



AEROSPACE MATERIAL SPECIFICATION	AMS2411™	REV. K
	Issued 1966-09 Reaffirmed 1984-01 Revised 2024-02	
Superseding AMS2411J		
Plating, Silver for High Temperature Applications		

RATIONALE

AMS2411K made changes to clarify the adhesion requirements (see ordering information, 3.2.1.1, 3.4.3.2, 3.4.3.3, and 8.9.

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:

- AMS2411K
- Plating thickness desired (see 3.4.1)
- Basis metal to be plated
- Tensile strength or hardness of the basis metal
- If preplate stress relief is to be performed by plating processor and if different from 3.1.1, time and temperature are to be specified
- 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 3.3.1
- Minimum thickness on internal surfaces, if required (see 3.4.1.4)
- Quantity of pieces to be plated
- If steel parts were machined, ground, cold formed, or cold straightened after heat treat (see 3.1.1)
- If steel parts have been shot peened, specify if required stress relief has been completed (see 3.1.1.3)
- Optional: If blisters less than 0.015 inch (0.38 mm) diameter are limited to no more than 25 per square inch (6.5 cm²) (see 3.4.3.2)

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SAE WEB ADDRESS:

For more information on this standard, visit
<https://www.sae.org/standards/content/AMS2411K>

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 requirements for silver deposited on metal parts with a nickel strike between the basis metal and the silver deposit.

1.2 Application

This process has been used typically to prevent galling or seizing of surfaces of parts, such as fasteners, made of low alloy steel, corrosion- and heat-resistant steel, and nickel alloys for use up to 1400 °F (760 °C), 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 +1 724-776-4970 (outside USA), www.sae.org.

AMS2430	Shot Peening
AMS2750	Pyrometry
AMS2759/9	Hydrogen Embrittlement Relief (Baking) of Steel Parts
AMS5616	Steel, Corrosion and Heat-Resistant, Bars, Wire, Forgings, Mechanical Tubing, and Rings, 13Cr - 2.0Ni - 3.0W, Annealed
AMS5640	Steel, Corrosion-Resistant, Bars, Wire, and Forgings, 18Cr - 9.0Ni, Free Machining
AMS5643	Steel, Corrosion-Resistant, Bars, Wire, Forgings, Mechanical Tubing, and Rings, 16Cr - 4.0Ni - 0.30Cb (Nb) - 4.0Cu, Solution Heat Treated, Precipitation Hardenable
AMS5709	Nickel Alloy, Corrosion- and Heat-Resistant, Bars and Forgings, 58Ni - 19.5Cr - 13.5Co - 4.3Mo - 3.0Ti - 1.4Al - 0.05Zr - 0.006B, Consumable Electrode or Vacuum Induction Melted, 1975 °F (1079 °C) Solution, Stabilization, and Precipitation Heat Treated
AMS5732	Steel, Corrosion- and Heat-Resistant, Bars, Wire, Forgings, Tubing, and Rings, 15Cr - 25.5Ni - 1.2Mo - 2.1Ti - 0.006B - 0.30V, Consumable Electrode Melted, 1800 °F (982 °C), Solution and Precipitation Heat Treated

AMS6304	Low-Alloy Steel, Heat-Resistant, Bars, Forgings, Mechanical Tubing, and Forging Stock 0.95Cr - 0.55Mo - 0.30V (0.40 - 0.50C)
ARP1917	Clarification of Terms Used in Aerospace Metals Specifications
ARP4992	Periodic Test Plan for Process Solutions
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 B374	Terminology Relating to Electroplating
ASTM B487	Measurement of Metal and Oxide Coating Thicknesses 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 the Thickness of Metallic Coatings by the Coulometric Method
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 ANSI Accredited Publications

Copies of these documents are available online at <https://webstore.ansi.org/>.

ASME B46.1 Surface Texture (Surface Roughness, Waviness, and Lay)

3. TECHNICAL REQUIREMENTS

3.1 Preparation

3.1.1 Stress Relief Treatment

All steel parts having a hardness of 40 HRC and above and that are machined, ground, cold formed, or cold straightened after heat treatment shall be cleaned to remove surface contamination and thermally stress relieved before plating. (Residual tensile stresses have been found to be damaging during electroplating.) 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 stress relief is obtained while still maintaining hardness of parts within drawing limits. Unless otherwise specified, the following treatment temperatures and times shall be used:

- 3.1.1.1 For parts, excluding nitrided parts, having a hardness of 55 HRC and above, and for carburized and induction hardened parts, stress relieve at 275 °F ± 25 °F (135 °C ± 14 °C) for 5 to 10 hours.
- 3.1.1.2 For parts having a hardness less than 55 HRC and for nitrided parts, stress relieve at 375 °F ± 25 °F (191 °C ± 14 °C) for a minimum of 4 hours. Higher temperatures shall be used only when specified or approved by the cognizant engineering organization.

3.1.1.3 For Peened Parts

If stress relief temperatures above 375 °F (191 °C) are elected (see 8.6), the stress relieve shall be performed prior to peening or the cognizant engineering organization shall be consulted and shall approve the stress relief temperature.

3.1.2 Nickel strike plating shall be applied over a clean surface that will result in a deposit that meets the adhesion and quality requirements of this specification. The pretreatment process shall not produce pitting or intergranular attack of the basis metal and shall preserve dimensional requirements.

3.1.3 Except for barrel plating, electrical contact points shall be as follows:

3.1.3.1 For parts which are to be plated all over, and electrical contact points are not specified, contact locations shall be at the discretion of the processor (see 4.4.3).

3.1.3.2 For parts which are not to be plated all over, and electrical contact locations are not specified, locations shall be in areas on which plate is not required.

3.2 Procedure

3.2.1 Parts shall be plated using a three-step process: nickel strike, silver strike, and silver plate.

3.2.1.1 When approved by the cognizant engineering organization, an alternative to nickel strike is permitted (see 8.9).

3.2.2 The use of organic base grain refining and brightener additives shall be prohibited in both the silver strike and silver plate solutions.

3.2.3 Double plating and spotting in are prohibited.

3.3 Post Treatment

3.3.1 Hydrogen embrittlement relief treatment of steel parts 40 HRC or higher shall be in accordance with AMS2759/9.

3.4 Properties

Plated parts shall conform to the following requirements:

3.4.1 Thickness of the deposit shall be as specified on the drawing, determined in accordance with any of the following methods as applicable: ASTM B487, ASTM B499, ASTM B504, ASTM B567, ASTM B568, ASTM E376, or other method acceptable to the cognizant engineering organization.

3.4.1.1 When machining of plated metal is required, deposit thickness shall be sufficient to allow specified dimensions to be met.

3.4.1.2 Where silver flash is specified, plate thickness shall be approximately 0.0001 inch (2.5 µm).

3.4.1.3 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, 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 Composition of the deposit shall be not less than 99.9% silver determined by a method acceptable to the cognizant engineering organization.

3.4.3 Adhesion

The deposit shall firmly adhere to the basis metal.

3.4.3.1 Parts or test panels to be adhesion tested shall be heated in an air atmosphere to the following applicable temperature, held at heat within ±15 °F (±8 °C) for not less than 2 hours, and cooled in still air.

WARNING: The following are destructive tests and parts so tested are not acceptable for shipment as production end use parts.

- 3.4.3.1.1 Parts or test panels made of low-alloy steels, such as AMS6304, and martensitic or precipitation-hardenable corrosion-resistant steels, such as AMS5616 or AMS5643, shall be heated at 900 °F (482 °C).
- 3.4.3.1.2 Parts or test panels made of austenitic corrosion-resistant steels, such as AMS5640, and precipitation-hardenable, corrosion and heat resistant steels, such as AMS5732, shall be heated at 1200 °F (649 °C).
- 3.4.3.1.3 Parts or test panels made of precipitation-hardenable and corrosion and heat-resistant nickel alloys, such as AMS5709, shall be heated at 1400 °F (760 °C).
- 3.4.3.1.4 Parts or test panels made of materials of a type not listed in 3.4.3.1.1 through 3.4.3.1.3 shall be heated at the temperature specified on the drawing or as directed by the cognizant engineering organization.
- 3.4.3.2 After heating as in 3.4.3.1, parts or test panels shall be examined at 10X magnification. Parts or test panels shall be free of blisters and of indications of poor bond such as flaking and lifting of the plating. Individual blisters less than 0.015 inch (0.38 mm) diameter are acceptable. Interconnecting blisters of any diameter, or blisters 0.015 inch (0.38 mm) and larger in diameter, measured at a maximum of 10X magnification are not acceptable. When specified by the cognizant engineering organization, blisters less than 0.015 inch (0.38 mm) diameter shall be limited to no more than 25 blisters per square inch (6.5 cm²).
- 3.4.3.3 After visual examination as in 3.4.3.2, parts or test panels shall be chisel-knife tested in accordance with ASTM B571. There shall be no signs of peeling of the plating from the underlying metal except where the chiseling or whittling action cuts through blisters permitted by 3.4.3.2. Parts or test panels shall not show lifting and/or peeling, or both, of the plating except where the cutting is through blisters unless there is indication of shearing or cutting effect on the plating adjacent to the area from which blisters have been removed.

3.4.4 Hydrogen Embrittlement

The plating process after baking shall not cause hydrogen embrittlement in steel parts 40 HRC and over determined in accordance with 4.3.3.4.

3.5 Quality

- 3.5.1 Plating, as received by the purchaser, shall be smooth, continuous, adherent to basis metal, uniform in appearance, and visually free from pin holes, blisters, nodules, pits, and other imperfections detrimental to usage of the parts. Slight staining or discoloration is permissible. There shall be no evidence of electrical arcing or local overheating.
- 3.5.2 Silver plate which is to be machined shall be free from excessive nodulation or treeing at edges. Finished parts shall be free from visible pits excessive porosity, and other imperfections detrimental to fabrication or to performance of parts.
- 3.5.3 Abrasion of plating on corners and edges of threaded fasteners is acceptable but plate shall be continuous on threads. Marking of the cone section of self-locking nuts, produced in offsetting the locking beams or other deformation, is acceptable.

4. QUALITY ASSURANCE PROVISIONS

4.1 Responsibility for Inspection

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

4.2.2 Periodic Tests

Composition (see 3.4.2) is a periodic test and shall be performed at least once in each calendar quarter that parts are processed. Adhesion (see 3.4.3) 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 engineering organization (see 4.4.3 and 8.4). Hydrogen embrittlement (see 3.4.4) is a periodic test and shall be performed in accordance with 4.3.3.4 at least once each month that steel parts 40 HRC and over are processed unless frequency of testing is specified by the cognizant engineering organization.

4.2.2.1 Periodic testing may be suspended in any test period when parts are not processed; however, preproduction testing may be required by the cognizant quality organization upon resumption of processing.

4.2.3 Preproduction Tests

All property verification tests (see 3.4) are preproduction tests and shall be performed prior to production and when the cognizant engineering organization deems confirmatory testing to be required.

4.3 Sampling for Testing

Shall be not less than the following:

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 1.

Table 1 - Sampling for acceptance tests

Number of Parts in Lot	Quality	Thickness
Up to 7	All	All or 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
701 to 1200	75	10
Over 1200	125	15

* Whichever is less.

4.3.2 Periodic Tests

Sample quantities shall be selected at the discretion of the processor, unless otherwise specified. When test specimens are used for adhesion testing, 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 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.

4.3.3.2 Thickness Testing

When used, separate test specimens for thickness shall be annealed, low carbon steel approximately $0.032 \times 1 \times 4$ inches ($1 \times 25 \times 102$ mm) distributed within the lot for plating.

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 and processed along with the parts. The test specimens shall be 0.025 inch (0.6 mm) minimum thickness and not less than 1×4 inches (25×102 mm).

4.3.3.4 Hydrogen Embrittlement Relief Test

Test shall be in accordance with the requirements of ASTM F519 Type 1a.1 using notched round 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 $0.002 \text{ inch} \pm 0.0002 \text{ inch}$ ($51 \mu\text{m} \pm 5 \mu\text{m}$) measured on the smooth, unnotched sections of the specimen but with visual evidence of plating in 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 or a preproduction sample or 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 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 Control factors shall include, but not be limited to, the following:

- Surface preparation and cleaning method
- Plating bath composition and composition control limits
- Plating bath temperature limits and controls
- Current (current density)/voltage limits and controls as applicable
- Thermal post treatment times and temperatures
- Method for determining plating thickness
- Rack locations
- Electrical contact locations, when required
- Stripping procedure, when applicable
- Periodic test plan for cleaning and processing (see 8.4)

4.5 Reports

The processor shall furnish with each shipment a report stating that the parts have been processed and tested in accordance with the specified requirements and that they conform to all test requirements. This report shall include the purchase order number, AMS2411K, part number, lot identification number, and quantity.

4.6 Resampling and Retesting

4.6.1 If any acceptance test fails to meet specified test requirements, the parts in that lot may be stripped, pretreated, plated, and post treated as defined herein and retested. Alternatively, all parts in the lot may be inspected for the nonconforming attribute, and the nonconforming parts may be stripped, pretreated, plated, post treated as defined herein, and retested. After stripping and replating, parts shall meet the dimensions on the drawing.