International Standard

ISO 9466

# Railway applications — Coating of passenger rail vehicles

*Applications ferroviaires — Peinturage des véhicules ferroviaires destinés au transport de passagers*

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# Foreword

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This document was prepared by Technical Committee ISO/TC 269, *Railway applications*, Subcommittee SC 2, *Rolling stock*, in collaboration with the European Committee for Standardization (CEN) Technical Committee CEN/TC 256, *Railway applications,* in accordance with the Agreement on technical cooperation between ISO and CEN (Vienna Agreement).

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# Railway applications — Coating of passenger rail vehicles

## 1 Scope

This document establishes the performance requirements and acceptance criteria for coating material used for passenger rolling stock, locomotives and components.

This document also provides guidance on the coating application processes, product selection, surface preparation, coating application, verification and inspection methods, repairs, refurbishment (refresh, etc.), and tests to measure the minimum performance for the final product.

This document applies to all types of coating materials (liquid, powder, etc.) used on

— railway vehicle bodies, and

— on-board equipment and constituent parts.

## 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 1518-1, *Paints and varnishes — Determination of scratch resistance — Part 1: Constant-loading method*

ISO 1519, *Paints and varnishes — Bend test (cylindrical mandrel)*

ISO 2409:2020, *Paints and varnishes — Cross-cut test*

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

ISO 2811-1, *Paints and varnishes — Determination of density — Part 1: Pycnometer method*

ISO 2812-3, *Paints and varnishes — Determination of resistance to liquids — Part 3: Method using an absorbent medium*

ISO 2813, *Paints and varnishes — Determination of gloss value at 20°, 60° and 85°*

ISO 3233-3, *Paints and varnishes — Determination of the percentage volume of non-volatile matter — Part 3: Determination by calculation from the non-volatile-matter content determined in accordance with ISO 3251, the density of the coating material and the density of the solvent in the coating material*

ISO 3251:2019, *Paints, varnishes and plastics — Determination of non-volatile-matter content*

ISO 3668, *Paints and varnishes — Visual comparison of colour of paints*

ISO 4545-1:2023, *Metallic materials — Knoop hardness test — Part 1: Test method*

ISO 4618:2023, *Paints and varnishes — Vocabulary*

ISO 4624:2023, *Paints and varnishes — Pull-off test for adhesion*

ISO 4628-2:2016, *Paints and varnishes — Evaluation of degradation of coatings — Designation of quantity and size of defects, and of intensity of uniform changes in appearance — Part 2: Assessment of degree of blistering*

ISO 4628-3:2024, *Paints and varnishes — Evaluation of quantity and size of defects, and of intensity of uniform changes in appearance — Part 3: Assessment of degree of rusting*

ISO 4628-4:2016, *Paints and varnishes — Evaluation of degradation of coatings — Designation of quantity and size of defects, and of intensity of uniform changes in appearance — Part 4: Assessment of degree of cracking*

ISO 4628-5:2022, *Paints and varnishes — Evaluation of quantity and size of defects, and of intensity of uniform changes in appearance — Part 5: Assessment of degree of flaking*

ISO 4628-8, *Paints and varnishes — Evaluation of degradation of coatings — Designation of quantity and size of defects, and of intensity of uniform changes in appearance — Part 8: Assessment of degree of delamination and corrosion around a scribe or other artificial defect*

ISO 6270-2, *Paints and varnishes — Determination of resistance to humidity — Part 2: Condensation (in-cabinet exposure with heated water reservoir)*

ISO 6272-1, *Paints and varnishes — Rapid-deformation (impact resistance) tests — Part 1: Falling-weight test, large-area indenter*

ISO 6344-2:2021, *Coated abrasives — Determination and designation of grain size distribution — Part 2: Macrogrit sizes P12 to P220*

ISO 6344-3, *Coated abrasives — Determination and designation of grain size distribution — Part 3: Microgrit sizes P240 to P5000*

ISO 6504-3:2019, *Paints and varnishes — Determination of hiding power — Part 3: Determination of hiding power of paints for masonry, concrete and interior use*

ISO 6507-1:2023, *Metallic materials — Vickers hardness test — Part 1: Test method*

ISO 7784-1, *Paints and varnishes — Determination of resistance to abrasion — Part 1: Method with abrasive-paper covered wheels and rotating test specimen*

ISO 8130-1, *Coating powders — Part 1: Determination of particle size distribution by sieving*

ISO 8130-13, *Coating powders — Part 13: Particle size analysis by laser diffraction*

ISO 8130-8:2021, *Coating powders — Part 8: Assessment of the storage stability of thermosetting powders*

ISO 8501-1:2007, *Preparation of steel substrates before application of paints and related products — Visual assessment of surface cleanliness — Part 1: Rust grades and preparation grades of uncoated steel substrates and of steel substrates after overall removal of previous coatings*

ISO 8502-3, *Preparation of steel substrates before application of paints and related products — Tests for the assessment of surface cleanliness — Part 3: Assessment of dust on steel surfaces prepared for painting (pressure-sensitive tape method)*

ISO 8503-1, *Preparation of steel substrates before application of paints and related products — Surface roughness characteristics of blast-cleaned steel substrates — Part 1: Specifications and definitions for ISO surface profile comparators for the assessment of abrasive blast-cleaned surfaces*

ISO 9227, *Corrosion tests in artificial atmospheres — Salt spray tests*

ISO 9514, *Paints and varnishes — Determination of the pot life of multicomponent coating systems — Preparation and conditioning of samples and guidelines for testing*

ISO 11890-1, *Paints and varnishes — Determination of volatile organic compounds (VOC) and/or semi volatile organic compounds (SVOC) content — Part 1: Gravimetric method for VOC determination*

ISO 11890-2, *Paints and varnishes — Determination of volatile organic compounds(VOC) and/or semi volatile organic compounds (SVOC) content — Part 2: Gas-chromatographic method*

ISO 16276-2, *Corrosion protection of steel structures by protective paint systems — Assessment of, and acceptance criteria for, the adhesion/cohesion (fracture strength) of a coating — Part 2: Cross-cut testing and X-cut testing*

ISO 16474-2:2013/Amd 1:2022, *Paints and varnishes — Methods of exposure to laboratory light sources — Part 2: Xenon-arc lamps — Amendment 1: Classification of daylight filters*

ISO 16862:2003, *Paints and varnishes — Evaluation of sag resistance*

ISO 17872, *Paints and varnishes — Guidelines for the introduction of scribe marks through coatings on metallic panels for corrosion testing*

ISO 18768-1, *Organic coatings on aluminium and its alloys — Methods for specifying decorative and protective organic coatings on aluminium — Part 1: Powder coatings*

ISO 19840, *Paints and varnishes — Corrosion protection of steel structures by protective paint systems — Measurement of, and acceptance criteria for, the thickness of dry films on rough surfaces*

ISO 20567-1:2017, *Paints and varnishes — Determination of stone-chip resistance of coatings — Part 1: Multi-impact testing*

ISO 22163:2023, *Railway applications — Railway quality management system — ISO 9001:2015 and specific requirements for application in the railway sector*

ISO/CIE 11664-1, *Colorimetry — Part 1: CIE standard colorimetric observers*

ISO/CIE 11664-2, *Colorimetry — Part 2: CIE standard illuminants*

ISO/CIE 11664-3, *Colorimetry — Part 3: CIE tristimulus values*

ISO/CIE 11664-4, *Colorimetry — Part 4: CIE 1976 L*a*b* colour space*

ISO/CIE 11664-5, *Colorimetry — Part 5: CIE 1976 L*u*v* colour space and u', v' uniform chromaticity scale diagram*

ISO/CIE 11664-6, *Colorimetry — Part 6: CIEDE2000 colour-difference formula*

## 3 Terms, definitions, abbreviated terms and symbols

For the purposes of this document, the terms and definitions given in ISO 4618 and the following apply.

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

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

— IEC Electropedia: available at https://www.electropedia.org/

### 3.1 Terms and definitions

**3.1.1**
**coater**
paint applicator
operator which applies the *coating material* (3.1.2)

**3.1.2**
**coating material**
product, in liquid, paste or powder form, that, when applied to a substrate, forms a layer possessing protective, decorative and/or other specific properties

[SOURCE: ISO 4618:2023, 3.48]

**3.1.3**
**technical data sheet**
document released by the *coating material* (3.1.2) supplier which details all the technical parameters needed to prepare and apply the coating material

**3.1.4**
**coating system**
layer combined of all coats of the same or multiple coating materials

[SOURCE: ISO 4618:2023, 3.51]

**3.1.5**
**qualification**
process that proves that a set of technical requirements are fulfilled

**3.1.6**
**refurbishment time**
expected duration of use not linked to warranty time

**3.1.7**
**work sample**
representative part (same material, same pretreatment) which is produced under qualified production conditions

**3.1.8**
**standard atmosphere**
atmosphere for conditioning or testing according to ISO 554:1976, 2.2 (ordinary tolerances) with 23 °C ± 2 °C and 50 % ± 5 % of relative humidity

## 3.2 Abbreviated terms and symbols

### 3.2.1 Abbreviated terms

| | |
|---|---|
| AASS | acetic acid salt spray |
| AHT | alternating humidity and air temperature |
| CH | constant humidity |
| FRP | fibre reinforced plastic |
| GU | gloss unit |
| NSS | neutral salt spray |
| SCI | specular component included |
| VOC | volatile organic compound |

### 3.2.2 Symbols

| | | |
|---|---|---|
| $a$ | thickness | µm |
| $C^*$ | colourimetric variance according to the chroma axis | |
| $R_a$ | arithmetic mean height of the roughness according to ISO 21920-2 | |
| $R_z$ | roughness based on themaximum height according to ISO 21920-2 | |
| Ri | degree of rusting according to ISO 4628-3 | |
| $g_{spe}$ | specific gravity | |
| Sa | surface preparation by blast-cleaning according to ISO 8501-1 (the optional number following Sa refers to ISO 8501-1:2007, Table 1) | |

St surface preparation by hand and power tool cleaning according to ISO 8501-1 (the optional number following St refers to ISO 8501-1:2007, Table 2)

# 4 Coating systems, locations and environment and design recommendations

## 4.1 General

The coating system shall be qualified based on its location within the vehicle.

## 4.2 Types of locations

The locations are defined in Table 1.

**Table 1 — Types of location**

| Type of location | Decorative location (visible to passengers and crew) | Non-decorative location (non-visible) |
|---|---|---|
| Interior (walls and ceilings) and equipment | Examples include:<br>Ceiling<br>Side ceiling<br>Side walls<br>Grab-handles<br>Cab desk<br>Luggage racks | Carbody side walls and ceiling<br>Parts behind ceilings and side walls (C rail, hooks, etc.) |
| Interior needing higher resistance to corrosion (floor and elements mounted on the floor) | Seating (pedestal)<br>Mounting of seats<br>Mounting of support bars<br>Bottom of side of walls<br>Vestibule | Carbody floor<br>Toilet walls<br>Mounting parts<br>Interior of equipment boxes on the roof |
| Exterior (direct UV exposure) | Examples include:<br>Carbody side<br>Exterior doors<br>Fairings/roof fin<br>Carbody roof (rounded)<br>Carbody ends (if decorative)<br>Cab front/front end<br>Equipment (outside window frames, door gutters, etc.)<br>Devices (cameras, speakers, etc.) | Examples include:<br>Carbody roof (tube)<br>Carbody ends<br>Equipment boxes<br>Fairings (for HVAC unit, pantograph, insulator head, etc.)<br>Handrail (for inspection of the roof)<br>Drain pipe/gutter<br>Fresh air duct<br>Intercar barrier bracket |
| Exterior (indirect or no UV exposure) | No | Carbody underframe<br>Equipment mounted on the underframe<br>Coupler<br>Buffer<br>Bogie frame and bogie components<br>Axles, wheelsets |



## 4.3 Standard support and substrates

Table 2 lists the supports and substrates that shall be used for the tests described in Table 3, Table 4, Table 5, Table 6, Table 7 and Table 8.

For the chemical pretreatments described in Table 2, the name of each product used for pretreatment (degreasing, etching, passivation, pickling) should be included in the qualification report.

**Table 2 — Standard support and substrates**

| Type | Standard support | Support for elasticity tests |
|---|---|---|
| Steel | Substrate S2 defined in this document as:<br>Material: cold rolled steel (steel grade: DC01/SPCC-SD)<br>Thickness: 2 mm<br>Size:<br>— depends on the test machine;<br>— for corrosion tests min. 150 mm × 200 mm.<br>Pretreatment:<br>— powder: zinc phosphate pretreatment or abrasive blast cleaning (surface quality: Sa 2½; roughness $R_z$ value between 25 and 40 µm) or both;<br>— liquid: abrasive blast cleaning (surface quality: Sa 2½; roughness fine G in accordance with ISO 8503-1). | Substrate S1 defined in this document as:<br>Material: steel<br>Thickness: 0,7 mm to 1 mm<br>Size: depends on test machine<br>Pretreatment: zinc phosphated or bare surface or both |
| Aluminium | Substrate A2 defined in this document as:<br>Material: aluminium grade: AlMg3 (Al5754), AlMg2.5 (A5052), AlSi1MgMn (A6082) or AlMg1SiCu (A6061/Al6061T6)<br>Thickness: 2 mm min.<br>Size:<br>— depends on the test machine;<br>— for corrosion tests: min. 100 mm × 150 mm.<br>Pretreatment:<br>— powder: chemical treatment in accordance with ISO 18768-1 or abrasive blast cleaning (surface quality: Sa 2½; roughness $R_z$ value between 25 µm and 40 µm) or both;<br>— liquid: abrasive blast cleaning (the degree of cleanliness shall have a flat, uniform and clean blasting pattern); roughness $R_z$ value between 25 µm and 40 µm. | Not required |

In the case of abrasive blast cleaning and if the surface is not protected from contamination and oxidation, the coating should be applied immediately after.

The results are not valid for other substrates (e.g. FRP or plastic). A process qualification (see 5.3) is necessary in any case on the substrate of the project and needs to be performed with the original pretreatment.

## 4.4 Coating system qualification

### 4.4.1 General

The coating system shall be qualified in accordance with Table 3, Table 4, Table 5, Table 6, Table 7 and Table 8.

All tests should be performed with the nominal thickness mentioned in Table 4. If single tests are carried out with a different nominal layer thickness, this shall be explicitly indicated in the test report.

### 4.4.2 Chemical and physiochemical characteristics of products for each layer

**Table 3 — Chemical and physiochemical characteristics of products for each layer**

| Characteristic | Method | Results required | Type of coating material |
|---|---|---|---|
| Flash point | References [1] and [2] are given as examples | Temperature in °C is given in accordance with the safety data sheet.<br>If a standard or regulation has been followed, please record its details in the report. | Powder and liquid coats |
| Solid content by mass ready to use | ISO 3251:2019, Table A.1, 60 min, 105 °C | Solid content in % is given in accordance with the technical data sheet and in the technical report. | Liquid coat only |
| Theoretical yield for liquid coating material (theoretical spreading rate) ($m^2$/kg/µm) | ISO 3233-3: Calculating the non-volatile matter content in accordance with ISO 3251, the density of the coating material and the density of the solvent in the coating material. | Theoretical yield in $m^2$/kg/µm is given in accordance with the technical data sheet and in the technical report. | Liquid coat only |
| Theoretical yield for powder coating material (theoretical spreading rate) ($m^2$/kg/µm) | $\frac{1\,000}{g_{spe} * a}$ | Theoretical yield in $m^2$/kg/µm is noted in the technical report. | Powder coat only |
| Particle size distribution | ISO 8130-1<br>ISO 8130-13 | Particle size in % is given in accordance with the technical data sheet and in the technical report. | Powder coat only |
| Quantity of VOCs (g/l) | ISO 11890-1 or ISO 11890-2, or both | VOC in g/l is given in accordance with the technical data sheet and in the technical report. | Liquid coat only |

### 4.4.3 Application properties of products

## Table 4 — Application properties of products

| Characteristic | Method | Coating material drying | Results required | Locations (Table 1) and type of coating material |
|---|---|---|---|---|
| Nominal dry film thickness | ISO 2808 or ISO 19840, or both | Data given in accordance with the technical data sheet | Thickness in µm is given in accordance with the technical data sheet. | All locations<br>Powder and liquid coats |
| Nominal wet thickness | ISO 2808 | Not applicable | Thickness in µm is given in accordance with the technical data sheet. | All locations<br>Liquid coat only |
| Sagging or run off limit | ISO 16862:2003, method "sag index applicator" | Not applicable | Thickness in µm is given in the technical report.<br>Min. 1,5 times the nominal wet thickness. | All locations<br>Liquid coat only |
| Storage stability (powder coat) | ISO 8130-8:2021, 8.2.1 b) | After artificial storage, cure completely in accordance with technical data sheet. | Similar results of values checked before and after artificial storage:<br>— topcoat and clear coat: gloss in accordance with ISO 2813;<br>— primer: NSS (steel) or AASS (aluminium) in accordance with ISO 9227, 240 h;<br>— topcoat and primer: impact test in accordance with ISO 6272-1. | All locations<br>Powder coat only |
| Storage stability (liquid coat) | Recommended artificial storage at 30 °C to 40 °C depending on technical data sheet and for 28 days' duration | After artificial storage of the liquid coating material and panels conditioning, condition for 14 d in a standard atmosphere or for 21 d for water borne coating materials | Similar results of values checked before and after artificial storage:<br>— colour checked by human eyes;<br>— topcoat and clear coat: gloss in accordance with ISO 2813;<br>— primer: NSS (steel) or AASS (aluminium) in accordance with ISO 9227, 240 h. | All locations<br>Liquid coat only |
| Theoretical pot life | ISO 9514 | Not applicable | Time in h is given in accordance with the technical data sheet. | All locations<br>Only liquid coat |
| Method of application process | According to coating material supplier | Not applicable | Methods listed in the technical data sheet | All locations<br>Powder and liquid coats |
| Viscosity or flow time | EXAMPLE 1 ISO 2431 (flow time in seconds).<br>EXAMPLE 2 ISO 2555 (viscosity). | Not applicable | Data is given in accordance with the technical data sheet and in the technical report: specify the name of the standards and the parameters.<br>EXAMPLE 1 ISO 2431: flow time of 30 s through cup 6 at 23 °C.<br>EXAMPLE 2 ISO 2555: 3 000 mPa·s at 21 °C. | All locations<br>Only liquid coat |
| Density | ISO 2811-1 | Not applicable | Density in g/cm$^3$ is given in accordance with the technical data sheet for each component and in the technical report. | All locations<br>Powder and liquid coats |
| Re-usability of powder over spray | According to coating material supplier | Not applicable | Information (yes or no) is given in accordance with the technical data sheet: possibility and conditions, if relevant, given by the coating material supplier. | All locations<br>Powder coat only |

#### 4.4.4 Physical characteristics of products

All tests in Table 5 should be performed with the nominal thickness mentioned in Table 4 with a minimum of deviation. If single tests are carried out with a different nominal layer thickness, this shall be explicitly indicated in the report.

All tests in Table 5 shall be performed after a minimum of two weeks drying in a standard atmosphere for liquid coating material and in accordance with the technical data sheet for powder coating material.

**Table 5 — Physical characteristics**

| Characteristic | Method | Results required | Locations (Table 1) and type of coating material | Type of support (Table 2) |
|---|---|---|---|---|
| Hiding power | Check the hiding power in accordance with ISO 6504-3:2019, Method B with black or white cards.<br>Three colours shall be checked, depending on the chroma level:<br>— level 1: $C^* \leq 7$;<br>— level 2: $7 < C^* \leq 30$;<br>— level 3: $C^* > 30$.<br>Powder: with black or white metal panels instead | Hiding power in % is calculated by nominal thickness:<br>— good hiding power ≥98 %;<br>— 95 % ≤ limited hiding power < 98 %;<br>— weak hiding power <95 %. | All decorative locations<br>Liquid and powder coats | Liquid coating material: black or white cards<br>Powder coating material: black or white metal panels |
| Drying time (liquid coating material) | The recommended stages from ISO 9117-5 are:<br>— stage 1 (dust-free): ISO 9117-3 and ISO 9117-5;<br>— stage 3 (touch dry): ISO 9117-5;<br>— stage 6 (through dry): ISO 9117-5. | Time in h for each stage is given in accordance with the technical data sheet for each component and in the technical report. | All locations<br>Liquid only | A2 |
| Curing conditions (powder coating material) | After curing, perform all mechanical and chemical resistance tests in accordance with this document.<br>All tests in the reference with powder coat shall be performed using the minimum temperature and time from the technical data sheet. | Time in min and object temperature in °C is given in accordance with the technical data sheet and in the technical report:<br>— min. temperature with time, and<br>— max. temperature with time. | All locations<br>Powder only | A2 |
| Drying time before sanding | Perform sanding with grit P120 at different times until clogging on the paper is no longer noticed.<br>After sanding, the aspect should have a homogeneous mat surface. | Time of drying in h by which clogging is no longer visible after sanding. | All location<br>Liquid only | A2 |
| Dry-to-tape | Apparatus: drying coating material at defined standard conditions:<br>a) ambient drying in a standard atmosphere<br>b) forced curing at 50 °C object temperature<br>c) powder coat curing in accordance with technical data sheet<br>Type of tape: adhesion power on greased-free steel panel between 2 N/cm and 4 N/cm<br>Apply the tape and smooth the surface with a plastic applicator (i.e. squeegee).<br>Duration of the tape contact time: 60 min in standard atmosphere<br>Remove tape in accordance with ISO 2409:2020, Annex A:<br>— peeling angle: 60° in accordance with ISO 2409;<br>— peeling speed: between 0,5 s and 1 s.<br>Apply the final coating layer.<br>Observe the aspect of the final coating layer after curing. | Time in h for dry to tape is given by the supplier: drying time and condition of tested layer.<br>Time in h is without any residues of coating material on the tape after removing.<br>After drying the final layer (in accordance with technical data sheet): no marks of tape after application of the final coating layer. | All locations<br>Liquid only | A2 |

**Table 5** *(continued)*

| Characteristic | Method | Results required | Locations (Table 1) and type of coating material | Type of support (Table 2) |
|---|---|---|---|---|
| Recoatability with following layer | Recoatability with following layer: defining the time during which it is not necessary to grind before applying the following coating material layer.<br>Liquid: conditioning of the 2nd layer for 7 d in a standard atmosphere<br>Powder: standard curing<br>Test: 72 h condensed water test in accordance with ISO 6270-2:<br>— immediately after the test: check blistering in accordance with ISO 4628-2;<br>— 24 h after the test: check adhesion in accordance with ISO 2409. | Time in h is linked to the drying conditions and type of 2nd layer with:<br>— blistering: 0(S0);<br>— adhesion: cross-cut value ≤1. | All locations<br>Liquid and powder coats | A2 |
| Maximum time between coating operation – Recoatability with itself after storage in a standard atmosphere | Test method: establishing the time during which it is not necessary to grind before applying the same layer again.<br>— recoatability with itself to the nominal film thickness of the technical data sheet by spraying;<br>— drying time of the first coat: 1,5 h at 50 °C object temperature;<br>— possible stages for qualification depending on the coating system:<br>— stage 1: 16 h storage in a standard atmosphere, without sanding,<br>— stage 2: 72 h storage in a standard atmosphere without sanding;<br>— curing;<br>— 30 min flash-off time in a standard atmosphere;<br>— 7 d at 50 °C object temperature in circulating air oven – subsequently cool down to standard atmosphere;<br>— 72 h condensed water test in accordance with ISO 6270-2;<br>— after reconditioning for 24 h in a standard atmosphere, perform cross-cut test<br>in accordance with ISO 2409 (type of tape for removing loose coating material: adhesion power on degreased steel panel between 6 N and 10 N for a tape width of 25 mm). | Achieved stage with cross-cut value ≤1 | All locations<br>Liquid only | A2 |

#### 4.4.5 Decorative characteristics

All tests in Table 6 should be performed with the nominal thickness mentioned in Table 4. If single tests are carried out with a different nominal layer thickness, this shall be explicitly indicated in the test report.

All tests in Table 6 shall be performed after a minimum of two weeks drying in a standard atmosphere for liquid coating material and in accordance with the technical data sheet for powder coating material.

**Table 6 — Decorative characteristics**

| Characteristic | Methods | Results required | Locations and type of coating material | Type of support (Table 2) |
|---|---|---|---|---|
| Gloss (measurement of gloss for the master sample) | ISO 2813 only for topcoat and clearcoat without texture.<br>Textured coating material shall be checked visually with the naked eye, or, if possible, using gloss measurement without texture.<br>Metallic coating material can only be compared using the same system. The gloss level will be different to the visual assessment because of measurement errors. | There shall be 5 measurement points per surface of 20 cm × 30 cm (~ A4 paper size).<br>The average shall be documented, only one point out of tolerance is allowed.<br>GU and angle are given in accordance with the technical data sheet and in the technical report allowed tolerance, for example:<br>— <10 GU (+3 GU) at 60° or at 85°;<br>— between 10 GU and 29 GU ± 5 GU at 60°;<br>— between 30 GU and 64 GU ± 7 GU at 60°;<br>— between 65 GU and 89 GU ± 8 GU at 60°;<br>— >90 GU (−10 GU) at 60° or >80 GU (−5 GU) at 20°. | Liquid and powder coats<br>Mandatory for all decorative locations<br>Optional for non-decorative locations | A2 |
| Colour measurement or evaluation | Plain colours: ISO/CIE 11664-6<br>Kind of light: D65<br>Measurement angle: 8°<br>Calculation method: dE2000 (SCI)<br>Non-uniform colours (e.g. metallic colours or pearl effect): can be checked only visually by human eye in accordance with ISO 13076.<br>Visual inspection shall be performed under two different angles. | Plain colours – tolerance between primal sample and standard:<br>— dE2000 (SCI) ≤ 1 according to ISO/CIE 11664-6 of the primal sample and standard for colour matching;<br>— note single values $L^*a^*b^*$ according to ISO/CIE 11664-4 of the primal sample and standard for colour matching.<br>Metallic colours value is in accordance with ISO 3668 ≤1 (very slight, i.e. just perceptible changes). | Liquid and powder coats<br>Mandatory for all decorative locations | A2 |

#### 4.4.6 Mechanical characteristics

All tests in Table 7 should be performed with the nominal thickness mentioned in Table 4. If singles tests are carried out with a different nominal layer thickness, this shall be explicitly indicated in the test report.

All tests in Table 7 shall be performed after a minimum of two weeks drying in a standard atmosphere for liquid coating material and in accordance with the technical data sheet for powder coating material.

**Table 7 — Mechanical characteristics**

| Characteristic | Methods | Results required | Locations and type of coating material | Type of support (Table 2) |
|---|---|---|---|---|
| Cross-cut and X-cut testing | In accordance with ISO 2409:<br>— adhesion with adhesive tape<br>— dry film thickness up to 250 µm in accordance with ISO 2409;<br>— dry film thickness higher than 250 µm in accordance with ISO 16276-2.<br>— type of tape: adhesion power on degreased steel panel between 6 N and 10 N for a tape width of 25 mm<br>— knives: only single blades with template, multi-knife tools shall not be used.<br>Remove the tape in accordance with ISO 2409:2020, Annex A:<br>— peeling angle: 60° in accordance with ISO 2409;<br>— peeling speed: between 0,5 s and 1 s. | Cross-cut value ≤1 | Liquid and powder<br>Mandatory for all locations | S2 and A2 if applicable |
| Pull off test | ISO 4624<br>System with and without putty:<br>— breaking strength in accordance with ISO 4624;<br>— nature of fracture in accordance with ISO 4624. | Breaking strength is in MPa and the nature of fracture is in accordance with ISO 4624. | Liquid and powder coats<br>Mandatory for all locations | S1, S2 and A2 if applicable |
| Bend test | ISO 1519<br>For liquid coating material, mandrel size depending on zone:<br>— decorative without putty: 20 mm mandrel;<br>— non-decorative: 10 mm mandrel.<br>For powder coating material, mandrel size depending on zone and number of layers:<br>— decorative and 2-layer systems: 12 mm mandrel;<br>— non-decorative: 10 mm mandrel. | No exfoliation, no cracking down to substrate (bare metal) allowed | Liquid and powder coating material<br>Mandatory for all locations<br>The mandrel depends on the location (decorative or non-decorative) and the type of coating material (liquid or powder). | S1 |
| Impact resistance test | In accordance with ISO 6272-1 for 1 kg falling mass | Evaluate the maximum height in mm without exfoliation and cracking down to substrate (bare metal).<br>The height shall be evaluated, when the impact is on the intrusion side and the extrusion side (optional).<br>Start height intrusion side: 250 mm<br>Start height extrusion side: 50 mm (extrusion side optional, only when extra required by customer) | All locations<br>Liquid and powder coats | S1 |

**Table 7** *(continued)*

| Characteristic | Methods | Results required | Locations and type of coating material | Type of support (Table 2) |
|---|---|---|---|---|
| Chipping resistance or multi-impact testing (mandatory for vehicles running on tracks with ballast and tracks on streets) | ISO 20567-1:2017: M4 steel nuts (hardness in accordance with Vickers ISO 6507-1:2023 and ISO 4545-1:2023: 210 HV5) Method B with the following parameters:<br>— load: 2 × 500 g;<br>— pressure: 2 bar;<br>— time: 2 × 10 ± 2 s.<br>Evaluation: remove loss particles by tape. | Type of tape: adhesion power on degreased steel panel between 6 N and 10 N for a tape width of 25 mm<br>Apply the tape and smooth the surface with plastic applicator (i.e. squeegee).<br>Rating:<br>— damage ("flaking" also includes breakdown): ≤4,0 (breaks in the coating system)<br>— "breakdown" to the substrate (when steel, checked with copper sulfate to colour the steel: ≤3,0 for the "black spots" | Liquid and powder coats<br>Location:<br>— exterior (indirect or no UV exposure), and<br>— axles or wheelsets | S2 and A2 if applicable |
| Determination of resistance to abrasion | Determination of resistance to abrasion is in accordance with ISO 7784-1 with the following parameters:<br>— 100 cycles;<br>— 1 N ± 0,02 N;<br>— abrasive paper P180 in accordance with ISO 6344-2 and ISO 6344-3. | Loss of mass in mg | Liquid and powder coats<br>Location: technical location in<br>— exterior (direct UV exposure), and<br>— exterior (indirect or no UV exposure) | S1 |

#### 4.4.7 Ageing characteristics

All tests in Table 8 should be performed with the nominal thickness mentioned in Table 4. If single tests are carried out with a different nominal layer thickness, this shall be explicitly indicated in the test report.

At least two out of three test panels shall pass the test requirements for corrosion in artificial atmospheres (AASS and NSS) and for resistance to condensation-water atmospheres tests.

Values are given in Annex B for corrosion, humidity and weathering tests.

All tests in Table 8 shall be performed after a minimum of two weeks drying in a standard atmosphere for liquid coating material and in accordance with the technical data sheet for powder coating material.

## Table 8 — Ageing characteristics

| Characteristic | Methods | Results required | Locations (Table 1) and type of coating material | Type of support (Table 2) |
|---|---|---|---|---|
| Corrosion tests in artificial atmospheres – salt spray tests (NSS) | The corrosion tests in artificial atmospheres shall be:<br>— salt spray tests in accordance with ISO 9227;<br>— width of the scratch (see ISO 17872): 0,5 mm;<br>— scribe form (see ISO 17872): vertical cut.<br>The average corrosion width and delamination are evaluated:<br>— in accordance with ISO 4628-8, and<br>— with the evaluation method by blade angle between 40° and 60°.<br>The performance levels are:<br>— low: 240 h;<br>— medium: 480 h;<br>— advanced: 720 h;<br>— high: 960 h;<br>— very high: 1 440 h.<br>The required time and level are given by the customer depending on the train type, the location and expected refurbishment time (see Annex B for examples). | The average corrosion (after 48 h) is ≤2 mm in accordance with ISO 4628-8.<br>The average delamination (after 48 h) is ≤3 mm for a powder coat in accordance with ISO 4628-8. The value for a liquid coat should be noted in the report.<br>The blistering (immediately after testing) outside scribe area and excluding edges (5 mm from the edge) is 0 (S0) in accordance with ISO 4628-2.<br>The degree of rusting outside scribe area is Ri 0 in accordance with ISO 4628-3.<br>The degree of cracks outside scribe area is 0 (S0) in accordance with ISO 4628-4.<br>The degree of flaking outside scribe area is 0 (S0) in accordance with ISO 4628-5.<br>The cross-cut (after 48 h) value is ≤1 in accordance with Table 7 “cross-cut and X cut testing”. | Liquid and powder coats<br>The required time and level are given by the customer depending on the train type, the location and expected refurbishment time.<br>A proposal of minimum level depending on location and expected refurbishment time is given in Annex B. | S2 |
| Corrosion tests in artificial atmospheres – salt spray tests (AASS) | The corrosion tests in artificial atmospheres are:<br>— salt spray tests in accordance with ISO 9227;<br>— width of the scratch (ISO 17872): 0,5 mm;<br>— scribe form (ISO 17872): vertical cut.<br>The average corrosion width and delamination are evaluated:<br>— in accordance with ISO 4628-8, and<br>— with the evaluation method by blade angle between 40° and 60°.<br>The performance levels are:<br>— low: 240 h;<br>— medium: 480 h;<br>— advanced: 720 h;<br>— high: 960 h;<br>— very high: 1 440 h.<br>The required time and level are given by the customer depending on the train type, the location and expected refurbishment time (see Annex B for examples).<br>Alternative: When no AASS test is available, a CASS test may be performed according to ISO 9227. | The average corrosion (after 48 h) is ≤2 mm in accordance with ISO 4628-8.<br>The average delamination (after 48 h) is ≤3 mm for a powder coat in accordance with ISO 4628-8. Note the value for a liquid coat.<br>The blistering (immediately after testing) outside scribe area and excluding edges (5 mm from the edge) is 0(S0) in accordance with ISO 4628-2.<br>The degree of rusting outside scribe area is Ri 0 in accordance with ISO 4628-3.<br>The degree of cracks outside scribe area is 0 (S0) in accordance with ISO 4628-4.<br>The degree of flaking outside scribe area is 0 (S0) in accordance with ISO 4628-5.<br>The cross-cut or X cut (after 48 h) value is ≤1 in accordance with Table 7 “cross-cut and X cut testing” . | Liquid and powder coats<br>The required time and level are given by the customer depending on the train type, the location and expected refurbishment time.<br>A proposal of minimum level depending on location and expected refurbishment time is given in Annex B. | A2 |

[a] Perform subsequent condensation water test in accordance with ISO 6270-2 CH, 72 h. 24 h after condensation test, perform a cross-cut test.

**Table 8** *(continued)*

| Characteristic | Methods | Results required | Locations (Table 1) and type of coating material | Type of support (Table 2) |
|---|---|---|---|---|
| Resistance to condensation-water atmospheres | In accordance with ISO 6270-2, CH.<br>The required time and level are given by the customer depending on the train type, the location and expected refurbishment time.<br>A proposal of minimum level depending on location and expected refurbishment time is available in Annex B.<br>The performance levels are:<br>— low: 120 h;<br>— medium: 240 h;<br>— advanced and high: 480 h;<br>— very high: 720 h.<br>— immersion: water storage in accordance with ISO 2812-2 and for 30 d at 40 °C.<br>Alternative test when a condensation-water atmospheres test is not available:<br>— cataplasm test:<br>— resistance to humid poultice in accordance with ISO 9142 for 7 d;<br>— level:<br>— low and medium: 40 °C,<br>— advanced and very high: 60 °C;<br>— AHT (20 cycles), for a coating system with putty, in accordance with ISO 6270-2 or 3 d cataplasm in accordance with ISO 9142 at 20 °C. | For condensation-water atmospheres test: in accordance with ISO 4628-2:2016:<br>— blistering: 0(S0);<br>— adhesion (after 24 h): cross-cut value ≤1 with adhesive tape:<br>— dry film thickness up to 250 µm in accordance with ISO 2409;<br>— dry film thickness higher than 250 µm in accordance with ISO 16276-2.<br>For cataplasm test: in accordance with ISO 4628-2:<br>— blistering: 2 (S3) or 3 (S2);<br>— adhesion (after 24 h): cross-cut value ≤1 with adhesive tape:<br>— dry film thickness up to 250 µm in accordance with ISO 2409;<br>— dry film thickness higher than 250 µm in accordance with ISO 16276-2. | Liquid and powder coating material<br>The required time and level are given by the customer depending on the train type, the location and the expected refurbishment time.<br>A proposal of minimum level depending on location and expected refurbishment time is given in Annex B. | S2 and A2 if applicable |
| Resistance to cleaning agent | The ISO 2812-3 tools are:<br>— cotton wool;<br>— watch glass;<br>— cleaning agent defined by customer.<br>Duration time of cleaning agents application from the car wash: 24 h<br>Duration time of cleaning agents (e.g. phosphoric, hydrochloric or oxalic acid) application: 4 h<br>Duration time of de-icing agents application: 4 h<br>Duration time of graffiti remover application:<br>— tested for 15 min<br>— tested for 1 h<br>— tested for 2 h.<br>Check the panel immediately and 24 h after the test. | Note the results of the checking after the test and after 24 h in the test report:<br>— softening in accordance with ISO 1518-1 (e.g. 5 N): the scratches should have the same appearance before and after;<br>— no swelling, peeling off;<br>— decrease of gloss level in accordance with ISO 2813: max. 10 % of initial value. | a) decorative coating material interior and exterior:<br>— car wash cleaning agent (only exterior)<br>— cleaning agent<br>— de-icing agent (only exterior)<br>— graffiti remover<br>b) technical coating material interior and exterior:<br>— car wash cleaning agent (only exterior)<br>— cleaning agent<br>— de-icing agent (only exterior). | A2 |
| [a] Perform subsequent condensation water test in accordance with ISO 6270-2 CH, 72 h. 24 h after condensation test, perform a cross-cut test. | | | | |

**Table 8** *(continued)*

| Characteristic | Methods | Results required | Locations (Table 1) and type of coating material | Type of support (Table 2) |
|---|---|---|---|---|
| Weathering with Xenon arc lamps | ISO 16474-2:2013/Amd 1:2022, Method A, Cycle 1.<br>One colour is assigned for each chroma: white, blue and red. See criteria:<br>— white: $C^* < 7$;<br>— blue: $7 \leq C^* \leq 30$;<br>— red: $C^* > 30$.<br>After the Xenon test, colour and gloss is evaluated.<br>The required time and level are given by the customer depending on the train type, the location and expected refurbishment time.<br>A proposal for minimum levels depending on location and expected refurbishment time can be found in Annex B.<br>The minimum duration times are:<br>— low: 1 000 h;<br>— medium: 1 500 h;<br>— advanced: 2 000 h;<br>— very high: 4 000 h[a]. | Criteria<br>Colourimetric variances in accordance with the chroma axis ($C^*$) of the colours tested:<br>— if $C^* \leq 7$ $\Delta E^*_{ab} \leq 1$<br>— if $C^*$: between 7 and 30 $\Delta E^*_{ab} \leq 2$<br>— if $C^* > 30$ $\Delta E^*_{ab} \leq 4$<br>where $\Delta E^*_{ab}$ is the CIELAB colour difference.<br>No change visible to the naked eye (cracking or blistering).<br>When the duration time is very high:<br>— the cross-cut value shall be ≤1 in accordance with ISO 2409;<br>— the blistering shall be 0(S0) in accordance with ISO 4628-2.<br>Gloss reduction: note the reduction of gloss units in % at 60° and 20° for a specific duration time. | Liquid and powder coats<br>Location: decorative exterior and interior<br>The required time and level are given by the customer depending on the train type, the location and expected refurbishment time.<br>A proposal of minimum level depending on location and expected refurbishment time is given in Annex B. | A2 |

[a] Perform subsequent condensation water test in accordance with ISO 6270-2 CH, 72 h. 24 h after condensation test, perform a cross-cut test.

**Table 8** *(continued)*

| Characteristic | Methods | Results required | Locations (Table 1) and type of coating material | Type of support (Table 2) |
|---|---|---|---|---|
| Removability of graffiti (optional) | Apply and dry the coating material using the following parameters:<br>— colour of the samples: white: $C^* < 7$;<br>— liquid coating material: min. 2 weeks storage in a standard atmosphere;<br>— powder coat: after curing.<br>Proposed graffiti products are given in Annex A.<br>The types of graffiti are:<br>— spray can, applied in one cross pass;<br>— signature (pen), applied in one cross pass.<br>Number of cycles: 5<br>The test cycle process is:<br>a) apply graffiti and condition in a standard atmosphere;<br>b) after 96 h, remove graffiti, then perform 1st check;<br>c) after 72 h, perform 2nd check;<br>d) start the next cycle, if applicable.<br>The graffiti removal process is as follows:<br>1) apply the graffiti remover with synthetic brush;<br>2) duration time graffiti remover: max. 15 min<br>3) remove the graffiti remover, e.g. by brush, squeegee, puller, cloth;<br>4) clean or rinse with water.<br>NOTE For signature (pen), steps 1) to 3) can be repeated up to 3× with an interval of ~ 5 min to 10 min. For spray can, the number of removal process iterations necessary to remove the graffiti is noted in the report. | The following criteria is checked for every cycle.<br>Evaluation of the visual aspect is the leading parameter (human eye). Changes of the visual aspect are noted in the report:<br>— softening,<br>— swelling,<br>— colour change,<br>— gloss change,<br>— scratches,<br>— shadows,<br>— peeling,<br>— cracks,<br>— delamination,<br>— other abnormalities.<br>The following additional assessment and values shall be noted in the report:<br>— gloss: in accordance with ISO 2813<br>— colour measurement:<br>— in accordance with Table 6 “Colour measurement or evaluation”<br>— note every single value $L^*a^*b^*$ in accordance with ISO/CIE 11664-4, where $L^*$ is CIE 1976 lightness (CIELAB lightness), and $a^*$ and $b^*$ are CIELAB $a^*$ and $b^*$ coordinates respectively;<br>— note dE2000 in accordance with ISO/CIE 11664-6<br>— hardness: evaluation (scratch stylus in accordance with ISO 1518-1) with 5 N before first cycle (outside graffiti test field) and at the end of the last cycle (inside graffiti test field).<br>The scratches should have the same appearance before and after. | Liquid and powder coats<br>Location: decorative<br>— exterior (direct UV exposure), and<br>— interior | A2 |

[a] Perform subsequent condensation water test in accordance with ISO 6270-2 CH, 72 h. 24 h after condensation test, perform a cross-cut test.

**Table 8** *(continued)*

| Characteristic | Methods | Results required | Locations (Table 1) and type of coating material | Type of support (Table 2) |
|---|---|---|---|---|
| Thermal cycle resistance test (optional) | Only for coating material system with putty (thickness of the putty 1 mm)<br>Perform 3 cycles.<br>The cycles require two programmable climatic chambers, capable of meeting the required temperature and humidity conditions.<br>One cycle (day 1 to day 7) consists of the following operations:<br>Phase 1 day 1:<br>— 2 h at 60 °C ± 2 °C with a relative humidity <50 %,<br>— time from 1st to 2nd chamber: 5 min max.<br>— 2 h at – 20 °C ± 2 °C<br>— time from 1st to 2nd chamber: 5 min max.<br>— 2 h at 60 °C ± 2 °C with a relative humidity >50 %,<br>— time from 1st to 2nd chamber: 5 min max.<br>— 2 h at – 20 °C ± 2 °C<br>Phase 2: leave to stand for 16 h at 23 °C ± 2 °C.<br>— day 2: same as day 1<br>— day 3: same as day 1<br>— day 4: same as day 1<br>— day 5: same as day 1<br>— day 6 and day 7: leave to rest at 23 °C ± 2 °C. | No cracks down to substrate (bare metal) after bending 100 mm mandrel in accordance with ISO 1519. | Decorative location only<br>Liquid coating material with putty. | S1 |

[a] Perform subsequent condensation water test in accordance with ISO 6270-2 CH, 72 h. 24 h after condensation test, perform a cross-cut test.

## 4.5 Design recommendations

### 4.5.1 General

To avoid corrosion during the life of the coated parts, the following recommendations should be applied.

— The shape of edges should be defined according to ISO 13715. Sharp edges should be broken according to ISO 8501-3, which can also be used as a reference for aluminium, on areas exposed to corrosion, humidity or abrasion based on the return of the producer and operator's experience (e.g. inside underframe, frame with thermal contact with outside, outside, toilets, catering zones, drainage holes).

— Any areas where it is difficult to obtain the specified film thickness should be pre-coated.

— Drainage holes should be included to avoid water pooling.

— Any areas that are exposed to abrasion should be treated with additional films or higher thickness of the exposed layer.

— Where intermittent fillet welds are used, full penetration should be achieved or gaps should be filled with sealant in order to avoid capillary action.

— Contact corrosion should be prevented by using suitable material pairing. The corrosivity of the environment should also be considered.

### 4.5.2 Coated parts specifications

For each coated part, the following information shall be provided:

— the limits of coated, partially coated and uncoated areas,

— the location of the part (whether the location is decorative or technical, and internal or external),

— the limits between the areas to be coated with different colours,

— the holes, screws, threads or other parts that remain free of the coating material.

This information may be presented as a drawing or in a document (e.g. technical specification).

# 5 Process establishment and qualification

## 5.1 General

This clause describes the technical requirements for the coating system and the preparation of the surfaces to be coated.

Each step of the process shall be established to ensure the performance of the coating system described in Clause 4. The process takes into account the specific and local conditions at the pretreatment and coater facilities.

It is recommended to involve the coating material supplier in the establishment of the coating process.

The process shall be established and documented to ensure that final product is at the expected performance level.

For any coated area or part of a vehicle, the coating system shall be chosen from a coating system that has been qualified in accordance with 4.4.

## 5.2 Establishing the process steps

### 5.2.1 General

Establishing the complete coating process steps ensures the expected performance of the coating system. It includes:

— cleaning and pretreatment;

— coating material application;

— drying or curing;

— repair methods (6.5.1).

### 5.2.2 Ambient conditions

During the complete process, when necessary, the ambient conditions shall be established (e.g. temperature, relative humidity, dew point) for

— the coating facility;

— transport and storage;

— pretreatment;

— coating material application (parts, coating material, etc.).

### 5.2.3 Cleaning and degreasing the surface

During the complete coating process (including pretreatment), the substrate shall be clean (e.g. dry, free of grease, oil, dust or other contaminants).

If it is determined (e.g. visually, with inks, pencils, a contact angle-meter, a white cloth) that there are impurities, these impurities shall be removed.

The following methods, among others, are commonly used:

— spray or immersion degreasing;

— steam;

— wipes.

### 5.2.4 Pretreatment and surface preparation methods

#### 5.2.4.1 General

Proper surface preparation is key to the performance of the coating system. For this reason, it is an important part of the process establishment and qualification.

#### 5.2.4.2 Surface preparation (removal of contaminants)

The base material can be contaminated by oil, grease, chalk markings, coating material, stickers, as well as dirt, oxidation or salts on the surface. This contamination shall be removed with appropriate agents prior to the pretreatment step or the application of a coating system.

#### 5.2.4.3 Pretreatment operations for chemical or mechanical treatment of surfaces

##### 5.2.4.3.1 General

The coater either has a mechanical pretreatment process (e.g. blasting process) or uses a chemical pretreatment process. It is possible to use an initial mechanical process followed by a chemical process.

##### 5.2.4.3.2 Mechanical treatment of surfaces

There are different methods of mechanical treatments to be chosen depending on the parts to be coated (e.g. shot blasting, grinding).

Table 9 shows recommended abrasive media for different materials.

**Table 9 — Recommended abrasive media**

| | Corundum (free of iron) | Steel abrasive | Stainless steel abrasive | Adapted abrasive (glass, plastic media, etc.) |
|---|---|---|---|---|
| Carbon steel | ✓ | ✓ | ✓ | ✓ |
| Stainless steel | ✓ | — | ✓ | ✓ |
| Aluminium | ✓ | — | — | ✓ |
| Composite | — | — | — | ✓ |

For additional abrasive media recommendations, see References [3], [4], [5], [6], [7], [8], [9], [10], [11], [12], [13], [14] and [15].

To visually assess cleanliness for substrates, the following conditions shall be met at the point of first coating application:

— For carbon steel:
  — the degree of cleanliness shall be at least Sa 2½ in accordance with ISO 8501-1;
  — the roughness range should be between 3,2 $R_a$ and 12,5 $R_a$ according to ISO 21920-2 and ISO 13565-1 or between 25 $R_z$ and 59 $R_z$ according to ISO 8503-2:2012;
  — in case of difficult to reach areas (area that cannot be accessed directly), the degree of cleanliness shall be at least Sa 2 in accordance with ISO 8501-1, and St 2 for hand or power tool cleaning.
— For aluminium:
  — the degree of cleanliness shall have a flat, uniform and clean blasting pattern;
  — the roughness range should be between 3,2 $R_a$ and 12,5 $R_a$ according to ISO 21920-2 and ISO 13565-1 or between 15 $R_z$ and 59 $R_z$ according to ISO 8503-2:2012;
  — in case of difficult to reach areas (area that cannot be accessed directly), the surface shall be free of all visible oil, grease, dirt, dust, corrosion, oxides and foreign matter, except for staining; staining shall be limited to no more than one third of surface area, shall be evaluated visually, and may consist of light shadows, slight streaks or minor discoloration caused by stains of corrosion or of mill scale.
— For stainless steel:
  — the degree of cleanliness shall have a flat, uniform and clean blasting pattern,
  — the roughness range should be between 3,2 $R_a$ and 12,5 $R_a$ according to ISO 21920-2 and ISO 13565-1 or between 15 $R_z$ and 59 $R_z$ according to ISO 8503-2:2012,
  — in case of difficult to reach areas (area that cannot be accessed directly), the surface shall be free of all visible oil, grease, dirt, dust, corrosion, oxides and foreign matter, except for staining; staining shall

be limited to no more than one third of surface area, shall be evaluated visually, and may consist of light shadows, slight streaks or minor discoloration caused by stains of corrosion or of mill scale.

The time between the beginning of mechanical treatment and the end of the first coating layer application should not exceed:

— for carbon steel: 24 hours at a minimum temperature of 15 °C and a relative humidity lower than 75 % – if these conditions cannot be met, the substrate should be covered with an anti-corrosion system less than four hours after mechanical treatment;

— for aluminium: seven days at a minimum temperature of 15 °C and a relative humidity lower than 75 % – if these conditions cannot be met, the substrate should be covered with an anti-corrosion system less than 24 hours after mechanical treatment;

— for stainless steel: seven days at a minimum temperature of 15 °C and a relative humidity lower than 75 % – if these conditions cannot be met, the substrate should be covered with an anti-corrosion system less than 24 hours after mechanical treatment.

If a treatment by abrasive blast cleaning is not possible, other mechanical treatments can be proposed and applied such as

— sanding for composites,

— sanding, flame, cold plasma or laser for plastic materials.

#### 5.2.4.3.3 Chemical pretreatment

A possible chemical pretreatment can be integrated in the coating process.

All relevant parameters (e.g. concentration of the pretreatment process batches, pH value, conductivity, conductivity of the final rinse, temperature of pretreatment process batches, drying temperature, evaluation of the conversion, mass of the conversion coating) and test methods of each step of the chemical pretreatment process shall be established in accordance with the specification of the company that supplies products for the chemical pretreatment.

### 5.2.5 Coating application

All relevant coating application parameters shall be established, such as

— the coating material preparation parameter in accordance with technical data sheet,

— the spraying parameters,

— the thickness (wet and dry),

— the sanding of the putty layer,

— the sanding of the intermediate layer.

As long as the parameters are in the specified range (e.g. defined by the technical data sheet), a new qualification is not required.

### 5.2.6 Drying

All relevant drying parameters shall be defined, for example:

— temperature;

— time;

— relative humidity.

As long as the parameters are in the specified range (e.g. as defined by the technical data sheet), a new qualification is not required.

#### 5.2.7 Inter-operation time

At each step of the whole coating process, the minimum and the maximum required times shall be defined (e.g. maximum time between pretreatment and first coating layer, time between coating layers).

### 5.3 Process qualification

#### 5.3.1 General

Before starting the production, the coating process shall be qualified.

The following different steps of the process qualification shall be carried out to ensure the performance of the coating system defined in Clause 4 as well as the performance of the final product.

For any coated location or part of a vehicle, the coating system shall be chosen from a coating system qualified in accordance with 4.4.

The process qualification takes into account the specific and local conditions at the pretreatment and coater facilities.

The process qualification shall be performed for every coating facility.

The process qualification shall be performed on a representative part or a sample coated with at least one specified coating system under serial conditions for this part or sample.

If required by the contractors, the process qualification can be performed for each specified coating system under serial conditions for this part or sample.

The coating process qualification shall include the specific surface preparation process (with regard to substrate, parameters, etc.) under serial conditions.

#### 5.3.2 Tests for process qualification

The tests can be made during the process qualification. In that case, they shall be in accordance with 4.4 and Table 10.

**Table 10 — Test for process qualification**

| Characteristic | Method | Criteria |
|---|---|---|
| Nominal dry film thickness | The method shall be in accordance with Table 4. | Criteria shall be in accordance with Table 4 or project specification (including technical data sheet). |
| Nominal wet thickness | The method shall be in accordance with Table 4. | Criteria shall be in accordance with Table 4 or project specification (including technical data sheet). |
| Flow time | The method shall be in accordance with the technical data sheet of the coating material supplier. | Criteria shall be in accordance with the technical data sheet of the coating material supplier or project specification. |
| Drying time (liquid coating system) | The method shall be in accordance with the technical data sheet of the coating material supplier. | Criteria shall be in accordance with the technical data sheet of the coating material supplier or project specification. |
| Curing time (powder coating system) | The method shall be in accordance with the technical data sheet of the coating material supplier. | Criteria shall be in accordance with the technical data sheet of the coating material supplier or project specification. |
| Cross-cut and X-cut testing | The method shall be in accordance with Table 7. | Criteria shall be in accordance with Table 7. |

**Table 10** *(continued)*

| Characteristic | Method | Criteria |
|---|---|---|
| Bend test [only for powder with representative test panel (same alloy), max. thickness 1 mm] | The method shall be in accordance with Table 7. | Criteria shall be in accordance with Table 7. |
| Impact resistance test [only for powder with representative test panel (same alloy), max. thickness 1 mm] | The method shall be in accordance with Table 7. | Criteria shall be in accordance with Table 7. |
| Gloss | The method shall be in accordance with Table 6. | Criteria shall be in accordance with Table 6. |
| Colour | Compare with master sample and follow the conditions described in ISO 13076.<br>In case of visible deviation, colour shall be measured in accordance with ISO/CIE 11664-6 (in accordance with Table 6). | Human eye rating in accordance with ISO 3668: max. 2.<br>Rating by measurement dE2000 (SCI): max. 1,5. |
| Corrosion tests in artificial atmospheres – salt spray tests (NSS) | The method shall be in accordance with Table 8. | Criteria shall be in accordance with Table 8 but for blistering, which shall be in accordance with ISO 4628-2:2016 rating: 1(S3) max. except for blistering occurring from handling of the sample where higher blistering is acceptable. |
| Corrosion tests in artificial atmospheres – salt spray tests (AASS) | The method shall be in accordance with Table 8. | Criteria shall be in accordance with Table 8 but for blistering, which shall be accordance with ISO 4628-2:2016 rating: 1(S3) max. except for blistering occurring from handling of the sample where higher blistering is acceptable. |
| Resistance to condensation-water atmospheres | The method shall be in accordance with Table 8. | Criteria shall be in accordance with Table 8 but for blistering, which shall be accordance with ISO 4628-2:2016 rating: 1(S3) max. except for blistering occurring from handling of the sample where higher blistering is acceptable. |



### 5.3.3 Process qualification report

The process qualification report shall include all the relevant parameters, such as

— the parts concerned by the qualification (e.g. bogie, interior aluminium parts, underframe),

— the coating system used (coating system supplier references),

— the coating material preparation parameters in accordance with technical data sheet,

— the type of equipment (spray gun, brush, etc.),

— the spraying parameters,

— humidity,

— temperature,

— thickness (wet, if relevant, and dry),

— the sanding of the putty layer,

— the sanding of the intermediate layer,

— the tests conditions (parameters etc.) and results in accordance with 5.3.2.

### 5.4 Supplier process information

A document which describes the whole process shall be written and delivered to the customer. This shall include:

— all the relevant process parameters,

— the coating systems used,

— the parts concerned.

## 6 Serial production

### 6.1 General

The serial production shall be performed in accordance with the coating process qualified in Clause 5.

All the relevant parameters shall be recorded.

This clause details:

— the conditions to authorize the start of production,

— the process parameters for monitoring,

— the tests for serial parts' sampling (including final approval).

### 6.2 First article inspection

The serial production shall not start before a first article inspection of one representative part is conducted in accordance with ISO 22163:2023, 8.9.

The first article inspection shall contain the following documents with regards to the location of the parts (in accordance with 4.2):

— the coating qualification report (see 4.4) for the coating material (liquid and powder);

— the process qualification report (see 5.3);

— documentation of mandatory identification of all equipment (by providing maintenance plan, calibration requirements, cleaning requirements, regular controls, etc.) for the production facilities;

— documentation of mandatory qualifications and training of the workforce – the content of the staff's qualification is under the responsibility of the company responsible for the workforce;

— documentation of the environment's compliance with 5.2.2;

— drawings, data sheets, working instructions, serial control plans, etc.

### 6.3 Local work instruction document

A local work instruction document, describing all the relevant steps of preparation and coating application (including in-house controls during the process execution), shall be created. The local work instruction document should be available for the producer and the customer.

This local work instruction document is valid for a specific part and a specific location, or a group of parts if they

— use the same substrate,

— are applied in the same location,

— are applied using the same coating system, and

— are applied using the same coating process.

The local work instruction document should at least include the content detailed in Table 11 and Table 12.

**Table 11 — Preparation steps before application process**

| Process step | | Powder coating material | Liquid coating material | Quality check |
|---|---|---|---|---|
| Incoming inspection | | — | | Before cleaning, check the preparation (edges, radius), if FRP has been tempered. |
| Cleaning | | Manual: Specify the degreaser, the wipes and the way to proceed, etc.<br>Automatic: Specify the chemical, concentration, time of immersion or aspersion, temperature, rinsing steps, etc. | | Visually check with a defined method (e.g. test of the white cloths or water break test). |
| Pretreatment | mechanical | Quality control the blasting materials at given frequency (e.g. grain size, salt content, grease freeness, of the metallic blasting material). Frequency and parameters shall be defined by the coater.<br>Blasting duration.<br>Blasting pressure.<br>For other mechanical pretreatments (e.g. sanding, laser), describe the way to proceed and all relevant parameters to be checked. | | Check the roughness ($R_z$, $R_a$) in accordance with ISO 8503-2:2012, ISO 8503-4 and ISO 8503-5, the level of surface preparation (e.g. Sa 2½ according to ISO 8501-1), the dust freeness in accordance with ISO 8502-3, and the surface energy. |
| | chemical | Define the way to hang the parts, if relevant.<br>All relevant parameters shall be mentioned and monitored (e.g. concentration, pH, temperature, pressure in case of aspersion, duration of immersion or aspersion, conductance of the rinsing baths, max. drying temperature).<br>Describe the steps to check the mass of the passivation layer (in-house or by external laboratory). | | Check the layer thickness if possible (e.g. by mass): critical for aluminium external parts (in this case, a photometer should be used) and the homogeneity of the treatment (visual check, if possible). |
| Transportation | | All the relevant parameters shall be mentioned and monitored (conditions temperature, relative humidity, etc.). Specify the packaging and storage methods to prevent touch or shock of the parts. | | Time between pretreatment and first layer of cleanliness |

**Table 12 — Application process (including single layer or multilayer coating system)**

| Process step | Powder coating material | Liquid coating material | Quality check |
|---|---|---|---|
| Incoming inspection | Check the surface to be coated and correct in case of deviation. | | Check, if necessary (after transportation or process steps between pretreatment and first layer, etc.), the relevant surface parameters (e.g. cleanliness, roughness) before application.<br>Check dew point before application. |
| Application | All relevant parameters shall be mentioned and monitored, such as:<br>— coating material flow rate;<br>— air pressure(s);<br>— number of runs;<br>— voltage;<br>— earth connection;<br>— curing conditions (consider the substrate, thickness, geometry of the part, etc.). | All relevant parameters shall be mentioned and monitored, such as:<br>— coating material mixed and stored in accordance with data sheets (including shelf life) and qualification tests;<br>— nozzle and spray gun;<br>— coating material flow rate (only for automatic spraying);<br>— air pressure(s);<br>— number of runs (liquid on liquid coating material);<br>— temperature (ambient, parts surface, coating material);<br>— humidity;<br>— min. and max. time between each run of application;<br>— min. and max. time before masking or sanding;<br>— wet film thickness – pot life. | Check undercoats before the next step: no defects in sanded areas and edges:<br>— dry film thickness (e.g. primer, putty, filler after sanding, topcoat, basecoat, clearcoat) shall be in the defined range;<br>— time for over-coating. |
| Preparation between or inside process | All relevant parameters shall be mentioned and monitored, such as:<br>— masking devices and drawings (e.g. tapes, paper, plugs, masks, stencils, jigs);<br>— sand paper grades;<br>— way to proceed: either manually or with mechanical tools (e.g. sanders, grinders), or both;<br>— wipes (antistatic, etc.).<br>Take care to not remove the coating at the edges. If rework or touch-up is needed, follow the dedicated work instruction. | | Check for compliance with the drawing and for cleanliness. |

## 6.4 In-house testing of serial parts

### 6.4.1 General

Serial parts shall be tested regularly in accordance with the requirements defined in in 4.1.

Some tests can be done on serial parts or on work samples.

The test results shall be recorded in a control plan released in accordance with the customer specifications.

Table 13 summarizes which test shall be done depending on the type of location (based on the definitions in 4.2).