SAE Aerospace
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AEROSPACE MATERIAL SPECIFICATION

SAE AMS2451 REV. C

Issued 1998-07
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Superseding AMS2451B

Plating, Brush
General Requirements

RATIONALE

AMS2451C results from 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:

- AMS2451 detail specification number and revision letter.
- Plating thickness desired. See 3.5.1.
- 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 3.3.1.
- 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 3.4.3.1.
- Provisions peculiar to parts or assemblies to be repaired or overhauled.
- Optional: Periodic testing frequency (4.2.2) and sample quantity (4.3.2) if different from 4.2.2 and 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/AMS2451C

1. SCOPE

1.1 Purpose

This specification and its supplementary detail specifications establish the requirements for electrodeposition of metals by brush plating.

1.2 Application

This process has been used typically to improve surface properties such as corrosion resistance, wear resistance, and brazeability or to repair damaged, worn, or mismachined parts, but usage is not limited to such applications. This process is particularly useful for plating localized areas on-site, especially on large parts or assemblies, and for minimizing masking.

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.

AMS2759 Heat Treatment of Steel Parts - General Requirements

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 Measurements 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 Metal

ASTM B 504 Measurement of Thickness of Metallic Coatings by the Coulometric Method

ASTM B 530 Measurements of Coating Thicknesses by Magnetic Method: Electrodeposited Nickel Coatings on Magnetic and Nonmagnetic Substrates

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 E 384 Knoop and Vickers Hardness of Materials

ASTM F 519 Mechanical Hydrogen Embrittlement Testing of Plating Processes and Aircraft Maintenance Chemicals

3. TECHNICAL REQUIREMENTS

3.1 Detail Specification

The requirements for a specific brush plating shall consist of all requirements specified herein in addition to requirements specified in the applicable detail specification. In case of conflict between requirements of this basic specification and the applicable detail specification, requirements of the detail specification shall govern.

3.2 Parts and test specimens shall be plated by trained operators who have been approved initially and periodically thereafter for plating on the basis material with the equipment and processing materials to be used. Operator training shall include plating of simulated parts and specimens, and approval shall be based on evaluation of the operator's familiarity with the brush plating equipment/solutions, and the specification requirements. See 8.3.

3.3 Preparation

3.3.1 All steel parts having a hardness of 40 HRC and above and that are machined, ground, cold formed or cold straightened shall be cleaned to remove surface contamination and thermally stress relieved before plating for relief of residual tensile stresses. 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 5 hours for parts having hardness of 55 HRC or higher or not less than 375 °F (191 °C) for not less than 4 hours for other parts. Residual tensile stresses have been found to be damaging during plating.

3.3.1.1 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 a minimum of 5 hours.

3.3.1.2 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.

3.3.1.3 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.

3.3.1.4 Assemblies shall be treated in a manner acceptable to the cognizant engineering organization.

3.3.2 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.

3.3.3 For parts that are to be plated all over, electrical contact locations shall be acceptable to purchaser. For parts that are not to be plated all over, locations shall be in areas on which plating is not required.

3.4 Procedure

3.4.1 The equipment, materials, and procedures used to process specimens and parts shall conform to a schedule of control factors (4.4.3) and to the recommendations of the manufacturer of the selective plating equipment and processing materials.

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

3.4.2 After plating, parts shall be rinsed with water, to remove residual plating solution, and immediately dried.

3.4.3 Post Treatment

3.4.3.1 Hydrogen Embrittlement Relief

Treatment of steel parts shall be in accordance with AMS2759/9 except baking of parts plated in accordance with AMS2451/4, AMS2451/9, and AMS2451/10 is not required when compliance with 3.5.3.6 is achieved without baking.

3.4.3.2 Assemblies shall be treated in a manner acceptable to the cognizant engineering organization.

3.5 Properties

The following requirements apply to all detail specifications.

3.5.1 Thickness

Plating thickness shall be as specified on the drawing/purchase order and shall be in accordance with any of the following methods as applicable: ASTM E 376, ASTM B 487, ASTM B 499, ASTM B 504, ASTM B 530, ASTM B 567, ASTM B 568, or other method acceptable to the cognizant engineering organization. Unless otherwise specified, plating thickness shall be uniform within ±20%, except within 1/8 inch (3.2 mm) of exterior edges and corners where thicker plating (buildup) is permissible.

3.5.1.1 Where “nickel flash” is specified, plate thickness shall be approximately 0.0001 inch (3 µm).

3.5.2 Adhesion to Parts

There shall be no visual evidence of plating separation from the underlying substrate when the following test is performed. Tape, 1-inch (25 mm) wide or wider, having adhesive strength of not less than 60 ounces per inch (0.66 N/mm) of width, shall be firmly applied to the plated area. It shall then be pulled manually from the plated area at approximately 90 degrees to the plated surface in one sharp movement. When both unplated and plated areas can be covered by the tape, it shall be pulled from the unplated area toward the plated area.

3.5.2.1 When plating is to be subsequently machined, this test may be omitted if acceptable to the cognizant engineering organization.

3.5.3 The following requirements only apply when specified in a detail specification.

3.5.3.1 Adhesion to Specimens

Adhesion shall meet the requirements of ASTM B 571 by the Bend Test method. There shall be no evidence of separation of plating from the basis metal when examined at 4X magnification; cracks which do not result in flaking or peeling of the plate are acceptable.

3.5.3.2 Hardness

Hardness values shall be as specified and shall be determined in accordance with ASTM E 384.

3.5.3.3 Stress

The residual surface stress in the deposit shall be as specified in a detailed specification and shall be determined by X-Ray diffraction or another method which is acceptable to the cognizant engineering organization.

3.5.3.4 Heat Resistance

3.5.3.4.1 Plated ferrous and corrosion-resistant parts or specimens shall withstand without blistering, cracking, or debonding, being heated in air to 700 °F ± 15 (371 °C ± 8) and held at temperature for not less than 23 hours, followed by heating in air to 1000 °F ± 15 (538 °C ± 8) and holding at temperature for not less than 60 minutes, then air cooling to room temperature.

3.5.3.4.2 Plated aluminum and aluminum-alloy, and copper and copper-alloy parts or specimens, shall pass the heat-quench test of ASTM B 571.

3.5.3.5 Corrosion Resistance

Representative specimens shall be plated and post-plating treated as specified in a detail specification. There shall be no visual evidence of corrosion of the basis metal on plated surfaces after continuous exposure to salt spray, in accordance with ASTM B 117, for 48 hours, -0, +1, unless another period is specified. Where plating is used only to aid brazing or where used only for dimensional restoration, corrosion testing may be waived if acceptable to the cognizant engineering organization.

3.5.3.6 Hydrogen Embrittlement

The plating process shall not cause hydrogen embrittlement in steel parts 36 HRC and over determined in accordance with 4.3.3.3.

3.6 Quality

To the unaided eye, the plating shall be continuous and free from plating defects such as frosty areas, pin holes, blisters, porosity, nodules, and pits; slight staining or discoloration is permissible. Parts shall be free from evidence of arcing and of overheating.

4. QUALITY ASSURANCE PROVISIONS

4.1 Responsibility for Inspection

The processor shall be responsible for performance of all tests and shall supply all specimens required for processor's tests. When parts are to be tested, such parts shall be supplied by purchaser. The cognizant engineering organization reserves the right to sample and perform any confirmatory testing deemed necessary to ensure that plating conforms to specified requirements.

4.2 Classification of Tests

4.2.1 Acceptance Tests

Thickness (3.4.1.1), adhesion to parts (3.4.1.2), and quality (3.5) are acceptance tests and shall be performed on each lot.

4.2.2 Periodic Tests

When required by the applicable detail specification, adhesion to specimens (3.5.3.1), hardness (3.5.3.2), stress (3.5.3.3), heat resistance (3.5.3.4) and corrosion resistance (3.5.3.5) are periodic tests and shall be performed at least quarterly unless frequency of testing is specified by the cognizant engineering organization. When required by the applicable detail specification, hydrogen embrittlement (3.5.3.6) is a periodic test and shall be performed at least once in each month that steel parts 36 HRC and over are plated to the applicable detail specification unless frequency of testing is specified by the cognizant engineering organization. Tests of preparatory 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 engineering organization.

4.2.3 Preproduction Tests

All property verification tests (3.4) are preproduction tests and shall be performed for each schedule of control factors prior to initial shipment of plated parts to a purchaser and when the cognizant engineering organization requires confirmatory testing.

4.3 Sampling for Testing

4.3.1 Acceptance Test

Test samples shall be randomly selected from all parts in the lot. A lot shall be all parts plated by the same schedule of control factors, processed without a change of setup within a 7 day period by the same operator, and presented for processor's inspection at one time and presented for processor's inspection at one time. Unless the cognizant engineering organization provides a sampling plan, 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	Adhesion
1 to 6	All	All	All
7 to 15	All	7	All
16 to 40	All	8	16
41 to 100	All	10	20
101 to 300	All	12	24
301 to 500	All	14	28
Over 500	All	16	32

4.3.2 Periodic Tests

Sample quantity shall be selected at the discretion of the processor, unless otherwise specified.

4.3.3 Sample Configuration

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 so 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 Representative test specimens may be used in lieu of parts 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, 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 Corrosion Testing

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 1 x 4 inches (25 x 102 mm) or bars approximately 1 inch (25 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 acceptable to the cognizant engineering organization. Alternative alloy or configuration may be used when acceptable to the cognizant engineering organization. Plating thickness shall be 0.0003 to 0.0006 inch (8 to 15 µm) unless otherwise specified or acceptable to the cognizant engineering organization.

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 or Type 2a, unless a different specimen is specified by the cognizant engineering organization, stressed in tension under constant load. For test purposes, the plating thickness shall be 0.0003 to 0.0006 inch (8 to 15 µm) on the smooth section of the Type 1a.1 specimen and visual evidence of plating at the root of the notch.

4.4 Approval

4.4.1 The schedule of control factors shall be approved by the cognizant engineering organization before production parts are supplied. The schedule of control factors shall contain a level of detail sufficient to ensure reproduction of preproduction characteristics in production parts. If supplier-proprietary information is involved, the supplier may certify that the information is proprietary and is available for review by the cognizant engineering organization.

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, 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.

4.4.3 The schedule of control factors shall be maintained and shall include:

Basis metal and condition
Stress relief treatment prior to plating, if any
Surface preparation and cleaning
Preplate, if required
Equipment description
Anode design/designation
Plating solution composition or manufacturer's designation
Voltage and current ranges
Relative motion between anode and workpiece during deposition
Restrictions on interrupted plating
Embrittlement relief time and temperature, if required
Test methods
Periodic test plan

4.5 Reports

The processor of plated parts shall furnish with each shipment a report stating that the parts have been processed and tested in accordance with AMS2451C and applicable slash (/) number, and that they conform to the specified requirements. This report shall include the purchase order number, lot number, part number, and quantity.