AEROSPACE MATERIAL SPECIFICATION

AMS2416™	REV. N
Issued 1955-08 Revised 2024-09 Superseding AMS2416M	

Plating, Nickel-Cadmium Diffused

RATIONALE

AMS2416N results from a Five-Year Review and update of this specification with changes to Ordering Information, Stress-Relief Treatment (see 3.1.1.3), Fixture/Electrical Contact Locations(see 3.1.3), Nickel Plating (see 3.2.1.1), Conversion Coating (see 3.2.3), Thickness (see 3.3.1.1), Corrosion Resistance (see 3.3.3.1), Quality (see 3.4.4 and 3.4.5), Periodic Tests (see 4.2.2.1), Sampling for Testing (see 4.3.1), Sample Configuation (see 4.3.4.3), control factors (see 4.4.3), and Notes (see 8.7 and 8.8).

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:

    - AMS2416N
    - Quantity of pieces to be plated
    - Plating thickness desired (see 3.3.1)
    - Basis metal to be plated
    - Tensile strength or hardness of the basis metal
    - 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 were machined, ground, cold formed or cold straightened after heat treat (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 3.1.3)
    - Special features, geometry, or processing present on parts that requires special attention by the plating processor
    - Minimum thickness on internal surfaces, if required (see 3.3.1.1)

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For more information on this standard, visit
https://www.sae.org/standards/content/AMS2416N/

- Optional: periodic testing frequency (see 4.2.2) and sample quantity (see 4.3.3)
- Critical areas of nickel plating coverage to prevent cadmium liquid metal embrittlement (see 1.4, 3.2.2, and 8.6)

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 (CEO) 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 3.4.4).

1. SCOPE

1.1 Purpose

This specification covers the requirements for an electrodeposit of cadmium diffused into an electrodeposit of nickel on carbon, low-alloy, and corrosion-resistant steels.

1.2 Application

This coating has been used typically to prevent corrosion of carbon, low-alloy, and corrosion-resistant steel parts that may operate in service up to 900 °F (482 °C), but usage is not limited to such applications. This process is not suitable for use on parts of complex shape where minimum nickel plate thickness requirements cannot be met and on parts whose hardness or strength would be reduced below drawing or specification requirements by heating to 640 °F (338 °C).

1.3 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 sole 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.

1.4 Warning

This document includes cadmium as a plating material. The use of cadmium has been restricted and/or banned for use in many countries due to environmental and health concerns. The user should consult with local officials on applicable health and environmental regulations regarding its use. Great care is necessary during this duplex plating process. Cadmium must only be plated directly onto the nickel plate; otherwise, liquid cadmium metal embrittlement may occur in the base metal (see 8.5).

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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.

AMS2451 Plating, Brush, General Requirements

AMS2750 Pyrometry

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 B374 Terminology Relating to Electroplating

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

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

ASTM B504 Measurement of Thickness of Metallic Coatings by the Coulometric Method

ASTM B567 Measurement of Coating Thickness by the Beta Backscatter Method

ASTM B568 Measurement of Coating Thickness by X-ray Spectrometry

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

ASTM E376 Measuring Coating Thickness by Magnetic-Field or Eddy Current (Electromagnetic) Testing Methods

2.3 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 hardness 40 HRC or 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 and Type D instrumentation. Temperatures to which parts are heated shall be such that stress relief is obtained while still maintaining hardness of parts within specified 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 and for 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 and for nitrided parts, stress relieve at 375 °F ± 25 °F (191 °C ± 14 °C) for a minimum of 4 hours. 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 specified, the stress relieve shall be performed prior to peening.

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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.

3.1.3 Fixture/Electrical Contact Locations

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

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

3.1.3.3 Alternative methods for process completion of fixture contact points is permitted when approved by the CEO (see 8.8).

3.2 Procedure

3.2.1 Nickel Plating

Nickel shall be electrodeposited from a sulfamate solution, or other plating bath acceptable to the CEO, containing no substances that might have a detrimental effect on the properties of the plate or the basis metal; stress-reducing agents shall not be used unless authorized by the CEO. The nickel plate shall be deposited directly on the basis metal. A preliminary strike of nickel, especially on corrosion-resistant steels or similarly passive materials, is permissible. A strike of any metal other than nickel is prohibited. Spotting-in is not permitted.

3.2.1.1 After being nickel plated, parts shall be thoroughly rinsed and transferred directly to the cadmium plating solution. Parts to be used for determining thickness of the nickel plate may be rinsed after neutralization in alkaline solution and dried. Parts shall be reactivated and cadmium plated as soon as possible after determination of nickel plate thickness.

3.2.1.2 Specimens to be used for determining stress in the nickel plate shall be processed in the same manner as specified for parts to be used for determining nickel plate thickness.

3.2.2 Cadmium Plating

Cadmium shall be electrodeposited from a suitable cadmium plating solution. The cadmium shall be deposited directly on the nickel plate.

CAUTION: Cadmium shall not be deposited on any area not covered by nickel plate (see 8.6). Parts, after plating to desired thickness, shall be thoroughly rinsed and, if not subjected to conversion coating as in 3.2.3, dried.

3.2.3 Conversion Coating

After rinsing following cadmium plating and without drying, parts shall be conversion coated unless otherwise specified. The processor shall prevent fingerprints and stains from occurring on parts. Parts shall be thoroughly rinsed and dried after conversion coating. Parts that are not treated with a conversion coating shall be marked with a suitable dye that will change color during the diffusion treatment.

3.2.4 Diffusion Treatment

Parts, after conversion coating or dyeing, shall be heated in a circulating-air furnace conforming to AMS2750 for steel tempering furnaces and having a uniformity of ±10 °F (±6 °C). The set temperature shall be 630 °F (332 °C). Parts shall be held at heat for not less than 30 minutes and cooled in air. For steel parts having a hardness greater than 40 HRC, this diffusion treatment shall start within 4 hours of completion of plating.

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3.3 Properties

The diffused nickel-cadmium plate shall conform to the following requirements:

3.3.1 Thickness

3.3.1.1 Nickel plate shall, except as specified in 3.3.1.1.1, be 0.0002 to 0.0004 inch (5 to 10 µm) thick on surfaces of parts except that it shall be not less than 0.00005 inch (1.3 µm) thick on surfaces of parts on which a controlled deposit cannot be maintained, such as holes, grooves, recesses, etc. Nickel plate thickness greater than 0.0004 inch (10 µm) will be permissible in high current density areas. Uncontrolled plate deposits are defined as those areas that cannot be touched by a 0.75-inch (19-mm) diameter sphere except for the threaded portion of externally threaded fasteners, for which thickness shall be not less than 0.0001 inch (2.5 µm). Thickness of nickel plate shall be determined, prior to cadmium plating, in accordance with ASTM B487, ASTM B499, ASTM B504, ASTM B567, ASTM B568, ASTM E376, direct dimensional inspection (provided the resolution of the measuring instrument is ten times more precise than the attribute being measured), or other method acceptable to the CEO on representative parts or on test panels processed and plated simultaneously with the parts (see 4.3.4.2).

3.3.1.1.1 If nickel plate thickness greater than 0.0002 to 0.0004 inch (5 to 10 µm) is desired, such thickness may be specified by this specification number followed by a slash and a number indicating the minimum nickel plate thickness in ten-thousandths of an inch (2.5 µm); a tolerance of +0.0002 inch (+5 µm) will be permitted when the minimum thickness is 0.0003 inch (7.6 µm) and +0.0003 inch (+7.6 µm) will be permitted when the minimum thickness is 0.0004 inch (10 µm) or more. Thus, AMS2416/3 indicates nickel plate thickness of 0.0003 to 0.0005 inch (7.6 to 12.5 µm) and AMS2416/5 indicates nickel plate thickness of 0.0005 to 0.0008 inch (12.7 to 20 µm).

3.3.1.2 Cadmium Plate

Before the diffusion treatment of 3.2.4, thickness shall be 0.0001 to 0.0003 inch (2.5 to 7.6 µm).

3.3.2 Heat Resistance

Representative parts or specimens as in 4.3.4.1 shall show no cracks or blisters in the plate after being heated in air, preferably in a circulating-air furnace, as specified in 3.3.2.1 and 3.3.2.2. The presence of weakly adhering oxide scale is acceptable. The following tests are distinct from each other and, as such, require separate test specimens:

3.3.2.1 Heat to 700 °F ± 10 °F (371 °C ± 6 °C), hold at heat for 23 hours ± 0.5 hour, transfer without intentional cooling to a furnace at 1000 °F ± 10 °F (538 °C ± 6 °C), hold at heat for 60 minutes ± 5 minutes, and cool to room temperature. In lieu of transferring to the second higher-temperature furnace, the furnace may be stepped up to 1000 °F providing the temperature rise can be accomplished within 15 minutes.

3.3.2.2 Heat to 700 °F ± 10 °F (371 °C ± 6 °C), hold at heat for 2 hours ± 0.25 hour, transfer without intentional cooling to a furnace at 1000 °F ± 10 °F (538 °C ± 6 °C), hold at heat for 2 hours ± 0.25 hour, and cool to room temperature. In lieu of transferring to the second higher-temperature furnace, the furnace may be stepped up to 1000 °F providing the temperature rise can be accomplished within 15 minutes.

3.3.3 Corrosion Resistance

Parts, other than externally threaded fasteners, or test specimens as in 4.3.4.1 shall show no visual evidence of corrosion of the basis metal, determined by exposure for 96 hours to salt spray corrosion test conducted in accordance with ASTM B117. This requirement applies to parts or specimens both after diffusion heating as in 3.2.4 and after the heat-resistance test of 3.3.2.1 and 3.3.2.2.

3.3.3.1 For externally threaded fasteners, unless otherwise permitted by the CEO, representative parts shall show no visual evidence of corrosion of the basis metal, determined by exposure for 96 hours to salt spray corrosion test conducted in accordance with ASTM B117. This requirement applies to parts only after diffusion heating as in 3.2.4.

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3.3.4 Nickel Plate Stress

Nickel plate stress shall be in the range of 5000 psi (34 MPa) in compression to 15000 psi (103 MPa) in tension, determined in accordance with ASTM B636 on specimens having nickel plate thickness of 0.0003 inch (7.6 µm) or greater (see 3.2.1.2).

3.4 Quality

3.4.1 Nickel plate shall be firmly and continuously bonded to the basis metal and shall be free of delamination within the plating, smooth, uniform in appearance on areas of equivalent hardness and surface finish, and free from frosty areas, pin holes, nodules, blisters, and other imperfections detrimental to performance of the plate.

3.4.2 Cadmium plate shall be firmly and continuously bonded to the nickel plate and shall be uniform in appearance and free from pin holes, porosity, blisters, nodules, pits, and other imperfections detrimental to performance of the plate.

3.4.3 Diffused nickel-cadmium plate shall have a smooth, dull, matte finish, shall be free from balling when examined under magnification up to 10X, and shall be smooth to the touch. Color of conversion-coated parts may vary. Color need not be uniform on any one part, but mottled, blotched, or sharply streaked areas are not acceptable. Color of dye marking shall be characteristic of the dye used.

3.4.4 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 8.7).

3.4.5 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 specimens for the processor's tests and shall be responsible for the performance of all required tests. Where parts are to be tested, such parts shall be supplied by the purchaser. The CEO reserves the right to sample and to perform any confirmatory testing deemed necessary to ensure that processing conforms to specified requirements.

4.2 Classification of Tests

4.2.1 Acceptance Tests

Thickness of nickel plate (see 3.3.1.1) and quality (see 3.4) are acceptance tests and shall be performed on parts, or specimens representing parts when permitted herein, from each lot (see 4.3.4.1).

4.2.2 Periodic Tests

Thickness of cadmium plate (see 3.3.1.2), heat resistance (see 3.3.2), corrosion resistance (see 3.3.3), and nickel plate stress (see 3.3.4) are periodic tests and shall be performed in any quarter that parts are processed. 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 8.2).

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 cognizant quality organization upon resumption of processing.

4.2.3 Preproduction Tests

All property verification tests (see 3.3) are preproduction tests and shall be performed prior to or on the initial shipment of plated parts to a purchaser and when the CEO requires confirmatory testing.

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4.3 Sampling for Testing

4.3.1 Sampling for acceptance testing shall be not less than the following: 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.

4.3.2 Acceptance Tests

Test samples shall be selected randomly from all parts in the lot. Unless the CEO provides a sampling plan, the minimum number of samples shall be as shown in Table 1.

Table 1 - Sampling for acceptance tests

Number of Parts in Lot	Quality and Thickness
Up to 6	All
7 to 15	7
16 to 40	10
41 to 110	15
111 to 300	25
301 to 500	35
501 to 700	50
701 to 1200	75
Over 1200	125

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4.3.3 Periodic Tests

Sample size shall be two for corrosion resistance. Sample quantity for other periodic tests shall be at the discretion of the processor unless otherwise specified by the CEO or herein.

4.3.4 Sample Configuration

4.3.4.1 Separate test specimens may be used under any one of the following circumstances: The plated parts are of such configuration or size as to be not readily adaptable to specified tests, nondestructive testing is not practical on actual parts, or it is not economically acceptable to perform destructive tests on actual parts. 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.

4.3.4.2 For thickness tests, specimens shall be nominally 1/32 x 4 x 1 inch (0.8 x 102 x 25 mm) or bars approximately 0.5 inch (13 mm) in diameter and 4 inches (102 mm) long.

4.3.4.3 For corrosion tests, specimens shall be annealed carbon or low-alloy steel specimens 0.025 to 0.125 inch (0.6 to 3.18 mm) in nominal thickness and not less than 4 inches (102 mm) long by 3 inches (76 mm) wide except that, when parts being plated are externally threaded fasteners, actual parts shall be used unless otherwise permitted by the CEO.

4.4 Approval

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