INTERNATIONAL STANDARD

ISO 18768-1

First edition
2022-06

Organic coatings on aluminium and its alloys — Methods for specifying decorative and protective organic coatings on aluminium —

Part 1: Powder coatings

Couches organiques sur l'aluminium et ses alliages — Méthodes de spécification des revêtements décoratifs et protecteurs sur aluminium —

Partie 1: Revêtements par poudre

Reference number
ISO 18768-1:2022(E)

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Published in Switzerland

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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 79, *Light metals and their alloys*, Subcommittee SC 2, *Organic and anodic oxidation coatings on aluminium*.

A list of all parts in the ISO 18768 series can be found on the ISO website.

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

Introduction

There are three major surface treatments on aluminium and its alloys:

a) anodic oxidation coatings;

b) organic coatings;

c) combined coatings of anodic oxidation coatings and organic coatings.

This document and ISO 18768-2 provide the performance requirements and test methods for b) organic coatings.

Performance requirements and test methods for a) anodic oxidation coatings are given in ISO 7599 and for c) combined coatings of anodic oxidation coatings and organic coatings in ISO 28340.

It is assumed that users are familiar with other relevant international and regional standards. Those standards should be respected, and this document adopts optional systems in such cases.

Organic coatings on aluminium and its alloys — Methods for specifying decorative and protective organic coatings on aluminium —

Part 1:
Powder coatings

1 Scope

This document specifies methods for specifying decorative and protective powder coatings on aluminium and its alloys. It defines the characteristic properties of powder coatings and provides testing methods with minimum performance requirements, with reference to the application and the aggressiveness of the environment in which the coated aluminium exists.

This document does not apply to coil coatings on aluminium.

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 1463, *Metallic and oxide coatings — Measurement of coating thickness — Microscopical method*

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

ISO 1520, *Paints and varnishes — Cupping test*

ISO 2360, *Non-conductive coatings on non-magnetic electrically conductive base metals — Measurement of coating thickness — Amplitude-sensitive eddy-current method*

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

ISO 2810, *Paints and varnishes — Natural weathering of coatings — Exposure and assessment*

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

ISO 2815, *Paints and varnishes — Buchholz indentation test*

ISO 3892, *Conversion coatings on metallic materials — Determination of coating mass per unit area — Gravimetric methods*

ISO 4623-2, *Paints and varnishes — Determination of resistance to filiform corrosion — Part 2: Aluminium substrates*

ISO 4628-1, *Paints and varnishes — Evaluation of degradation of coatings — Designation of quantity and size of defects, and of intensity of uniform changes in appearance — Part 1: General introduction and designation system*

ISO 4628-2, *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 4628-10, *Paints and varnishes — Evaluation of degradation of coatings — Designation of quantity and size of defects, and of intensity of uniform changes in appearance — Part 10: Assessment of degree of filiform corrosion*

ISO 6270-1, *Paints and varnishes — Determination of resistance to humidity — Part 1: Condensation (single-sided exposure)*

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

ISO 6270-3, *Paints and varnishes — Determination of resistance to humidity — Part 3: Condensation (in-cabinet exposure with heated, bubbling water reservoir)*

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

ISO 6272-2, *Paints and varnishes — Rapid-deformation (impact resistance) tests — Part 2: Falling-weight test, small-area indenter*

ISO 8251, *Anodizing of aluminium and its alloys — Measurement of abrasion resistance of anodic oxidation coatings*

ISO 8993, *Anodizing of aluminium and its alloys — Rating system for the evaluation of pitting corrosion — Chart method*

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

ISO 15184, *Paints and varnishes — Determination of film hardness by pencil test*

ISO 16474-2, *Paints and varnishes — Methods of exposure to laboratory light sources — Part 2: Xenon-arc lamps*

ISO 16474-3, *Paints and varnishes — Methods of exposure to laboratory light sources — Part 3: Fluorescent UV lamps*

ISO 22479, *Corrosion of metals and alloys — Sulfur dioxide test in a humid atmosphere (fixed gas method)*

ISO 28340:2013, *Combined coatings on aluminium — General specifications for combined coatings of electrophoretic organic coatings and anodic oxidation coatings on aluminium*

ASTM C207, *Standard Specification for Hydrated Lime for Masonry Purposes*

ASTM D2794, *Standard Test Method for Resistance of Organic Coatings to the Effects of Rapid Deformation (Impact)*

ASTM D7869, *Standard Practice for Xenon Arc Exposure Test with Enhanced Light and Water Exposure for Transportation Coatings*

ASTM G85-19, *Standard Practice for Modified Salt Splay (Fog) Testing*

GSB International, GSB QR AL 631-7 ST 663-7, *International Quality Regulations For the Coating of Building Components*

3 Terms and definitions

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

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

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

3.1
powder coating
continuous layer of coating powder applied to the aluminium or aluminium alloy substrate, which is protective and/or decorative

3.2
reference sample
reference specimen
sample which defines the criteria for acceptable properties

Note 1 to entry: This may be agreed between the customer and the surface processor.

3.3
significant surface
part of the article covered or to be covered by the coatings, and for which the coatings are essential for service and/or appearance

3.4
test specimen
single sample of the final product to be used for testing

4 Information to be supplied by the customer to the surface processor

In order to coat the product correctly and depending on the application, the following information should be supplied by the customer to the surface processor, if necessary, in consultation with the aluminium supplier and/or the surface processor.

A summary of the references to this information is given in Annex A.

a) a reference to this document, i.e. ISO 18768-1;

b) the intended service use of the article to be coated;

c) the environmental categories of the intended service (see Clause 6);

d) the specification of the aluminium (chemical composition and temper designations) to be coated;

e) an indication of the significant surface(s) of the product to be coated;

f) the preferred position and maximum size of contact marks;

g) details of any formal sampling plans required;

h) the type of pretreatment;

i) mass loss by etching;

j) thickness of the anodic oxidation coating or mass of the chemical conversion coating used for pretreatment;

k) the type of coating process to be used;

l) the quality of appearance required;

m) the acceptable limits of colour variation by agreed reference samples;

n) the colour difference of the coating between the test specimen and the reference samples using a colour difference meter;

o) the acceptable limits of gloss variation by agreed reference samples;

p) the value range of the gloss measured by equipment;

q) the thickness of coating;

r) the hardness of coating;

s) the dry adhesion of coating;

t) the wet adhesion of coatings (boiling water resistance);

u) the impact resistance (excluding anodic oxidation coating for pretreatment);

v) the abrasion resistance of coating;

w) the cupping resistance (excluding anodic oxidation coating for pretreatment);

x) the flexibility of coating (excluding anodic oxidation coating for pretreatment);

y) the processing resistance, such as cutting, milling or drilling;

z) the solvent resistance of coating;

aa) the humidity resistance;

bb) the type of chemical resistance to be used;

cc) the detergent resistance;

dd) the alkali resistance;

ee) the mortar resistance;

ff) the acid resistance;

gg) the corrosion resistance;

hh) the resistance to a humid atmosphere containing sulfur dioxide;

ii) the filiform corrosion resistance;

jj) the weathering resistance;

kk) the accelerated weathering resistance;

ll) the sealing compounds adhesion.

5 Metal preparation and pretreatment

5.1 Material (substrate)

Aluminium and its alloys are classified in accordance with ISO 209.

5.2 Pretreatment of the substrate

5.2.1 General

Before the application of the coating, a pretreatment coating should be applied. This pretreatment may be one of the following:

a) anodic oxidation coating;

b) chemical conversion coating with aqueous solutions containing either chromate ions or chromate and phosphate ions, without applying an electric current;

c) alternative pretreatment (e.g. chromium-free systems).

After the chemical conversion coating process, the substrate is normally rinsed with deionized water (preferably below 30 µS/cm at 20 °C) and dried.

There are also some coatings used mainly for decorative purposes, which do not need to be pretreated before coating.

If a non-rinsing pretreatment is applied, the last rinsing is carried out before the conversion coating process.

5.2.2 Degreasing, etching and rinsing

All surface contaminants such as greases, lubricants and residues shall be removed using alkaline or acidic solutions and/or solvents in appropriate combinations. Before the conversion stage, the substrate shall be thoroughly cleaned.

Mass loss before and after etching should be measured by the mass of a test specimen. It should be no less than 1 g/m^2, and preferably 2 g/m^2 or more.

5.2.3 Anodic oxidation coatings

The anodic oxidation coating for pretreatment should be chosen so as to produce an anodic oxidation coating with a thickness of 3 µm to 10 µm without chalking and surface flaws. It shall be measured using an eddy current meter in accordance with ISO 2360. After the pretreatment, rinse the test specimen with deionized water to remove the acid from the surface. The anodic oxidation coating should not be sealed.

The time between anodic oxidation pretreatment and powder coating should be less than 72 h. If the time between the anodic oxidation pretreatment and powder coating is more than 24 h, the anodic oxidation pretreatment should be tested by a dye spot test in accordance with ISO 2143. The intensity of the stain should be level 5.

5.2.4 Chemical conversion coatings

A chemical conversion coating shall be produced by application of the appropriate solution.

Chromate conversion coatings vary in colour from iridescent yellow to golden tan. The coatings are characterized by the presence of chromium and the absence of phosphate.

Phosphate conversion coatings vary in colour from iridescent to various shades of green. The coatings are characterized by the presence of both chromate and phosphate.

The surface density of conversion coatings shall be agreed between the customer and the surface processor. In the absence of such an agreement, the mass of the chromate coatings should be between 0,4 g/m^2 and 1,0 g/m^2 for chromate conversion coatings and between 0,4 g/m^2 and 1,2 g/m^2 for chromate-phosphate conversion coatings. They shall be measured in accordance with ISO 3892.

If the coating is applied with delay or interruption after pretreatment (within 16 h), the maximum temperature on the metal surface of drying should be as follows:

— 65 °C for chromate coatings;

— 85 °C for chromate-phosphate coatings.

5.2.5 Alternative pretreatment

Alternative pretreatments, e.g. chromium-free system, or other processes may be specified but shall be agreed between the customer and the surface processor taking into consideration the recommendations from the chemical supplier.

6 Categories

Typical applications of the powder coating are shown in Table B.1.

There are two typical environmental categories: corrosivity and UV radiation.

The corrosion protection and the adhesion of the coating on the aluminium is mainly determined by the surface pretreatment before coating. For this reason, the surface pretreatment should be selected according to the corrosivity category. It is recommended that the corrosivity category is defined in the specification.

The permanent colour stability of a coating and the decorative appearance of the coated surface depends on the UV resistance of the coating material. For this reason, the coating material should be selected based on the UV category. It is recommended that the UV category is defined in the specification.

Examples of typical applications of powder coatings for architectural application are shown in Tables C.1 and C.2.

The corrosivity category defined by the corrosion effects given in ISO 9223 are shown in Table 1. The UV categories are shown in Table 2.

Table 1 — Description of typical atmospheric environments related to the estimation of corrosivity categories

Corrosivity category[a]	Corrosivity	Typical environments — Examples[b]	
		Indoor	**Outdoor**
C1	Very low	Heated spaces with low relative humidity and insignificant pollution, e.g. offices, schools, museums.	Dry or cold zone, atmospheric environment with very low pollution and time of wetness, e.g. certain deserts, Central Arctic/Antarctica.
C2	Low	Unheated spaces with varying temperature and relative humidity. Low frequency of condensation and low pollution, e.g. storage, sport halls.	Temperate zone, atmospheric environment with low pollution ($SO_2 < 5$ µg/m^3), e.g. rural areas, small towns. Dry or cold zone, atmospheric environment with short time of wetness, e.g. deserts, subarctic areas.
C3	Medium	Spaces with moderate frequency of condensation and moderate pollution from production process, e.g. food-processing plants, laundries, breweries, dairies.	Temperate zone, atmospheric environment with medium pollution (SO_2: 5 µg/m^3 to 30 µg/m^3) or some effect of chlorides, e.g. urban areas, coastal areas with low deposition of chlorides. Subtropical and tropical zone, atmosphere with low pollution.
C4	High	Spaces with high frequency of condensation and high pollution from production process, e.g. industrial processing plants, swimming pools.	Temperate zone, atmospheric environment with high pollution (SO_2: 30 µg/m^3 to 90 µg/m^3) or substantial effect of chlorides, e.g. polluted urban areas, industrial areas, coastal areas without spray of salt water or, exposure to strong effect of de-icing salts. Subtropical and tropical zone, atmosphere with medium pollution.
C5	Very high	Spaces with very high frequency of condensation and/or with high pollution from production process, e.g. mines, caverns for industrial purposes, unventilated sheds in subtropical and tropical zones.	Temperate and subtropical zone, atmospheric environment with very high pollution (SO_2: 90 µg/m^3 to 250 µg/m^3) and/or significant effect of chlorides, e.g. industrial areas, coastal areas, sheltered positions on coastline.

Table 1 *(continued)*

Corrosivity category[a]	Corrosivity	Typical environments — Examples[b]	
		Indoor	Outdoor
CX	Extreme	Spaces with almost permanent condensation or extensive periods of exposure to extreme humidity effects and/or with high pollution from production process, e.g. unventilated sheds in humid tropical zones with penetration of outdoor pollution including airborne chlorides and corrosion-stimulating particulate matter.	Subtropical and tropical zone (very high time of wetness), atmospheric environment with very high SO_2 pollution (higher than 250 µg/m^3) including accompanying and production factors and/or strong effect of chlorides, e.g. extreme industrial areas, coastal and offshore areas, occasional contact with salt spray.

NOTE 1 Deposition of chlorides in coastal areas is strongly dependent on the variables influencing the transport inland of sea salt, such as wind direction, wind velocity, local topography, wind sheltering islands outside the coast, distance of the site from the sea, etc.

NOTE 2 Extreme effect by chlorides, which is typical of marine splash or heavy salt spray, is outside of the scope of this document.

NOTE 3 Corrosivity classification of specific service atmospheres, e.g. in chemical industries, is outside of the scope of this document.

NOTE 4 Surfaces that are sheltered and not rain-washed in marine atmospheric environments where chlorides are deposited and cumulated can experience a higher corrosivity category due to the presence of hygroscopic salts.

NOTE 5 A detailed description of types of indoor environments within corrosivity categories C1 and C2 is given in ISO 11844-1. Indoor corrosivity categories IC1 to IC5 are defined and classified.

NOTE 6 Source: ISO 9223:2012, Table C.1.

[a] In environments with expected “CX category”, it is recommended that the atmospheric corrosivity classification from one-year corrosion losses be determined.

[b] The concentration of sulfur dioxide (SO_2) should be determined during at least one year and is expressed as the annual average.

Table 2 — UV categories (information only)

UV category	UV radiation	Typical environments
UV1	Low	Solar radiation intensity is mild
UV2	Medium	Solar radiation intensity is relatively strong
UV3	High	Solar radiation intensity is very strong

7 Tests

7.1 General

The required properties and quality for the products should be chosen from the following testing methods according to the agreement between the customer and the surface processor, before application. Other test methods may be agreed between the customer and the surface processor.

The test specimens shall be cut from the significant surfaces of the products. However, if they cannot be taken from the products, substitute test specimens produced together with the products may be used for testing. The sampling lot size shall be agreed between the customer and the surface processor considering the kind of products, size and quantity. Guidance on the choice of suitable sampling procedures is given in ISO 2859-1.

In the absence of such an agreement, the size of test specimens shall be chosen from the following: 150 mm × 70 mm or 150 mm × 75 mm.

The surface of test specimens shall be wiped clean. For example, by using soft wet cloth with deionized water or ethanol. Use deionized water for the coating attacked by ethanol.

Acceptance tests shall be specified by the customer.

In the absence of agreed procedures and for the resolution of disputes, the test methods given in this clause shall be used.

Tests for production control purposes shall be at the discretion of the surface processor.

In cases where different requirements are not specified for individual corrosivity categories or UV categories, the most demanding category should be applied.

7.2 Appearance

7.2.1 General

The coating shall be assessed by viewing from a distance of 5 m for parts used outside, of 3 m for parts used inside and of 0,5 m for parts used for decoration. The observing angle shall be agreed between the customer and the surface processor.

7.2.2 Measurement

Visual inspection shall be carried out under uniform artificial light or diffuse daylight in accordance with ISO 4628-1. The lightness on the test specimens should be over 600 lx.

The reference sample shall be agreed between the customer and the surface processor.

7.2.3 Requirement

The coating shall be free from visible defects, such as excessive roughness, runs, blisters, inclusions, craters, dull spots, pinholes, scratches or any damage breaking through to metal basis on the significant surface.

The structure on the coating shall be distinct, have integrity and be uniform.

7.3 Colour

7.3.1 General

The colour of the coating shall be assessed by the visual method (see 7.3.2) or the instrumental method (see 7.3.3).

7.3.2 Visual method

7.3.2.1 Measurement

The colour of the coating shall be assessed by viewing from a distance agreed between the customer and the surface processor. Visual inspection shall be carried out under diffuse light, the source and strength of which shall be agreed between the customer and the surface processor. The lightness on the test specimens should be over 600 lx. Unless otherwise agreed, the colours shall be compared in diffuse daylight from the direction of higher latitudes. If the coloured coatings are to be used in artificial light, this lighting shall be used for colour comparison.

7.3.2.2 Requirement

Colour shall be judged using the standard colour samples which have been agreed between the customer and the surface producer. Colour differences may also apply upper and lower reference samples to check which have been agreed between the customer and the surface processor.

7.3.3 Instrumental method

7.3.3.1 Measurement

For instrumental colour measurement, measure the colour difference between the test specimen and the reference sample by using a colour difference meter.

The colour may be measured by colourimetry in accordance with ISO/CIE 11664-1, ISO 11664-2, ISO/CIE 11664-3, ISO/CIE 11664-4 and CIE 15. The customer and the surface processor should agree on the measurement condition, including colorimetric system, illuminate, observation angle and geometric light system.

7.3.3.2 Requirement

The colour tolerance shall be agreed between the customer and the surface processor.

This method does not apply to metallic paint finishes, textured coatings and embossed surfaces.

7.4 Gloss

7.4.1 General

The gloss of the coating shall be assessed by a visual method (see 7.4.2) an or instrumental method (see 7.4.3).

7.4.2 Visual method

7.4.2.1 Measurement

The gloss of coated articles shall be assessed by viewing from a distance agreed between the customer and the surface processor.

Visual inspection shall be carried out under diffuse light, the source and strength of which shall be agreed between the customer and the surface processor. The lightness on the test specimens should be over 600 lx. Unless otherwise agreed, the gloss shall be compared in diffuse daylight from the direction of higher latitudes. If the coloured coatings are to be used in artificial light, this lighting shall be used for gloss comparison.

7.4.2.2 Requirement

Gloss shall be judged using the standard gloss samples which have been agreed between the customer and the surface processor.

7.4.3 Instrumental method

7.4.3.1 Measurement

The gloss measurement should be carried out in accordance with ISO 2813 using 60° geometry. The test is carried out on flat samples.

NOTE The 60° geometry is suitable for all the coatings. However, when the gloss is below 10 and over 70, the 85° geometry or 20° geometry for each can be more appropriate.

7.4.3.2 Requirement

Standard gloss range reference values and the permissible variation from the nominal value specified by the surface processor are:

- low gloss: 30 or less (±5);
- medium gloss: 31 to 70 (±7);
- high gloss: over 70 (±10).

7.5 Thickness

7.5.1 General

The thickness of the coating shall be assessed by the microscopical method (see 7.5.2.1) or the eddy current method (see 7.5.2.2).

7.5.2 Measurement

7.5.2.1 Microscopical method

The microscopical method shall be carried out in accordance with ISO 1463, using microscopy to examine the cross-section of the test specimen.

7.5.2.2 Eddy current method

The eddy current method shall be carried out in accordance with ISO 2360.

The thickness of the coating to be tested shall be measured on the significant surface. Take three to five readings per point. The average of the separate readings taken at one measuring area gives a measured value to be recorded.

In case of dispute, ISO 1463 (destructive method) shall be used.

7.5.3 Requirement

The thickness of coating shall be consistent with the thickness established between the customer and the surface processor.

Evaluation of degree of measured thickness:

- average thickness ≥ specified thickness;
- minimum local thickness ≥ 80 % of the specified thickness.

For architectural applications, the minimum local thickness shall not be less than 40 µm.

7.6 Hardness

7.6.1 General

The hardness test of coating shall be selected from the tests given in 7.6.2 and 7.6.3 according to the application by agreement between the customer and the surface processor.

7.6.2 Pencil hardness test

7.6.2.1 Measurement

The pencil hardness test shall be carried out in accordance with ISO 15184. The hardest pencil that will not rupture or scratch the coatings is the so-called “pencil hardness”.

The test specimen should be stored for 24 h or more in an adequate condition after finishing.

7.6.2.2 Requirement

Evaluation of the pencil hardness:

— no rupture or scratch by the pencil hardness specified by the supplier of coating material.

After the pencil hardness test, the hardness shall not be less than 1H. For special cases, the hardness shall be agreed between the customer and the surface processor.

7.6.3 Buchholz indentation test

7.6.3.1 Measurement

The Buchholz indentation hardness shall be tested by the method specified in ISO 2815.

7.6.3.2 Requirement

Indentation resistance shall be higher than the limit value decided by agreement between the customer and the surface processor. The indentation length shall be lower than the limit length (mm) decided by agreement between the customer and the surface processor.

Suggested evaluation of the indentation resistance:

— indentation resistance: minimum 80 at the required thickness.

7.7 Adhesion

7.7.1 Dry adhesion test

7.7.1.1 Measurement

The dry adhesion test shall be carried out in accordance with ISO 2409.

Make six parallel cuts which are 1 mm, 2 mm or 3 mm apart from each other through the coating and make similar cuts crossing at a right angle to the first six cuts to make 25 squares.

Then put an adhesive tape on the cut area of the test specimen. Immediately pull the tape off perpendicularly from the test specimen.

For the adhesive tape, an equivalent product to IEC 60454-2 can be used.

7.7.1.2 Requirement

Evaluation of the number of squares of lattice in which no detachment of the coating appears after the operation of applying and removing the adhesive tape

The adhesion shall be evaluated by using the classifications 0 to 5 in accordance with ISO 2409. The dry adhesion of the coating shall be grade 0 or according to the agreement between the customer and the surface processor.

7.7.2 Wet adhesion test

7.7.2.1 Measurement

7.7.2.1.1 Method 1: Boiling water

Immerse a test specimen in boiling deionized water using method 1 or 2 as described in 7.17. Remove the test specimen and evaluate the coating appearance in 5 min. Carry out the cross-cut test as detailed in 7.7.1. The test shall be made after 1 h but within 2 h.

Prior to the immersion in boiling water or autoclave test, making cross-cuts is also permissible.

7.7.2.1.2 Method 2: Hot water

Make cross-cuts on the test specimen in accordance with 7.7.1 and immerse test specimen in the 38 °C deionized water for 24 h. Take the test specimen out and wipe it dry. Then test and evaluate the test specimen in 5 min.

7.7.2.2 Requirement

7.7.2.2.1 Appearance

Evaluate the degree of blistering and detachment of the coating.

There shall be no blistering in excess of 2 (S2) in accordance with ISO 4628-2. There shall not be any defects or detachment. Some colour change is acceptable.

7.7.2.2.2 Adhesion

If there are no defects, evaluate according to the cross-cut test specified in 7.7.1. If there are defects, the specimen for which defects occurred on the significant surface shall be rejected.

The result shall be classification 0 in accordance with ISO 2409. Corner chippings are permissible.

7.8 Impact resistance

7.8.1 General

The impact resistance test shall be selected from the tests given in 7.8.2 and 7.8.3 according to the application by agreement between the customer and the surface processor. The tape pull-off test shall be carried out after the impact test in accordance with the agreement between the customer and the surface processor.

7.8.2 Falling-weight test

7.8.2.1 Measurement

The falling-weight test shall be carried out in accordance with ISO 6272-1 or ISO 6272-2.

This test shall be carried out as follows:

- weight diameter: 15,9 mm ± 0,06 mm;
- impact energy: 2,5 Nm;
- material and thickness of test specimen: 5005-H24/H14 (0,8 mm to 1 mm), unless otherwise approved by the customer.

Whether the impact is applied to the coated surface or the reverse side of test specimen shall be agreed between the customer and the surface processor.

Whether the tape pull-off test is applied after applying the impact shall be agreed between the customer and the surface processor. In case of applying the tape pull-off test, carry it out as specified in ISO 2409. Cover the area by pressing down firmly against the coating to eliminate voids or air pockets. Pull the tape off perpendicularly to the test specimen.

7.8.2.2 Requirement

The impact resistance shall be assessed with the degree of cracking and detachment of the coating.

The coating shall be no cracking unless allowed by agreement between the customer and the surface processor. No detachment is allowed after applying the tape pull-off test.

7.8.3 DuPont test

7.8.3.1 Measurement

The impact shall be carried out in accordance with ASTM D2794.

This test shall be carried out as follows:

— mass × falling height: 4,9 N × 50 cm.

The material and the thickness of the test specimen shall be defined by agreement between the customer and the surface processor.

Whether the impact is applied to the coated surface or the reverse side of test specimen shall be agreed between the customer and the surface processor.

Whether the tape pull-off test is applied after applying the impact test shall be agreed between the customer and the surface processor.

7.8.3.2 Requirement

The resistance to impact shall be assessed with the degree of cracking and detachment of the coating.

The coating shall be no cracking unless allowed by agreement between the customer and the surface processor. No detachment is allowed after applying the tape pull-off test.

7.9 Abrasion resistance

7.9.1 Measurement

The falling sand test shall be carried out in accordance with ISO 8251.

7.9.2 Requirement

The quality shall be assessed with the time taken until the base metal of test specimen is exposed.

Quality assessment shall be agreed between the customer and the surface processor. In the absence of such an agreement, the abrasion coefficient should be at least 0,8 l/µm after the falling sand test.

7.10 Cupping test

7.10.1 Measurement

The cupping test of coatings shall be carried out in accordance with ISO 1520. Visually inspect the coating around the bulge. In the case of applying the tape pull-off test, immediately cover the adhesive tape on the impacted surface of the specimen after the cupping test, pressing down firmly to eliminate air bubbles under the tape, and immediately pull the tape off perpendicularly from the specimen. Then evaluate the adhesion of coatings.

The press depth of the cupping test shall be 5 mm or according to the agreement between the customer and the surface processor.

For the adhesive tape, an equivalent product to IEC 60454-2 can be used.

7.10.2 Requirement

The coating shall be no cracking unless allowed by agreement between the customer and the surface processor. No detachment is allowed after applying the tape pull-off test.

7.11 Cylindrical mandrel bend test

7.11.1 Measurement

The cylindrical mandrel bend test shall be carried out in accordance with ISO 1519.

Whether the tape pull-off test is applied after applying the bending shall be agreed between the customer and the surface processor.

7.11.2 Requirement

The quality shall be assessed with the degree of defects of the coating.

The coating shall be no cracking unless allowed by agreement between the customer and the surface processor. No detachment is allowed after applying the tape pull-off test.

7.12 Processing resistance

7.12.1 Measurement

The processing resistance test shall be carried out using sharpened tools suitable for aluminium, e.g. by cutting, milling and/or drilling the test specimen.

The test method shall be agreed between the customer and the surface processor.

7.12.2 Requirement

The quality shall be assessed with the degree of defects of the coating. As the example of evaluation, the quality can be assessed with the degree of cracking or detachment occurred in the coating. The quality assessment shall be agreed between the customer and the surface processor. In the absence of such an agreement, the evaluation shall be no cracking or chipping when sharp tools are used.

7.13 Chemical resistance

7.13.1 General

Chemical resistance shall be assessed by the method of acid resistance (see 7.13.2), alkali resistance (see 7.13.3), detergent resistance (see 7.13.4) and mortar resistance (see 7.13.5).

The test method shall be selected according to the service environment.

7.13.2 Acid resistance

7.13.2.1 Measurement

7.13.2.1.1 Dropping method

Prepare an HCl solution with hydrochloric acid (ρ_{20} = 1,19 g/ml) and deionized water as the volume proportion of 1:9. Apply 10 drops of HCl solution to the coating surface of test specimen and cover with a watch glass. Keep it at a temperature of between 18 °C to 27 °C for 15 min. Wash off the acid solution on the test specimen thoroughly with tap water and dry. Then inspect the coating surface visually.

7.13.2.1.2 Immersion method

The immersion method shall be carried out in accordance with ISO 28340:2013, 7.2.12.2. Place a ring, which is 32 mm in diameter and 30 mm in height and which is made of a material such as glass or plastic resistant to corrosion, on the surface of the test specimen with petrolatum or wax, and seal the outside part of the ring to prevent a leak of the test solution. Then fill the solution, which is prepared in the same way as the liquid drop test, up to a half of the ring and cover the top of the ring with glass or plastic. Keep it at room temperature for 15 min. Wash off the acid solution on the test specimen thoroughly with tap water and dry. Then inspect the coating surface visually.

7.13.2.2 Requirement

The surface of the coating shall not have defects such as blisters and other obvious changes (except for coatings with a metallic or metalized effect).

7.13.3 Alkali resistance

7.13.3.1 Measurement

The alkali resistance test shall be carried out in accordance with ISO 28340:2013, 7.2.12.2.

The alkali solution shall be selected between saturated calcium hydroxide or 5 g/l sodium hydroxide by agreement between the customer and the surface processor.

7.13.3.2 Requirement

Each test specimen shall be evaluated by determining the ratio of the area of corrosion pits and/or blisters to the area of the test specimen or by the chart rating in accordance with ISO 8993 if rating the pitting area is feasible in powder coated aluminium.

When saturated calcium hydroxide is used as the test solution, the coating surface shall have no change.

When 5 g/l sodium hydroxide is used as the test solution, the protective rate shall exceed Grade 9,5.

7.13.4 Detergent resistance

7.13.4.1 Measurement

Immerse the test specimen into the test solution for 72 h, keep it at 38 °C, then rinse it in deionized water, dry it with absorbent paper and apply the tape pull-off test.

The test solution (30 g/l) is prepared using the detergent shown in Table 3 and deionised water.

For the adhesive tape, an equivalent product to IEC 60454-2 can be used.

Table 3 — Contents of test solution

Composition	**Content** (g/kg)
Tetrasodium pyrophosphate	530
Sodium sulfate anhydyous	190
Sodium linear alkylarylsulfonate	200
Sodium metasilicate hydrated	70
Sodium carbonate anhydrous	10
Totals	1 000

7.13.4.2 Requirement

The surface of the coating shall not have defects such as blisters, stripping and other obvious changes.

7.13.5 Mortar resistance

7.13.5.1 Measurement

7.13.5.1.1 Method 1

Prepare mortar by mixing 15 g of hydrate lime, 41 g of cement and 244 g of sand with sufficient tap water to make a soft paste. Apply four portions of this mortar, about 15 mm in diameter and about 6 mm thick, to the coating on the test specimen. Place the test specimen in an environment of 38 °C ± 3 °C and 95 % RH ± 5 % RH for 24 h.

7.13.5.1.2 Method 2

Prepare mortar by mixing 7,5 g of building lime (conforming to ASTM C207) and 225 g of dry sand, both passing through a 10 mesh wire screen with sufficient water, approximately 100 g, to make a soft paste. Immediately apply wet pats of mortar about 1 300 mm^2 in area and 12 mm in thickness to coated specimens which have been aged at least 24 h after coating. Immediately expose test sections for 24 h to 100 % RH at 38 °C.

At the end of this period, dislodge the mortar by hand from the surface of the coating and remove any residue with a damp cloth. Allow to dry and examine the coating with normal or corrected vision.

7.13.5.2 Requirement

The mortar shall be easily removed and there shall be no detachments of the coating nor any staining. As the example of evaluation, the quality may be assessed with the following:

- no mechanical damage to the coating;
- no change in appearance and colour of the coating (except for coatings with a metallic or metalized effect).

The quality assessment shall be agreed between the customer and the surface processor.

7.14 Solvent resistance

7.14.1 Measurement

The test solution and the number of rubbing test shall be selected by agreement between the customer and the surface processor.

In the absence of such an agreement:

- test solvent: isopropyl alcohol (IPA) or Xylene;
- rubbing test: back and forth 30 times using cotton swab.

7.14.2 Requirement

In cases using IPA, the coating shall not have the remarkable change of colour and gloss.

In cases using Xylene, it shall not be possible to scratch the coating with a fingernail. No perceptible change is allowed, while slight loss of gloss (≤ 5 units) is permitted.

7.15 Corrosion resistance

7.15.1 General

One or more of the corrosion resistance tests given in 7.15.2 to 7.15.7 shall be selected according to the application and by agreement between the customer and the surface processor.

The copper-accelerated acetic acid salt spray (CASS) test is intended to be a quick test to detect defects (porosity, discontinuities, etc.) in the coatings. All these tests allow for comparing relative performances between coatings. Their results should be used with reservations when assessing real performances. It is recommended to take into consideration that “results from continuous salt spray testing seldom correlate well with in-service performance” as described in ISO/TR 16335 and that those tests are not always useful unless for quality control of the same product.

7.15.2 Neutral salt spray (NSS) test

7.15.2.1 Measurement

The NSS test shall be carried out in accordance with ISO 9227.

The cut incision(s) with a width of 1 mm shall be made to cut the powder coating down to the metal.

The test shall be carried out on three (replicate) test specimens.

The method of making cuts including cross-cuts shall be agreed between the customer and the surface processor.

When calculating the ratio of the corrosion pits area, it is recommended to use a magnifying glass (10 to 15 magnification with scale). When the test specimens in standard size are tested, it is allowed to evaluate the area of the test specimen except 25 mm from the up and down edges and 10 mm from the right and left edges.

The test period shall be agreed between the customer and the surface processor.

7.15.2.2 Requirement

The quality shall be assessed with the degree of change in colour or blisters in accordance with ISO 4628-2 and the width of infiltration on both sides of the cut incisions. The corrosion rating shall be assessed in accordance with ISO 8993 if rating the pitting area is feasible in powder coated aluminium. The quality shall be assessed in accordance with the agreement between the customer and the surface processor.

EXAMPLE

- flat portions: blistering ≤ 2 (S2);
- cross-cut portions: infiltration ≤ 1 mm (width);

- corrosion: rating number ≥ 8.

7.15.3 Acetic acid salt spray (AASS) test

7.15.3.1 Measurement

The AASS test shall be carried out in accordance with ISO 9227.

The cut incision(s) with a width of 1 mm shall be made to cut the powder coating down to the metal.

The test shall be carried out on three (replicate) test specimens.

The method of making cuts including cross-cuts shall be agreed between the customer and the surface processor.

The test period shall be agreed between the customer and the surface processor.

7.15.3.2 Requirement

The quality shall be assessed with the degree of change in colour or blisters in accordance with ISO 4628-2 and the width of infiltration on both sides of the cut incisions. The corrosion rating shall be assessed in accordance with ISO 8993 if rating the pitting area is feasible in powder coated aluminium. The quality shall be assessed in accordance with the agreement between the customer and the surface processor.

EXAMPLE

- flat portions: blistering ≤ 2 (S2);
- cut portions: infiltration ≤ 2 mm (width);
- corrosion: rating number ≥ 8.

7.15.4 Copper-accelerated acetic acid salt spray (CASS) test

7.15.4.1 Measurement

The CASS test shall be carried out in accordance with ISO 9227.

The cut incisions with a width of 1 mm shall be made to cut the powder coating down to the metal.

The test shall be carried out on three (replicate) test specimens.

The method of making cuts including cross-cuts shall be agreed between the customer and the surface processor.

The test period shall be agreed between the customer and the surface processor.

7.15.4.2 Requirement

The quality shall be assessed with the degree of change in colour or blisters in accordance with ISO 4628-2 and the width of infiltration on both sides of the cut incisions. The corrosion rating shall be assessed in accordance with ISO 8993 if rating the pitting area is feasible in powder coated aluminium.

EXAMPLE

- flat portions: blistering ≤ 2 (S2);
- cut portions: infiltration ≤ 2 mm (width);
- corrosion: rating number ≥ 8.

7.15.5 Cyclic corrosion test

7.15.5.1 Measurement

The cyclic corrosion test shall be carried out in accordance with ASTM G85-19, Annex A5, dilute electrolyte cyclic fog/dry test.

The test period shall be agreed between the customer and the surface processor.

7.15.5.2 Requirement

The quality shall be assessed with the degree of change in colour or blisters in accordance with ISO 4628-2 and the width of infiltration on both sides of the cut incisions. The corrosion rating shall be assessed in accordance with ISO 8993 if rating the pitting area is feasible in powder coated aluminium. The quality shall be assessed in accordance with the agreement between the customer and the surface processor.

EXAMPLE

— cut portions: infiltration ≤ 2 mm (width);

— corrosion: rating number ≥ 8.

7.15.6 Filiform corrosion resistance

7.15.6.1 General

The filiform corrosion resistance test is applied for C4 to CX and, by agreement, the category C3.

7.15.6.2 Measurement

The filiform corrosion test shall be carried out in accordance with ISO 4623-2. The test condition shall be agreed between the customer and the surface processor. In the absence of such an agreement, the test period should be 1 000 h.

7.15.6.3 Requirement

Using a ruler, determine the length of the longest filament L (mm) in accordance with ISO 4628-10

The quality assessment shall be agreed between the customer and the surface processor. In the absence of such an agreement, the following quality assessment should be used.

Assess by the length of filament:

— M (the average length of filament) ≤ 2 mm;

— L (the longest filament) ≤ 4 mm.

7.15.7 Resistance to humid atmosphere containing sulfur dioxide

7.15.7.1 Measurement

The contact test with humid atmosphere containing sulfur dioxide (Kesternich test) shall be carried out in accordance with ISO 22479.

The volume of SO_2 and the number of cycles should be agreed between the customer and the surface processor. In the absence of such an agreement, it should be SO_2 and 24 cycles, using method B specified in ISO 22479.

7.15.7.2 Requirement

The single infiltration on both sides of the scratch not exceeding 1 mm. The other area of the coating should have no colour change or blister.

7.16 Humidity resistance

7.16.1 Measurement

The resistance to humidity shall be tested using the test method specified in ISO 6270-1, ISO 6270-2 and ISO 6270-3.

The test period shall be agreed between the customer and the surface processor. In the absence of such an agreement, the test period should use the following hours:

- 1 000 h for C1 to C4;
- 2 000 h for C5 to CX.

A cut incisions with a width of 1 mm should be made to cut the powder coating down to the metal before the test. The test conditions shall be agreed between the customer and the surface processor.

7.16.2 Requirement

The surface of the coating shall not have defects such as stripping, blisters and other obvious changes by visual examination, but some colour change is permissible. Loss of adhesion of the coating from the scratches shall be no more than 1 mm.

7.17 Boiling water resistance

7.17.1 Measurement

7.17.1.1 General

The boiling water test is the test method to evaluate the visual change of the specimens caused by the boiling water as well as the resulting adhesion.

This test shall be carried out as given in 7.17.1.2 and 7.17.1.3.

7.17.1.2 Method 1: With boiling water

Immerse the test specimen in boiling deionized water (maximum conductivity 10 µS at 20 °C) for a specified time (e.g. 2 h or 5 h). Remove the test specimen and allow it to cool down to room temperature. Apply an adhesive tape (see 7.7.1) to the surface, ensuring that no air is trapped. After 1 min, remove the tape at an angle of 45° with a sharp even pull.

7.17.1.3 Method 2: With autoclave

Add deionized water (maximum conductivity 10 µS at 20 °C) to an autoclave with an internal diameter of about 200 mm to a depth of 25 mm and place a test specimen measuring 50 mm in it.

Place the lid in position and heat the autoclave until steam escapes from the valve. The weighted needle valve shall be adjusted to produce an internal pressure of 100 kPa ± 10 kPa (1 bar). Continue heating for 1 h, timing from the moment when steam first escapes from the valve. Cool the autoclave, remove the test specimen and allow it to cool down to room temperature.

Apply an adhesive tape (see 7.7.1) to the surface, ensuring that no air is trapped. After 1 min, remove the tape at an angle of 45° with a sharp even pull.

7.17.2 Requirement

Evaluate the degree of blistering and detachment of the coating.

There shall be no blistering in excess of 2 (S2) in accordance with ISO 4628-2. There shall not be any defects or detachment. Some colour change is acceptable.

7.18 Weathering resistance

7.18.1 General

Either the outdoor exposure test (see 7.18.2) or the accelerated weathering resistance test (see 7.18.3) shall be carried out according to the agreement between the customer and the surface processor.

7.18.2 Outdoor exposure test

7.18.2.1 Measurement

The outdoor exposure test shall be carried out in accordance with ISO 2810.

When testing corrosion performance, ISO 8565 provides additional guidelines.

The exposure site shall be selected by agreement between the customer and the surface processor depending on the purpose of UV exposure or corrosion resistance.

A typical exposure site for UV exposure is South Florida (USA), and other exposure sites include Lisbon (Portugal) and Sanary-sur-Mer (France).

The exposure sites for the corrosion resistance (outdoor exposure) testing are Hoek van Holland (the Netherlands), Brest (France), Sines (Portugal) and Bohus-Malmön Kvarnvik (Sweden).

Miyako-Jima Island (Japan) and Hainan Island (China) are both used for UV exposure and corrosion resistance.

The test period shall be agreed between the customer and the surface processor. In the absence of such an agreement, the test period should use the following years for UV exposure:

— 1 year for UV1 with mild UV exposure;

— 5 years for UV2 with strong UV exposure;

— 10 years for UV3 with very strong UV exposure.

For corrosion resistance, exposure periods depend on the intensity of the exposure site. Consider a minimum of two years exposure at one of the sites indicated above.

Outdoor corrosion testing exposure is carried out mainly to assess the efficacy of the pretreatment and is more significant for architectural applications.

7.18.2.2 Requirement

After the natural weathering test, assessment items and degrees are selected by agreement between the customer and the surface processor. The examples of the assessment of the test results are:

— colour change: ΔE ≤ the prescribed limits;

— gloss retention: ≥ 50 %;

— thickness loss rate: ≤ 10 %;

— no blistering and detachment of the coating.

7.18.3 Accelerated weathering resistance

7.18.3.1 General

One of the accelerated weathering resistance tests given in 7.18.3.2 and 7.18.3.3 shall be carried out according to the agreement between the customer and the surface processor.

7.18.3.2 Xenon-arc exposure test

7.18.3.2.1 Measurement

The xenon-arc exposure test shall be carried out in accordance with method A given in ISO 16474-2 or ASTM D7869.

The test period shall be agreed between the customer and the surface processor. In the absence of such an agreement, the test period should use the following hours:

- 1 000 h for category 1 with mild UV exposure;
- 2 000 h for category 2 with strong UV exposure;
- 4 000 h for category 3 with very strong UV exposure.

Except at the time of the xenon-arc lamp exchange, filter exchange and cleaning of the chamber, it is desirable not to stop the exposure test. When exchanging and cleaning parts, perform the processes in as short a time as is possible.

Spray water shall be deionized and its conductivity shall be not higher than 2 µS/cm at 25 °C.

NOTE It is very important to adequately control the purity of spray water. If impurities, particularly silicates, are not removed from the water by proper treatment, exposed test specimens can develop spots or contaminations that are not representative of degradation occurring during outdoor exposure.

7.18.3.2.2 Requirement

The colour change, gloss retention and chalking of the coatings shall be agreed between the customer and the surface processor. In the absence of such an agreement, the gloss retention should use the following value.

An example of the assessment of the test results in terms of gloss retention is ≥ 75 % for all UV categories.

7.18.3.3 Open-flame carbon-arc exposure test

7.18.3.3.1 Measurement

The open-flame carbon-arc exposure test shall be carried out in accordance with ISO 28340:2013, 7.2.6.3, Table 4. The spray cycle shall be agreed between the customer and the surface processor.

The test period shall be agreed between the customer and the surface processor. In the absence of such an agreement, the test period should use the following hours. The examples of the test period are as follows:

- UV category 1 with mild UV exposure: 750 h;
- UV category 2 with strong UV exposure: 1 500 h;
- UV category 3 with very strong UV exposure: 3 000 h.