A Leading Standard for Electroplating Fasteners Just Got Another Face-Lift

ISO 4042:2022 Was Released in May 2022

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Introduction

In the 1990s, an electroplated coating of fasteners was considered straightforward and was simply specified by zinc thickness (0.2 to 0.3 mil, or 5 or 8 µm, for example) often followed by passivation in chemical solutions containing hexavalent chromium Cr (VI), and without any requirement for corrosion resistance.

It is important to note that *ISO 4042*, same as *ASTM F1941/F1941M*, is a fastener electroplating standard that covers all electroplated coatings applied to fasteners. These standards are in contracts to *ASTM B633* for example, which is a general zinc electroplating standard that does not address fastener-specific concerns (e.g., thread fit, etc.).

ISO Technical Committee ISO/TC 2 Fasteners, Subcommittee SC 14, Surface coatings, has recently completed the latest revision of *ISO 4042:2018* Fasteners-Electrolytic coating systems. The 2022 version was recently published by **ISO** in May. This standard is released in parallel to a European standard circulated as *EN ISO 4042:2022* and is mandatorily adopted verbatim by European CEN countries (EU, EFTA, Turkey and Northern Macedonia).

This is the fourth edition of *ISO 4042*, which along with *ASTM F1941/F1941M*, are among the most widely used and important standards in the global fastener manufacturing industry. It is somewhat ironic that this latest revision was supposed to be a “quick and easy” update to the 2018 edition, to correct some minor inconsistencies and errors. Indeed, the 2018 edition had been published after a long and arduous revision process that lasted more than 11 years; it includes many fundamental changes and significant additions to the previous 1999 publication, which was limited primarily to descriptive aspects.

These 2018 changes represented a complete paradigm shift: e.g., for the different coating systems it offers options for passivation with/without hexavalent chromium, sealers and friction modifying finishes, in includes the addition of minimum corrosion resistance, and significantly more precise guidance for mitigating the risk of hydrogen embrittlement and baking. On these last two points, SC 14 has considered the latest published research and prevailing industry experience to make several (initially controversial) improvements to minimize the risk of hydrogen embrittlement. It is therefore understandable that a few “relatively minor” details lacked precision.

This latest 2022 version was therefore intended to make the necessary corrections quickly in a revision cycle that the committee expected to be completed in one year. But opening the 2018 *ISO 4042* standard for further review was akin to opening Pandora's box! A growing list of clauses was quickly identified for review by SC14 when the revision process was initiated. As a result, this revision became major. In the end it was extremely positive, the result being a comprehensive and recognized standard that represents the state of the art in electroplating for fasteners.

Today, complex electroplated coating systems are defined as follows:

- To meet a set of functional requirements in assemblies.
- For minimum corrosion resistance.
- To accommodate the wide variety of fasteners and their uses.
- For a sustainable cosmetic aspect.

The challenge in the fastener industry is to ensure the mechanical integrity of bolted assemblies and to guarantee durable fitness for function. To paraphrase a common adage: “in this world, nothing holds together without fasteners.”

The remainder of this article presents the key elements of *ISO 4042*, which were adopted in the 2018 edition and then refined in the 2022 edition.

Increasing Complexity of Electroplated Coatings for Fasteners

The first publication of *ISO 4042* goes back to 1989; this standard was specifically developed by fastener and surface treatment experts for the proper electroplating of metallic coatings (zinc, etc.) on mechanical fasteners with ISO metric threads (screws and nuts). Previously, a general standard *ISO 2081* was used for all steel parts: the latter was part of *TC 107*, Inorganic coatings, and was therefore not very well adapted to the requirements of the fastener industry, for the need to guarantee a functional clearance between the screws and the associated nuts, a clearance which depends on the thickness of the coating and the dimensions of the threads. This was the reason for the creation of *ISO 4042* to cover the main electroplated coatings applied to fasteners. The exact same narrative is true for *ASTM F1941/F1941M*, first published by ASTM Committee F16 on Fasteners in 1999. *ASTM F1941/F1941M* followed the trail blazed by *ISO 4042* in response to the inadequacies of *ASTM B633*, which is under the jurisdiction of ASTM Committee B08 on Coatings.

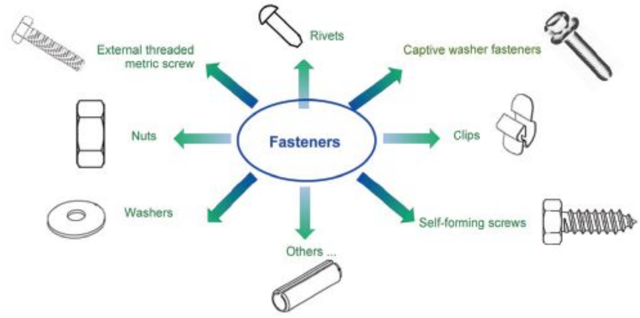
Since the 1990s, electroplating processes have undergone major technological developments. These advances have been aimed at meeting the increasing performance requirements of coated fasteners such as improved corrosion resistance, controlled lubrication to control surface friction during tightening, and appearance requirements of finished parts. In addition, the development of coating processes with alloys such as zinc-cobalt, zinc-iron and especially zinc-nickel, has led to much more complex surface treatment processes to manage. Similarly, the evolution of coating finishes, in particular the removal of hexavalent chromium and their replacement by finishes containing trivalent chromium, has been considered.

As a result, *ISO 4042* has also evolved to include an increasing list of technical characteristics to address performance requirements of the coatings, and to reflect the state of the art of electroplated coatings for fasteners.

Fasteners Covered by ISO 4042

In 1999, the only fasteners in *ISO 4042* were steel or copper alloy elements with ISO metric threads. All threaded and nonthreaded fasteners have been included in the 2018 and 2022 versions, including for example washers, pins, clips, and rivets. The same is true for *ASTM F1941/F1941M*, which now includes all threaded and nonthreaded fasteners.

ISO 4042 adapts the relevant content of the general standards for electroplating to fasteners. Above all, it sets out the applicable requirements and the corresponding inspection and test methods for finished parts.



***ISO 2081*, Metallic and other inorganic coatings - Electrolytic zinc coatings with additional treatments on iron or steel.**

Functional Properties of Coated Fasteners

Fastener coatings provide corrosion protection but with a cosmetic aspect, without impeding the function of the fastener, which must:

- Retain its initial mechanical and physical characteristics after coating.
- Retain its ability to be assembled.
- Be tightened to the required tension in bolted connections.
- Retain its appearance for cosmetic requirements.
- Resist corrosion for the intended duration.
- Not loosen/unscrew during service.
- Retain its ability to be dismantled at the end of its service life.

Fastener coating systems contribute to all these functions. The functional characteristics of electroplated coatings for fasteners were described for the first time in *ISO 4042:2018*. They also include chemical resistance, galvanic corrosion, electrical conductivity, and surface particulate cleanliness.

But the characteristic that has become increasingly important is tightening-ability, the subject of *ISO 16047* which defines torque/tension tests. The torque/tension ratio is most often expressed in terms of an overall coefficient of friction, μtot. It should be noted that *ISO 16047* was published in 2005 and developed as an international common core document; it is currently being revised to include more standardized procedures and reference conditions in the event of a dispute.

Corrosion Resistance & Testing

The primary objective of electroplated coatings is to provide corrosion resistance in service, by protecting the base metal (i.e., steel fastener) from oxidation. Corrosion resistance depends on the nature of the sacrificial coating and its finishes, the method of application of the treatments, thickness and coating distribution on the surface of the parts. Corrosion resistance also depends on the conditions of handling, transport, storage, assembly, and of course on the type of service environment to which the fastener is exposed.

Corrosion mechanisms of a coated fastener can occur through different chemical or electrochemical processes. *ISO 4042* defines two main types of corrosion:

- Functional corrosion is characterized by red oxidation (or red rust), which can affect the mechanical properties of steel fasteners.
- Cosmetic corrosion of the coating is characterized by white oxidation, which is the oxidation products of zinc-based sacrificial coatings, and which change the appearance of the fastener.

White corrosion or white oxidation should not be confused with white haze seen with zinc-nickel coatings. White haze with zinc-nickel coatings is the result of an interaction between the environment or test medium (e.g., neutral salt spray (NSS)) and is mainly observed in the naturally occurring microcracks of the metal layer and/or the passivation layer. This white film has the characteristic of stopping further corrosion and is the reason zinc-nickel coatings are highly stable in terms of corrosion resistance. The practical question is how to distinguish between white haze and white corrosion. White haze is only visible on dry parts, whereas white corrosion is visible on wet parts and can be identified by nonadherent corrosion salts.

For monitoring corrosion resistance, the reference test is the neutral salt spray (NSS) test as defined in *ISO 9227*, Corrosion tests in artificial atmospheres-Salt spray tests. The particularity of *ISO 4042* is that it conforms in all respects to this test, but also offers an alternative solution for the evaluation of the corrosiveness of the enclosure used. *ISO 9227* requires a method using uncoated steel plates, placed in the enclosure and the aggressiveness of the enclosure is measured after 48 hours by the loss of mass of the plates, after they have been stripped and the corroded elements removed.

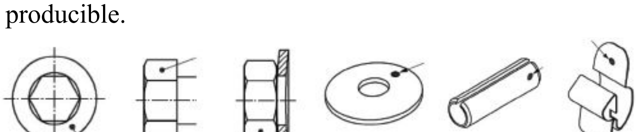
a) Room in wet state **b) Dry room**

***ISO 4042:2022*, Figure A.20h Examples of white haze on a zinc-nickel layer after 720h NSS test. ISO 16047, Fasteners - Torque/tension testing. This standard is currently undergoing revision in *ISO/TC 2*.**

White oxidation of a zinc layer with iridescent passivation after 240 h NSS test (left), Strong white oxidation of a zinc layer with iridescent passivation after 480 h test NSS (right). *ISO 4042:2022*, Figure A. 3—Examples of white oxidation.

The revision of *ISO 4042* also includes the so-called "Kesternich" sulfur dioxide test, which is primarily intended for building fixtures exposed to the exterior.

It should be noted that accelerated corrosion tests such as salt spray are used in practice for quality control. They are not representative of real corrosion in outdoor environments where many other factors come into play (e.g., cleaning with acid or alkaline products, physical damage, severe industrial or marine environments). Concerning the measurement of coating thickness on finished parts, *ISO 4042* lists a set of applicable methods, but above all defines the reference test method in case of dispute: the micrographic section method according to *ISO 1463* must be used on a reference area, defined according to the type of fastener to ensure it is both representative and reproducible.



***ISO 4042:2022*, Extract from Figure 2—Examples of reference areas for fasteners.**

Hydrogen Embrittlement: To Bake or Not to Bake When It is Useless?

Hydrogen embrittlement (HE), or more precisely the prevention of the risk of internal hydrogen embrittlement (IHE), where the sources of hydrogen are the chemical surface cleaning/preparation processes and the electrolytic plating process, was undoubtedly the most controversial and difficult topic on which the SC 14 subcommittee needed to reach consensus.

Prior to the 2018 edition of *ISO 4042*, baking (a heat treatment process at roughly 200°C or 400°F), applied after electroplating to remove hydrogen from coated steel parts, was recommended for fasteners with a hardness greater than 320 HV (i.e., 31 HRC). Even if this baking was not mandatory, the implication of risk had created the condition for it to be systematically required by customers as a precaution, for property class 10.9 screws (hardness 320 to 380 HV, 31 to 39 HRC), or even for property class 8.8 screws.

Although *ISO 4042* avoided giving recommendations on baking duration, four hours was generally required by the customers and OEMs. The 320 HV limit for baking was inherited from the general standard *ISO 2081 1*, which in turn followed the recommendations of *ISO 9588*, Metallic and other inorganic coatings—Post-coating treatments on iron or steel to reduce the risk of hydrogen embrittlement. But there is no scientific and experimental evidence to support the baking of fasteners at hardness as low as 320 HV. In fact, it has since been shown that there is no benefit below 390 HV, that it is costly, and that baking of fasteners with electroplated zinc coatings for as little as four hours may even be harmful in some cases.

In 1998, the ASTM Committee F16 on Fasteners adopted *ASTM F1941*, which required baking only at a specified hardness above 39 HRC (i.e., above 390 HV): this was a first step in the right direction.

Today, thanks to many years of research and accumulated industrial experience, it is known that steel fasteners with a specified hardness of less than 390 HV, such as property class 10.9 screws, do not exhibit significant sensitivity to HE. In other words, these steel fasteners can tolerate the presence of hydrogen without degradation of their mechanical strength and without delayed failure due to internal hydrogen embrittlement (IHE) or environmental hydrogen embrittlement (EHE), provided that the manufacturing processes are well controlled (metallurgy, heat treatments, and surface treatments).

Therefore, *ISO 4042*, same as *ASTM F1941/F1941M*, identifies susceptible fasteners requiring mandatory baking as those with a specified minimum hardness greater than 390 HV (39 HRC). For these fasteners, if they are subject to high tensile stresses in service, *ISO 4042* also requires process control and appropriate test methods as additional tools to minimize the risk of IHE.

In addition, new clauses and tables have been added as guidance on how to apply the requirements to different types of fasteners, depending on their mechanical and functional characteristics (e.g., ISO metric threaded screws, self-tapping screws, sheet metal screws, nuts and washers). During the latest revision leading to the adoption of *ISO 4042:2022, SC 14* carefully reviewed and modified these clauses to make them as clear, explicit, and consistent as possible.

The technical report *ISO/TR 20491*, Fasteners-Principles of hydrogen embrittlement for steel fasteners was adopted by *ISO/TC 2* after several years of hard work by experts and careful evaluations of all critical aspects, concluded by a final vote. It was published in 2019 shortly after *ISO 4042:2018*, and comprehensively describes the fundamental principles of HE. Today *ISO/TR 20491* represents a substantiated and recognized international guide for the fastener industry. Its fundamental principles are therefore practically applicable to electroplating of fasteners. The fact that it was developed at the same time as the major rewrite of *ISO 4042* was orchestrated to ensure the technical consistency of both documents.

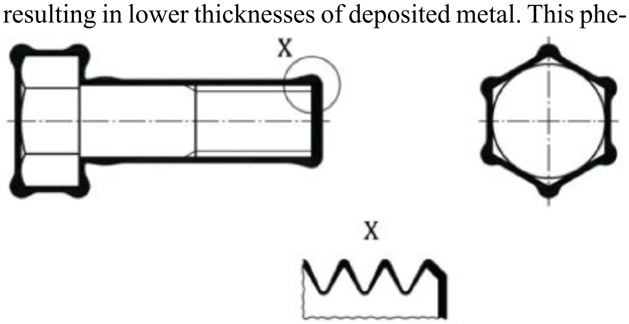
ISO Metric Threaded Fasteners: A Challenging Contradiction

A minimum coating thickness is needed for effective corrosion protection, but ease of assembly must also be ensured.

For threaded fasteners, it is necessary to consider the impact of the coating on dimensional characteristics. Indeed, if a link can be made between the thickness *t* of the coating and the corrosion resistance of the fastener, this thickness *t* results in an increase in the pitch diameter of the thread by +4t for external threads and a decrease of -4t for internal threads. The risk of eliminating the functional clearance between the two fasteners (e.g., screw and nut) is very real and can cause the inability to assemble the parts.

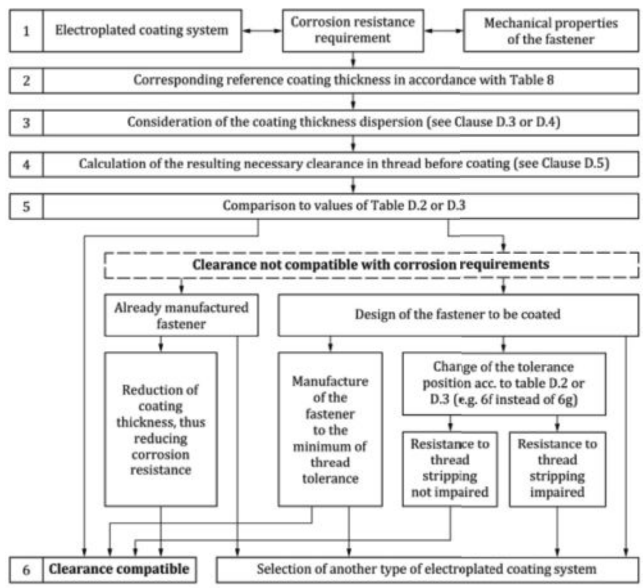
When designing the bolted joint and selecting fasteners, a compromise must therefore be found between the need for corrosion resistance obtained by a coating system of sufficient thickness for the conditions of use, and the tolerance class of the thread before coating. The common objective is, after coating, not to exceed the zero line in the thread (maximum of class 6h for screws and minimum of class 6H for nuts) as defined in *ISO 965 7*.

For electroplated coatings, another phenomenon must also be considered: the distribution of the thickness of the coating deposited on the a given part. This phenomenon, specific to electroplating, is called the point effect or dog bone effect. Extremities of bolts (i.e., head/end) and the crest of threads are subjected to higher current densities, resulting in greater thicknesses of deposited metal. Conversely, the middle part, especially of long bolts, thread roots and recesses are subjected to lower current densities, resulting in lower thicknesses of deposited metal. This phenomenon described in *ISO 4042* is to be considered when checking the coating thickness and conformity of threads. To verify conformance, the thread for each batch of coating at the end of screws, studs, or threaded rods over a length of one diameter must pass a GO ring gage. For nuts, a GO plug gage must pass the entire height of the threads.



***ISO 4042:2022*, Figure D.3 — Typical distribution of coating thickness on a bolt resulting from electroplating process (exaggerated for illustrative purposes).**

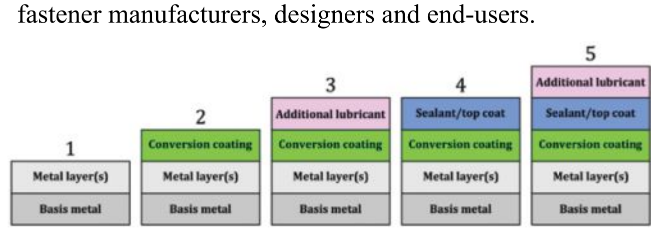
Note that adjusting the tolerances of the uncoated parts to ensure a functional screw/nut clearance is possible provided that it is limited to 6e for external threads and 6G for internal threads. Beyond that, the mechanical strength of the assembly is impacted and the risk of failure by thread stripping is increased. The compromise to be reached is illustrated by the flow chart in Appendix D.



ISO 4042:2022, Figure D.4 - Example of verification of compatibility between corrosion resistance and thread clearance.

Universal Terminology Understandable By All

Technical developments in electroplated coatings and the desire to write standards that can be used and understood by all in the same way have led *ISO/TC 2* to standardize the terms and definitions used in its standards. For fastener coatings, SC 14 has published *ISO 1891-2*, Fasteners-Terminology-Part 2: Vocabulary and definitions for coatings. This document is a useful complement to standards such as *ISO 4042* or *ISO 10683*, Fasteners-Non-electrolytic zinc flake coating systems. It allows the same concepts to be used and avoids misunderstandings and disputes between chemical suppliers, coating applicators, fastener manufacturers, designers and end-users.

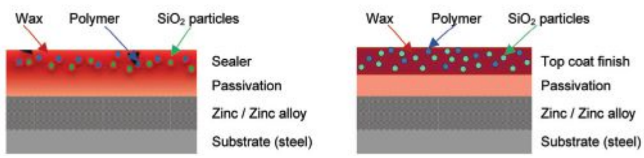


***ISO 4042:2022,* Figure 1 - Examples of electroplated coating systems.**

This standardized vocabulary is used in the description of the main coating systems in *ISO 4042*, for example the differences between Sealer and the Top Coat are defined as follows:

- Sealer: chemical substance (with or without integral lubricant) applied to the coating metal, forming a composite with the conversion layer, to improve chemical resistance, corrosion protection, etc.
- Top Coat: additional layer (with or without integral lubricant) applied to the coating metal to achieve the desired functional characteristics, such as additional corrosion protection, control of the torque/tension relationship, color, and chemical resistance.

We also note the appearance of the term passivation for conversion layers with trivalent chromium, as a substitute for chromating (which only applies to conversion layers with hexavalent chromium).



Examples of Coating Systems - Courtesy MacDermid Enthone Coventya.

These terms and definitions have also allowed the designations for fastener coatings to be reformulated. To avoid any ambiguity, SC 14 decided to harmonize the designations of electroplating with those of the general standards *ISO 2081 1* and *ISO 19598* .

Fasteners & Coatings – Shared Know-How

Fasteners are manufactured by companies that are specialized in different industrial sectors (e.g., automotive, equipment manufacturers, construction, rail and aerospace, but also defense, electronic equipment, household appliances, furniture, toys, etc.). Surface coatings must be applied by applicators who have real knowledge of the specific constraints inherent to fasteners to obtain the expected properties.

The fastener industry supplies very large quantities of parts at a low unit cost. This requires complex, high-capacity surface coating facilities that can integrate surface preparation, coating and finishing, baking as well as the means to characterize the finished fasteners (corrosion, thickness, ease of assembly, coefficient of friction, etc.).

Surface coating processes must be closely monitored, and quality control of products must be ensured, for example by means of audits. The fastener manufacturing and surface coating industries have developed process audit standards such as *AIAG CQI 11* for automotive electroplating.

Given the complexity of the technologies used, the experience of fastener manufacturers, chemical suppliers and coating applicators cannot be transcribed into a standard in the form of know-how. A standard of any kind must not delve into know-how; however, *ISO 4042* includes nonmandatory annexes in which typical difficulties and pitfalls to be avoided are listed. These annexes may be used as a checklist of discussion points between a supplier and customer. Some examples include the following:

- For larger fasteners, consider rack plating (as opposed to barrel plating in bulk) to avoid nicks and thread damage.
- Appropriate processing for washers to avoid "sticking" and uncoated areas.
- Processes adapted to avoid the entanglement of clips and lock washers.
- Suitability of the prevailing torque patch coating micro-encapsulated adhesive with the coating and its finish.

Conclusions

As mentioned in the introduction, in 1999 *ISO 4042* was intended as a complement to the general standards on electroplating. The evolution of the art of electroplating fasteners has led *ISO/TC 2/SC 14* to now take the position that *ISO 4042:2022* prevails over *ISO 2081* and *ISO 19598* for electroplating fasteners, because they are not adapted to requirements of fasteners. *ISO 4042:2022* takes precedence, especially in matters related to the mitigation of the risk of hydrogen embrittlement (HE), and to the methods of thickness measurement.

This follows the example set by *ASTM F1941/F1941M* in which the introduction includes the statement, "This standard shall be used in place of *ASTM B633* for mechanical fasteners."

The revision of *ISO 4042* was carried out in conjunction with the development of two other standard documents, which are also intended to serve as references for fastener coatings:

- *ISO/TR 20491*, Principles of hydrogen embrittlement for steel fasteners.
- *ISO 1891-2*, vocabulary standard for fastener coatings.

The work that led to the 2018 revision is now completed with the 2022 revision of *ISO 4042*. The latest technical knowledge on electroplated coatings, specifically applied to fasteners is included in *ISO 4042:2022*. This standard is now positioned serve as a complete, globally recognized, reference standard for electroplated coatings on fasteners. With the completion of this revision of *ISO 4042:2022* ASTM Committee F16 on Fasteners will begin in earnest a full revision of *ASTM F1941/F1941M-16*, with the objective of continuing to maintain harmony between these two very important standards.

Having good working knowledge of all these reference documents is highly recommended for everyone in the fastener supply chain. *www.indfast.org* FTI

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