AEROSPACE MATERIAL SPECIFICATION

AMS2404	REV. G

Issued 1957-09
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Superseding AMS2404F and AMS-C-26074

Plating, Electroless Nickel

RATIONALE

AMS2404G results from a Five Year Review and includes updated requirements for stress relief of steels prior to plating.

NOTICE

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

NOTE: This specification has been used to supersede AMS-C-26074 which employs Grade designations to convey thickness requirements. See 8.13 for a complete cross reference from AMS-C-26074 callouts to the technically identical provisions within this specification in order to comply with the following purchase order requirements.

1) Purchase order shall specify not less than the following:
   - AMS2404G and Class (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)
   - Pre-plate stress relief to be performed by plating processor (time and temperature) if different from 3.1.1
   - Special features, geometry or processing present on parts that requires special attention by the plating processor
   - Hydrogen embrittlement relief to be performed by plating processor if different from 3.3.1
   - Optional: Composition (3.4.7)
   - Optional: Hydrogen embrittlement acceptance testing requirements. See 8.13.1
   - Optional: Periodic testing frequency (4.2.2) and sample quantity (4.3.2)
   - Quantity of pieces to be plated
   - Shot peening, if required, on steel parts having a hardness of 40 HRC or above. See 8.12.

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

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**

SAE values your input. To provide feedback on this Technical Report, please visit
http://www.sae.org/technical/standards/AMS2404G

1. SCOPE

1.1 Purpose

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

1.2 Application

This deposit has been used typically to provide a uniform build-up 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 (540 °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.

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 nonheat-treatable aluminum alloys and beryllium alloys.

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

1.3.1 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 which 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 724-776-4970 (outside USA), www.sae.org.

AMS2759/9 Hydrogen Embrittlement Relief (Baking) of Steel Parts

AMS-C-26074 Electroless Nickel Coatings

AS2390 Chemical Process Test Specimen Material

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 B 117 Operating Salt Spray (Fog) Testing Apparatus

ASTM B 487 Measurement of Metal and Oxide Coating Thicknesses by Microscopical Examination of a Cross Section

ASTM B 499 Measurement of Coating Thicknesses by the Magnetic Method: Nonmagnetic Coatings on Magnetic Basis Metals

ASTM B 567 Method for Measurement of Coating Thickness by the Beta Backscatter Method

ASTM B 568 Measurement of Coating Thickness by X-Ray Spectrometry

ASTM B 571 Qualitative Adhesion Testing of Metallic Coatings

ASTM B 636 Measurement of Internal Stress of Plated Metallic Coatings with the Spiral Contractometer

ASTM B 748 Measurement of Thickness of Metallic Coatings by Measurement of Cross Section with a Scanning Electron Microscope

ASTM B 764 Simultaneous Thickness and Electrochemical Potential Determination of Individual Layers in Multilayer Nickel Deposit (STEP Test)

ASTM E 384 Microhardness of Materials

ASTM F 519 Mechanical Hydrogen Embrittlement Evaluation of Plating/Coating Processes and Service Environments

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 (135 °C ± 14) for 5 to 10 hours.

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

3.1.1.3 For peened parts

If stress relief temperatures above 375 °F (191 °C) are elected, the stress relieve shall be performed prior to peening or the cognizant engineering organization shall be consulted and shall approve the stress relief temperature.

3.1.2 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 coating onto a properly prepared surface.

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 8.9.1.

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, or 4 is specified, parts, after plating, rinsing, and drying, shall be thermally treated.

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 for sufficient time to increase hardness of the deposit. See 3.4.4 and 8.6. Hydrogen embrittlement relief (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 (191 °C ± 8) for 1 to 1.5 hours.

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

3.4 Properties

Plating shall conform to the following requirements:

3.4.1 Unless otherwise specified, minimum thickness of the nickel coating 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 B 487, ASTM B 499, ASTM B 567, ASTM B 568, ASTM B 748, ASTM B 764, or by other method acceptable to the cognizant engineering organization. See 8.13 for thickness requirements specified by AMS-C-26074 Grade designations.

3.4.2 Adhesion shall meet the requirements of ASTM B 571 bend test 180 degree with 4T mandrel or, when acceptable to the cognizant engineering organization, 3.4.2.1. may be used to demonstrate acceptable adhesion.

3.4.2.1 Plating on steel alloys shall comply with all criteria of 3.5 after being heated in air, preferably in a circulating-air furnace, at 700 °F ± 15 (371 °C ± 8) for 23 hours ± 1 followed by heating at 1000 °F ± 15 (538 °C ± 8) for 60 minutes ± 5.

3.4.3 Corrosion Resistance

Carbon and low-alloy steel parts or test panels (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 of the basis metal after being subjected for not less than 48 hours to continuous salt spray corrosion test conducted in accordance with ASTM B 117. See 4.3.1.3.

3.4.3.1 When AMS-C-26074 Grade A is specified, aluminum alloy parts or test panels having minimum plating thickness of 0.0010 inch (25 µm), shall, after plating and thermal treatment, show no visual evidence of corrosion of the basis metal after being subjected for not less than 100 hours to continuous salt spray corrosion test conducted in accordance with ASTM B 117.

3.4.3.2 When AMS-C-26074 Grade B is specified, corrosion resistance testing does not apply.

3.4.3.3 When AMS-C-26074 Grade C is specified, carbon and low alloy steel parts or test panels having minimum plating thickness of 0.0015 inch (38 µm), shall, after plating and embrittlement-relieving, show no visual evidence of corrosion of the basis metal after being subjected for not less than 100 hours to continuous salt spray corrosion test conducted in accordance with ASTM B 117.

3.4.4 Hardness

Class 2 plating shall be not lower than 800 HK100 (773HV100), or equivalent, determined in accordance with ASTM E 384. See 3.3.2.1.

3.4.5 Hydrogen Embrittlement

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

3.4.6 Internal Stress

The cognizant engineering organization may specify a compressive stress value for Class 1 plating up to 10 ksi (69 MPa), determined in accordance with ASTM B 636, or other test method acceptable to the cognizant engineering organization.

3.4.7 Composition

The cognizant engineering organization 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 cognizant engineering organization.

3.5 Quality

Plating, as received by 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 plating may discolor from thermal treatment.

4. QUALITY ASSURANCE PROVISIONS

4.1 Responsibility for Inspection

The processor shall supply all samples for processor's test and shall be responsible for the performance of all required tests. Parts, if required for tests, shall be supplied by purchaser. The cognizant engineering organization 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 (3.4.1), adhesion (3.4.2), and quality (3.5) are acceptance tests and shall be performed on parts, or samples representing parts when permitted herein on each lot. See 4.3.1.2.

4.2.2 Periodic Tests

When corrosion resistance testing is required by 3.4.3, corrosion resistance (3.4.3) is a periodic test and shall be performed at least monthly unless frequency of testing is specified by the cognizant engineering organization. Internal stress, if specified (3.4.6), and composition, if specified (3.4.7) are periodic tests and shall be performed at a frequency selected by the processor unless frequency of testing is specified by the cognizant engineering organization. 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 cognizant engineering organization. See 8.4 and 4.4.3. Testing for hydrogen embrittlement (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 (3.4.4) is a periodic test and shall be performed at least once in each month.

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 cognizant engineering organization (4.4.2), and when the cognizant engineering organization requires confirmatory testing.

4.3 Sampling for Tests

4.3.1 Sample 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, acceptance 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 (when required by 3.4.3)

In any month (or other specified test period) that ferrous alloy parts are plated, test panels 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. Aluminum alloy test panels, (same panel size as for steel) made of either 2024-T3 or the same generic class of alloy as the parts being plated, shall be used in any month (or other specified test period) when aluminum alloy parts are plated.

4.3.1.4 Hydrogen Embrittlement Test

Test shall be in accordance with the requirements of ASTM F 519 Type 1a.1 using round notched specimens, unless a different specimen is specified by the cognizant engineering organization, 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 cognizant engineering organization, test specimens shall be plated to a thickness not less than 0.0006 inch (15 µm) and shall conform to ASTM B 636 or other test method acceptable to the cognizant engineering organization.

4.3.2 Sample Quantity

4.3.2.1 Acceptance tests shall be in accordance with Table 1; a lot shall be all parts of the same part number, plated to the same range of plate thickness in the same solutions, in each 8 hours of continuous production, and presented for processor's inspection at one time.

TABLE 1 - SAMPLING FOR ACCEPTANCE TESTS

Number of Parts in Lot	Quality	Thickness and Adhesion
Up to 7	All	All or 3*
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

*Whichever is less

4.3.2.2 Periodic Tests

Sample size shall be four for corrosion resistance (when required by 3.4.3). For hydrogen embrittlement, sample size shall be as specified in ASTM F 519 unless otherwise specified by the cognizant engineering organization. Sample quantity for other tests and frequency of testing shall be at the discretion of the processor unless otherwise specified by the cognizant engineering organization or herein.

4.4 Approval

4.4.1 The process and control factors, a preproduction part, or both, whichever is specified, shall be approved by the cognizant engineering organization before production parts are supplied.

4.4.2 If the processor makes a significant change to any material, process, or control factor from that which was used for process approval, all preproduction tests shall be performed and the results submitted to the cognizant engineering organization. A significant change is one which in the judgment of the cognizant engineering organization could affect the properties or performance of the parts.

4.4.3 Control factors shall include, but not be limited to, the following:

Surface preparation, including strike if used
Plating bath composition and composition control limits
Plating bath temperature limits and controls
Thermal post treatment times and temperatures
Method for testing plate thickness
Method for testing plate adhesion
Method of stripping
Periodic test plan for cleaning and processing solutions. See 8.4.

4.5 Reports

The processor of plated parts shall furnish with each shipment a report stating that the parts have been processed and tested in accordance with specified requirements and that they conform to the acceptance test requirements. This report shall include the purchase order number, lot number, AMS2404G, part number, and quantity.

4.6 Resampling and Retesting

4.6.1 If any acceptance test fails to meet specified test requirements, the parts in that lot may be stripped, pretreated, plated, post treated as defined herein, and retested. Alternatively, all parts in the lot may be inspected for the nonconforming attribute, and the nonconforming parts may be stripped, pretreated, plated, post treated as defined herein, and retested.

4.6.1.1 When stripping is performed, the method shall be acceptable to the cognizant engineering organization and shall not roughen, pit, or embrittle the basis metal or adversely affect part dimensions. When parts have been stripped and replated, the purchaser shall be informed.

4.6.2 If any periodic test fails to meet specified test requirements, the process is nonconforming. No additional parts shall be plated until the process is corrected and new specimens are plated and tested. Results of all tests shall be recorded and, when requested, reported. Purchaser shall be notified of all parts plated since the last acceptable periodic test.

5. PREPARATION FOR DELIVERY

5.1 Plated parts shall be handled and packaged to ensure that required physical characteristics and properties of the plating are preserved.

5.2 Packages of plated parts shall be prepared for shipment in accordance with commercial practice and in compliance with applicable rules and regulations pertaining to the handling, packaging, and transportation of the plated parts to ensure carrier acceptance and safe delivery.

6. ACKNOWLEDGMENT

A processor shall mention AMS2404G in all quotations and when acknowledging purchase orders.

7. REJECTIONS

Parts on which plating does not conform to this specification, or to modifications authorized by the cognizant engineering organization, will be subject to rejection.

8. NOTES

8.1 A change bar (|) located in the left margin is for the convenience of the user in locating areas where technical revisions, not editorial changes, have been made to the previous issue of this document. An (R) symbol to the left of the document title indicates a complete revision of the document, including technical revisions. Change bars and (R) are not used in original publications, nor in documents that contain editorial changes only.

8.2 Part manufacturing operations, such as heat treatment, forming, joining, and media finishing, can affect the condition of the substrate for plating, or, if performed after plating, could adversely affect the plate. The sequencing of these operations should be specified by the cognizant engineering organization and is not controlled by this specification.

8.3 The parts manufacturer should ensure that the surfaces of the metal parts supplied to the plater are free from blemishes, pits, tool marks, and other irregularities that will affect the quality of the finished parts. Defects and variations in appearance that arise from surface conditions of the substrate, such as porosity, scratches or inclusions, that persist in the finish plate despite observance of accepted industry practices are not cause for rejection.

8.4 ARP4992, Periodic Test Plan for Process Solutions, is recommended to satisfy the requirements for the control of processing solutions.

8.5 An acid dip may be used for surface activation or neutralization of residual alkaline cleaner. However, the immersion time, as measured in seconds, should be minimized to preclude pitting.

8.6 The following thermal treatments have been used to achieve Class 2 hardness requirements. The supplier is cautioned to avoid a thermal treatment that could soften or otherwise degrade the substrate.

TABLE 2 - CLASS 2 THERMAL TREATMENTS

Temperature	Time, hours
450 °F (232 °C)	4, minimum
500 °F (260 °C)	4, minimum
550 °F (288 °C)	2, minimum
650 °F (343 °C)	1 to 1.5
750 °F (399 °C)	0.5 to 1

8.7 Special surface preparation techniques, such as electropolishing, may be employed to minimize plating porosity and maximize corrosion protection.

8.8 Phosphorus content of the plate may range from 1 to 13% by weight. Ductility is generally less for low phosphorus (2 to 8%) deposits compared with high phosphorus (8 to 13%) deposits. Class 1 deposits that are low in phosphorus generally have less corrosion resistance than Class 1 high-phosphorus deposits whereas Class 2 deposits that are high in phosphorus may provide less salt fog corrosion protection to steel than Class 2 low-phosphorus coatings.

8.9 Terms used in AMS are clarified in ARP1917. ASTM B 374 “Terminology Relating to Electroplating” should be utilized as a reference and referee document when areas of design definition or technical interpretation arise.

8.9.1 Plating is intended to be deposited in an uninterrupted process except as may be required by the operator for making thickness measurements. After the plate has dried, resumption of plating can result in detectable visual discontinuities or weak interlaminar adhesion that may not be readily apparent. Such resumption of plating is known as ‘double plating’ and localized addition of plate is known as ‘spotting-in.’

8.10 Dimensions and properties in inch/pound units and the Fahrenheit temperatures are primary; dimensions and properties in SI units and the Celsius temperatures are shown as the approximate equivalents of the primary units and are presented only for information.

8.11 AMS2404G has been written to provide equivalent technical requirements and to allow users to supersede AMS-C-26074 and MIL-C-26074.

8.12 Peening

A reduction in the fatigue life of plated parts may occur, attributed to the plating adhesion, physical characteristics, mechanical properties and state of stress. Parts designed for unlimited fatigue life under dynamic loads are generally peened prior to plating, particularly surfaces for which the plating is required, and on all immediately adjacent surfaces that contain notches, fillets or other abrupt changes of section size where stresses may be concentrated. AMS2430, AMS2432, AMS2546, or AMS-R-81841 are recommended. Peening is normally performed by the part fabricator or their subcontractor, and unless specifically directed, is not the responsibility of the plating processor.

8.13 AMS-C-26074 and its predecessor specifications encourage the use of Grade designations to specify thickness.

Grade A means that 0.0010 inch (25 μm) minimum plate thickness is applied. This applies normally to, but is not limited to, aluminum-based alloys.

Grade B means that 0.0005 inch (13 μm) minimum plate thickness is applied. This applies normally to, but is not limited to, copper, nickel, cobalt, titanium and beryllium alloys.

Grade C means that 0.0015 inch (38 μm) minimum plate thickness is applied. This applies normally to, but is not limited to, iron-based alloys.

8.13.1 AMS-C-26074 and its predecessor specifications permit the use of hydrogen embrittlement testing on parts which is different from the normal notched tensile bar testing in 4.3.1.4. When the cognizant engineering organization elects to use this option, such specifics need to be flowed to the processor.

8.13.2 Other paragraphs herein that form a bridge from AMS-C-26074 and predecessor specifications can be found in 3.4.3.

8.14 This process is not recommended for materials subject to overtempering or high temperature embrittlement when exposed to the post-plating heat treatment applicable to class 2, 3 or 4 as specified. See 3.3.2. Electroless nickel plating on steel parts having an ultimate tensile strength of 220 ksi (1517 MPa) or above (46 HRC and above) is not recommended.

PREPARED BY AMS COMMITTEE “B”