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AEROSPACE MATERIAL SPECIFICATION

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AMS 2402G

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Superseding AMS 2402F

Submitted for recognition as an American National Standard

(R) PLATING, ZINC

1. SCOPE:

1.1 Purpose:

This specification covers the engineering requirements for electrodeposition of zinc and the properties of the deposit.

1.2 Application:

This process has been used typically to provide corrosion resistance to metal parts, but usage is not limited to such applications.

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.

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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SAE reviews each technical report at least every five years at which time it may be reaffirmed, revised, or cancelled. SAE invites your written comments and suggestions.

AMS 2402G**SAE****AMS 2402G****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 555 Measurement of Electrodeposited Metallic Coating Thicknesses by the Dropping Test
- ASTM B 567 Measurement of Coating Thickness by the Beta Backscatter Method
- ASTM B 568 Measurement of Coating Thickness by X-Ray Spectrometry
- ASTM B 571 Adhesion of Metallic Coatings
- ASTM E 376 Measuring Coating Thickness by Magnetic-Field or Eddy-Current (Electromagnetic) Test Methods
- ASTM F 519 Mechanical Hydrogen Embrittlement Testing of Plating Processes and Aircraft Maintenance Chemicals

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 All fabrication-type operations, such as forming, machining, heat treating, brazing, and welding, of areas to be plated 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 Parts having part numbers with the prefix MA, AN, MS, or AS or parts where the drawing specifies dimensions apply after plating 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 or the applicable drawing.
- 3.1.3 Steel parts having hardness higher than 40 HRC and which have been ground after heat treatment shall be cleaned to remove surface contamination and suitably stress-relieved before preparation for plating, unless otherwise specified. 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 with hardness of 55 HRC or over, or 375 °F (191 °C) for four hours for other parts.

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- 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 Steel parts having hardness of 33 HRC or higher and parts roll-threaded after heat treatment shall not be cleaned with inorganic acids, such as hydrochloric or sulfuric acids, unless specifically approved. Cleaning of other parts with inorganic acids is not prohibited but permission to use such method on a particular part shall first be obtained from purchaser. In either case, a momentary dip in acid for activation purposes or neutralization after alkaline cleaning is permissible.
- 3.1.5.2 Alkaline cleaning of steel parts may be done with anodic current, but shall not be done with cathodic current or periodic current reversal.
- 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, except in the case of barrel plating, be located where specified or where agreed upon by purchaser and processor. 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 Parts shall be plated by electrodeposition of zinc from a suitable zinc plating solution such as zinc chloride, zinc cyanide, or zinc sulfate.
- 3.2.1.1 The zinc shall be deposited directly on the metal part, without a prior strike coating of other metal, such as copper or nickel. Parts, assemblies, and weldments made wholly or in part of corrosion-resistant steel or similarly passive materials, may receive a preliminary strike of nickel or other suitable metal.
- 3.2.1.2 Aluminum alloys may be zincate or stannate treated before plating.
- 3.3 Post Treatment:
- After plating, rinsing, and drying, steel parts shall be post treated as in 3.3.1, 3.3.2, or 3.3.3, as applicable, unless otherwise permitted, to minimize the effects of hydrogen embrittlement; heating shall be in air, preferably in a circulating-air furnace. Post treatment shall follow the plating operation with a maximum delay time of four hours between removal of the parts from plating bath and start of post thermal treatment.
- 3.3.1 Parts having specified hardness of 33 to 45 HRC shall be heated to $375^{\circ}\text{F} \pm 25$ ($191^{\circ}\text{C} \pm 14$) and held at heat for not less than eight hours. Parts having hardness of 46 HRC or higher shall be held at heat for 23 hours.

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- 3.3.2 Parts, including carburized parts, which will decrease in hardness or be otherwise deleteriously affected by heating to 375 °F (191 °C) shall be heated to 275 °F $\pm$ 25 (135 °C $\pm$ 14) and held at heat for not less than 23 hours.
- 3.3.3 Parts requiring special handling shall be post treated as specified by purchaser.
- 3.3.4 Zinc plated parts, after the embrittlement relief treatment, shall, unless otherwise specified, be chemically treated by a process which has been demonstrated to prevent formation of white corrosion products after 100-hour salt spray test in accordance with the procedure specified in 3.4.3. Waxes, or other water-repellent coatings, shall not be used for this purpose.
- 3.4 Properties:
- The plating shall conform to the following:
- 3.4.1 Thickness: Shall be as specified on the drawing, determined on representative parts or, when permitted by purchaser, on test panels in accordance with ASTM B 487, ASTM B 499, ASTM B 504, ASTM B 567, ASTM B 568, or ASTM E 376, the drop test of ASTM B 555, or other method acceptable to purchaser. When thickness is determined by the drop test method, plating shall not be perforated in less time than specified in Table 2.
- 3.4.1.1 Plate thickness may be specified by AMS 2402 and a suffix number normally designating the minimum thickness in ten-thousandths of an inch (μ m); except as indicated in Table 2, the maximum plate thickness shall be 0.0002 inch (5 μ m) greater than the minimum. Thus, AMS 2402-2 designates a thickness of 0.0002 to 0.0004 inch (5 to 10 μ m) and AMS 2402-6 designates a thickness of 0.0006 to 0.0008 inch (15 to 20 μ m).
- 3.4.1.1.1 Plate thickness, when specified by AMS 2402 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 "zinc strike" is specified, plate thickness shall be approximately 0.0001 inch (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 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. However, such surfaces shall show visual evidence of coverage. Except as specified in Table 2 for externally threaded sections, the resulting thickness shall be considered only when such surfaces of parts can be touched by a sphere 0.75 inch (19.0 mm) in diameter.

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- 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: Plating shall be firmly adhered to the basis metal.
- 3.4.2.1 Whenever practical, plating adhesion shall be tested on actual parts using one of the following methods:
- 3.4.2.1.1 The plating shall be scraped through to the basis metal with a sharp knife or awl to expose the basis metal and examined at approximately 5X for evidence of flaking off or separation.
- 3.4.2.1.2 The basis metal shall be plastically bent or deformed as required to cause it to crack and examined at approximately 5X for evidence of flaking or separation of the plating.
- 3.4.2.1.3 Test adhesion using the burnishing test, draw test, or heat quench test of ASTM B 571. Adhesion testing is not required for parts that are post treated by heating to at least 375 °F (191 °C), quenched, and examined for blisters or other signs of lack of adhesion.
- 3.4.2.2 Where testing of actual parts is impractical or not permitted by purchaser, specimens as in 4.3.3 may be used.
- 3.4.3 Corrosion Resistance: Except as specified in 3.4.3.1, ferrous metal parts or representative specimens as in 4.3.3 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. Intentionally unplated areas may be masked during testing. Where the drawing specifies a specific plating thickness, the most stringent test requirement for the minimum specified thickness shall apply.
- 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 (R) Hydrogen Embrittlement: When parts with hardness of 46 HRC or higher are plated, the process used shall not cause hydrogen embrittlement when tested in accordance with requirements of ASTM F 519, Type 1, using notched round bars stressed in tension under constant load. For test purposes, plating thickness shall be 0.002 inch $\pm$ 0.0002 (0.05 mm $\pm$ 0.005), measured on the smooth section of the specimen but with visual evidence of plating at the root of the notch.
- 3.5 Quality:
- Plated zinc, as received by purchaser, shall be continuous, adherent to basis metal, uniform in appearance, and not coarsely crystalline and shall be essentially free from pin holes, porosity, blisters, nodules, pits, and other imperfections detrimental to performance of the plated zinc. Slight staining or discoloration is permissible. There shall be no evidence of double plating and spotting-in after plating.

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4. QUALITY ASSURANCE PROVISIONS:

4.1 Responsibility for Inspection:

The processor shall supply all test 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 Tests for 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: Tests for corrosion-resistance (3.4.3), and hydrogen embrittlement (3.4.4) 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 processor unless frequency of testing is specified by purchaser.

4.2.3 Preproduction Tests: Tests for all technical requirements 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 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 range of plate thickness in the same set of solutions, in each consecutive 24 hours of operation, 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.
(R) Unless purchaser specifies a sampling plan, the minimum number of samples shall be as shown in Table 1.

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TABLE 1 - Sampling for Acceptance Tests

Number of Parts in Lot		Quality	Thickness and Adhesion
1 to	6	All	3
7 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
701 to	1200	75	10
Over	1200	125	15

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 made of the same generic class of alloy as the parts represented cleaned, plated, and post-treated with the parts represented may be used. For corrosion tests, such specimens shall be panels of annealed low-carbon steel.

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 of plated parts shall make no significant change to materials, processes, or control factors from those on which 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.

4.4.2.1 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
- Chemical post treatment
- Method for testing plating thickness
- Method for checking adhesion
- Stripping procedure, if required
- Periodic test plan

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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 specified requirements and that they conform to the acceptance test requirements. This report shall include the purchase order number, lot number, AMS 2402G, part number, and quantity.

4.6 Resampling and Retesting:

- 4.6.1 If the results of any acceptance test fail to meet specified test requirements, the parts in that lot may be stripped by a method acceptable to purchaser that does not roughen, pit, or embrittle the basis metal, pretreated, plated, and post treated as defined herein, and tested. Alternatively, all parts in the lot may be inspected for the nonconforming attribute, and the nonconforming parts may be stripped by a method acceptable to purchaser that does not roughen, pit, or embrittle the basis metal, pretreated, plated, post treated as defined herein, and tested.
- 4.6.2 If the results of any periodic test fail to meet specified requirements, the process is nonconforming. No additional parts shall be plated until the process is corrected and new specimens are plated and tested. Results of all tests shall be recorded and, when requested, reported. Purchaser shall be notified of all parts plated since the last acceptable test.

5. PREPARATION FOR DELIVERY:

- 5.1 Plated parts shall be handled and packaged to ensure that the required physical 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 transportation of the plated parts to ensure carrier acceptance and safe delivery.
- 5.3 For direct U.S. Military procurement, packaging shall be in accordance with MIL-STD-2073-1, Level C, unless Level A is specified in the request for procurement.

6. ACKNOWLEDGMENT:

A processor 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.