# Process Specification for Electroless Nickel Plating

## Engineering Directorate

## Structural Engineering Division

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# Process Specification for Electroless Nickel Plating

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| REVISIONS | | |
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| **VERSION** | **CHANGES** | **DATE** |
| -- | Original version | 5/14/1996 |
| A | Reviewed and update for accuracy; Author changed | 7/21/1999 |
| B | General changes due to reorganization (changed EM to ES). Updated references in 6.0 and updated section 3.0. Removed reference standard SAE AMS 2405B. Updated SAE AMS 2404 to revision E. | 12/14/2005 |
| C | Minor format changes | 3/26/2010 |
| D | Updated SAE AMS 2404E to Revision F | 7/12/2012 |
| E | Re-formatted. Author changed, reviewer added, approver changed. Major Rewrite of the entire document. Updated and added the drawing references. Added information on thickness callouts and classes. Added information on hydrogen embrittlement. Added information on phosphorus content. Added references. Added material requirements. Added process qualification and process information. Added verification requirements for hydrogen bakeouts. Added visual inspection requirements. Added definitions. | 5/15/2020 |
| F | Reviewed as a part of 5 year specification review process.<br><br>Reorganized sections for clarity, moving information into subcategories that more accurately describe the subject matter for additional clarity.<br><br>Added language on Scope, References, added Process Controls section, clarified requirements for processor vs designer. Clarified requirements for providing process verification test data.<br><br>Moved AMS2404 processing requirement reference to requirement section. Reviewed and corrected outdated references. Added minimum part corner radius. | 5/13/2026 |

## 1.0 SCOPE

This process specification establishes the technical requirements associated with the design, fabrication, and chemical processing of electroless nickel parts that are intended for use in human spaceflight applications. This document is intended to be used in conjunction with industry specification SAE AMS2404.

## 2.0 APPLICABILITY

This process specification is applicable for electroless nickel plating of the following materials:

- Steels & Stainless Steels
- Aluminum Alloys
- Copper Alloys
- Nickel & Nickel Alloys
- Cobalt Alloys

This process specification does **NOT** cover electroless nickel plating of:

- Titanium Alloys
- Beryllium Alloys

### 2.1 CLASSIFICATION

Plating covered by this specification shall be classified as follows:

| AMS2404 Class Designation | PRC-5007 Class Designation | Thermal Treatment |
|---|---|---|
| Class 1 | Class 1 | Except for hydrogen embrittlement relief, no post plating thermal treatment. |
| Class 2 | Class 2 | Thermal treatment at 450 °F (232 °C) or above to harden the deposit. |
| Class 3 | Class 3 | Thermal treatment at 375 °F (191 °C) to improve adhesion for nonheat-treatable aluminum alloys. |
| Class 4 | Class 4 | Thermal treatment at 250 °F (121 °C) to improve adhesion for heat- treatable aluminum alloys. |

## 3.0 USAGE

This document supplements SAE AMS2404 by listing specific inspection criteria, sampling, processing controls, and other technical requirements necessary to ensure the performance, reliability, durability, and quality of spaceflight hardware as produced by the National Aeronautics and Space Administration - Johnson Space Center (NASA - JSC) for Human Spaceflight.

The requirements listed within this document are not limited to the fabrication of hardware only at NASA – JSC. This document may be adopted by partner companies, partner organizations, suppliers or subcontractors performing work on behalf of or in service to NASA – JSC. This document is available for public use.

## 3.1 ENGINEERING DRAWING NOTES

The specification number, class, and thickness of electroless nickel plating shall be clearly stated in the Engineering Drawing Note. The drawing shall specify any critical locations where thickness must be controlled. Any required bakeouts shall be specified on the Engineering Drawing.

### Example Drawing Notes

The Engineering Drawing Notes below are provided as examples and do not encompass all materials variations detailed within this document. Additional or alternate notes may be written as needed for different material configurations.

| Note Type | Material | Engineering Drawing Note |
|---|---|---|
| General | Aluminum Alloy (6061-T6 or 7075-T73) | **ELECTROLESS NICKEL PLATE TO A THICKNESS OF 0.0010- 0.0012 INCH PER NASA/JSC PRC-5007, CLASS 4.** |
| General | Alloy Steel | **ELECTROLESS NICKEL PLATE TO A THICKNESS OF 0.0015- 0.0017 INCH PER NASA/JSC PRC-5007, CLASS 1.** |
| Hydrogen Bakeout Required | Alloy Steel (Hardness > 40HRC) | **A HYDROGEN BAKEOUT SHALL BE PERFORMED AT 375 F FOR 23 HOURS WITHIN 4 HOURS AFTER THE COMPLETION OF THE PLATING OPERATION.** |
| Solderability Required | Any | **AN ELECTROLESS NICKEL WITH A PHOSPHORUS CONTENT OF 1-3 % IS REQUIRED FOR SOLDERABILITY.** |

## 3.2 ENGINEERING DESIGN REQUIREMENTS

The following design requirements shall be adhered to when designing parts requiring the use of electroless nickel.

## Plating Thickness

The thickness of electroless nickel shall be in accordance with Table 1.

**Table 1: Thickness Requirements for Electroless Nickel Plate**

| Alloys | Minimum Thickness | Maximum Thickness* |
|---|---|---|
| Ferrous (Steels) | 0.0015 Inches | 0.0030 Inches |
| Aluminum | 0.0010 Inches | 0.0030 Inches |
| Copper-based Nickel-based Cobalt-based | 0.0005 Inches | 0.0030 Inches |

**Note:**
*Pitting and roughness are a process control problem with deposits greater 0.0030 inches.

## Hydrogen Bakeout

Materials whose base materials are high strength ferrous alloys shall require a hydrogen bakeout. Materials that are case hardened with a Hardness/Temper listed in Table 2 shall also require a hydrogen bakeout.

Hydrogen bakeouts shall be performed within 4 hours of completion of the plating operation.

**Table 2: Steels That Require a Hydrogen Bakeout after Electroless Nickel Plate**

| Alloys | Type | Hardness / Temper | Ultimate Tensile Strength |
|---|---|---|---|
| Carbon Steel Low Alloy Steel Martensitic Stainless Steels[1] | Fasteners | ≥ 36 HRC | ≥ 160 ksi |
| Carbon Steel Low Alloy Steel Martensitic Stainless Steels[1] | All Parts Other Than Fasteners | ≥ 40 HRC | ≥ 180 ksi |
| High Strength Precipitation Hardening Stainless Steels[2] | All Parts | See Tempers Listed in AMS2759/9 Table 1 | ≥ 150 ksi |
| Case-Hardened Steel Parts[2] | All Parts | See AMS2759/9 Table 2 | ≥ 255 ksi in the Case |
| Music Wire, 52100, 440C or Any Other Alloy Tempered Below 375°F[2] | All Parts | See AMS2759/9 Table 2 | ≥ 255 ksi |

**Notes:**
[1] Require a post-plating hydrogen baking procedure of 375°F for 23 hours.
[2] Require a post-plating hydrogen baking procedure listed in AMS2759/9.

**Phosphorous Coatings**

Medium phosphorous coatings (5 - 9 % P) are typically used to meet general-purpose requirements for wear and corrosion resistance. If a phosphorus content outside of this range is desired, it shall be explicitly stated on the Engineering Drawing.

A low phosphorous coating (1 - 3% P) shall be used if solderability is required.

A higher phosphorous coating (9 - 13% P) shall be used if increased corrosion resistance is required.

**Surface Roughness**

Smoothness and integrity of the original substrate surface are critical factors in the results of the electroplated surface. Typically, the smoother the original surface, the better the electroless nickel coating.

Poor surface integrity that may entrap fluids (Such as EDM oxide layer, porous casting surfaces, as-made additive manufactured parts, etc.) or poorly machined surfaces (rough & work-hardened material) can make it difficult or nearly impossible to produce a high quality electroless nickel coating.

Because the surface finish can become rougher with thicker coating layers, the post-machining (pre-coating) surface finish requirements shall be adjusted to achieve the post-coating default drawing surface finish of 32 RMS.

For parts receiving Anodize, Alodine, **AND** Electroless Nickel (AKA Triple Dipped Parts), the surface roughness shall be no smoother than 32 RMS.

A surface that is smoother than 32 RMS makes it difficult for the maskants used in the manufacturing process to adhere to the surface and may potentially lead to the maskant or coating peeling off due to a lack of strong mechanical bonds.

The maskant shall be used that is capable of remaining adhered to the masked area and preventing the bleed of processing fluid from coming into contact with a masked surface.

Sealant shall be applied at the interface of two coatings to prevent an electrochemical cell from forming when exposed to fluid, leading to corrosion.

**Minimum Corner Radius**

The minimum corner radius of parts shall be 0.005-0.015 inch such that during the plating process, electroless nickel can be adequately applied to the entirety of the part.

## 3.3 WORK INSTRUCTIONS

Work instructions shall be generated for implementing this process specification. The work instructions shall contain sufficient detail to ensure that the manufacturing process produces consistent, repeatable products that comply with this specification.

For work performed at JSC facilities, these work procedures consist of Detailed Process Instructions (DPI's). For contracted work, the contractor shall be responsible for preparing and maintaining and certifying written work procedures that meet the requirements of this specification.

## 4.0 REFERENCES

The following documents form a part of this specification to the extent they are specified herein. Should a conflict occur between this document and any of the documents referenced or specified herein, this document shall take precedence. Interpretation of this specification shall be at the sole discretion of the NASA- JSC Materials & Process (M&P) Engineering organization.

| | |
|---|---|
| ASTM B117 | Standard Practice for Operating Salt Spray (Fog) Apparatus |
| ASTM B571 | Standard Practice for Qualitative Adhesion Testing of Metallic Coatings |
| ASTM B733 | Standard Specification for Autocatalytic (Electroless) Nickel-Phosphorus Coatings on Metal |
| ASTM E384 | Standard Test Method for Microindentation Hardness of Materials |
| SAE AMS2404 | Plating, Electroless Nickel-Phosphorous |
| SAE AMS2759/9 | Hydrogen Embrittlement Relief (Baking) of Steel P |
| JPR 8500.4 | Engineering Drawing System Manual |
| SOP-007.1 | Preparation and Revision of Process Specifications |

### 4.1 Miscellaneous

MFSA Quality Metal Finishing Guide on Electroless Nickel Plating, 1988.

## 5.0 MATERIALS REQUIREMENTS

The materials used shall meet the requirements of SAE AMS2404.

## 6.0 PROCESS REQUIREMENTS

All parts shall be processed in accordance with SAE AMS2404 per the class specified on the Engineering Drawing.

## 7.0 PROCESS QUALIFICATION

The chemical processor shall be qualified to perform the processes detailed in this specification or in SAE AMS2404 for the applicable class of plating processes being performed.

The process shall have been evaluated and have undergone a qualification testing effort prior to becoming qualified to this document or to SAE AMS2404.

Evidence of that test effort and any disclosure of changes that may have invalidated that qualification test effort shall be made available to the purchaser upon request.

## 8.0 PROCESS VERIFICATION

Following processing, plating quality for each lot of parts shall be verified by visual examination, adhesion tests, and thickness measurements, as specified by SAE AMS2404.

### 8.1 Visual Inspection

The electroless nickel deposits shall be visually inspected per SAE AMS2404 for the following general defects:

- Regions with missing plating
- Poor coverage
- Edge pullback
- Frosted deposits or edges
- Roughness in the deposits
- Streaks in the deposits
- Pitting
- Dull or matte deposit
- Step plating
- Laminar plating
- Dark or black deposits
- Blistering

Acceptance and rejection criteria shall be in accordance with SAE AMS2404.

### 8.2 Thickness Verification

Thickness of the electroless nickel plating shall be measured and on the critical part locations specified on the Engineering Drawings. When no critical part locations are

specified, measurements shall be performed per SAE AMS2404. Thickness measurements shall be performed and recorded by the processor and provided to the purchaser on the Certificate of Analysis (COA).

### 8.3 Hydrogen Bakeout Documentation

When a hydrogen bakeout is required a quality record documenting the time and temperature of the oven (Such as a simple strip chart or a digital file of the bakeout run) shall be supplied to the purchaser by the processor with each oven run.

Hydrogen bakeout shall only be performed in a calibrated oven. A recent calibration record certifying the accuracy of the oven temperature and uniformity shall also be made available to the purchaser upon request.

A laboratory verification test (compared to known standards) of the ppm hydrogen on a simulation coupon (same material and mill lot as the parts being processed) can also be used to verify that hydrogen bakeout procedure was performed.

### 8.4 Adhesion Testing

For each lot of processed parts, test coupons shall be used to verify compliance to the requirements of ASTM B571. Test coupons shall undergo Bend Testing at 180° using a 4T mandrel to ensure good plating deposit adhesion.

Tribology and microhardness tests (ASTM E384) on test specimens may be required to ensure proper wear resistance. These shall be tested by the processor when explicitly indicated on the Engineering Drawing or required by SAE AMS2404.

### 8.5 Process Controls

The processor shall make reasonable efforts to control the processes they are qualified to perform.

The processor shall maintain a Process Control Document (PCD) or detailed written process procedures documenting how they intend to meet the periodic process monitoring requirements.

#### 8.5.1 Process Control Documents (PCDs)

The processor's Process Control Document (PCD) or detailed written process procedures shall address in writing how they intend to meet the requirements of this section. Information such as the inspection frequency and intervals shall be expressly indicated on the process control documents.

#### 8.5.2 Periodic Process Monitoring Requirements

The processor shall indicate how they intend to verify that the following process control requirements are being met:

1) The periodic monitoring, maintenance and verification of proper bath temperature and uniformity.

2) Control, analysis, and regular maintenance of chemistry, pH, and low levels of organic and metallic contamination levels for any processing baths and tanks used for cleaning, pickling (or any other activation methods) and rinsing.

3) Removal of abrasive blasting media prior to plating.

4) A cleaning procedure that shall not produce pitting or intergranular attack of the basis metal and shall preserve dimensional requirements.

5) Application of plating over a clean surface free of water breaks.

**Notes:**

Fluoride levels often deplete in nitric/hydrofluoric pickling tanks over time and the typical titration test for “total acids” analysis is not adequate to check the nitric-to-hydrofluoric ratio.

Periodic removal of the old pickling solution, cleaning of the drained tank, and creating a new pickling tank solution is often the easiest method to ensure the proper nitric-to-hydrofluoric ratio.

#### 8.5.2.1 Periodic Salt Spray Testing

Periodic corrosion testing shall be performed as a process control to verify that plating process is performing adequately. Test coupons shall be exposed to continuous salt spray for 48 hours in accordance with ASTM B117 and evaluated by the processor for compliance. The processor shall disclose to the purchaser any abnormal results that may introduce doubt as to the quality of the plated parts provided to the purchaser.

## 9.0 TRAINING AND CERTIFICATION OF PERSONNEL

This electroless nickel plating process shall be performed by personnel qualified to conduct the process through training or experience. If this process is performed by an outside vendor, the development of an appropriate training program shall be the responsibility of the vendor.

## 10.0 DEFINITIONS

| | |
|---|---|
| **Abrasive Blasting** | A process for cleaning or finishing by means of an abrasive directed at high velocity against a work piece. |
| **Activation** | Elimination of a passive condition on a surface, usually by chemical removal of oxides. |
| **Autocatalytic** | Deposition of a metal coating by controlled chemical reduction, catalyzed by the metal or alloy being deposited. |
| **Blister** | A dome-shaped imperfection or defect, resulting from loss of adhesion between a metallic deposit and the substrate. |
| **Electroless Plating** | Deposition of a metallic coating by a controlled chemical reduction that is catalyzed by the metal or alloy being deposited. |
| **Pickling** | The removal of oxides or other compounds from a metal surface by means of a chemical solution. |
| **Pit** | A small depression or cavity produced in a metal surface during deposition or by corrosion. |
| **Substrate** | The material, component, or workpiece to which the nickel plating is deposited. |
| **Water Break** | The appearance of a discontinuous film of water on a surface, signifying non-uniform wetting and usually associated with a surface contamination. |
| **Conditional Language** | "shall" or “must” indicates a requirement;<br>"should" indicates a recommendation;<br>"may" indicates a permission;<br>"can" indicates a possibility or a capability. |