INTERNATIONAL STANDARD

ISO 4042

Fourth edition
2022-06

Fasteners — Electroplated coating systems

Fixations — Systèmes de revêtements électrolytiques

Reference number
ISO 4042:2022(E)

Contents

Page

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 2, *Fasteners*, Subcommittee SC 14, *Surface coatings*, in collaboration with the European Committee for Standardization (CEN) Technical Committee CEN/TC 185, *Fasteners*, in accordance with the Agreement on technical cooperation between ISO and CEN (Vienna Agreement).

This fourth edition cancels and replaces the third edition (ISO 4042:2018), which has been technically revised. The main changes are as follows:

— in Clause 1, a statement has been added that the requirements of this document for electroplated fasteners have precedence over other documents dealing with electroplating;

— all references to ISO 2081 and ISO 19598 have been removed because ISO 4042 is a self-containing document for the purpose of fasteners;

— in 4.4, the measures to prevent internal hydrogen embrittlement for nuts, flat washers and case-hardened screws have been completely revised;

— in 6.4, the reference areas for thickness determination have been more clearly specified;

— wording in the whole document has been improved to be more accurate, especially for complex topics.

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

ISO 4042:1999 was completely revised to take into account new developments related to hexavalent chromium free passivations, application of sealants and top coats, requirements for functional properties as well as results of research work to minimize the risk of hydrogen embrittlement. This revision was published in 2018.

The last editions of ISO 2081:2018 as well as ISO 19598:2016, which are general standards for electroplating, are not adequate to cover the requirements for electroplated fasteners dealt with in ISO 4042, especially with regard to hydrogen embrittlement and baking. Therefore, a new revision of ISO 4042:2018 was necessary to delete all references to these two general standards to avoid any contradictions.

For electroplated nuts, flat washers, and case-hardened screws, measures to mitigate the risk of hydrogen embrittlement, especially in relation to baking, have been revised to be consistent with revisions of ISO 898-2 and ISO 2702, and to reflect findings from the latest research works. For electroplated flat washers in accordance with ISO 898-3, it is generally accepted that tensile stress resulting from intended and unintended bending in service may increase the risk of hydrogen embrittlement. An appropriate test method to simulate such a scenario is currently under investigation.

Fasteners — Electroplated coating systems

1 Scope

This document specifies requirements for steel fasteners with electroplated coatings and coating systems. The requirements related to dimensional properties also apply to fasteners made of copper or copper alloys.

It also specifies requirements and gives recommendations to minimize the risk of hydrogen embrittlement, see 4.4 and Annex B.

It mainly applies to fasteners with zinc and zinc alloy coating systems (zinc, zinc-nickel, zinc-iron) and cadmium, primarily intended for corrosion protection and other functional properties:

— with or without conversion coating,

— with or without sealant,

— with or without top coat,

— with or without lubricant (integral lubricant and/or subsequently added lubricant).

Specifications for other electroplated coatings and coating systems (tin, tin-zinc, copper-tin, copper-silver, copper, silver, copper-zinc, nickel, nickel-chromium, copper-nickel, copper-nickel-chromium) are included in this document only for dimensional requirements related to fasteners with ISO metric threads.

The requirements of this document for electroplated fasteners take precedence over other documents dealing with electroplating.

This document applies to steel bolts, screws, studs and nuts with ISO metric thread, to other threaded fasteners and to non-threaded fasteners such as washers, pins, clips and rivets.

NOTE Electroplating is also applied to stainless steel fasteners, e.g. for the purpose of lubrication in order to avoid galling.

Information for design and assembly of coated fasteners is given in Annex A.

This document does not specify requirements for properties such as weldability or paintability.

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 1456, *Metallic and other inorganic coatings — Electrodeposited coatings of nickel, nickel plus chromium, copper plus nickel and of copper plus nickel plus chromium*

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

ISO 1502, *ISO general-purpose metric screw threads — Gauges and gauging*

ISO 1891-2, *Fasteners — Terminology — Part 2: Vocabulary and definitions for coatings*

ISO 2082, *Metallic and other inorganic coatings — Electroplated coatings of cadmium with supplementary treatments on iron or steel*

ISO 2093, *Electroplated coatings of tin — Specification and test methods*

ISO 2177, *Metallic coatings — Measurement of coating thickness — Coulometric method by anodic dissolution*

ISO 2178, *Non-magnetic coatings on magnetic substrates — Measurement of coating thickness — Magnetic method*

ISO 3497, *Metallic coatings — Measurement of coating thickness — X-ray spectrometric methods*

ISO 3613, *Metallic and other inorganic coatings — Chromate conversion coatings on zinc, cadmium, aluminium-zinc alloys and zinc-aluminium alloys — Test methods*

ISO 4521, *Metallic and other inorganic coatings — Electrodeposited silver and silver alloy coatings for engineering purposes — Specification and test methods*

ISO 8991, *Designation system for fasteners*

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

ISO 15330, *Fasteners — Preloading test for the detection of hydrogen embrittlement — Parallel bearing surface method*

ISO 15726, *Metallic and other inorganic coatings — Electrodeposited zinc alloys with nickel, cobalt or iron*

ISO 16047, *Fasteners — Torque/clamp force testing*

ISO 16228, *Fasteners — Types of inspection documents*

ISO 21968, *Non-magnetic metallic coatings on metallic and non-metallic basis materials — Measurement of coating thickness — Phase-sensitive eddy-current method*

ASME B18.6.3, *Machine Screws, Tapping Screws, and Metallic Drive Screws (Inch Series)*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 1891-2 and the following apply.

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

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

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

3.1
reference panel
reference material that is to be exposed to check the corrosivity level of the test cabinet used for fastener testing

4 General characteristics of the coating

4.1 Coating metals or alloys and main purposes

Electroplated coating systems for steel fasteners are primarily applied for corrosion protection and functional properties, such as torque/clamp force relationship.

In addition, other functional properties or decorative properties can be specified; see Annex A.

Commonly used electroplated coatings for fasteners are given in Table 1 along with their main purpose(s). Additional information, such as designation or decorative aspects, can be found in other relevant ISO standards listed in the last column of Table 1.

Table 1 — Electroplated coatings in accordance with their main purpose(s) and related ISO standards

Coating metal(s)		Nature	Main purpose of the coating for fasteners	ISO standard
Symbol	Element			
Zn	Zinc	Metal	P/D/F	—
ZnNi	Zinc-nickel	Alloy	P/D/F	ISO 15726
ZnFe	Zinc-iron	Alloy	P/D/F	ISO 15726
Cd	Cadmium [a]	Metal	P/F	ISO 2082
Ni	Nickel	Metal	D/F	ISO 1456
Ni+Cr	Nickel+chromium	Multi-layer	D	ISO 1456
Cu+Ni	Copper+nickel	Multi-layer	D	ISO 1456
Cu+Ni+Cr	Copper+nickel+chromium	Multi-layer	D	ISO 1456
CuZn	Brass	Alloy	D	—
CuSn	Copper-tin (bronze)	Alloy	F	—
Cu	Copper	Metal	F/D	—
Ag	Silver	Metal	F/D	ISO 4521
CuAg	Copper-silver	Alloy	F	—
Sn	Tin	Metal	F	ISO 2093
SnZn	Tin-zinc	Alloy	F/P	—

P corrosion **p**rotection

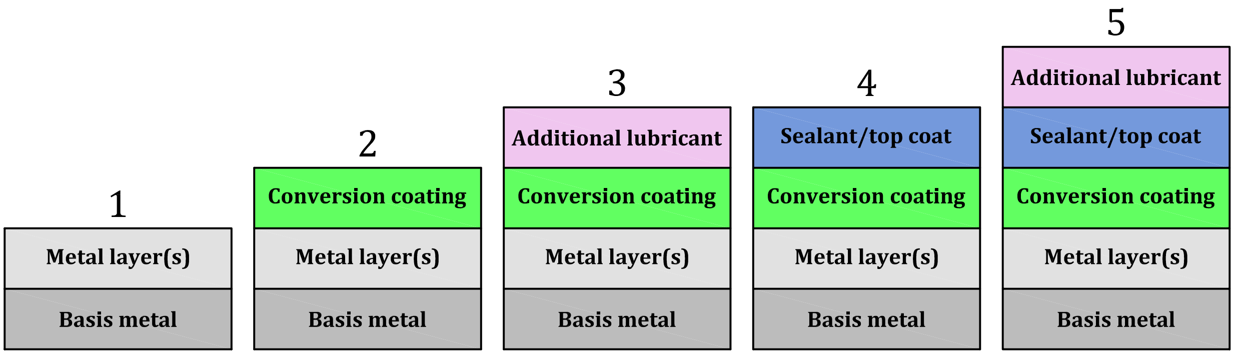
F **f**unctional properties

D **d**ecorative properties (colour, aspect)

[a] Cadmium is restricted or prohibited for many applications (remaining cadmium users are predominantly military and aerospace industries).

4.2 Build-up of basic electroplated coating systems

Figure 1 shows basic electroplated coating systems.



Key

1 only metal layer(s)

2 metal layer(s) + conversion coating

3 metal layer(s) + conversion coating + additional lubricant

4 metal layer(s) + conversion coating + sealant/top coat

5 metal layer(s) + conversion coating + sealant/top coat + additional lubricant

Figure 1 — Basic electroplated coating systems (schematic)

A conversion coating increases corrosion protection on zinc, zinc alloy and cadmium coatings. It may be a passivation (chromium VI free) or a chromatation (chromium VI containing). The conversion coating can also provide better adhesion for additional layer(s) and/or additional colour/paint.

An additional sealant/top coat (with or without integral lubricant) may be chosen to increase corrosion resistance and/or to achieve other specific properties (e.g. torque/clamp force properties, resistance to chemicals, mechanical resistance, aspect, colour, thermal stability, increased electrical resistance, UV radiation resistance). The selection of the nature of a sealant or top coat should be based on the desired additional properties.

An additional lubricant may be applied to adjust or amend the torque/clamp force relationship.

NOTE Electroplating is also applied on stainless steel fasteners, e.g. for the purpose of lubrication in order to avoid galling.

4.3 Coating systems and coating processes

The type and geometry of the fastener should be considered when selecting a coating system and the related coating process (see Annex A) as well as hydrogen embrittlement considerations (see Annex B).

The electroplating process shall be under control, in accordance with a recognized standard and/or a specification by agreement with the purchaser. Recommendations for supplemental process verification with regard to internal hydrogen embrittlement are given in 4.5 and B.4.

4.4 Internal hydrogen embrittlement

4.4.1 General

The three following conditions shall be **concurrently** present for fasteners to generate a risk of Internal Hydrogen Embrittlement (IHE), see also Annex B:

— high tensile strength or high hardness, including case-hardening;

— tensile stress, including residual tensile stress;

— atomic hydrogen absorbed by the steel.

The susceptibility to IHE increases with increasing hardness of the fastener. Appropriate measures for prevention of IHE for quenched and tempered fasteners depending on hardness are specified in Table 2.

Table 2 and 4.4.2 to 4.4.4 provide the general guidelines for measures related to IHE as a function of hardness.

The general guidelines of Table 2 are translated in 4.4.5 and 4.4.6 into normative requirements applicable specifically to each type of fasteners in relation to its property class (see Tables 3 to 5) or its core hardness (see Tables 6 and 7). These specific normative requirements are based on both hardness and the degree of tensile stress experienced by each type of fasteners by its design and function.

Table 2 — Measures related to IHE for quenched and tempered fasteners with regard to hardness [a]

	360 HV	390 HV
A	**B**	**C**
No supplemental process verification or product testing with regard to IHE	Supplemental process verification and/or product testing with regard to IHE	Supplemental process verification and/or product testing with regard to IHE
AND	OR	AND
No baking necessary	Baking	Baking (baking temperature and duration shall be specified)
—	At the discretion of the fastener manufacturer	—
See 4.4.2	See 4.4.3 and B.6	See 4.4.4 and B.6

[a] For fasteners work hardened to high hardness, see 4.4.7 and B.5.

4.4.2 Fasteners with hardness up to 360 HV

When electroplating quenched and tempered fasteners with specified maximum hardness up to 360 HV (**A** in Tables 2, 3, 4 and 5), no supplemental process verification with regard to IHE and no baking are necessary.

4.4.3 Fasteners with hardness above 360 HV and up to 390 HV

When electroplating quenched and tempered fasteners with specified maximum hardness above 360 HV and up to and including 390 HV (**B** in Tables 2, 3 and 5), at the choice of the fastener manufacturer baking is not required provided supplemental process verification and/or product testing with regard to IHE have been performed.

For fasteners in this specified hardness range, electroplating does not pose a risk of IHE. In case of a failure in a product test, it cannot be assumed that baking the parts would have prevented such failure: the metallurgical and physical conditions of the fastener material should be investigated for non-conformances. For more information, see B.2 and B.4.

4.4.4 Fasteners with hardness above 390 HV

When electroplating quenched and tempered fasteners with specified maximum hardness above 390 HV (**C** in Tables 2 and 3), baking is required; see B.4 for minimum recommended baking temperature and duration.

The following exemptions apply:

— for fasteners which are not specified to be under tensile stress by design or standard (e.g. set screws in accordance with ISO 898-5), baking is not required (see B.2);

— induction hardened ends (e.g. for thread forming screws) shall not be considered for determining measures related to IHE in relation to Table 2, because they are normally not subjected to tensile stress provided that the end protrudes through the mating thread;

— alkaline zinc-nickel electroplatings with nickel content of 12 % to 16 % present a lower risk of IHE (see B.3), therefore it is possible to avoid baking; the decision to not carry out baking shall be based on testing (see B.6) and be agreed between the supplier and the purchaser.

NOTE 1 Alkaline zinc-nickel electroplating processes with typical nickel content of 12 % to 16 % are also known as "low hydrogen embrittlement" processes (LHE) in the aerospace industry, see B.3.

NOTE 2 For acid zinc-nickel electroplatings, studies have shown similar benefits as for alkaline zinc-nickel electroplatings, however more data are necessary to confirm baking avoidance.

4.4.5 Fasteners in accordance with ISO 898-1, ISO 898-2 and ISO 898-3

For fasteners in accordance with ISO 898-1, ISO 898-2 and ISO 898-3, Tables 3, 4 and 5 apply.

Table 3 — Measures related to IHE for fasteners in accordance with ISO 898-1

Property class	**< 10.9**	**10.9**	**12.9/12.9**
Measures related to IHE	**A**	**B**	**C**
	No supplemental process verification or product testing with regard to IHE AND No baking necessary	Supplemental process verification and/or product testing with regard to IHE OR Baking	Supplemental process verification and/or product testing with regard to IHE AND Baking [a, b]
	—	At the choice of the fastener manufacturer	—
	See 4.4.2	See 4.4.3 and B.6	See 4.4.4 and B.6

[a] For alkaline zinc-nickel electroplatings with nickel content of 12 % to 16 %, the decision to not carry out baking shall be based on testing (see B.6) and be agreed between the supplier and the purchaser.

[b] For baking temperature and duration, see B.4.

Table 4 — Measures related to IHE for nuts in accordance with ISO 898-2

Property class	**≤ 12**
Measures related to IHE	**A**
	No supplemental process verification or product testing with regard to IHE AND No baking necessary [a, b]
	See 4.4.2

[a] Investigations have shown that tensile stress in critical areas of nuts (including nuts with flange) is always lower than tensile stress in the thread of the mating bolts, screws or studs with corresponding property class (see measures related to IHE in Table 3); nuts in accordance with ISO 898-2 (all property classes) always have a hardness less than 390 HV, therefore baking is not necessary.

[b] For all-metal prevailing torque nuts of property classes 10 and 12, supplemental process verification or baking is required, at the choice of the manufacturer.

Table 5 — Measures related to IHE for flat washers in accordance with ISO 898-3

Property class	≤ 300HV	380HV
Measures related to IHE	**A**	**B**
	No supplemental process verification or product testing with regard to IHE AND No baking necessary [a]	Supplemental process verification and/or product testing with regard to IHE OR Baking [b]
	—	At the choice of the fastener manufacturer
	See 4.4.2	See 4.4.3

[a] When flat washers of property class 300HV are to be used in special applications (e.g. enlarged or slotted holes) where bending stress may be present, baking may be necessary and shall be required by the purchaser at the time of the order. For baking temperature and duration, see B.4.

[b] When flat washers of property class 380HV are to be used in special applications (e.g. enlarged or slotted holes) where bending stress may be present, baking is necessary and shall be required by the purchaser at the time of the order. For baking temperature and duration, see B.4.

4.4.6 Case-hardened fasteners

Fasteners where the surface is intentionally case-hardened to fulfil specific function(s) include:

— tapping screws (see ISO 2702),

— thread-forming screws for metallic materials,

— self-drilling screws (see e.g. ISO 10666),

— screws for soft materials (e.g. plastic, wood).

Measures related to IHE for case-hardened screws are based on core hardness, which has the most significant effect on IHE susceptibility (see B.3).

Case-hardened screws are grouped into two different categories, a) and b).

a) Case hardened screws not designed for high clamp force

This category includes tapping screws and self-drilling screws with thread according to ISO 1478, screws for soft materials, etc.

As these screws are typically not designed for high clamp force, the risk of IHE is significantly reduced.

Measures related to IHE for this category are specified in Table 6.

NOTE Non-threaded case-hardened fasteners not subjected to tensile stress by design (such as pins or washers) do not need special measures related to IHE, unless specifically agreed between the purchaser and the manufacturer for a particular application.

b) Case hardened and tempered screws intended to be preloaded

This category includes case-hardened and tempered screws that form ISO metric mating threads according to ISO 965-1 and other case-hardened and tempered thread-forming or self-drilling screws intended to be preloaded.

Measures related to IHE for this category are specified in Table 7.

Table 6 — Measures related to IHE for case-hardened screws typically not designed for high clamp force

Core hardness	≤ 360 HV	> 360 HV and ≤ 390 HV	> 390 HV
Measures related to IHE	Supplemental process verification with regard to IHE OR Product testing OR Baking	Supplemental process verification with regard to IHE AND Product testing and/or baking	Supplemental process verification with regard to IHE AND Baking [a] AND Product testing for each manufacturing lot [b]
	At the choice of the fastener manufacturer		—

[a] For baking temperature and duration, see B.4.

[b] For alkaline zinc-nickel electroplatings with nickel content of 12 % to 16 %, product testing shall be considered as part of in-process control (not mandatory for each manufacturing lot).

Table 7 — Measures related to IHE for case-hardened and tempered screws intended to be preloaded

Core hardness	≤ 360 HV	> 360 HV and ≤ 390 HV	> 390 HV
Measures related to IHE	Supplemental process verification with regard to IHE OR Product testing OR Baking	Supplemental process verification with regard to IHE AND Baking [a]	Supplemental process verification with regard to IHE AND Baking [a] AND Product testing for each manufacturing lot [b]
	At the choice of the fastener manufacturer	Product testing solely at the manufacturer's choice	—

[a] For baking temperature and duration, see B.4.

[b] For alkaline zinc-nickel electroplatings with nickel content of 12 % to 16 %, product testing shall be considered as part of in-process control (not mandatory for each manufacturing lot).

When product testing with regard to IHE is performed on case-hardened screws, it shall be in accordance with ISO 15330 or ASME B18.6.3; see also B.6.

4.4.7 Work hardened fasteners and fasteners with threads rolled after heat treatment

For fasteners not intended to be quenched and tempered that are work hardened to high hardness resulting in high residual stress, stress relief prior to electroplating may be necessary. See B.5.

For fasteners with threads rolled after heat treatment (i.e. after quenching and tempering), the measures in Table 3 for fasteners in accordance with ISO 898-1 shall apply without modification, as a local increase of surface hardness by work hardening combined with residual compressive stress have no negative impact on susceptibility to IHE.

4.4.8 Fasteners with bainitic structure

Fasteners with bainitic structure are not addressed in 4.4. A written agreement between the supplier and the purchaser with regard to IHE is necessary.

4.5 Baking

When baking is performed, baking conditions including temperature and duration shall be based on fastener material properties, electroplating process, and coating material. See B.4 for more detailed guideline/recommendations.

Baking is usually performed before application of a conversion coating and/or before application of an additional sealant/top coat. In case of passivation (with or without sealant) and depending on baking temperature, baking in the passivated and/or sealed condition may be suitable provided corrosion resistance is not impaired.

NOTE With proper care, many steel fasteners are electroplated without baking by correlating process conditions and coating material to the susceptibility of the fastener material to hydrogen embrittlement, and by applying adequate process control procedures. DIN 50969-2 and ASTM F1940 are recognized methods for process control to evaluate the risk of IHE. These or other similar test methods are used as the basis for determining if baking is required.

However, prevention of the risk of IHE does not only depend on baking (see 4.4 and Annex B).

5 Corrosion protection and testing

5.1 General

The corrosion protection of an electroplated coating system depends to a considerable extent on the thickness of the metal layer(s). Conversion coatings and/or sealants and/or top coats on zinc, zinc-iron, zinc-nickel and cadmium coatings provide protection against coating metal corrosion (formation of white corrosion), thus providing additional protection against basis metal corrosion.

Metallic coatings such as zinc, zinc alloys and cadmium are less electropositive than the steel basis metal, which is the condition to provide cathodic protection. In contrast, metals more electropositive than the steel basis metal (e.g. nickel, copper, silver) cannot provide cathodic protection, which can intensify corrosion of the fastener if the coating is damaged or pitted.

The frequency and duration of wetting and service temperatures, contact with corrosive chemicals, and contact with other metals and materials (galvanic corrosion/contact corrosion), can influence the protective performance of coatings.

Corrosion resistance is a product characteristic that can be reduced as a consequence of the following factors:

— physical damage to the coating from handling and transportation, and

— oxidation of the coating or reaction with the environment during transportation and storage.

Before selecting a coating system, all functions and conditions of the assembly should be considered and not just the fastener; see Annex A. An appropriate choice for a given application should be made between the purchaser and the fastener supplier and/or the coater and/or the chemical supplier.

Corrosion resistance in accelerated corrosion tests (e.g. neutral salt spray test, sulfur dioxide test) cannot be directly related to corrosion protection behaviour in service environments. However, accelerated tests are commonly used to evaluate the corrosion resistance of the coating system.

