AEROSPACE MATERIAL SPECIFICATION

AMS2402™	REV. M

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Revised 2024-01

Superseding AMS2402L

Plating, Zinc

RATIONALE

AMS2402M results from a Five-Year Review and update of this specification with changes to Ordering Information, Stress Relief Treatment (see 3.1.2), Fixture/Electrical Contact Locations (see 3.1.4), Corrosion Resistance (see 3.4.3.1), Quality (see 3.5), Periodic Tests (see 4.2.2.1), Acceptance Tests (see 4.3.1), control factors (see 4.4.3), and to Notes (see 8.3 and 8.8).

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:

- AMS2402M
- Plating thickness desired (see 3.4.1)
- Basis metal to be plated
- Tensile strength or hardness of the basis metal (applies to steel alloys only)
- If preplate stress relief is to be performed by plating processor and if different from 3.1.2, time and temperature are to be specified
- If steel parts were machined, ground, cold formed or cold straightened after heat treat (see 3.1.2)
- If steel parts have been shot peened, specify if required stress relief has been completed (see 3.1.2.3)
- Special features, geometry or processing present on parts that require 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)
- Periodic testing frequency and sample quantity, if different from 4.2.2 and 4.3.2

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**

For more information on this standard, visit
https://www.sae.org/standards/content/AMS2402M

- Whether approval is based on approval of process/control factors or sample part or both (see 4.4.1)
- Quantity of pieces to be plated
- Optional: Fixture/Electrical contact locations, when not specified (see 3.1.4)

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.

1. SCOPE

1.1 Purpose

This specification covers the requirements for electrodeposited zinc plating.

1.1.1 Unless otherwise specified, high strength steel parts having a hardness of HRC 40 or greater shall not be electroplated to this document (see 8.8).

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 that 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 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 +1 724-776-4970 (outside USA), www.sae.org.

AMS2750	Pyrometry
AMS2759/9	Hydrogen Embrittlement Relief (Baking) of Steel Parts
ARP4992	Periodic Test for Processing Solutions
AS2390	Chemical Process Test Specimen Material
AS7766	Terms Used in Aerospace Metals Specifications

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 B117 Operating Salt Spray (Fog) Apparatus

ASTM B253 Preparation of Aluminum Alloys for Electroplating

ASTM B374 Terminology Relating to Electroplating

ASTM B487 Measurement of Metal and Oxide Coating Thickness by Microscopical Examination of 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 B555 Measurement of Electrodeposited Metallic Coating Thicknesses by Dropping Test

ASTM B567 Measurement of Coating Thickness by the Beta Backscatter Method

ASTM B568 Measurement of Coating Thickness by X-Ray Spectrometry

ASTM B571 Qualitative Adhesion Testing of Metallic Coatings

ASTM E376 Measuring Coating Thickness by Magnetic-Field or Eddy-Current (Electromagnetic) Testing Methods

ASTM F519 Mechanical Hydrogen Embrittlement Evaluation of Plating/Coating Processes and Service Environments

2.3 Terms used in AMS are defined in AS7766. ASTM B374 should be utilized as a reference and referee document when areas of design definition or technical interpretation arise.

3. TECHNICAL REQUIREMENTS

3.1 Preparation

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

3.1.1.1 Parts having part numbers with the prefix MA, AN, MS, or AS or parts where the specified 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 specified by the cognizant engineering organization.

3.1.2 Stress Relief Treatment

All steel parts having a hardness of HRC 36 and above and that are machined, ground, cold formed, or cold straightened after heat treatment shall be cleaned to remove surface contamination and then thermally stress relieved before plating for relief of residual tensile stresses. (Residual tensile stresses have been found to be damaging during electrofinishing.) Furnaces used for stress relief shall be controlled per AMS2750; the minimum requirements shall be Class 5 and Type D Instrumentation. Temperatures to which parts are heated shall be such that maximum stress relief is obtained while still maintaining hardness of parts within specified 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 HRC 55 and above, including carburized and induction hardened parts, stress relieve at 275 °F ± 25 °F (135 °C ± 14 °C) for 5 to 10 hours.

3.1.2.2 For parts having a hardness less than HRC 55, stress relieve at 375 °F ± 25 °F (191 °C ± 14 °C) 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 specified, the stress relieve shall be performed prior to peening.

3.1.3 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.

3.1.4 Fixture/Electrical Contact Locations

3.1.4.1 Except for barrel plating, for parts that are to be electroplated/coated all over, and contact locations are not specified, contact locations shall be at the discretion of the processor.

3.1.4.2 For parts that are not to be electroplated/coated all over, and contact locations are not specified, contact locations shall be in areas on which plate/coating is not required.

3.2 Procedure

3.2.1 Except as noted, the zinc shall be deposited directly on the metal surface from a suitable zinc plating solution.

3.2.1.1 Nickel or cobalt alloys, corrosion resistant steels and aluminum may be given a nickel or other suitable metal strike prior to zinc plating.

3.2.1.2 Aluminum alloys shall be zincate treated prior to plating in accordance with ASTM B253 or other method permitted by the cognizant engineering organization.

3.2.2 After rinsing in water and without allowing the parts to dry, unless otherwise specified, plated parts shall be chemically treated by a process that has been demonstrated to prevent the formation of white corrosion products. If trivalent chromium treatment is elected, it may be applied prior to hydrogen embrittlement thermal treatment (see 3.3) without subsequent reactivation retreatment, provided it has demonstrated acceptable corrosion resistance (see 3.4.3). When plated parts specifying a traditional type of supplementary treatment, such as hexavalent chromate, require post thermal treatment as in 3.3, surface reactivation and supplementary treatment shall follow hydrogen embrittlement relief.

3.2.3 Spotting-in and double plating are prohibited.

3.2.4 The use of metallic brighteners is prohibited. Organic brighteners may be used to the extent necessary to produce acceptable corrosion and appearance characteristics while at the same time minimizing embrittlement tendencies.

3.3 Post Treatment

3.3.1 Hydrogen Embrittlement Relief

Treatment of steel parts HRC 36 or higher shall be in accordance with AMS2759/9.

3.4 Properties

3.4.1 Plate thickness shall be as specified, determined in accordance with any of the following methods as applicable: ASTM B487, ASTM B499, ASTM B504, ASTM B567, ASTM B568, direct dimensional inspection provided the resolution of the measuring instrument is ten times more precise than the attribute being measured or ASTM E376, the drop test of ASTM B555, or other method permitted by the cognizant engineering organization. When thickness is determined by the drop test method, plating shall not be perforated in less time than specified in Table 1C.

3.4.1.1 Plate thickness may be specified by AMS2402 and a suffix number normally designating the minimum thickness in ten-thousandths of an inch (µm); except as indicated in Tables 1A and 1B, the maximum plate thickness shall be 0.0002 inch (5 µm) greater than the minimum. Thus AMS2402-2 designates a thickness of 0.0002 to 0.0004 inch (5 to 10 µm) and AMS2402-6 designates a thickness of 0.0006 to 0.0008 inch (15 to 20 µm).

3.4.1.1.1 Plate thickness, when specified by AMS2402 and a suffix number, shall be as specified in Tables 1A and 1B 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 µm).

Table 1A - Plate thickness, salt spray corrosion resistance, and perforation time requirements, inch/pound units

AMS2402 Thickness Designation Specified[1]	External Threads Thickness Inches	External Threads Salt Spray Resistance Hours, Min	External Threads Perforation Time Seconds, Min	Nuts, Washers, & Unthreaded Surfaces of Bolts, Screws, Studs, & Other Parts Externally Threaded Thickness Inches	Nuts, Washers, & Unthreaded Surfaces of Bolts, Screws, Studs, & Other Parts Externally Threaded Salt Spray Resistance Hours, Min	Nuts, Washers, & Unthreaded Surfaces of Bolts, Screws, Studs, & Other Parts Externally Threaded Perforation Time Seconds, Min	Other Parts Thickness Inches	Other Parts Salt Spray Resistance Hours, Min	Other Parts Perforation Time Seconds, Min[2]
2402	0.0001 to 0.0004	100	10	0.0002 to 0.0005	150	20	0.0005 to 0.0007	200	51
2402-1	0.0001 to 0.0003	100	10	0.0002 to 0.0004	150	20	0.0001 to 0.0003	100	10
2402-2	0.0001 to 0.0004	100	10	0.0002 to 0.0004	150	20	0.0002 to 0.0004	150	20
2402-3	0.0002 to 0.0005	150	20	0.0003 to 0.0005	168	30	0.0003 to 0.0005	168	30
2402-4	0.0003 to 0.0006	168	30	0.0004 to 0.0006	185	41	0.0004 to 0.0006	185	41
2402-5	0.0004 to 0.0007	185	41	0.0005 to 0.0007	200	51	0.0005 to 0.0007	200	51

[1] For thickness designations AMS2402-X, where X is greater than five, 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 hours and plating shall not be perforated in less than 10X seconds in thickness determinations by drop test.

[2] Perforation times specified above are for the drop test solution of 3.4.1 at 70 °F; equivalent perforation times at other temperatures are as shown in Table 1C.

Table 1B - Plate thickness, salt spray corrosion resistance, and perforation time requirements, SI units

AMS2402 Thickness Designation Specified[1]	External Threads Thickness µm	External Threads Salt Spray Resistance Hours, Min	External Threads Perforation Time Seconds, Min	Nuts, Washers, & Unthreaded Surfaces of Bolts, Screws, Studs, and Other Parts Externally Threaded Thickness µm	Nuts, Washers, & Unthreaded Surfaces of Bolts, Screws, Studs, and Other Parts Externally Threaded Salt Spray Resistance Hours, Min	Nuts, Washers, & Unthreaded Surfaces of Bolts, Screws, Studs, and Other Parts Externally Threaded Perforation Time Seconds, Min	Other Parts Thickness µm	Other Parts Salt Spray Resistance Hours, Min	Other Parts Perforation Time Seconds, Min[2]
2402	3 10	100	10	5 13	150	20	13 18	200	51
2402-1	3 8	100	10	5 10	150	20	3 8	100	10
2402-2	3 10	100	10	5 10	150	20	5 10	150	20
2402-3	5 13	150	20	8 13	168	30	8 13	168	30
2402-4	8 15	168	30	10 15	185	41	10 15	185	41
2402-5	10 18	185	41	13 18	200	51	13 18	200	51

[1] For thickness designation AMS2402-X where X is greater than five, plate thickness in micrometers shall be 2.5X to 2.5 (X+2) except for external threads where the plate thickness shall be 2.5 (X-1) to 2.5 (X+2); such parts shall withstand salt spray for not less than 250 hours and plating shall not be perforated in less than 10X seconds in thickness determinations by drop test.

[2] Perforation times specified above are for the drop test solution of 3.4.1 at 21 °C; equivalent perforation times at other temperatures are as shown in Table 1C.

Table 1C - Equivalent perforation time

Perforation Time, Seconds at 70 °F (21 °C)	Seconds at Temperature Shown 75 °F (24 °C)	Seconds at Temperature Shown 80 °F (27 °C)
10	10	10
20	20	19
30	30	29
41	39	37
51	49	47

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 specified dimensions are met.

3.4.1.4 All surfaces of the part, except those that cannot be touched by a sphere 0.75 inch (19 mm) in diameter, shall be plated to the specified thickness. Unless otherwise stated in Tables 1A, 1B, or as otherwise specified, surfaces 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.

3.4.2 Adhesion

Plating shall be firmly adhered to the basis metal and shall be tested using one of the following methods:

3.4.2.1 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 magnification for evidence of flaking off or separation.

3.4.2.2 The basis metal shall be plastically bent or deformed as required to cause it to crack and examined at approximately 5X magnification for evidence of flaking or separation of the plating.

3.4.2.3 Test adhesion using the burnishing test, draw test, or heat quench test of ASTM B571.

3.4.2.4 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.

3.4.3 Corrosion Resistance

Except as specified in 3.4.3.1, plated carbon and alloy steel parts or test panels (see 4.3.3.2) plated 0.0001 to 0.0003 inch (3 to 8 µm) thick and that have received a supplementary chemical treatment as in 3.2.2 shall show no visual evidence of reddish corrosion product of the basis metal or whitish corrosion product of the plate after being subjected to 96 hours of continuous salt fog exposure in accordance with ASTM B117. Intentionally unplated areas may be masked during testing. The cognizant engineering organization may specify an alternative plate thickness and/or salt fog exposure time (see Tables 1A and 1B).

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, to parts made from nickel or cobalt alloys, to parts made from aluminum, 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 HRC 36 and over determined in accordance with 4.3.3.4.

3.5 Quality

Plated zinc, as received by the purchaser, shall be continuous, adherent to basis metal, uniform in appearance, and not coarsely crystalline and shall be free from pin holes, porosity, blisters, nodules, pits, and other imperfections detrimental to performance of the plated zinc. There shall be no evidence of electrical arcing or local overheating. Slight staining or discoloration is permissible.

4. QUALITY ASSURANCE PROVISIONS

4.1 Responsibility for Inspection

The processor shall supply all specimens for processor's tests and shall be responsible for performance of all required tests. Where parts are to be tested, such parts shall be supplied by the purchaser. The 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 (see 3.4.1), and quality (see 3.5) are acceptance tests and shall be performed on parts, or specimens representing parts, when permitted herein from each lot (see 4.3.3).

4.2.2 Periodic Tests

Corrosion resistance (see 3.4.3) is a periodic test and shall be performed at least quarterly unless frequency of testing is specified by the cognizant quality organization. Adhesion (see 3.4.2) is a periodic test that shall be performed no less than daily for each generic class of alloy as defined by AS2390 processed during that day. Tests of cleaning and plating solutions are periodic tests and shall be performed at a frequency established by the processor unless frequency of testing is specified by the cognizant quality organization (see 8.5 and 4.4.3). Hydrogen embrittlement (see 3.4.4) is a periodic test and shall be performed at least once in each month that steel parts HRC 36 and over are plated unless frequency of testing is specified by the cognizant quality organization.

4.2.2.1 Periodic testing may be suspended in any test period when parts are not processed but shall be performed before or at time such processing is resumed. Preproduction testing may be required by the cognizant quality organization upon resumption of processing.

4.2.3 Preproduction Tests

All property verification tests are preproduction tests and shall be performed prior to initial shipment and when the purchaser deems confirmatory testing to be required.

4.3 Sampling and testing

4.3.1 Acceptance Tests

Test samples shall be randomly selected from all parts in the lot. A lot is a group of parts, all of the same part number, processed through the same chemical solutions in the same tanks under the same conditions, which have completed the chemical processing within a period of 24 hours of each other and are presented to inspection at the same time. Unless the cognizant quality 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
Up to 6	All	All or 3[1]
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

[1] Whichever is less.

4.3.2 Periodic Tests and Preproduction Tests

Sample quantity shall be four each for corrosion and hydrogen embrittlement unless otherwise specified. For adhesion tests, when test specimens are used, four test specimens of each generic class of alloy, as defined by AS2390, that have been processed through the same cleaning and plating operations as the parts that they represent. These adhesion test specimens shall be processed prior to the first production lot of parts or with the first production lot of parts.

4.3.3 Sample Configuration

4.3.3.1 Nondestructive testing shall be performed wherever practical. Except as noted, actual parts shall be selected as samples for tests. When representative specimens are used for acceptance testing, values obtained shall be correlated with those of parts since properties, such as thickness, may differ between parts and representative test specimens.

4.3.3.1.1 Representative test specimens may be used in lieu of parts under any one of the following circumstances:

4.3.3.1.1.1 The plated parts are of such configuration or size as to be not readily adaptable to specified tests.

4.3.3.1.1.2 Nondestructive testing is not practical on actual parts.

4.3.3.1.1.3 It is not economically acceptable to perform destructive tests on actual parts. Except as specified below, representative 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 represented.

4.3.3.2 When ferrous alloy parts are processed within the test period (quarter), representative test specimens shall be low carbon or low alloy steel 0.025 inch (0.63 mm) minimum thickness and not less than 4 × 6 inches (102 × 152 mm) or bars approximately 0.5 inch (13 mm) in diameter and 4 inches (102 mm) long having a surface roughness not to exceed 40 microinches (1 µm) AA. Representative test specimens for aluminum alloy parts (same specimen size as for steel) made of either 2024-T3 or the same generic class of alloy as the parts processed within the test period when aluminum alloy parts are plated. Representative test specimens, made of the predominant generic class of alloy as the parts and plated within the test period may be used when permitted by the cognizant engineering organization. Alternative alloy or configuration may be used when permitted by the cognizant engineering organization.

4.3.3.3 Adhesion Testing

Test specimens for adhesion testing shall be made of the same generic class of alloy as defined by AS2390 as the parts processed. The test specimens shall be 0.025 inch (0.46 mm) minimum thickness and not less than 1 x 4 inches (25 x 102 mm).

4.3.3.4 Hydrogen Embrittlement Test

Test shall be in accordance with ASTM F519 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, with visual evidence of 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, 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 If the processor of plated parts makes a significant change to any material, process, or control factor from that which was used for process approval, 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 that, 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.