to level fluid material.

Figure 5 — Measurement method for concave and convex seat cushion top surfaces

- f) Apply a vertical load of $135 \text{ N} \pm 5 \text{ N}$.

- g) Measure the vertical distance from the horizontal supporting surface to the inferior surface of the LCI after $300\text{ s} \pm 10\text{ s}$ to the nearest 1 mm (L_{135}).
- h) Increase the load on LCI to $180\text{ N} \pm 5\text{ N}$.
- i) Re-measure vertical distance from the horizontal supporting surface to the inferior surface of the LCI to the nearest 1 mm (L_{180}) $60\text{ s} \pm 5\text{ s}$ after the increased load is applied.
- j) Increase the load on LCI to $225\text{ N} \pm 5\text{ N}$.
- k) Re-measure vertical distance from the horizontal supporting surface to the inferior surface of the LCI to the nearest 1 mm (L_{225}) $60\text{ s} \pm 5\text{ s}$ after the increased load is applied.
- l) Repeat steps e) to k) two times for a total of three measurements, allowing $300\text{ s} \pm 10\text{ s}$ between measurements and resetting the cushion between measurements as specified in [6.3 b\)](#).

11.3 Method of calculation

- a) Using the median L_{th} and L_{135} values, calculate *loaded contour depth* = $L_{th} - L_{135}$ and record to the nearest 1 mm.
- b) Using the median L_{135} and L_{180} values, calculate L_{180} *overload deflection* = $L_{135} - L_{180}$ and record to the nearest 1 mm.
- c) Using the median L_{135} and L_{225} values, calculate L_{225} *overload deflection* = $L_{135} - L_{225}$ and record to the nearest 1 mm.

11.4 Test report

In addition to the information required as specified in [Clause 16](#), report *loaded contour depth*, L_{180} *overload deflection* and L_{225} *overload deflection*.

12 Water spillage

12.1 Rationale

Cushions may be exposed to spillage of liquids or exposure to urine. This test determines the time for penetration of liquids through the cover (strike-through).

NOTE This test might not be appropriate for use with rubber or film-backed products that form a fluid tight seal with the test fixture. Doing so results in test times that far exceed being reasonable and fail to measure strike-through because evaporation and wicking dramatically exceed the observed strike-through.

12.2 Test method

Apply methods specified in ISO 9073-8 with a time limit of $3\,600\text{ s} \pm 10\text{ s}$.

12.3 Test report

The requirements for reporting results are specified in [Clause 16](#).

13 Biocompatibility

13.1 Rationale

Tissue integrity can be compromised by contact between the skin and seat cushion components. This test method specifies how to test the biocompatibility of cushion components that could make direct contact with the skin in normal use, if misused or if there is a failure to contain cushion components

such that they make skin contact. This test is also intended to demonstrate biocompatibility if cushion components make contact with open wounds.

13.2 Test method

Apply the test method specified in ISO 10993-1 to any parts of the seat cushion that has the potential to make contact with the user's skin.

13.3 Test report

The requirements for reporting results are specified in [Clause 16](#).

14 Hysteresis test

14.1 Rationale

The hysteresis test provides information about the hysteresis characteristics of a seat cushion. Hysteresis is a measure of the energy lost to the cushion during a cycle of loading and unloading. Hysteresis is often related to impact damping ([Clause 9](#)). Cushions with larger hysteresis values will tend to absorb energy when used on rough surfaces or when dropping down steps, rather than transfer the impact energy to the user's tissues.

14.2 Test method

- a) Precondition and adjust the cushion as specified in [6.2](#) and [6.3](#).
- b) Using the loading rig, bring the RCLI into contact with the test surface used to support the seat cushion; zero the height gauge or otherwise compensate for the height of the indenter portion of the fixture.
- c) Raise the RCLI so that the cushion can be placed on the base of the rig.
- d) Place the RCLI in contact with the cushion so that the base points of the indenter are $125 \text{ mm} \pm 10 \text{ mm}$ forward of the back edge of the cushion or are aligned with the analogous part of the cushion.
- e) Apply a preload force of 8 N to the cushion.
- f) Cycle from 8 N to 750 N and back to 8 N once, at a rate of 1 mm/s.
- g) Continuously record force, thickness and time.
- h) Allow $300 \text{ s} \pm 10 \text{ s}$ for cushion recovery, resetting cushion as specified in [6.3](#) b).
- i) Repeat steps b) to h) two more times to generate a total of three data sets.

14.3 Method of calculation

Determine the following.

- a) The thickness at the following forces: 8 N, 250 N, 500 N, 750 N, 500 N, 250 N, 8 N. Report thickness for each force value.
- b) The average compressive thicknesses at 8 N, 250 N, 500 N, 750 N from the three data sets.
- c) The average unloading thicknesses at 500 N, 250 N, 8 N from the three data sets.

d) The hysteresis indices:

$$\text{hysteresis at 250 N} = 1 - \frac{\text{average unloading thickness at 250 N}}{\text{average compressive thickness at 250 N}}$$

$$\text{hysteresis at 500 N} = 1 - \frac{\text{average unloading thickness at 500 N}}{\text{average compressive thickness at 500 N}}$$

14.4 Test report

In addition to the information required as specified in [Clause 16](#):

- a) report the 250 N and 500 N hysteresis indices calculated in [14.3 d](#));
- b) plot the average compressive and unloading thicknesses calculated in [14.3 b](#)) and [14.3 c](#)).

15 Test report

The test report shall contain the following information:

- a) reference to this document, i.e. ISO 16840-2:2018;
- b) name, address and accreditation status of the testing institution;
- c) date of issue of the test report;
- d) name and address of the manufacturer of the cushion;
- e) model, type and nominal size that uniquely describes the test cushion, including serial and batch numbers, and internal tracking numbers, if available;
- f) cushion cover used;
- g) preparation of the test cushion including set-up and adjustment, and RCLI used for test;
- h) characteristics of the test cushion as determined in [Clauses 8 to 14](#);
- i) calculations and disclosure of uncertainty as specified in ISO/IEC Guide 98-3
- j) any deviations from the test methods defined herein.

16 Disclosure requirement

When disclosing test results in specification sheets, manufacturers shall include the information below:

- a) model type and nominal size that uniquely describes the cushion;
- b) cover used during testing;
- c) date of manufacture of cushion and cover.

Annex A (normative)

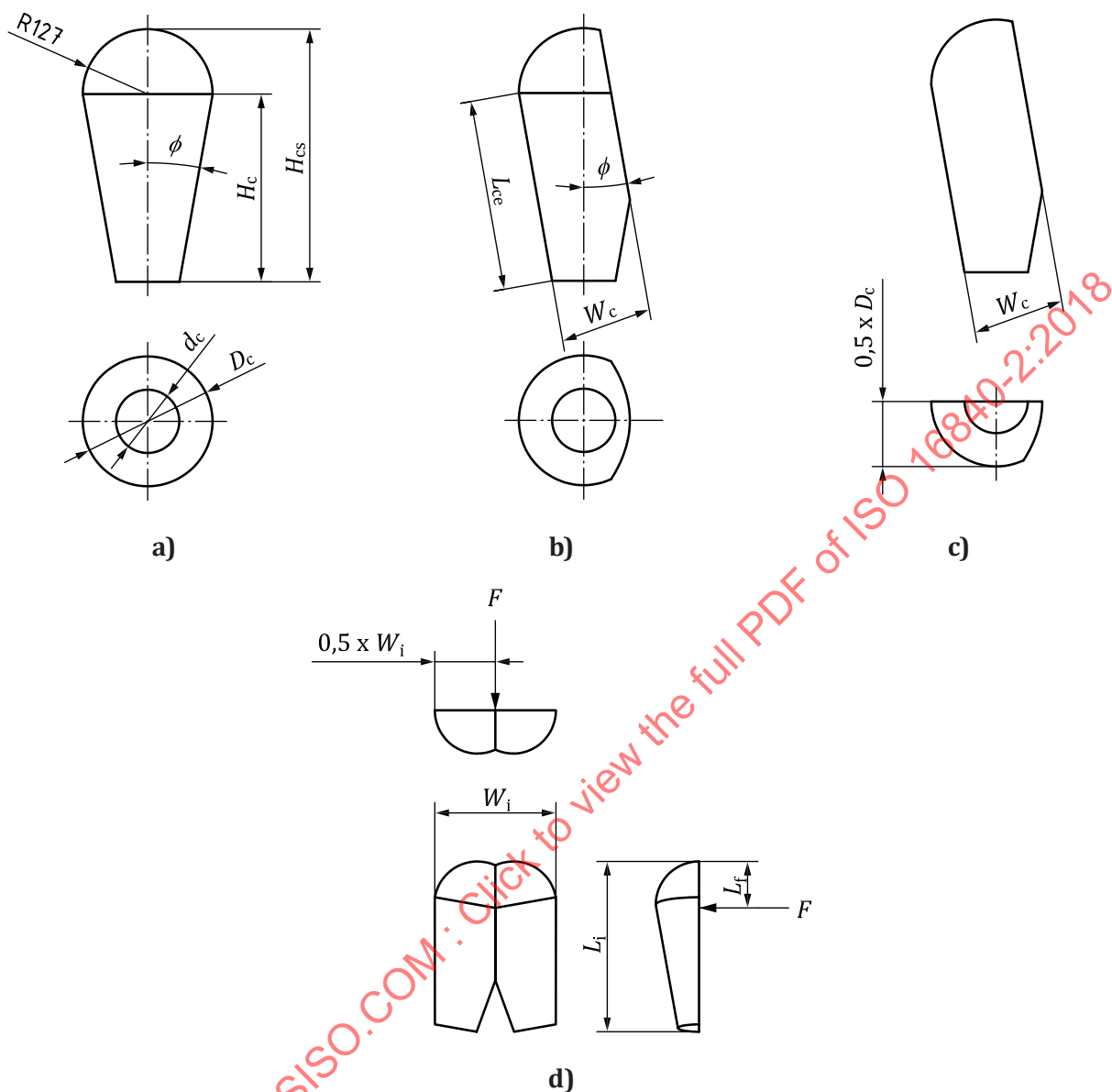
Tapered uniform geometry RCLI

The RCLI is a modified version of an indenter designed in 1995 and is an easily reproducible geometrically based indenter shape relying on the combination of a cone and sphere to generate a representation of human anatomy. The method of cutting the cone and sphere components is represented diagrammatically in [Figure A.1](#) and the dimensions of the components and the cut lines are tabulated in [Table A.1](#).

Fabrication of the RCLI may be accomplished as follows using the dimensions of the components specified in [Table A.1](#).

- a) Turn a cone of the appropriate diameter and taper.
- b) Dress the end to form a hemisphere.
- c) Surface finish to at least N7 (ISO 1302:2002; approximate average surface roughness $<1,7 \mu\text{m}$).
- d) Make the first cut through the cone parallel to the tapered edge of the cone [[Figure A.1 b](#)]. This cut shall not be through the small circular end. It should reduce the overall length of the RCLI.
- e) Make a cut that bisects the plane created by the first cut parallel to the major axis of the cone [[Figure A.1 c](#)].
- f) The two pieces generated by d) are then located as represented in [Figure A.1 d](#); these two pieces are then bonded together.
- g) Attach to loading rig.

NOTE This RCLI is intended to approximate adult human anatomy. Other anatomical sizes can be readily developed by scaling the dimensions of the RCLI and modifying the loading applied to it. Future work is anticipated to validate other sizes of RCLI.



NOTE Dimensions are given in [Table A.1](#).

Figure A.1 — Assembly of components for RCLI

Table A.1 — Cone and sphere dimensions

Cushion width	Indenter width	Indenter length	Anterior posterior location of load	Cone angle	Cone width first cut	Cone height w/o sphere	Height with sphere	Major diameter of cone	Minor diameter of cone	Length of cone edge
(nom.) mm	(W_i) mm	(L_i) mm	(l_f) mm	(ϕ) °	(W_c) mm	(H_c) mm	(H_{cs}) mm	(D_c) mm	(d_c) mm	mm
400	360	500	127	10	180	367	494	254	124	373

NOTE 1 All tolerances (except cushion width) ± 2 mm.

NOTE 2 The RCLI is constructed from cones and spheres machined according to [Figure A.1](#). These components are assembled to form the required shape according to [Table A.1](#).

Annex B

(informative)

Typical ranges for ISO 16840-2 tests and indicative cushion implications

[Table B.1](#) presents typical ranges for the measurement data that have been provided by laboratories utilizing these tests since 2002. HR45 reference foam refers to 75 mm (3 in) thick, flat urethane foam with a 45 IFD with no cover. Ranges of measured data are provided for the reference foam as a measurement reference to allow test laboratories to assess the results they are getting when applying the test methods. The reference foam does not represent target or threshold values, nor does it set material or design requirements.

Table B.1 — Typical ranges

Clause and test type	Test overview	Expected range of results	Typical range on HR 45 reference foam	Cushion attribute guidance
Clause 8: Frictional properties — Sliding resistance	This measurement provides an indication of the slipperiness of the cushion cover. The result of this test is the force measured at the point of slide.	1,8 N to 8,0 N	2,5 N to 5,4 N	Slipperiness. High force = less slippery; Low force = more slippery. A more slippery cushion may increase tendency to slide out of position, but it may also make transfers easier. A less slippery cushion may reduce the tendency to slide out of position, but may make transfers more difficult.
Clause C.2: Frictional properties — Horizontal stiffness	Measurement of lateral or forward stiffness, characterize the interaction between the cushion and the skin following slight perturbations in the horizontal forces at the interface between the seat cushion and the buttocks. The results of this test are the lateral and forward forces at 60 s measured in N.	Lateral force @60 s: 60–215 (Note: 5 mm pull data) Forward force @60s: 48–168 (Note: 5 mm pull data)	Lateral force @60s: 184–215 (Note: 5 mm pull data) Forward force @60s: 152–168 (Note: 5 mm pull data)	High horizontal stiffness = may offer more stability but also potentially more tissue deformation and shear. Low horizontal stiffness = may offer less stability but also potentially less tissue deformation and shear.
Clause 9: Impact dampening	This test measures the characteristics of a wheelchair cushion that indicate its ability to reduce impact loading on tissues and help to maintain postural stability. The results of this test are the average Impact 1 and ratio of Impact 2 to Impact 1 as a percentage, and a plot of smoothed acceleration against time in milliseconds.	Impact 1: 20,00 m/s ² to 44,00 m/s ² Ratio of Impact 2 to 1: 14 % to 38 %	Impact 1: 21,50 m/s ² to 2,75 m/s ² Ratio of Impact 2 to 1: 14 % to 14,2 %	Shock absorption. Higher Impact 1 = harder cushion on impact. Lower ratio = better dampening of energy after impact.
Clause 10: Recovery	The recovery characteristic of a seat cushion indicates the ability of the cushion to return to its pre-loaded shape and dimensions following a period of loading. The results of this test are the average original thickness of the cushion at the base-point location of the RCLI in mm, the average ratio of the 25 s recovery thickness to the original thickness at the base-point location, and the average ratio of the 1,200 s recovery thickness to the original thickness at the base-point location.	25 s Recovery Ratio: 0,61–1 1 200s Recovery Ratio: 0,88–1,04	25 s Recovery Ratio: 0,97–1 1 200s Recovery Ratio: 0,98–1	The closer the ratio is to 1, the faster the cushion returns to its original dimensions.

Table B.1 (continued)

Clause and test type	Test overview	Expected range of results	Typical range on HR 45 reference foam	Cushion attribute guidance
Clause 11: Loaded contour depth and overload deflection	The overload test measures the amount of deflection resulting from increases in load of 33 % and 66 % over the nominal test load. The results of this test are <i>loaded contour depth</i> , <i>L₁₈₀ overload deflection</i> and <i>L₂₂₅ overload deflection</i> measured in mm.	Loaded Contour Depth: 10–90 <i>L₁₈₀</i> : 0–15 <i>L₂₂₅</i> : 0–10	Loaded Contour Depth: 40–45 <i>L₁₈₀</i> : 5–10 <i>L₂₂₅</i> : 5	The depth a person sinks into the cushion.
Clause 12: Water spillage	This test determines the time for penetration of liquids through the cover (strike-through).	No range data available		Spill resistance.
Clause 13: Bio-compatibility	This test method specifies how to test the biocompatibility of cushion components that could make direct contact with the skin in normal use, or if misused or if there is a failure to contain cushion components such that they make skin contact. This test is also intended to demonstrate biocompatibility if cushion components make contact with open wounds.	No range data available		A pass/fail criterion applies to avoid creating biological harm to human tissue.
Clause 14: Hysteresis	Hysteresis is a measure of the energy lost to the cushion during a cycle of loading and unloading. The results of this test are the 250 N and 500 N hysteresis indices as a %.	250 N Hysteresis: 2,8–36,8 500 N Hysteresis: 2,8–31,0	250 N Hysteresis: 25,3–36,8 500 N Hysteresis: 15,9–31,0	The ability for a cushion to maintain its supportive force after being loaded. Lower ratio = less energy lost to cushion.