
Wheelchair seating —
Part 12:
Envelopment and immersion
characterization of seat cushions
using a dual semispherical indenter

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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 of 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 www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 173, *Assistive products*, Subcommittee SC 1, *Wheelchairs*.

This first edition of ISO 16840-12 cancels and replaces ISO/TS 16840-12:2015, which has been technically revised.

The main changes are as follows:

- clarification of technical ambiguities;
- the removal of a gel cap to protect the pressure sensors;
- removal of former Annex A (which addressed method adaptations for cushions that utilize offloading);
- addition of a new [Annex A](#) giving guidance on the estimation of uncertainty.

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

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Introduction

This document provides details of test equipment (an 'indenter'), and a method, for the measurement of 'performance' of a wheelchair cushion intended to use immersion and envelopment to reduce local areas of pressure (by effectively supporting more tissue). Envelopment is maximized when the contact area between the support surface and the body part increases which thereby reduces the pressure across the weight bearing surface. The method as presented in this document is intended to quantify envelopment and immersion of the body by the cushion. Alternatively, the test method and resulting data can provide an indication of other cushion construction and seating and positioning strategies, such as strategic pressure offloading.

Issues related to the use of devices that measure interface pressure between the body and a support surface (e.g. a pressure mapping system) have led to the use of an instrumented indenter, which has fewer sensors, but sensors that are high quality and exhibit repeatability and accuracy and thus reliability.

In this test, the distribution of pressure across the surface of the indenter is evaluated with multiple indenter sizes and loads. The pressure sensors within the indenter are positioned at multiple elevations along the buttock form, to simulate and record the pressures experienced at the ischial tuberosities of the pelvis, the greater trochanters, and at positions along the curve of the buttocks between those anatomical markers. The review of the values at these various positions, and the variation, or lack of variation, in the readings, is an indication of the mechanics of the cushion's interaction with the body and ability to envelop and protect the tissues.

EXAMPLE A fluid filled cushion with the ability to transfer material between cells can have the potential to distribute the load to maintain consistent interface pressure regardless of the depth at which the measurement is taken, as opposed to a foam or other homogeneous surface that behaves more like a spring, in that the greater the depth of immersion, the greater the interface pressure.

The accommodation of the cushion to the changes in indenter size and load are representative of the changes in size and mass of the occupant that can occur in the life of a user or between different users. The indenters are sized to represent changes in size and shape as a user of an approximately 410 mm width cushion gains weight, and the size of the buttocks increases. The overall width of the indenters stays the same, but the size of the semi spheres changes. The loads used in this document are approximate to the 50th percentile user and are not intended to characterize envelopment or immersion under higher loading conditions, nor to assess the weight capacity of a cushion.

This document describes test methods that might not be appropriate for all cushions, and therefore the tester is responsible for determining which, if any, are appropriate for their cushion construction and use.

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Wheelchair seating —

Part 12:

Envelopment and immersion characterization of seat cushions using a dual semispherical indenter

1 Scope

This document specifies apparatus, test methods, and disclosure requirements for characterization of wheelchair seat cushion immersion and envelopment properties using indenters instrumented with pressure sensors.

This document expands the characterization of products intended to manage tissue integrity (ISO 16840-2) and provides a standardized indenter for other wheelchair seating tests.

It does not provide information specific to cushion performance for a particular individual user, nor is it intended to characterize envelopment or immersion under higher loading conditions, nor to assess the weight capacity of a cushion.

This document includes a method that is specific to 220 mm and 255 mm indenters. Dimensions are provided for a 380 mm indenter to allow for extension of the method to larger patient simulation.

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, *Geometrical Product Specifications (GPS) — Indication of surface texture in technical product documentation*

3 Terms and definitions

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

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

- ISO Online browsing platform: available at <https://www.iso.org/obp>
- IEC Electropedia: available at <https://www.electropedia.org/>

3.1

clinical offloading

reduction, removal, or transfer of pressure from one area of the body to another

EXAMPLE Reduction of pressure under the ischial tuberosities, but increased pressure on the thighs or other parts of the seated body.

3.2

cushion envelopment

ability to conform around a shape

3.3

cushion immersion

depth from an uppermost plane to which a body penetrates

3.4

cushion performance

ability to immerse and envelop

3.5

indenter

shaped item designed to simulate the shape of the buttocks area of the human body

3.6

indenter base point

lowest point on the curved surface of each of the two halves of the *indenter* (3.5)

Note 1 to entry: The base points correspond with the ischial tuberosities on the human pelvis.

3.7

indenter sensor elevation

location of sensors relative to the *indenter base points* (3.6)

4 Indenter construction

4.1 Materials

The indenter shall be constructed from hardwood or similar material that is sufficiently rigid so as not to deform when subjected to the forces required for simulating the application of a human body mass to surfaces. The indenter material shall be treated (if necessary) to minimize the effects of moisture, and shall not be adversely affected by normal laboratory testing conditions (0 °C to 35 °C; 25 % to 75 % relative humidity). Surface finish shall be at least N_7 , in accordance with ISO 1302, approximate average surface roughness.

4.2 Tolerances and finishes

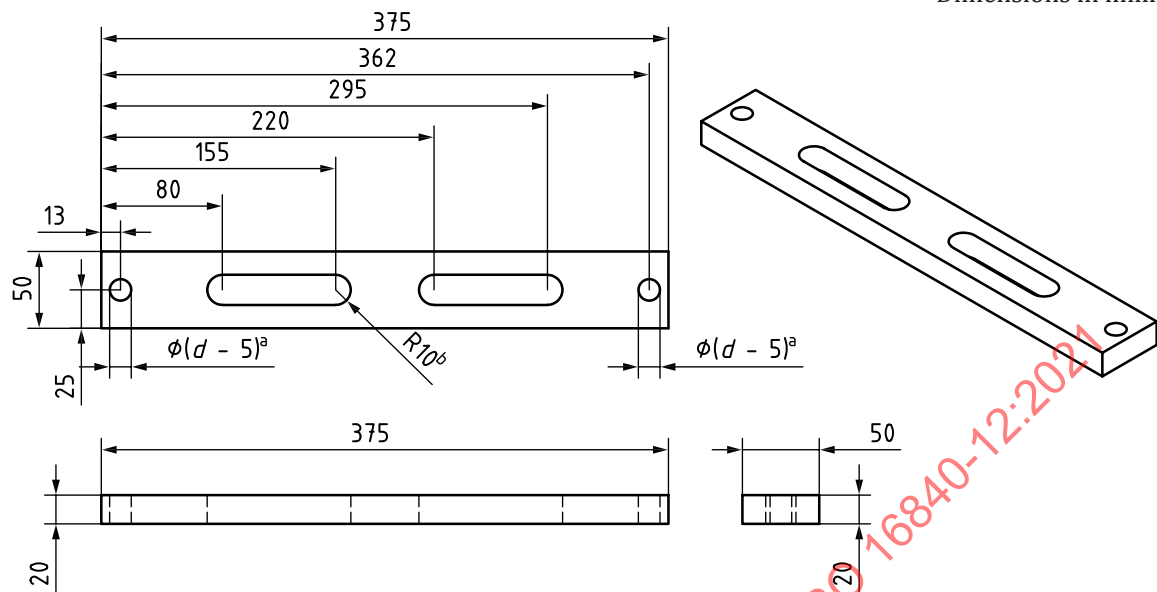
Unless otherwise stated, all dimensions in [Clause 4](#) shall be $\pm 0,5$ mm and all edges and corners shall be finished with a minimum 5 mm radius.

4.3 Indenter elements

4.3.1 Trochanter bar

A 375 mm x 50 mm x 20 mm bar with a series of openings as shown in [Figure 1](#). These openings are for mounting the indenter halves and trochanter blocks as well as for routing of wires.

Dimensions in millimetres



a THRU ALL.

b Typ. THRU ALL.

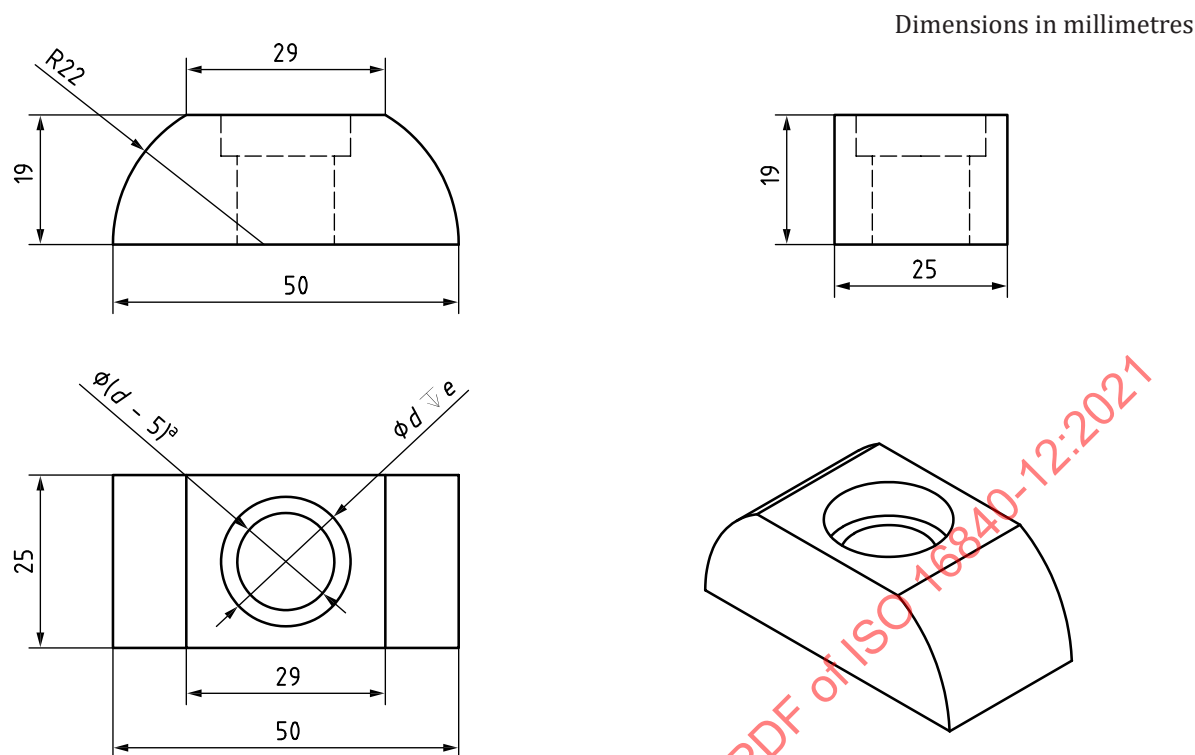
d is the diameter of the pressure sensor selected to meet requirements of 5.1. See 4.1 and 4.2 for materials, tolerances, and finishes.

Figure 1 — Trochanter bar construction

4.3.2 Trochanter blocks

50 mm × 25 mm × 19 mm blocks as shown in Figure 2, which emulate the trochanters. Each trochanter bar shall have two trochanter blocks that house the sensors.

NOTE Trochanter bar and blocks are not required on the 380 mm indenter.



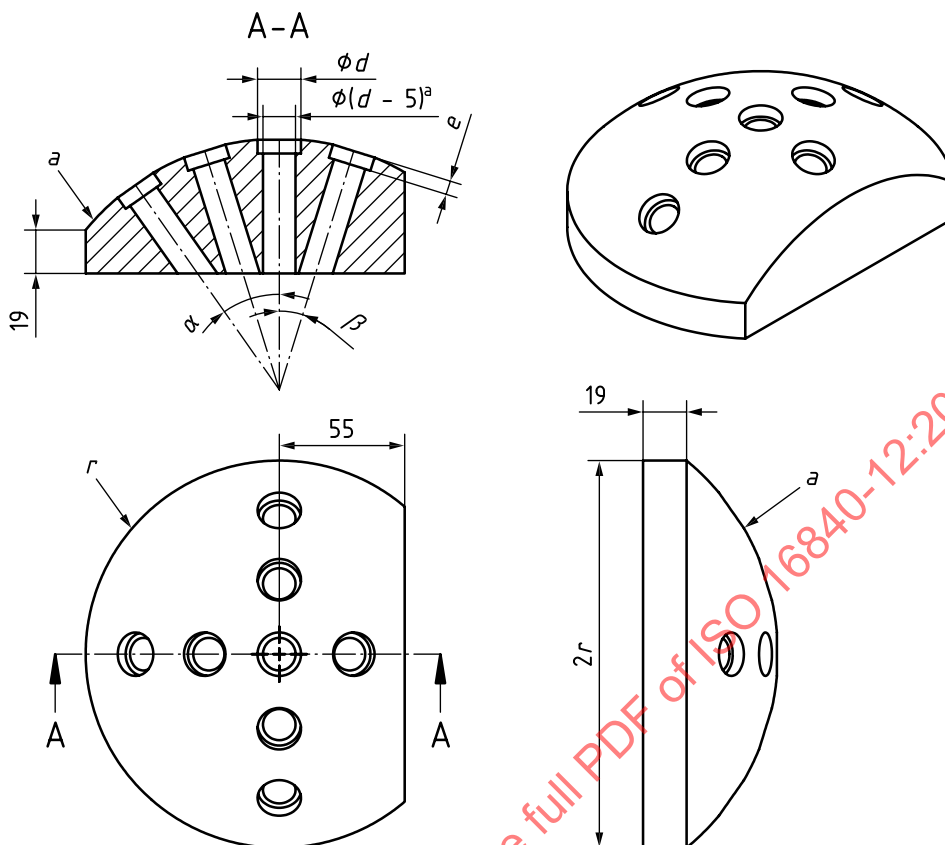
a THRU ALL.

d is the diameter of the pressure sensor selected to meet the requirements of 5.1. Sensor location depth e shall be such that the sensing surface is flush with the indenter surface. See 4.1 and 4.2 for materials, tolerances and finishes.

Figure 2 — Trochanter block construction

4.3.3 Semispherical indenter half

The semispherical indenter half is a portion of a sphere (see Figure 3). The sphere diameter defines the size of the indenter (e.g. a 220 mm indenter has two semispherical halves sectioned from a 220 mm diameter sphere) (see Table 1). Each half has eight sensor locations, as described in 4.5.



- a surface of a sphere with radius value of a (Table 1)
 α angle from centre sensor to farthest sensor (in all directions except cut direction)
 β angle from centre sensor to sensor adjacent to cut
 d diameter of hole for pressure sensor specified in 5.1
 e depth of hole for pressure sensor specified in 5.1
 r radius of disc
 a THRU ALL.

See Table 1 for dimensions. Sensor location depth e shall be such that the sensing surface is flush with the indenter surface. See 4.1 and 4.2 for materials, tolerances, and finishes.

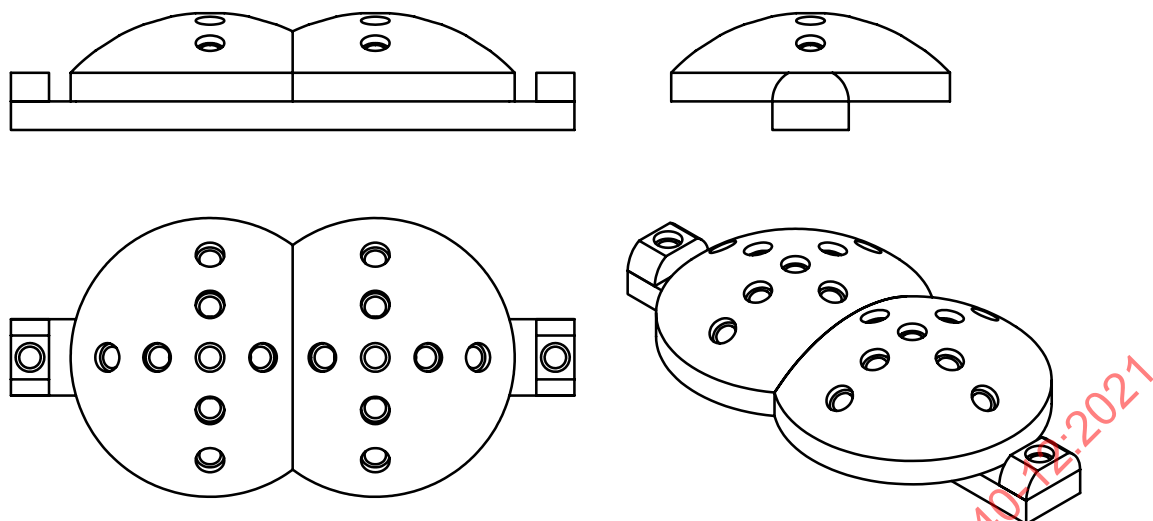
Figure 3 — Semispherical indenter half

Table 1 — Semispherical indenter dimensions

INDENTER	a	α	β	r
220 mm	110 mm	35,0°	17,5°	85,0 mm
255 mm	127,5 mm	32,5°	16,0°	92,5 mm
380 mm	190 mm	26,5°	13,0°	128,5 mm

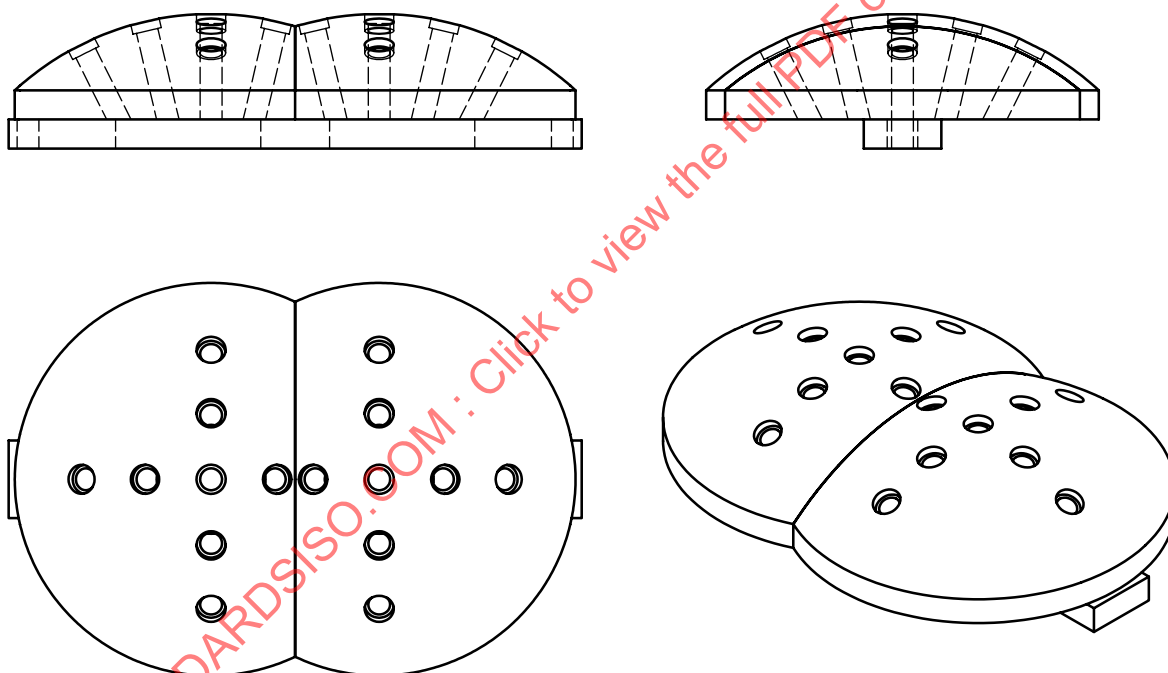
4.4 Indenter assembly

Assemble the indenter using appropriate fasteners that will maintain the structural integrity of the indenter in all aspects of testing. See Figure 4 for assembly drawings for the 220 mm and 255 mm indenter and Figure 5 for the 380 mm indenter.



NOTE See 4.1 and 4.2 for materials, tolerances, and finishes.

Figure 4 — Indenter assembly for 220 mm and 255 mm indenters



NOTE See 4.1 and 4.2 for materials, tolerances, and finishes.

Figure 5 — Indenter assembly for 380 mm indenter

4.5 Sensor locations

4.5.1 General

The following is a list of sensor locations and abbreviations. All sensors are symmetric about the midline of the instrumented indenter. For left and right sensor location configurations and elevations, see Figure 6 and Figure 7.

4.5.2 Elevation a

The left and right base points along the spherical surface on the instrumented indenter.

4.5.3 Elevation b

The pressure sensor locations along the spherical contour of the surface with a vertical height difference of 5 mm from the base point elevation.

NOTE These sensors are placed to the outside of the base point locations and are off-axis from the normal load.

4.5.4 Elevation c

The pressure sensor locations along the spherical surface of the indenter with a vertical height difference of 20 mm from the base point elevation.

NOTE These sensors are placed to the outside of the base point locations and are off-axis from the normal load.

4.5.5 Elevation d

In the testing configuration, the sensor locations are 40 mm superior to the base point elevation in the vertical direction.

NOTE 1 These sensors are placed to the outside of the base point locations and are normal to the application load.

NOTE 2 Elevation d represents the location of the trochanter blocks.

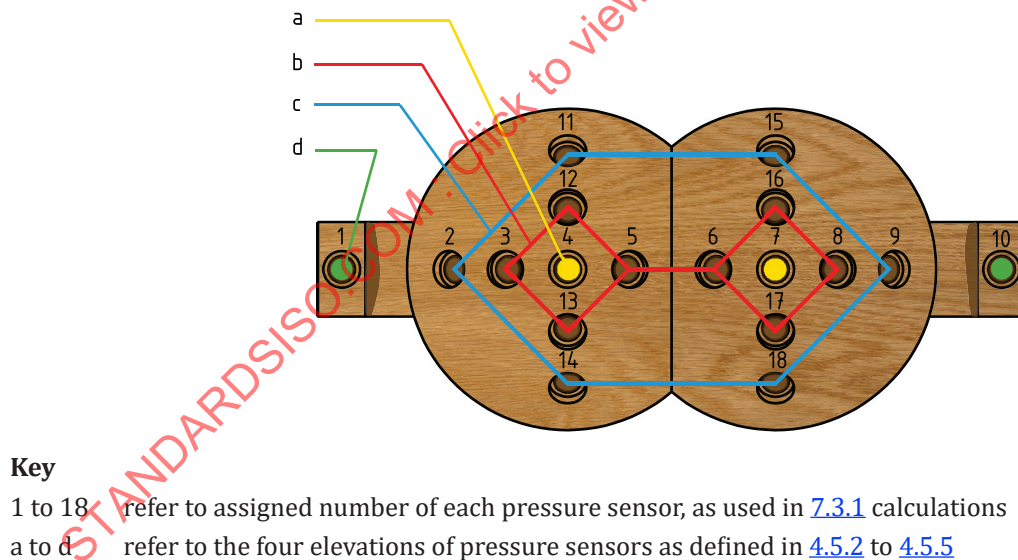


Figure 6 — Sensor port location layout

The 18 pressure sensor ports are distributed across the instrumented indenter as shown in Figure 6. The same sensor port design is applied to the three sizes of indenters, but without the trochanter blocks on the 380 mm indenter.



Key

a to d refer to the four elevations of pressure sensors as defined in 4.5.2 to 4.5.5

Figure 7 — Sensor elevation layout

5 Instrumentation hardware

5.1 Sensors

A series of 18 sensors with a sensing area diameter of $19 \text{ mm} \pm 1 \text{ mm}$. These sensors shall be pressure transducers with a range of at least 0 mmHg to 370 mmHg and accuracy of 0,5 % with a response frequency of at least 1 Hz.

The values from each sensor shall be captured at 1 Hz or higher, on a computer or other data logging device.

5.2 Timer

A device for measuring time with an accuracy of $\pm 1 \text{ s}$.

5.3 Loading equipment

5.3.1 A vertical load-application device capable of applying 800 N, with an accuracy of $\pm 5 \text{ N}$, at a rate of 1 mm/s. The device shall be capable of being mounted to the indenter such that the surface of the indenter remains parallel with the horizontal test surface during loading.

5.3.2 An instrument with the capacity to measure the height of the cushion, with a resolution of 1 mm.

5.4 Rigid board

A board that is $500 \text{ mm} \pm 5 \text{ mm}$ wide and $140 \text{ mm} \pm 5 \text{ mm}$ deep with a weight of $1\,300 \text{ g} \pm 1 \text{ g}$

6 Preparation of test cushion

6.1 Cushion set up

Select an appropriately sized test cushion, as wide, or wider than the indenter, to ensure full contact. If a cushion can be adjusted by adding or removing fluid or components, adjust per manufacturer's instructions to accommodate the load and respective indenter for each of the testing conditions. All adjustments shall be recorded.

NOTE The indenters are the same width and are sized for a 410 mm cushion but can be used on cushions with greater widths, depending on cushion design.

Where a cushion can be set up in multiple configurations, each configuration should be tested and reported separately.

EXAMPLE A cushion can allow addition and removal of inserts, or a cushion intended to be used to create offloading can require movement of material within the cushion away from the area to be offloaded.

6.2 Preconditioning the cushion to the test environment

Allow the cushion to rest at $23\text{ °C} \pm 2\text{ °C}$ and $50\% \pm 5\%$ relative humidity for a minimum of 24 h prior to testing.

7 Envelopment test method

7.1 Rationale

This test characterizes and compares wheelchair cushions by their ability to immerse and envelop the body. The test applies two loads (425 N and 525 N) through each of two indenters (220 mm and 255 mm indenter) to the cushion, to assess different weights and shapes between users, as well as the potential changes in an individual user over time. The immersion, and pressure distribution are examined through the use of pressure sensors mounted in a dual semispherical indenter loaded onto the cushion surface.

7.2 Method

7.2.1 Setting the datum height for the indenter

Set the datum height for the indenter by attaching the indenter to the load applicator, such that the surface of the indenter is parallel with the testing surface. Apply a $5,0\text{ N} \pm 0,5\text{ N}$ contact load with the indenter to the testing surface and set the height above the testing surface at that moment to zero (the datum height).

7.2.2 Pre-conditioning the cushion

The cushion shall be preconditioned as for the 220 mm indenter specification in [Clause 4](#), without sensors.

- Adjust the cushion to accommodate the testing conditions.
- Apply $780\text{ N} \pm 10\text{ N}$ for $120\text{ s} \pm 10\text{ s}$ using the 220 mm indenter, with the base points positioned $125\text{ mm} \pm 25\text{ mm}$ from the rear of the cushion, or a location appropriate for the contour of the cushion.
- Unload and allow the cushion to recover for $60\text{ s} \pm 10\text{ s}$.
- Repeat loading and unloading two more times for a total of three compression cycles.
- Allow the cushion to recover for a minimum of 5 min after preconditioning.

NOTE The Rigid Cushion Loading Indenter (RCLI) and preconditioning method specified in ISO 16840-2:2018 can be substituted for the 220 mm indenter.

7.2.3 Seat cushion thickness measurement

- If the cushion contains a material that remains displaced after loading, re-set the cushion by flattening or according to the instructions for use, in preparation for measuring the thickness.
- Place the cushion under the indenter so that the base points are positioned at the intended location. Unless otherwise indicated for flat cushions, the anterior-posterior position of the base points of

the indenter shall be $125 \text{ mm} \pm 25 \text{ mm}$ from the rear of the cushion or a location appropriate for the contour of the cushion.

- c) Place a rigid board (5.4) with the longest side parallel with the rear of the cushion such that the board is centred over the buttocks recess of the cushion. In the absence of a buttocks recess, place the board with the rear edge $55 \text{ mm} \pm 25 \text{ mm}$ from the rear of the cushion.
- d) Apply a vertical force of $5,0 \text{ N} \pm 0,5 \text{ N}$ to the centre of the board.
- e) Measure the height above the base of the cushion at its centreline to the underside of the board.
- f) Repeat a) to e) two more times for a total of three times.
- g) Report the average seat cushion thickness. This is defined as d_{sc} .

7.2.4 Load application and data collection

7.2.4.1 For each of the following conditions, adjust the cushion according to the instructions for use, to accommodate the specified load and shape. The following test conditions shall be followed:

- a) Using the 220 mm indenter, apply a $425 \text{ N} \pm 5 \text{ N}$ load, and a $525 \text{ N} \pm 5 \text{ N}$ load.
- b) Using the 255 mm indenter, apply a $425 \text{ N} \pm 5 \text{ N}$ load, and a $525 \text{ N} \pm 5 \text{ N}$ load.

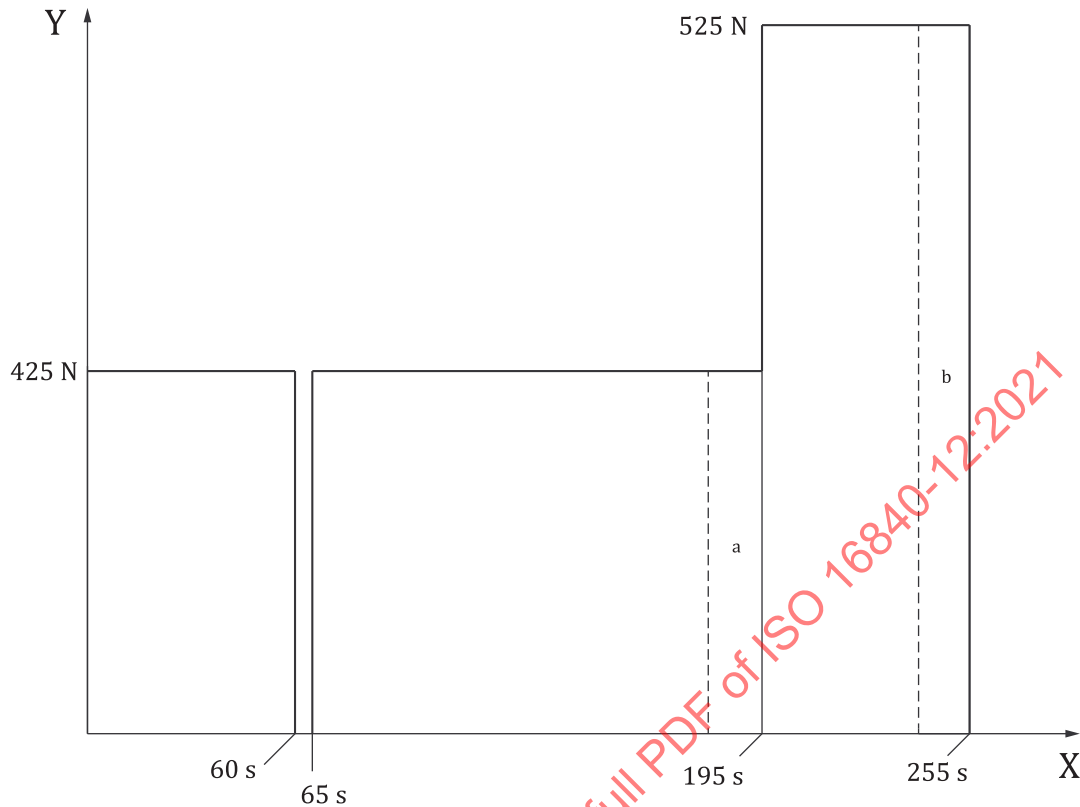
NOTE 1 The conditions are intended to provide an indication of adaptability of the cushion to an increased load and increased user size.

NOTE 2 A 380 mm indenter may be selected by the test facility based on the mass of the intended cushion user and loaded accordingly. See ISO 16840-2: 2018, Annex D, for cushion size and indenter load guidance.

7.2.4.2 Each condition shall be tested as follows (see Figure 8).

- a) If the cushion contains a material that remains displaced after loading, re-set the cushion by flattening or according to the manufacturer's instructions.
- b) Gradually lower the indenter to avoid an impact that could disrupt the cushion setting.
- c) Apply the $425 \text{ N} \pm 5 \text{ N}$ load for $60 \text{ s} \pm 5 \text{ s}$.
- d) Remove the load for $5 \text{ s} \pm 1 \text{ s}$, then reapply the load for $130 \text{ s} \pm 5 \text{ s}$.
- e) Record data from the sensors in the last $15 \text{ s} \pm 1 \text{ s}$.
- f) Record the cushion thickness below a base point of the loaded indenter $125 \text{ s} \pm 5 \text{ s}$ after loading (d_{190}). Constrain the indenter to avoid tilt: the two base points shall always be at the same elevation.
- g) Apply the $525 \text{ N} \pm 5 \text{ N}$ load for $60 \text{ s} \pm 5 \text{ s}$.
- h) Record data from the sensors in the last $15 \text{ s} \pm 1 \text{ s}$.
- i) Record the cushion thickness below a base point of the loaded indenter $55 \text{ s} \pm 5 \text{ s}$ after commencing the $525 \text{ N} \pm 5 \text{ N}$ load (d_{250}).
- j) Remove the load and allow cushion to recover for a minimum of 300 s.
- k) Repeat a) to j) for a total of 3 trials per condition.

This subclause, i.e. 7.2.4.2, can be repeated to allow longer loading times in steps d) and g) for cushions that need a longer time to adjust and accommodate the load. The times used and the additional results shall be added to the Test Report (Clause 8).

**Key**

- X time (s)
 Y load (N)
 a Record 15 s.
 b Record 15 s.

Figure 8 — Load application description

7.2.4.3 Any trial that demonstrates a difference greater than 10 % variation in the cushion thickness measured during the $425 \text{ N} \pm 5 \text{ N}$ load (d_{190}) should be discarded and repeated.

7.3 Calculations**7.3.1 Envelopment**

Calculate and report the average pressures during the last 10 s of the recording periods, at each elevation for $425 \text{ N} \pm 5 \text{ N}$ load and $525 \text{ N} \pm 5 \text{ N}$ load.

- Elevation a: Average of the three trials of sensors (sensors 4 and 7 in [Figure 6](#));
- Elevation b: Average of the three trials of sensors (sensors 3, 5, 6, 8, 12, 13, 16, and 17 in [Figure 6](#));
- Elevation c: Average of the three trials of sensors (sensors 2, 9, 11, 14, 15, and 18 in [Figure 6](#));
- Elevation d: Average of the three trials of sensors (sensors 1 and 10 in [Figure 6](#)).

NOTE 1 See [Figure 6](#) for the referenced sensor numbers.

NOTE 2 The pressure averages at each of the four elevations provide a quick reference to a cushion's ability to redistribute forces. A cushion where reported pressure values at each elevation are similar would be considered a high-envelopment cushion.