Society of Automotive Engineers, Inc.
400 COMMONWEALTH DRIVE, WARRENDALE, PA. 15096

AEROSPACE MATERIAL SPECIFICATION

AMS 2401C
Superseding AMS 2401B
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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 (1241 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 (AMS) shall apply. The applicable issue of other documents shall be as specified in AMS 2350.

2.1 SAE Publications: Available from Society of Automotive Engineers, Inc., 400 Commonwealth Drive, Warrendale, PA 15096.

2.1.1 Aerospace Material Specifications:

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

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 the 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 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 or assemblies ø 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, ø 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. 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 cyanide 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, ø 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, or cadmium sulfamate solution containing no brightening agents (See 8.2). The ø cadmium shall be deposited directly on the metal part without a 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. (0.013 mm), parts shall be plated to the thinner requirement 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 (82°C) for 15 - 20 min. and then 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 ± 15 (190°C ± 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 ± 15 (190°C ± 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:

3.4.1 Thickness: Shall be as specified on the drawing, determined on representative parts or test panels in accordance with ASTM B487, ASTM B504, the drop test of 3.4.1.5, or other suitable method agreed upon by purchaser and vendor. When thickness is determined by the drop test method, plating shall not be perforated in less time than specified in Table I.

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; except as indicated in Table I, the maximum plate thickness shall be 0.0002 in. (5.1 μm) greater than the minimum. Thus, AMS 2401-2 designates a thickness of 0.0002 - 0.0004 in. (5.1 - 10.2 μm) and AMS 2401-6 designates a thickness of 0.0006 - 0.0008 in. (15.2 - 20.3 μm).

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 μm).

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.

3.4.1.5 Drop Test for Thickness Determination: Allow an aqueous solution of 200 g of chromic acid and 27 mL of sulfuric acid (sp gr 1.84) per litre to drop at a rate of 100 drops ± 5 per min. directly upon properly cleaned surfaces of plated parts until the basis metal is exposed. The solution shall be maintained at a temperature within the range 70° - 80°F (21° - 27°C). The dripping apparatus may be a laboratory separatory funnel equipped with a stopcock to regulate solution flow. The discharge orifice of the outlet tube shall be constricted to deliver drops of 0.045 - 0.055 mL each. The surface to be tested shall be supported at an angle of 45 deg ± 5 to the horizontal and placed approximately 7/8 in. (20 mm) below the discharge orifice.

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 ø 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 ø 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 ø 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 ø requirements; tests shall be conducted in accordance with ASTM E292:

3.4.4.1 A test specimen machined to the dimensions shown in Fig. 1 and Table II, maintained at room temperature while a load sufficient to produce an initial axial stress of 75% of the average ø 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 ø 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 ø detrimental to performance of parts. 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, unless otherwise specified.

4. QUALITY ASSURANCE PROVISIONS:

4.1 Responsibility for Inspection: The processing vendor shall supply all samples and shall be responsible for performing all required tests. Results of such tests shall be reported to the purchaser ø as required by 4.5. Purchaser reserves the right to perform such confirmatory testing as he deems 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 thickness (3.4.1) and quality (3.5) requirements are classified as acceptance tests.

4.2.2 Periodic Tests: Tests to determine conformance to adhesion (3.4.2), corrosion-resistance (3.4.3), and stress-rupture (3.4.4) requirements 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.

4.2.3 Preproduction Tests: Tests to determine conformance to all technical requirements of this specification are classified as preproduction tests.

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:

4.3.1 Acceptance Tests:

4.3.1.1 Thickness: Three parts for each consecutive 8 hr of operation of the same set of solutions, except as specified in 4.3.4.

4.3.1.2 Quality: As agreed upon by purchaser and vendor.

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

4.3.2.1 For stress-rupture tests, six specimens as in 3.4.4.1 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.

4.3.3 Preproduction Tests: As agreed upon by purchaser and vendor and as follows:

4.3.3.1 For preproduction tests of new or revised plating procedures, the test 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. (0.013 mm), dipped in chromic acid as in 3.2.3, and heated at 375°F ±15 (190°C ± 8) for 23 - 23-1/2 hours.

4.3.4 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 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 shall be approved by purchaser before parts for production use are supplied, unless such approval be waived. 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 any change is necessary in type of equipment or in established composition limits and operating conditions ø 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 three copies of a report stating that the parts have been processed and tested in accordance with the requirements of this ø specification and that they conform to the acceptance test requirements. This report shall include the purchase order number, this specification number and its revision letter, 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 ø 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 ø purchaser which does not roughen, pit, or embrittle the basis metal, replated, post-treated, and retested.

5. PREPARATION FOR DELIVERY:

5.1 Parts shall be handled and packaged in such a manner as will ensure that the required physical ø characteristics and properties of the plating are preserved.

5.2 Packages of 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 transø portation 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, ø Level A or Level C, as specified in the request for procurement. Commercial packaging as in 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 authorized modifications will be subject to rejection.

8. NOTES:

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

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

8.3 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
Applicable level of packaging (See 5.3).

TABLE I

Plate Thickness, Salt Spray Corrosion Resistance, and Perforation Time Requirements

AMS 2401 Thickness Designation Specified	External Threads			Nuts, Washers, and Unthreaded 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	Perforation Time sec, min	Thickness Inch	Salt Spray Resistance hr, min	Perforation Time sec, min	Thickness Inch	Salt Spray Resistance hr, min	Perforation Time sec, min
2401	0.0001 - 0.0004	100	7	0.0002 - 0.0005	150	14	0.0003 - 0.0005	200	22
2401-1	0.0001 - 0.0003	100	7	0.0002 - 0.0004	150	14	0.0001 - 0.0003	100	7
2401-2	0.0001 - 0.0004	100	7	0.0002 - 0.0004	150	14	0.0002 - 0.0004	150	14
2401-3	0.0002 - 0.0005	150	14	0.0003 - 0.0005	200	22	0.0003 - 0.0005	200	22
2401-4	0.0003 - 0.0006	200	22	0.0004 - 0.0006	225	29	0.0004 - 0.0006	225	29
2401-5	0.0004 - 0.0007	225	29	0.0005 - 0.0007	250	36	0.0005 - 0.0007	250	36

Note. For thickness designations AMS 2401-X, where X is greater than 5, plate thickness in ten-thousandths 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 250 hr and shall not be perforated in less than 7X sec in thickness determinations by drop test (See 3.4.1.5).