

Plating, Silver  
for High Temperature Applications

### RATIONALE

This specification revision was issued as part of the SAE Five Year Review process.

### 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 2411F
- Plating thickness desired (see 3.4.1)
- Basis metal to be plated
- Tensile strength or hardness of the basis metal
- Preplate stress relief to be performed by plating processor (time and temperature) if different from 3.1.1
- 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 3.3.1
- Minimum thickness on internal surfaces, if required (see 3.4.1.3)
- 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.

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Fax: 724-776-0790  
Email: [custsvc@sae.org](mailto:custsvc@sae.org)  
**SAE WEB ADDRESS:** <http://www.sae.org>

## 1. SCOPE

### 1.1 Purpose

This specification covers the 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).

### 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](http://www.sae.org).

AMS 2759/9	Hydrogen Embrittlement Relief (Baking) of Steel Parts
AMS 5616	Steel, Corrosion and Heat-Resistant, Bars, Wire, Forgings, Tubing and Rings, 13Cr - 2.0Ni - 3.0W, Annealed
AMS 5640	Steel, Corrosion-Resistant, Bars, Wire, and Forgings, 18Cr - 9.0Ni (SAE 30303, 30303Se, 30303Mod), Free Machining
AMS 5643	Steel, Corrosion-Resistant, Bars, Wire, Forgings, Tubing, and Rings, 16Cr - 4.0Ni - 0.30 (Cb + Ta) - 4.0Cu, Solution Heat Treated, Precipitation Hardenable
AMS 5709	Nickel Alloy, Corrosion and Heat-Resistant, Bars and Forgings, 58Ni - 19.5Cr - 13.5Co - 4.3Mo - 3.0Ti - 1.4Al, Consumable Electrode or Vacuum Induction Melted, 1975 °F (1080 °C) Solution, Stabilization, and Precipitation Heat Treated
AMS 5732	Steel, Corrosion and Heat-Resistant, Bars, Forgings, Tubing, and Rings, 15Cr - 25.5Ni - 1.3Mo - 2.1Ti - 0.006B - 0.30V, Consumable Electrode Melted, 1800 °F (980 °C) Solution and Precipitation Heat Treated
AMS 6304	Steel, Low Alloy, Heat-Resistant, Bars, Forgings, and Tubing, 0.95Cr - 0.55Mo - 0.30V (0.40 - 0.50C)

### 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](http://www.astm.org).

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 the Thickness of Metallic Coatings by the Coulometric Method
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

### 2.3 ANSI Publications

Available from American National Standards Institute, 25 West 43rd Street, New York, NY 10036, Tel: 212-642-4900, [www.ansi.org](http://www.ansi.org).

ASME B46.1 Surface Texture

## 3. TECHNICAL REQUIREMENTS

### 3.1 Preparation

3.1.1 Steel parts having a hardness of 40 HRC or higher and which have been ground, machined, or cold straightened after heat treatment shall be cleaned to remove surface contamination and 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 having hardness of 55 HRC or higher or not less than 375 °F (191 °C) for not less than four hours for other parts.

3.1.2 Nickel plating shall be applied over a clean and active surface that will result in a deposit that meet 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 Surface roughness of surfaces to be plated, other than that of nuts, shall be 80 microinches (2 μm) Ra or smoother determined in accordance with ASME B46.1.

3.1.4 Except for barrel plating, electrical contact points shall be as follows. For parts which are to be plated all over, locations shall be acceptable to the cognizant engineering organization. For parts which are not to be plated all over, locations shall be in areas on which plating is not required or other location acceptable to the cognizant engineering organization.

### 3.2 Procedure

3.2.1 Parts shall be plated using a three-step process: nickel strike, silver strike, and silver plate. The nickel strike shall 0.0005 inch (13 μm) maximum.

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

3.2.2 Double plating and spotting in are prohibited.

### 3.3 Post Treatment

3.3.1 Hydrogen embrittlement relief treatment of steel parts shall be in accordance with AMS 2759/9.

### 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 B 487, ASTM B 499, ASTM B 504, ASTM B 567, ASTM B 568, ASTM E 376, or other method acceptable to the cognizant engineering organization (See 8.6).

3.4.1.1 Nickel strike shall not exceed 0.0005 inch (13 μm).

- 3.4.1.2 Where silver flash is specified, plate thickness shall be approximately 0.0001 inch (2.5  $\mu$ m).
- 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  $\pm 15$  °F ( $\pm 8$  °C) for not less than two hours, and cooled in still air.

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

- 3.4.3.1.1 Parts or test panels made of low-alloy steels, such as AMS 6304, and martensitic or precipitation-hardenable corrosion resistant steels, such as AMS 5616 or AMS 5643, 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 AMS 5640, and precipitation-hardenable, corrosion and heat resistant steels, such as AMS 5732, shall be heated at 1200 °F (648 °C).
- 3.4.3.1.3 Parts or test panels made of precipitation-hardenable, corrosion and heat resistant nickel alloys, such as AMS 5709, 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 shall be free of blisters and of indications of poor bond such as flaking and lifting of the plating. Small blisters are acceptable provided the parts meet the adherence requirements of 3.4.3.3. Blisters 0.015 inch (0.38 mm) and larger in diameter, measured under 10X magnification are not acceptable.
- 3.4.3.3 After visual examination as in 3.4.3.2, parts or test panels, shall be shear or chisel-tested in accordance with ASTM B 571. 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. If parts show lifting and/or peeling, or both, of the plating except where the cutting is through blisters, all parts of the lot represented shall be rejected 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 shall not cause hydrogen embrittlement in steel parts, determined in accordance with 4.3.3.2.

### 3.5 Quality

- 3.5.1 Plating, as received by 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. There shall be no evidence of spotting-in or double plating.
- 3.5.2 Silver plate which is to be machined shall be free from excessive modulation 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 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 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 (3.4.3), 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

Composition (3.4.2) and hydrogen embrittlement (3.4.4) are periodic tests and shall be performed at least once each month that parts are processed. 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).

###### 4.2.3 Preproduction Tests

All property verification tests (section 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; a lot shall be all parts of the same part number plated to the same range of plate thicknesses 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 randomly selected from all parts in the lot. 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 and Adhesion
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.

#### 4.3.3 Sample Configuration

4.3.3.1 Separate test specimens may be used any under 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 made of the same generic class of alloy as the parts, distributed within the lot, cleaned, plated and post treated with the parts represented. For adhesion tests, such specimens shall be panels fabricated from a material generically similar to the parts being plated approximately 0.032 x 1 x 4 inch (1 x 25 x 102 mm) and for thickness tests shall be panels of annealed, low carbon steel approximately 0.032 x 1 x 4 inches (1 x 25 x 102 mm).

#### 4.3.3.2 Hydrogen Embrittlement Relief Test

Test shall be in accordance with the requirements of ASTM F 519 Type 1a.1 using round notched specimens, 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 0.002 inch  $\pm$  0.0002 (51  $\mu\text{m}$   $\pm$  5) or plated to a thickness not less than twice the maximum thickness to which the plate is to be qualified, whichever is less. Thickness shall be measured on the smooth, unnotched sections of the specimens but with visual plating in the root of the notch.

#### 4.4 Approval

4.4.1 The process and control factors or a preproduction 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  
Thermal post treatment times and temperatures  
Method for determining plating thickness  
Rack locations  
Stripping procedure, when applicable  
Current density (amps per part or amps per total surface area of the parts plated at one time in each tank)  
Periodic test plan (See 8.4).

#### 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 the specified requirements and that they conform to the acceptance test requirements. This report shall include the purchase order number, AMS 2411F, part number, lot identification 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.

4.6.1.1 When stripping is performed, the method shall be acceptable to the cognizant engineering organization and shall not roughen, pit, or embrittle the basis metal or adversely affect part dimensions. When parts have been stripped and replated, the cognizant engineering organization shall be informed unless directed otherwise.