International Standard ISO 7599

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Anodizing of aluminium and its alloys — General specifications for anodic oxide coatings on aluminium

Anodisation de l'aluminium et de ses alliages — Spécifications générales pour couches anodiques sur aluminium

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Foreword

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Draft International Standards adopted by the technical committees are circulated to the member bodies for approval before their acceptance as International Standards by the ISO Council.

International Standard ISO 7599 was developed by Technical Committee ISO/TC 79, *Light metals and their alloys*, and was circulated to the member bodies in March 1982.

It has been approved by the member bodies of the following countries:

Australia	Iraq	Saudi Arabia
Austria	Ireland	South Africa, Rep. of
China	Japan	Spain
Czechoslovakia	Korea, Rep. of	Sweden
Egypt, Arab Rep. of	Mexico	Switzerland
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Hungary	Poland	USA
India	Romania	USSR

The member bodies of the following countries expressed disapproval of the document on technical grounds:

Italy
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Anodizing of aluminium and its alloys — General specifications for anodic oxide coatings on aluminium

1 Scope

This International Standard lays down general specifications for anodic oxide coatings on aluminium. It defines the characteristic properties of anodic oxide coatings on aluminium, lists methods of test for checking the characteristic properties, specifies minimum performance requirements, gives information on the grades of aluminium suitable for anodizing and describes the importance of pretreatment to ensure the required appearance or texture of the finished work.

2 Field of application

This International Standard is applicable to coatings mainly of aluminium oxide, which are formed on aluminium by an electrolytic oxidation process in which the aluminium acts as the anode.

It is not applicable to

a) non-porous oxide coatings of the barrier layer type;

b) oxide coatings intended merely to prepare the substrate for subsequent application of organic coatings or electrodeposition of metals;

c) "hard anodized" coatings, used mainly for engineering purposes, for which abrasion and wear resistance are the primary characteristics.

3 References

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

ISO 2064, *Metallic and other non-organic coatings — Definitions and conventions concerning the measurement of thickness.*

ISO 2079, *Surface treatment and metallic coatings — General classification of terms.*

ISO 2085, *Anodizing of aluminium and its alloys — Check of continuity of thin anodic oxide coatings — Copper sulphate test.*

ISO 2106, *Anodizing of aluminium and its alloys — Determination of mass per unit area (surface density) of anodic oxide coatings — Gravimetric method.*

ISO 2128, *Anodizing of aluminium and its alloys — Determination of thickness of anodic oxide coatings — Non-destructive measurement by split-beam microscope.*

ISO 2135, *Anodizing of aluminium and its alloys — Accelerated test of lightfastness of coloured anodic oxide coatings using artificial light.*

ISO 2143, *Anodizing of aluminium and its alloys — Estimation of loss of absorptive power of anodic oxide coatings after sealing — Dye spot test with prior acid treatment.*

ISO 2360, *Non-conductive coatings on non-magnetic basis metals — Measurement of coating thickness — Eddy current method.*

ISO 2376, *Anodization (anodic oxidation) of aluminium and its alloys — Insulation check by measurement of breakdown potential.*

ISO 2767, *Surface treatment of metals — Anodic oxidation of aluminium and its alloys — Specular reflectance at 45° — Total reflectance — Image clarity.*

ISO 2813, *Paints and varnishes — Measurement of specular gloss of non-metallic paint film at 20°, 60° and 85°.*

ISO 2859, *Sampling procedures and tables for inspection by attributes.*

ISO 2931, *Anodizing of aluminium and its alloys — Assessment of quality of sealed anodic oxide coatings by measurement of admittance or impedance.*

ISO 2932, *Anodizing of aluminium and its alloys — Assessment of sealing quality by measurement of the loss of mass after immersion in acid solution.*

ISO 3210, *Anodizing of aluminium and its alloys — Assessment of quality of sealed anodic oxide coatings by measurement of the loss of mass after immersion in phosphochromic acid solution.*

ISO 3211, *Anodizing of aluminium and its alloys — Assessment of resistance of anodic oxide coatings to cracking by deformation.*

ISO 3769, *Metallic coatings — Acetic acid salt spray test (ASS test).*

ISO 3770, *Metallic coatings — Copper-accelerated acetic acid salt spray test (CASS test).*

ISO 6581, *Anodizing of aluminium and its alloys — Determination of the fastness to ultraviolet light of coloured anodic oxide coatings.*

ISO 6719, *Anodizing of aluminium and its alloys — Measurement and calculation of reflectance characteristics of aluminium surfaces using integrating sphere instruments.*[1)]

ISO 7583, *Anodizing of aluminium and its alloys — Vocabulary.*[1)]

ISO 7759, *Anodizing of aluminium and its alloys — Measurement of reflectivity characteristics of aluminium surfaces using abridged goniophotometer or goniophotometer.*[1)]

4 Definitions

For the purpose of this International Standard, the definitions given in ISO 2064, and the following, apply.

NOTES

1 For definitions of terms specific to the anodizing of aluminium and its alloys see ISO 7583.

2 Some of the terms and definitions in this clause (marked by an asterisk) have been taken from ISO 2064 and are included for information only.

4.1 aluminium: Aluminium and aluminium-based alloys.

4.2 anodized aluminium: Aluminium with an anodic coating, produced by an electrolytic oxidation process in which the surface of aluminium is converted to a coating, generally an oxide, having protective, decorative or functional properties.

4.3 clear anodized aluminium: Aluminium with a substantially colourless, translucent anodic oxide coating.

4.4 colour anodized aluminium: Aluminium with an anodic oxide coating that is coloured by absorptive dies.

4.5 integral colour anodizing: Anodizing of aluminium using an appropriate (usually organic acid-based) electrolyte which produces coloured oxide coating during the anodizing process itself on specific aluminium alloys.

4.6 electrolytic colouring: The colouring of an anodic oxide coating by the electrolytic deposition of metals or metal oxides in the pore structure.

4.7 bright anodized aluminium: Anodized aluminium with a high specular reflectance as the primary characteristic.

4.8 protective anodizing: Anodizing where protection against corrosion or wear is the primary characteristic and appearance is secondary or of no importance.

4.9 decorative anodizing: Anodizing where a decorative finish with a uniform or aesthetically pleasing appearance is the primary characteristic.

4.10 architectural anodizing: Anodizing to produce an architectural finish to be used in permanent, exterior and static situations where both appearance and long life are important.

4.11 sealing: A hydration treatment of anodic oxide coatings on aluminium applied after anodizing to reduce porosity and/or the absorption capacity of the coating.

4.12 significant surface*: The part of the article covered or to be covered by the coating and for which the coating is essential for serviceability and/or appearance.

4.13 measuring area*: The area of the significant surface over which a single measurement is made.

"Measuring area" for the following methods is defined as

a) for analytical methods, the area over which the coating is removed;

b) for the anodic dissolution method, the area enclosed by the sealing ring of the cell;

c) for the microscopical method, the place at which a single measurement is made;

d) for non-destructive methods, the probe area or the area influencing the reading.

4.14 reference area*: The area within which a specified number of single measurements is required to be made.

4.15 local thickness*: The mean of the thickness measurements, of which a specified number is made within a reference area.

4.16 minimum local thickness*: The lowest value of the local thickness found on the significant surface of a single article.

4.17 maximum local thickness*: The highest value of the local thickness found on the significant surface of a single article.

1) At present at the stage of draft.

4.18 average thickness*: Either the value obtained by analytical methods, or the mean value of a specified number of local thickness measurements that are evenly distributed over the significant surface.

5 Guide to grades of aluminium for anodizing

5.1 General

Most aluminium, in any of its forms, can be anodized (see 5.5), but the results differ widely in appearance, colour, maximum coating thickness, reflectivity, abrasion resistance, corrosion resistance and electrical breakdown potential. The protective value of the coating is excellent on much aluminium produced for general engineering purposes, but for uniformity of appearance or other special effects (for example bright finishes) special grades of aluminium have been produced where close control of chemical composition and metallurgical practices is combined with special production procedures to provide high standards of surface finish and a guaranteed response to anodizing. These grades cannot readily be classified because companies have developed their range of products to meet the requirements of particular industries or customers and there is no clear dividing line between the various categories.

The categories listed below are given for general guidance and are based on the end-use of the aluminium. The anodizer must be aware of the end-use, and it is stressed that, for this reason, there must be close co-operation between the supplier of the aluminium, the customer and the anodizer.

5.2 Architectural quality

Semi-finished products of this grade will give a substantially uniform appearance after anodizing when viewed from a distance of not less than 3 m.

Some variations in appearance and colour can be expected after anodizing, between different batches of the same material and between different forms of the same material. It is sometimes possible to observe on close inspection, or from certain viewing angles, variations in brightness, banding, streaking and other visual defects. These do not affect in any way the quality of the coating. The extent to which such defects can be accepted shall be specified by the customer (see clause 6).

Special alloys have been developed for use with integral colour anodizing processes and these may have to be specified for particular coloured finishes.

5.3 Decorative quality

Semi-finished products of this category have a particularly homogeneous appearance when viewed from a distance of 0,5 m. The finish may be matt, bright or semi-diffuse according to the material and anodizing treatment, but freedom from defects is assured.

5.4 Bright anodizing quality

Materials in this category will normally be based on ingot metal of high purity (99,7 %) or very high purity (99,99 %) aluminium. Proper manufacturing control of the metal is essential. Special mechanical, chemical or electrochemical treatments may be used to guarantee a highly specular or mirror finish after anodizing.

5.5 General engineering quality

Most aluminium will come within this category; that is to say it will anodize to give a continuous coating of good protective value but with no guarantee about appearance, although this may be good.

Alloys containing high proportions of copper, silicon or zinc are likely to present problems in anodizing and advice should be sought from the manufacturer and the anodizer. In particular, if the copper content is high (> 3 %), the coatings will offer only limited protection.

6 Surface texture

6.1 The pretreatment given before anodizing largely determines the final appearance and texture of the anodized aluminium surface. Different surface textures may be obtained by a variety of treatment processes.

The work may be mechanically polished to obtain a smooth or a bright surface.

Chemical or electrochemical brightening may be employed with special aluminium to obtain a very bright finish.

More usually, the work, either polished or unpolished, is subjected to a chemical etching procedure to provide a range of textures from light satin with varying degrees of gloss to full matt, according to the type of etch used.

Alternatively, the texture may be produced mechanically by brushes, abrasive belts or wheels to give a range of matt finishes which are lined or directional in contrast to the essentially non-directional etched finishes. Mechanical finishes have good reproducibility and are less dependent on metal structure and composition than chemical pretreatments. Surface irregularities, if not too deep, can be removed by mechanical means.

6.2 The desired surface texture shall be agreed between the anodizer and the customer, if necessary on the basis of agreed samples. The provision of such samples is a useful guide in production, but it should be recognized that they are of limited value in assessing surface finish, since different forms and sizes of material may respond to pretreatments in slightly different ways.

7 Characteristic properties

The following is a list of the characteristic properties of anodic oxide coatings that may require to be specified and measured, or otherwise agreed upon.

Only some of the properties will be significant in any particular application. The anodizer shall be notified of the end-use or of any specific properties required.

Some properties (for example specular reflectance) are only obtainable by the use of special alloys, and some properties may be mutually incompatible with others.

a) Thickness ..... (see clause 9)

b) Quality of sealing ..... (see clause 10)

c) Colour and appearance ..... (see clause 11)

d) Corrosion resistance ..... (see clause 12)

e) Abrasion resistance ..... (see clause 13)

f) Resistance to crazing by deformation . (see clause 14)

g) Fastness to light ..... (see clause 15)

h) Fastness to ultraviolet radiation ..... (see clause 15)

j) Light reflection properties ..... (see clause 16)

1) Total reflectance

2) Specular reflectance

3) Diffuse reflectance

4) Distinctness of reflected image

k) Electrical breakdown potential ..... (see clause 17)

m) Continuity of the coating ..... (see clause 18)

n) Mass per unit area (surface density) of the coating ..... (see clause 19)

8 Tests

8.1 Sampling procedures

Sampling procedures shall be agreed between the anodizer and the purchaser. Guidance on the choice of suitable sampling procedures can be found in ISO 2859.

8.2 Test pieces

Wherever practicable, test pieces shall be production components. However, if, by agreement, special test pieces are prepared for convenience in referee or acceptance tests they shall be processed in the same way as the production components.

8.3 Acceptance tests

Acceptance tests shall be agreed between the anodizer and the customer.

8.4 Referee tests

In cases of dispute, the appropriate referee tests specified in this International Standard shall be used.

8.5 Control tests

Tests for control purposes shall be at the discretion of the anodizer.

9 Thickness

9.1 General

Anodic oxide coatings are designated by their thicknesses, in micrometres (μm). The required thickness of a coating is of the utmost importance and it shall always be specified.

9.2 Classification

Anodic oxide coatings are graded according to the minimum value of the average thickness (minimum average thickness) in micrometres. The thickness classes are designated by the letters AA followed by the thickness grade; typical examples are given in the table.

For anodic coatings designed to impart particular surface properties, a higher average thickness may be selected, and additional, if necessary, intermediate values of average thickness can be specified, but in no cases shall the minimum local thickness be less than 80 % of the minimum average thickness. The choice of thickness class will depend on relevant national standards.

Table

Class	Minimum average thickness, μm	Minimum local thickness, μm
AA 5	5	4
AA 10	10	8
AA 15	15	12
AA 20	20	16
AA 25	25	20

For certain applications, for instance those where resistance to corrosion is paramount, the anodizer and the customer may agree to specify a minimum local thickness, with no restriction as to the average thickness.

9.3 Measurement of thickness and mass per unit area (surface density)

Thickness measurements shall be carried out by one or more of the following methods:

a) microscopical examination of cross-section (see ISO 1463);

b) eddy current method (see ISO 2360);

c) split beam microscope method (see ISO 2128);

d) gravimetric method (see ISO 2106).

In cases of dispute, the microscopical method [a)] shall be the referee method for coatings of thickness 5 µm and greater. For coatings of thickness less than 5 µm, the microscopical method cannot normally be used and a minimum mass of coating per unit area, measured by the gravimetric method [d)], shall be agreed between the interested parties.

Thickness measurements shall be made on the significant surfaces, but no measurements shall be made within 5 mm of the areas of anodic contact, nor in the immediate neighbourhood of a sharp edge.

10 Quality of sealing

10.1 General

The quality of sealing is of great importance and sealing is always essential, whether stated or not, except where an unsealed coating is expressely requested.

10.2 Assessment of quality of sealing

10.2.1 Referee test

In cases of dispute, the quality of sealing shall be determined by the method specified in ISO 3210*, which is the referee method. The sealing shall be considered to be satisfactory if the loss of mass does not exceed 30 mg per square decimetre of the anodic oxide coating.

10.2.2 Alternative acid dissolution tests (see ISO 2932)

The sealing shall be considered to be satisfatory if the loss of mass in these tests* does not exceed 20 mg per square decimetre of the anodic oxide coating.

10.2.3 Admittance or impedance measurements (see ISO 2931)

For undyed anodic oxide coatings sealed in steam or hot water, the sealing shall be considered to be satisfactory if the corrected admittance value is less than 20 µS (relative to a 20 µm coating). This value of 20 µS cannot be achieved with all dark coloured coatings. Alternatively, if impedance is measured, the sealing shall be considered to be satisfactory if the corrected impedance value is more than 50 kΩ.

Other values may need to be agreed between the anodizer and the customer for some types of colour anodized aluminium.

Certain additions to hot water sealing baths may affect the admittance and impedance values, in which case the referee method (see 10.2.1) shall be used to determine the quality of sealing.

10.3 Estimation of loss of absorptive power of oxide coatings after sealing (see ISO 2143)

The sealing shall be considered to be satisfactory if dye absorption ratings of 0 or 1 or 2 on the colour scale are obtained.

Certain additions to hot water sealing baths may affect the dye absorption tests, in which case the referee method (see 10.2.1) shall be used to determine the quality of sealing.

11 Appearance and colour

11.1 Anodized articles shall be free from visible defects on the significant surface(s) when viewed from an agreed distance. If important to the customer, the position(s) and maximum size(s) of the contact mark(s) shall be agreed between the anodizer and the customer.

11.2 The colour and surface texture, and their tolerances, shall be agreed between the anodizer and the customer. If required for matching purposes, the acceptable limits of variation shall be defined by agreed samples.

The surface of anodized aluminium has the property of double reflection from the surface of the basis metal. Therefore, when matching colour samples, they shall be held in the same plane and viewed as near to normal as is practicable, the direction of working being always the same. A diffuse source of illumination shall be placed behind the viewer.

11.3 Unless otherwise agreed, the colours shall be compared in diffuse daylight from a northern aspect north of the equator and from a southern aspect south of the equator.

If the coloured coatings are to be used in service in artificial light, this lighting shall be used for colour comparison.

The agreed colour samples shall be stored in a dry place in the dark.

11.4 For production control purposes, it may be convenient to use colour measuring instruments for recording or grading colours.

12 Corrosion resistance

If required by the customer, the anodic oxide coating shall be tested for resistance to corrosion by, for example, the ASS test (specified in ISO 3769) or the CASS test (specified in ISO 3770). The choice of method and period of exposure shall be agreed between the anodizer and the customer.

13 Abrasion resistance

If required by the customer, the abrasion resistance of the anodic oxide coating shall be tested using a method agreed between the anodizer and the customer. The performance requirements shall be agreed between the anodizer and the customer.

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* Some organically dyed coatings may give high losses of mass in these tests, and acceptance levels may have to be agreed between the anodizer and the customer.

14 Resistance to crazing by deformation

If required by the customer, the resistance to crazing by deformation of the anodic oxide coating shall be tested by the method specified in ISO 3211. The performance requirements shall be agreed between the anodizer and the customer.

15 Fastness to light and to ultraviolet radiation

15.1 General

For evaluating exterior colour fastness only, outdoor exposure under conditions comparable to actual service use is satisfactory. Accelerated testing is only suitable as a quality control test of coloured anodic oxide coatings where the fastness of the colouring medium has already been established by outdoor exposure tests.

The lightfastness of colour anodized aluminium depends upon the method of colouring and the colouring medium used, and only a limited range of coloured finishes may be suitable in any particular application. Advice from the anodizer should be sought.

15.2 Fastness to light

An accelerated method of testing the fastness of coloured anodic oxide coatings to light is specified in ISO 2135. The performance of colour anodized aluminium, when tested by this method, shall be:

a) for interior applications: at least 5;

b) for exterior applications: at least 9.

15.3 Fastness to ultraviolet radiation

A method of testing the fastness of coloured anodic oxide coatings to ultraviolet radiation is specified in ISO 6581. This is a relatively severe test in comparison with other tests for fastness to light and colour changes take place with many colour anodized finishes in very short exposure times. The method is particularly suitable as a production control test for assessing the fastness to light of the extremely light-resistant anodic oxide coatings used in architecture.

16 Light reflection properties

16.1 General

The following characteristic properties may be measured:

a) total reflectance (or total reflectivity);

b) specular reflectance for surfaces with high gloss
   - at 45°,
   - at 30°,
   - at 20°;

c) specular reflectance for surface with medium or low gloss
   - at 60°,
   - at 85°,
   - at 45°;

d) diffuse reflectance.

These properties can be determined using a variety of optical instruments, which differ in degree of sophistication, cost, and the type of surface for which they are designed. These differences relate to the illumination system, the angle of the incident light, the angle at which the reflected light is measured and the geometry of the light collecting system. The properties are not, therefore, completely independent of the instrument used for measurement.

Several of the properties require the provision of very flat surfaces and measurements can only be carried out on special test pieces (see 8.5).

The customer, as necessary, shall inform the anodizer of the properties to be measured; they shall agree on the instrument that is to be employed for this purpose and its method of use.

Bright finishes with a high specular gloss can only be obtained by the use of special grades of aluminium and co-operation with the metal supplier is essential (see 5.3).

16.2 Total reflectance

Total reflectance can be measured by:

a) the PRS head method specified in ISO 2767;

b) the integrating sphere method described in ISO 6719.

16.3 Specular reflectance (high gloss)

The determination of the specular reflectance of bright anodized surfaces, where a high specular reflectance is the primary characteristic, can be carried out on flat surfaces by measurement of

a) specular reflectance at 45°, using the method specified in ISO 2767. This method employs a low cost instrument of good discrimination which can be used for this one function only;

b) specular reflectance at 30°, using the method specified in ISO 7759. The abridged goniophotometer is a high cost, sophisticated apparatus, but it measures a number of optical parameters with great accuracy;

c) specular gloss at 20°, using the method specified in ISO 2813.

16.4 Specular gloss (medium or low gloss)

The determination of the specular gloss of surfaces which are semi-diffuse, or which are mainly diffuse, can be carried out by measurement of

a) specular gloss at 60°, using the method specified in ISO 2813;

b) specular gloss at 85°, using the method specified in ISO 2813;

c) specular gloss at 45°, using the method specified in ISO 2813.

The 60° method relies on a good general purpose instrument which is applicable over the range 30 to 70 and also classifies other surfaces as high or low gloss. On matt surfaces below 30, the 45° geometry is more applicable. Above 70, the methods specified in 16.3 should be used.

16.5 Diffuse reflectance

By definition, the diffuse reflectance and the specular reflectance together give the total reflectance. It is not therefore an independent property and can be measured by the integrating sphere method specified in ISO 6719 or calculated from measurements of specular reflectance made by the methods specified in 16.4.

17 Electrical breakdown potential

If required, the electrical breakdown potential of the anodic oxide coating shall be determined by the method specified in ISO 2376. The acceptable breakdown potential shall be agreed between the anodizer and the customer.

18 Continuity of the coating

If required, the continuity of the anodic oxide coating shall be determined by the method specified in ISO 2085. The test for continuity is applicable only to coatings of thickness less than 5 µm.

The requirements for continuity shall be agreed between the anodizer and the customer.

19 Mass per unit area (surface density) of the coating

If required, the mass per unit area of the anodic oxide coating shall be determined by the method specified in ISO 2106 (see also 9.3). This is a destructive test.

If the coating thickness is already known accurately by another method, the apparent density of the coating can be determined.

By assuming a value for the density, the method enables the thickness of the coating to be calculated. For conventional oxide coatings produced in sulphuric acid at 20 °C, the density is assumed to be 2,6 g/cm³ for sealed coatings and 2,4 g/cm³ for unsealed coatings.