
**Paints and varnishes — Evaluation of
properties of coating systems related
to the spray application process —**

Part 1:
**Vocabulary and preparation of test
panels**

*Peintures et vernis — Évaluation des propriétés des systèmes de
revêtement liés au mode d'application par pulvérisation —*

Partie 1: Vocabulaire et préparation des panneaux d'essai

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

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

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

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

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

This document was prepared by Technical Committee ISO/TC 35, *Paints and varnishes*, Subcommittee SC 9, *General test methods for paints and varnishes*, in collaboration with the European Committee for Standardization (CEN) Technical Committee CEN/TC 139, *Paints and varnishes*, in accordance with the Agreement on technical cooperation between ISO and CEN (Vienna Agreement).

This second edition cancels and replaces the first edition (ISO 28199-1:2009), which has been technically revised. It also incorporates the Technical Corrigendum ISO 28199-1:2009/Cor.1: 2009.

The main changes to the previous edition are as follows:

- the terms "minimum film-build", "locally related measurements" and "locally unrelated measurements" have been deleted;
- the terms "bubble formation limit" and "cratering" have been moved to ISO 28199-3;
- the terms "measurement pattern" and "dynamic spray pattern" have been added;
- the distinction between long-wavelength and short-wavelength ranges for the surface texture (3.13) has been deleted;
- the descriptions of the automatic painting machine (5.1) and the device for automatic positioning of measuring devices (5.2) have been revised;
- the description of the film thickness wedge (8.4) has been revised;
- the measurement pattern for colour measurement (9.4.3) has been adapted in line with the measurement pattern for texture measurement (9.4.4) for version A of the samples;
- the measurements of mottling (9.4.5) and gloss (9.4.6) have been added;
- examples of applications with high-speed rotation have been added as new Figure 2 and in Annex A;
- the normative references have been updated;

— the text has been editorially revised.

A list of all parts in the ISO 28199 series can be found on the ISO website.

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

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Introduction

In many areas (e.g. car manufacture, industrial coatings, coatings for plastics) the coating materials used are adapted to the specific application equipment and settings of the particular user. A coating material is, therefore, to be understood as a semi-manufactured product that only achieves its final form in combination with the specific application conditions. The adaptation to the application conditions is therefore decisive for the quality of the coated product.

The test methods specified in ISO 28199 are based on studies by a working group of the European Council for Automotive R&D (EUCAR).

They may be used for evaluation of coating materials in research, development and production with regard to their suitability and safety for industrial processes, and error analysis. The properties to be evaluated for coating materials and coatings depend on the film thickness, so a coating system of increasing or constant thickness is applied to one or more test panels under defined conditions depending on the surface properties to be tested.

The following characteristics are measured (in this document):

- film thickness in accordance with ISO 2808;
- surface texture;
- colour in accordance with ISO 18314-1;
- mottling;
- gloss in accordance with ISO 2813.

In combination with visual assessment, the following properties are determined:

- Colour stability or colour evaluation, process hiding power, redissolving, overspray absorption, wetting, surface texture and mottling (ISO 28199-2). The surface texture can be measured both independently of the film thickness and at constant film thickness. Mottling is preferably measured at constant film thickness.
- Tendency to sagging, formation of bubbles, pinholing and hiding power (see ISO 28199-3).

Paints and varnishes — Evaluation of properties of coating systems related to the spray application process —

Part 1: Vocabulary and preparation of test panels

1 Scope

This document defines terms relating to the evaluation of coating materials in research, development and production with regard to their suitability and safety for industrial processes and error analysis.

This document also specifies methods for the preparation of test panels and the subsequent measurement of film thickness, colour, surface texture and other measurable surface properties.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 1513, *Paints and varnishes — Examination and preparation of test samples*

ISO 2808, *Paints and varnishes — Determination of film thickness*

ISO 3270, *Paints and varnishes and their raw materials — Temperatures and humidities for conditioning and testing*

ISO 15528, *Paints, varnishes and raw materials for paints and varnishes — Sampling*

ISO 18314-1, *Analytical colorimetry — Part 1: Practical colour measurement*

ISO 28199-2, *Paints and varnishes — Evaluation of properties of coating systems related to the spray application process — Part 2: Colour stability, process hiding power, re-dissolving, overspray absorption, wetting, surface texture and mottling*

ISO 28199-3, *Paints and varnishes — Evaluation of properties of coating systems related to the spray application process — Part 3: Visual assessment of sagging, formation of bubbles, pinholing and hiding power*

3 Terms and definitions

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

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

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

**3.1
bubble**

closed or already burst blister in a layer, arising when solvents or cleavage products evaporate from chemical crosslinking

Note 1 to entry: If bubbles are caused by the process control, the formulation components or both, the viscosity of the paint film has increased too rapidly during the drying phase so that solvents or reaction products still in the paint film have built up at the polymer paint skin which forms, usually resulting in closed blisters and sometimes resulting in burst blisters. Discontinuities can be identified in more detail using a cross-section.

**3.2
colour stability**

non-variability, or variability within agreed tolerances, of colour despite variation of influencing factors

Note 1 to entry: Examples of influencing factors are thickness and application method.

**3.3
measurement pattern**

distance between individual measurements on the test panel in the dx and dy directions

**3.4
mottling**

non-uniform appearance of a film caused by the presence of irregularly shaped, randomly distributed areas on the surface that vary in colour and/or gloss

[SOURCE: ISO 4618:2014, 2.160]

**3.5
overspray absorption**

ability of a coating material already applied to absorb overspray particles of the same coating material resulting from a subsequent application

Note 1 to entry: Evidence of poor overspray absorption is shown, for example, by raised *surface texture* (3.12) and low *colour stability* (3.2) as well as *mottling* (3.4).

**3.6
pinholing**

presence of small holes in a film or coating resembling those made by a pin

Note 1 to entry: Pinholes can be caused by gas inclusions in the base coat that reveal a discontinuity after the application of the clear coating material. They are often the result of inappropriate process parameters. Pinholes are similar to craters and *bubbles* (3.1). Discontinuities can be identified in more detail using a cross-section.

[SOURCE: ISO 4618:2014, 2.195, modified — Note 1 to entry added.]

**3.7
process hiding power**

minimum thickness above which the complete coating system in combination with the colour of the complete substrate achieves *colour stability* (3.2) or the colour location achieves a value agreed by the interested parties

Note 1 to entry: See also “hiding power”, defined in ISO 4618:2014, 2.138, as “ability of a coating material or a coating to obliterate the colour or the differences in colour of a substrate”.

**3.8
redissolving**

mutual effects between an already applied coating material and a subsequently applied coating material where components of the subsequently applied coating interact with the already applied coating

Note 1 to entry: The interaction can be recognizable by a change in colour, for example.

3.9

sagging

downward movement of a coating material during application and/or drying or curing in a vertical or an inclined position that results in irregularities in the dry coat

[SOURCE: ISO 4618:2014, 2.221, modified — "or curing" added in the definition.]

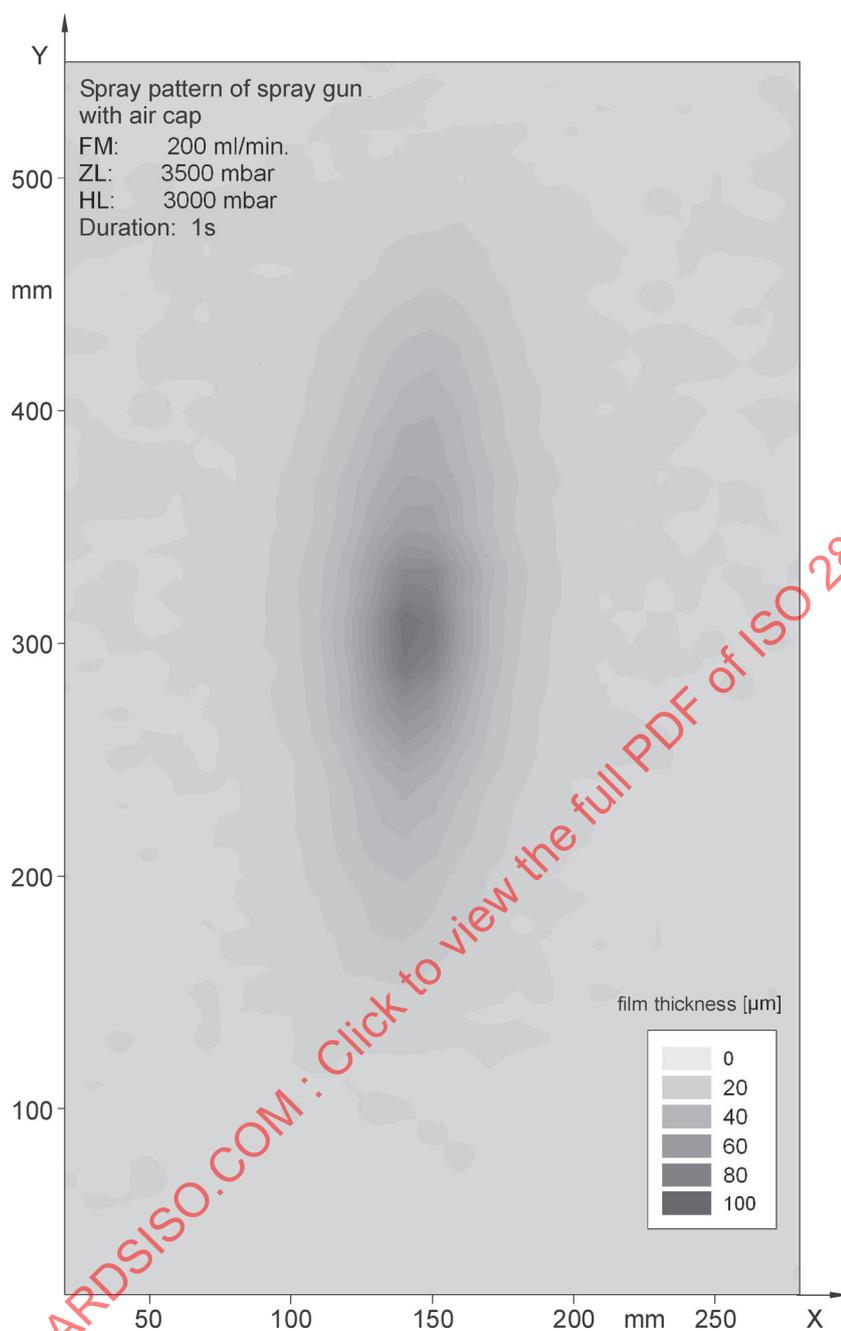
3.10

static spray pattern

distribution of the coating material after spray application using defined parameters, with both coated object and spray application system at rest

Note 1 to entry: See [Figure 1](#).

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Key

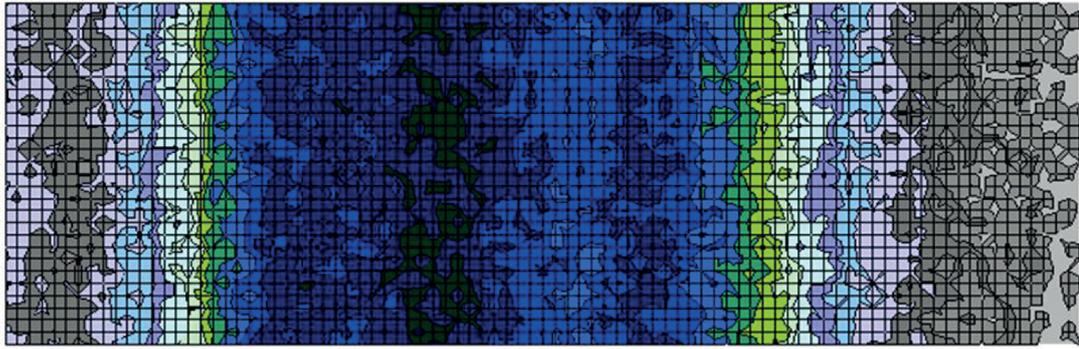
- X width of the test panel, in millimetres
- Y length of the test panel, in millimetres

Figure 1 — Example of a static spray pattern

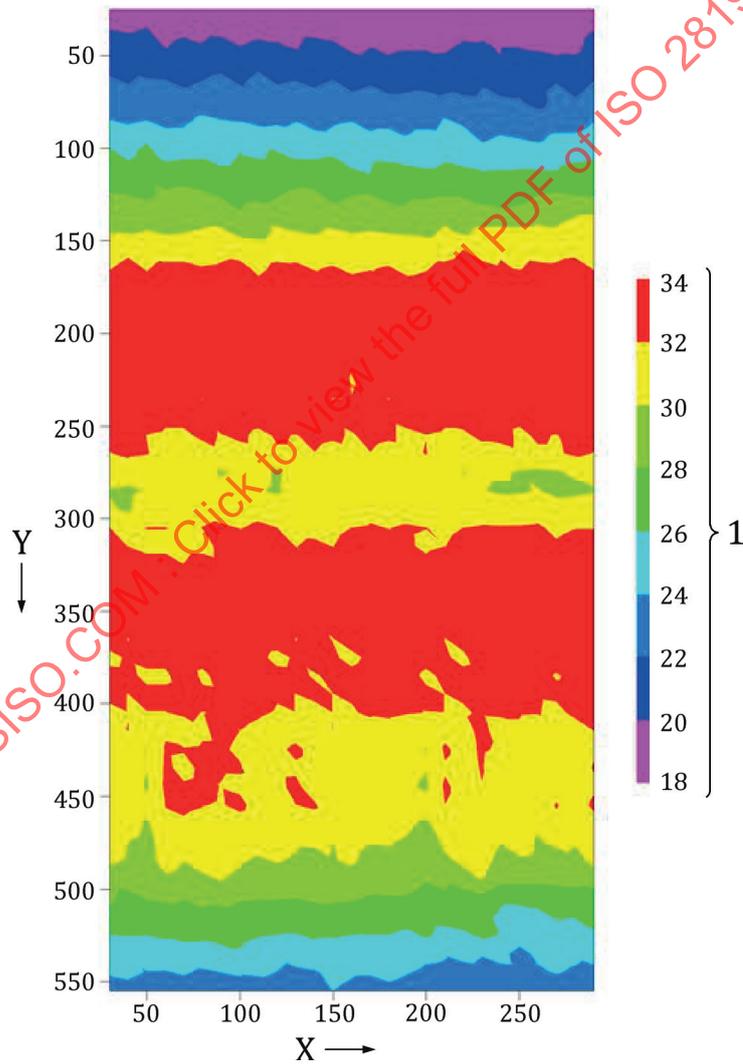
3.11 dynamic spray pattern

distribution of the coating material after spray application using defined parameters, with coated object and spray application system in relative motion

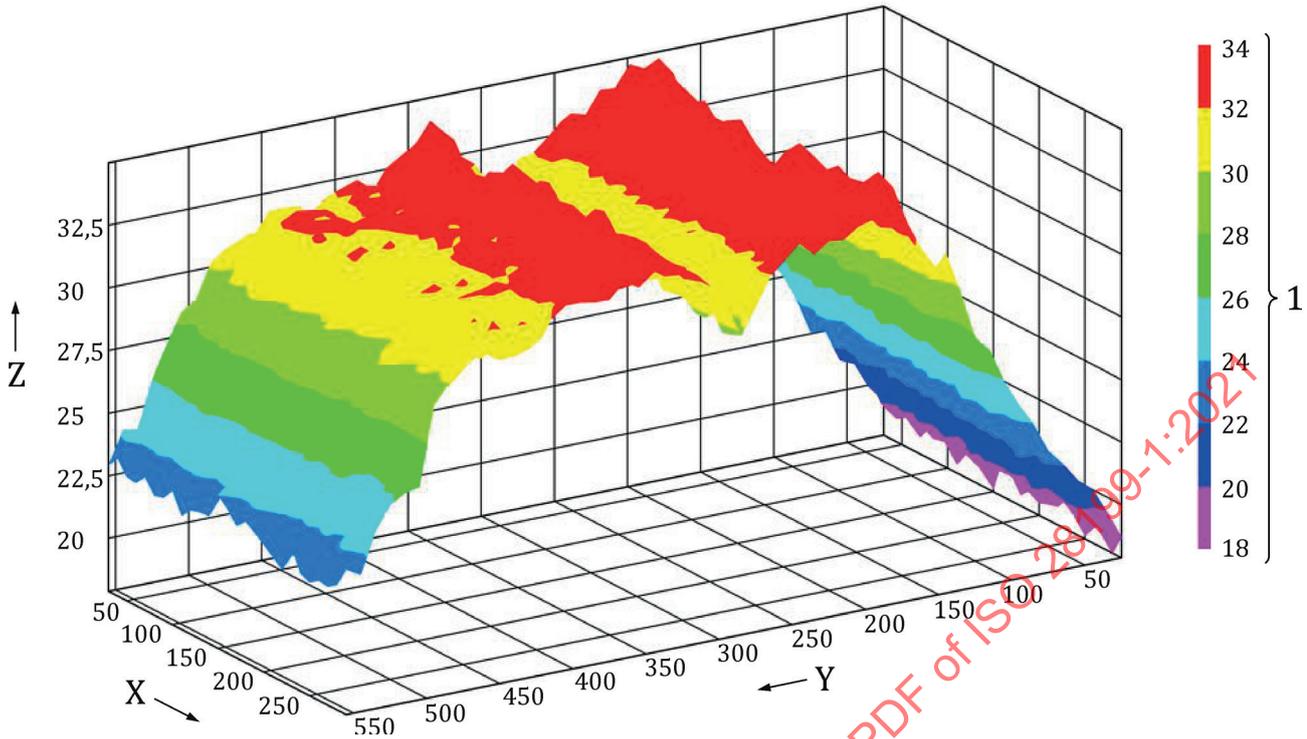
Note 1 to entry: See [Figure 2](#).



a) Pneumatically sprayed



b) Applied with high-speed electrostatic rotation — two-dimensional view



c) Applied with high-speed electrostatic rotation — three-dimensional view

Key

- X width of the test panel, in millimetres
- Y length of the test panel, in millimetres
- Z film thickness, in micrometres
- 1 film thickness, in micrometres

NOTE Film thickness ranges shown in different colours.

Figure 2 — Example of a dynamic spray pattern

3.12 surface texture

visual appearance and visible recognisability of structures in the coating surface

Note 1 to entry: The recognizability of the surface texture depends on the topographic characteristics, the observation distance and the image clarity of the surface. In the case of the so-called “orange peel” texture that can occur with coatings, the ranges of surface wavelength are between 0,1 mm and 30 mm.

Certain characteristic parameters are calculated from these wavelength ranges by the interested parties. The surface texture is influenced by the levelling (as defined in ISO 4618) of the still-liquid coating and by the substrate, for example.

3.13 wetting

complete coverage of a substrate when a coating material forms a continuous film on a substrate

4 Principle

The coating material to be tested is applied to a test panel. Various optical properties are measured by an appropriate procedure dependent on the film thickness.

5 Apparatus

Use ordinary laboratory apparatus and the following.

5.1 Automatic painting machine, used to coat the specified test panels according to the procedure and accuracy specified in this document.

The accuracy of the film thickness profiles (wedge-shaped or constant) produced has a decisive influence on the reproducibility and repeatability of the results obtained when using this procedure, and the application parameters should therefore be as close as possible to those of the process to be simulated.

NOTE Examples of suitable application parameters are given in [Annex A](#).

5.2 Device for automatic positioning of measuring devices. It shall be possible to position the measuring devices that are used on the coated test panels based on the specified measurement pattern ([9.4.1](#)) in a reproducible manner using the device for automatic positioning of measuring devices.

6 Calibration

The measuring devices are calibrated and, if necessary, adjusted in accordance with the specifications or standards of the relevant manufacturers. The positioning accuracy of the measuring devices in accordance with the manufacturers' specifications shall be ensured by regular maintenance of the equipment (control of inspection, measuring and test equipment).

7 Sampling

Take a representative sample of the product to be investigated, in accordance with ISO 15528.

Examine and prepare each sample for testing, in accordance with ISO 1513.

8 Test panels

8.1 Substrate

Unless otherwise agreed, use either:

- a) version A: perforated panel (see [Figure 3](#)) of dimensions 300 mm × 570 mm × 0,75 mm; or

NOTE The perforation is needed for the determination of sagging only.

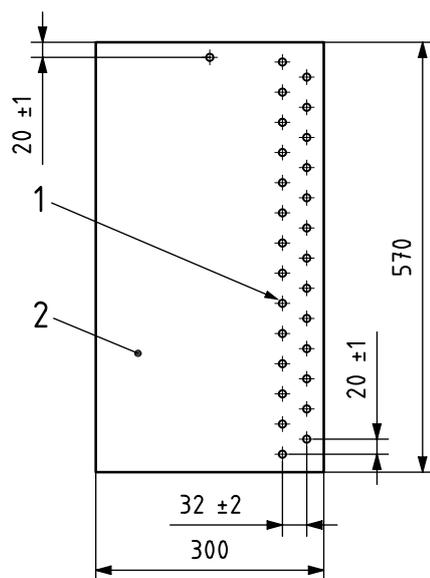
- b) version B: panel (see [Figure 3](#)) of dimensions 200 mm × 500 mm × 0,75 mm.

Only metal panels of defined surface quality as agreed between interested parties shall be used for testing.

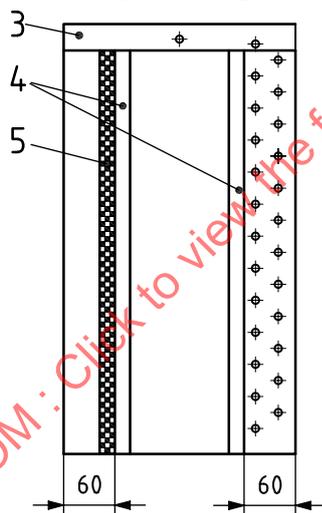
8.2 Preparation of the test panel

[Figure 3](#) shows examples of usual preparations for test panels.

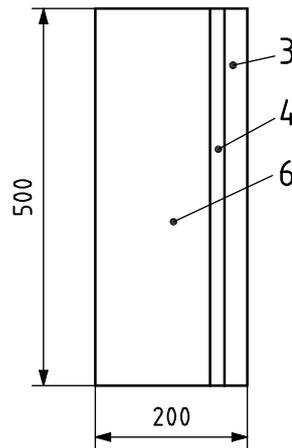
Dimensions in millimetres



a) Example 1 (version A) — Test panel before masking



b) Example 1 (version A) — Test panel after masking



c) Example 2 (version B) — Test panel after masking

Key

- 1 holes of diameter 7 mm
- 2 coil-coated metal panel
- 3 adhesive tape, width \approx 30 mm (reference strip 1)
- 4 adhesive tape, width \approx 19 mm (reference strip 2)
- 5 contrast strip, width 20 mm (black/white strip)
- 6 surface-coated metal panel

Figure 3 — Examples of test panels

8.3 Coating of the test panel

8.3.1 General

The parameters for the application of the coating materials to be tested (air temperature and humidity, flash-off and drying or curing times, drying or curing temperatures) result in part directly from the coating process to be simulated. Other parameters (e.g. atomizer type, application parameters) are to be established by trials in order to get as close as possible to those of the process to be simulated.

The suitability in principle of the selected parameters can be tested using a static ([Figure 4](#)) or dynamic ([Figure 5](#)) spray pattern.

The desired film thickness should preferably be achieved by adapting the stroke speed of the atomizer, substrate or both.

Coat the test panels in accordance with the procedure in [8.3.2](#) or [8.3.3](#), for example.

8.3.2 Version A (perforated panel)

Apply a 30-mm-wide strip of adhesive tape on the test panel at the upper edge (see [Figure 3 b](#)), reference strip 1). Keep this in place until the final coat has been applied.

Apply two 19-mm-wide strips of adhesive tapes parallel to the longer side of the test panel (see [Figure 3 b](#)), reference strip 2).

Apply the base coat.

Pull off the two 19-mm-wide strips of adhesive tape (reference strip 2).

Apply the clear coating material.

Pull off the 30-mm-wide strip of adhesive tape (reference strip 1).

Adhere to the drying or curing times specified by the manufacturer for the individual product.

8.3.3 Version B (non-perforated panel)

8.3.3.1 Version B1 with reference strips

Apply on the right side of the test panel a 30-mm-wide strip of adhesive tape (see [Figure 3 c](#)), reference strip 1) and a 19-mm-wide strip of adhesive tape (see [Figure 3 c](#)), reference strip 2).

Apply the base coat and then pull off the 19-mm-wide strip of adhesive tape (reference strip 2).

Apply the clear coating material and then pull off the 30-mm-wide strip of adhesive tape (reference strip 1).

Adhere to the drying or curing times specified by the manufacturer for the individual product.

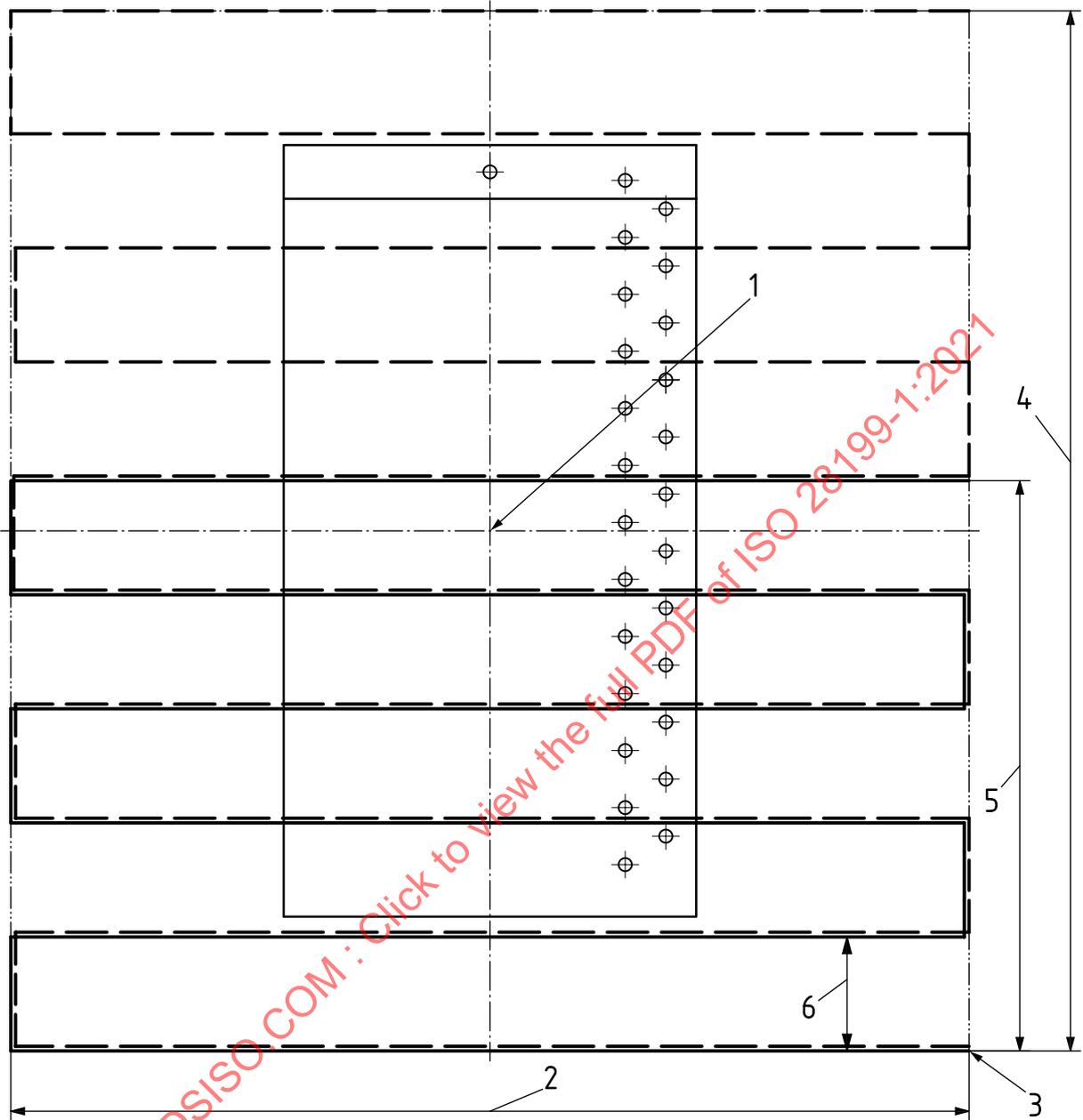
8.3.3.2 Version B2 without reference strips

This version shall be used when the film thicknesses of the cathodic electrodepositon coat, surfacer, base coat and clear coat are measured after each application. In this case, the individual coats shall be dried, cured or stoved prior to measurement.

A coating system generally consists of several layers (e.g. base coat and clear coat), of which one is applied as a wedge. The other layers are applied with constant thickness.

Apply the wedge of coating material in accordance with [Figure 4](#), using two overlapping spraying stages. The first coating stage ends at the point where the test panel is fully coated, and the second ends just beyond the middle of the test panel.

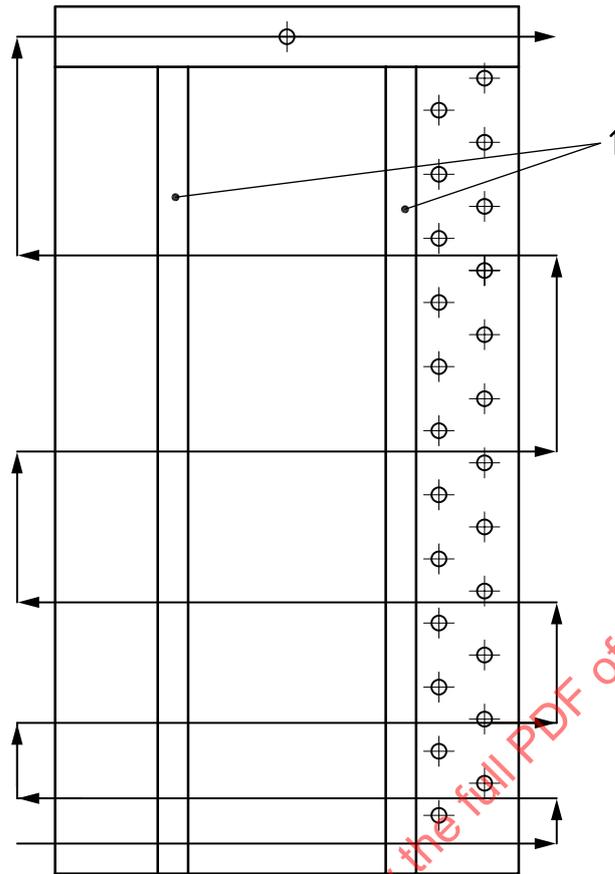
Carry out the coating procedure so that the film thickness on the test panel increases from the top towards the bottom. Then fix the test panels in a defined position so that reproducible coating wedges are obtained.



Key

- 1 midpoint of panel or coating area
- 2 width of coating area
- 3 starting point of first and second spraying stages (first coating stage: dashed line, second coating stage: continuous line)
- 4 height of coating area for first coating stage
- 5 height of coating area for second coating stage
- 6 pitch between horizontal traverses of automatic painting machine

Figure 4 — Creation of a wedge-shaped coating by means of two consecutive spraying applications (static spray pattern)



Key

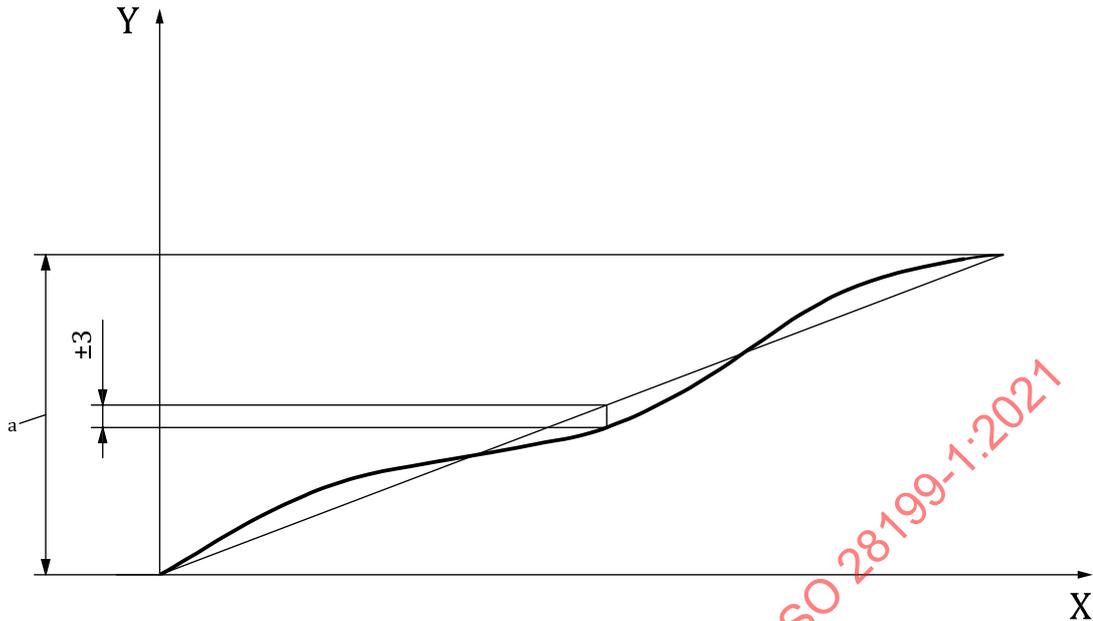
1 reference strip

NOTE Small path separation distance at bottom, large path separation distance at top.

Figure 5 — Creation of a wedge-shaped coating by means of dynamic enlarging of the spraying path separation distance during the coating step (dynamic spray pattern)

8.4 Film thickness

Certain film thickness ranges can be selected depending on the surface features to be evaluated. The film thickness of the steadily monotonically increasing coating wedge can start at 0 μm as a preliminary test and should increase continuously with a fluctuation $\leq (\pm 3) \mu\text{m}$ up to an agreed maximum value (see [Figure 6](#)). Other film thickness ranges to be selected shall be defined depending on the surface features that are of interest.

**Key**

- X measuring range, cm
- Y film thickness, μm
- a Upper limit of film thickness.

Figure 6 — Film thickness of the coating wedge

Apply all coats vertically. Flashing-off as well as drying or curing of the wedge-shaped layer shall also take place vertically, while the constant-thickness layer(s) are horizontal during the final flashing-off and drying or curing. Deviations from this procedure are to be agreed for other simulations.

9 Procedure

9.1 Conditioning the test panels

Unless otherwise agreed, condition the test panels at $(23 \pm 2)^\circ\text{C}$ (standard temperature) in accordance with ISO 3270 for at least 16 h before testing.

9.2 Test conditions

The test should preferably be carried out at $(23 \pm 2)^\circ\text{C}$ (standard temperature in accordance with ISO 3270).

9.3 Number of test panels to be measured

Unless otherwise agreed, carry out a single determination.

9.4 Test

9.4.1 Measurement pattern

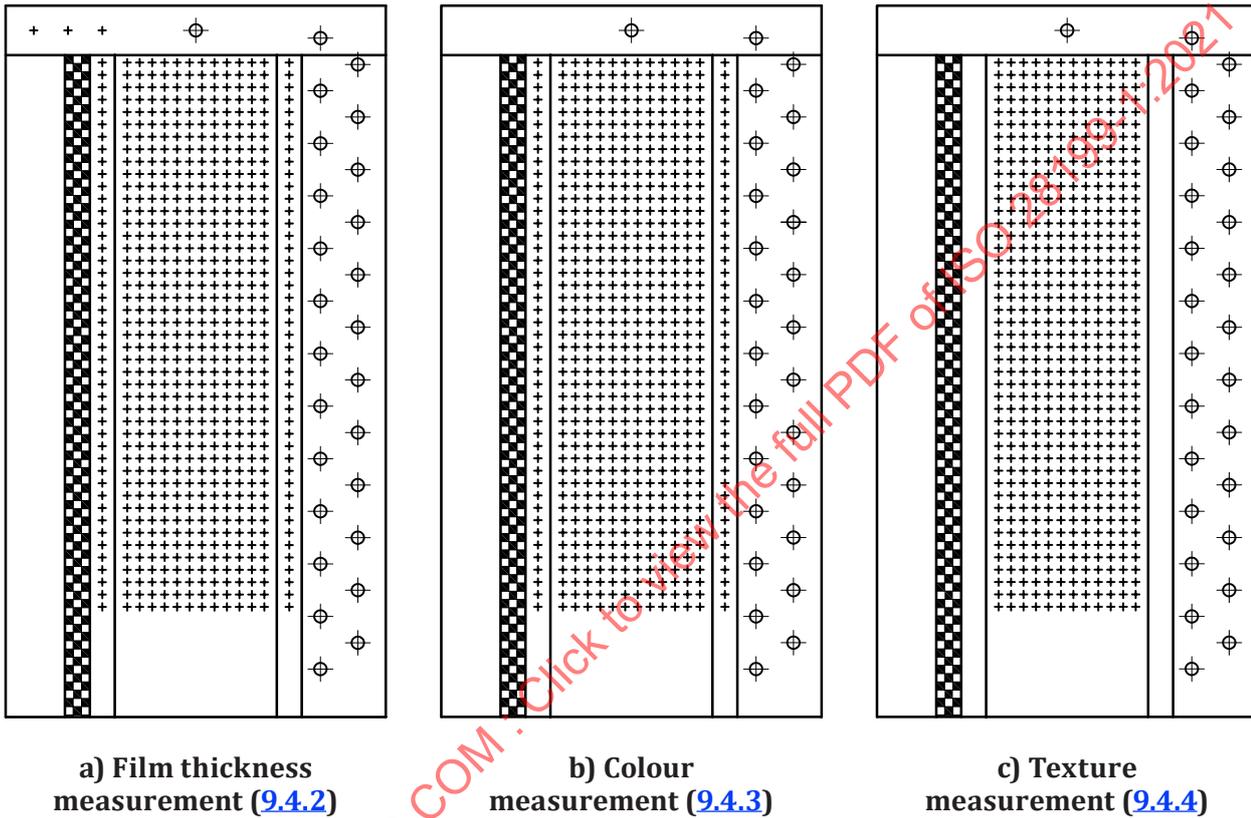
For spot measurements on wedge-shaped coatings, the measurement pattern shall be chosen so that at least five measurements can be taken at different points (X direction) on a single film thickness line. At least 20 such lines shall be distributed over the length (Y direction) of the test panel.

Other measurement patterns can be agreed for coatings with constant film thickness.

Examples of measurement patterns are given in [Figures 7](#) and [8](#).

Describe the relationship between the measured film thickness and one or more surface measurement values as one of the following types:

- locally related, i.e. film thickness and surface measurement value taken at the same point;
- locally unrelated, i.e. film thickness and surface measurement value taken at different, non-overlapping points.

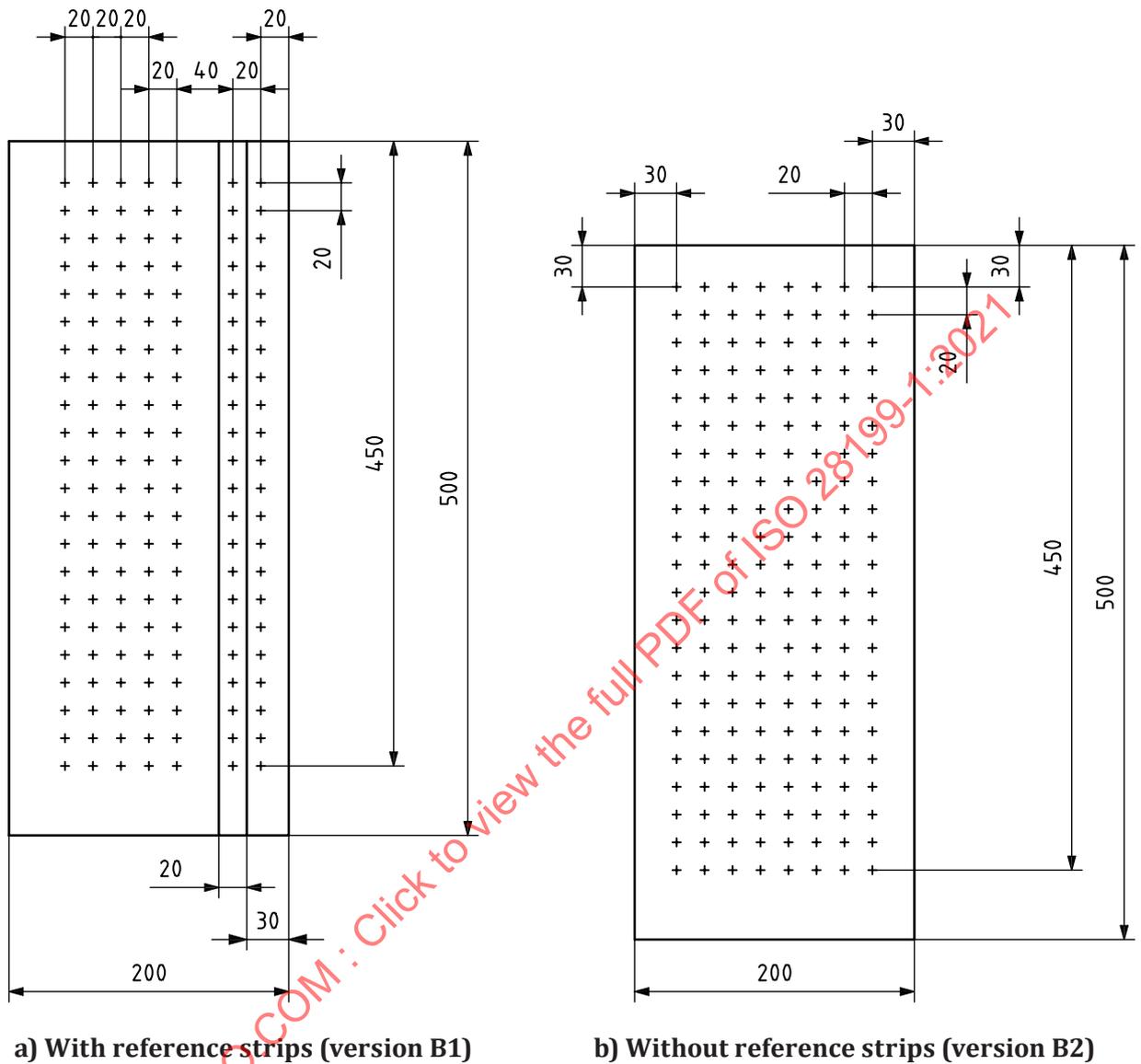


Key

+	measuring point
⊕	hole (7 mm diameter)

Figure 7 — Measurement pattern for version A

Dimensions in millimetres



Key

+ measuring point

Figure 8 — Measurement pattern for version B

9.4.2 Film thickness

Measure the film thickness in accordance with one of the procedures given in ISO 2808.

9.4.3 Colour

Measure the colour in accordance with ISO 18314-1.

Calculate the values of L^* , a^* , b^* , C^* , h^* , for example at the five angles of 15° , 25° , 45° , 75° and 110° , with standard illuminant D65 and 10° standard observer. Depending on colour location, it shall be agreed as to whether L^* , a^* , b^* or L^* , C^* , h^* are used for the subsequent evaluation.

9.4.4 Surface texture

Measure the surface texture using a suitable measurement method. Using mathematical functions, evaluate the intensity profile obtained in various wavelength ranges of at least 0,1 mm to 30 mm (see 3.12, Note 1 to entry).

9.4.5 Mottling

Mottling refers to local differences in brightness or colour that are measured and evaluated either using a suitable measuring device or else visually.

9.4.6 Gloss

Measure gloss in accordance with ISO 2813.

10 Evaluation

Evaluate the results of the individual derived test parameters in accordance with ISO 28199-2 and ISO 28199-3.

Assess the coating system with regard to process suitability, process safety and an analysis of the relationship between the film thickness and the errors in the measured quantities.

11 Precision

No precision data are currently available.

12 Test report

The test report shall contain at least the following information:

- a) all information necessary to identify the coating material tested;
- b) a reference to this document, i.e. ISO 28199-1:2021;
- c) the method of application of the test coating to the substrate, including drying or curing conditions for all layers;
- d) details of the conditioning of the test panels;
- e) the temperature and humidity during the test;
- f) the results of the test in accordance with ISO 28199-2 and ISO 28199-3;
- g) any deviations from the test procedure specified;
- h) any unusual features (anomalies) observed during the test;
- i) the date of the test;
- j) the name of the person performing the test.

Annex A (informative)

Examples of suitable application parameters

A.1 Single-colour water-based paint (constant film thickness) — Clear coat (wedge)

Programme parameters for the single-colour water-based paint and clear coat are given in [Table A.1](#) and [Table A.2](#).

Atomizer:	pneumatic
Distance to object:	30 cm
Drying: water-based coat:	10 min at 80 °C
Drying: clear coat:	20 min at 145 °C

Table A.1 — Programme parameters — Single-colour water-based paint

Parameter	First spraying stage	Second spraying stage
Width of area sprayed	76 cm	76 cm
Height of area sprayed	76 cm	76 cm
Starting point ("3" in Figure 4)	X = -38 cm/Y = -38 cm	X = -38 cm/Y = -38 cm
Pitch between traverses	3 cm	3 cm
Speed of travel	0,6 m/s	0,6 m/s
Atomizer air pressure	500 kPa	500 kPa
Fan air pressure	500 kPa	500 kPa
Intermediate flash-off time	240 s	—
Flow rate	160 ml/min	160 ml/min
Flash-off time before drying	—	5 min

Table A.2 — Programme parameters — Clear coat

Parameter	First spraying stage	Second spraying stage
Width of area sprayed	60 cm	60 cm
Height of area sprayed	50 cm	30 cm
Starting point ("3" in Figure 4)	X = -38 cm/Y = -38 cm	X = -38 cm/Y = -38 cm
Pitch between traverses	4 cm	4 cm
Speed of travel	0,7 m/s	0,7 m/s
Atomizer air pressure	450 kPa	450 kPa
Fan air pressure	450 kPa	450 kPa
Intermediate flash-off time	0 s	—
Flow rate	180 ml/min	210 ml/min
Flash-off time before drying	—	5 min

A.2 Single-colour water-based paint (wedge) — Clear coat (constant film thickness)

Programme parameters for the single-colour water-based paint and clear coat are given in [Table A.3](#) and [Table A.4](#).

Atomizer:	pneumatic
Distance to object:	30 cm
Drying: water-based paint:	10 min at 80 °C
Drying: clear coat:	15 min at 140 °C

Table A.3 — Programme parameters — Base coat

Parameter	First spraying stage	Second spraying stage
Width of area sprayed	76 cm	76 cm
Height of area sprayed	50 cm	30 cm
Starting point ("3" in Figure 4)	X = -38 cm/Y = -38 cm	X = -38 cm/Y = -38 cm
Pitch between traverses	3 cm	3 cm
Speed of travel	0,6 m/s	0,6 m/s
Atomizer air pressure	450 kPa	450 kPa
Fan air pressure	450 kPa	450 kPa
Intermediate flash-off time	240 s	—
Flow rate	230 ml/min	230 ml/min
Flash-off time before drying	—	5 min

Table A.4 — Programme parameters — Clear coat

Parameter	First spraying stage	Second spraying stage
Width of area sprayed	60 cm	60 cm
Height of area sprayed	76 cm	76 cm
Starting point ("3" in Figure 4)	X = -38 cm/Y = -38 cm	X = -38 cm/Y = -38 cm
Pitch between traverses	4 cm	4 cm
Speed of travel	0,7 m/s	0,7 m/s
Atomizer air pressure	450 kPa	450 kPa
Fan air pressure	450 kPa	450 kPa
Intermediate flash-off time	0 s	—
Flow rate	140 ml/min	140 ml/min
Flash-off time before drying	—	5 min