BS EN 62929:2014

BSI Standards Publication

Cleaning robots for household use — Dry cleaning: Methods of measuring performance

bsi.

...making excellence a habit.™

National foreword

This British Standard is the UK implementation of EN 62929:2014. It is identical to IEC 62929:2014.

The UK participation in its preparation was entrusted by Technical Committee CPL/59, Performance of household electrical appliances, to Subcommittee CPL/59/6, Floor treatment appliances.

A list of organizations represented on this committee can be obtained on request to its secretary.

This publication does not purport to include all the necessary provisions of a contract. Users are responsible for its correct application.

Published by BSI Standards Limited 2014

ISBN 978 0 580 71222 7
ICS 97.080

Compliance with a British Standard cannot confer immunity from legal obligations.

This British Standard was published under the authority of the Standards Policy and Strategy Committee on 30 September 2014.

Amendments/corrigenda issued since publication

Date	Text affected

EUROPEAN STANDARD

NORME EUROPÉENNE

EUROPÄISCHE NORM

EN 62929

September 2014

ICS 97.080

English Version

Cleaning robots for household use - Dry cleaning: Methods of measuring performance (IEC 62929:2014)

Robots de nettoyage à usage domestique - Nettoyage à sec: Méthodes de mesure de l'aptitude à la fonction (CEI 62929:2014)

Reinigungsroboter für den Hausgebrauch - Trockenreinigung: Verfahren zur Messung der Gebrauchseigenschaften (IEC 62929:2014)

European Committee for Electrotechnical Standardization
Comité Européen de Normalisation Electrotechnique
Europäisches Komitee für Elektrotechnische Normung

CEN-CENELEC Management Centre: Avenue Marnix 17, B-1000 Brussels

Ref. No. EN 62929:2014 E

Foreword

The text of document 59F/258/FDIS, future edition 1 of IEC 62929, prepared by SC 59F "Surface cleaning appliances" of IEC/TC 59 "Performance of household and similar electrical appliances" was submitted to the IEC-CENELEC parallel vote and approved by CENELEC as EN 62929:2014.

The following dates are fixed:

–	latest date by which the document has to be implemented at national level by publication of an identical national standard or by endorsement	(dop)	2015-05-26
–	latest date by which the national standards conflicting with the document have to be withdrawn	(dow)	2017-08-26

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. CENELEC [and/or CEN] shall not be held responsible for identifying any or all such patent rights.

Endorsement notice

The text of the International Standard IEC 62929:2014 was approved by CENELEC as a European Standard without any modification.

In the official version, for Bibliography, the following notes have to be added for the standards indicated:

IEC 60335-1:2001 + A1:2004 + A2:2006	NOTE	Harmonized as EN 60335-1:2002 (modified) + A1:2004 (not modified) + A2:2006 (not modified).
IEC 60335-2-2:2009	NOTE	Harmonized as EN 60335-2-2:2010 (not modified).

Annex ZA
(normative)

Normative references to international publications with their corresponding European publications

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

NOTE 1 When an International Publication has been modified by common modifications, indicated by (mod), the relevant EN/HD applies.

NOTE 2 Up-to-date information on the latest versions of the European Standards listed in this annex is available here: www.cenelec.eu.

Publication	Year	Title	EN/HD	Year
IEC 60312-1 (mod)	2010	Vacuum cleaners for household use - Part 1: Dry vacuum cleaners - Methods for measuring the performance	EN 60312-1	2013
+ A1	2011		-	-
ISO 554	-	Standard atmospheres for conditioning and/or testing - Specifications	-	-
ISO 679	2009	Cement - Test methods - Determination of strength	-	-
ISO 2768-1	1989	General tolerances - Part 1: Tolerances for linear and angular dimensions without individual tolerance indications	EN 22768-1	1993

CONTENTS

INTRODUCTION

In addition to the performance measurement methods which are included in this International Standard, a few more performance items have been reviewed and considered. The list of the performance items which have been discussed over time but have not yet been included comprises corner/edge dust pick-up, noise, docking, fall-off prevention, fibre pick-up and emissions.

The performance items which have been left out in this edition will be continuously reviewed and will soon be included in future editions of this standard.

CLEANING ROBOTS FOR HOUSEHOLD USE – DRY-CLEANING: METHODS OF MEASURING PERFORMANCE

1 Scope

This International Standard is applicable to **dry cleaning robots** for household use in or under conditions similar to those in households.

The purpose of this standard is to specify the essential performance characteristics of dry **cleaning robots** and to describe methods for measuring these characteristics.

This standard is neither concerned with safety nor with performance requirements.

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC 60312-1:2010, *Vacuum cleaners for household use – Part 1: Dry vacuum cleaners – Methods for measuring the performance*[1]
IEC 60312-1:2010/AMD1:2011

ISO 554, *Standard atmospheres for conditioning and/or testing – Specifications*

ISO 679:2009, *Cement – Test methods – Determination of strength*

ISO 2768-1:1989, *General tolerances -- Part 1: Tolerances for linear and angular dimensions without individual tolerance indications*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in IEC 60312-1, as well as the following apply.

3.1
cleaning robot
automatic battery-powered cleaners
automatic floor cleaner that operates autonomously without human intervention within a defined perimeter

Note 1 to entry: The **cleaning robot** consists of a mobile part and may have a **docking station** and/or other accessories to assist its operation.

3.2
dry cleaning robot
cleaning robot that is intended to remove only non-liquid material from the floor using by means other than with the aid of solutions or liquids

---

[1] There is a consolidated edition 1.1 (2011), that includes IEC 60312-1:2010 and its amendment IEC 60312-1:2010/AMD1:2011.

Note 1 to entry: Typical means of cleaning include vacuum, brush(es), pad(s) and duster.

3.3
cleaning head
air intake nozzle at the bottom of the **cleaning robot**

Note 1 to entry: The width of the **cleaning head** is the width of the air intake nozzle in the direction of forward travel.

Note 2 to entry: It does not include any **agitation device**.

3.4
agitation device
motorized mechanical part or an air-blower attached to the **cleaning robot** used to assist dirt removal

3.5
docking station
base unit
unit that may provide manual or automatic battery charging facilities, dust removal from the robot, data processing facility or other robot support functions

3.6
passive cleaning head
cleaning head without agitation device

[SOURCE: IEC 60312-1:2010, 3.5, modified – "nozzle" has been replaced by "**cleaning head**".]

3.7
visual tracking system
VTS
measurement system which enables the tracking of robot position and orientation

3.8
secondary collection system
peripheral device outside of the robot that collects the dust from the **cleaning robot**

3.9
dust receptacle
container inside of the robot used to hold the collected dust

3.10
test
entirety / superset of all (**test**) **runs** and (**test**) **trials** of all samples to be measured for a single robot

3.11
trial
single instance of a performance measurement carried out under identical conditions that can be repeated multiple times

3.12
run
subset of a **trial** where one or more factors affecting the **test** results is (are) changed

3.13
pass
traverse of the **cleaning head** over the **test** area

Note 1 to entry: The number of passes refers to the number of times the same **test** area has been traversed by the **cleaning head**.

3.14
dust area
area where the **test** dust is distributed for the dust removal **test**

4 General conditions for testing

4.1 Atmospheric conditions

Unless otherwise specified, the **test** procedures and measurements shall be carried out under the following atmospheric conditions (in accordance with ISO 554):

Temperature: (23 ± 2) °C

Relative humidity: (50 ± 5) %

Air pressure: 86 kPa to 106 kPa

Temperature and humidity conditions within the specified ranges are required for good repeatability and reproducibility. Care shall be taken to avoid changes during a **test**.

4.2 Lighting conditions

Unless otherwise specified, the **test** procedures and measurements shall be carried out under the following lighting conditions:

Intensity: (200 ± 50) lx

Colour temperature: 2 000 K to 6 000 K

Measurements shall be made on the floor level.

4.3 Test equipment and materials

To minimize the influence of electrostatic phenomena, measurements on carpets shall be carried out on a level floor consisting of a smooth untreated pine plywood or equivalent panel, at least 15 mm thick and of a size appropriate for the **test**.

Equipment and materials for measurements (devices, **test** carpets, **test** dust, etc.) to be used in a **test** shall, prior to the **test**, be kept for at least 16 h at standard atmospheric conditions according to 4.1.

Carpets that have already been used shall be stored unbeaten at standard atmospheric conditions according to 4.1.

When not in use, carpets shall be hanging free, or lying flat, pile upwards and uncovered. Carpets shall not be rolled when stored between testing. Carpets that have been rolled shall be laid flat for a minimum of 16 h before use.

4.4 Number of samples

All measurements of performance shall be carried out on the same sample(s) of the **cleaning robot** with its attachments, if any. During a set of tests the sample robot shall not be changed.

A minimum of three samples of the same model shall be tested.

4.5 Running-in of a new cleaning robot

Prior to the first **test** on a new **cleaning robot** it shall be kept running on a clean hard floor for at least 10 min to ensure adequate running-in.

Prior to conducting any series of tests, the age, condition, and history of the product shall be recorded.

4.6 Preparation of battery

Any unused battery shall need to go through at least one full charge and complete discharge cycle prior to conducting any series of **tests**.

Complete discharge shall be done by carrying out a normal cleaning operation following the manufacturer's instructions.

4.7 Operation of the cleaning robot

Unless otherwise specified,

- the **cleaning robot**, its attachments, the **docking station** and any accessories shall be used and adjusted in accordance with the manufacturer's instructions for normal operation before a **test** is carried out, and
- the operation mode of the robot can be selected and adjusted according to the manufacturer's published instructions only before the **test** to fit the environment to be cleaned.

Any safety-related device shall be able to operate.

4.8 Measurement of dust receptacle weight

For the dust removal **test**, it is required to weigh the **dust receptacle**. If the **dust receptacle** is removable the receptacle shall be carefully removed from the robot and the receptacle shall be weighed.

If the **dust receptacle** is not removable and a **secondary collection system** needs to be used to remove the dust collected in the receptacle the weight increase of the removable receptacle in the **secondary collection system** shall be weighed and recorded.

For the robot that does not have a **dust receptacle** and only uses wiping pad the weight of the pad shall be measured instead of the **dust receptacle**.

If the **dust receptacle** is not removable and a **secondary collection system** is not used to remove the dust collected in the receptacle the complete **cleaning robot** shall be reweighed.

4.9 Measurement resolution and accuracy

Unless specified in the **test** methods the resolution and the accuracy of the measurement device shall be as follows.

Weight measurement:

Resolution ≤ 0,01 g

Accuracy ≤ 0,02 g

Position measurement by vision:

Coverage **test**

Position resolution ≤ 3 cm

Position accuracy ≤ 5 cm

Sampling rate ≥ 30 Hz

Straight line **test**

Position resolution ≤ 1 cm

Position accuracy ≤ 1 cm

Sampling rate ≥ 30 Hz

Average speed **test**

Position resolution ≤ 1 cm

Position accuracy < 1 cm

Sampling rate ≥ 30 Hz

Time measurement:

Resolution ≤ 0,01 s

Accuracy ≤ 0,02 s

4.10 Tolerance of dimensions

For all dimensions which are not presented as a range and no tolerance is specified the tolerance shall be determined as Table 1.

Table 1 – Tolerance of dimensions

Nominal size range mm	**Tolerance** mm
3 ≤ 6	± 0,5
> 6 ≤ 30	± 1,0
> 30 ≤ 120	± 1,5
> 120 ≤ 400	± 2,5
> 400 ≤ 1 000	± 4,0
> 1 000 ≤ 2 000	± 6,0
> 2 000 ≤ 5 000	± 8,0
NOTE Values are taken from Table 1 of ISO 2768-1:1989.	

5 Dust removal test – Box

5.1 General

This **test** is designed to give indicative data on the dust removal capability of a robotic cleaner, while allowing it to function and move in an autonomous way in an open area with no obstacles. Navigation strategies differ, so the dust removal result shall always be reported with time taken to deliver that score, to allow for relative comparison between different products.

NOTE 1 Dust removal scores are a factor of both the unit's dust removal system and navigation strategy so cannot be directly compared with dust removal results from manually operated vacuum cleaners as per IEC 60312-1.

NOTE 2 As robotic cleaners can and will make autonomous decisions about how best to navigate the box **test** area, it is unlikely that any two **runs** of a robot with same **test** conditions will ever follow exactly the same cleaning pattern. As such, it is understood that there will be a level of inherent variation in this **test** that cannot be designed out, which could be reflected in the dust pick up scores even over the same length of time from the same start position.

5.2 Dust removal from hard flat floors

5.2.1 Test bed

The length and the width of the **test** bed shall be 2 000 mm × 1 150 mm as specified in Figure 1. The height of the wall surrounding the **test** bed floor shall be 300 mm tall. The inner

side of the wall shall be untreated pine wood colour. The ceiling height of the room in which the **test** is executed shall not be higher than 3 500 mm. The **test** bed has one **dust area** of 1 300 mm × 500 mm centred in the **test** bed as shown in Figure 1. The **test** floor shall be untreated laminated pine tree plate or equivalent (more detail of the floor specification is under consideration) and its thickness shall be at least 15 mm.

To prevent the entrapment of the **test** dust beneath the wall during the **test** the gap between the wall and the floor shall be properly sealed.

5.2.2 Preparation of test

5.2.2.1 Preconditioning of test floor

The **test** floor shall be cleaned so that no dust remains prior to any subsequent **test**.

5.2.2.2 Pre-treatment of cleaning robot

If the **cleaning robot** is designed to be used with disposable **dust receptacles** it shall, prior to each **test**, be equipped with a new **dust receptacle** of the type recommended or supplied by the manufacturer of the **cleaning robot**.

If the **cleaning robot** is provided with a reusable **dust receptacle** (as the sole original **dust receptacle** or as an enclosure for disposable **dust receptacles**) the **dust receptacle** shall, prior to each measurement, be cleaned according to the manufacturer's instructions until its weight is within 1 % of its original weight.

A **dust receptacle** made of textile is not permitted to be cleaned by brush and water.

A plastic **dust receptacle** shall be cleaned following the instructions in the user manual. If the **dust receptacle** is cleaned with water it shall be dried well before any **test** and measurement.

Some reusable receptacles consist of a rigid container and an integral filter. In this case the container and the filter are considered to be the receptacle and shall be treated as if they were a single component.

Any replaceable filters and dust collection parts (e.g. dust pad) shall be preconditioned as instructed in each **test** procedure.

Dust collecting parts shall be pre-treated in order to minimize the influence of humidity.

Prior to each **test run**, replaceable filter(s) and dust collection parts (e.g. wiping pad) in the robot (or in the **secondary collection system**) shall be replaced with new ones.

The battery shall be fully re-charged prior to each **run** following the manufacturer's instructions.

5.2.2.3 Distribution of test dust

The **test** dust shall consist of dolomite sand with the grain size distribution as defined in the Mineral dust – Type 1 table in 7.2.2.1 of IEC 60312-1:2010.

Dimensions in millimetres

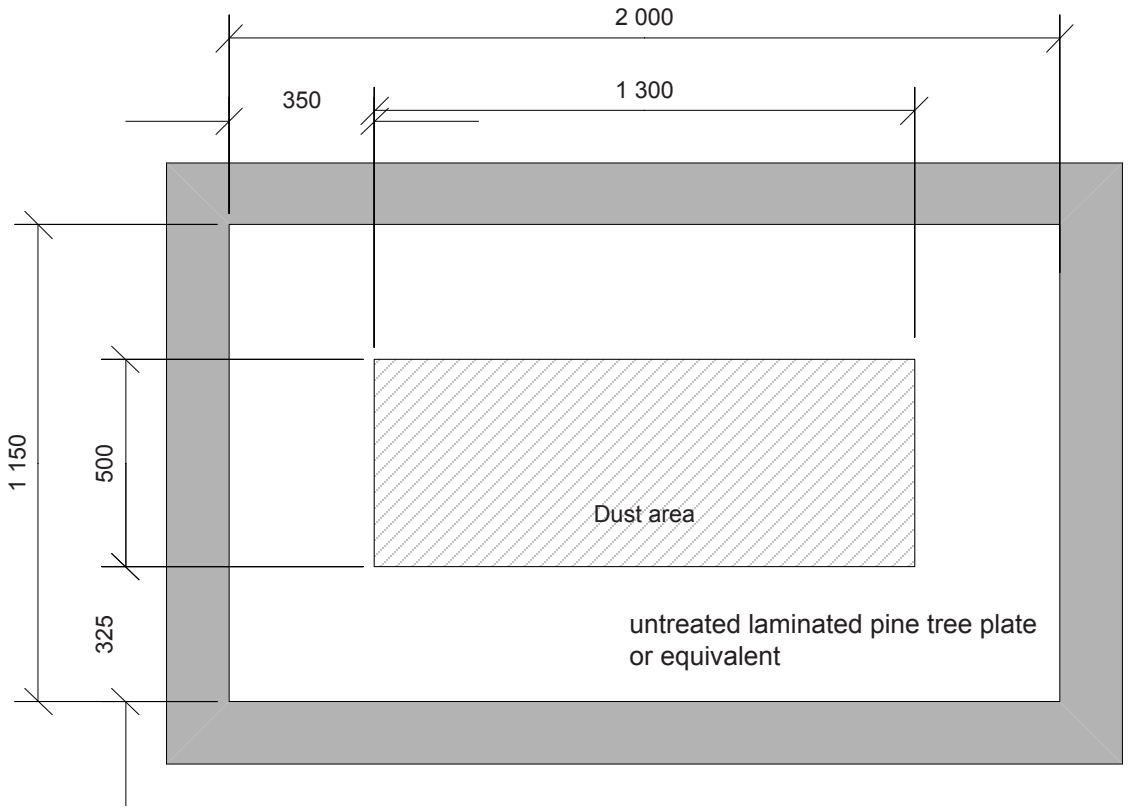


Figure 1 – Dust removal from hard flat floor test bed configuration

The **test** dust shall be distributed only within the **dust area** with a mean coverage of 50 g/m^2 as uniformly as possible.

NOTE 1 For uniform distribution of the **test** dust, a manual dust spreader as described in Figure 2 can be used.

NOTE 2 To ensure the distribution of the **test** dust only within the **dust area**, a masking frame with size of the **dust area** or marker can be used.

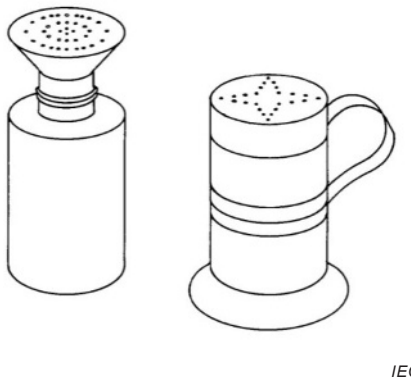
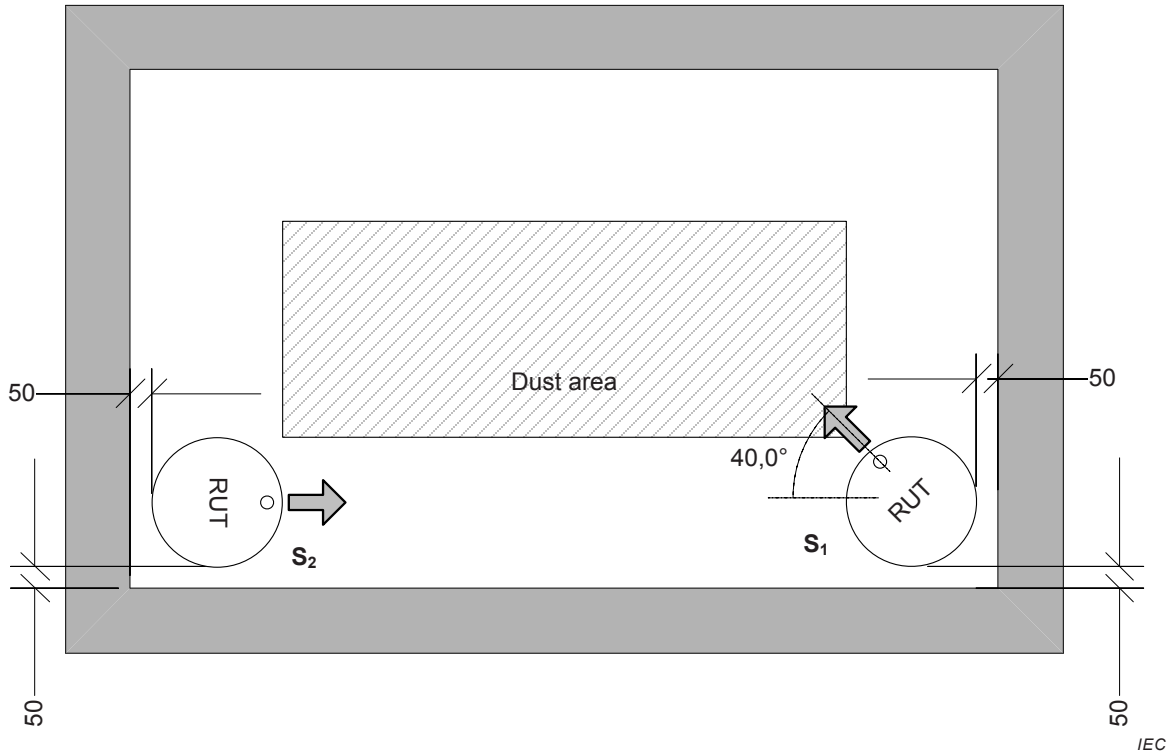


Figure 2 – Dust distribution devices

Dimensions in millimetres



The arrow indicates the forward direction of the robot.

Key

RUT robot under test

Figure 3 – Starting positions and orientations

5.2.3 Test method

After the preparation process is completed according to 5.2.2 the **dust receptacle** shall be weighed ($m_{0,i,j}$) as specified in 4.8.

A single cleaning **trial** consists of a **run** from each of the two starting positions specified in Figure 3. The starting positions are defined as follows.

S_1: At 45° pointing into the **test** bed starting at the bottom right hand corner

S_2: Parallel to the long side of the **test** bed starting at the bottom left hand corner.

Each of the two **runs** for each **trial** shall be performed with a fully charged battery.

Additional equipment which is not attached as part of the **cleaning robot** shall not be placed inside the **test** bed during the **test**. If a **docking station** is required in order to start the cleaning operation it may be placed inside the **test** bed. After the start of the robot the **docking station** and other additional equipment shall be removed, if no longer required.

The operation mode of the **cleaning robot** shall be set according to the manufacturer's recommendations for the environment to be cleaned. Then the autonomous operation of the **cleaning robot** shall be started according to the instruction of manufacturer.

The operation mode used in the **test** shall be one of the modes normally available to the users and the mode used in the **test** shall be reported in the **test** result.

If the **cleaning robot** stops operating its active cleaning function within 15 min the measurement is finished and the operation time shall be recorded.

If the **cleaning robot** is still operating at 15 min the **cleaning robot** movement, including dust collecting function, shall be stopped using the method provided by the manufacturer. The operation time shall be recorded as 15 min.

After the **cleaning robot** movement has stopped the receptacle shall be carefully removed and reweighed as specified in 4.8.

During the **test** it shall be ensured that the robot is not affected by any electro-magnetic and physical interference. Dynamic changes within the **test** environment which may influence optical sensors or vision based navigation systems shall be minimized.

For each **run** the dust removal ability shall be determined according to 5.2.4.

Prior to subsequent **run**, the **test** bed and the robot shall be prepared for the next **run** according to 5.2.2.

The cleaning **trial** (with two **runs**) shall be repeated twice more. Before each **trial** the robot and the **test** bed shall be conditioned according to 5.2.2.

If the spread (maximum value minus the minimum value) of the three **runs** per position is greater than 10 % of the mean dust removal rate (K_i) defined in 5.2.4 two more **trials** for that position shall be added and all five **trial** data shall be used for the determination of dust removal ability specified in 5.2.4.

NOTE One **run** means one operation of the robot from one starting position. One **trial** consists of one **run** from each of the two starting positions. A single **test** consists of three **trials** per robot.

5.2.4 Determination of dust removal ability and operation time

The dust removal ability is calculated as the ratio of the weight increase of the **dust receptacle** (or the weight of other alternative parts of the robot as specified in 4.8) from its initial weight to the weight of the **test** dust distributed on the **dust area**.

The mean dust removal rate for the starting position S_i shall be calculated as follows using the three measurements obtained from the three **trials**

$$K_i = (K_{i1} + K_{i2} + K_{i3})/3$$

or if five **trials** were executed

$$K_i = (K_{i1} + K_{i2} + K_{i3} + K_{i4} + K_{i5})/5$$

where

K_i is the mean dust removal for starting condition S_i over three (or five) **trials** (%)

$K_{i,j}$ is the dust removal with starting condition S_i for the jth **trial** (%)

$$K_{i,j} = (m_{f,i,j} - m_{0,i,j}) \times 100 / m_D$$

m_D is the weight of the dust distributed on the **dust area** (g)

$m_{0,i,j}$ is the weight of the preconditioned dust receptacle before the run for the starting position S_i in the jth **trial** (alternative options for how to measure the **dust receptacle** are specified in 4.8) (g)

$m_{f,i,j}$ is the weight of the **dust receptacle** at the end of the run for the starting position S_i in the jth **trial** (alternative options for how to measure the **dust receptacle** are specified in 4.8) after cleaning (g).

The mean operation time of the robot for the starting position S_i shall be calculated as follows using the three measurements obtained from the three **trials**:

$$t_i = (t_{i,1} + t_{i,2} + t_{i,3}) / 3$$

or if five **trials** were executed

$$t_i = (t_{i,1} + t_{i,2} + t_{i,3} + t_{i,4} + t_{i,5}) / 5$$

where

$t_{i,j}$ is the operation time for starting condition S_i for the jth **trial** (minutes)

t_i is the mean operation time for starting condition S_i over three **trials** (minutes).

The overall mean dust pickup value K is then calculated as

$$K = \frac{(K_1 + K_2)}{2}$$

The overall mean operation time t is calculated as

$$t = \frac{(t_1 + t_2)}{2}$$

The dust pickup value K and the mean operation time t shall be recorded as the final result.

5.3 Dust removal from carpets

5.3.1 Test bed

The **test** bed is identical to that defined in 5.2.1 except the floor is covered with **test** carpet which is the Wilton type carpet in accordance with IEC 60312-1:2010, Clause C.1 – Wilton Carpet.

The pile direction of the carpet shall be installed as specified in Figure 4.

Dimensions in millimetres

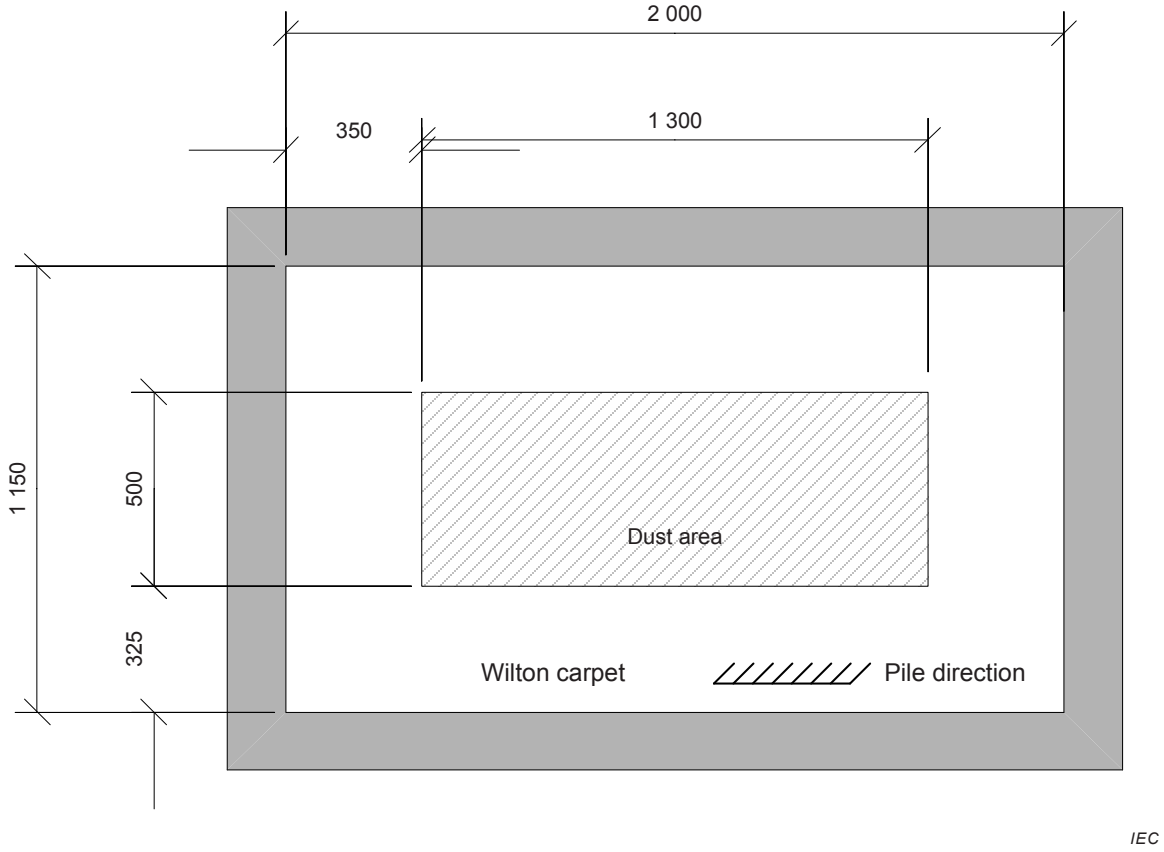


Figure 4 – Dust removal (box test) from carpet floor test bed configuration

5.3.2 Preparation of test

5.3.2.1 Pre-treatment of test carpet

A new carpet shall be pre-conditioned in the following manner before recordable testing is carried out.

Using a suitable vacuum cleaner all loose pile and fibre is removed over the entire surface of the carpet until an amount no greater than 0,5 g/m^2 is removed during a 5 min cleaning process.

Using an in-house reference vacuum cleaner, a dust removal **test** according to 7.2.1.4 in IEC 60312-1:2010 is carried out and the result recorded and plotted on a graph.

This is repeated until the resulting curve is parallel with the horizontal axis and the difference between the average results of two consecutive tests is no greater than 1 percentage point.

Due to the significant influence of humidity on this **test** the carpet shall be left in the **test** environment at standard atmospheric conditions (refer to 4.1) for at least 16 h before the **test** is due to commence.

5.3.2.2 Conditioning of test carpet

Prior to each **run** the **test** carpet shall be cleaned to remove remaining dust and preconditioned as described below.

For cleaning of the **test** carpet it is recommended to use a suitable carpet-beating machine such as described in 5.3.3.2 in IEC 60312-1:2010.

If a carpet-beating machine is not used the carpet shall be placed upside down on a rigid mesh support and beaten by hand or with an active nozzle. After the beating, one cleaning cycle with a vacuum cleaner, which has good dust removal ability shall be carried out to remove remaining dust.

5.3.2.3 Verification and preconditioning of test carpet

After cleaning the **test** carpet an in-house reference vacuum cleaner with minimum dust removal ability on Wilton carpet of 65 % after 5 double strokes in parallel to the pile direction according to IEC 60312-1 shall be equipped with a clean **dust receptacle** and be used to verify that the carpet has been cleaned to the point where no dust pick-up is discernible. This point is considered to be reached if the amount of dust removed from the carpet during five cleaning cycles is less than 2,0 g (also refer to 5.3.3.3 in IEC 60312-1:2010). If the amount is greater than 2,0 g this step is repeated until the requirement is achieved.

To prevent a gradual filling of the carpet with dust the weight of the **test** carpet shall be maintained as close as possible to that of the initially clean carpet.

5.3.2.4 Pre-treatment of cleaning robot

Refer to 5.2.2.2.

5.3.2.5 Distribution of test dust

Prior to each **run** the floor of the **test** bed shall be cleaned carefully. After the placement of the conditioned **test** carpet on the floor of the testbed the **test** dust (see below) shall be distributed with a mean coverage of 125 g/m^2 as uniformly as possible across the **dust area**. The following **test** dust shall be used:

Sieved from CEM 1 according to ISO 679

Grain size: 0,09 mm to 0,20 mm

NOTE 1 For uniform distribution of the **test** dust, a manual dust spreader as described in IEC 60312-1 can be used.

NOTE 2 To ensure the distribution of the **test** dust only within the **dust area**, a masking frame with interior dimensions equal to the specified **dust area** can be used.

5.3.2.6 Embedding test dust into the test carpet

The dust shall be embedded into the **test** carpet by carrying out ten double strokes over the carpet, parallel with the direction of the pile, using a roller in accordance with 5.3.5 in IEC 60312-1:2010.

The speed of the roller over the **dust area** shall be a uniform 0,5 m/s ± 0,02 m/s with the forward stroke being in the direction of the pile. It is important to ensure that the **dust area** is completely and evenly rolled. The carpet is then left for a period of 10 min to recover from rolling.

5.3.2.7 Removal of remaining dust

Before the initiation of the next **run** remaining dust shall be removed according to 5.3.2.2.

5.3.3 Test method

Test according to 5.2.3.

5.3.4 Determination of dust removal ability and operation time

Test according to 5.2.4.

6 Dust removal – Straight line

6.1 General

This **test** is designed to isolate the dust removal system of the robot from the autonomous movement, in order to assess only the ability to remove dust. This facilitates direct comparison between robotic cleaners.

6.2 Test Mode

6.2.1 General

The straight line cleaning **test** requires the robot to move straightforward at a nominal speed calculated from normal operation mode. There are some other functions required for the straight line cleaning **test**, which shall be provided within a **test** mode.

This mode shall enable the robot to perform a repeatable **test** mode action in which it shall be driven forward in a straight line, at a fixed speed for the defined minimum distance (refer to 6.2.3). The **test** mode shall satisfy the entire relevant safety requirement.

This **test** mode action can then be repeated multiple times depending on the nature of the **test** (e.g. for multiple-**pass** pick up testing).

In the absence of the **test** mode, the robot shall be tested with a mode (e.g. a remote-control mode) that generates a reasonably straight motion (**dust area** coverage more than 75 %). The fact that the straight motion was generated by the mode other than the **test** mode shall be reported.

NOTE If a reasonably straight motion cannot be generated, then the **test** cannot be properly executed and the **test** can be skipped.

6.2.2 Access to test mode

The precise nature of access to the **test** mode shall be clearly stated by the manufacturer and it shall be simple to execute. Once the access operation is complete it shall leave the machine in an idle state.

NOTE Examples of access methods to the **test** mode could be to require the user to have a combination of buttons on the machine pressed when the robot is switched on or for a combination of buttons to be held for a period of time which would not occur during normal robot operation. The only condition is that this access method is to be documented.

Once in the idle state the user shall be able to initiate the execution of a single **test** mode action (refer to 6.2.3) at one of two speeds, s_{avg_hard} and s_{avg_carpet}, either by a method available on the robot (such as a button press) or a remote method (such as pressing a button on a remote control). s_{avg_hard} and s_{avg_carpet} shall be calculated following the method described in Clause 8.

Once the **test** mode action has been completed then the machine shall return to its idle state, ready to execute another **test** mode action if required.

It shall be possible to pick the machine up and reposition it without the machine exiting the idle state.

It is expected that the user shall be able to exit this mode either via an instruction or via a power down/up cycle.

6.2.3 Test mode action

The **test** mode action involves the machine starting from a stationary pose and driving in a straight line before coming to a halt.

A part of the straight-line motion shall maintain the speed at the average speed of the robot, either s_{avg_hard} or s_{avg_carpet} as defined and measured in 8.3.

The straight-line motion consists of an acceleration period, a constant period, and a deceleration period as shown in Figure 5. The acceleration area of 200 mm is provided during which the machine shall accelerate up to the average speed, either s_{avg_hard} or s_{avg_carpet}. Once past this acceleration area the machine shall maintain the required average speed for at least 700 mm plus the longitudinal length of the robot as indicated in Figure 6 (which is explained in 6.3.1 in detail). The deceleration area of 200 mm corresponds to the surface during which the robot shall decelerate to a stationary pose.

NOTE The velocity and the distance mentioned above are the observed quantities not the commanded input.

During the execution of the **test** mode the robot's basic cleaning systems shall be active in their standard operating mode. All other "enhanced" cleaning systems that would prevent the straight motion of the robot (e.g. dust sensor) shall not be active.

6.2.4 Test mode speed verification

It is understood that the actual motion executed by the robot will not be precisely as described above due to various external influencing factors such as slip on the traction systems or resolution of the guidance system, etc. The actual observed speed at which the action is executed shall be (the required speed ±10 %).

If the speed does not comply to the conditions specified above the failure in compliance shall be reported and the **test** shall not be continued.

NOTE 1 For the same reasons as above, it is understood that the robot cannot execute a precise straight line path and a curved path could result.

NOTE 2 The inaccuracies of the path performed in **test** mode are accounted for by using a **VTS** which can report the actual path executed.

6.3 Dust removal from hard floor

6.3.1 Test bed

The length and the width of the **test** bed shall be 2 000 mm (minimum) × 600 mm as specified in Figure 6).

The **dust area** shall be 700 mm × (W – 20) mm, where W is the **cleaning head** width.

NOTE The 20 mm reduction in width of the **dust area** is to avoid spreading dust outside of reachable width by the robot. The additional 200 mm on each end of the **dust area** is designed to enable the robot to reach its specified speed before it enters the **dust area**.

The **test** floor shall be untreated laminated pine tree plate or equivalent and its thickness shall be at least 15 mm.

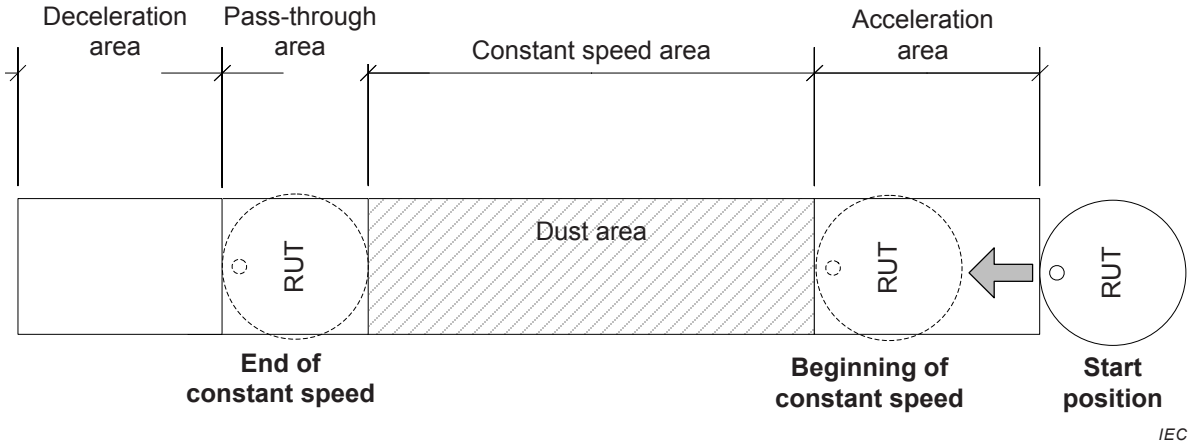
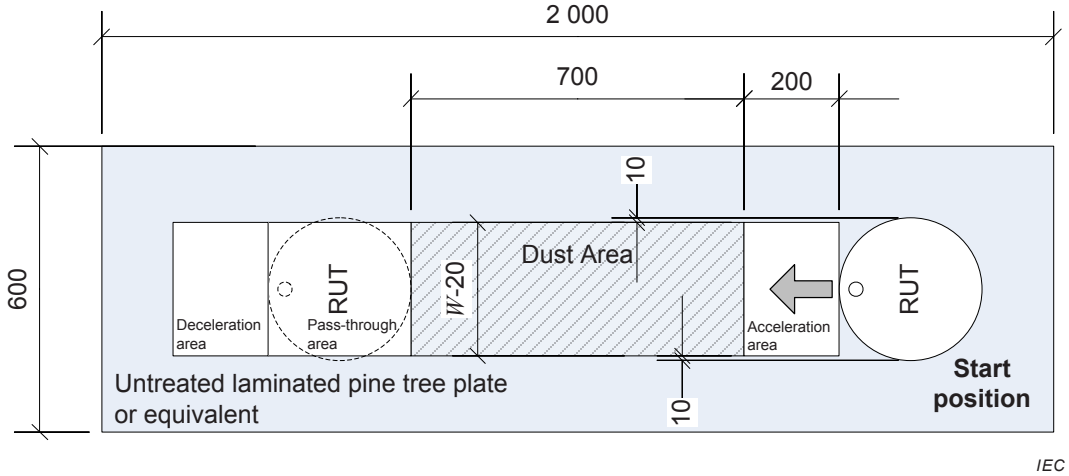


Figure 5 – Description of test mode action

Dimensions in millimetres



Key

W Width

Figure 6 – Straight line dust removal from hard floor test bed configuration

6.3.2 Preparation of test

6.3.2.1 Preconditioning of test floor

Refer to 5.2.2.1.

6.3.2.2 Pre-treatment of cleaning robot

Refer to 5.2.2.2.

Exception is that replaceable filters and dust collection parts (e.g. dust pad) shall not be replaced within the same cleaning **trial**.

6.3.2.3 Visual tracking system

During the **test** the testbed shall be monitored using a **visual tracking system** (**VTS**). A proper **VTS** shall be installed and the functionality of **VTS** shall be verified to satisfy the specifications in 4.9.

6.3.2.4 Speed of test run on hard floor

The **test runs** shall be executed at the speed s_{avg_hard}.

Before running the **test**, the actual speed of the robot in **test** mode shall be verified to be within ± 10 % range of s_{avg_hard} per Clause 8.

6.3.2.5 Distribution of test dust

Test dust Type 1 in accordance with 7.2.2.1 in IEC 60312-1:2010, shall be distributed with a mean coverage of 50 g per square metre as uniformly as possible over the **test** area.

NOTE 1 For uniform distribution of the **test** dust, a manual dust spreader as described in Figure 2 can be used.

NOTE 2 To ensure the distribution of the **test** dust only within the **dust area**, a masking frame with size of the **dust area** can be used.

6.3.3 Test method

After the preparation process is completed according to 6.3.2 the **dust receptacle** shall be weighed as specified in 4.8 (M_0).

If the robot is equipped with removable side brush it shall be removed from the robot before the placement of the **cleaning robot** on the **test** bed,

NOTE The straight line **test** is strictly for the **test** of dust removal from the floor.

The **cleaning robot** shall be switched on and placed into **test** mode using the method provided by the manufacturer (refer to 6.2.2).

The **cleaning robot** shall be placed at the start position specified in Figure 6 with the centre of the **cleaning head** aligned to the centreline of the **dust area**.

It is important to ensure the proper consistent alignment of the robot with the **dust area** on the testbed. During the setup process an alignment device such as a laser pointer can be used for the validation of a proper alignment.

The **cleaning robot** shall perform a single **run** using the method supplied by the manufacturer (refer to 6.2.2) at speed s_{avg_hard}. The **run** shall be monitored and recorded by the **VTS**.

The acceleration area shall be used for the robot to increase its speed to constant speed, s_{avg_hard}.

The robot shall maintain its constant speed s_{avg_hard} from the time when the front-end of the robot enters the constant speed area until the rear-end exits the constant speed area (refer to Figure 5 and Figure 6). The deceleration area shall be used for the robot to reduce its speed to rest.

In order to satisfy the constant speed requirement the robot may move at its constant speed s_{avg_hard} even after the whole body of the robot exits the constant area. Pass-through area is designed for this purpose.

After the movement of the **cleaning robot** has stopped the receptacle shall be carefully removed and reweighed as specified in 4.8.

Without cleaning the robot and the receptacle, the next **run** shall be repeated. After each **run** the receptacle shall be carefully removed and reweighed as specified in 4.8.

A single cleaning **trial** consists of N **runs** (straightforward motion), where the number N shall be chosen by the tester.

The dust on the testbed (even outside of the **dust area**) shall not be cleaned before the end of whole **trial**.

If the area coverage of any or the **runs** is smaller than 75 % the whole **trial** shall be discarded and the **trial** shall be repeated.

The cleaning **trial** (with N **runs**) shall be repeated twice more. Before each **trial** the robot and the receptacle shall be conditioned according to 5.2.2.2.

If the spread of any of accumulative dust pickup rates p_i (defined in 6.3.4) from three **trials** is larger than 10 %, two more **trials** shall be added.

6.3.4 Determination of dust removal ability

On each **run** the **VTS** shall record an accurate measurement of the path of the robot. Once the designated numbers of **test runs** (N) have been completed the **VTS** will combine the motion data and report the percentage of the **dust area** which has been passed by the machine j times, at the end of each **run**.

The number N is solely chosen by the need of the tester but minimum three are recommended for the **test**.

The dust pickup rate can be calculated with

$$p_i = \frac{\frac{M_i}{M} - \sum_{k=1}^{i-1} C_{ki} \times p_k}{C_{ii}}$$

where

M total weight of dirt initially distributed in the **dust area** (g)

M_i measured accumulative weight of dirt picked up after the ith **run** (g)

C_{ki} percentage of **dust area** passed by the robot **cleaning head** only k times after the ith **run** (percent)

p_i accumulated dust pick up rate from the i-**pass dust area** (%)

NOTE 1 The i-pass **dust area** means the area in the **dust area** where the **cleaning head** of the **cleaning robot** has traversed i times.

Upon completion of three **trials** the final pickup percentages for hard floor P_i is calculated as follows

$$P_i = \frac{\left(p_{i,1} + p_{i,2} + p_{i,3}\right)}{3}$$

or if five **trials** were executed

$$P_i = \frac{\left(p_{i,1} + p_{i,2} + p_{i,3} + p_{i,4} + p_{i,5}\right)}{5}$$

where

$p_{i,n}$ accumulated dust pick up rate from the i-**pass dust area** calculated from the nth **trial** (percent)

P_i final accumulated **i-pass** pickup rate (percent) where i=1,2,3,…,N

NOTE 2 Once the first **run** of the **test** mode action has completed the single-**pass** pickup percentage, p_1, is calculated as follows. At this time C_{21} and C_{31} are both zero.

$$p_1 = \frac{M_1}{M \times C_{11}}$$

After the second **run** the two-**pass** pickup percentage, $p_{2,}$ is calculated as follows. Still C_{32} remains zero.

$$p_2 = \frac{\frac{M_2}{M} - C_{12} \times p_1}{C_{22}}$$

Finally after the third **run** the three-**pass** pickup percentage, p_3, is calculated as follows.

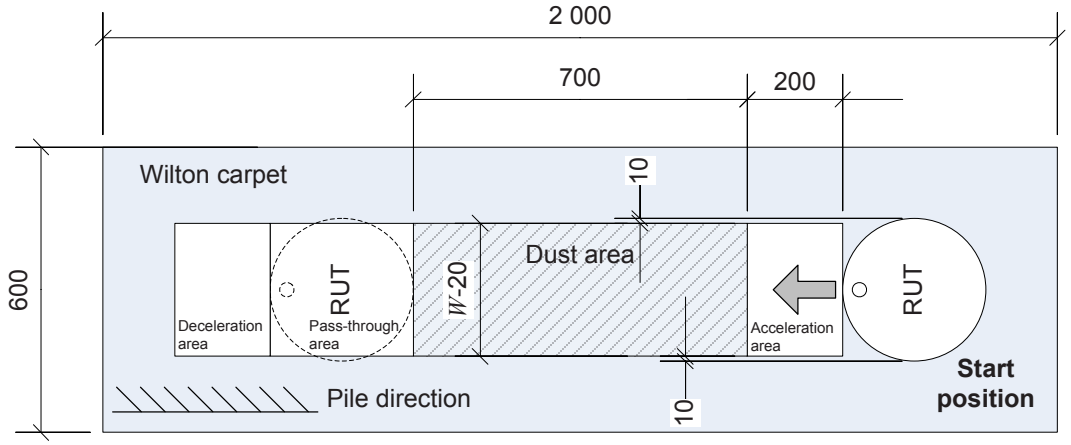
$$p_3 = \frac{\frac{M_3}{M} - C_{13} \times p_1 - C_{23} \times p_2}{C_{33}}$$

Therefore the accumulative weight of the dust measured after the ith **run** M_i shall satisfy the equation below.

$$M_i = M \times \sum_{k=1}^{n} \left(C_{ki} \times p_k \right)$$

NOTE 3 There are two methods for reporting pickup values from the straight line **test** method: absolute pickup and relative pickup. Absolute pickup is the dust picked up at the conclusion of a chosen number of **passes** made by the robot, reported irrespective of the number of **passes** that the robot's navigation system dictates during actual operation. For example, 1, 3, 5 or 10 **pass** cumulative pick-up measurements can be made, even if the robot's navigation system makes only two **passes** during actual operation. This allows comparison of the vacuum system performance in isolation from the navigation system, and facilitates comparison to manually operated vacuum cleaners if required. Relative pickup is the dust pick up recorded after each **pass**, up to the total number of **passes** reported for that product from the autonomous navigation/coverage **test** result (refer to Clause 7). This ensures that the pickup capability reported is relative to the robots navigation strategy and therefore representative of actual operation when comparing robotic products. The limit for number of additional cumulative **trials** to be measured is when less than or equal to 1 % pick up increase is measured between **trial** n and n-1.

Dimensions in millimetres



IECIECIECIEC

Key

W Width

Figure 7 – Straight line dust removal from carpet floor test bed configuration

6.4 Dust removal from carpet

6.4.1 Test bed

The **test** bed is identical to that defined in 6.3.1 except the floor is covered with **test** carpet which is the Wilton type carpet in accordance with IEC 60312-1:2010, Annex C.1 – Wilton Carpet. Figure 7 shows the configuration of the testbed.

6.4.2 Preparation of test

6.4.2.1 Pre-treatment of test carpet

Refer to 5.3.2.1.

6.4.2.2 Conditioning of test carpet

Refer to 5.3.2.2.

6.4.2.3 Verification and preconditioning of test carpet

Refer to 5.3.2.3.

6.4.2.4 Pre-treatment of cleaning robot

Refer to 5.2.2.2.

6.4.2.5 Visual tracking system

Refer to 6.3.2.3.

6.4.2.6 Speed of test run on carpet

The **test runs** shall be executed at speed s_{avg_carpet}.

Before running the **test**, the actual speed of the robot in **test** mode shall be verified to be within ± 10 % range of s_{avg_carpet} according to Clause 8.

6.4.2.7 Distribution of test dust

Test dust Type 2, in accordance with 7.2.2.2 in IEC 60312-1:2010, shall be distributed with a mean coverage of 125 ± 0,1g per square metre as uniformly as possible over the **test** area.

NOTE 1 For uniform distribution of the **test** dust, a manual dust spreader as described in IEC 60312-1 can be used.

NOTE 2 To ensure the distribution of the **test** dust only within the **dust area**, a masking frame with size of the **test** distribution can be used.

6.4.2.8 Embedding test dust into test carpet

Refer to 5.3.2.6.

6.4.2.9 Removal of remaining dust

The remaining dust shall be removed according to 5.3.2.2 only after each **trial** (not **run**). Verification and pre-conditioning shall be performed according to 5.3.2.3 before each **trial**.

6.4.3 Test method

Refer to 6.3.3.

6.4.4 Determination of dust removal ability

Refer to 6.3.4.

7 Autonomous navigation/coverage test

7.1 General

The purpose of the autonomous navigation/coverage **test** is to measure the ability of floor **cleaning robots**, as defined within this standard, to cover the available floor space against a standardized room configuration as defined in 7.2. The measure of performance for this **test** is the cumulative percent floor space traversed during a period of time. Multiple **passes** of the robot over the same floor space is also measured in this **test**.

7.2 Test bed

7.2.1 Test conditions

For this **test**, the ambient temperature and humidity shall be stated. It does not have to satisfy the conditions stated in 4.1.

7.2.2 Floor configuration

The **test** area shall consist of a space measuring 4 000 mm × 5 000 mm ($L \times W$) (tolerance ±50 mm) enclosed by four walls and a ceiling.

The **test** floor shall be untreated laminated pine tree plate or suitable alternative.

The floor of the **test** bed for the navigation/coverage performance **test** shall be as described in Figure 8 to Figure 12. The furniture and obstacles shall be placed as shown in Figure 8.

The dimensions and characteristics of the furniture and obstacles on the floor are specified in Table 2.

Dimensions in millimetres

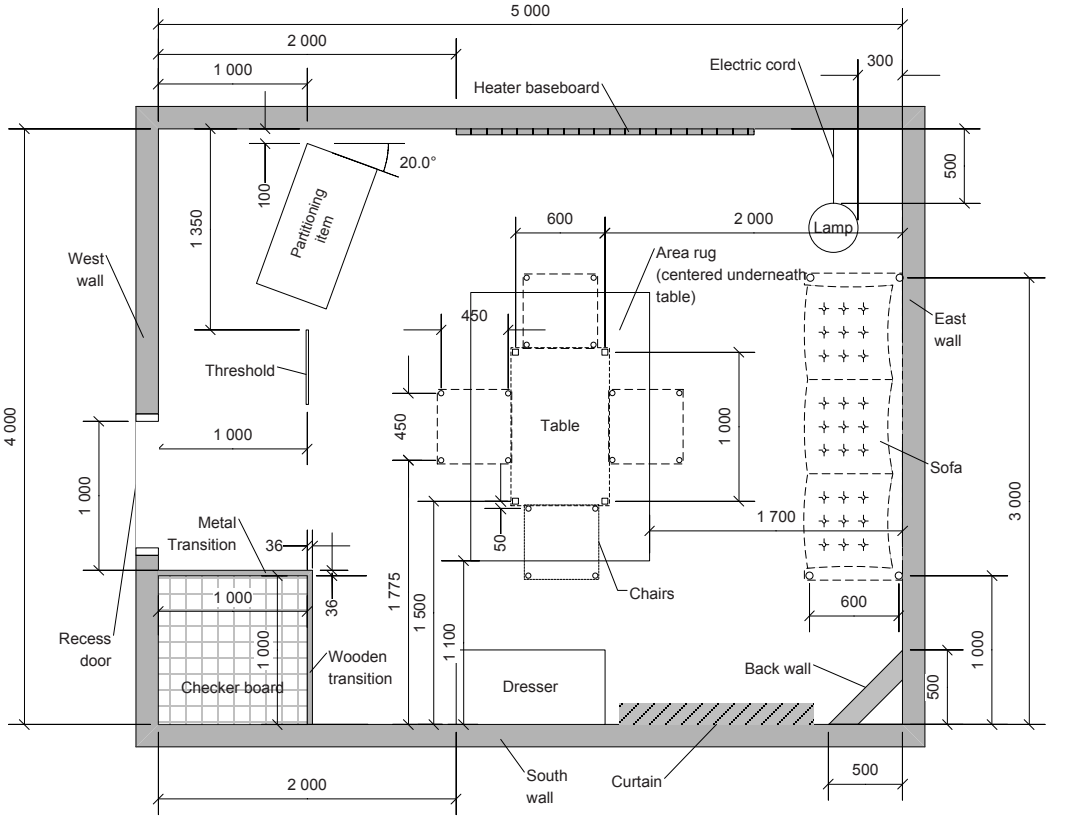


Figure 8 – Navigation/Coverage test bed configuration

Dimensions in millimetres

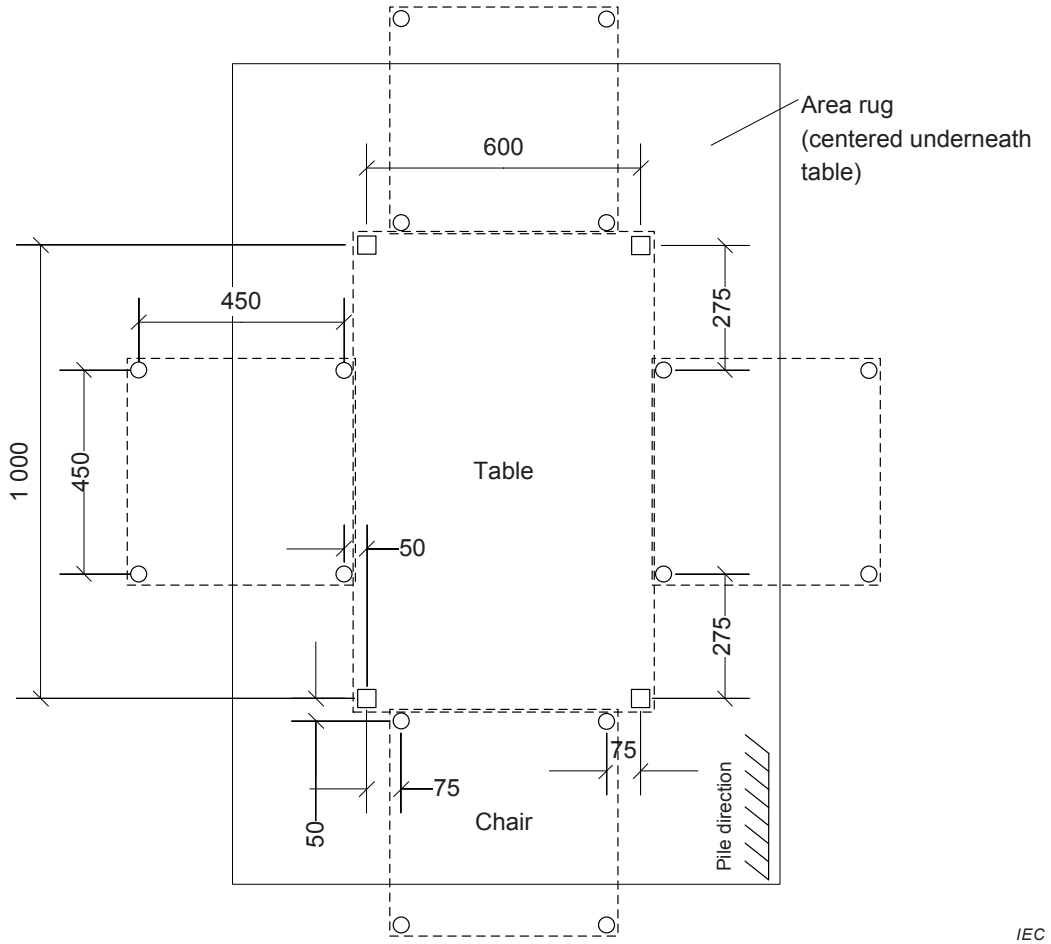


Figure 9 – Details of obstacles around table

Table 2 – Dimensions of furniture and obstacles

Item	Quantity	Dimensions (mm)	Surface/ Colour	Remarks
Dresser	1	1 000 (L) 500 (W) 300 (H)	White	It is fixed to the floor. Underneath of the dresser shall be blocked. No legs.
Table	1	1000 (L) 600 (W)	Natural Cherry	4 legs of 40 mm (L) × 40 mm (W) × 300 mm (H) Distance of 1 000 mm (L) and 600 mm (W) are between centrelines of legs. Legs are fixed to the floor.
Chairs	4	450 (L) 450 (W)	Natural Cherry	4 legs of 35 mm (D) × 300 mm (H). Distance between centrelines of legs is 450 mm. Legs are fixed to the floor.
Sofa	1	2 000 (L) 600 (W)	White	4 legs of 48 mm (D) × 300 mm (H). Distance of 2 000 mm (L) and 600 mm (W) are between centrelines of legs. Legs are fixed to the floor.
Partitioning Item	1	1 000 (L) 500 (W) 300 (H)	18 % grey	No legs. All sides are enclosed. It is fixed to the floor.
Floor lamp	1	330 (D) 300 (H)	White	Base is 5 mm (H) at the outer edge with 10° upward slope. Diameter of the pole at the centre is 30 mm. It is fixed to the floor.
Floor electrical wire	1	6 (D) 900 (L)	Black	One end is fixed at the plug on the north wall at height of 350 mm and the other end is fixed at the side of the lamp base of the lamp. It is not fixed on the floor.
Cylindrical bar	1	15 (D) 500 (L)	Untreated or unground surface	It is cylindrical shape and made of Aluminium. It is fixed to the floor. NOTE It represents a cylinder shape support of chairs.
Heater baseboard	1	2 000 (L) 40 (W) 300 (H)	Natural Cherry	It is secured on the wall and floor. It is fixed on the floor.
Area rug	1	1 680 (L) 1 200 (W) 10 (H)	Ivory	Wilton type area rug It is fixed to the floor.
Checker board	1	1 000 (L) 1 000 (W) 7 (H)	Black and White	Each tile shall be of the following dimensions: 100 mm (W) × 100 mm (D) × 7 mm (H). White tile surface shall be polished. Matt black is without polishing. Tiles shall be fixed on the floor with no gaps between tiles. The transitions shall be fixed on the floor.

Item	Quantity	Dimensions (mm)	Surface/ Colour	Remarks
Metal transition	1	36 (W) 2 (H)	Untreated or unground surface	Aluminium (refer to Figure 10 and Figure 12 for installation) It is M-D Building Products®[2] (36 in $L \times 2$ in W, Model #43858, polished) or similar. It is fixed to the floor. For the corner where the metal transition meets the wooden transition both transitions shall be cut with 45°.
Wooden transition	1	36,5 (W) 11 (H)	Finished wood	Wood (Refer to Figure 11 and Figure 12 for installation). It is a Bruce Natural Reducer®[3] (Model #11177810) or similar. It is fixed to the floor.
Key L Length W Width H Height D Diametre				

Dimensions in millimetres

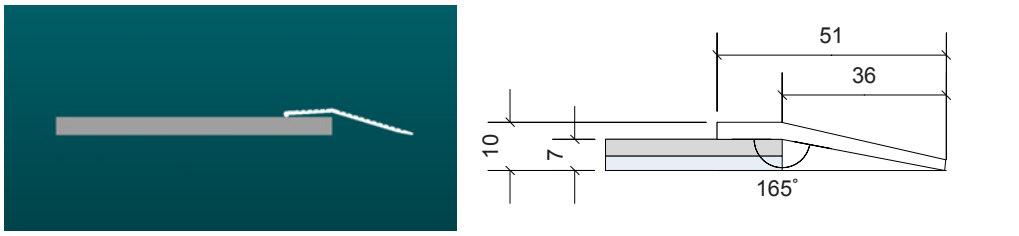


Figure 10 – Illustration of metal transition installation

Dimensions in millimetres

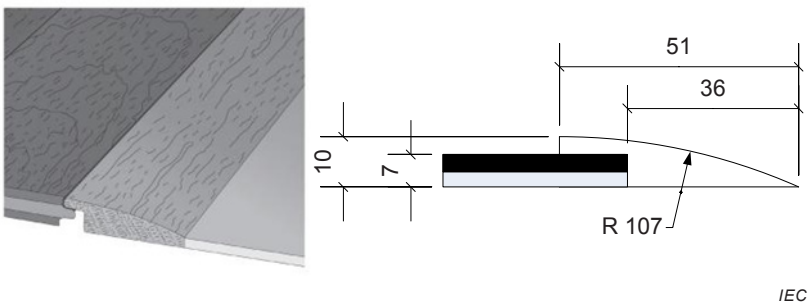


Figure 11 – Illustration of wood transition Installation

---

2 Model #43858 is the trade name of a product supplied by M-D Building Products®. This information is given for the convenience of users of this document and does not constitute an endorsement by IEC of the product named. Equivalent products may be used if they can be shown to lead to the same results.

3 Model #11177810 is the trade name of a product supplied by Bruce and Armstrong®. This information is given for the convenience of users of this document and does not constitute an endorsement by IEC of the product named. Equivalent products may be used if they can be shown to lead to the same results.

Dimensions in millimetres

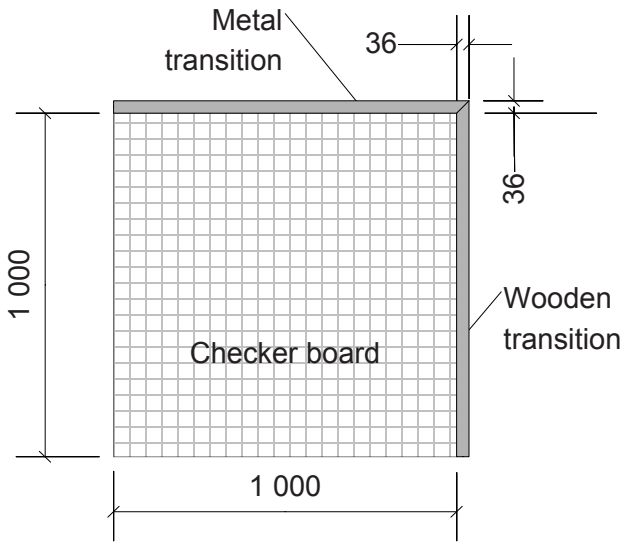


Figure 12 – Detail view of checker board and transitions

Dimensions in millimetres

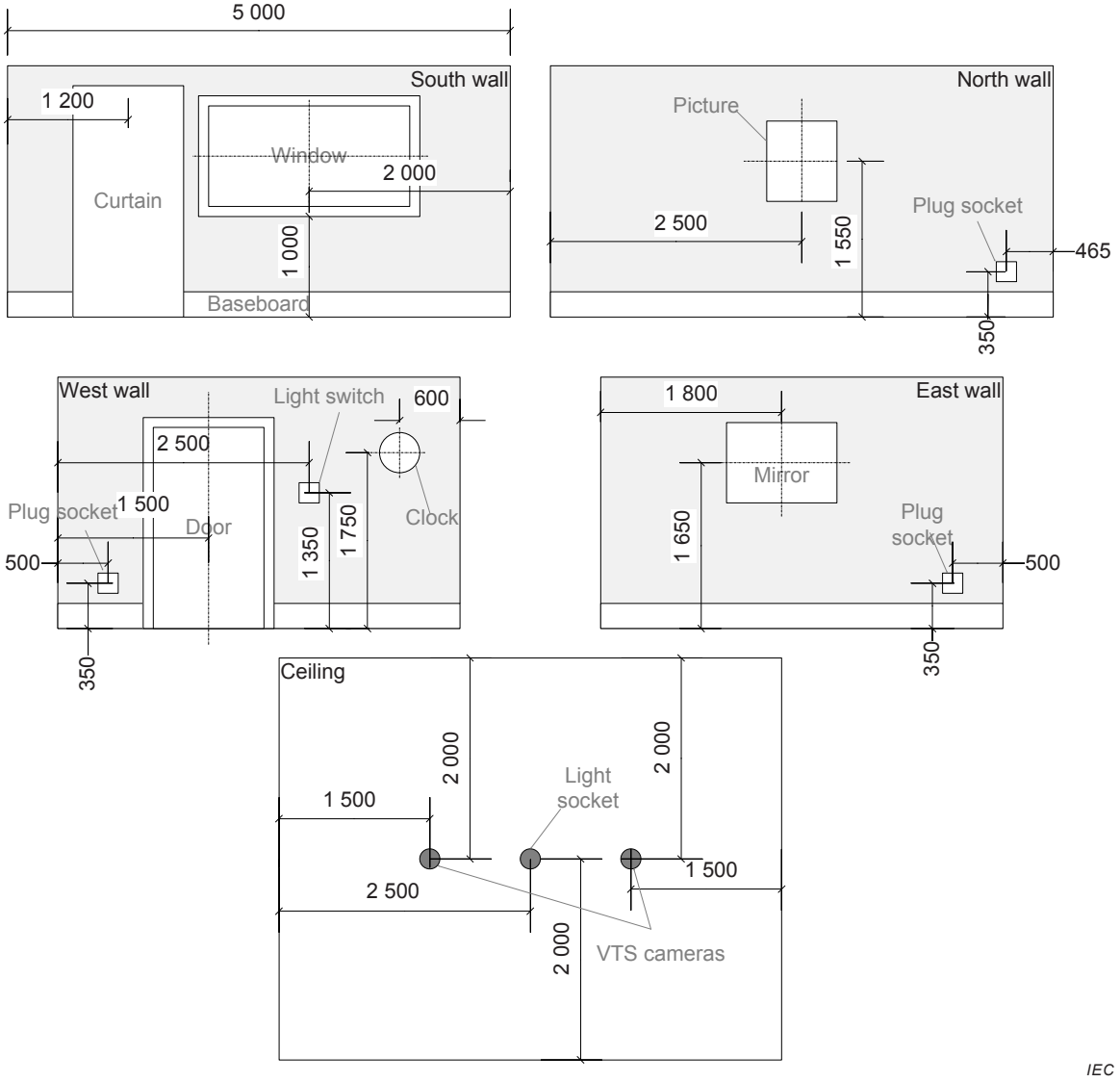


Figure 13 – Configuration of four walls and ceiling

7.2.3 Wall and ceiling configuration

7.2.3.1 General

The configuration of wall and ceiling of the **test** bed shall be Figure 13. The ceiling shall be at a height of 2 500 mm (±50 mm) from the surface of the **test** bed floor. The ceiling shall be level and parallel to the floor.

Table 3 contains a list of the objects and features which shall be present on the walls, no other visible features are permissible. This table also provides the dimensions, characteristics and locations for each item.

The walls shall be full height from floor to ceiling with no gaps or discontinuities other than those described in Table 3. The walls shall be vertical and perpendicular to both the floor and ceiling.

The walls and ceilings shall be covered or painted as described in Table 3. The surfaces of the walls and ceilings shall be level and have no discernible texture (maximum local geometric variation ±1 mm).

Table 3 – Wall and ceiling furniture

Item	Quantity	Dimensions (mm)	Surface details	Remarks
North wall	1	5 000 (L)	Matt: Magnolia RGB #EEE8EB 0 % to 10 % reflectance	All walls shall be constructed in such a manner that they do not move or deform in any way when the robot comes into contact with them
South wall	1	5 000 (L)	Matt: Magnolia RGB #EEE8EB 0 % to 10 % reflectance	See above
East wall	1	4 000 (L)	Matt: Magnolia RGB #EEE8EB 0 % to 10 % reflectance	See above
West wall	1	4 000 (L)	Matt: Magnolia RGB #EEE8EB 0 % to 10 % reflectance	See above
Ceiling	1	4 000 (W) 5 000 (L)	Matt: Magnolia RGB #EEE8EB 0 % to 10 % reflectance	See above
Door	1	750 to 850 (W) 1 950 to 2 050 (H)	Gloss: White 60 % to 80 % reflectance	Refer to Figure 14 and associated text With a silver door handle
Window	1	1 800 to 2 200 (W) 900 to 1 100 (H)	Gloss: White 60 % to 80 % reflectance A panel shall be mounted on the back of the window, behind the panes, which shall be painted matt blue (RGB #99CCFF, 0 % to 10 % reflectance).	Refer to Figure 15 and associated text
Baseboard	4	75 to 125 (H) 10 (D)	Two Sides (North and West): Gloss White 60 % to 80 % reflectance Two Sides (East and South): Untreated Natural wooden board	Refer to Figure 16 and associated text
Light switch	1	70 to 100 (W) 70 to 100 (H) 0 to 15 (D)	Plastic: White	Single switch. Does not have to be connected to the light in the **test** area
Plug socket	1	70 to 100 (W) 70 to 100 (H) 0 to 15 (D)	Plastic: White	Single socket. Does not need to be live
Pendant light socket	1	120 to 250 (L)	White	Length indicates drop height from ceiling to base of bulb. Refer to Figure 17.
VTS camera	2			Mounted flush to the ceiling

Item	Quantity	Dimensions (mm)	Surface details	Remarks
Clock	1	300 (D)	Frame: Gloss Grey RGB #808080 60 % to 80 % reflectance Face: Matt White RGB #FFFFFF 0 % to 10 % reflectance	The clock does not have to be a real clock. Refer to Figure 18.
Mirror	1	1 000 (W) 750 (H)	Frame: Gloss Grey RGB #808080 60 % to 80 % reflectance	Refer to Figure 19
Picture	1	600 (W) 750 (H)	Frame: Gloss Grey RGB #808080 60 % to 80 % reflectance Face: Matt Green RGB #99FF99 0 % to 10% reflectance	Refer to Figure 20.
Curtains	1	1 100 to 1 300 (W) 2 000 to 2 200 (H)	Brown RGB #333300	Material used shall be plain, opaque, and heavy enough to hang without creasing. Centreline of the curtain shall be 1 200 mm from the wall. Refer to Figure 21.

Key

L Length

W Width

H Height

D Diametre

NOTE All colours are specified in web colour RGB format and intended to be an indicative guide of the proposed colour. Colour can vary by ±5 % in each RGB value.

7.2.3.2 Door specification

The configuration of the door shall be as in Figure 14. The door shall have four inset panels. The door shall be surrounded by a frame of 50 mm (W) that shall be mounted flush to the wall (resulting in the door being recessed from the wall by 50 mm). The frame may be shaped on its inner edge only, by a single curved feature with a maximum radius of 50 mm. The handle shall be mounted on the right hand side (when viewed from inside the **test** area). The door may be able to be opened. If so, the door shall open outwards from the **test** area.

7.2.3.3 Window specification

The configuration of the window shall be as Figure 15. The window shall consist of three equally sized window panes. A frame shall surround each pane. The frames shall be 50-100 mm (W) and shall protrude from the wall by 50 mm to 100 mm. The panes can be made from either glass or any clear acrylic material. The pane shall be recessed from the front face of the frame by 10 mm. A panel shall be mounted on the back of the window, behind the panes, which shall be painted matt blue (RGB #99CCFF, 0 % to 10 % reflectance).

7.2.3.4 Baseboard (skirting board) specification

The configuration of the baseboard shall be as Figure 16. The baseboard may be shaped on its top edge only, by a single curved feature with a maximum radius of 10 mm.

7.2.3.5 Pendant light specification

The configuration of the pendant light shall be as Figure 17. The height of the pendant light fitting measured from the ceiling to the base of the light bulb shall be in the range of 120 mm to 250 mm.

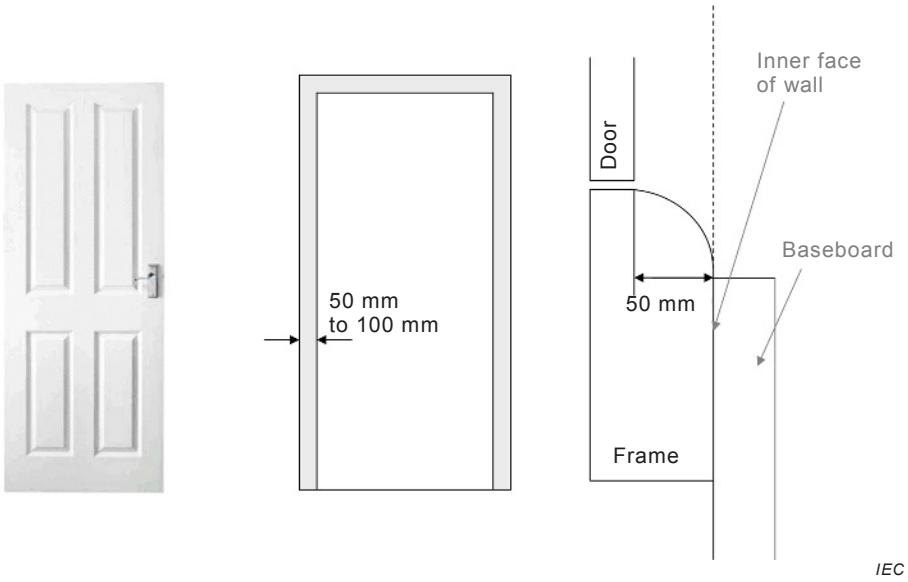


Figure 14 – Illustration of four-panel door

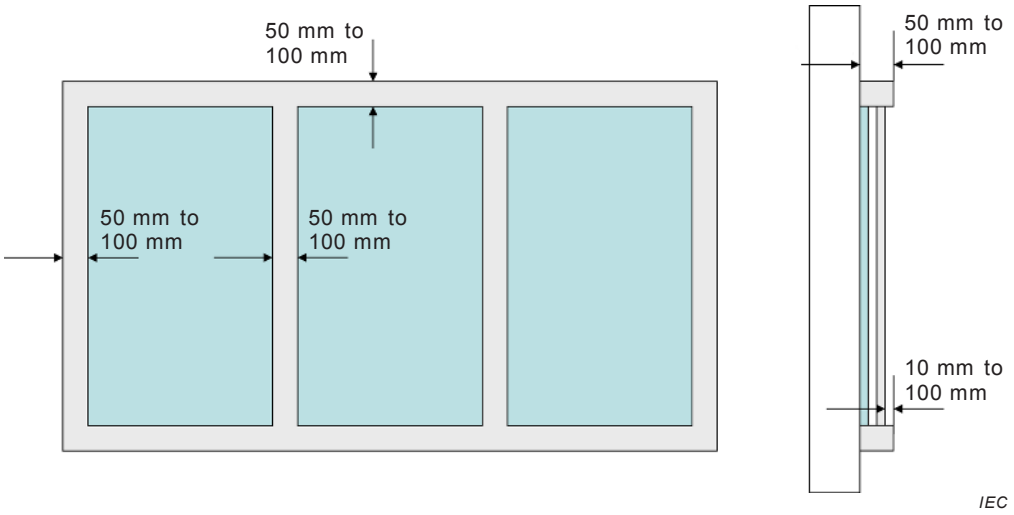


Figure 15 – Illustration of window

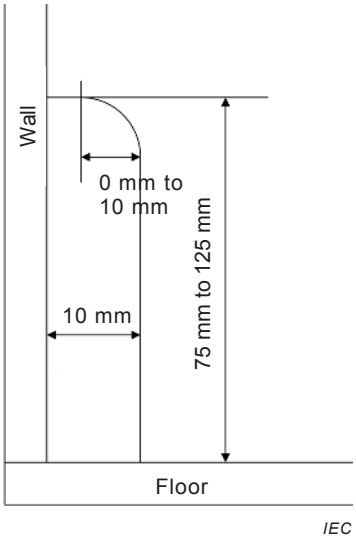


Figure 16 – Illustration of baseboard

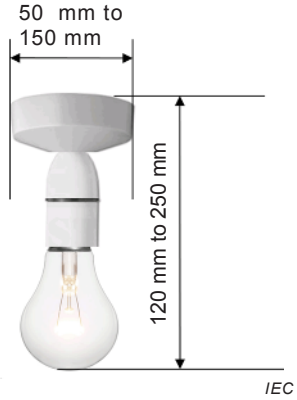


Figure 17 – Illustration of pendant light

7.2.3.6 Clock specification

The configuration of the clock shall be as Figure 18. The clock shall be represented by a gloss grey (RGB #808080, 60 % to 80% reflectance) circular frame enclosing a white matt face (RGB #FFFFFF, 0 % to 10% reflectance). No hands or other display shall be included. The frame shall be 75 mm (W) and shall protrude from the wall by 50 mm. The face shall be recessed from the front face of the frame by 25 mm.

7.2.3.7 Mirror specification

The configuration of the mirror shall be as Figure 19. The mirror shall be surrounded by a gloss grey (RGB #808080, 60 % to 80 % reflectance) frame. The frame shall be 100 mm (W) and shall protrude from the wall by 50 mm. The mirror shall be recessed from the front face of the frame by 25 mm. The mirror itself shall be a flat glass based mirror and have a reflectance of at least 85 %.

7.2.3.8 Picture specification

The configuration of the picture shall be as Figure 20. The picture shall consist of a green panel behind a clear panel, all surrounded by a frame. The gloss grey (RGB #808080, 60 % to 80 % reflectance) frame shall be 50 mm (W) and shall protrude from the wall by 50 mm. The clear panel can be made from either glass or any clear acrylic material. The clear panel shall

be recessed from the front face of the frame by 25 mm. A panel shall be mounted on the back of the picture frame, behind the clear panel, which shall be painted matt green (RGB #99FF99, 0 % to 10 % reflectance).

7.2.3.9 Curtains specification

The configuration of the curtains shall be as Figure 21. The extent of the width of curtains shall be 1 100 mm to 1 300 mm and the width of the material used shall be 3 400 mm. It shall be hung in such a way that the amplitude of the undulation created by folding of the material is not larger than 100 mm. The average distance of the curtain from the wall shall be 100 mm. The method for hanging the material shall not be visible when stood in front of the curtain. There shall be a gap of no less than 5 mm and no more than 20 mm between the floor and the base of the curtain.

7.2.4 General conditions

The **test** area will be illuminated using a compact fluorescent or incandescent light bulb placed in a pendant light fitting as described in Table 3. The illumination conditions for the **test** shall be maintained at between 40 lux and 200 lux with colour temperature of 2 000 K to 6 000 K (measured at floor height at all locations).

The temperature and humidity conditions shall only need to satisfy the manufacturer's written requirement for normal use in the room. When the door to the **test** area is closed, all lighting within the **test** turned off, and all external lighting which surrounds the **test** area turned on, no location within the **test** area shall measure greater than 2 lux.

Any safety-related device required by the local regulation (for example, sprinkler and smoke detectors on the ceiling) shall be allowed to be installed.

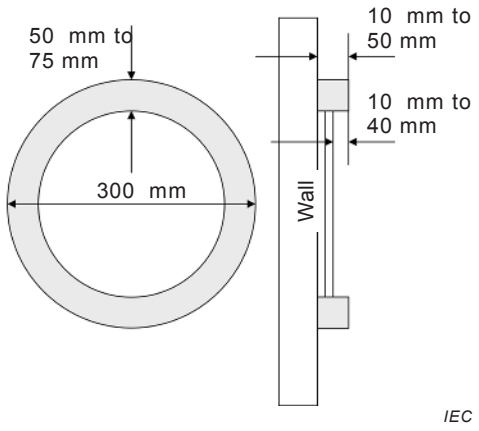


Figure 18 – Illustration of clock

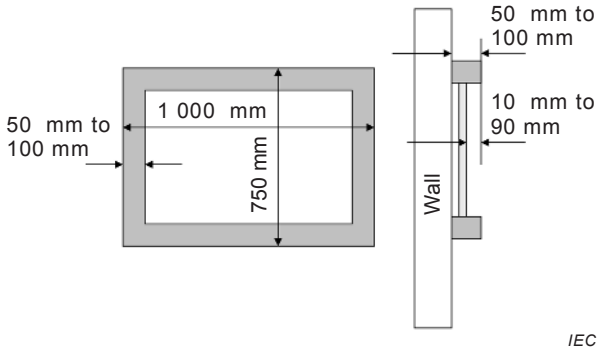


Figure 19 – Illustration of mirror

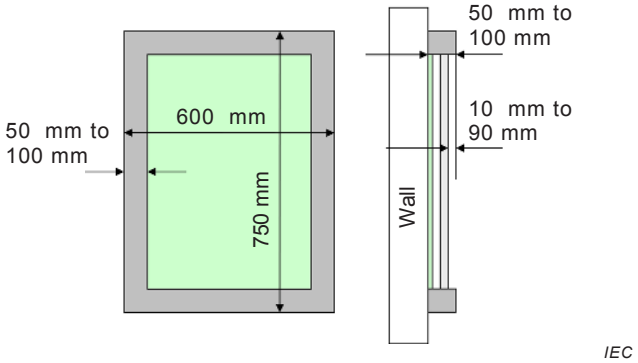


Figure 20 – Illustration of picture

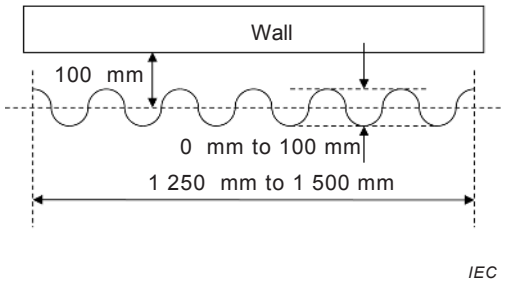


Figure 21 – Illustration of curtains

7.3 Preparation of test

7.3.1.1 Preconditioning of test floor

Refer to 5.2.2.1.

7.3.1.2 Pre-treatment of cleaning robot

Refer to 5.2.2.2.

7.3.1.3 Visual tracking system (VTS)

Refer to 6.3.2.3.

7.4 Test method

A single **test trial** consists of one **run** from each of the three starting locations. The starting locations and orientation specified in Figure 22 shall be followed.

Before each **trial** the robot and the testbed shall be conditioned according to 7.3.

Before each **run** the battery of the robot shall be fully charged.

For each **run** the robot shall be started based on the manufacturer's instructions.

The use of the **docking station** is allowed for the two starting locations 1 and 2 if it is required by the manufacturer. The fact that the robot requires the **docking station** to be able to perform has to be stated in the report. If the **docking station** was used for the start of the **test** it shall be kept at the same position throughout the **run**. Then the footprint of the station shall be subtracted from the total reachable area.

For the starting location 3 the **cleaning robot** shall start without a **docking station**. If the robot cannot be started without the **docking station** the **runs** from the location 3 shall be skipped and the fact shall be stated in the report.

It is important to ensure the proper consistent alignment of the robot with the wall on the testbed. During the setup process an alignment device such as a laser pointer can be used for the validation of a proper alignment.

For starting position 1, a backwall shall be installed as shown in Figure 22 behind position 1. The backwall is installed in the testbed only for the **runs** from position 1 only. When it is installed the space behind the wall including the footprint of the wall itself shall be defined as unreachable.

The backwall shall be removed for **runs** from other starting positions.

The power cable from the base station shall be fixed on the wall and to be painted with the same colour as the wall.

The **test** shall be continued until the cleaning operation is terminated. The termination of the cleaning process shall be determined by the user manual.

NOTE 1 The termination of the operation can be determined based one or more of the following events for examples.

- Reported termination message from the robot indicating the end of cleaning cycle (sound, light, text as described in the manual)
- Stopped motion on the floor for more than 3 min (not on the base station, because it might continue the operation after recharging).

If the robot is still in the middle of cleaning process at the end of the 2 h **run** it is recommended to stop the robot and the **test**.

If it is needed to continue the **run** after 2 h for any reason the tester's discretion shall be applied for the continuation of the **test**. The reason for the continuation of the **test** after 2 h shall be reported.

Visitation to the station for recharging during the **run** is allowed but the time used for recharging shall be included as **run** time.

During the **run** the area covered, in terms of percentage covered by the **cleaning head**, and number of **passes** will be tracked and recorded using a **VTS**.

NOTE 2 It is suggested that three batteries are prepared before testing to avoid interrupting the **test** due to recharging the battery.

Before conducting the **test** all robots under **test** should pass a functional **test**, for example a built-in-**test** (BIT) if applicable, based on the manufacturer's instruction to make sure they are in an acceptable condition.

The navigation **test trial** (with three **runs**) shall be repeated twice more. A complete set of **test** consists of three **trials**, which gives a total of nine **runs**.

If the robot fails for any reason other than the normal completion of **run** the robot shall be restarted from the starting location and the failed result shall be discarded. However, a maximum of one restart per starting position is allowed throughout the whole **test**. Further failed results shall be included in the **test** results without restarting. The number of failures shall be reported.

Dimensions in millimetres

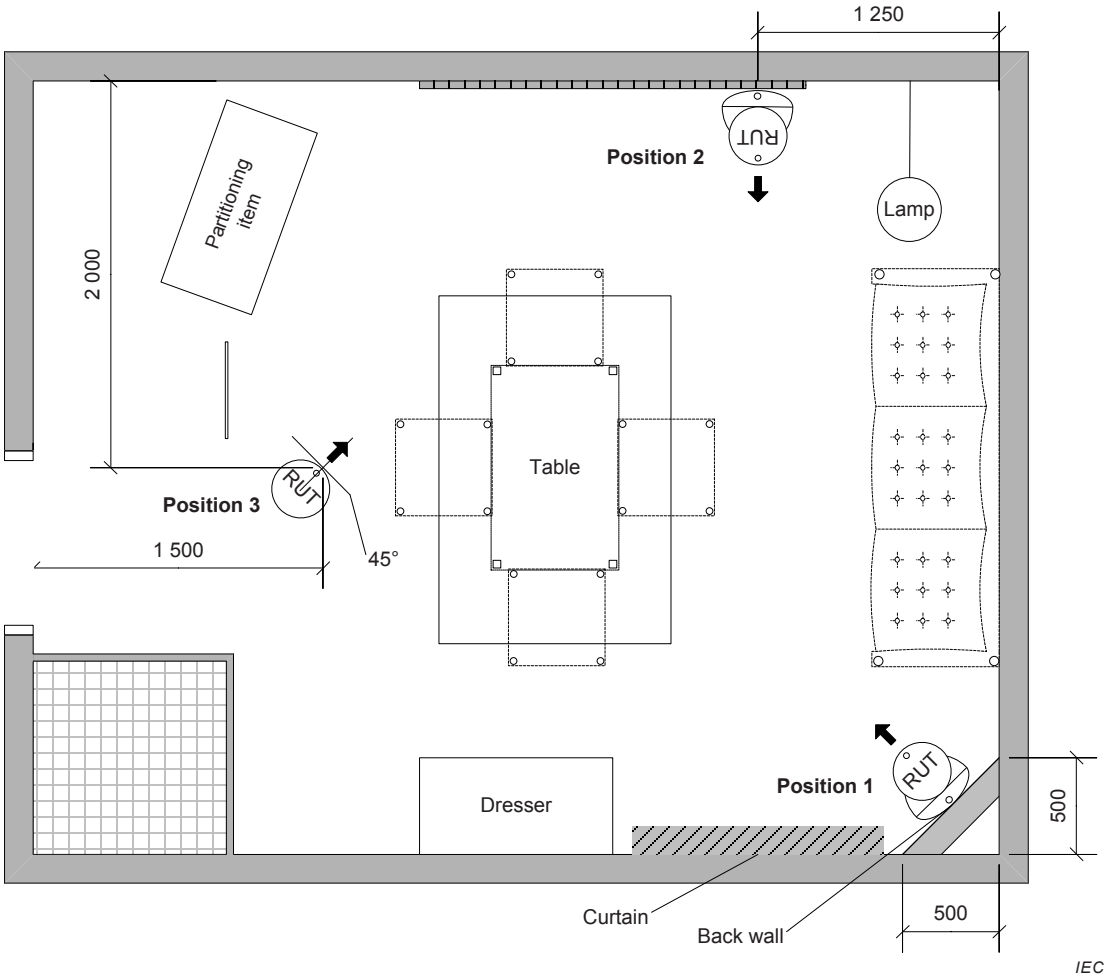


Figure 22 – Starting positions for navigation test

7.5 Performance measurement

The **cleaning head** coverage shall be obtained throughout the **test**. The **cleaning head** coverage is defined as the area covered by the **cleaning head** of the robot during a certain period of time.

The percentage of **cleaning head** coverage over time is calculated using the following equation:

$$C_{i,j}(t)=\{A_{i,j}(t)/A\} \times 100$$

where

i is 1, 2, and 3

j is 1, 2, and 3

$C_{ij}(t)$ is the percentage of **cleaning head** coverage at time t for the **run** started from the ith position in jth **trial** (i = 1, 2 and 3, j = 1, 2, and 3) (%)

$A_{i,j}(t)$ area over which the **cleaning head** has passed at least one times at time t for the **run** started from the ith position in jth **trial** (m^2)

t **run** time (in minutes)

A total reachable area (m^2) which is computed by total floor area minus the area occupied by the legs, heater baseboard, dresser, cylindrical bar, partitioning item, the base of the lamp, the backwall and the space behind the wall (only when the backwall was installed for the **runs** for starting position 1). The area under sofa is considered reachable area. If the **docking station** was left in the testbed the footprint of the station shall be subtracted from the total reachable area.

The number A shall be calculated based exactly on the actual setting of the testbed built in the **test** laboratory. If the setting changes (because of the tolerance for an example) the number shall be changed accordingly.

NOTE 1 By using a **VTS**, the percentage coverage for each **pass** at a certain time can be calculated with a simple image processing program automatically.

The percentage *of* multiple **pass** coverage over time is calculated using the following equation:

$$C_{ij\_\mathrm{double}}(t)=\{A_{ij\_\mathrm{double}}(t)/A\} \times 100$$

$$C_{ij\_\mathrm{triple}}(t)=\{A_{ij\_\mathrm{triple}}(t)/A\} \times 100$$

where

i is 1, 2, and 3

j is 1, 2, and 3

$C_{ij\_\mathrm{double}}(t)$ percentage of area passed by the **cleaning head** at least two times at time t for the **run** started from the ith position in jth **trial** (percent)

$C_{ij\_\mathrm{triple}}(t)$ percentage of area passed by the **cleaning head** at least three times at time t for the **run** started from the ith position in jth **trial** (percent)

$A_{ij\_\mathrm{double}}(t)$ area over which the **cleaning head** has passed at least two times at time t for the **run** started from the ith position in jth **trial** (m^2)

$A_{ij\_\mathrm{triple}}(t)$ area over which the **cleaning head** has passed at least three times at time t for the **run** started from the ith position in jth **trial** (m^2)

NOTE 2 Percentage of multiple **pass** coverage for more than three times can be obtained in a similar way.

It is recommended that the percentage coverage over time $C_i(t)$ are reported in a graph with a 25th percentile and 75th percentile envelope. The percentage coverage for single **pass**, double **pass** and triple **pass** shall be presented in the same graph with a 25th percentile and 75th percentile envelope. The time resolution for the graph shall not be greater than 2 min intervals and the percentage resolution shall not be greater than 1 %.

For example, the 75th percentile point of $C_{ij}(t)$ for a given time t would be the 7th largest value among nine $C_{ij}(t)$. The 75th percentile envelop is the group of 75th percentile points connected by a line. The 25th percentile point of $C_{ij}(t)$ for a given time t is the second largest value among nine $C_{ij}(t)$. The 25th percentile envelop is the group of 25th percentile points connected by a

line. The median point of $C_{ij}(t)$ for a given time t is the average of the 5th largest value among nine $C_{ij}(t)$. The median envelop is the group of median points connected by a line.

For the **run** completed earlier than the longest **run** the last coverage percentage value should be maintained for the calculation of percentile envelop for the period beyond.

NOTE 3 All the curves can be placed in one graph or in separate graphs as the exemplary graph shown in Figure 23.

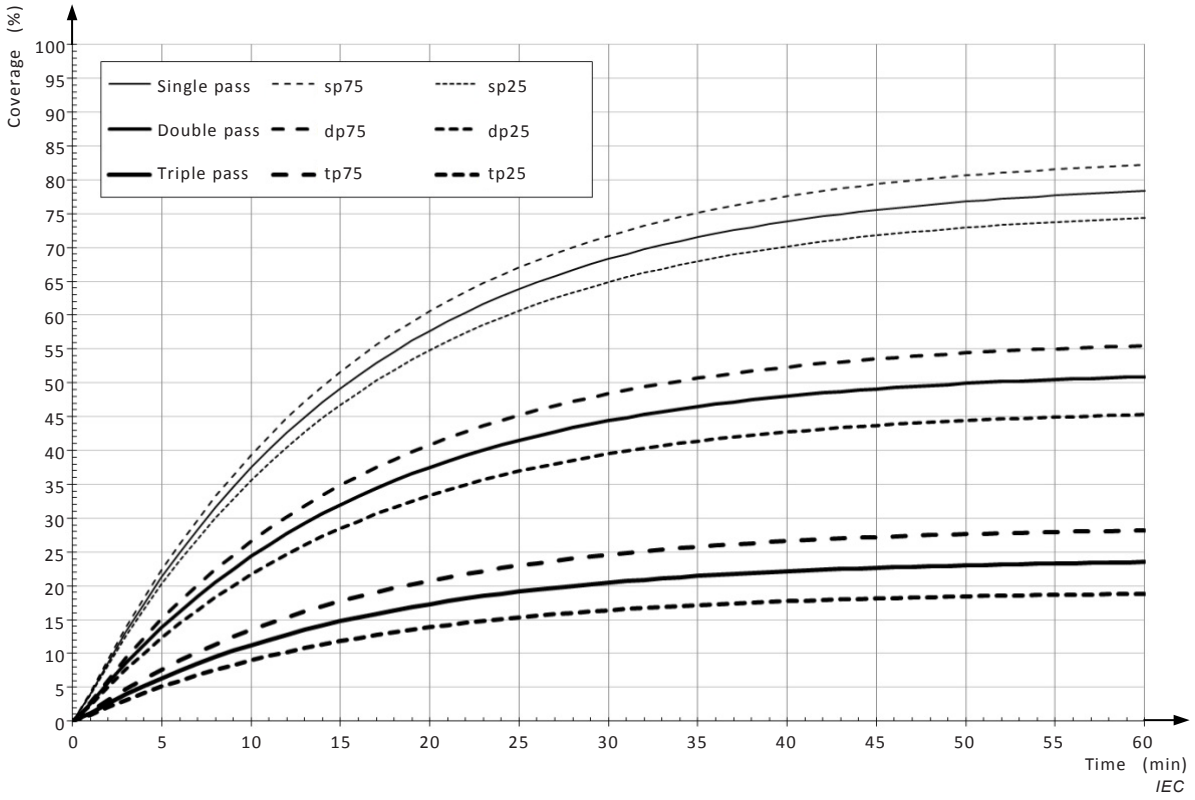


Figure 23 – Exemplary graph of coverage test result

8 Average robot speed

8.1 Test bed

For the robot's average speed **test** the box-shaped wall sections as described in 5.2.1 are set up within the autonomous navigation/coverage testbed which is shown in Figure 8. The **test** box shall be set up at the location in the coverage **test** area as described in Figure 24.

When establishing the hard floor average speed, s_{avg_hard}, the box is laid directly on the hard floor of the autonomous navigation/coverage testbed.

When establishing the carpet average speed, s_{avg_carpet}, a piece of Wilton carpet (IEC 60312-1:2010, Clause C.1 – Wilton Carpet) shall be placed such that it fills the area enclosed by the boundary walls.

NOTE The reason to perform this **test** within the Autonomous Navigation/Coverage testbed is to easily allow the motion of the machine to be tracked during the **test** using the **VTS** which has been set up for the Autonomous Navigation/Coverage **test** already. The Autonomous Navigation/Coverage testbed is enclosed, so this would reduce the amount of variability in the **test** from visible regions outside of the **test** bed, making a repeatable assessment of the average speed of the machine more likely.

Dimensions in millimetres

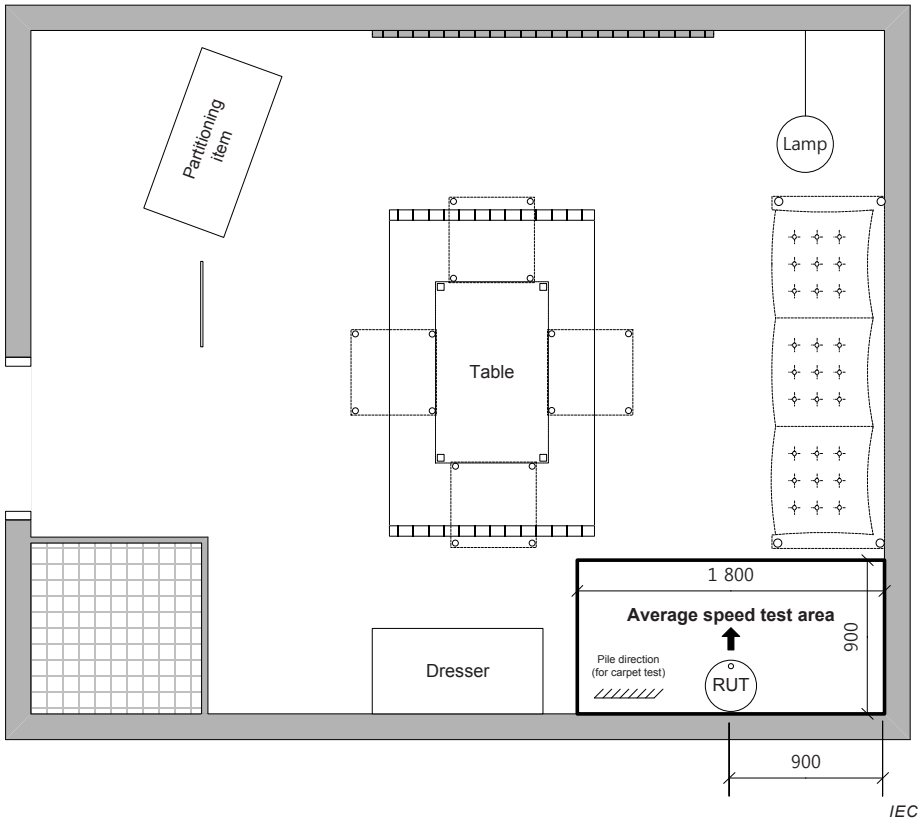


Figure 24 – Location of average speed test area within coverage test environment

8.2 Preparation

8.2.1 Preconditioning of test floor

Refer to 5.2.2.1.

8.2.2 Pre-treatment of cleaning robot

Refer to 5.2.2.2

8.2.3 Visual tracking system (VTS)

Refer to 6.3.2.3.

8.3 Test method

The robot shall be placed and started in the start position defined in Figure 24.

The operation mode used in the **test** shall be the same mode used for the Dust Removal **Test** – Box in Clause 5.

If the **cleaning robot** stops operating its active cleaning function within 15 min the measurement is finished and the operation time shall be recorded.

If the **cleaning robot** is still operating at 15 min the **cleaning robot** movement, including dust collecting function, shall be stopped using the method provided by the manufacturer.

The entire duration of the **test** shall be monitored using the **VTS**. Upon completion of the **run** the **VTS** shall provide the machine poses for the duration of the **run** at 500 ms intervals. From this data the average robot speed shall be calculated according to 8.4.

Total three **runs** shall be performed following the preparation as specified in 8.2 for each **run**.

8.4 Determination of average speed

For two consecutive poses (x, y, θ) and (x', y', θ') the translational velocity, $\hat{v}$, between the two points can be estimated by the following equations if the assumption is made that both the rotational and translational velocities are constant between them.

NOTE The velocity motion model is based on chapter 5 of THRUN, S., BURGARD, W., and FOX, D. *Probabilistic Robotics*. MIT Press, Cambridge, MA, 2005.

$$\mu = \frac{1}{2}\frac{(x-x')\cos\theta + (y-y')\sin\theta}{(y-y')\cos\theta - (x-x')\sin\theta}$$

$$x^* = \frac{x+x'}{2} + \mu(y-y')$$

$$y^* = \frac{y+y'}{2} + \mu(x'-x)$$

$$r^* = \sqrt{(x-x^*)^2 + (y-y^*)^2}$$

$$\Delta\theta = a\tan 2(y'-y^*, x'-x^*) - a\tan 2(y-y^*, x-x^*)$$

$$\hat{v} = \frac{\Delta\theta}{\Delta t} r^*$$

$$\hat{\omega} = \frac{\Delta\theta}{\Delta t}$$

where

x^*, y^* centre or the arc describing the curve between the poses (mm)

r^* radius of the arc (mm)

Δt time difference between poses (s).

Only the average straight line speed of the robot on hard floor and carpet is of interest. For this reason it is necessary to extract only the sequential pairs of poses from the **VTS** track result which represent the machine when travelling in a straight line. This can be achieved by removing pairs which represent when the machine is stationary and when it is rotating.

The machine can be considered stationary (or rotating on the spot) when the distance travelled between poses, d, is small.

$$d = \sqrt{(x-x')^2 + (y-y')^2}$$

So pairs of poses shall be rejected when either,

$$d \leq 1\,\text{cm}$$

$$\hat{\omega} \geq 10^\circ\,\text{s}^{-1}$$

From the remaining pose pairs, which now represent the times when the robot is performing straight line motion, the average straight line speed can be calculated.

$$s_{avg,i} = \frac{\sum_{k=1}^{n} \hat{v}_k}{n}$$

where

n number of pose pairs remaining after rejections

$s_{\text{avg},i}$ average robot speed for the ith **run**.

Then the average robot speed, s_{avg}, shall be calculated as follows.

$$s_{avg} = \frac{(s_{avg,1} + s_{avg,2} + s_{avg,3})}{3}$$

The average speed, s_{avg}, measured on the hardwood floor is called s_{avg_hard} and the average speed, s_{avg}, measured on the carpet floor is called $s_{\text{avg\_carpet}}$.

9 Instructions for use

The manufacturer's instructions for use shall contain information about the use of the appliance and its accessories, if any, and about the cleaning necessary to ensure the proper performance of the appliance.

Annex A
(informative)

Calculation of coverage

A.1 Robot metrics

When using the **visual tracking system (VTS)** the robot coordinates system should be centred at the mid-point of the wheel base (the point around which the robot turns when turning on the spot) on ground level. The x axis should point forward in the direction in which the machine moves. The y axis should point towards the left wheel (positive rotation is anti-clockwise). The z axis should point upwards from the floor through the machine. See Figure A.1. All tracking data should report the current real world location of this point.

The cleaning orifice should be described by a single straight line which is the width of the cleaning orifice and aligned with its centre. It is assumed to be located at floor level. The offset to the orifice from the robot origin should be provided by the vector, d_{orifice}.

The key parameter for the **VTS** is the position of the centre of the target which is placed on top of the robot. The offset to the centre of the target from the robot origin should be provided by the vector, d_{target}.

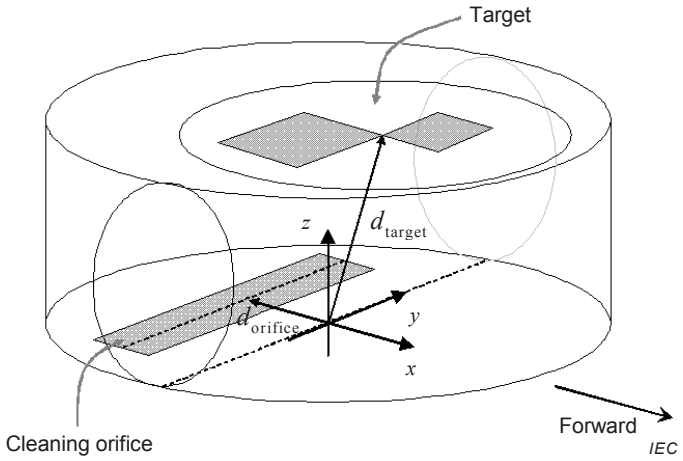


Figure A.1 – Robot coordinate frame

A.2 Calculating robot coverage

A coverage “image” is created which has the same pixel dimensions as the unwarped image of the area in which the robot is being tracked. If this is made from multiple camera images the coverage image will have dimensions which are sufficient to cover all images once they have been repositioned to be aligned correctly with each other.

Initially all pixel values in the coverage image are set to zero. As the robot moves around the area the pixel values at the locations where the cleaning orifice passes over are incremented for every pass of the machine. This means that the coverage image can record a maximum of 255 passes for any one pixel location, assuming an 8bit pixel depth.

The two ends of the cleaning orifice at time t can be represented by two points b_{lt} and b_{rt}.

At some point in time, t=0, the cleaning orifice is positioned as shown in Figure A.2, with end points positioned at b_{l0} and b_{r0}.

The robot then moves and is captured in the next image frame, t = 1, such that the new orifice position is defined by b_{l1} and b_{r1}.

To calculate the coverage achieved between the two frames a quadrilateral is created connecting the two orifice locations as shown in Figure A.2. All pixels in the coverage image which lie within this quadrilateral are incremented to indicate the occurrence of a new pass of the cleaning orifice across them.

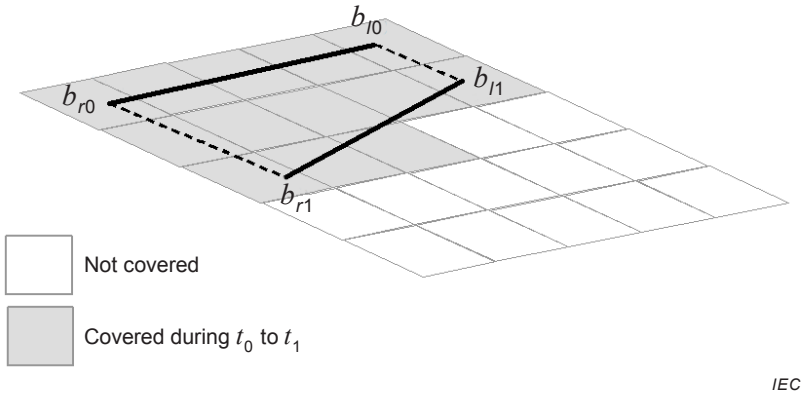


Figure A.2 – The first coverage step

In the next iteration the orifice moves to a location defined by b_{l2} and b_{r2}, *see* Figure A.3. A new quadrilateral is established which connects this location to that defined in the previous frame, b_{l1} and b_{r1}.

Firstly this quadrilateral is compared with that created at the previous iteration. Any overlapping pixels are removed from the new quadrilateral. Then, as before, all pixels in the newly clipped quadrilateral are incremented in the coverage image. This ensures that only newly encountered pixel locations are incremented in the coverage image and avoids the continual incrementing of a stationary element of the cleaning orifice.

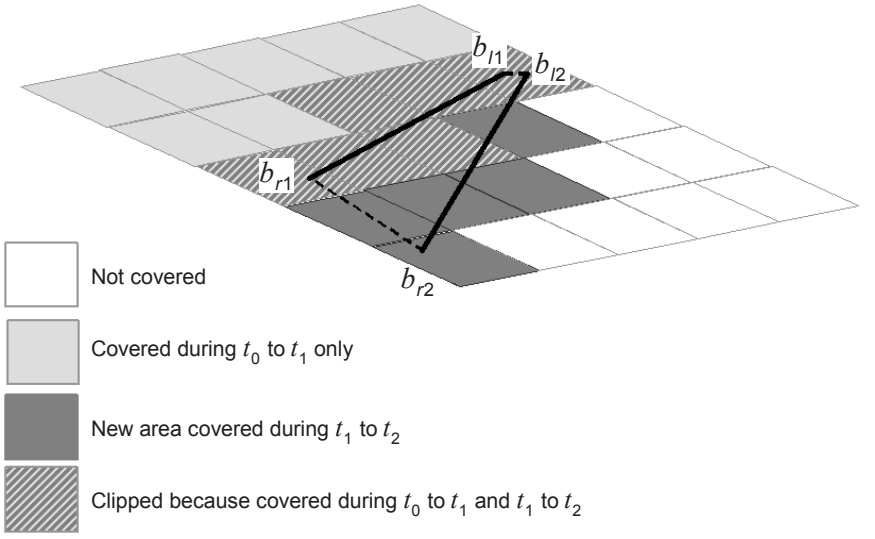


Figure A.3 – Incremental coverage step

This process continues such that each new quadrilateral is clipped to remove any elements which are common with the previous frame and then the remaining pixels are incremented.

In the situation where the machine is stationary, after the first frame all newly created quadrilaterals will be placed at exactly the same location as those from the previous frame. Thus the whole quadrilateral will be clipped and no new path will have been prescribed, hence no pixels will be incremented.

Annex B
(informative)

Comprehensive cleaning performance metric

When a single performance metric combining the coverage performance and the dust pickup performance is required there are various ways of combining the performance measurements illustrated in this document. For an example of such attempts a performance metric, named the comprehensive cleaning performance (P_{CC}), is presented as a guide. The comprehensive cleaning performance is calculated using the straight-line dust removal performance measurement results and the autonomous navigation/coverage performance measurement results as follows

$$P_{CC}(t) = \sum_{k=1}^{N} \{C_k(t) \times P_k\}$$

where

$P_{CC}(t)$ is the comprehensive cleaning performance at time t

$C_k(t)$ is the average coverage rate of the area traversed just k-times by the **cleaning head** area at time t (k = 1, 2,…, N) from the Autonomous Navigation/Coverage **test** (percent). This value can be obtained as follows (refer to 7.5 for detail definitions)

$$C_1 = \sum_{i=1}^{3}\sum_{j=1}^{3} C_{ij}(t), \quad C_2 = \sum_{i=1}^{3}\sum_{j=1}^{3} C_{ij\_double}(t), \quad C_3 = \sum_{i=1}^{3}\sum_{j=1}^{3} C_{ij\_triple}(t), \quad \cdots$$

P_k is the final accumulated k-**pass** pickup rate (percent). This value comes from the Dust Removal – Straight line **test** in Clause 6.

N is the maximum number of **passes** of **cleaning head** considered in the P_{CC} calculation

NOTE Different comprehensive cleaning performance values can be obtained by using different pick up performance measures established using different pick-up **test** approaches.

The comprehensive cleaning performance over time, $P_{CC}(t)$, may be presented in a graph with a 25th percentile and 75th percentile envelope. The resolution in time and the resolution in the percentage for the graph could be regulated by the conditions listed in 4.9 or something similar.

Bibliography

IEC 60335-1:2006, *Safety of household and similar electrical appliances – Part 1: General requirements*

IEC 60335-2-2:2009, *Household and similar electrical appliances – Safety – Part 2-2: Particular requirements for vacuum cleaners and water-suction cleaning appliances*

ASTM F2607–08, *Standard test method for measuring the hard surface floor-cleaning ability of household/commercial vacuum cleaners*

THRUN, S., BURGARD, W., and FOX, D. *Probabilistic Robotics*. MIT Press, Cambridge, MA, 2005

_____

This page deliberately left blank

This page deliberately left blank

British Standards Institution (BSI)

BSI is the national body responsible for preparing British Standards and other standards-related publications, information and services.

BSI is incorporated by Royal Charter. British Standards and other standardization products are published by BSI Standards Limited.

About us

We bring together business, industry, government, consumers, innovators and others to shape their combined experience and expertise into standards -based solutions.

The knowledge embodied in our standards has been carefully assembled in a dependable format and refined through our open consultation process. Organizations of all sizes and across all sectors choose standards to help them achieve their goals.

Information on standards

We can provide you with the knowledge that your organization needs to succeed. Find out more about British Standards by visiting our website at bsigroup.com/standards or contacting our Customer Services team or Knowledge Centre.

Buying standards

You can buy and download PDF versions of BSI publications, including British and adopted European and international standards, through our website at bsigroup.com/shop, where hard copies can also be purchased.

If you need international and foreign standards from other Standards Development Organizations, hard copies can be ordered from our Customer Services team.

Subscriptions

Our range of subscription services are designed to make using standards easier for you. For further information on our subscription products go to bsigroup.com/subscriptions.

With **British Standards Online (BSOL)** you'll have instant access to over 55,000 British and adopted European and international standards from your desktop. It's available 24/7 and is refreshed daily so you'll always be up to date.

You can keep in touch with standards developments and receive substantial discounts on the purchase price of standards, both in single copy and subscription format, by becoming a **BSI Subscribing Member**.

PLUS is an updating service exclusive to BSI Subscribing Members. You will automatically receive the latest hard copy of your standards when they're revised or replaced.

To find out more about becoming a BSI Subscribing Member and the benefits of membership, please visit bsigroup.com/shop.

With a **Multi-User Network Licence (MUNL)** you are able to host standards publications on your intranet. Licences can cover as few or as many users as you wish. With updates supplied as soon as they're available, you can be sure your documentation is current. For further information, email bsmusales@bsigroup.com.

BSI Group Headquarters

389 Chiswick High Road London W4 4AL UK

Revisions

Our British Standards and other publications are updated by amendment or revision.

We continually improve the quality of our products and services to benefit your business. If you find an inaccuracy or ambiguity within a British Standard or other BSI publication please inform the Knowledge Centre.

Copyright

Useful Contacts:

Customer Services
Tel: +44 845 086 9001
Email (orders): orders@bsigroup.com
Email (enquiries): cservices@bsigroup.com

Subscriptions
Tel: +44 845 086 9001
Email: subscriptions@bsigroup.com

Knowledge Centre
Tel: +44 20 8996 7004
Email: knowledgecentre@bsigroup.com

Copyright & Licensing
Tel: +44 20 8996 7070
Email: copyright@bsigroup.com

bsi.

...making excellence a habit.™