

SAE-AMS2401

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400 Commonwealth Dr., Warrendale, PA 15096

AEROSPACE MATERIAL SPECIFICATION

Submitted for recognition as an American National Standard

SAE AMS 2401D

Issued 7-15-63
Revised 1-1-86

Superseding AMS 2401C

CADMIUM PLATING Low Hydrogen Content Deposit

1. SCOPE:

- 1.1 Purpose: This specification covers the engineering requirements for electrodeposition of cadmium on ferrous metals and the properties of the deposit.
- 1.2 Application: Primarily to provide corrosion resistance to steel parts heat treated to tensile strength of 180,000 psi (1240 MPa) and higher and used at temperatures not higher than 450°F (230°C). For plating of other basis metals and of steels which are carburized or heat treated to lower strength levels, AMS 2400 should be specified.

2. APPLICABLE DOCUMENTS: The following publications form a part of this specification to the extent specified herein. The latest issue of Aerospace Material Specifications shall apply. The applicable issue of other documents shall be as specified in AMS 2350.

- 2.1 SAE Publications: Available from SAE, 400 Commonwealth Drive, Warrendale, PA 15096.

2.1.1 Aerospace Material Specifications:

AMS 2350 - Standards and Test Methods
AMS 2760 - Heat Treatment, Carbon, Low-Alloy, and Specialty Steels
AMS 6415 - Steel Bars, Forgings, and Tubing, 0.80Cr - 1.8Ni - 0.25Mo (0.38 - 0.43C) (SAE 4340)

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- 2.2 ASTM Publications: Available from American Society for Testing and Materials, 1916 Race Street, Philadelphia, PA 19103.

ASTM B117 - Salt Spray (Fog) Testing

ASTM B487 - Measurement of Metal and Oxide Coating Thicknesses by Microscopical Examination of a 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 E8 - Tension Testing of Metallic Materials

ASTM E290 - Semi-Guided Bend Test for Ductility of Metallic Materials

ASTM E292 - Conducting Time-for-Rupture Notch Tension Tests of Materials

- 2.3 U.S. Government Publications: Available from Commanding Officer, Naval Publications and Forms Center, 5801 Tabor Avenue, Philadelphia, PA 19120.

2.3.1 Military Standards:

MIL-STD-794 - Parts and Equipment, Procedures for Packaging and Packing of

3. TECHNICAL REQUIREMENTS:

3.1 Preparation:

- 3.1.1 All forming, heat treating, brazing, and welding shall be completed before parts are plated.

- 3.1.2 Parts shall be within drawing dimension limits before plating, except as specified in 3.1.2.1.

- 3.1.2.1 In lieu of the requirement of 3.1.2 and unless otherwise specified on the drawing, all engine and propeller utility parts having part numbers with the prefix MS or AS and required to be plated in accordance with this specification shall be made to such dimensions that parts will be within drawing limits after plating. Undercutting before plating shall not be permitted unless specifically authorized by specifications referenced on the applicable drawing.

- 3.1.3 Parts shall be stress relieved before plating if they have been subjected to any of the following operations after heat treatment: machining, grinding, straightening, or other cold deformation (except residual compressive stress-inducing operations, such as shot peening), and proof testing. Parts stress relieved before application of a prior plate such as chromium or nickel shall not be stress relieved again unless, following such plating, they have been subjected to any of the operations listed above. Temperatures to which parts are heated and time of heating shall be such that maximum stress relief is obtained without reducing mechanical properties of parts below drawing limits.

- 3.1.4 Residual compressive stress-inducing operations, such as shot peening, shall follow stress-relieving.
- 3.1.5 Parts shall have chemically clean surfaces, prepared with minimum abrasion, erosion, or pitting, prior to immersion in the plating solution.
- 3.1.5.1 Parts shall not be cleaned with hydrochloric, nitric, or sulfuric acids unless specifically approved by purchaser. If parts are cleaned by abrasive blasting, blasting with dry abrasive is preferred.
- 3.1.5.2 Following cleaning, parts shall be immersed in an alkaline solution until transferred, after rinsing in clean water but without drying, to the plating solution. Abrasively cleaned parts shall be agitated in the alkaline solution to remove residual abrasive. Parts may be held in the solution for not more than 4 hr before being transferred to the plating solution.
- 3.1.6 Electrical contacts between the parts and power source shall be made in such a manner as will 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, except in case of barrel plating, 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 an area on which plating is not required or is optional.
- 3.2 Procedure:
- 3.2.1 Parts shall be plated by electrodeposition of cadmium from a cadmium cyanide, cadmium fluoborate, cadmium sulfamate, cadmium sulfate, or cadmium sulfate-fluoborate solution (See 8.2). The cadmium shall be deposited directly on the basis metal without a prior flash coating of other metal, such as copper or nickel underneath, except in the case of parts, assemblies, and weldments made wholly or in part of corrosion-resistant steel or similarly inactive materials, on which a preliminary flash of nickel or other suitable metal is permissible.
- 3.2.2 If parts require plating to two thicknesses in different areas and the thickness of the thinner plate is not more than 0.0005 in. (12.5 μm), parts shall be plated to the thinner requirements and areas on which this thickness is required shall be masked. Parts shall then be anodically cleaned in an alkaline cleaning solution, rinsed, and plated to the greater plate thickness.
- 3.2.2.1 Parts which require plating to two or more thicknesses in different areas with requirements other than specified in 3.2.2 shall be plated using a procedure agreed upon by purchaser and vendor.
- 3.2.3 After rinsing in water, plated parts shall be dipped, with agitation, in a 3 - 5% solution of chromic acid and again thoroughly rinsed.

- 3.3 Post Treatment: After rinsing, plated parts shall be immersed in hot water at a temperature not lower than 180°F (80°C) for 15 - 20 min. and treated as follows; heating shall be in air, preferably in a circulating-air furnace.
- 3.3.1 Parts heat treated to minimum tensile strength of 220,000 psi (1520 MPa) or higher but not higher than 260,000 psi (1790 MPa) and all externally threaded parts heat treated to minimum tensile strength of 180,000 psi (1240 MPa) or higher but not higher than 260,000 psi (1790 MPa) shall be heated to 375°F $\pm$ 15 (190°C $\pm$ 8) and held at heat for not less than 23 hours.
- 3.3.2 Parts, other than externally threaded parts, heat treated to minimum tensile strength of 180,000 psi (1240 MPa) or higher but not higher than 220,000 psi (1520 MPa) shall be heated to 375°F $\pm$ 15 (190°C $\pm$ 8) and held at heat for not less than 8 hours.
- 3.3.3 Parts heat treated to minimum tensile strength higher than 260,000 psi (1790 MPa) shall be treated as agreed upon by purchaser and vendor.
- 3.4 Properties: Plating shall conform to the following requirements:
- 3.4.1 Thickness: Shall be as specified on the drawing, determined on
Ø representative parts or test panels in accordance with ASTM B487, ASTM B504, or other method agreed upon by purchaser and vendor.
- 3.4.1.1 Plate thickness may be specified by AMS 2401 and a suffix number normally designating the minimum thickness in ten-thousandths of an inch (μ m); except as indicated in Table I, the maximum plate thickness shall be 0.0002 in. (5 μ m) greater than the minimum. Thus AMS 2401-2 designates a thickness of 0.0002 - 0.0004 in (5 - 10 μ m) and AMS 2401-6 designates a thickness of 0.0006 - 0.0008 in. (15 - 20 μ m).
- 3.4.1.1.1 Plate thickness, when specified by AMS 2401 and a suffix number, shall be as specified in Table I for the specified suffix number and type of part or surface.
- 3.4.1.2 Where "cadmium flash" is specified, plate thickness shall be approximately 0.0001 in. (2.5 μ m).
- 3.4.1.3 The plate shall be substantially uniform in thickness on significant surfaces except that slight build-up on exterior corners or edges will be permitted provided finished drawing dimensions are met.
- 3.4.1.4 No requirements are established for minimum plate thickness for surfaces of holes, recesses, internal threads except as specified in Table I, contact areas of parts plated all over, and other areas where a controlled deposit cannot be obtained under normal plating conditions but such areas shall not be masked to prevent plating. Except as specified in Table I for externally threaded sections, the resultant thickness shall be considered only when such surfaces of parts can be touched by a sphere 0.75 in. (19 mm) in diameter.

- 3.4.1.4.1 If internal surfaces as defined in 3.4.1.4 are required to be plated to a specified thickness, notes on the drawing will so specify.
- 3.4.2 Adhesion: Specimens as in 4.3.4 shall not show separation of the plating from the basis metal, when examined at approximately 4X magnification, after being bent rapidly, in accordance with ASTM E290, through an angle of 180 deg around a diameter equal to the thickness of the specimen. Formation of cracks which do not result in flaking or blistering of the plating is acceptable.
- 3.4.3 Corrosion Resistance: Except as specified in 3.4.3.1, ferrous metal parts or representative test panels shall show no visual evidence of corrosion of the basis metal after being subjected for a time not less than specified in Table I to continuous salt spray corrosion test conducted in accordance with ASTM B117.
- 3.4.3.1 Salt spray corrosion tests shall not apply to plated parts made of austenitic corrosion-resistant steels, to parts made of any corrosion-resistant steel or alloy when not plated all over, and to parts made of any steel when thickness is specified as "flash".
- 3.4.4 Room-Temperature Notched Stress-Rupture Properties: Specimens shall meet the following requirements; tests shall be conducted in accordance with ASTM E292:
- 3.4.4.1 A specimen machined as in 4.3.2.1 maintained at room temperature while a load sufficient to produce an initial axial stress of 75% of the average tensile strength of duplicate but unplated specimens is applied continuously, shall not rupture in less than 200 hours. Tensile strength of the unplated specimens shall be determined in accordance with ASTM E8.
- 3.4.4.1.1 Following the test of 3.4.4.1, one plated specimen shall be sectioned axially across the notch, polished, and examined at 100X magnification to determine that the notch was covered with plate.
- 3.5 Quality: Plated cadmium shall be continuous, adherent to basis metal, uniform in appearance, and essentially free from pin holes, porosity, blisters, nodules, pits, and other imperfections detrimental to usage of the plating. Slight staining or discoloration is permissible. Standards for acceptance shall be as agreed upon by purchaser and vendor.
- 3.5.1 Double plating except as specified in 3.2.2 and spotting-in after plating are not permitted.
4. QUALITY ASSURANCE PROVISIONS:

4.1 Responsibility for Inspection: The processing vendor shall supply all
Ø samples for vendor's tests and shall be responsible for performing all required tests. Results of such tests shall be reported to the purchaser as required by 4.5. 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: Tests to determine conformance to requirements for
Ø thickness (3.4.1) and quality (3.5) are classified as acceptance tests and shall be performed to represent each lot.

4.2.2 Periodic Tests: Tests to determine conformance to requirements for
Ø adhesion (3.4.2), corrosion-resistance (3.4.3), and stress-rupture properties (3.4.4) and of cleaning and plating solutions to ensure that the deposited metal will conform to the requirements of this specification are classified as periodic tests and shall be performed at a frequency selected by the processing vendor unless frequency of testing is specified by purchaser.

4.2.3 Preproduction Tests: Tests to determine conformance to all technical
Ø requirements of this specification are classified as preproduction tests and shall be performed prior to or on the first-article shipment of plated parts to a purchaser, when a change in material, processing, or both requires reapproval as in 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, the contracting officer, or the request for procurement.

4.3 Sampling: Shall be not less than the following; a lot shall be all parts
Ø made of the same alloy, plated to the same range of plate thickness in the same set of solutions, in each consecutive 24-hr period of operation, and presented for vendor's inspection at one time:

4.3.1 For Acceptance Tests:

4.3.1.1 Thickness: Three parts, except as specified in 4.3.3, for each lot.
Ø

4.3.1.2 Quality: As agreed upon by purchaser and vendor.

4.3.2 For Periodic Tests and Preproduction Tests: As agreed upon by purchaser and vendor and as follows:

- 4.3.2.1 For stress-rupture tests, six specimens machined to the dimensions shown in Fig. 1 and Table II shall be prepared. Specimens shall be of the same type of steel as the parts they represent and shall be heat treated in accordance with AMS 2760 to the same tensile strength level as the parts. Four of the specimens, to be used for stress-rupture tests, shall be completely processed with parts; the other two specimens, to be used for tensile tests, shall not be plated. Testing as in 4.3.2.2 may be used as an alternate test procedure.
- 4.3.2.2 For preproduction tests of new or revised plating procedures, the specimens of 4.3.2.1 shall be made of AMS 6415 steel, heat treated in accordance with AMS 2760 to tensile strength of 260,000 - 280,000 psi (1790 - 1930 MPa), plated to a plate thickness not less than 0.0005 in. (12.5 μ m), dipped in chromic acid as in 3.2.3, and heated at 375°F $\pm$ 15 (190°C $\pm$ 8) for 23 - 23-1/2 hours.
- 4.3.3 When plated parts are of such configuration or size as to be not readily adaptable to the specified tests, separate specimens cleaned, plated, and post-treated with the parts they represent may be used. For adhesion tests, such specimens shall be panels of annealed low-carbon steel approximately 0.032 x 4 x 1 in. (1 x 100 x 25 mm) and for thickness and quality tests shall be panels of the same size and type or shall be bars approximately 0.5 in. (10 mm) in diameter and 4 in. (100 mm) long. For corrosion resistance tests, specimens shall be panels 0.062 - 0.125 in. (1.5 - 3 mm) in nominal thickness and not less than 4 in. (100 mm) long by 3 in. (75 mm) wide.
- 4.4 Approval:
- 4.4.1 Plated parts and, when specified, plating fixtures shall be approved by purchaser before parts for production use are supplied, unless such approval be waived by purchaser. Results of tests on production parts shall be essentially equivalent to those on the approved sample parts.
- 4.4.2 Vendor shall use manufacturing procedures, processes, and methods of inspection on production parts which are essentially the same as those used on the approved sample parts. If necessary to make any change in type of equipment or in established composition limits and operating conditions of process solutions, vendor shall submit for reapproval of the process a statement of the proposed changes in processing and, when requested, sample plated parts, test panels, or both. Production parts plated by the revised procedure shall not be shipped prior to receipt of reapproval.
- 4.5 Reports: The vendor of plated parts shall furnish with each shipment a report stating that the parts have been processed and tested in accordance with the requirements of this specification and that they conform to the acceptance test requirements. This report shall include the purchase order number, AMS 2401D, part number, and quantity.

4.6 Resampling and Retesting: If any specimen used in the above tests fails to meet the specified requirements, disposition of the parts may be based on the results of testing three additional specimens for each original nonconforming specimen. Except as specified in 4.6.1, failure of any retest specimen to meet the specified requirements shall be cause for rejection of the parts represented and no additional testing shall be permitted. Results of all tests shall be reported.

4.6.1 If any part fails to meet the specified requirements, either on the original sampling as in 4.3 or upon resampling as in 4.6, the parts in that lot may be stripped by a method approved by purchaser which does not roughen, pit, or embrittle the basis metal, replated, post-treated, and retested.

5. PREPARATION FOR DELIVERY:

5.1 Plated parts shall be handled and packaged in such a manner as will ensure that the 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 parts to ensure carrier acceptance and safe delivery. Packaging shall conform to carrier rules and regulations applicable to the mode of transportation.

5.3 For direct U.S. Military procurement, packaging shall be in accordance with MIL-STD-794, Level A or Level C, as specified in the request for procurement. Commercial packaging as in 5.1 and 5.2 will be acceptable if it meets the requirements of Level C.

6. ACKNOWLEDGMENT: A vendor shall mention this specification number and its revision letter in all quotations and when acknowledging purchase orders.

7. REJECTIONS: Parts on which the plating does not conform to this specification or to modifications authorized by purchaser will be subject to rejection.

8. NOTES:

8.1 Marginal Indicia: The phi (ϕ) symbol is used to indicate technical changes from the previous issue of this specification.

8.2 Required current density of the plating solution will vary with the type of solution used and shall be adjusted to minimize entrapment of hydrogen during processing.

8.3 Brightening agents generally increase the susceptibility of the plating to hydrogen embrittlement.

- 8.4 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.
- 8.5 For direct U.S. Military procurement, purchase documents should specify not less than the following:
- Title, number, and date of this specification
 - Plate thickness desired
 - Quantity of pieces to be plated
 - Quality standards for acceptance (See 3.5)
 - Applicable level of packaging (See 5.3)
- 8.6 Plating meeting the requirements of this specification has been classified under Federal Standardization Area Symbol "MFFP".

This specification is under the jurisdiction of AMS Committee "B".

TABLE I

Plate Thickness and Salt Spray Corrosion Resistance Requirements

Ø

AMS 2401 Thickness Designation Specified	External Threads		Nuts, Washers, and Un- threaded Surfaces of Bolts, Screws, Studs, and Other Parts Externally Threaded		Parts Not Externally Threaded except Nuts and Washers	
	Thickness Inch	Salt Spray Resistance hr, min	Thickness Inch	Salt Spray Resistance hr, min	Thickness inch	Salt Spray Resistance hr, min
2401	0.0001 - 0.0004	100	0.0002 - 0.0005	150	0.0003 - 0.0005	200
2401-1	0.0001 - 0.0003	100	0.0002 - 0.0004	150	0.0001 - 0.0003	100
2401-2	0.0001 - 0.0004	100	0.0002 - 0.0004	150	0.0002 - 0.0004	150
2401-3	0.0002 - 0.0005	150	0.0003 - 0.0005	200	0.0003 - 0.0005	200
2401-4	0.0003 - 0.0006	200	0.0004 - 0.0006	225	0.0004 0.0006	225
2401-5	0.0004 - 0.0007	225	0.0005 - 0.0007	250	0.0005 0.0007	250

Note: For thickness designations AMS 2401-X, where X is greater than 5, plate thickness in ten-thousands of an inch shall be X to X+2 except on external threads where the plate thickness shall be X-1 to X+2; such parts shall withstand salt spray for not less than 240 hours.