AEROSPACE MATERIAL SPECIFICATION

AMS2404™	REV. K
Issued 1957-09 Revised 2024-10 Superseding AMS2404J	

Plating, Electroless Nickel-Phosphorous

RATIONALE

AMS2404K is the result of a Five-Year Review and update of this specification with changes to Ordering Information, Purpose (see 1.1), Classification (see 1.3), Stress-Relief Treatment (see 3.1.1.3), Fixture/Contact Locations (see 3.1.2), Procedure (see 3.2.1.1), Heat Treatment for Hardness or Adhesion Enhancement (see 3.3.2), Thickness (see 3.4.1), Adhesion (see 3.4.2), Corrosion Resistance (see 3.4.3), Quality (3.5), Periodic Tests (see 4.2.2), Corrosion Testing (see 4.3.1.3), Adhesion Test (see 4.3.1.6), Sample Quantity (see 4.3.2.1), control factors (see 4.4.3), and Notes (see 8.2 and 8.14).

NOTICE

ORDERING INFORMATION: The following information shall be provided to the plating processor by the purchaser:

1. The purchase order shall specify not less than the following:

- AMS2404K and class (see 1.3)
- Plating thickness desired (see 3.4.1 and 8.13)
- Basis metal to be plated
- Tensile strength or hardness of the basis metal (steel alloys only)
- If pre-plate stress relief is to be performed by plating processor and if different from 3.1.1, time and temperature are to be specified
- If steel parts are to be machined, ground, cold formed, or cold straightened after heat treatment (see 3.1.1)
- If steel parts have been shot peened, specify if required stress relief has been completed (see 3.1.1.3)
- Optional: Fixture/electrical contact locations, when not specified (see 3.1.2)
- Special features, geometry, or processing present on parts that requires special attention by the plating processor
- Hydrogen embrittlement relief to be performed by the plating processor if different from 3.3.1
- Post-plate thermal treatment (see 3.3.2) if different; time and temperature to be specified

TO PLACE A DOCUMENT ORDER: **Tel: 877-606-7323 (inside USA and Canada)**
Tel: +1 724-776-4970 (outside USA)
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SAE WEB ADDRESS: **http://www.sae.org**

For more information on this standard, visit
https://www.sae.org/standards/content/AMS2404K/

- Post-plate Class 5 thermal treatment (see 3.3.2.4) when specified for titanium parts that have been shot peened, if different, temperature to be specified
- Optional: Plating on steel and nickel alloys tested for adhesion using the heat test in 3.4.2.2. For alloys other than steel and nickel, temperatures and times are to be specified.
- Optional: Composition (see 3.4.7)
- Optional: Hydrogen embrittlement acceptance testing requirements (see 4.3.1.4)
- Optional: Periodic testing frequency (see 4.2.2) and sample quantity (see 4.3.2)
- Optional: Corrosion testing exposure time and plating thickness to be specified for base material alloys other than steel alloys (see 3.4.3 and 8.12)
- Quantity of pieces to be plated
- Shot peening, if required, on steel parts having a hardness of 40 HRC or above (see 8.11)
- Special processing, when required, to avoid or remove discoloration (see 3.5)

2. Parts manufacturing operations such as heat treating, forming, joining, and media finishing can affect the condition of the substrate for plating or could adversely affect the plated part if performed after plating. The sequencing of these types of operations should be specified by the cognizant engineering organization or the purchaser and is not controlled by this specification.

3. The parts manufacturer shall ensure that surfaces of metal parts supplied to the processor are free from blemishes, pits, tool marks, and other irregularities that will affect the quality of the finished parts (see 3.5.2).

1. SCOPE

1.1 Purpose

This specification covers the requirements for electroless nickel with phosphorus deposited on various materials.

1.2 Application

This deposit has been used typically to provide a uniform buildup on intricate shapes, to improve wear and/or corrosion resistance, or to improve solderability on or for selected materials, but usage is not limited to such applications. The deposit has been used in service up to 1000 °F (538 °C), although wear and/or corrosion resistance may degrade as service temperature increases.

1.2.1 Application of electroless nickel plating to steel parts having a hardness of 46 HRC (ultimate tensile strength of 220 ksi [1517 MPa]) or higher shall not be performed unless authorized by the design documentation or specific approval has been received from the cognizant engineering organization (CEO).

1.3 Classification

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 non-heat-treatable aluminum alloys and beryllium alloys.

Class 4: Thermal treatment at 250 °F (121 °C) to improve adhesion for heat-treatable aluminum alloys.

Class 5: Thermal treatment at 450 °F (232 °C) or above for required adhesion on titanium alloys, when Class 2 heat treatment for deposit hardening is not required.

Unless a specific class is specified, Class 1 shall be supplied.

1.4 Safety - Hazardous Materials

While the materials, methods, applications, and processes described or referenced in this specification may involve the use of hazardous materials, this specification does not address the hazards that may be involved in such use. It is the responsibility of the user to ensure familiarity with the safe and proper use of any hazardous materials and to take necessary precautionary measures to ensure the health and safety of all personnel involved.

2. APPLICABLE DOCUMENTS

The issue of the following documents in effect on the date of the purchase order forms a part of this specification to the extent specified herein. The supplier may work to a subsequent revision of a document unless a specific document issue is specified. When the referenced document has been cancelled and no superseding document has been specified, the last published issue of that document shall apply.

2.1 SAE Publications

Available from SAE International, 400 Commonwealth Drive, Warrendale, PA 15096-0001, Tel: 877-606-7323 (inside USA and Canada) or +1 724-776-4970 (outside USA), www.sae.org.

AMS2430	Shot Peening
AMS2432	Shot Peening, Computer Monitored
AMS2451	Plating, Brush, General Requirements
AMS2546	Laser Peening
AMS2750	Pyrometry
AMS2759/9	Hydrogen Embrittlement Relief (Baking) of Steel Parts
AMS-C-26074	Electroless Nickel Coatings
AMS-R-81841	Rotary Flap Peening of Metal Parts
ARP4992	Periodic Test for Processing Solutions
AS2390	Chemical Process Test Specimen Material
AS7766	Terms Used in Aerospace Metals Specifications

2.2 ASTM Publications

Available from ASTM International, 100 Barr Harbor Drive, P.O. Box C700, West Conshohocken, PA 19428-2959, Tel: 610-832-9585, www.astm.org.

ASTM B117	Operating Salt Spray (Fog) Apparatus
ASTM B253	Preparation of Aluminum Alloys for Electroplating
ASTM B374	Standard Terminology Relating to Electroplating

ASTM B487 Measurement of Metal and Oxide Coating Thicknesses by Microscopical Examination of Cross Section

ASTM B499 Measurement of Coating Thicknesses by the Magnetic Method: Nonmagnetic Coatings on Magnetic Basis Metals

ASTM B567 Measurement of Coating Thickness by the Beta Backscatter Method

ASTM B568 Measurement of Coating Thickness by X-Ray Spectrometry

ASTM B571 Qualitative Adhesion Testing of Metallic Coatings

ASTM B636 Measurement of Internal Stress of Plated Metallic Coatings with the Spiral Contractometer

ASTM B748 Measurement of Thickness of Metallic Coatings by Measurement of Cross Section with a Scanning Electron Microscope

ASTM B764 Simultaneous Thickness and Electrode Potential Determination of Individual Layers in Multilayer Nickel Deposit (STEP Test)

ASTM E384 Microindentation Hardness of Materials

ASTM F519 Mechanical Hydrogen Embrittlement Evaluation of Plating/Coating Processes and Service Environments

2.3 U.S. Government Publications

Copies of these documents are available online at https://quicksearch.dla.mil.

MIL-DTL-26074 Coatings, Electroless Nickel, Requirements for

2.4 Definitions

Terms used in AMS are defined in AS7766.

3. TECHNICAL REQUIREMENTS

3.1 Preparation

3.1.1 Stress-Relief Treatment

All steel parts having a hardness of 40 HRC and above and that are machined, ground, cold formed, or cold straightened after heat treatment shall be cleaned to remove surface contamination and thermally stress relieved before plating. (Residual tensile stresses have been found to be damaging during electroplating.) Furnaces used for stress relief shall be controlled per AMS2750. The minimum requirements shall be Class 5 with Type D instrumentation. Temperatures to which parts are heated shall be such that stress relief is obtained while still maintaining hardness of parts within drawing limits. Unless otherwise specified, the following treatment temperatures and times shall be used:

3.1.1.1 For parts, excluding nitrided parts, having a hardness of 55 HRC and above, including carburized and induction-hardened parts, stress relieve at 275 °F ± 25 °F (135 °C ± 14 °C) for 5 to 10 hours.

3.1.1.2 For parts having a hardness less than 55 HRC, stress relieve at 375 °F ± 25 °F (191 °C ± 14 °C) for a minimum of 4 hours. Nitrided parts fall into this category. Higher temperatures shall be used only when specified or approved by the CEO.

3.1.1.3 For peened parts, if stress-relief temperatures above 375 °F (191 °C) are specified, the stress relieve shall be performed prior to peening.

3.1.2 Fixture Contact Locations

3.1.2.1 Except for barrel plating, for parts that are to be plated all over, and contact locations are not specified, contact locations shall be at the discretion of the processor.

3.1.2.2 For parts that are not to be plated all over, and contact locations are not specified, contact locations may be in areas on which the plating is not required or may be in areas being plated provided the parts are moved to prevent contact marks/voids within the plating.

3.1.2.3 Alternative methods for process completion of fixture contact points is permitted when approved by the CEO (see 8.14).

3.1.3 Cleaning

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.

3.2 Procedure

3.2.1 Plating shall be performed by chemical deposition of a nickel-phosphorus plate onto a properly prepared surface. For example, an activating treatment such as nickel strike may be applied.

3.2.1.1 Aluminum alloys may be zincate treated and copper plated in accordance with ASTM B253 immediately prior to electroless nickel plating.

3.2.2 Plated parts shall be removed from the plating solution, thoroughly rinsed, and dried.

3.2.3 Double plating and spotting-in are prohibited (see 8.9).

3.3 Post-Treatment

3.3.1 Hydrogen Embrittlement Relief

Treatment of steel parts shall be in accordance with AMS2759/9. Other metals and alloys do not require hydrogen embrittlement relief baking.

3.3.2 Heat Treatment for Hardness or Adhesion Enhancement

When Class 2, 3, 4, or 5 is specified, parts, after plating, rinsing, and drying, shall be thermally treated. Furnaces used for this purpose shall be controlled in accordance with AMS2750 using Type D instrumentation and the minimum Class specified.

3.3.2.1 When Class 2 is specified, parts shall be heated to a selected temperature within the range of 450 to 800 °F (232 to 427 °C) and held at the selected temperature ±15 °F (±8 °C) for sufficient time to increase hardness of the deposit (see 3.4.4 and 8.5). Hydrogen embrittlement relief (see 3.3.1) may be omitted if Class 2 hardening is started within 4 hours after plating.

3.3.2.2 When Class 3 is specified, parts shall be heated to 375 °F ± 15 °F (191 °C ± 8 °C) for 1 to 1.5 hours.

3.3.2.3 When Class 4 is specified, parts shall be heated to 250 °F ± 10 °F (121 °C ± 6 °C) for 1 to 1.5 hours.

3.3.2.4 When Class 5 is specified, parts shall be heated to a selected temperature within the range of 450 to 800 °F (232 to 427 °C) and held at ±15 °F (±8 °C) for 1 to 5 hours.

3.4 Properties

Plating shall conform to the following requirements:

3.4.1 Thickness

Unless otherwise specified, minimum thickness of the nickel plate shall be 0.0010 inch (0.025 mm) for aluminum-based alloys, 0.0005 inch (0.013 mm) for copper, nickel, cobalt, titanium, and beryllium alloys, and 0.0015 inch (0.038 mm) for iron-based alloys. Thickness shall be determined in accordance with ASTM B487, ASTM B499, ASTM B567, ASTM B568, ASTM B748, ASTM B764, or by a dimensional gauging method provided the resolution of the measuring instrument is ten times more precise than the attribute being measured or by other method acceptable to the CEO.

3.4.2 Adhesion

Adhesion of the plate shall conform to 3.4.2.1 or when acceptable to the CEO (see 3.4.2.2).

3.4.2.1 Adhesion testing shall be in accordance with the ASTM B571 single bend test method with the specimens, as in 4.3.1.6, bent rapidly over a mandrel 4X the thickness of the test specimen. The portion of the specimen that is bent shall not show any separation or peeling of the plate when examined at low magnification, such as 4X. Except at the very edges of the test specimens at the point of bending, the plate shall not detach from the base metal using a sharp instrument. Formation of cracks that do not result in flaking or blistering of the plating is acceptable.

3.4.2.2 Plating on steel and nickel alloys shall comply with all criteria of 3.5 after being heated in air, preferably in a circulating-air furnace, at 700 °F ± 15 °F (371 °C ± 8 °C) for 23 hours ± 1 hour followed by heating at 1000 °F ± 15 °F (538 °C ± 8 °C) for 60 minutes ± 5 minutes. Temperatures and times for other alloys shall be specified by the CEO.

3.4.3 Corrosion Resistance

Carbon and low-alloy steel parts or test panels (see 4.3.1.3) having minimum plating thickness of 0.001 inch (25 µm) shall, after plating and embrittlement relieving, show no visual evidence of corrosion (i.e., brownish-red rust) of the basis metal after being subjected for not less than 48 hours to a continuous salt-spray corrosion test conducted in accordance with ASTM B117. Corrosion resistance of plate applied to other base material alloys may be specified by the CEO (see 8.12).

3.4.4 Hardness

Class 2 plating shall be not lower than 800 HK100 (773 HV100), or equivalent, determined in accordance with ASTM E384 (see 3.3.2.1).

3.4.5 Hydrogen Embrittlement

The plating process after baking shall not cause hydrogen embrittlement in steel parts, determined in accordance with 4.3.1.4.

3.4.6 Internal Stress

The CEO may specify a compressive stress value for Class 1 plating up to 10 ksi (69 MPa), determined in accordance with ASTM B636 or other test method acceptable to the CEO.

3.4.7 Composition

The CEO may specify a phosphorus content range of the deposit. When specified, the composition of the deposit shall be determined by a method acceptable to the CEO.

3.5 Quality

3.5.1 Plating, as received by the purchaser, shall be smooth, continuous, and uniform in appearance and shall be free from frosty areas, pinholes, blisters, and other imperfections detrimental to usage of the plate. Slight staining or discoloration is permissible. Class 2 and Class 5 plating and non-plated exposed base material may discolor from thermal treatment.

3.5.2 Imperfections in appearance that arise from surface conditions of the substrate, such as weld areas, variations in surface finish roughness, porosity, scratches, or inclusions, that persist in the finished plating/coating despite observance of industry-accepted plating practices shall not be considered as cause for rejections (see 8.2).

3.5.3 If the plating is specified to be subsequently ground or machined, the above requirements are not required to be inspected for.

4. QUALITY ASSURANCE PROVISIONS

4.1 Responsibility for Inspection

The processor shall supply all samples for the processor's test and shall be responsible for the performance of all required tests. Parts, if required for tests, shall be supplied by the purchaser. The CEO reserves the right to sample and to perform any confirmatory testing deemed necessary to ensure that plating conforms to specified requirements.

4.2 Classification of Tests

4.2.1 Acceptance Tests

Thickness (see 3.4.1) and quality (see 3.5) are acceptance tests and shall be performed on parts, or specimens representing parts, when permitted herein on each lot (see 4.3.1.2).

4.2.2 Periodic Tests

Corrosion resistance, when required (see 3.4.3), is a periodic test and shall be performed at least monthly unless frequency of testing is specified by the CEO. Adhesion (see 3.4.2) is a periodic test that shall be performed no less than daily for each generic class of alloy as defined by AS2390 processed during that day. Internal stress, if specified (see 3.4.6), and composition, if specified (see 3.4.7), are periodic tests and shall be performed at least quarterly unless frequency of testing is specified by the CEO. Tests of cleaning and plating solutions are periodic tests and shall be performed at a frequency established by the processor unless frequency of testing is specified by the CEO (see 4.4.3 and 8.3). Testing for hydrogen embrittlement (see 3.4.5) is a periodic test and shall be performed in accordance with 4.3.1.4 at least once in each month that parts 36 HRC and over are plated. Testing for hardness (see 3.4.4) is a periodic test and shall be performed at least once in each month that Class 2 parts are processed.

4.2.2.1 Periodic testing may be suspended in any test period when parts are not processed but shall be performed before or at time such processing is resumed. Preproduction testing may be required by the CEO upon resumption of processing.

4.2.3 Preproduction Tests

All technical requirements are preproduction tests and shall be performed prior to or on the initial shipment of plated parts to a purchaser, when a change in material and/or processing requires approval by the CEO (see 4.4.2), and when the CEO requires confirmatory testing.

4.3 Sampling for Tests

4.3.1 Specimen Configuration

4.3.1.1 Nondestructive testing shall be performed wherever practical. Except as noted below, actual parts shall be selected as samples for tests.

4.3.1.2 Except as specified below, test specimens shall be made of the same generic class of alloy as the parts, established in accordance with AS2390, distributed within the lot, cleaned, plated, and post-treated with the parts. Separate test specimens shall be used when plated parts are of such configuration or size as to be not readily adaptable to specified tests, when nondestructive testing is not practical on actual parts, or it is not economically acceptable to perform destructive tests on actual parts.

4.3.1.3 Corrosion Testing

In any month that carbon and low-alloy steel parts are plated, test specimens shall be low-carbon or low-alloy steel 0.025 inch (0.6 mm) minimum thickness and not less than 4 inches (102 mm) wide by 6 inches (152 mm) long. When corrosion testing is specified for other base materials (see 3.4.3), specimens shall be of the same generic class of alloy as the parts being plated, and the test frequency and specimen size shall be the same as that specified for steel.

4.3.1.4 Hydrogen Embrittlement Test

Test shall be in accordance with the requirements of ASTM F519, Type 1a.1 using round notched specimens, unless a different specimen is specified by the CEO, stressed in tension under sustained load. For test purposes, the plating thickness shall be 0.001 to 0.002 inch (25 to 51 µm) measured on the smooth section of the test specimen but with visual evidence of plating at the root of the notch. Testing beyond the 200-hour test period is not required.

4.3.1.5 Internal Stress Test

When an internal stress requirement is imposed by the CEO, test specimens shall be plated to a thickness not less than 0.0006 inch (15 µm) and shall conform to ASTM B636 or other test method acceptable to the CEO.

4.3.1.6 Adhesion Test

Test specimens for adhesion testing (see 3.4.2) shall be made of the same generic class of alloy as defined by AS2390 and processed the same as the parts they represent. The test specimens shall be 0.025 inch (0.6 mm) minimum thickness and not less than 1 x 4 inches (25 x 102 mm).

4.3.2 Sample Quantity

4.3.2.1 Acceptance tests shall be in accordance with Table 1. A lot is a group of parts, all of the same part number, processed through the same chemical solutions in the same tanks under the same conditions, which have completed the chemical processing within a period of 24 hours of each other and are presented to inspection at the same time.

Table 1 - Sampling for acceptance tests

Number of Parts in Lot	Quality	Thickness
Up to 7	All	All or 3[(1)]
8 to 15	7	4
16 to 40	10	4
41 to 110	15	5
111 to 300	25	6
301 to 500	35	7
501 to 700	50	8
701 to 1200	75	10
Over 1200	125	15

(1) Whichever is less.