



Designation: B1025 – 24

Standard Specification for Electrodeposited Nanostructured Zinc-Nickel Coatings¹

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1. Scope

1.1 This specification covers requirements for electrodeposited nanostructured zinc-nickel alloy coatings. The coatings can be applied to iron and steel, as well as other substrates, such as stainless steel and aluminum bronze, when an appropriate barrier coating is used.

1.2 The coatings are intended to provide corrosion protection to oil and gas, automotive, and aerospace components such as fasteners, brackets, and housings. The coatings may also be used in other industrial applications in which enhanced corrosion resistance is desired.

1.3 The coatings provide durability and corrosion resistance in diverse challenging environments, ranging from atmospheric exposures with variable humidity, offshore and marine settings subjected to saline conditions, to scenarios with fluctuating temperatures and potential chemical interactions found in automotive and aerospace applications.

NOTE 1—Nanostructured zinc-nickel alloy coatings exhibit superior corrosion resistance due to their ultrafine grain size in the nanometer (10^{-9} m) range. In addition to the nanoscale grains, the unique non-porous laminar microstructure (that is, layers or banding observed after chemical etching) also contributes to this enhanced protection. The ultrafine/nanocrystalline grains, with their higher specific grain boundary surface area, increase galvanic electrochemical activity, leading to an enhanced passivation response. This heightened passivation helps in forming a more stable and protective oxide layer on the surface, further mitigating corrosion. Simultaneously, the non-porous layered microstructure acts to increase corrosion resistance and overall durability, while allowing for hydrogen relief. As a result, nanostructured zinc-nickel coatings enhance the galvanic/barrier properties compared to standard continuous DC electrodeposited zinc-nickel coatings. Validation of the nanostructured nature of these coatings is achieved through a combination of microstructure evaluation, corrosion testing, and open circuit potential (OCP) periodic testing, ensuring the effectiveness of the processing methods.

NOTE 2—Nanostructured ultrafine grain sizes are obtained using adjustments to the DC electrodeposition process, including modifications to the applied current, specific bath chemistries, bath temperature, and other parameters. Detailed methods can be found in [Appendix X1](#).

1.4 *Units*—The values stated in SI units are to be regarded as the standard. No other units of measurement are included in this standard.

1.5 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety, health, and environmental practices and determine the applicability of regulatory limitations prior to use.*

1.6 *This standard has been revised to comply with the Restriction of Hazardous Substances (RoHS) Requirements that seek to limit the exposure of workers and the public to toxic metals. The alloy does not contain any of the six restricted hazardous substances.*

1.7 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 ASTM Standards:²

- [B117 Practice for Operating Salt Spray \(Fog\) Apparatus](#)
- [B183 Practice for Preparation of Low-Carbon Steel for Electroplating](#)
- [B242 Guide for Preparation of High-Carbon Steel for Electroplating](#)
- [B320 Practice for Preparation of Iron Castings for Electroplating](#)
- [B322 Guide for Cleaning Metals Prior to Electroplating](#)
- [B374 Terminology Relating to Electroplating](#)
- [B487 Test Method for Measurement of Metal and Oxide Coating Thickness by Microscopical Examination of Cross Section](#)
- [B499 Test Method for Measurement of Coating Thicknesses by the Magnetic Method: Nonmagnetic Coatings on Magnetic Basis Metals](#)
- [B504 Test Method for Measurement of Thickness of Metallic Coatings by the Coulometric Method](#)
- [B507 Practice for Design of Articles to Be Electroplated on Racks](#)
- [B568 Test Method for Measurement of Coating Thickness](#)

¹ This specification is under the jurisdiction of ASTM Committee B08 on Metallic and Inorganic Coatings and is the direct responsibility of Subcommittee B08.03 on Engineering Coatings.

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² For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at www.astm.org/contact. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

by X-Ray Spectrometry
B571 Practice for Qualitative Adhesion Testing of Metallic Coatings
B602 Guide for Attribute Sampling of Metallic and Inorganic Coatings
B697 Guide for Selection of Sampling Plans for Inspection of Electrodeposited Metallic and Inorganic Coatings
B762 Guide of Variables Sampling of Metallic and Inorganic Coatings
B841 Specification for Electrodeposited Coatings of Zinc Nickel Alloy Deposits
B849 Specification for Pre-Treatments of Iron or Steel for Reducing Risk of Hydrogen Embrittlement
B850 Guide for Post-Coating Treatments of Steel for Reducing the Risk of Hydrogen Embrittlement
D1193 Specification for Reagent Water
D1735 Practice for Testing Water Resistance of Coatings Using Water Fog Apparatus
D3951 Practice for Commercial Packaging
E1621 Guide for Elemental Analysis by Wavelength Dispersive X-Ray Fluorescence Spectrometry
E2465 Test Method for Analysis of Ni-Base Alloys by Wavelength Dispersive X-Ray Fluorescence Spectrometry
F519 Test Method for Mechanical Hydrogen Embrittlement Evaluation of Plating/Coating Processes and Service Environments
F1941/F1941M Specification for Electrodeposited Coatings on Mechanical Fasteners, Inch and Metric
G5 Reference Test Method for Making Potentiodynamic Anodic Polarization Measurements
G59 Test Method for Conducting Potentiodynamic Polarization Resistance Measurements
G61 Test Method for Conducting Cyclic Potentiodynamic Polarization Measurements for Localized Corrosion Susceptibility of Iron-, Nickel-, or Cobalt-Based Alloys
G85 Practice for Modified Salt Spray (Fog) Testing
G102 Practice for Calculation of Corrosion Rates and Related Information from Electrochemical Measurements
G193 Terminology and Acronyms Relating to Corrosion
 2.2 *GMW Standard:*
GMW 14872 Cyclic Corrosion Laboratory Test³

3. Terminology

3.1 *Definitions*—Many items used in this specification are defined in Terminology **B374**.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *nanolaminar, pulsed, and reverse pulsed electrodeposition, n*—electrodeposition techniques for nanostructured coatings using short, defined waveform current pulses.

3.2.1.1 *Discussion*—Unlike standard electrodeposition, these advanced methods modulate the direct current with a customizable waveform through a PLC and digital controller. Refer to **Appendix X1** Review of Nanostructured Electrode-

position Technologies, for details on these techniques and their relation to nanostructured grains.

3.2.2 *nanolaminar microstructure, n*—a unique layered (banded) microstructure observable in etched non-baked electrodeposited coatings. This microstructure results from the modulated electrodeposition process, which utilizes nanolaminar, pulsed, and reverse pulsed electrodeposition techniques as described in 3.2.1.1. An example of the microstructure is shown in **Appendix X2**.

3.2.2.1 *Discussion*—The laminar microstructure is attributable to the modulated electrodeposition process. During high current stages, rapid deposition occurs, leading to the formation of dense (non-porous) layers with fine grains. Subsequent low (or zero or reversed) current stages limit deposition, allowing for a change in the microstructure, thereby creating distinct layers. This laminar microstructure serves as indirect validation of the intended nanoscale grain structure and the enhanced properties associated with such coatings.

3.2.3 *nanostructured, adj*—pertains to materials or coatings possessing structural grain sizes on the nanometer scale, typically ranging from 1 nm to 100 nm.

3.2.3.1 *Discussion*—The detailed characterization of grain size in nanostructured coatings is typically performed via X-ray diffraction (XRD) since nanoscale structures are not possible to resolve via light or scanning electron microscopy. However, due to its complexity, time consumption, and cost, XRD is not viable for routine validation and is more suited for research and development and first article applications. The validation strategy for confirming the nanostructured zinc-nickel coatings involves a combination of microstructure evaluation through optical or electron microscopy, corrosion resistance testing such as salt spray or cyclic corrosion tests, and periodic open circuit potential (OCP) measurements. These methods collectively ensure that the coatings meet the required performance standards without the need for routine grain size determination.

3.2.4 *open circuit potential (OCP), n*—potential of a corroding surface in an electrolyte, measured under open-circuit conditions, relative to a reference electrode. The OCP is considered an electrochemical parameter and can serve as an indicator of the corrosion rate of a material in a given environment (see Terminology and Acronyms **G193**).

3.2.5 *red corrosion, n*—corrosion of the coating substrate during the Salt Fog test. A more advanced stage of deterioration that occurs when the environment has penetrated the sacrificial coating and reached the substrate, indicating the coating's failure to protect the substrate.

3.2.6 *significant surface, n*—portion of a coated article's surface where the coating shall fulfill all requirements outlined in the coating specification for that article.

3.2.6.1 *Discussion*—Significant surfaces typically encompass areas critical to the article's serviceability or function or areas prone to corrosion products or tarnish films that may impede the article's function or desired appearance. Significant surfaces are identified by the purchaser through methods such as specifying them on an engineering drawing of the product or marking a sample item of the product.

³ Available from General Motors Worldwide (GMW), <https://global.ihs.com/standards.cfm?publisher=GMW>.

3.2.7 *white corrosion*, *n*—corrosion of the sacrificial galvanic zinc-nickel coating during the Salt Fog test. It signifies the active protection phase of the coating where the underlying substrate remains shielded.

4. Classification

4.1 *Scope of Classification*—This specification classifies nanostructured zinc-nickel coatings by their coating process, composition, thickness grades, post-treatment methods, and post-treatment sequences. The latter is particularly significant when baking is mandated for hydrogen stress relief.

4.2 *Coating Technologies*—Coatings derived from any nano-deposition technologies, encompassing nanolaminar, pulse, and pulse reverse plating, must adhere to the criteria outlined in 6.3.2.

4.3 *Composition Requirements*—The composition of the nanostructured zinc-nickel coatings shall have a minimum of 12 and a maximum of 16 mass % nickel, the balance being zinc.

4.4 *Thickness Grades*—There are three grades according to thickness as defined in Table 1.

4.5 *Post-treatment Types*—There are three types of tri-chrome passivate, with non-hexavalent chromium, that are defined in Table 2.

NOTE 3—The tri-chrome passivate designations follow the convention adopted for Specification B841 for the non-hexavalent conversion coatings.

5. Ordering Information

5.1 To facilitate the application of this specification, the purchaser shall provide the following information to the seller in both the purchase order and associated drawings:

5.1.1 *Standard Reference*—Title, designation number, and date of issue of this standard specification.

5.1.2 *Deposit Information*—Type and grade of deposit (refer to 4.4 and 4.5).

5.1.3 *Substrate Information*—The base metal alloy designation under ASTM standards or equivalent reporting tensile properties in MPa and including status of heat treatment for stress relief, specifying if it has been undertaken by the purchaser prior to ordering or if it is required to be conducted by the seller.

5.1.4 *Identification of Significant Surfaces*—Location of significant surfaces (see 3.2.6).

5.1.5 *Electroplating Specifics*—Whether or not location of rack marks is to be defined (see 6.4.1).

5.1.6 *Testing Requirements*—A test report is required for each batch of coated items to include:

5.1.6.1 Special test specimens if any (see Section 13).

5.1.6.2 Coating composition (see 6.3).

5.1.6.3 Thickness (see 6.5).

TABLE 1 Three Grades According to Thickness

Minimum Thickness, μm	ASTM Grade
4	4
8	8
12	12

TABLE 2 Non-Hexavalent Chromium Passivation Types

Type	Description	Non-Hexavalent Chromium
Type A	Colorless (Blue-bright) Conversion	AN
Type B	Black conversion	BN
Type C	Any of the above plus topcoat	CN

5.1.6.4 Adhesion (see 6.6).

5.1.6.5 Corrosion resistance (see Section 7).

5.1.6.6 Hydrogen embrittlement relief if required plus definition of sequence (see Section 8).

5.1.7 *Sampling Requirements*—Procedure to be used (see Section 12).

5.1.8 *Certification Requirements*—Any requirement for certification (see Section 15).

5.1.9 *Miscellaneous Items*—Any other items needing agreement.

5.1.10 *Finish Agreement*—For the purposes of this specification, prior agreement on the nature of the finish is required as items plated in bulk may differ in appearance from those that are rack plated.

6. Coating Requirements and Testing

6.1 *Scope*—This section establishes requirements for electrodeposited nanostructured zinc-nickel alloy coatings. These requirements for acceptance and qualification are to be summarized in a test report for certification. The requirements covered in this section include specifications for substrate preparation, coating composition, definition of the electroplating system, visual quality, coating thickness and adhesion.

6.2 *Substrate Preparation*—The metal to be plated shall be free of flaws and defects that will be detrimental to the zinc-nickel alloy coating.

6.2.1 *Cleaning and Pretreatment*—It shall be subjected to such cleaning, pickling, and electroplating procedures as are necessary to yield deposits with the desired quality.

6.2.2 *Electroplating Application*—The electroplating shall be applied after all basis metal heat treatments have been completed.

NOTE 4—Proper substrate preparation is crucial for adhesion and corrosion resistance. Recommended practices include Practices B183 and B320, and Guides B242 and B322.

6.3 *Coating Composition:*

6.3.1 *Coating Composition*—The zinc-nickel coating shall consist of a composition conforming to the requirements called out in 4.3.

6.3.1.1 *Composition Measurement*—The composition shall be verified using appropriate analytical methods, such as atomic absorption spectrophotometry (AA), inductively coupled plasma (ICP), or X-ray fluorescence (XRF) calibrated to within 10 % of known standards.

6.3.2 *Electroplating System Specifications:*

6.3.2.1 *Bath Composition*—The coating shall be produced from an alkaline aqueous electroplating system as specified by the manufacturer for processing nanostructured zinc-nickel alloy coatings.