

# AEROSPACE MATERIAL SPECIFICATION



AMS 2416H

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Superseding AMS 2416G

## Plating, Nickel-Cadmium Diffused

### 1. SCOPE:

#### 1.1 Purpose:

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

#### 1.2 Application:

This coating has been used typically to prevent corrosion of carbon, low-alloy, and corrosion resistant steel parts which 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 which 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.

##### 1.3.1 Numerous scientific studies have determined that cadmium and hexavalent chromium present a health hazard to persons exposed to them.

### 2. APPLICABLE DOCUMENTS:

The following publications form a part of this specification to the extent specified herein. The applicable issue of referenced publications shall be the issue in effect on the date of the purchase order.

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## 2.1 ASTM Publications:

Available from ASTM, 1916 Race Street, Philadelphia, PA 19103-1187.

ASTM B 117	Salt Spray (Fog) Testing
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 504	Measurement of Thickness of Metallic Coatings by the Coulometric Method
ASTM B 567	Measurement of Coating Thickness by Beta Backscatter Method
ASTM B 568	Measurement of Coating Thickness by X-ray Spectrometry
ASTM B 636	Measurement of Internal Stress of Plated Metallic Coatings With the Spiral Contractometer
ASTM E 376	Measuring of Coating Thickness by Magnetic-Field or Eddy-Current (Electromagnetic) Test Methods

## 2.2 U.S. Government Publications:

Available from DODSSP Subscription Services Desk, Building 4D, 700 Robbins Avenue, Philadelphia, PA 19111-5094.

MIL-STD-2073-1 DOD Materiel, Procedures for Development and Application of Packaging Requirements

## 3. TECHNICAL REQUIREMENTS:

### 3.1 Preparation:

- 3.1.1 Fabrication-type operations, such as forming, machining, heat treating, brazing, and welding, shall be completed before parts are plated.
- 3.1.2 Parts shall be within drawing dimension limits after plating.
- 3.1.3 Parts having hardness higher than 40 HRC, or equivalent, and which have been ground after heat treatment shall be suitably cleaned to remove contamination and stress-relieved before preparation for plating. Temperatures to which parts are heated shall be such that maximum stress relief is obtained without reducing hardness of parts below drawing limits, but, unless otherwise specified, not less than 275 °F (135 °C) for five hours for parts having hardness of 55 HRC or over, or 375 °F (191 °C) for other parts.
- 3.1.4 Any specified residual compressive stress-inducing operations, such as shot peening, shall follow stress-relieving but precede plating.
- 3.1.5 Parts shall have clean surfaces, free of waterbreak, prior to immersion in the plating solution.

- 3.1.5.1 Care must be used if parts are to be cleaned with acids which may pit the surfaces or induce hydrogen embrittlement in ferrous alloys. This includes, but is not limited to, hydrochloric and sulfuric acids. In general, a momentary dip in such acids for surface activation or neutralization, after alkaline cleaning, is permissible, but immersion for an extended time is prohibited.
- 3.1.6 Electrical contacts between the parts and power source shall be made to ensure that neither chemical or immersion deposition nor electrical arcing or overheating will occur. If parts are to be plated all over, contact points shall be located where specified or where agreed upon by purchaser and vendor. If parts are not required to be plated all over, contact points shall be located in areas on which plating is not required or is optional.
- 3.2 Procedure:
- 3.2.1 Nickel Plating: Nickel shall be electrodeposited from a sulfamate solution, or other plating bath acceptable to purchaser, containing no addition agents which 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 purchaser. The nickel shall be deposited directly on the basis metal without a preliminary strike or flash of any other metal, except that on corrosion-resistant steels or similarly passive materials a nickel strike is permissible.
- 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 shall 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. Extreme care shall be exercised to avoid deposition of cadmium on any area not previously covered by nickel. 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 may be treated by an approved conversion coating process which will prevent fingerprinting and staining. Parts shall be thoroughly rinsed and dried after conversion coating. Parts which are not treated with a conversion coating shall be marked with a suitable dye which will change color during the diffusion treatment.
- 3.2.4 Diffusion Treatment: Parts, after conversion coating or dyeing, shall be heated in air, preferably in a circulating-air furnace, to 630 °F ± 10 (332 °C ± 6), held at heat for not less than 30 minutes, and cooled in air.

### 3.3 Properties:

The diffused nickel-cadmium 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  $\mu\text{m}$ ) thick on significant surfaces of parts and not less than 0.00005 inch (1.27  $\mu\text{m}$ ) 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  $\mu\text{m}$ ) will be permissible in high current density areas. Uncontrolled plate thickness areas are defined as those areas which 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  $\mu\text{m}$ ). Thickness of nickel plate shall be determined, prior to cadmium plating, in accordance with ASTM B 487, ASTM B 499, ASTM B 504, ASTM B 567, ASTM B 568, ASTM E 376, or other method acceptable to purchaser on representative parts or on test panels processed and plated simultaneously with the parts (See 4.3.3).

3.3.1.1.1 If nickel plate thickness greater than 0.0002 to 0.0004 inch (5 to 10  $\mu\text{m}$ ) is desired, such thickness may be specified by this specification number followed by a dash and a number indicating the minimum nickel plate thickness in ten-thousandths of an inch (2.5  $\mu\text{m}$ ); a tolerance of +0.0002 inch (+5  $\mu\text{m}$ ) will be permitted when the minimum thickness is 0.0003 inch (7.6  $\mu\text{m}$ ) and +0.0003 inch (+7.6  $\mu\text{m}$ ) will be permitted when the minimum thickness is 0.0004 inch (10  $\mu\text{m}$ ) or more. Thus, AMS 2416-3 indicates nickel plate thickness of 0.0003 to 0.0005 inch (7.6 to 12.5  $\mu\text{m}$ ) and AMS-2416-5 indicates nickel plate thickness of 0.0005 to 0.0008 inch (12.7 to 20  $\mu\text{m}$ ).

3.3.1.2 Cadmium Plate: When measured before the diffusion treatment of 3.2.4, thickness shall be 0.0001 to 0.0003 inch (2.5 to 7.6  $\mu\text{m}$ ). Routine determination of cadmium plate thickness is not required; the process of plating, however, shall be controlled to produce the specified thickness.

3.3.2 Heat Resistance: Representative parts or specimens as in 4.3.3 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 products is acceptable. Only the test of 3.3.2.1 is required for routine inspection.

3.3.2.1 Heat to 700 °F  $\pm$  10 (371 °C  $\pm$  6), hold at heat for 23 hours  $\pm$  0.5, transfer without intentional cooling to a furnace at 1000 °F  $\pm$  10 (538 °C  $\pm$  6), hold at heat for 60 minutes  $\pm$  5, and cool to room temperature.

3.3.2.2 Heat to 700 °F  $\pm$  10 (371 °C  $\pm$  6), hold at heat for two hours  $\pm$  0.25, transfer without intentional cooling to a furnace at 1000 °F  $\pm$  10 (538 °C  $\pm$  6), hold at heat for two hours  $\pm$  0.25, and cool to room temperature.

3.3.3 Corrosion Resistance: Parts, other than externally threaded fasteners, or test specimens as in 4.3.3 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 B 117. This requirement applies to parts or specimens both after diffusion heating as in 3.2.4 and after heat resistance test of 3.3.2.1.

3.3.3.1 For externally threaded fasteners, unless otherwise permitted by purchaser, 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 B 117. This requirement applies to parts after diffusion heating as in 3.2.4.

3.3.4 Nickel Plate Stress: Shall be in the range of 5000 psi (34 MPa) in compression to 15,000 psi (103 MPa) in tension, determined in accordance with ASTM B 636 on specimens having nickel plate thickness of 0.0003 inch (7.6  $\mu\text{m}$ ) or greater.

#### 3.4 Quality:

3.4.1 Nickel Plate: Shall be firmly and continuously bonded to the basis metal and shall be 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. Specific standards for acceptance may be agreed upon by purchaser and vendor.

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. Specific standards for acceptance may be agreed upon by purchaser and vendor.

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 coating treated parts may vary from olive drab through gray to black. 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.

#### 4. QUALITY ASSURANCE PROVISIONS:

##### 4.1 Responsibility for Inspection:

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

#### 4.2 Classification of Tests:

- 4.2.1 Acceptance Tests: Thickness of nickel plate (3.3.1.1) and quality (3.4) are acceptance tests and shall be performed on each lot.
- 4.2.2 Periodic Tests: Heat resistance (3.3.2), corrosion resistance (3.3.3), and nickel plate stress (3.3.4) and tests of cleaning and plating solutions to ensure that the deposited metal will conform to specified requirements are periodic tests and shall be performed at a frequency selected by the vendor unless frequency of testing is specified by purchaser.
- 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 (See 4.4.2), and when purchaser deems confirmatory testing to be required.
- 4.2.3.1 For direct U.S. Military procurement, substantiating test data and, when requested, preproduction test material shall be submitted to the cognizant agency as directed by the procuring activity, contracting officer, or request for procurement.

#### 4.3 Sampling and Testing:

Shall be not less than the following: a lot shall be all parts of the same part number plated to the same specified thickness range, in the set of solutions processed in a continuous operation or within a 24-hour period, and presented for processor's inspection at one time:

- 4.3.1 For Acceptance Tests: Test samples shall be selected randomly from all parts in the lot. The minimum number of samples shall be as shown in Table 1.

TABLE 1 - Acceptance Test Sampling

Number of Parts in lot	Quality	Thickness Nondestructive	Thickness Destructive
Up to 500	8	8	3
501 to 3,200	13	13	5
3,201 to 35,000	20	20	5
35,001 and over	32	32	8

- 4.3.2 For Periodic Tests and Preproduction Tests: As agreed upon by purchaser and vendor.

4.3.3 When plated parts are of such configuration or size as to be not readily adaptable to the specified tests, separate test specimens cleaned, plated, and diffused with the parts represented may be used. For thickness tests, specimens shall be annealed carbon or low-alloy steel panels, 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. For corrosion and heat resistance tests, specimens shall be annealed carbon or low-alloy steel panels 0.062 to 0.125 inch (1.57 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 purchaser.

#### 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 cognizant engineering organization before production parts are supplied.

4.4.2 The processor shall make no significant change to materials, processes, or control factors from those on which the approval was based, unless the change is approved by 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 and cleaning procedures
- Surface activation procedures
- Plating bath composition and composition control limits
- Plating bath temperature limits and controls
- Current/voltage limits and controls
- Post treatment time and temperature
- Method for testing plating thickness
- Periodic test plan

#### 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, AMS 2416H, part number, and quantity.