BRITISH STANDARD

BS EN 15646:2009

Electrodeposited coatings — Electroplated coatings of aluminium and aluminium alloys with supplementary treatment — Requirements and test methods

ICS 25.220.40,

BSI British Standards

National foreword

This British Standard is the UK implementation of EN 15646:2009.

The UK participation in its preparation was entrusted to Technical Committee STI/33, Electrodeposited and related coatings.

A list of organizations represented on this committee can be obtained on request to its secretary.

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This British Standard was published under the authority of the Standards Policy and Strategy Committee on 30 April 2009

ISBN 978 0 580 58335 3

Amendments/corrigenda issued since publication

Date	Comments

EUROPEAN STANDARD

NORME EUROPÉENNE

EUROPÄISCHE NORM

EN 15646

March 2009

ICS 25.220.40

English Version

Electrodeposited coatings - Electroplated coatings of aluminium and aluminium alloys with supplementary treatment - Requirements and test methods

Revêtements électrolytiques - Dépôts électrolytiques d'aluminium et d'alliages d'aluminium avec traitement complémentaire - Exigences et méthodes d'essai

Galvanische Überzüge - Galvanische Aluminium- und Aluminium-Legierungs-Überzüge mit zusätzlicher Behandlung - Anforderungen und Prüfverfahren

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Foreword

This document (EN 15646:2009) has been prepared by Technical Committee CEN/TC 262 “Metallic and other inorganic coatings”, the secretariat of which is held by BSI.

This European Standard shall be given the status of a national standard, either by publication of an identical text or by endorsement, at the latest by September 2009, and conflicting national standards shall be withdrawn at the latest by September 2009.

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Introduction

Electroplating of aluminium and aluminium alloy coatings provides several advantages:

— coating temperature (approximately 80 °C to 100 °C);

— no hydrogen embrittlement due to the electrodeposition of aluminium.

Prevention of hydrogen embrittlement results from the (process) technology of electroplating, because it is conducted in aprotic, organic solvents, in which the aluminium is dissolved as an aluminium-organic complex. To protect these electroplating solutions from humidity (water) and air oxygen, the electroplating of aluminium is performed under an inert gas atmosphere of nitrogen or argon. For anodic material aluminium is used, which has a purity of > 99,7 %. During electroplating of aluminium a purification (electrolytic refining) takes place, which results in an aluminium coating with a purity of 99,99 % Al percentage by mass. The high level of purity of the aluminium forms the basis for corrosion protection. The corrosion protection of the aluminium coating can be increased by common procedures of aluminium after-treatment, e.g. conversion coatings. The corrosion behaviour in chlorine-containing media is based on the fact that pure aluminium has a low self-corrosion because the aluminium is passivated by a thin oxide layer due to air oxygen. The oxide layer of the pure-aluminium coating is stable in the pH range from 4,0 to 8,5. Corrosion damage does not result in voluminous corrosion products.

The electrodeposited aluminium coatings cathodically protect iron materials. However, polarization effects in chlorine-free media, e.g. condensed water, may result in an anodic protective behaviour in such electrolytes. This effect can be reduced by alloying, for example, zinc or magnesium to the aluminium. Due to low dissolution current densities and extensive freedom of pores, the coatings can be suitable as galvanic corrosion protection on less reactive (more precious) materials like stainless steels and copper alloys. For adhesion reasons the application of a nickel strike may become necessary.

High ductility of the coatings allows an extreme deformation of the work pieces in the electroplated state.

The European Committee for Standardization (CEN) draws attention to the fact that it is claimed that compliance with this document may involve the use of a patent concerning the use of individual electrolyte (electroplating solution) formulations to electrodeposit aluminium and/or aluminium alloys as given in Subclause 3.2 and Annex C. CEN takes no position concerning the evidence, validity and scope of this patent right.

The holder of this patent right has assured CEN that he is willing to negotiate licences under reasonable and non-discriminatory terms and conditions with applicants throughout the world. In this respect, the statement of the holder of this patent right is registered with CEN. Information may be obtained from:

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1 Scope

This European Standard specifies requirements for electrodeposited aluminium and aluminium alloy coatings on iron materials, plastic substrates, titanium materials, nickel materials and non-metallic substrate materials rendered conductive, such as plastics. The coatings serve either as corrosion or galvanic corrosion protection, as well as for other technical applications.

2 Normative references

The following referenced documents are indispensable for the application 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.

EN 10025-2, *Hot rolled products of structural steels – Part 2: Technical delivery conditions for non-alloy structural steels*

EN 12487:2000, *Corrosion protection of metals – Rinsed and non-rinsed chromate conversion coatings on aluminium and aluminium alloys*

EN 12508:2000, *Corrosion protection of metal and alloys – Surface treatment, metallic, and other inorganic coatings – Vocabulary*

EN 12540, *Corrosion protection of metals – Electrodeposited coatings of nickel, nickel plus chromium, copper plus nickel and copper plus nickel plus chromium*

EN ISO 2819:1994, *Metallic coatings on metallic substrates – Electrodeposited and chemically deposited coatings – Review of methods available for testing adhesion* (ISO 2819:1980)

EN ISO 4527, *Metallic coatings – Autocatalytic (electroless) nickel-phosphorous alloy coatings – Specification and test methods* (ISO 4527:2003)

EN ISO 9227:2006, *Corrosion tests in artificial atmospheres – Salt spray tests* (ISO 9227:2006)

EN ISO 10289, *Methods for corrosion testing of metallic and other inorganic coatings on metallic substrates – Rating of test specimens and manufactured articles subjected to corrosion tests* (ISO 10289:1999)

EN ISO 11130:1999, *Corrosion of metals and alloys – Alternate immersion test in salt solution (ISO 11130:1999)*

ISO 554:1976, *Standard atmospheres for conditioning and/or testing – Specifications*

ISO 4519, *Electrodeposited metallic coatings and related finishes – Sampling procedures for inspection by attributes*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in EN 12508:2000 and the following apply.

3.1
aprotic solution
solution using non-aqueous inert solvent

EXAMPLE Aromatic hydrocarbons.

3.2
complex aluminium compound
compound based on trialkylaluminium compounds (AlR_3 with R = H, CH_3, C_2H_5 or higher homolog(ue)s as well as mixtures of these) with at least one alkaline metal (Li, Na, K, Cs, Rb) or one ammonium ion (NH_4^+)

4 Information to be supplied by the purchaser

4.1 Essential information

The purchaser shall supply the following information:

a) the designation (see Clause 5) of the particular coating required;

b) the requirements for tensile strength of steel and any requirement for heat treatment before (see 5.4) and/or after (see C.2.2) electrodeposition;

c) the significant surface, indicated by drawings of the articles or by suitably marked samples;

d) the nature, condition and finish of the substrate, if any of these could affect the serviceability and/or the appearance of the coating;

e) the position on the surface for unavoidable defects, such as rack or contact marks and the limits for acceptable defects on the refined and non-refined product (see 7.2);

f) the finish required, for example bright, dull, satin or other finish, preferably with a sample of the finish;

g) sampling methods, acceptance levels or any other inspection requirements, if different from those given in ISO 4519 (see Clause 9);

h) the standards for any thickness, corrosion or adhesion test requirements (see Clause 8);

i) requirements for supplementary treatment if applicable (see 5.5);

j) any requirements for a mass fraction of alloy elements greater than 30 % (see 6.2).

4.2 Additional information

When applicable, the following additional information shall be supplied by the purchaser:

a) any special requirements for, or restrictions on, preparation of the articles to be coated;

b) any special requirements for recovering rejected articles;

c) any special requirements that depend on the shape or method of manufacturing of the component;

d) any other special requirements (e.g. roughness and tolerances).

5 Designation

5.1 General

The designation shall comprise the following:

a) electrodeposited coating;

b) the number of the European Standard to which the required coating shall conform;

c) a hyphen;

d) the substrate code (see 5.2);

e) a solidus;

f) the additional applicable codes separated by solidi for every stage of the coating sequence, in the order of application (see 5.3, 5.4 and 5.5).

NOTE 1 Examples of codes are given in Table 1 and examples of full designations are given in 5.6.

Double separators shall be used to indicate any missing stages (i.e. when a particular stage is not required).

NOTE 2 The purchaser should be guided in his choice of designation by the severity of service conditions to be withstood by the coating, expressed as the service condition number (see ISO 27830 [1]).

5.2 Substrate

For the designation of the substrate Table 1 shall apply. Additionally nickel materials shall be identified with the chemical symbol Ni and titanium materials with the chemical symbol Ti.

Table 1 — Code examples

Substrate code (see 5.2)		**Electrodeposited coating code (see 5.3)**		**Chromate conversion code (see 5.5)**	
Fe	iron or steel	Al	Aluminium	A	colourless
Ti	titanium			C1	yellow iridescent
Ni	nickel			E1	light green
PL	plastics				
NM	non-metallic materials				

NOTE If the standard designation of the metal is to be provided, references to the appropriate literature can be found in Bibliography references [2], [3], [4], [5], [6] and [7].

The letters PL shall be used for electroplatable plastics and the letters NM for other non-metallic materials.

The intermediate layers shall be designated in accordance with EN 12540 and EN ISO 4527.

5.3 Metallic coatings

5.3.1 General

The designation of electrodeposited aluminium coatings shall be its chemical symbol Al.

The designation of aluminium alloy coatings shall be as follows.

The metal coating layer is designated by the chemical symbol(s) for the electrodeposited metal, or metals (in the case of an alloy coating), immediately followed by:

a) a number indicating the minimum local thickness of the layer in micrometres (see Clause 6);

b) upper case letters indicating the type of coating, if applicable (see below).

When the coating metal is an aluminium alloy, the symbol Al shall be followed by the chemical symbol for each minor component. Each chemical symbol for a minor component shall be followed by a whole number in parentheses designating its nominal percentage by mass. However, if the percentage mass of a minor component is less than 1 %, then it shall be designated to one decimal place.

The decimal sign shall be indicated by a comma on the line.

5.3.2 Intermediate coatings

The intermediate layers shall be designated in accordance with EN 12540 or EN ISO 4527, respectively.

5.4 Heat treatment

The heat treatment designation shall comprise:

a) the letters "HT";

b) in parentheses, the minimum temperature specified, in degrees Celsius;

c) the duration, in hours.

EXAMPLE A heat treatment to be carried out for 3 h at a minimum temperature of 190 ºC has the following designation: HT(190)3.

5.5 Supplementary treatment

5.5.1 General

The supplementary treatments, if required, shall be conducted immediately after electroplating.

5.5.2 Conversion coatings

The application of conversion coatings shall be agreed upon between the contracting parties.

Conversion coatings shall be designated in accordance with EN 12487:2000, Table 1.

5.5.3 Other supplementary treatments

Other supplementary treatment shall be agreed upon between the contracting parties.

EXAMPLE Other supplementary treatments include the use of a sealant coating on a polymer base (polyester varnish), or the application of a lubricant for reducing the friction values.

5.6 Designation examples

The following are examples of designations.

EXAMPLE 1

A coating of 12 µm aluminium (Al12) on a component of iron (Fe) with a yellow iridescent chromate conversion coating (C1) has the following designation:

Electrodeposited coating EN 15646 — Fe/Al12/C1

EXAMPLE 2

A coating of 12 µm aluminium (Al12) on a component of iron (Fe) with a yellow iridescent chromate conversion coating (C1), which has been subsequently treated with an inorganic or organic sealant (T2), has the following designation:

Electrodeposited coating EN 15646 — Fe/Al12/C1/T2

EXAMPLE 3

A coating of 12 µm aluminium (Al12) on top of an intermediate coating of 2 µm non-polished dull nickel (Nis2) on a component of iron (Fe) with a yellow iridescent chromate conversion coating (C1) has the following designation:

Electrodeposited coating EN 15646 — Fe/Nis2/Al12/C1

6 Coating types and application

6.1 Aluminium coatings

The electrodeposited aluminium coatings shall be deposited from an aprotic solution. For this, e.g. compounds of the type $MX{\cdot}2\ AlR_3$ should be used (cf. [8], [9], [10], [11]) where:

— M is an alkali metal (Na, K, Cs, Rb) or ammonium (NH_4^+);

— X is a halide (F, Cl, Br, I), preferably fluoride or hydride, and

— R are alkyl groups, preferably with one, two or three carbon atoms.

Mixtures of electrolytes of this type with varying compositions may also be used.

NOTE When using soluble anodes with a purity corresponding to a mass fraction > 99,7 % Al the coatings have a purity of more than 99,99 % Al (percentage by mass) and a non-oriented (disordered) crystal structure.

6.2 Aluminium alloy coatings

Mass fractions of an alloy element that are greater than 30 % are to be agreed upon between the contracting parties.

The properties of coatings can vary according to the type and proportion of the alloying element.

When using separate soluble anodes their purity level shall be greater than 99,7 % Al (mass fraction) or greater than 99,7 % (mass fraction) alloying component.

When using alloying anodes, the individual components of the alloying anode shall match the given degrees of purity.

The alloying component may also be added to the electroplating solutions as a liquid complex organometallic compound.

7 Requirements

7.1 General

It is possible that on parts, e.g. for constructional reasons, the requirement cannot be fulfilled on all locations of the finished surface. In this case, the significant surface shall be agreed and specified on the drawing (see EN ISO 2064 [12]). The requirements of this standard shall only apply to these essential areas.

7.2 Appearance

Unless otherwise agreed, the electrodeposited coating on the significant surface shall be bright, semi-bright or dull as specified by the manufacturer.

When visually inspected, unless otherwise agreed upon, the electrodeposited coating shall be free from pores, blisters, delamination, knot-like blooms (efflorescence), cracks and other defects that might detrimentally affect the final appearance and the corrosion protection. For the purposes of comparison, reference samples with the required appearance shall be used.

Defects and changes due to the surface condition of the substrate (scratches, pores, rolling marks inclusions), which impair the impression of good surface refinement, shall not be a reason for rejection. The purchaser shall specify the limits for acceptable defects on the refined and non-refined product. Any substrate that does not conform to the purchaser-specified limits for acceptable defects shall not be coated.

Blow-holes or cracks which can be seen with the naked eye and are caused by thermal treatments of the coating by the worker in charge shall represent a reason for rejection.

NOTE Defects which are present in the substrate before coating, including hidden defects, may be reproduced by the coating.

7.3 Coating thickness

The thickness of a coating specified in the designation shall be the minimum local thickness. The minimum local thickness of an electrodeposited coating shall be measured at any point of the significant surface that can be touched by a ball 20 mm in diameter, unless otherwise specified.

The method of measurement for the determination of coating thickness shall be agreed upon between the contracting parties.

In case of disagreement the coulometric method given in EN ISO 2177:2004 [15] shall be used.

7.4 Adhesion

One of the following methods in accordance with EN ISO 2819:1994 shall be agreed upon between the contracting parties and applied:

a) the fissure and cross-cut adhesion tests in accordance with EN ISO 2819:1994, 2.8;

b) the bending test in accordance with EN ISO 2819:1994, 2.9;

c) the winding test in accordance with EN ISO 2819:1994, 2.10; and

d) the thermal shock test in accordance with EN ISO 2819:1994, 2.12.

After the test, the coatings shall show no voids and/or separation when inspected with the naked eye.

After the test, there shall be no stain spots or, when an intermediate layer is used, no point dissolution of aluminium.

7.5 Corrosion resistance in accelerated salt spray test

7.5.1 General

The test for corrosion resistance of coating by salt spray is performed in accordance with EN ISO 9227:2006, using the test EN ISO 9227-NSS and the corrosion rating is evaluated in accordance with EN ISO 10289.

NOTE See also Annex A.

7.5.2 Samples

Hot-rolled structural steel S235JR that conforms to EN 10025-2 shall be used as samples. When using an intermediate coating, a corrosion test shall be performed with the corresponding intermediate coating as well. The dimensions of samples shall be at least 120 mm × 60 mm.

NOTE The thickness of the sample is not be specified.

Three samples shall be used for each test.

7.5.3 Requirements for corrosion resistance

During the tests for corrosion resistance, samples shall meet the requirements specified in Table 2, in order to demonstrate their usability for the various fields of application.

NOTE 1 Some of the most common fields of application are listed in Annex B.

NOTE 2 The duration and results of artificial atmosphere corrosion tests may bear little relationship to the service life of the coated article and, therefore, the results obtained are not to be regarded as a direct guide to the corrosion resistance of the tested coatings in all environments where these coatings may be used.

Table 2 — Requirements for spray test in accordance with EN ISO 9227:2006 and alternating immersion test in accordance with EN ISO 11130:1999

<table>
<tr><th rowspan="2">Coating system with pure aluminium</th><th colspan="2">Duration of tests in accordance with EN ISO 9227 NSS and EN ISO 11130:1999</th><th rowspan="2">Requirement</th></tr>
<tr><th>Barrel product</th><th>Rack product</th></tr>
<tr><td>System 1</td><td>480 h</td><td>480 h</td><td rowspan="8">Corrosion of substrate
< 2 %</td></tr>
<tr><td>System 2</td><td>600 h</td><td>600 h</td></tr>
<tr><td>System 3</td><td colspan="2" rowspan="2">Duration and thickness requirements to be agreed between the purchaser and user.</td></tr>
<tr><td>System 4</td></tr>
<tr><td>System 5</td><td>480 h</td><td>480 h</td></tr>
<tr><td>System 6</td><td>600 h</td><td>600 h</td></tr>
<tr><td>System 7</td><td colspan="2" rowspan="2">Duration and thickness requirements to be agreed between the purchaser and user.</td></tr>
<tr><td>System 8</td></tr>
</table>

7.6 Corrective actions

After-treatment or secondary re-treatment of parts not complying with the requirements is only allowed on the basis of an agreement between the contracting parties.

The type of treatment shall be part of the agreement.

8 Test methods

The refined parts (or sample plates treated with them) shall be subjected to the tests in accordance with this European Standard. This includes, for example, adhesion tests and tests for coating thickness as agreed by the contracting parties.

9 Sampling

The method of sampling shall be selected from the procedures specified in ISO 4519. The acceptance levels shall be specified by the purchaser.

Annex A
(normative)

Corrosion tests

A.1 Alternating immersion test in accordance with EN ISO 11130:1999

For the requirements of this standard, the test conditions of A.2 to A.4 in accordance with EN ISO 11130 shall be applied.

A.2 Test solution

The test solution shall be a sodium chloride solution with a mass fraction of 3,5 % sodium chloride.

Prepare the test solution by dissolving 35 g of analytical grade sodium chloride in 965 ml deionized or distilled water.

A.3 Standard atmosphere

To ensure comparability, corrosion tests shall be conducted in the standard atmosphere ISO 554-20/65. If the test is carried out under different ambient conditions, temperature and relative humidity shall be specified.

A.4 Test

During the alternating immersion test, samples are placed alternately in the test solution and in the standard atmosphere for a specified sequence of time.

One test hour consists of 10 min holding time in the test solution and 50 min in the standard atmosphere.

Annex B
(informative)

Fields of application

B.1 Riveted joints, retaining ring bolts

The excellent ductility of the aluminium coating in combination with the prevention of hydrogen embrittlement during electrodepositing allows for an efficient corrosion protection on steel rivets.

B.2 Welded components, e.g. welding studs

There is no negative influence on the welding properties of the substrate due to electrodeposited aluminium coatings.

B.3 High temperature applications

Aluminium coatings are temperature stable up to 400 °C (e.g. engine and exhaust pipe area).

B.4 Sea water resistance

The high corrosion resistance in combination with good properties for painting allows for off-shore applications.

B.5 Aerospace

The decreased dissolution rate of pure-aluminium coatings in chloride-containing electrolytes compared to cadmium coatings allows for their use on stainless steels and copper alloys (e.g. bolts, bushings/sleeves, bearing materials and connection elements) as a substitute for cadmium as galvanic corrosion protection, and it allows for possible applications on titanium alloys.

Annex C
(informative)

General process information

NOTE The processes described in this informative annex may involve the use of patented processes.

C.1 Procedure

The components which are to be electrodeposited shall have no material, processing and surface defects which impair corrosion protection and/or appearance of coatings.

NOTE For work-pieces made of rolled products, defects can include cracks, cluster porosity, inclusions, lamination defects. For castings, defects can include sagging defects, cold sets, shrink and indent cracks, whirlings and shrinkage cavities.

C.2 Surface pretreatment

C.2.1 General

The procedures of pretreatment (for example cleaning, degreasing, activation, electrodeposition of metallic intermediate coatings) should be performed in aqueous solutions. For improving adhesion, a nickel intermediate layer may be electrodeposited if no adverse changes of the properties of the substrate occur.

If the substrates are susceptible to hydrogen induced delayed brittle fracture, pretreatment procedures shall be applied to ensure that no damage can be caused by hydrogen.

If shot peening is intended, it shall be performed before thermal treatment.

C.2.2 Heat treatment

Parts that can have internal stresses caused by preliminary machining (such as welding, forming, cutting and other procedures), parts that are case-hardened and parts with a strength greater than or equal to 1 000 MPa shall be heat treated before electroplating. Standard values for thermal treatment shall be in accordance with Tables C.1 and C.2.

Table C.1 — Standard values for heat treatment before electroplating (see ISO 9587 [13])

Strength/type of parts R_m in MPa	**Heat treatment**	
	Temperature, °C	**Minimum duration**, h
≤ 1 000	Not required	
1 000 ≤ R_m ≤ 1 400	200 to 230	3
Surface hardened parts < 1 400	130 to 160	8

Table C.2 — Embrittlement-relief heat treatment for high strength steels (see Clauses 4, 5 and 6 of ISO 9588:2007 [14])		
Steels of tensile strength R_m, MPa	**Temperature, °C**	**Minimum duration** (see Clause 4, ISO 9588:2007) h
< 1 000 MPa	Not applicable	
1 000 ≤ R_m ≤ 1 100	190 to 220	8
1 101 ≤ R_m ≤ 1 200	190 to 220	10
1 201 ≤ R_m ≤ 1 300	190 to 220	12
1 301 ≤ R_m ≤ 1 400	190 to 220	14
Surface hardened articles R_m ≤ 1 400 electroplated with nickel as intermediate layer for improving adhesion	130 to 160	16

C.3 Coating systems

The structures of the eight coating systems shall be in accordance with Table C.3.

Table C.3 — Systems with pure aluminium or aluminium alloy coatings				
Coating system	**Intermediate layer**	**Pure aluminium or aluminium alloy coating standard coating thickness** µm	**Conversion coating**	**Sealing**
System 1	Without	12	Without	Without
System 2				Present
System 3			Present	Without
System 4				Present
System 5	Present	12	Without	Without
System 6				Present
System 7			Present	Without
System 8				Present

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[1] ISO 27830, *Metallic and other inorganic coatings – Guidelines for specifying metallic and inorganic coatings*

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[3] EN 1412, *Copper and copper alloys – European numbering system*[1)]

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[12] EN ISO 2064, *Metallic and other inorganic coatings – Definitions and conventions concerning the measurement of thickness (ISO 2064:1996)*

[13] ISO 9587, *Metallic and other inorganic coatings – Pretreatment of iron or steel to reduce the risk of hydrogen embrittlement*

[14] ISO 9588:2007, *Metallic and other inorganic coatings – Post-coating treatments of iron or steel to reduce the risk of hydrogen embrittlement*

[15] EN ISO 2177:2004, *Metallic coatings – Measurement of coating thickness – Coulometric method by anodic dissolution (ISO 2177:2003)*

1) These documents contain the standard designations of metals and alloys.

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