Process Specification for Electroless Nickel Plating

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REVISIONS		
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

1.0 SCOPE

This process specification establishes additional requirements to AMS 2404J for electroless nickel plating in the manufacture of JSC flight hardware.

2.0 APPLICABILITY

This process specification applies to electroless nickel plating for use on steels, stainless steels, aluminum alloys, copper alloys, nickel and nickel alloys and cobalt alloys. This PRC does not cover electroless nickel plating for use on titanium alloys and beryllium alloys.

3.0 USAGE

This process specification and thickness (see Table 1) shall be called out on the engineering drawing by using a drawing note. In addition, the AMS 2404J class shall be called out in the drawing note.

An example for an alloy steel:

ELECTROLESS NICKEL PLATE TO A THICKNESS OF 0.0015-0.0017 INCH PER NASA/JSC PRC-5007, CLASS 1.

An example for a 6061-T6 or 7075-T73 aluminum alloy:

ELECTROLESS NICKEL PLATE TO A THICKNESS OF 0.0010-0.0012 INCH PER NASA/JSC PRC-5007, CLASS 4.

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

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

If there are critical locations on thickness, the drawing needs to specify them.

Plating covered by this specification is classified as follows:

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

If the base material is a high strength ferrous alloy or case hardened and has a Hardness/Temper as defined in Table 2, a hydrogen bakeout shall be required within four hours after the 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**	Fasteners	≥ 36 HRC	≥ 160 ksi
Carbon Steel, Low Alloy Steel, & Martensitic Stainless Steels**	All Parts Other Than Fasteners	≥ 40 HRC	≥ 180 ksi
High Strength Precipitation Hardening Stainless Steels***	All Parts	See Tempers Listed in Table 1 Located in AMS 2759/9	≥ 150 ksi
Case-hardened Steel Parts***	All Parts	See Table 2 Located in AMS 2759/9	≥ 255 ksi in the Case
Music Wire, 52100, 440C, or Any Other Alloy Tempered Below 375 °F***	All Parts	See Table 2 Located in AMS 2759/9	≥ 255 ksi

**Require a post-plating hydrogen baking procedure of 375 ^{o}F for 23 hours.
*** Require a post-plating hydrogen baking procedure listed in AMS 2759/9.

An example for an alloy steel with a hardness greater than 40 HRC:

A HYDROGEN BAKEOUT SHALL BE PERFORMED AT 375 F FOR 23 HOURS WITHIN 4 HOURS AFTER THE COMPLETION OF THE PLATING OPERATION.

The medium phosphorous coatings (5 - 9 % P) are most widely used to meet the general-purpose requirements of wear and corrosion resistance. If a phosphorus content outside of this range is desired, must be specified on the drawing.

A low phosphorous coating 1 - 3% P is used for solderability. An example of a low phosphorus drawing callout is as follows:

AN ELECTROLESS NICKEL WITH A PHOSPHORUS CONTENT OF 1-3 % IS REQUIRED FOR SOLDERABILITY.

A higher phosphorous coating in the range of 9 - 13% P is increased corrosion resistance.

3.1 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

SAE AMS 2404J	Electroless Nickel Plating
SOP-007.1	Preparation and Revision of Process Specifications
JPR 8500.4	Engineering Drawing System Requirements
SAE AMS 2759/9	Hydrogen Embrittlement Relief (Baking) of Steel Parts
ASTM B733	Autocatalytic (Electroless) Nickel-Phosphorus Coatings on Metal
ASTM B571	Qualitative Adhesion Testing of Metallic Coatings ASTM
E384	Standard Test Method for Microindentation Hardness of Materials

ASTM B117 Operating Salt Spray (Fog) Apparatus

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

5.0 MATERIALS REQUIREMENTS

The materials used shall meet the requirements of SAE AMS 2404J.

Smoothness and integrity of the original substrate surface are critical factors in final results of the electroplated surface. Typically, the smoother the original surface, the better the electroless nickel coating. Since surface finish can become rougher with thicker coating layers, post-machining (pre-coating) surface finish requirements need to be adjusted to achieve the post-coating default drawing surface finish of 32 RMS. In addition, poor surface integrity that might entrap fluids (EDM oxide layer, porous casting surfaces, as-made additive manufactured parts, etc.) or very poorly machined surfaces (rough & work-hardened material) can make it difficult-to- impossible to produce a high quality electroless nickel coating.

6.0 PROCESS REQUIREMENTS

Periodic chemical analysis shall be performed to insure:

1. Proper overall bath chemistry
2. Proper pH of the bath
3. Low levels of organic contamination
4. Low levels of metallic contamination

The JSC DPI or vendor’s written procedure shall include:

- Monitoring of Proper bath temperature and uniformity and must be periodically checked and maintained.

- Tanks used for cleaning, pickling (or other activation methods) and rinsing are critical for proper surface preparation for plating. These tanks shall be controlled and maintained for proper chemistry, pH and low contamination levels using documented procedures.

- Abrasive blasting media to be removed prior to plating.

- The plating shall be applied over a surface free from water breaks. The cleaning procedure shall not produce pitting or intergranular attack of the basis metal and shall preserve dimensional requirements.

Please note that 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 out the drained tank, and creating a new pickling tank solution is often the easiest method to insure the proper nitric-to-hydrofluoric ratio.

7.0 PROCESS QUALIFICATION

Adhesion shall meet the requirements of ASTM B571 bend test 180 degrees with 4T mandrel to insure good plating deposit adhesion. Plating adhesion can be a problem with aluminum alloys.

Tribology and microhardness tests (ASTM E384) on test specimens may be required to insure proper wear resistance. Design Engineers shall consult with the responsible Materials and Processes Organization for severe wear applications where these tests may be required.

Periodic corrosion test panel shall be periodically tested 48 hours to continuous salt spray corrosion test conducted in accordance with ASTM B117.

8.0 PROCESS VERIFICATION

The process verification shall include visual examination, adhesion tests, and thickness measurements, as specified by AMS 2404J.

The electroless nickel deposits shall be visually examined for the following general problems:

1. Regions with missing plating
2. Poor coverage
3. Edge pullback
4. Frosted deposits or edges
5. Roughness in the deposits
6. Streaks in the deposits
7. Pitting
8. Dull or matte deposit
9. Step plating
10. Laminar plating
11. Dark or black deposits
12. Blistering

The thickness of the electroless nickel plating shall be measured in critical locations as noted on the drawing. These measurements shall be performed and recorded by the vendor.

If a hydrogen bakeout is performed, a quality record documenting the time and temperature shall be supplied. A simple strip chart on the oven is adequate to

document the process. A digital file of the bakeout run is also adequate. In addition, a recent record certifying the accuracy of the oven temperature and uniformity is needed.

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.

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.