

Plating, Zinc

RATIONALE

AMS 2402H is a Five Year Review and update of this specification.

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:

- AMS 2402J
- 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 such as may be required by 3.4.1.4.
- 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)
- Optional: Sample quantity and frequency of periodic testing (see 4.2.2 and 4.3.2)
- 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

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. Unless otherwise specified on the engineering drawing, high strength steel parts having a hardness of 45 HRC or greater shall not be electroplated.

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1. SCOPE

1.1 Purpose

This specification covers the requirements for electrodeposited zinc plating. Unless otherwise stated on the engineering drawing, high strength steel parts having a hardness of 45 HRC or greater shall not be electroplated.

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 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.

AMS 2759/9 Hydrogen Embrittlement Relief (Baking) of Steel Parts

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 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 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 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 referenced or the applicable drawing.

3.1.2 Steel parts having hardness higher than 36 HRC and which have been ground after heat treatment shall be cleaned to remove surface contamination and suitably stress-relieved before preparation for plating. 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 not less than five hours for parts with hardness of 55 HRC or over, or not less than 375 °F (191 °C) for not less than four hours for other parts.

3.1.3 Any specified residual compressive stress-inducing operations, such as shot peening, shall follow stress relieving but 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.

3.1.5 Except for barrel plating, electrical contact points shall be as follows. For parts which are to be plated all over, location shall be acceptable to purchaser. For parts which are not to be plated all over, location shall be in areas on which plating is optional.

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

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

3.2.2 After rinsing in water and without allowing the parts to dry, plated parts shall unless otherwise specified be chemically treated by a process which has been demonstrated to prevent the formation of white corrosion products. When plated parts require post thermal treatment as in 3.3, surface reactivation and the 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 Hydrogen Embrittlement Relief

Treatment of steel parts shall be in accordance with AMS 2759/9 using the baking parameters for cadmium plate unless otherwise specified in AMS 2759/9.

3.4 Properties

3.4.1 Thickness shall be as specified on the drawing, determined on representative parts or, when permitted by 4.3.3, on test specimens 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 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 1D.

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 (μm); except as indicated in Table 1, the maximum plate thickness shall be 0.0002 inch ($5\ \mu\text{m}$) greater than the minimum. Thus AMS 2402-2 designates a thickness of 0.0002 to 0.0004 inch (5 to $10\ \mu\text{m}$) and AMS 2402-6 designates a thickness of 0.0006 to 0.0008 inch (15 to $20\ \mu\text{m}$).

3.4.1.1.1 Plate thickness, when specified by AMS 2402 and a suffix number, shall be as specified in Table 1 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 ($2.5\ \mu\text{m}$).

TABLE 1A - PLATE THICKNESS, SALT SPRAY CORROSION RESISTANCE, AND PERFORATION TIME REQUIREMENTS, INCH/POUND UNITS

AMS 2402 Thickness Designation Specified	External Threads Thickness Inch	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 Inch	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 Inch	Other Parts Salt Spray Resistance hours, min	Other Parts Perforation Time seconds, min
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

Note 1: For thickness designations AMS 2402-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.

NOTE 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 2B.

TABLE 1B - EQUIVALENT PERFORATION TIME

Perforation Time Seconds at 70 °F	Seconds at Temperature Shown 75 °F	Seconds at Temperature Shown 80 °F
10	10	10
20	20	19
30	30	29
41	39	37
51	49	47

TABLE 1C - PLATE THICKNESS, SALT SPRAY CORROSION RESISTANCE,
AND PERFORATION TIME REQUIREMENTS, SI UNITS

AMS 2402 Thickness Designation Specified	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
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

Note 1: For thickness designation AMS 2402-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.

Note 2: Perforation times specified above are for the drop test solution of 3.4.1 at 70 °F (21 °C); equivalent perforation times at other temperatures are as shown in Table 1D.

TABLE 1D - EQUIVALENT PERFORATION TIME

Perforation Time, Seconds at 21 °C	Seconds at Temperature Shown at 24 °C	Seconds at Temperature Shown at 16 °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 drawing dimensions are met.

3.4.1.4 All surfaces of the part, except those which cannot be touched by a sphere 0.75 inch (19 mm) in diameter, shall be plated to the specified thickness. Unless otherwise specified in Table 1 or on the drawing, 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 B 571.

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, ferrous metal parts or representative specimens as in 4.3.3 plated 0.0001 to 0.0003 inch (3 to 8 μm) thick and which 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 B 117. 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 Table 1.

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

When parts with hardness of 36 HRC or higher are plated, the process used shall not cause hydrogen embrittlement when tested in accordance with requirements of ASTM F 519.

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.

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 purchaser. The cognizant engineering organization 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 plating solutions to ensure that the deposited metal will conform to specified requirements (See 8.5) are periodic tests and shall be performed at a frequency selected by the processor unless frequency of testing is specified by the cognizant engineering organization. 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 are preproduction tests and shall be performed prior to initial shipment and when the cognizant engineering organization deems confirmatory testing to be required.

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 Acceptance Tests

Test samples shall be selected randomly from all parts in the lot. Unless the cognizant engineering organization supplies 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 6	All	All or 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

*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 by purchaser.

4.3.3 Nondestructive testing shall be performed wherever practical. Except as noted, actual parts shall be selected as samples for tests.

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 the specified tests, nondestructive testing is not practical on actual parts, or it is not economically acceptable to perform destructive tests on actual parts. When used, separate test specimens shall be of the same generic class of alloy as the parts represented, distributed within the lot, cleaned, plated, and post-treated with the represented parts may be used.

4.3.3.2 Test specimens for corrosion testing, when required, shall be fabricated from low carbon steel, approximately $0.032 \times 1 \times 4$ inches ($0.8 \times 25 \times 102$ mm) or bars approximately, 0.5 inch (13 mm) in diameter and 4 inches (102 mm) long.

4.3.3.3 Hydrogen embrittlement test specimens shall conform to ASTM F 519 Type 1a.1 using notched round bars stressed in tension under constant load. For test purposes, 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 evidence of plating in the root of the notch.

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 purchaser 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.