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# AEROSPACE MATERIAL SPECIFICATION

SAE AMS 2401E

Issued JUL 1963
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Superseding AMS 2401D

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## Plating, Cadmium
## Low Hydrogen Content Deposit



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 strength of 180,000 psi (1240 MPa) and higher and used at temperatures not higher than 450 °F (232 °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.

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:

Numerous scientific studies have determined that cadmium can present a health hazard to persons exposed to it.

2. APPLICABLE DOCUMENTS:

The issue of the following documents in effect on the date of the purchase order form 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.



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2.1 SAE Publications:

Available from SAE, 400 Commonwealth Drive, Warrendale, PA 15096-0001.

AMS 2759/1 Heat Treatment of Carbon, Low-Alloy Steel Parts
AMS 2759/9 Hydrogen Embrittlement Relief (Baking) of Steel Parts

2.2 ASTM Publications:

Available from ASTM, 100 Barr Harbor Drive, West Conshohocken, PA 19428-2959.

ASTM B 117 Operating Salt Spray (Fog) Testing Apparatus
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 571 Adhesion of Metallic Coatings
ASTM E 8 Tension Testing of Metallic Materials
ASTM E 292 Conducting Time-for-Rupture Notch Tension Tests of Materials

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 Parts shall be cleaned to remove surface contamination and 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), or 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. Unless otherwise specified, the stress relief shall not be less than 275 °F (135 °C) for not less than five hours for parts with hardness of 55 HRC or greater or for parts that would be harmed by higher exposure temperatures, or not less than 375 °F (191 °C) for not less than four hours for other parts.

3.1.3 Residual compressive stress-inducing operations, such as shot peening, shall follow stress-relieving.

3.1.4 Parts shall have clean surfaces, free of waterbreak.

3.1.4.1 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 four hours before being transferred to the plating solution.

3.1.5 When not otherwise specified by the purchaser, the location of electrical contact points shall be as follows (not applicable to barrel plating).

3.1.5.1 For parts which are to be plated all over, locations shall be acceptable to the purchaser

3.1.5.2 For parts which are not to be plated all over, locations shall be in areas on which plating is not required or is optional.

3.2 Procedure:

3.2.1 Cadmium shall be deposited 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.

3.3 Hydrogen Embrittlement Relief Treatment:

After rinsing, plated parts shall be immersed in hot water at a temperature not lower than 180 °F (82 °C) for 15 to 20 minutes followed by baking in accordance with AMS 2759/9.

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: Shall be as specified on the drawing, determined on representative parts or test panels in accordance with ASTM B 487, ASTM B 499, ASTM B 504 or other method acceptable to purchaser.

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 (µm); except as indicated in Table 2, the maximum plate thickness shall be 0.0002 inch (5 µm) greater than the minimum. Thus AMS 2401-2 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 AMS 2401 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 No requirements are established for minimum plate thickness for surfaces of holes, recesses, internal threads except as specified in Table 2, 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 2 for externally threaded sections, the resultant thickness shall be considered only when such surfaces of parts can be touched by a sphere 0.75 inch (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.

TABLE 2A - Plate Thickness and Salt Spray Corrosion Resistance Requirements

| AMS 2401 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 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 240 hours.

TABLE 2B - Plate Thickness and Salt Spray Corrosion Resistance Requirements, SI Units

| AMS 2401 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 AMS 2401-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: Specimens as in 4.3.3 tested in accordance with the bend test in ASTM B 571 shall not show separation of the plating from the basis metal.

3.4.3 Corrosion Resistance: Except as specified in 3.4.3.1, 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 2 to continuous salt spray 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 shall not cause hydrogen embrittlement in ferrous metal when tested in accordance with ASTM F 519 Type 1A using notched round specimens, stressed in tension under constant load. For test purposes, plating thickness shall be 0.0005 to 0.0007 inch (13 to 18 mm), measured on the smooth section of the specimen, but with visual plating at the root of the notch.

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. There shall be no evidence of double plating or spotting-in.

4. QUALITY ASSURANCE PROVISIONS:

4.1 Responsibility for Inspection:

The processor shall supply all samples for processor’s tests and shall be responsible for 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 the requirements of this specification.

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 to represent each lot.

4.2.2 Periodic Tests: Corrosion-resistance (3.4.3) and hydrogen embrittlement (3.4.4) and tests of cleaning and plating solutions (See 8.6) to ensure that the deposited metal will conform to the requirements of this specification are periodic tests and shall be performed at a frequency selected by the processor unless frequency of testing is specified by purchaser.

4.2.3 Preproduction Tests: All technical requirements of this specification are 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 and/or processing requires reapproval as in 4.4.2, and when purchaser deems confirmatory testing to be required.

4.3 Sampling:

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. The minimum number of samples shall be as shown in Table 1.

TABLE 1 - Sampling for Acceptance Tests

| Number of Parts in Lot | Quality | Thickness and Adhesion |
|---|---|---|
| Up to 7 | All | 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 |



4.3.2 Sample quantities for periodic and preproduction tests shall be selected at the discretion of the processor unless otherwise specified by purchaser.

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 fabricated from an alloy generically similar to the parts represented approximately 0.032 x 4 x 1 inch (1 x 102 x 25 mm) and for thickness tests shall be panels of the same size, fabricated from annealed low-carbon steel or shall be bars approximately 0.5 inch (10 mm) in diameter and 4 inch (102 mm) long. For corrosion resistance tests, specimens shall be panels 0.062 to 0.125 inch (1.5 to 3 mm) in nominal thickness and not less than 4 inch (102 mm) long by 3 inch (76 mm) wide.