

# INTERNATIONAL STANDARD

## NORME INTERNATIONALE



**Cleaning robots for household use – Dry-cleaning: Methods of measuring performance**

**Robots de nettoyage à usage domestique – Nettoyage à sec: Méthodes de mesure de l'aptitude à la fonction**

Withdrawing



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## INTERNATIONAL ELECTROTECHNICAL COMMISSION

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

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International Standard IEC 62929 has been prepared by subcommittee 59F: Surface cleaning appliances, of IEC technical committee 59: Performance of household and similar electrical appliances.

The text of this standard is based on the following documents:

| FDIS         | Report on voting |
|--------------|------------------|
| 59F/258/FDIS | 59F/262/RVD      |

Full information on the voting for the approval of this standard can be found in the report on voting indicated in the above table.

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- amended.

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## 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.

Withdrawn

# 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*<sup>1</sup>  
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

<sup>1</sup> 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:  $(23 \pm 2) ^\circ\text{C}$

Relative humidity:  $(50 \pm 5) \%$

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:  $(200 \pm 50) \text{ lx}$

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  $\leq 0,01$  g

Accuracy  $\leq 0,02$  g

Position measurement by vision:

Coverage **test**

Position resolution  $\leq 3$  cm

Position accuracy  $\leq 5$  cm

Sampling rate  $\geq 30$  Hz

Straight line **test**

Position resolution  $\leq 1$  cm

Position accuracy  $\leq 1$  cm

Sampling rate  $\geq 30$  Hz

#### Average speed **test**

Position resolution  $\leq 1$  cm

Position accuracy  $< 1$  cm

Sampling rate  $\geq 30$  Hz

Time measurement:

Resolution  $\leq 0,01$  s

Accuracy  $\leq 0,02$  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<br>mm                               | Tolerance<br>mm |
|--------------------------------------------------------|-----------------|
| $3 \leq 6$                                             | $\pm 0,5$       |
| $> 6 \leq 30$                                          | $\pm 1,0$       |
| $> 30 \leq 120$                                        | $\pm 1,5$       |
| $> 120 \leq 400$                                       | $\pm 2,5$       |
| $> 400 \leq 1\,000$                                    | $\pm 4,0$       |
| $> 1\,000 \leq 2\,000$                                 | $\pm 6,0$       |
| $> 2\,000 \leq 5\,000$                                 | $\pm 8,0$       |
| 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  $\times$  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.

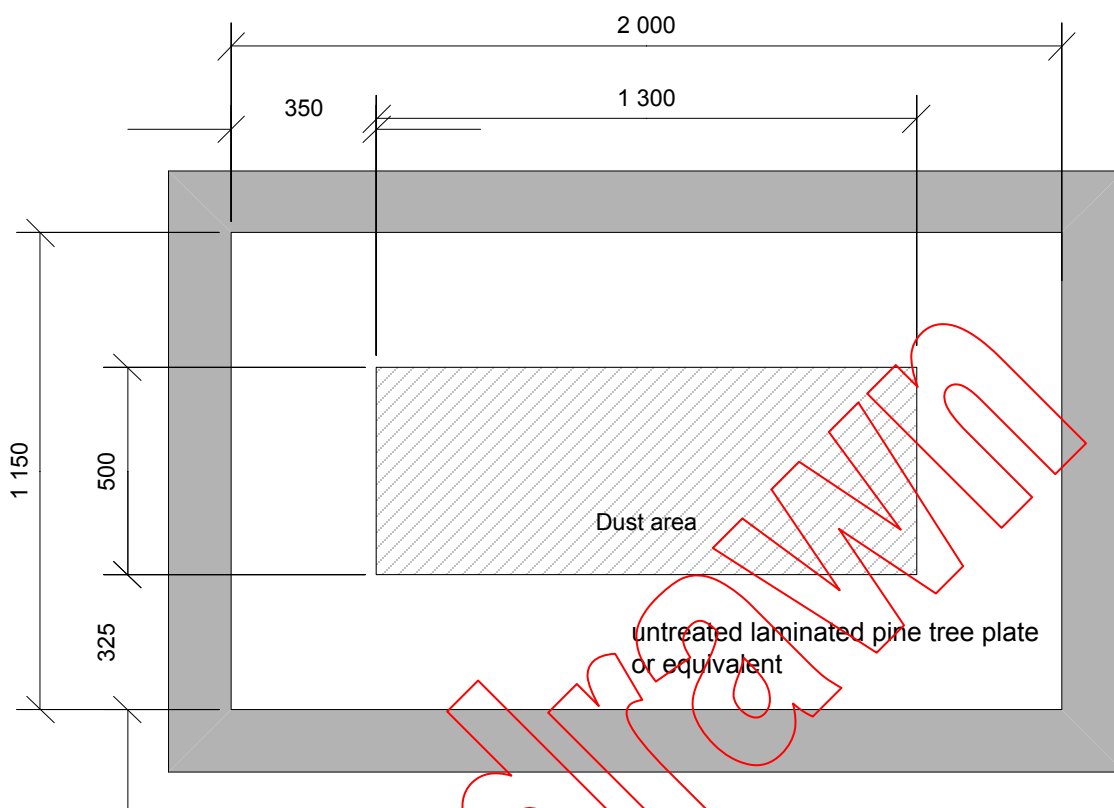
Prior to each **test run**, replaceable filter(s) and dust collection parts (e.g. wiping pad) in the robot (or in the **secondary collection system**) shall be replaced with new ones.

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



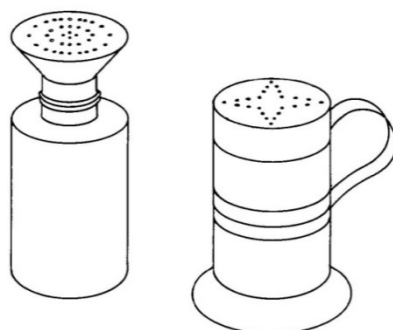
IEC

**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<sup>2</sup> 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.

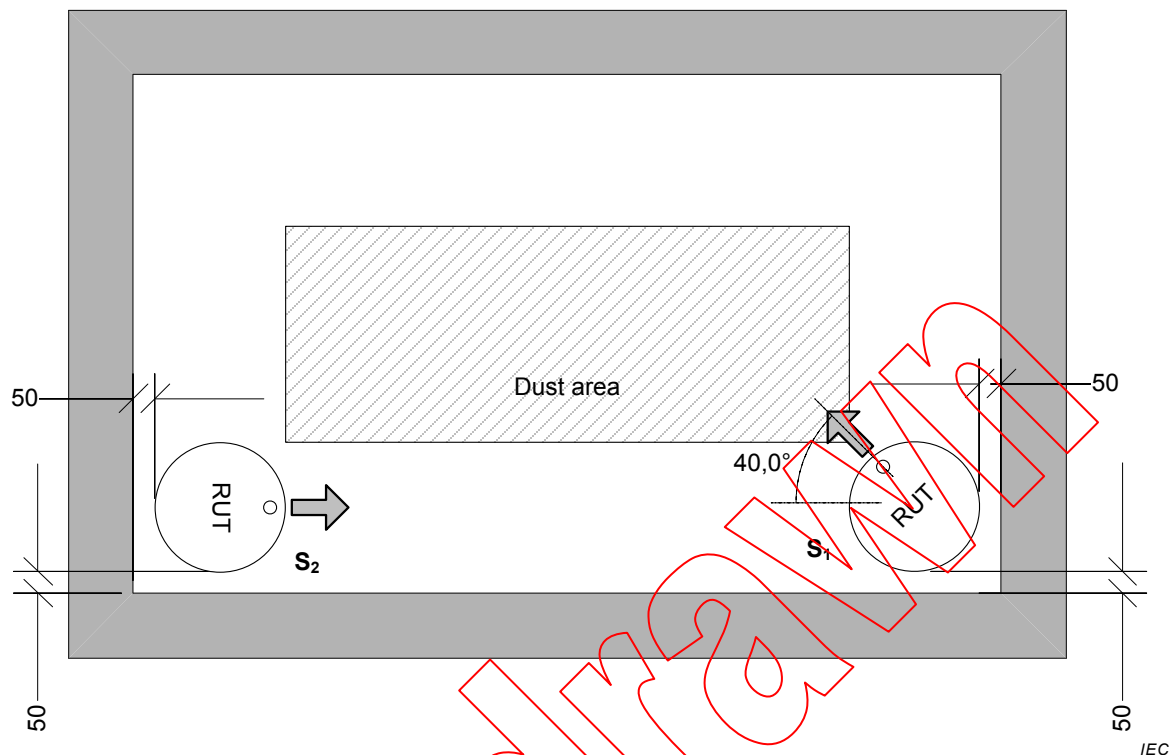
NOTE 2 To ensure the distribution of the **test** dust only within the **dust area**, a masking frame with size of the **dust area** or marker can be used.



IEC

**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  $j$ th **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  $j$ th **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  $j$ th **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  $j$ th **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.

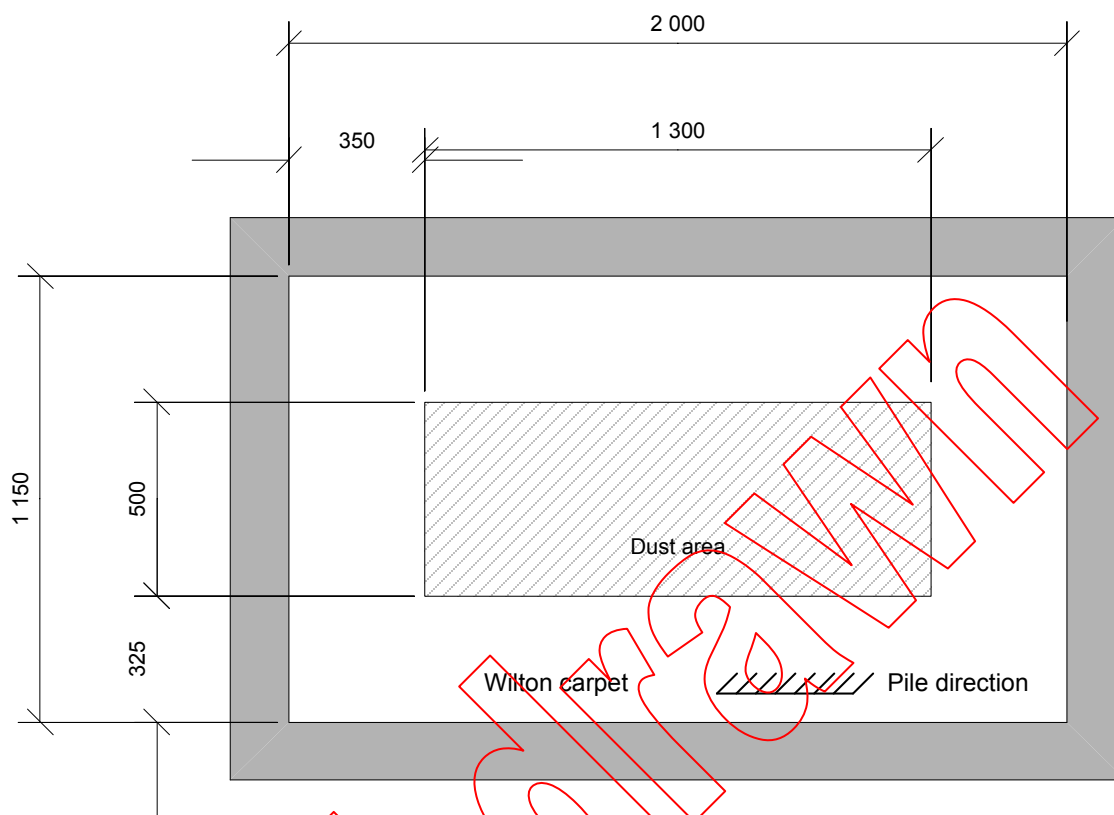
### 5.3 Dust removal from carpets

#### 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*



IEC

**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<sup>2</sup> 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<sup>2</sup> 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  $\pm 10\%$ ).

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)  $\times$  600 mm as specified in Figure 6).

The **dust area** shall be 700 mm  $\times$  ( $W - 20$ ) 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.

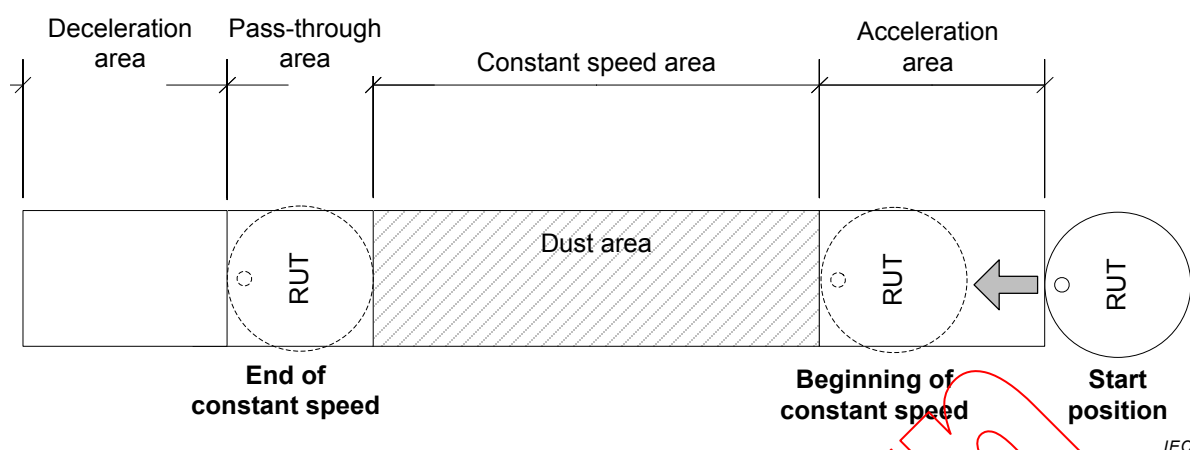
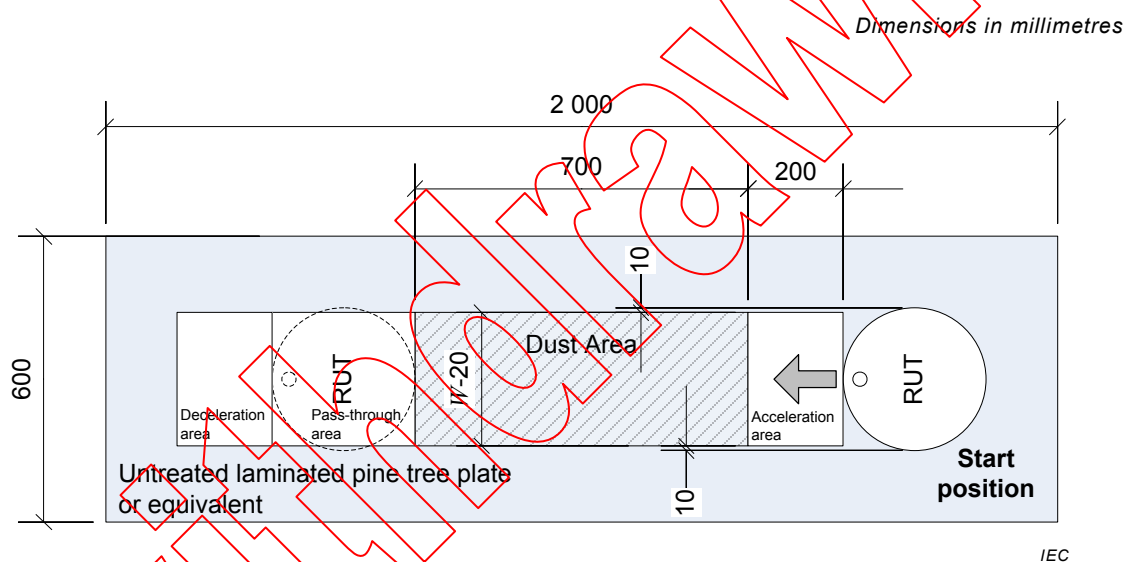


Figure 5 – Description of test mode action



**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  $s_{\text{avg\_hard}}$ .

Before running the **test**, the actual speed of the robot in **test** mode shall be verified to be within  $\pm 10\%$  range of  $s_{\text{avg\_hard}}$  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  $s_{\text{avg\_hard}}$ . 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,  $s_{\text{avg\_hard}}$ .

The robot shall maintain its constant speed  $s_{\text{avg\_hard}}$  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  $s_{\text{avg\_hard}}$  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

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

where

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

$M_i$  measured accumulative weight of dirt picked up after the  $i$ th **run** (g)

$C_{ki}$  percentage of **dust area** passed by the robot **cleaning head** only  $k$  times after the  $i$ th **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

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

or if five **trials** were executed

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

where

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

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

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.

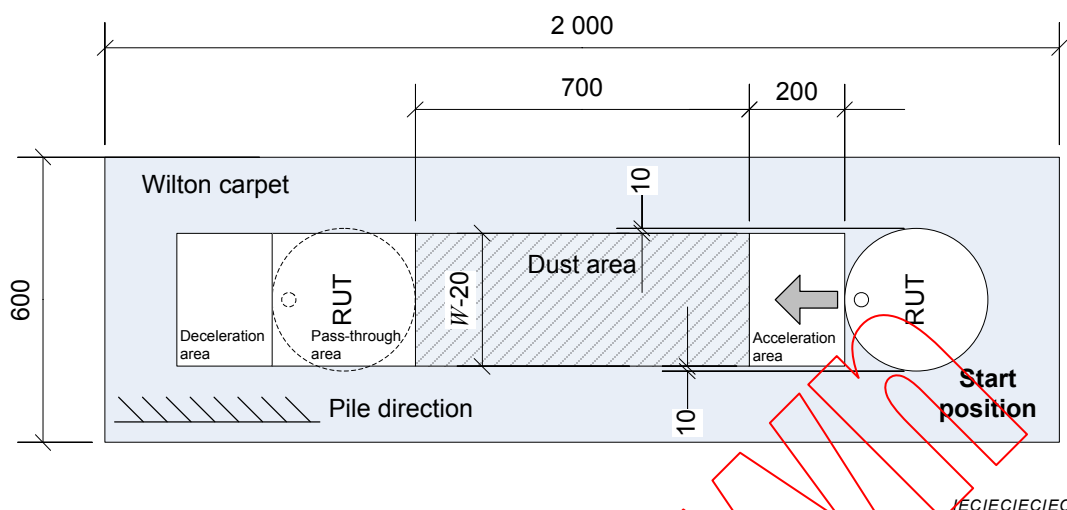
$$p_3 = \frac{\frac{M_3}{M} - C_{13} \times p_1 - C_{23} \times p_2}{C_{33}}$$

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

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

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



#### 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  $s_{\text{avg\_carpet}}$ .

Before running the **test**, the actual speed of the robot in **test** mode shall be verified to be within  $\pm 10\%$  range of  $s_{\text{avg\_carpet}}$  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  $125 \pm 0,1\text{g}$  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 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

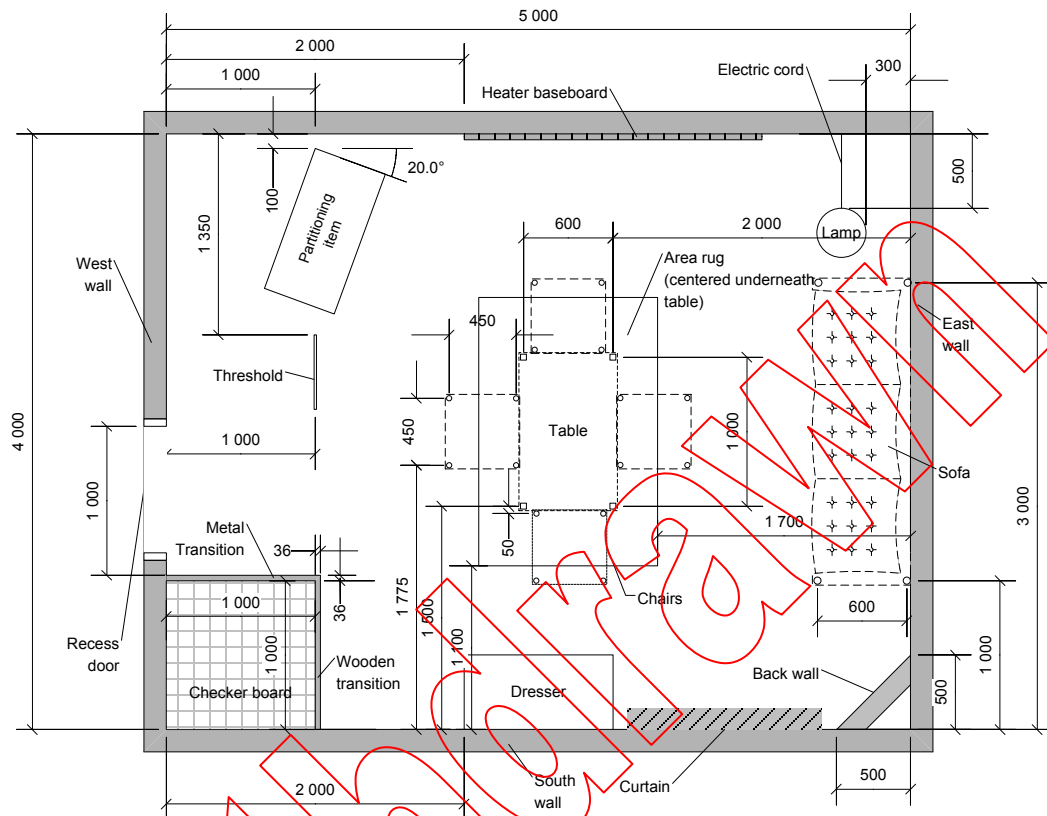
The **test** area shall consist of a space measuring  $4\,000\text{ mm} \times 5\,000\text{ mm}$  ( $L \times W$ ) (tolerance  $\pm 50\text{ mm}$ ) enclosed by four walls and a ceiling.

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*



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**Figure 8 – Navigation/Coverage test bed configuration**

*Dimensions in millimetres*

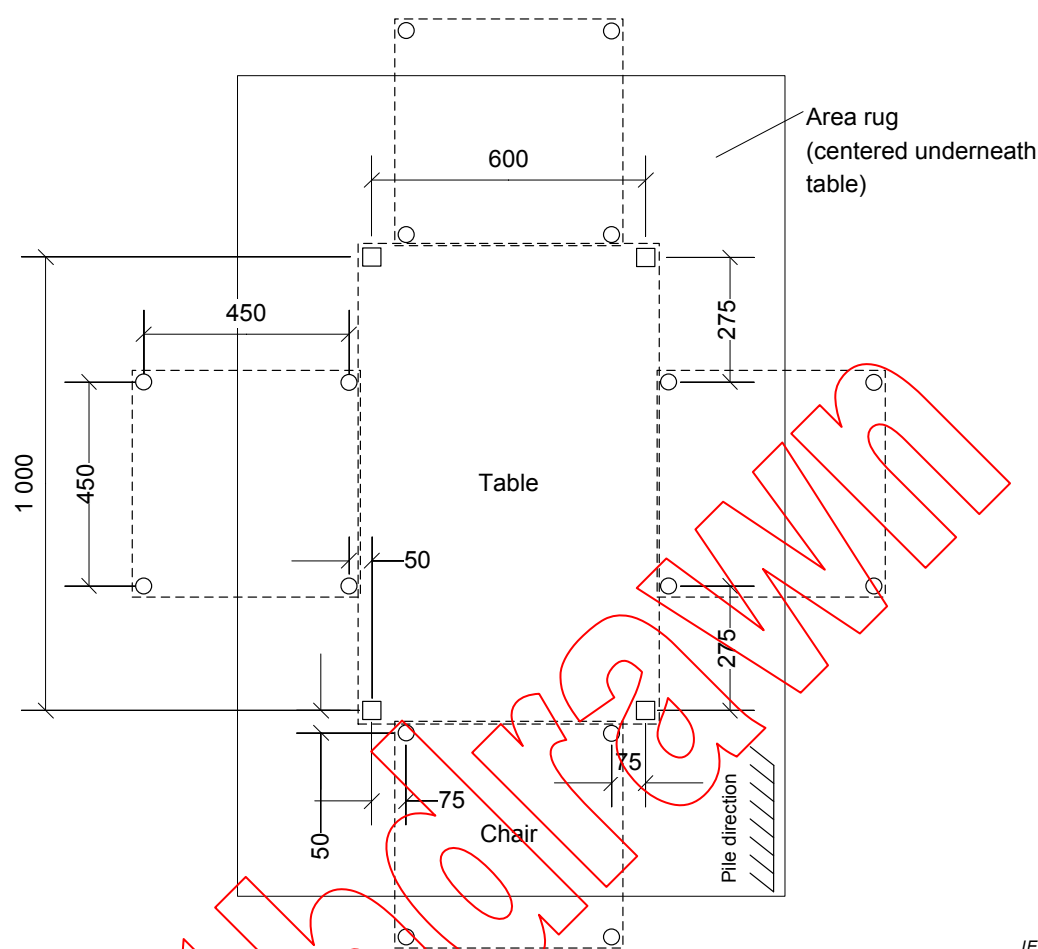


**Table 2 – Dimensions of furniture and obstacles**

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

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

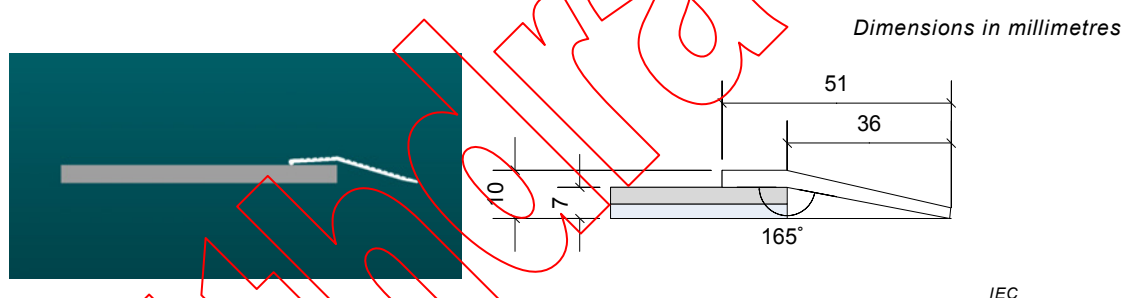


**Figure 10 – Illustration of metal transition installation**

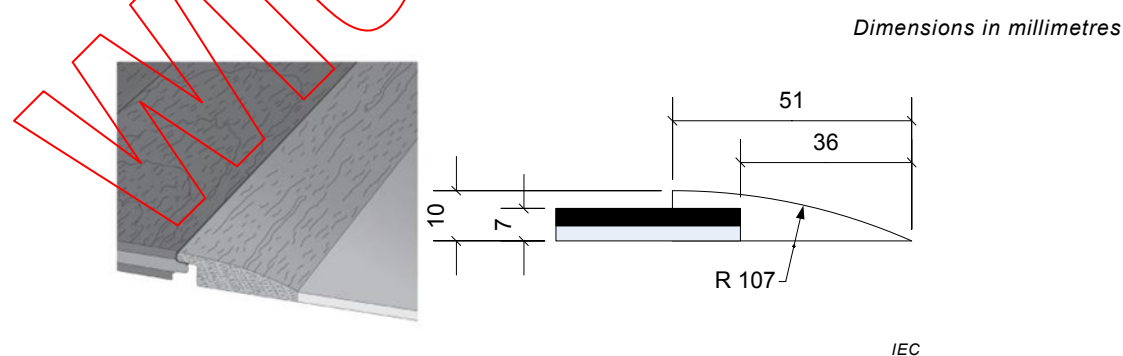


**Figure 11 – Illustration of wood transition Installation**

<sup>2</sup> 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.

<sup>3</sup> 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.