SAE Aerospace
An SAE International Group

AEROSPACE MATERIAL SPECIFICATION

SAE AMS2401 | REV. J

Issued 1963-07
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Superseding AMS2401H

Plating, Cadmium
Low Hydrogen Content Deposit

RATIONALE

AMS2401J results from a Five Year Review and update of this specification and includes procedures for stress relief of steel parts prior to plating.

NOTICE

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

1) Purchase order shall specify not less than the following:

- AMS2401J
- Plating thickness desired. See 3.4.1
- Basis metal to be plated
- Tensile strength or hardness of the basis metal
- Pre-plate stress relief to be performed by plating processor (time and temperature) if different from 3.1.2
- 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 (parameters or reference document) if different from 3.3
- Minimum thickness on internal surfaces, if required. See 3.4.1.4.1
- Optional: Periodic testing frequency (4.2.2) and sample quantity (4.3.2)
- Quantity of pieces to be plated

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)
Fax: 724-776-0790
Email: CustomerService@sae.org
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/AMS2401J

1. SCOPE

1.1 Purpose

This specification covers the engineering requirements for cadmium deposited on ferrous metals.

1.2 Application

This process has been used typically to provide corrosion resistance to steel parts heat treated to tensile strengths of 180 ksi (1240 MPa) and higher and used at temperatures not higher than 450 °F (232 °C), but usage is not limited to such aplications.

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.

1.4 Warning

This process uses 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.

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

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 253 Preparation of Aluminum Alloys for Electroplating

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

ASTM E 292 Conducting Time-for-Rupture Notch Tension Tests of Materials

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

3. TECHNICAL REQUIREMENTS

3.1 Preparation

3.1.1 Parts shall be within drawing dimension limits before plating, except as specified in 3.1.1.1.

3.1.1.1 In lieu of the requirement of 3.1.1 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.

3.1.2 Stress Relief Treatment

All steel parts having a hardness of 36 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. Temperatures to which parts are heated shall be such that maximum 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:

3.1.2.1 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.

3.1.2.2 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.

3.1.2.3 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.

3.1.3 Any specified residual compressive stress-inducing operations, such as shot peening, shall precede plating.

3.1.4 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. See 8.6.

3.1.5 Except for barrel plating, electrical contact points shall be as follows. For parts which are to be plated all over, locations shall be specified or approved by the cognizant engineering organization. For parts which are not to be plated all over, locations shall be in areas on which plating is not required, or locations shall be specified or approved by the cognizant engineering organization.

3.1.6 Aluminum alloys shall be zincate treated in accordance with ASTM B 253 or other method acceptable to the cognizant engineering organization prior to plating.

3.2 Procedure

3.2.1 Parts shall be plated by electrodeposition of cadmium from a suitable cadmium plating solution without brighteners directly on the basis metal without a prior flash of other metal, such as copper or nickel, except in the case of parts fabricated from corrosion-resistant steel or similarly passive alloys on which a preliminary flash of nickel or other suitable metal is permissible.

3.2.2 Spotting-in and double plating are prohibited.

3.3 Hydrogen Embrittlement Relief Treatment (Baking)

After rinsing, steel parts shall be immersed in hot water at a temperature not lower than 180 °F (82 °C) for 15 to 20 minutes followed by treatment in accordance with AMS2759/9.except all parts plated per this specification Rc 36 and higher shall be baked.

3.3.1 Following hydrogen embrittlement relief baking, plating shall be reactivated and parts shall be immersed in a 3 to 6% solution of chromic acid, followed by rinsing and drying.

3.4 Properties

Plating shall conform to the following requirements:

3.4.1 Thickness

The finished thickness shall be as specified on the drawing, determined on representative parts or on test panels in accordance with ASTM B 487, ASTM B 499, ASTM B 504, ASTM B 567, ASTM B 568, ASTM B 748, ASTM B 764 or other method permitted by the cognizant engineering organization.

3.4.1.1 Plate thickness may be specified by AMS2401 and a suffix number normally designating the minimum thickness in ten-thousandths of an inch (µm); except as indicated in Table 2, the maximum plate thickness shall be 0.0002 inch (5 µm) greater than the minimum. Thus AMS2401-2 designates a thickness of 0.0002 to 0.0004 inch (5 to 10 µm) and AMS 2401-6 designates a thickness of 0.0006 to 0.0008 inch (15 to 20 µm).

3.4.1.1.1 Plate thickness, when specified by AMS2401 and a suffix number, shall be as specified in Table 2 for the specified suffix number and type of part or surface.

3.4.1.2 Where “flash” is specified, plate thickness shall be approximately 0.0001 inch (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 See Table 1 for thickness requirements on listed surfaces. All other surfaces of the part that cannot be touched by a sphere 0.75 inch (19 mm) in diameter, such as holes, recesses, threads and other areas where a controlled deposit cannot be obtained under normal plating conditions, may be under the specified limit provided they show visual plating coverage. Such surfaces shall not be masked to prevent plating.

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.

TABLE 1A - PLATE THICKNESS AND SALT SPRAY CORROSION RESISTANCE REQUIREMENTS

AMS2401 Thickness Designation Specified	External Threads Thickness Inch	External Threads Salt Spray Resistance Hours, min	Nuts, Washers, and Unthreaded Surfaces of Bolts, Screws, Studs, and Other Parts Externally Threaded Thickness Inch	Nuts, Washers, and Unthreaded Surfaces of Bolts, Screws, Studs, and Other Parts Externally Threaded Salt Spray Resistance Hours, min	Parts Not Externally Threaded Except Nuts and Washers Thickness Inch	Parts Not Externally Threaded Except Nuts and Washers Salt Spray Resistance Hours, min
2401	0.0001 to 0.0004	100	0.0002 to 0.0005	150	0.0003 to 0.0005	200
2401-1	0.0001 to 0.0003	100	0.0002 to 0.0004	150	0.0001 to 0.0003	100
2401-2	0.0001 to 0.0004	100	0.0002 to 0.0004	150	0.0002 to 0.0004	150
2401-3	0.0002 to 0.0005	150	0.0003 to 0.0005	200	0.0003 to 0.0005	200
2401-4	0.0003 to 0.0006	200	0.0004 to 0.0006	225	0.0004 to 0.0006	225
2401-5	0.0004 to 0.0007	225	0.0005 to 0.0007	250	0.0005 to 0.0007	250

Note: For thickness designations AMS2401-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 240 hours.

TABLE 1B - PLATE THICKNESS AND SALT SPRAY CORROSION RESISTANCE REQUIREMENTS, SI UNITS

AMS2401 Thickness Designation Specified	External Threads Thickness mm	External Threads Salt Spray Resistance Hours, min	Nuts, Washers, and Unthreaded Surfaces of Bolts, Screws, Studs, and Other Parts Externally Threaded Thickness mm	Nuts, Washers, and Unthreaded Surfaces of Bolts, Screws, Studs, and Other Parts Externally Threaded Salt Spray Resistance Hours, min	Parts Not Externally Threaded Except Nuts and Washers Thickness mm	Parts Not Externally Threaded Except Nuts and Washers Salt Spray Resistance Hours, min
2401	0.002 to 0.010	100	0.005 to 0.012	150	0.008 to 0.012	200
2401-1	0.002 to 0.008	100	0.005 to 0.010	150	0.002 to 0.008	100
2401-2	0.002 to 0.010	100	0.005 to 0.010	150	0.005 to 0.010	150
2401-3	0.005 to 0.012	150	0.008 to 0.012	200	0.008 to 0.012	200
2401-4	0.008 to 0.015	200	0.010 to 0.015	225	0.010 to 0.015	225
2401-5	0.010 to 0.018	225	0.012 to 0.018	250	0.012 to 0.018	250

Note: For thickness designations AMS2401-X where X is greater than 5, plate thickness in millimeters shall be 0.0025X to 0.0025 (X+2) except on external threads where the plate thickness shall be 0.0025 (X-1) to 0.0025 (X+2); such parts shall withstand salt spray for not less than 250 hours.

3.4.2 Adhesion shall meet the requirements of ASTM B 571 by the Bend Test method except without using a mandrel.

3.4.3 Corrosion Resistance

Except as specified in 3.4.3.1, carbon and alloy steel parts or representative test panels plated to a thickness of 0.0003 to 0.0005 inch (0.008 to 0.013 mm) shall show no visual evidence of corrosion of the basis metal after being subjected for a time not less than 200 hours to continuous salt fog corrosion test conducted in accordance with ASTM B 117.

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 Hydrogen Embrittlement

The plating process after baking shall not cause hydrogen embrittlement in steel parts 36 HRC and over when tested in accordance with 4.3.3.3.

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.

4. QUALITY ASSURANCE PROVISIONS

4.1 Responsibility for Inspection

The processor shall supply all samples for processor’s tests and shall be responsible for the performance of all required tests. When parts are to be tested, such parts shall be supplied to the purchaser. Purchaser 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 (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, from each lot.

4.2.2 Periodic Tests

Corrosion-resistance (3.4.3) is a periodic test and shall be performed at least quarterly unless frequency of testing is specified by the cognizant engineering organization. Tests of cleaning and processing 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 8.7 and 4.4.3. Hydrogen embrittlement (3.4.4) is a periodic test and shall be performed in accordance with ASTM F 519 at least once in each month that steel parts 36 HRC and over are plated unless frequency of testing is specified by the cognizant engineering organization.

4.2.3 Preproduction Tests

All property verification tests (See 3.4) are preproduction tests and shall be performed prior to production and when the cognizant engineering organization requires confirmatory testing.

4.3 Sampling for testing shall be not less than the following; a lot shall be all parts made of the same alloy and same hardness range, plated to the same range of plate thickness in the same set of solutions, in each consecutive 24-hour period of operation, and presented for processor’s inspection at one time.

4.3.1 Acceptance Tests

Test samples shall be randomly selected from all parts in the lot. Unless the cognizant engineering organization provides a sampling plan, the minimum number of samples shall be as shown in Table 2.

TABLE 2 - 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
Over 700	75	10

*Whichever is less

4.3.2 Periodic Tests

Sample size shall be four for corrosion resistance and as specified in ASTM F 519 unless otherwise specified by the cognizant engineering organization.

4.3.3 Sample Configuration

4.3.3.1 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.

4.3.3.2 For adhesion tests, specimens shall be panels approximately 0.032 x 4 x 1 inch (1 x 102 x 25 mm). For corrosion resistance tests, specimens shall be panels 0.025 inch (6.2 mm) minimum and not less than 4 inch (102 mm) long by 3 inch (76 mm) wide plated in accordance with 3.4.3.

4.3.3.3 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 0.0005 to 0.0007 inch (13 to 18 µm) measured on the smooth section of the specimen, but with visual plating at the root of the notch. Testing beyond the 200 hour test period is not required.

4.4 Approval

4.4.1 The process and control factors, and/or a preproduction part, 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 was based, all preproduction tests shall be performed and the results submitted to the cognizant engineering organization for process reapproval 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. Production parts plated by the revised procedure shall not be shipped prior to receipt of reapproval.